NAVAL AIR TRAINING COMMAND

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JOINT AEROSPACE PHYSIOLOGY STUDENT GUIDE

MARCH 2002

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250 LEXINGTON BLVD SUITE 102
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Subj: JOINT AEROSPACE PHYSIOLOGY STUDENT GUIDE

1. CNATRA P-204 (Rev 03-02) PAT, Joint Aerospace Physiology Student Guide is issued for information, standardization of instruction, and guidance to instructors and students in the Naval Air Training Command. This publication issues AETC/BUMED Student Guide PV4AA-JP-SG of March 2002.

2. This publication will be used to supplement the Introduction to the Joint Aerospace Physiology portion of the Preflight Curriculum.

3. Recommendations for changes shall be submitted to the CNATRA Naval Aviation Schools Command Academics Officer, Code N3121. POC is Mr. Larry R. Wardle, DSN 861-3824, COMM (361) 961-3824. CNATRA FAX is DSN 861-3398.

4. CNATRA P-203 (REV 6-98) is hereby cancelled and superseded.

R. E. BIRD
Assistant Chief of Staff for
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Joint Specialized Undergraduate Flying Training

Aerospace Physiology

March 2002

Air Education and Training Command/Bureau of Medicine and Surgery

Designed for Joint AETC/BUMED Course Use

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March 2002

This student guide lists all the objectives for each unit of instruction in Joint Aerospace Physiology. These objectives identify what you need to learn. Develop an understanding of the material by answering the review questions at the end of each unit. These questions also provide an excellent review for the exam. The answers to these questions are in the back of this book. The next planned revision is March 2005.

OFFICIAL

THOMAS A. O'RIORDAN
Major General, USAF
Director of Operations

M. W. DOUGLASS
Commander, USN
Chief of Naval Operations (N789J3)

Summary of Changes

This revision changes the publication number to include all Air Force and Navy JSUFT syllabuses that require these lessons. Information was added to altitude threats lesson to include hypoxia corrective procedures for all primary JSUFT aircraft. Added information to the acceleration lesson on the Push-Pull Effect.

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Contents

Note 1 — Selected portions of this course are taught by enlisted instructors. Specific guidance in provided by AFI 11-403, *Aerospace Physiological Training Program* and by Naval Aviation Survival Training Program Standard Operating Procedures. Additional time must be allocated when scheduling large classes.

Note 2 — Lessons JP(0)109 and JP(0)110 are required as part of the Aerospace Physiology course for Navy Aviation Pre-Flight Indoctrination (NP1) students only. See aircraft-specific Life Support courses for parasail requirements for all other syllabuses.

Note 3 — Lessons JP(0)101, JP(0)102 and JP(0)106 may be presented as Instructor-Based Training or Self-Study for NP1 students based on available time.

IBT — Instructor-Based Training

Summary of Changes

This revision brings the Joint Aerospace Physiology courseware in line with all JSUFT training tracks. The publication number has been changed to include all Air Force and Navy JSUFT syllabuses requiring these lessons. JP0109 and JP0110 have been included in this course for NP1 students only and have been moved to the aircraft-specific life support courses as applicable for all other syllabuses. Material has been added to the Altitude Threats lesson to include corrective procedures for hypoxia for the T-37, T-34, T-6, and T-43. The acceleration lesson has added information on the Push-Pull Effect. Spelling and grammatical errors have been corrected throughout.

Lesson JP(0)101 — 0.5 Hours (IBT)

Course Introduction and the Atmosphere

Objectives

1. Identify the composition of the earth's atmosphere.
2. Identify atmospheric pressure and describe how it is caused.
3. Identify the pressure of the U.S. Standard Atmosphere and where the greatest pressure change takes place.
4. Identify standard units used to measure atmospheric pressure.
5. Compute a temperature for a given altitude using the standard temperature lapse rate.
6. Define the physiological divisions of the atmosphere.
7. Define partial pressure and identify its notation.
8. Describe each of the gas laws.
9. Identify the physiological consequences of each gas law.

Assignment

Read JP(0)101 in the SG and answer the review questions.

Introduction

Today, as never before, you face the challenge of expanding technology and a rapidly changing world. The ever increasing complexity of weapon systems and mission requirements place greater and more diverse stress on crewmembers. The Aerospace Physiology (AP) course prepares you to successfully cope with these stresses, whether they are the physical requirements of egress, physiological stresses of loss of aircraft pressurization, or performance decrements caused by self-imposed stress. We have reached a point where the major limiting factor to weapon system performance is the human limitations of the crewmember. These human limitations form the basis of a field of study, *Human Factors*, that is a part of this course.

Human factors is defined as the study of the physiological, physical, psychological, and pathological limitations and capabilities of people as they interact with their environment. This definition is broad and includes everything determining and influencing human behavior.

In modern aviation, human factors have historically accounted for the majority (60-80 percent) of aircraft accidents. As a result, we continue to develop and improve programs to eliminate human factors errors. These programs emphasize crewmember safety, awareness, effectiveness, and teamwork.

In the midst of all of today's technological changes, there are two factors that have undergone little change — (1) the atmosphere in which we conduct aerospace operations, and (2) the physiologic requirements unique to our human nature. Each time you fly, you enter an environment where changes in ambient pressure (the immediate surrounding atmospheric pressure), weather and temperature can pose significant hazards. Therefore, it's imperative for you to know the characteristics of the atmosphere. This knowledge will form a basis to understand the physiological limits to functioning in this dynamic environment.

Complete each lesson's assignment before reporting to class. Answers to the review exercises are located in *Attachment 1* of this student guide. If you answer incorrectly, review the material until you understand it. Review the material to ensure comprehension and retention.

Portions of this course are designated as High-Risk Training and are voluntary. A Training Time Out (TTO) may be called in any training situation whenever a student or instructor expresses concern for personal safety or a need for clarification of procedures or requirements exists. TTO is also an appropriate means for a student to obtain relief if he/she is experiencing pain, heat stress, or other physical discomfort. Calling "Time Out" or "Training Time Out," crossing the hands in a "T," or raising a clenched fist overhead constitutes request for a TTO.

Accordingly, students have the option to individually request termination of training. Any time the student makes a statement such as "I quit," "DOR", or words to that effect, the student shall be immediately removed from the training environment and referred to the appropriate division or training officer for administrative action.

Information

The Atmosphere

Objective 1 — Identify the composition of the earth's atmosphere.

For simplicity, the atmosphere is defined as the gaseous envelope surrounding the Earth. The atmosphere includes a vast mixture of gases and trace quantities of liquids and solids.

Atmospheric Functions

The atmosphere provides some unique functions that help sustain our existence on Earth.

1. It contains oxygen, essential for animal life and carbon dioxide, essential for plant life.
2. It is a shield that attenuates cosmic and ultraviolet radiation.
3. Precipitation occurs in the atmosphere, helping maintain the temperature and climate.

Atmospheric Composition

The composition of the atmosphere is remarkably constant up to about 300,000 feet. The gaseous envelope surrounding the Earth contains nitrogen, oxygen and argon with traces of carbon dioxide and inert gases (such as helium and neon). The approximate percentages of gases in the atmosphere are 78 percent nitrogen, 21 percent oxygen and 1 percent other gases (including 0.03 percent carbon dioxide). These percentages remain relatively constant with increased altitude.

Atmospheric Characteristics

Objective 2 — Identify atmospheric pressure and describe how it is caused.

Objective 3 — Identify the pressure of the U.S. Standard Atmosphere and where the greatest pressure change takes place.

Objective 4 — Identify standard units used to measure atmospheric pressure.

Objective 5 — Compute a temperature for a given altitude using the standard temperature lapse rate.

Pressure

Pressure is defined as force/area. Atmospheric or barometric pressure is the combined weight of all the atmospheric gases acting to create a force upon the surface of the Earth. This force is caused by gravity pulling gas molecules earthward and thermal and solar radiation expanding the gases outward toward space. The atmospheric density and resulting pressure decrease exponentially as one ascends from the earth's surface. Pressure can be measured at any altitude. Figure 1-1 indicates different methods of measuring the weight (pressure) of a column of the atmosphere. The weight of the atmosphere can be measured in pounds per square inch (psi), millimeters of mercury (mmHg), or inches of mercury (inHg). Atmospheric pressure readings will vary daily, depending on changing surface temperatures and high and low pressure areas.

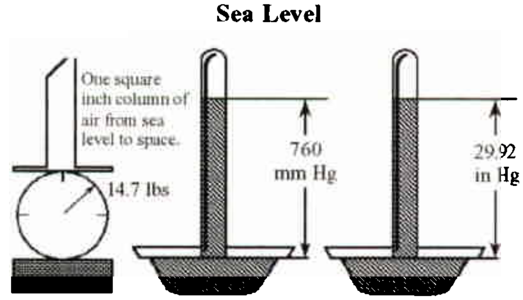


Figure 1-1 — Atmospheric Pressure Measurement

Pressure altimeters sense atmospheric pressure and convert the data into feet above mean sea level. To construct an instrument of this nature, a standard pressure reading for each altitude had to be developed. This standard which is referred to as U.S. Standard Atmosphere was computed by taking the average pressure and temperature readings for a year at mid-latitude locations. At sea level, these readings were determined to be +15 °C and 760 mmHg (29.92 inHg) pressure. Figure 1-2 shows the U.S. Standard Atmosphere pressures at various altitudes. The pressure at 18,000 feet is 379.4 or about one half of the pressure encountered at sea level. This illustrates that the greatest pressure change occurs at lower atmospheric levels between sea level and 18,000 feet.

When considering physiological effects of ambient pressure, we are interested in pressure altitude. Pressure altitude is your *actual* altitude above or below the *standard* sea level pressure of 29.92 inHg. Because the atmosphere is always changing, standard atmospheric pressures are seldom encountered. Pressure values at your location will be above or below the standard values. This difference in pressure affects your altitude above or below mean sea level (MSL) and is used to compute pressure altitude.

Note — At or above 18,000 feet in the United States, pressure altitudes are referred to as flight levels (FL). For example, 25,000 feet is referred to as FL250.

Temperature

The earth's surface temperatures vary day to day and season to season. Altitudes up to about 35,000 feet reflect a constant decrease in temperature of about 2 °C (3.6 °F) per 1,000 feet. This constant decrease is referred to as the standard temperature lapse rate. If it is 30 °C on the runway at sea level, then the temperature would be about -10 °C at 20,000 feet. By using the standard temperature lapse rate you can determine that there is a 40 degree Celsius change in temperature (-2 °C/1,000 feet).

Altitude (feet)	Barometric Pressure (mm Hg)	Difference per 1000 feet (mm Hg)
50,000	87.3	4.2
49,000	91.5	
43,000	121.9	6.0
42,000	127.9	
35,000	178.7	8.6
34,000	187.3	
25,000	281.8	12.6
24,000	294.4	
18,000	379.4	15.9
17,000	395.3	
10,000	522.6	20.6
9,000	543.2	
Sea Level	760.0	

Figure 1-2 — U. S. Standard Atmosphere

Physiological Divisions of the Atmosphere

Objective 6 — Identify the physiological divisions of the atmosphere.

Physiological Zone

The physiological zone extends from sea level to approximately 10,000 feet and is the zone the human body is adapted to. Life above this zone requires considerable acclimatization. During ascent in the physiological zone, atmospheric pressure drops from 760 mmHg to 523 mmHg. Even though the oxygen partial pressure (PO_2) falls, the body's compensatory mechanisms keep oxygen delivery within normal limits. Only at the upper boundary of the physiological zone and in tissues with very high O_2 requirements, e.g., the retina, are symptoms of O_2 deficiency noted. When flying unpressurized above 10,000 feet MSL, the use of supplemental oxygen is required. Also, trapped gas problems in body cavities can be a problem if not dealt with effectively.

Physiological Deficient Zone

This zone extends from approximately 10,000 feet to approximately 50,000 feet. Because of reduced atmospheric pressure, inadequate oxygen is available to sustain normal physiologic functions. Also, decompression sickness (caused by evolved gas) can occur in the body tissues and joints. This phenomena will be dealt with in later chapters. Atmospheric pressure decreases from 523 mmHg at 10,000 feet to 87 mmHg at 50,000 feet. Pressure suits are required above FL500.

Space Equivalent Zone

The space equivalent zone exists above 50,000 feet. The physiological problems of flight above 50,000 feet are essentially the same as those for space. The need for protection in a sealed cabin or pressure suit, the problem of ebullism (tissue water vaporization) above 63,000 feet, and other adverse influences on the body make this area of the atmosphere extremely hazardous for the human body (Figure 1-3).

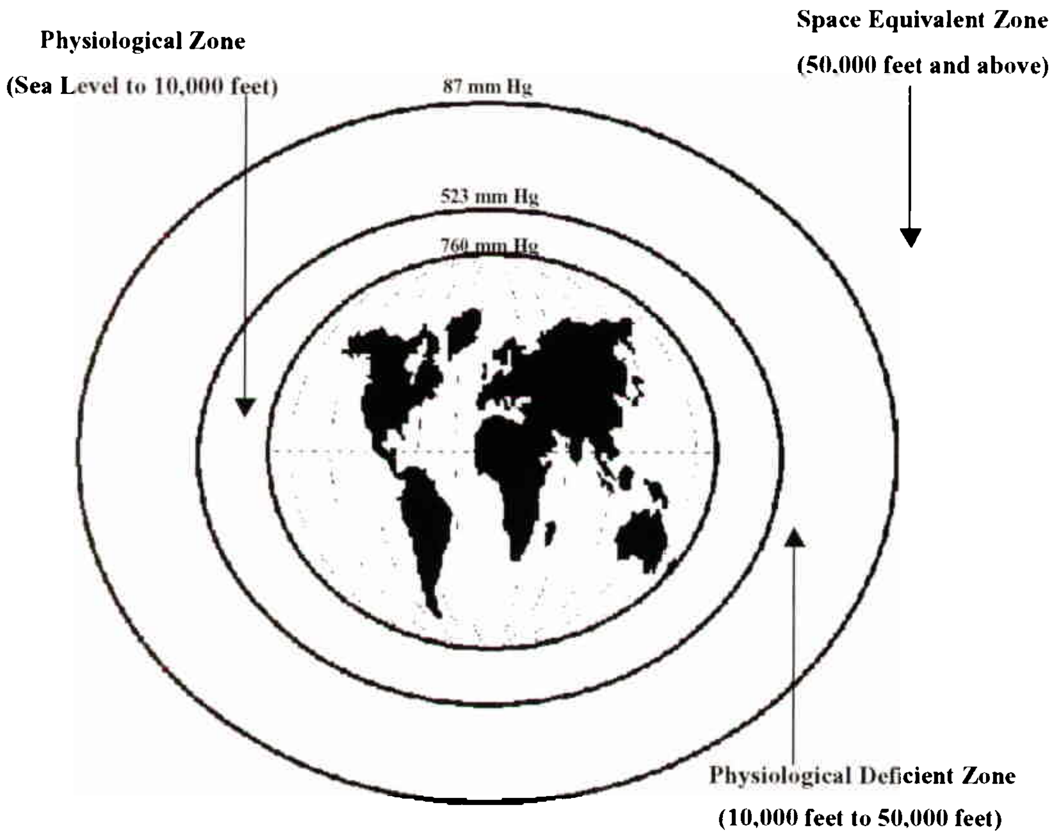


Figure 1-3 — Physiological Divisions of the Atmosphere

Gas Laws

Objective 7 — Define partial pressure and identify its notation.

Objective 8 — Describe each of the gas laws.

Objective 9 — Identify the physiological consequences of each gas law.

Most of the physiological results of ascent and descent within the earth's atmosphere can be explained by several elementary principles of gas behavior. These gas laws are the basis for much of the information in future lessons. To understand the gas laws you should have an understanding of the term "partial pressure."

Partial Pressure

Partial Pressure is defined as the amount of pressure that a single gas out of a mixture of gases contributes to the sum or total pressure of that mixture. The denotation for the partial pressure of Nitrogen, Oxygen, and Carbon Dioxide is PN_2, PO_2, PCO_2, respectively.

Dalton's Law

The total pressure of a mixture of gases is equal to the sum of the partial pressures of each gas in the mixture. The pressure exerted by each gas in a mixture is independent of other gases in the mixture. For example, the total pressure of the atmosphere at sea level is 760 mmHg this pressure equals $PN_2 + PO_2 + PCO_2$ and the partial pressure of other trace gases.

Dalton's Law explains how exposure to a high ambient altitude can reduce the available oxygen. As ambient altitude increases, the partial pressure of oxygen (PO_2) decreases even though the *percentage* of oxygen remains the same. For example, at sea level the PO_2 is 21 percent of 760 mmHg or 160 mmHg. Correspondingly, with a reduction of total pressure, the partial pressure of each gas will decrease. At 18,000 feet, PO_2 is 21 percent of 380 mmHg or 80 mmHg.

Boyle's Law

When the temperature remains constant, as in the human body, a volume of gas is inversely proportional to the pressure surrounding it. This principle explains why a balloon expands as it ascends and also why a volume of air expands when trapped in a body cavity when the pressure is reduced around it. Boyle's Law explains for the effects of pressure changes in the ears, sinuses, teeth and gastrointestinal tract.

Henry's Law

The amount of gas in a solution varies directly with the partial pressure of that gas over the solution. Therefore, if pressure is reduced above the solution, some gas will come out of solution. This principle explains why carbon dioxide bubbles are released when a carbonated beverage container is opened or why nitrogen bubbles may come out of solution in body tissues during ascent. The nitrogen bubbles can lead to altitude-induced decompression sickness.

The Law of Gaseous Diffusion

A gas will diffuse from an area of higher concentration or pressure to an area of lower concentration or pressure until equilibrium is reached. The speed of this movement depends on the relative concentrations of the gases (strength of the diffusion gradient). The physiological significance of this law relates to transfer of gases between the blood or other body fluids and the tissues they contact. For example, the gas transfer that takes place in the lungs by oxygen moving out of the lungs to the bloodstream and carbon dioxide moving from the bloodstream into the lungs.

Charles' Law

When volume is constant, the pressure of a gas increases or decreases proportionally to an increase or decrease in its temperature. Evidence of this law can be seen in the small decrease in pressure recorded from an oxygen cylinder taken from ground level on a hot day to an unpressurized aircraft altitude of 10,000 feet. Consequently, the cooler temperature at this altitude leads to a decrease in the pressure within the cylinder.

Summary

The overall goal of Aerospace Physiology is to train crewmembers to increase safety and mission effectiveness through the identification and elimination of physical, physiological, and psychological limitations of the flying environment. We began by examining the physical environment in which aircraft operate, the atmosphere, and how those gasses behave according to various gas laws. As altitude increases the ambient pressure decreases but the relative makeup of the gasses in the atmosphere remains the same. Human adaptation to these changes led to the definition of three physiological zones within the atmosphere — the physiological zone, the physiological deficient zone, and the space equivalent zone. Finally, in order to understand some of the physiological changes that occur with changes in altitude, we must first understand their cause. Most of these physiological changes are caused by elementary principles of gas behavior, the gas laws. Now that we have a better understanding of the aerospace environment, we can examine how our body is affected by this environment as we travel through it.

Review Exercise JP(0)101

Complete the following review exercise by choosing the correct answer(s) or filling in the blanks. Answers are at Attachment 1.

1. What is the approximate percentage of oxygen, nitrogen and other gases at 18,000 feet MSL?

   a. 21 percent oxygen, 78 percent nitrogen and 1 percent other gases.

   b. 15 percent oxygen, 39 percent nitrogen and 0.015 other gases.

   c. 78 percent oxygen, 21 percent nitrogen and 3 percent other gases.

2. Which of the following is the best description of atmospheric pressure and its cause?

   a. The combined weight of all the atmospheric gases which is caused by thermal and solar radiation.

   b. The combined weight of all the atmospheric gases which is caused by gravity pulling the gas molecules earthward and thermal and solar radiation expanding the gases outward toward space.

   c. The weight of gas around the Earth which is caused by thermal and solar radiation.

3. What are the common units used to measure atmospheric pressure?

   a. Inches of mercury (inHg)

   b. Millimeters of mercury (mmHg)

   c. Pounds per square inch (psi)

   d. All the above are correct.

4. Which of the following represents the notation for the partial pressure of gases?

   a. PPO_2 partial pressure of oxygen, $PPCO_2$ partial pressure of carbon dioxide, PPN_2 partial pressure of nitrogen.

   b. PO_2 partial pressure of oxygen, PCO_2 partial pressure of carbon dioxide, PN_2 partial pressure of nitrogen.

   c. psi O_2 partial pressure of oxygen, psi CO_2 partial pressure of carbon dioxide, psi N_2 partial pressure of nitrogen.

5. PO_2 increases and the percentage of oxygen decreases as the altitude increases.

   a. True

   b. False

6. What is the temperature lapse rate up to approximately 35,000 feet?

   a. About 2 °C per 1,000 feet

   b. 3.25 °C per 1,000 feet

   c. About 1 °C per 2,000 feet

7. The human body is adapted to which physiological division of the atmosphere?

   a. Space equivalent zone

   b. Physiological deficient zone

   c. Physiological efficient zone

   d. Physiological zone

8. Match each gas law with its explanation

   a. ____ Boyle's law

   b. ____ Henry's law

   c. ____ Dalton's law

   d. ____ Charles' law

   e. ____ The law of gaseous diffusion

   A. Explains why the temperature increases in a cylinder that is being pressurized.

   B. Explains why a balloon expands as it ascends and also why a volume of air expands when trapped in a body cavity when the pressure is reduced around it.

   C. Explains how oxygen moves out of the lungs into the bloodstream.

   D. Explains why a soda pop bubbles after it is opened.

   E. Explains how exposure to a high altitude can reduce the available oxygen

Lesson JP(0)102 — 0.5 Hours (IBT)

Respiration and Circulation

Objectives

1. Identify the structures and functions of the respiratory system.
2. Identify the primary control of normal respiration.
3. Identify the structures and functions of the circulatory system.
4. Identify factors affecting oxygen delivery to the tissues.

Assignment

Read JP(0)102 in the SG and answer the review questions.

Introduction

Respiration is the process our body uses to exchange gases with our environment. The primary purpose of respiration is to provide oxygen to, and remove excess carbon dioxide from, the body. The respiratory process also helps maintain the acid-base balance (pH) of the blood.

Respiration involves ventilation of the lungs, oxygen diffusion from the lungs to the blood, circulation of the blood throughout the body delivering oxygen to body cells, and the diffusion of oxygen from the blood into each individual cell. Oxygen is then used in cellular respiration (metabolism). Metabolism is defined as the sum of all the physical and chemical processes used by cells to produce energy and building materials needed to sustain life.

Information

Respiration

Objective 1 — Identify the structures and functions of the respiratory system.

Objective 2 — Identify the primary control of normal respiration.

Phases of Respiration

Respiration encompasses three distinct phases — ventilation, transportation and utilization (Figure 2-1). Each phase has a specific function in the overall exchange of gases.

Ventilation — is the volume of gas exchanged between the lungs and the ambient environment per unit time. This process is regulated to provide adequate delivery of oxygen and removal of carbon dioxide to satisfy the demands of metabolism.

Transportation — links the transfer of gases from the lungs to their site of production or use in the cells of the body.

Utilization — is cellular metabolism. This phase involves the use of oxygen in energy production and the production of carbon dioxide and water.

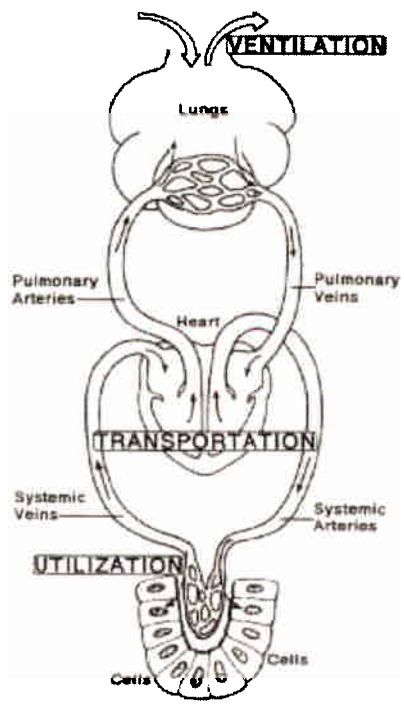


Figure 2-1 — Phases of Respiration

Anatomy and Physiology of the Respiratory System

The more important structures of the respiratory system are shown in Figure 2-2.

The Oral-Nasal Cavities — (mouth, pharynx, etc.) are lined with a mucous membrane. Hair like structures (cilia) in the nasal cavity mucous membrane filter inspired air. The oral cavity plays a lesser role in filtering the air, but regardless of the pathway, air is humidified and heated to body temperature before entering the lungs. Humidifying and warming the air protects the lungs from being cooled or dried out. Inhaling through the mouth, especially in cold, dry climates, does not allow air to be sufficiently warmed or humidified. Long term exposure of the lower lung to cool dry air can lead to infection.

Trachea — or windpipe divides into two branches, one each to the left and right lung. These branches (bronchi) form part of the root structures of the lungs' air passages.

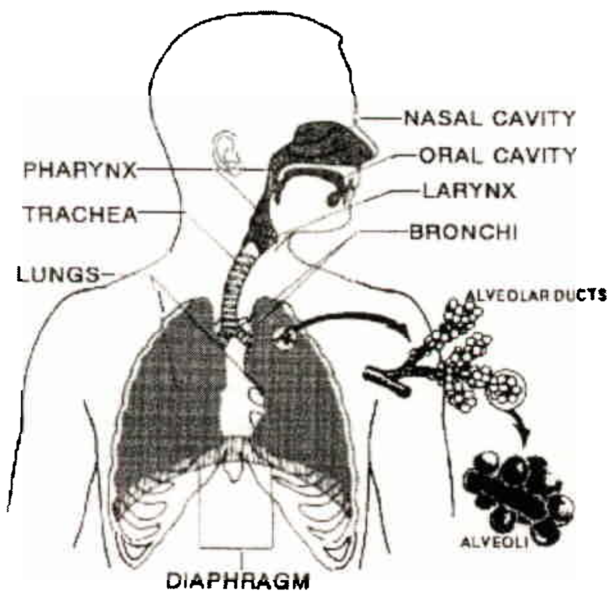


Figure 2-2 — Anatomy of Respiration

Lungs — occupy the greatest part of the chest or thoracic cavity and connect to the bronchi. The lungs' prime function is to allow oxygen to move from the air to the microscopic blood vessels (capillaries) and carbon dioxide to move from the capillaries into the lungs. The bronchi of each lung subdivide becoming narrower, shorter and more numerous as they penetrate deeper into the lung. The bronchi branch until they become bronchioles. The bronchioles continue to branch until they become the alveolar ducts, leading to the alveoli.

Alveoli — are tiny air sacs in the lungs. Their walls have an excellent blood supply provided by capillaries. In the lung, gas exchange between the respiratory and circulatory systems occurs at the alveolar-capillary interface. Oxygen and carbon dioxide move between air and blood by simple diffusion, (Law of Gaseous Diffusion) from an area of high to low partial pressure, much like water flows downhill.

Composition of Inspired Air — Excluding trace amounts of other gases, air is composed of nitrogen and oxygen. Although the partial pressure of oxygen (PO_2) at sea level is about 160 mm Hg, the PO_2 of alveolar air is only about 100 mm Hg. This difference occurs because air becomes saturated with water vapor before reaching the alveoli and because the alveolar air contains a significant concentration of CO_2 Both factors reduce the PO_2 in the alveoli. Oxygen partial pressure is the driving force for the flow of O_2 from the lungs to the site of use. For this reason, decreased oxygen availability becomes a critical factor during high altitude aircraft decompressions.

Oxygen regulators typically used in fighter and trainer- type aircraft are designed to increase the fraction of oxygen in the inspired air as altitude increases. These oxygen regulators deliver 100 percent oxygen by FL340; breathing this oxygen is equivalent to breathing ambient air at sea level. At FL400, breathing 100 percent oxygen at ambient pressure is equivalent to breathing air at 10,000 feet. At altitudes greater than FL400, even while breathing 100 percent oxygen, the alveolar PO_2 is insufficient to maintain normal body function. To achieve higher altitudes, additional methods of increasing alveolar PO_2 must be used, i.e., 100 percent oxygen must be delivered at greater than ambient pressure.

The Dynamic Nature of the Lungs — In adults, the tidal volume (the amount of gas inspired or expired with each normal breath) is about 500 milliliters. This air is normally exchanged an average of 12 to 16 times per minute.

The *active* phase of respiration is *inspiration*. It is accomplished by the contraction (downward movement) of the diaphragm and external intercostal muscles. This contraction increases the dimensions of the chest cavity, resulting in an overall increase in lung volume and a drop in lung pressure below ambient pressure. The decrease in pressure and increase in volume permits the lungs to expand, filling the chest cavity.

During routine exhalation, as the diaphragm relaxes, the lungs return to their original position. Lung volume decreases and internal lung pressure increases. Once again, a momentary pressure differential exists between the lungs and ambient air. However, the greater pressure now exists within the lungs, and air moves from the lungs to the environment.

Muscular effort is not required during exhalation. Therefore, *exhalation* is referred to as the *passive* phase of respiration. Continuous positive pressure breathing tends to reverse the normal breathing pattern with inspiration becoming passive and expiration becoming active.

Integrated Responses

Now that we have looked at the various units which make up the respiratory control system, it's useful to consider the overall response of the system to changes in the arterial PCO_2, PO_2 and pH.

Response to PCO_2 — *The most important factor in the control of ventilation under normal conditions is the PCO_2 of the arterial blood.* The sensitivity of this control is remarkable. In the course of daily activity with periods of rest and exercise, the arterial PCO_2 is probably held to within 3 mm Hg of 45 mm Hg.

A reduction in arterial PCO_2 is very effective in reducing the stimulus for ventilation. For example, if you hyperventilate voluntarily for a few seconds, you will find that you have no urge to breathe for a short period.

Response to PO_2 — Arterial PO_2 can normally be reduced from the normal 100 mm Hg to 50–60 mm Hg without evoking a ventilatory response, showing that the role of this hypoxic (low oxygen) stimulus in the day by day control of ventilation is small. However, on ascent to high altitude, a large increase in ventilation can occur in response to lack of sufficient PO_2 (your tidal volume and respiratory rate both increase at higher altitudes).

Response to pH — A reduction in arterial blood pH increases ventilation. It is difficult to separate the ventilatory response caused by a fall in pH from that caused by an accompanying increase in PCO_2. However, it has been shown that ventilation is stimulated whenever PCO_2 is held constant and the pH allowed to fall. The chief site of this action is probably the peripheral chemoreceptors.

Note — Breathing can also be controlled by involuntary means. Involuntary control occurs when certain emotional stresses such as fear, anxiety, or apprehension cause an abnormal increase in your breathing. This mechanism may take precedence over normal chemical control. Involuntary control can be overcome by consciously controlling your rate and depth of breathing. In this way, you can combat the adverse effects of certain stresses on the process of ventilation.

Circulation (Transportation)

Objective 3 — Identify the structures and functions of the circulatory system.

Objective 4 — Identify factors affecting oxygen delivery to the tissues.

The circulatory system (Figure 2-3) transports and distributes nutrients and oxygen to the tissues and removes waste products of metabolism. It also shares in the regulation of body temperature, hormonal communication throughout the body, and the adjustment of oxygen and nutrient supplies during different physiological states. The cardiovascular system that accomplishes these tasks is made up of a pump (heart), a series of distributing and collecting tubes (arteries and veins), and an extensive system of thin vessels that allow the rapid exchange between the tissues and the vascular channels (the capillaries). Before, however, discussing the function of the part of the circulatory system, it is important to describe the system as a whole.

Anatomy and Physiology of the Circulatory System

The Heart — consists of four chambers, but functions as two pumps in series — one to propel blood through the lungs, exchanging O_2 and CO_2 (the pulmonary circulation) and one to drive blood to all other tissues of the body (systemic circulation). Unidirectional flow through the heart is achieved by an arrangement of flap-like valves. Although the blood is pumped by the heart intermittently, continuous flow to the tissues is achieved by expansion and recoil of the arteries. Blood flows from the larger arterial vessels into progressively smaller arteries and finally into the arterioles. Since the size of the arterioles can be altered, tissue blood flow and arterial blood pressure may be regulated. Even smaller vessels, the capillaries, branch out from a single arteriole so that the cross-sectional area of the capillary bed is very large. As a result, blood flow becomes quite slow. Since the capillaries are normally short, have walls which are only one cell thick, and a slow

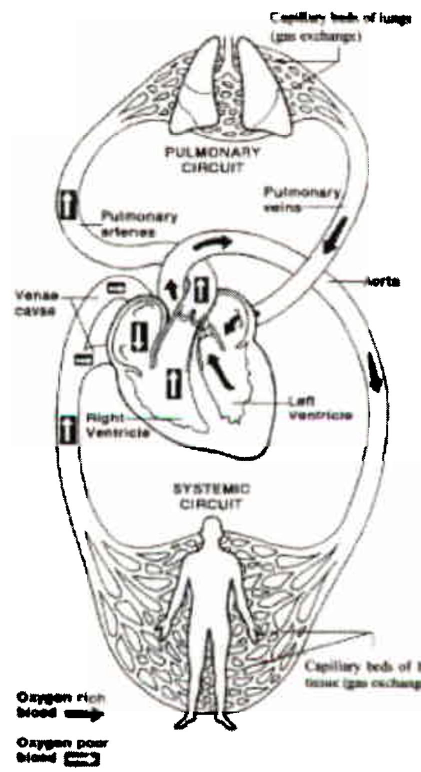


Figure 2-3 — Circulation (Transportation)

flow rate, conditions are ideal for diffusion of substances between blood and tissue.

On its return to the heart from the capillaries, blood passes through a series of progressively larger veins. However, as the heart is approached, the number of veins decreases, progressively reducing the cross-sectional area of the venous channels, which consequently increases the velocity of blood flow. Blood entering the right ventricle via the right atrium is then pumped through the pulmonary arterial system at a reduced pressure. The blood then passes through the pulmonary capillaries in the lungs where CO_2 is released and O_2 is taken up. Finally, the oxygen rich blood returns via the pulmonary veins to the left atrium and ventricle to complete the cycle. Circulation and blood volume remain relatively (i.e. a closed loop system) constant and an increase in the volume of blood in one area must be accompanied by a decrease in another.

Blood — circulating through the cardiovascular system is a mixture of cells within a liquid called plasma. The cells of the blood serve multiple functions essential for metabolism and defense of the body. However, in the brief discussion which follows, only O_2 and CO_2 delivery within blood will be discussed.

In the normal human adult, plasma makes up approximately 55 percent of the blood. The cellular constituents of blood include red blood cells, a variety of white blood cells, and platelets.

Red Blood Cells — The primary purpose of the red blood cell (RBC) is to transport O_2 and CO_2. It accomplishes this due to it's unique shape. RBCs are small biconcave, circular disks. They function as a transport mechanism for gases in particular oxygen and carbon dioxide. It is the hemoglobin in the RBCs that is responsible for this activity. Each RBC contains up to 300 million hemoglobin molecules. This gives RBCs a substantial oxygen carrying capacity. Although the hemoglobin can carry CO_2, it usually does not. The main function of hemoglobin is to transport oxygen.

Factors affecting oxygen delivery to the tissues

Several aviation-related factors can effect the delivery of oxygen to the tissues. A lack of oxygen in body tissues that is sufficient to cause an impairment of function is called *hypoxia*.

1. **Altitude** — An increase in altitude will reduce the PO_2 of inspired air causing *hypoxic hypoxia*.

2. **G-forces** — Blood pooling in the lower extremities during increased-g maneuvering can cause *stagnant hypoxia*, another factor that can reduce oxygen delivery to tissues.

3. **Toxic gases** — Various types of toxic gases can cause the blood to carry less oxygen (*hypemic hypoxia*) or the tissues to be unable to take up or use oxygen (*histotoxic hypoxia*).

The effect of these factors is cumulative on the body and can and have resulted in aircraft mishaps.

Summary

The respiratory and circulatory systems are the primary method through which we bring oxygen and other vital nutrients to the different parts of the body and remove carbon dioxide and other waste products from the body. Respiration as a whole involves three phases — ventilation, transportation, and utilization. Ventilation involves inhalation and exhalation through the oral-nasal cavity and trachea to the lungs. Gas is exchanged at the alveolar level within the lung. Normal ventilation is controlled subconsciously and adapts to changes in PCO_2, PO_2, and pH.

The next phase of respiration, transportation, is accomplished by the circulatory system. The heart serves as the pump moving the blood throughout the body and through the lungs for gas exchange. The blood is made up of plasma and three types of blood cells. Of these blood cells, it is the red blood cells that contain the oxygen-carrying chemical hemoglobin. In aviation altitude, G forces, and toxic gasses all have the potential to affect the ability of the respiratory and circulatory systems to deliver adequate amounts of oxygen to the tissues. When this lack of oxygen is at a level where it begins to impair function it is known as hypoxia. Hypoxia, as well as the other physiological threats associated with altitude are discussed in the next lesson.

Review Exercise JP(0)102

Complete the following review exercise by choosing the correct answer(s) or filling in the blanks. Answers are at Attachment 1.

1. The purpose of respiration is to get_________________into the body and remove excess__________________ _______________.

2. What is/are the site(s) of gas exchange in the lung between the atmosphere and the blood?
   a. Trachea
   b. Bronchi
   c. Alveoli
   d. All the above are correct.

3. What is the normal breathing rate of an average adult?
   a. 8-10 breaths per minute
   b. 10-12 breaths per minute
   c. 12-16 breaths per minute
   d. 20-22 breaths per minute

4. What is the most important factor in the control of ventilation under normal conditions?
   a. PCO_2
   b. PO_2
   c. Red blood cells
   d. White blood cells

5. What is the main function of red blood cells?
   a. Fight infections
   b. Carry oxygen
   c. Transport nutrients
   d. All the above are correct.

Lesson JP(0)103 — 2.0 Hours (IBT)

Altitude Threats

Objectives

1. Identify the signs and symptoms of hypoxia.
2. Explain the importance of immediately correcting for hypoxia after a rapid decompression.
3. Identify the procedures to treat hypoxia.
4. Identify the procedures to treat hyperventilation.
5. Identify why the treatment procedures for hypoxia and hyperventilation are the same.
6. Identify the symptoms of trapped gas disorders.
7. Identify when trapped gas disorders are most likely to occur.
8. Explain how to treat and prevent trapped gas disorders.
9. Identify the symptoms of four common types of decompression sickness.
10. Identify the USAF/USN restrictions on SCUBA diving prior to flying.
11. Explain how to treat decompression sickness.
12. Identify the primary purpose for aircraft cabin pressurization.
13. Identify the physical indications of a rapid decompression.

Goal

Experience and treat hyperventilation under controlled classroom conditions.

Assignment

Read JP(0)103 in the SG and answer the review questions.

Introduction

Now that you have an understanding of the characteristics of the atmosphere and the functions of the circulatory and respiratory systems, we need to address how changes in atmospheric pressure effect the body. The following blocks of instruction will cover hypoxia, hyperventilation, trapped gas problems and decompression sickness. Also a detailed discussion of cabin pressurization systems will give you an understanding of how we prevent most of these physiological hazards of pressure change.

Information

Hypoxia

Objective 1 — Identify the signs and symptoms of hypoxia.

Objective 2 — Explain the importance of immediately correcting for hypoxia after a rapid decompression.

Objective 3 — Identify the procedures to treat hypoxia.

Hypoxia is an oxygen (O_2) deficiency sufficient to cause impairment of function. It occurs most frequently when protection against the fall in O_2 partial pressure at altitude fails.

The insidious onset is hypoxia's most dangerous characteristic. Hypoxia symptoms do not normally cause discomfort. In fact, many individuals perceive their symptoms as quite pleasant. During a slow decompression (where the cabin altitude gradually increases), hypoxia has a slow onset and the symptoms may be well developed before you recognize them. In some cases, you may not recognize the hypoxia and become impaired to the point of no longer being able to recover on your own.

Different types of hypoxia can occur at any altitude and at any time. In the following paragraphs, each form of hypoxia is defined and discussed in relation to its impact on oxygen delivery and utilization.

Types of Hypoxia

Hypoxic Hypoxia— results when there is a reduction of the PO_2 in the lungs. Hypoxic hypoxia is usually caused by exposure to low barometric pressure and is frequently referred to as *altitude hypoxia*. This reduced oxygen partial pressure can result from oxygen equipment malfunctions, improper use of oxygen equipment, and loss of cabin pressurization at altitude. It can also be produced by lung diseases such as emphysema.

The altitude threshold for hypoxic hypoxia is generally considered 10,000 feet MSL.

Hypemic Hypoxia — occurs when the O_2 carrying capacity of the blood is reduced. Hypemic hypoxia affects O_2 delivery by reducing the functional hemoglobin available for transporting O_2. Certain drugs and chemicals can combine with or alter the characteristics of hemoglobin and reduce its O_2 carrying capacity. For example, hemoglobin has an affinity for carbon monoxide (CO) about 200-250 times greater than with O_2.

The threat of inhaling carbon monoxide from smoke or fumes in the cockpit can be eliminated by using 100 percent oxygen.

Smoking cigarettes prior to flight, increases the amount of CO in the bloodstream and raises your physiological altitude. You then become more susceptible to hypoxic hypoxia because of the preexisting hypemic hypoxia.

Blood donation and bleeding injuries also deplete the RBC/hemoglobin supply and cause hypemic hypoxia. Therefore, donating blood while on flying status is not recommended. If you choose to donate blood you will be grounded for a period of time. (USAF: 72 hours; USN: up to 28 days)

Stagnant Hypoxia — occurs when reduction in cardiac output, pooling of the blood, or restriction of blood flow reduces O_2 delivery. Several conditions cause stagnant hypoxia. Two of these will be discussed in detail during subsequent instruction — hyperventilation and acceleration (G forces).

Stagnant hypoxia can also be caused by shock (blood pooling in dilated blood vessels) or cold temperatures (constricting the blood vessels of the extremities, causing pooling of blood in the body core). Even sitting very still for long periods of time can result in stagnant hypoxia. An individual passing out while standing in formation is an example of stagnant hypoxia.

Histotoxic Hypoxia— results when the O_2 delivered to the cells cannot be used for energy production. Adequate O_2 is available to the lungs and the blood is capable of carrying it to the tissues. However, the tissues and cells are unable to use the available O_2.

The primary cause of histotoxic hypoxia in a crewmember is cyanide. Cyanide, in the form of hydrogen cyanide gas (HCN), is a by-product of the combustion of plastics, insulation, seat covers, and other synthetic substances found on aircraft. HCN is highly toxic and extremely small concentrations (300 parts per million) cause incapacitation within seconds; death occurs within minutes. Therefore, you must not hesitate in donning oxygen equipment and breathing 100 percent oxygen.

Secondary causes of histotoxic hypoxia are alcohol and some medications. To reduce the possibility of mishaps, AFI 11-202, Volume 3, *General Flight Rules*, restricts alcohol consumption 12 hours prior to flight. OPNAVINST 3710.7 restricts alcohol consumption for 12 hours prior to flight planning. Both USAF and USN instructions restrict medication unless prescribed by a flight surgeon.

Factors Influencing Hypoxia

Altitude — Because of the low PO_2 above 10,000 feet MSL, both the USAF and USN require supplemental oxygen for flight above a cabin altitude of 10,000 feet.

Rate of Pressure Change — During an extremely rapid pressure change — such as a rapid decompression — the normal time of useful consciousness can be reduced by as much as 50 percent. Rapid decompression may reduce alveolar pressure below that of arterial blood, thereby reversing the direction of O_2 diffusion so that the blood is actually giving up O_2 through the lungs.

Duration of Exposure — There is a direct correlation between the effects of hypoxia and the duration of the exposure. The effects of an exposure become more detrimental as exposure time increases.

Individual Tolerance — There are variations in the tolerance of crewmembers to hypoxia. The reasons are not completely understood but individual metabolic rate and acclimatization to altitude are important factors.

Physical Activity — The times of useful consciousness at altitude are reduced with physical activity. Metabolic oxygen requirements are increased several times during exercise. The physical activity factor is most significant if you are required to be active while performing crew duties. For example, flying a contact mission and pulling Gs is more strenuous than flying a h igh altitude navigation mission.

Self-Imposed Stress — Your life-style effects all facets of your flying environment, including tolerance to hypoxia. Often, crewmembers impose unnecessary stresses upon themselves through tobacco use, poor sleep patterns, excessive alcohol consumption, improper diet, etc. Self-imposed stress and its overall impact on the crewmember will be discussed in detail in a subsequent lesson.

Recognition of Hypoxia

One of the reasons you attend aerospace physiology is to witness other crewmembers' signs and experience your own hypoxic hypoxia symptoms in the controlled environment of an altitude chamber. This experience enables you to identify signs of hypoxia in fellow crewmembers and experience your own individual symptoms.

The warning signals most important to you are those you actually feel or sense. They are emphasized to help you recognize hypoxia during flight.

Signs — of hypoxia can often be recognized by another individual. These include an *increase in rate and or depth of breathing*, *cyanosis* (blueness of the skin, because of insufficient oxygenation of the blood), *mental confusion*, *poor judgment*, *loss of muscle coordination*, and *unconsciousness*. Behavioral changes, such as *euphoria* (an exceptional feeling of well-being) or *belligerence*, may be noticed by the hypoxic individual as well as other observers.

Symptoms — are the warning signals most important to the crewmember. These are the symptoms only *you* can actually sense and identify. Subjective symptoms are emphasized as a means to recognize hypoxia during flight. Hypoxia symptoms are very individualized and can include *dizziness*, *fatigue*, *hot and cold flashes*, *blurred vision*, *tunnel vision*, *tingling* and *numbness*. *Euphoria* and *belligerence* may also be experienced. Occasionally, unpleasant symptoms such as *headache*, *nausea*, *a feeling of apprehension* and *air hunger* are experienced by crewmembers. The altitude chamber hypoxia demonstrations allow you to experience your own personal symptoms so you may identify hypoxia should it happen to you in the aircraft.

Altitude	TUC
FL180	20 to 30 minutes
FL250	3 to 5 minutes
FL300	1.5 to 2 minutes
FL350	0.5 to 1 minute
FL400	15 to 20 seconds
FL430	9 to 12 seconds
FL500 and above	9 to 12 seconds

Figure 3-1 — Times of Useful Consciousness

Time of Useful Consciousness (TUC) — is the period of time from the interruption of the oxygen supply or exposure to an oxygen poor environment, to the time when useful function is lost. You are no longer capable of taking proper corrective and protective action, but are still conscious. I is *not* the time to total unconsciousness. At higher altitudes, the TUC becomes very short. Figure 3-1 shows mean TUC for resting individuals at various altitudes. Exercise or stress will reduce these times. Additionally, a rapid decompression can reduce TUC by as much as 50 percent. For example, at FL350, the mean TUC is approximately 30 to 60 seconds. After a rapid decompression, the mean TUC would only be 15 to 30 seconds.

Prevention of Hypoxia

You are responsible for your own oxygen equipment. You must ensure your equipment is working correctly. Always preflight your helmet and oxygen mask at the life support shop or paraloft to ensure correct function. If problems are detected, they can be corrected prior to reaching the aircraft.

Once in the aircraft, thoroughly preflight your oxygen regulators and systems prior to takeoff. After the aircraft is airborne, additional checks are required to ensure the aircraft oxygen and pressurization systems are functioning correctly. Reference your *Dash 1* or *NATOPS* manual for specific procedures.

Treatment of Hypoxia

Immediate corrective actions must be taken when hypoxia symptoms are recognized or when a decompression occurs. 100 percent oxygen must be administered through an oxygen mask. The type of mask and delivery system used depends on the aircraft flown, your crew position and your immediate location in the aircraft during the emergency. Specific corrective actions are listed in each aircraft's flight manual. The following procedures are generalized to include corrective actions for all the aircraft used in joint undergraduate flying training.

1. **Maximum Oxygen Under Pressure** — is your first priority when correcting for hypoxia. When using narrow panel pressure demand or diluter demand-type regulators, like those found in the T-34, T-6, T-37, T-43 flight deck, and the altitude chamber, this is accomplished by placing all three switches in the full-up position. This is known as "gangloading" the regulator. For speed, the procedure should be accomplished with a single sweep of the hand. "Gangloading" the regulator will place it in the On, 100 percent/Max oxygen, emergency pressure setting. In the training compartment of the T-43 the flow 100 percent oxygen under pressure is started by pulling on the passenger oxygen mask enough to remove the valve pin after the mask has dropped from its storage compartment.

Note — If you suspect a problem with your aircraft oxygen supply or regulator, you may need to activate an alternate oxygen system (such as an emergency oxygen cylinder located in a parachute or seat kit in a single/dual-seat aircraft and the yellow walk around bottle or protective breathing equipment located in multi-place aircraft).

2. **Connections - Check Security** — Equipment function, connections and oxygen system pressures must be quickly evaluated when hypoxia symptoms are recognized or suspected. Equipment preflight and frequent inflight monitoring will reduce the occurrence of hypoxia.

Note — Immediately after completing the first two steps of your emergency procedures, communicate with fellow crewmembers.

3. **Breathe at a Rate and Depth Slightly Less Than Normal Until Symptoms Disappear** — Recovery from hypoxia usually occurs in a few seconds following the administration of 100 percent oxygen. However, if the cause of hypoxia is smoke and fumes or chemicals, the recovery period may be considerably longer. For this reason it is imperative to continue breathing 100 percent oxygen. Your respiratory rate may increase because of anxiety from the incident. If your respiratory rate is not controlled, hyperventilation may result. Respiration monitoring should be accomplished simultaneously with the initial corrective steps. If your subjective symptoms have been caused by hyperventilation rather than hypoxia, monitoring your rate and depth of breathing should eliminate them.

4. **Descend Below 10,000 Feet and Land as Soon as Possible** — If your symptoms persist after completing the initial corrective steps, descend below 10,000 feet MSL. Descending will not counteract hyperventilation and you must continue to monitor your rate and depth of breathing.

Monitor and control your rate and depth of breathing to prevent hyperventilation during recovery from hypoxia. Doing so is particularly important during recovery from hypoxia for crewmembers using passenger masks. Do not overbreathe the reservoir bag. Overbreathing causes the bag to collapse and ambient cabin air to be inhaled.

Pressure Breathing — delivers oxygen, under pressure, through the crewmember's oxygen mask. It is a method of maintaining adequate PO_2 in the lungs at cabin altitudes above 40,000 ft.

The aircraft oxygen system provides an increased fraction of oxygen as cabin altitude is increased above 1,000ft. Breathing 100 percent oxygen at FL340 is equivalent to breathing ambient air at sea level. Above FL400 (cabin altitude) , breathing 100 percent oxygen alone is not adequate to prevent hypoxia and positive pressure breathing is needed.

Pressure breathing has limitations. It reverses the normal breathing cycles; inspiration becomes passive and expiration now requires active effort. Over-inflation of the lungs from pressure breathing inhibits exhalation and reduces venous return to the heart. This reduction in venous return may result in stagnant hypoxia and is the most limiting factor of pressure breathing.

Note — Hyperventilation may occur during pressure breathing if you do not control your rate and depth of breathing. Pausing between breathing phases will help prevent hyperventilation and can be learned with practice in the altitude chamber. Familiarize yourself with the process to minimize or eliminate problems when treating for hypoxia symptoms or following a loss of cabin pressurization.

Interim Summary

Hypoxia means low oxygen. Remember, hypoxia can occur at any altitude and at any time.

To prevent hypoxia, preflight your oxygen systems and constantly monitor the aircraft oxygen and pressurization systems. If cabin pressurization is lost, initiate steps for your oxygen system in your aircraft to deliver maximum oxygen under pressure, don your oxygen mask, check connections (notify the crew), monitor your rate and depth of breathing, and descend to an altitude not requiring supplemental oxygen.

Hyperventilation

Objective 4 — Identify the procedures to treat hyperventilation.

Objective 5 — Identify why the treatment procedures for hypoxia and hyperventilation are the same.

Goal — Experience and treat hyperventilation under controlled classroom conditions.

Hyperventilation is a condition in which the rate and or depth of breathing is abnormally increased. This increase causes an excessive loss of carbon dioxide (CO_2) from the blood. The excessive loss of CO_2 changes the acid-base balance of the blood making it more alkaline.

It is very important for you to understand the causes and recognize the symptoms of hyperventilation to avoid the associated problems. Hyperventilation can occur in a number of different ways, but the primary cause of hyperventilation in crewmembers is emotional; e.g. fear, anxiety or stress.

Causes of Hyperventilation

Voluntary— The normal respiratory rate is 12 to 16 cycles per minute. Normally, we are not aware of respiratory rate because breathing requires no conscious effort. However, we can voluntarily alter our breathing rate at will. Therefore, hyperventilation can be voluntarily induced or corrected by consciously increasing or decreasing the rate and depth of breathing. In a classroom demonstration, you will experience the symptoms of hyperventilation.

Involuntary — Emotional stress can also override normal respiratory controls. Fear, apprehension, tension or stress will sometimes cause an individual to subconsciously increase their rate and or depth of breathing. These stress factors are the most frequent causes of hyperventilation. However, positive pressure breathing can also contribute to hyperventilation.

Pay particular attention to possible increased rates and or depths of breathing during initial flying sorties or whenever new flying techniques are encountered or stressful situations are experienced. Changes in breathing can occur very insidiously.

While hyperventilation occurs more frequently with inexperienced crewmembers, it will remain a potential hazard throughout your flying career. Always be aware of the possibility of hyperventilation.

Recognition of Hyperventilation

Signs — most often observed in hyperventilation are increased rate and depth of breathing, muscle tightness and twitching, paleness, cold clammy skin, muscle spasms, rigidity and unconsciousness.

Symptoms — most often noted are dizziness, faintness, slight nausea, numbness, tingling or coolness and muscle tremors.

Prevention of Hyperventilation

The most effective way to prevent hyperventilation is to *control your rate and depth of breathing*. Continually monitor your rate and depth of breathing, especially during stressful situations.

Treatment of Hyperventilation

Since hyperventilation and hypoxia may be confused or occur at the same time, identical corrective procedures should be followed. Immediate corrective actions are required. Your most urgent requirement is a voluntary reduction in *your rate and depth of breathing*. In fact, when you treat for hyperventilation, you are also treating for hypoxia. Be certain to advise the other crewmember(s) of your hyperventilation symptoms.

1. **Maximum oxygen under pressure**

Note — 100 percent/max oxygen does not compensate for decreased blood-carbon dioxide saturation caused by hyperventilation but serves to ensure that hypoxia is not mistaken for hyperventilation.

2. **Connections - Check Security** — Equipment function, connections and oxygen system pressures must be quickly evaluated when hyperventilation symptoms are recognized or suspected.

Note — Immediately after completing the first two steps of your emergency procedures, communicate with fellow crewmembers.

3. **Breathe at a Rate and Depth Slightly Less Than Normal Until Symptoms Disappear** — Respiratory monitoring should be accomplished simultaneously with the initial two corrective steps. If the symptoms you have recognized have been stimulated by hyperventilation, respiratory monitoring should eliminate them.

4. **Descend Below 10,000 Feet MSL and Land as Soon as Possible** — If your symptoms persist after completing the initial corrective steps and monitoring your respiratory rate, descend below 10,000 feet MSL. Descending will not counteract hyperventilation and you must continue to monitor your rate and depth of breathing.

Notes — (1) It may take longer to recover from hyperventilation than it does from hypoxia, assuming the correct treatment is applied for both conditions.

(2) If you recover from your symptoms and the aircraft's pressurization and oxygen equipment checks good, immediate descent below 10,000 feet MSL may not be necessary. However, a physiological incident has occurred. The mission should be terminated and a flight surgeon consulted.

(3) In multiplace aircraft, speaking is often the best method of controlling hyperventilation.

Interim Summary

Hyperventilation is a condition where your rate and or depth of respiration is abnormally increased. It is caused primarily by emotional stress (fear, stress, anxiety, etc.). Hyperventilation will result in an excessive loss of CO_2.

As CO_2 is eliminated during hyperventilation, the acid-base balance of the blood and tissues becomes more alkaline (basic). This change reduces your urge to breathe. The symptoms of hyperventilation are similar to hypoxia, including nausea, tingling, muscle tremors and cold, clammy skin. Unconsciousness may occur.

Since the symptoms of hyperventilation are very similar to hypoxia symptoms, diagnosis of hyperventilation in the aircraft is difficult. Therefore, the treatment for hyperventilation is the same as for hypoxia.

Trapped Gas Disorders

Objective 6 — Identify the symptoms of trapped gas disorders.

Objective 7 — Identify when trapped gas disorders are most likely to occur.

Objective 8 — Explain how to treat and prevent trapped gas disorders.

Boyle's Law states the volume of a gas is *inversely* proportional to the ambient pressure. Therefore, changes in ambient pressure during flight will result in changes in the volume of body gases.

The human body can withstand these changes, including expanding gas pressure buildup, when the pressure can be relieved. However, difficulty (usually in the form of pain) results when the expanding gas cannot escape. The gas is then considered "trapped." With further decrease of ambient pressure (ascent), a greater increase in volume or pressure within the cavity occurs. These increases sometimes result in pain. Figure 3-2 shows the areas most often affected by the change in pressure.

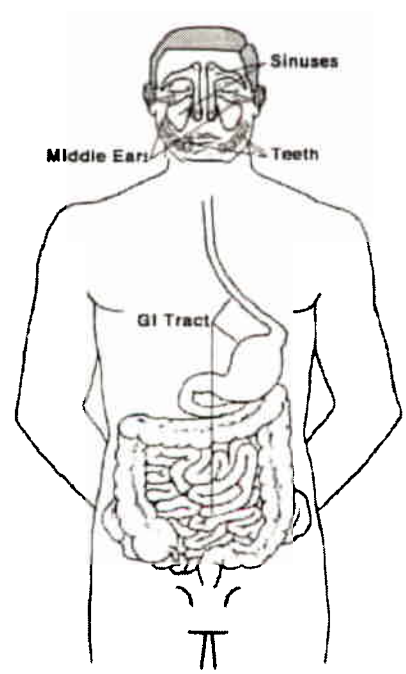


Figure 3-2 — Areas of Trapped Gas

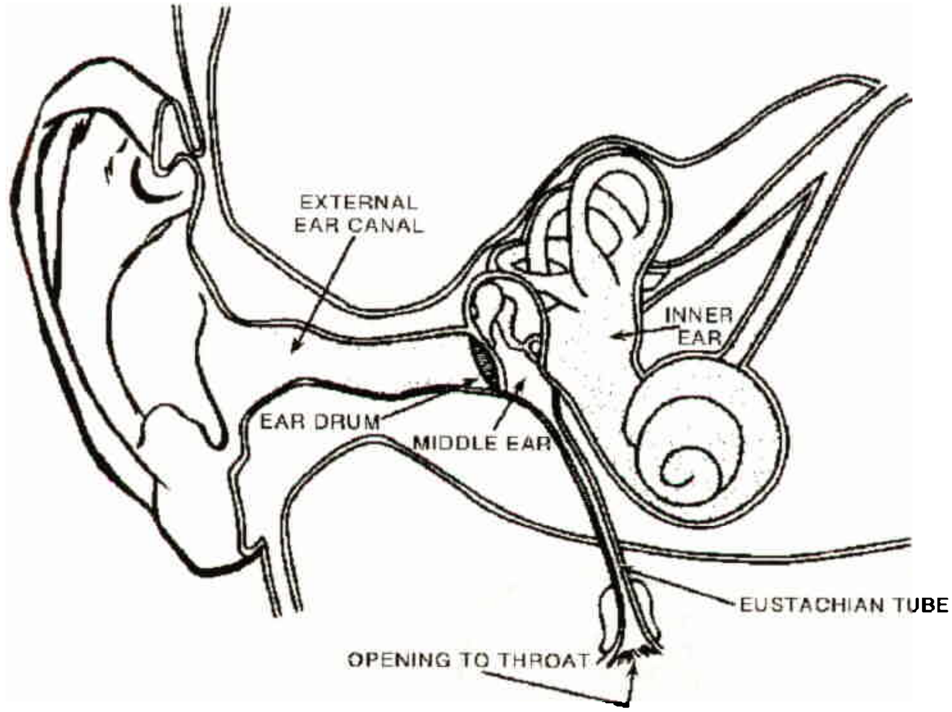


Figure 3-3 — Anatomy of the Ear

Middle Ear

Anatomy— The middle ear cavity is connected to the throat by the eustachian tube (Figure 3-3). The eustachian tube has a slit-like opening at the throat end, allowing middle ear air pressures to vent outwardly more easily than inwardly. During ascent, excess pressure in the middle ear caused by gas expansion will escape through the unobstructed eustachian tube with little or no effort. The released pressure is often accompanied by a physical "click" in the ears. During descent, however, the opening of the eustachian tube acts as a one-way flapper valve and resists equalization of ambient and middle ear air pressures. The increased ambient pressure forces the eardrum inward and you must assist the equalization process.

The Valsalva Maneuver — Equalizing air pressure during descent may be accomplished by swallowing, yawning, tensing the muscles in the throat, moving the head from side to side, extending the jaw forward or rocking the jaw from side to side. However, the most effective way to equalize the pressure in the middle ear is the use of the Valsalva maneuver; force air into the middle ear by closing the mouth, pinching the nose closed and forcefully exhaling. This method forces air through the previously closed eustachian tube and equalizes the pressure differential between the middle ear and the atmosphere. Practice in clearing the ears can improve and sustain the rate of descent without discomfort. Some crewmembers find they must use the Valsalva maneuver frequently during descent without waiting for a sensation of discomfort. Others use the Valsalva maneuver as soon as they recognize fullness, ringing of the ears, decreased ability to hear or pain. With experience you will develop your own technique, but it is best to not wait until you feel pain before you do the Valsalva.

Ear Block — Problems with the ears occur more often at altitudes closer to the earth's surface where there are greater pressure changes. If the pressure differential of the atmosphere over the middle ear exceeds 80 mmHg, it may be impossible to open the eustachian tube with equalization pressure methods. This condition is known as an *ear block*. If descent is continued, increasing pain and eardrum rupture will result. Prior to eardrum rupture, relief from pain can best be obtained by ascending to an altitude where pressure equalization methods can be used; a slow descent is then recommended. If an eardrum is ruptured, most pain will cease and healing normally occurs in 3 to 5 weeks. Usually there is no hearing impairment. This condition should always be reported to your flight surgeon.

An ear block is characterized by congestion, inflammation, discomfort, pain, and is usually followed by a temporary impairment of hearing. The eustachian tube opening is restricted by inflammation or infection from a head cold, allergy, sore throat, infection of the middle ear, sinusitis or tonsillitis. Forceful opening of the tube under these conditions may introduce infection into the middle ear and cause severe ear problems. In addition, infection can cause difficulty in clearing the ears resulting in sudden pressure changes. These pressure changes in the middle ear can affect the vestibular system of the inner ear, causing dizziness or disruption of equilibrium referred to pressure vertigo. If you are suffering from upper respiratory infections or apparent allergic reactions, **you should not fly or participate in an altitude chamber flight**. Consult a flight surgeon.

Delayed Ear Block (Post-Flight ear block) — can occur up to 2 to 6 hours after landing. It results from breathing a high percent oxygen for an extended period of time. As oxygen diffuses out of the middle ear into the surrounding tissues, a relative low pressure area results. The low pressure area allows the now greater ambient pressure on the exterior surface of the ear drum to deflect the ear drum inward, dulling the hearing and producing pain. Performing the Valsalva maneuver several times after flight can prevent a delayed ear block.

Sinuses

Anatomy — Sinuses are cavities in the bone of the skull and are lined with moist mucous membranes (Figure 3-4). Sinuses vent to the atmosphere through tiny slit-like openings into the nasal cavity. Under normal circumstances, the pressure is equal to the outside barometric pressure. The sinuses most frequently affected by pressure changes are the frontal sinuses, located above and behind each eye, and the maxillary sinuses, located in the bones of the cheeks beneath the eyes.

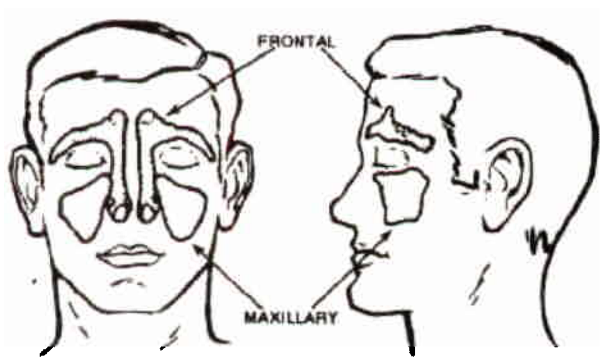


Figure 3-4 — Sinuses

Sinus Block — When pressure changes occur during ascent or descent, the gases in the sinuses increase or decrease in volume. Normally, sinuses vent with no discomfort. However, if the sinus ducts are swollen because of an upper respiratory infection, there may be a blockage of the ducts. This condition is called a *sinus block*. On ascent, blockage at the opening of the duct may prevent the expanding gas from venting to the outside, and localized pain will occur. However, blockage occurs more often on descent when the pressure difference across the duct is increased without relief. To prevent pain during descent, pressure must be equalized as rapidly as possible to relieve the differential and discomfort. The degree of pain will naturally depend on the pressure across the duct. The onset of sinus pain due to barometric pressure change is rapid. The Valsalva maneuver will usually alleviate the problem. If necessary, relief from pain can be obtained by ascending to an altitude where pressure equalization can be accomplished.

Blockage of the ducts leading to the maxillary sinuses may be mistaken for upper tooth pain because of their proximity to the upper teeth. All of the upper teeth will be affected as opposed to one isolated tooth and may be treated like any other sinus block. If isolated tooth problems continue on ascent, discomfort can be resolved by descent and landing. The flight surgeon and dental surgeon should be consulted after the flight.

Gastrointestinal (GI) Tract

Expansion of Trapped GI Gas — A problem that may be experienced with a decrease in atmospheric pressure is discomfort from expansion of gases in the GI tract. This problem is not usually serious at low altitudes. However, at the higher altitudes, enough expansion may occur to produce pain. Extreme discomfort may result unless the pressure is relieved by belching and or passing flatus. Sometimes relief is only gained by descent.

Crewmembers participating regularly in unpressurized high altitude flights should learn to avoid foods they know disagree with them. These foods may include onions, cabbage, raw apples, radishes, dried beans, cucumbers, melons and carbonated beverages. Eating irregularly or hastily also makes a crewmember more susceptible to gas pains. To reduce your chances of GI tract problems before flights, avoid hasty, irregular, and heavy meals, especially foods and beverages you know produce excess gas.

Notes — (1) Swallowed air is the primary source of stomach gas and digested food is the primary source of intestinal gas. At high altitudes, gas expansion in the GI tract may elevate the diaphragm and interfere with respiration.

(2) The relative change in volume produced by the same change in pressure is greater for a wet gas than for a dry gas.

Teeth

Tooth Pain can be experienced by crewmembers during ascent and is usually correctable. The altitude where tooth pain occurs varies. However, pain in a specific tooth can consistently occur at the same altitude at which it first occurred. The pain may or may not become severe as altitude increases. Descent invariably brings relief, with the pain disappearing at the same altitude where it was first observed. The incidence of tooth pain is low, but when it occurs, it can be excruciating.

Untreated cavities, especially those under restorations and where the pulp has become exposed, may be the cause of tooth pain at altitude. A less frequent cause of tooth pain on ascent is the presence of a root abscess that produces a small amount of gas. This trapped gas may expand and cause severe pain that can only be relieved by descent. Good dental hygiene is the most practical way to prevent tooth problems at altitude.

Decompression Sickness

Objective 9 — Identify the symptoms of the four common types of decompression sickness.

Objective 10 — Identify the USAF/USN restrictions on SCUBA diving prior to flying.

Objective 11 — Explain how to treat decompression sickness.

One of the most potentially dangerous effects of exposure to high cabin altitudes is *decompression sickness* (DCS). DCS is the disorder produced by the evolution of gas from tissues and fluids of the body (nitrogen bubble formation).

Henry's Law states the amount of gas in a solution varies directly with the partial pressure of that gas over the solution. When the atmospheric pressure is decreased, the pressure difference between gases dissolved in body fluids and the ambient air may cause dissolved gases to come out of solution in the form of bubbles. This process can occur in the blood, other body fluids, and or body tissues.

Types of DCS and Their Symptoms

The Bends — is the evolution of nitrogen bubbles into the joints of the body, causing pain. The pain is generally localized in and around the bony joints of the body. The smaller joints, of the fingers for example, can be involved; however, the larger joints like the shoulders, elbows, knees, and ankles are the usual sites. The pain is variable in nature and may occur suddenly. It is usually a deep, dull and boring pain. Factors such as exercise, time at altitude, and increased altitude influence the degree of pain. With time, the pain may spread and seem to involve the muscles. Movement of the affected joint tends to increase the discomfort.

Descent below the altitude of occurrence will usually decrease or resolve the pain. Continued descent is required even if the pain completely resolves on initial descent. Ascent to the same altitude will cause the pain to return in the same location. Increasing the total barometric pressure on the body is the only effective means of eliminating bends. Any painful condition at high altitude is potentially dangerous and should be avoided. Alleged courage displayed by ignoring pain does not prevent the progress of the symptoms and can result in collapse. *Once bends have developed, breathing 100 percent oxygen while at altitude will not normally resolve the pain. Descent is the only cure and is mandatory for any DCS.*

Neurological Manifestations — In rare incidents of high altitude exposure, the brain and or spinal cord may be affected by nitrogen bubbles. The most common symptoms are disturbances in vision, varying from blind spots in the visual field to flashing and or flickering lights. Other symptoms include severe persistent headache, partial paralysis, loss of speech or hearing, vertigo, distinct sudden personality changes or loss of orientation. Numbness and tingling of one arm, leg, or side of the body may occur. One explanation for these symptoms theorizes the bubbles of evolved nitrogen circulate through the brain, reducing blood flow and causing localized, small regions of the brain to become hypoxic. These symptoms are attributed to abnormal brain function in the areas of localized hypoxia.

Since these problems affect the brain or spinal cord, they are considered the most dangerous and are known as central nervous system (CNS) manifestations. Circulatory shock, or failure of circulatory control, is a possible effect of neurological involvement. Typical symptoms of circulatory shock or circulatory failure are pale clammy skin, feeble rapid pulse, decreased breathing, and unconsciousness. Blood pressure may fall with severe blood pooling and resultant stagnant hypoxia. *Immediate descent is necessary after any evidence of CNS involvement.*

Chokes — are rare but potentially very dangerous. The cause of chokes symptoms are not fully understood. One hypothesis is that bubbles evolve in the smaller blood vessels in the lungs and in the tissue of the trachea (windpipe).

The symptoms are deep sharp pain centrally located under the sternum (breast bone), a dry progressive cough, and difficulty with inspiration. Increased expansion of the lungs causes the pain to increase and there is a sense of suffocation and apprehension. Symptoms of shock may appear — sweating, pallor, faintness, and cyanosis may be observed. *Immediate descent is necessary* and postflight shock is a possibility. The chokes symptoms may disappear with the descent but there can be some residual soreness in the chest and the crewmember should receive immediate postflight medical attention.

Note — False chokes may be experienced by crewmembers who are exposed to prolonged breathing of dry, aviators oxygen. False chokes are nonhazardous and represent a drying of the mucous membrane linings. Symptoms are a dry nonproductive cough and minor tissue irritation. They are quickly resolved by breathing moist air or by drinking water.

Skin Manifestations — One type of DCS involves peculiar sensations of the skin. In some instances, a mottled, reddish or purplish rash develops on the skin. The rash may be localized in a small area or may be diffused over the body. A slight swelling of the skin may be noted and a slight increase of temperature may exist. The rash may not disappear with descent and may last for hours. Skin manifestations of DCS may indicate bubbles in and around the skin or possibly bubbles affecting the peripheral nerves of the spinal column. Skin manifestations should be considered a serious type of DCS because of the possibility of CNS involvement.

It is important for you to realize there is no predictable progression of symptoms. It is possible to have several of the symptoms at the same time.

Delayed Reactions — Occasionally, the onset of DCS symptoms may appear after the flight. This condition is known as a delayed DCS and may occur within 12 hours. As always, treatment must be initiated and the affected individual referred to the flight surgeon.

Factors Affecting DCS Incidence and Severity

Decompression is not the only controlling factor in the evolution of nitrogen. There are other important factors which help to explain the unpredictably of bubble formation and DCS.

Altitude — Increasing the altitude contributes to an increased incidence of DCS. Considerable debate surrounds the minimum, or threshold altitude for DCS. Although no precise boundary exists, DCS almost never occurs below 18,000 feet MSL.

Rate of Ascent — A faster rate of ascent to altitude contributes to a greater incidence of DCS. For example, you are more susceptible to DCS after a rapid decompression than you would be from a slow decompression to the same altitude.

Note — Cabin pressurization systems protect against DCS by keeping the body below 25,000 feet cabin altitude. However, mechanical failure of the system is a common cause of cabin decompression and possible nitrogen evolution. In high altitude flights (above FL500), crewmembers are protected against DCS by prior denitrogenation and a pressure suit. If loss of cabin pressurization occurs and symptoms of DCS are not present, a descent must still be made immediately to a pressure altitude at or below 25,000 feet (unless a functioning pressure suit is worn).

Physical Activity — Exercise during altitude exposure increases DCS incidence. Factors that may contribute to this effect include the sliding movement of one tissue against another, such as in joints and in the muscles, which causes a shearing action to encourage bubble formation.

Persons exposed to high altitude should minimize exercise. Furthermore, if DCS does develop, any additional movement of the limb (in the case of the bends) may worsen the condition.

The effect of exercise on bubble formation after return to ground level following an altitude exposure remains unproven. Numerous anecdotal accounts, however, suggest that postflight exercise increases the probability of delayed DCS. Also, postflight exercise-induced injury may be confused with or mask DCS pain.

Finally, if during physical activity, asymptomatic bubbles caught in the lungs pass through to the arteries as cardiac output increases blood flow to the lungs, then very serious DCS symptoms may arise. For these reasons, persons exposed to high altitude should *not* perform strenuous exercise for 12 hours after exposure.

Previous Injury — There are numerous accounts of bends occurring preferentially in areas that have been previously injured. No objective data are available for analysis to support this theory. However, injury may cause blood diffusion changes or deposition of scar tissue. It's possible that these changes decrease nitrogen washout rates and predispose bubble formation in these areas. In addition, flight often involves extended periods in cramped conditions. Pain not actually associated with bubble formation may mimic bends pain. Since diagnosis under these conditions is difficult, such pain must be carefully considered.

Age — Before the age of about 40 years, no correlation between age and DCS incidence is clearly demonstrated. After age 40, DCS incidence increases with increased age. Factors contributing to this effect might be an increased deposition of fat within connective tissues, and changes in capillary density and permeability.

Body Composition — There are some indications that increased body fat levels increase the risk for DCS.

Repeated Exposure — There is controversy concerning the effects of repeated exposure, i.e., two or more altitude exposures in succession. It appears that exposures occurring in rapid succession within minutes or a few hours of a previous exposure increase the incidence of DCS during the subsequent exposure. This increase is presumably because some bubbles may remain from the previous exposure. Bubble growth is more likely under this condition. If the exposures occur on successive days, there may be no increase in the incidence of DCS, but the time to first appearance of symptoms is often decreased in the subsequent exposure.

Dehydration — There is substantial evidence that dehydration increases the likelihood of DCS.

Diving Prior to Flying — with a self-contained underwater breathing apparatus (SCUBA) vastly increases the incidence of DCS. Furthermore, the procedure decreases the minimum altitude at which DCS manifestations begin. This decrease allows the occurrence of DCS even during flight on aircraft equipped with excellent pressurization systems such as commercial airlines, whose cabin altitudes are 5,000 to 8,000 feet. Even helicopter flight or driving to altitudes only a few thousand feet above sea level have contributed to DCS after a SCUBA exposure.

USAF and USN regulations forbid flight within 24 hours of a compressed air exposure (SCUBA diving) for all normal flying operations.

Prevention of DCS

Adequate protection against DCS can be established by **aircraft pressurization and or denitrogenation**.

Aircraft Pressurization — Most military aircraft are pressurized and maintain a cabin altitude below 10,000 feet. In addition, the operational ceiling of unpressurized aircraft is FL250. Aircraft pressurization and limiting exposure to FL250 in unpressurized aircraft reduce exposure to the higher altitudes (where nitrogen bubbles are more likely to form) and significantly reduce the incidence of DCS. But remember, DCS can occur at lower altitudes.

Denitrogenation (preoxygenation) — is also very effective in decreasing your susceptibility to DCS. This method involves breathing 100 percent oxygen to eliminate nitrogen from the body. When 100 percent oxygen is breathed through a tightly fitted oxygen mask, no ambient nitrogen enters the lungs. This procedure eliminates the lung nitrogen partial pressure; nitrogen rapidly diffuses from the tissues to the blood then to the lungs and is exhaled. The amount of nitrogen eliminated during denitrogenation is dependent upon time. Assuming that the body contains 1200cc of dissolved nitrogen at sea level, Figure 3-5 shows the amount of nitrogen washed out by denitrogenation.

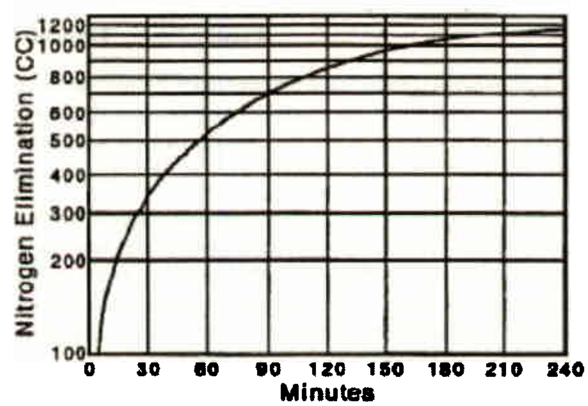


Figure 3-5 — Denitrogenation

Treatment of DCS

Anytime an occupant of an aircraft appears to be experiencing the symptoms of DCS, 100 percent/max oxygen should be administered and the affected area immobilized as much as possible.

1. A crewmember should administer 100 percent/max oxygen to that individual.

2. The pilot must descend as soon as practical and land at the nearest suitable installation where medical assistance can be obtained.

3. Before the affected person may continue the flight, consult a flight surgeon or civilian aeromedical examiner. (DCS may occur up to 12 hours after mission completion.)

Several considerations should be remembered. If symptoms of DCS are recognized, landing is mandatory and treatment should be initiated. If all symptoms disappear prior to landing, or immediately thereafter, 100 percent oxygen therapy should be continued as a precaution. A flight surgeon must be notified. If symptoms still persist after landing, compression therapy will be administered at the nearest hyperbaric facility. Compression therapy results in reduction of the nitrogen bubble size and resolves the DCS.

Aircraft Pressurization

Objective 12 — Identify the primary purpose for aircraft cabin pressurization.

Objective 13 — Identify the physical indications of a rapid decompression.

Pressurization is a mechanical means of maintaining greater than ambient pressure within an aircraft cabin. Pressurization systems provide the most effective method of protection from hostile high altitude environments by minimizing the hazards of decompression sickness (DCS), hypoxia and fatigue.

Pressurization Schedules

Conventional cabin pressurization systems (Figure 3-6) use engine bleed air. Cabin pressure and ventilation can be controlled by varying the amount of air forced into the cabin and adjusting the overflow.

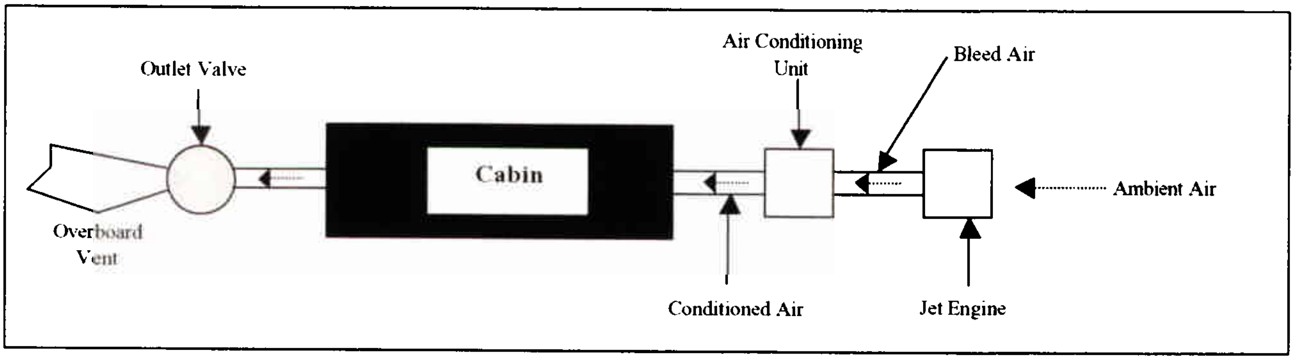


Figure 3-6 — Typical Aircraft Pressurization System

Aircraft pressurization may be regulated by maintaining a *constant* cabin pressure (isobaric system) as aircraft altitude increases. With this type system, the pressure difference between cabin pressure and ambient pressure increases with altitude. An example is the C-9 aircraft which maintains a pressure schedule slightly greater than ambient to 8,000 feet MSL and then maintains 8,000 feet MSL through its certified ceiling.

A more common type of pressurization system is the isobaric-differential system. With this system, the aircraft is unpressurized until a preset cabin pressure is reached. Once reached, the isobaric function of the system maintains a constant pressure within the cabin until a selected pressure *differential* (cabin pressure versus ambient pressure) is attained. Thereafter, as the aircraft climbs, the system maintains the designated pressure differential between cabin pressure and ambient pressure. With an isobaric-differential system, the cabin altitude varies with flight altitude, although at a reduced rate (it is not linear).

Multi-Place Aircraft — The C-141 cargo aircraft is equipped with an 8.6 psi isobaric-differential pressurization system. The cabin altitude will remain at sea level or ground level pressure until the aircraft reaches FL210. Above this level, the system maintains a pressure differential of 8.6 psi to the service ceiling of the aircraft. If this aircraft is flying at an altitude of FL400, where the ambient pressure is 2.72 psi (and assuming normal pressurization system operation), the cabin pressure will be 11.32 psi (8.6 psi plus 2.72 psi). On an atmospheric pressure table, 11.32 psi will indicate an approximate cabin altitude of 7,000 feet.

Fighter Aircraft — pressurization systems are set at a lower pressure differential, typically 5.0 psi. This safeguard is provided because of the smaller cabin volume and the increased danger of decompression during combat operations. Most of these aircraft do not employ pressurization until 8,000 feet MSL. Above this level, the cockpit remains at 8,000 feet pressure altitude until FL230. Thereafter, the system maintains a pressure differential of 5.0 psi. If this aircraft is flying at an altitude of FL400 (and assuming normal pressurization system operation), the cabin pressure will be 7.72

psi (5.0 psi plus 2.72 psi). On an atmospheric pressure table, 7.72 psi will indicate an approximate cabin altitude of 17,000 feet.

Advantages and Disadvantages of Pressurization Systems

Advantages — Aircraft pressurization provides the following advantages:

1. Reduced probability of DCS

2. Reduced possibility of hypoxia

Note — The *primary* purpose for aircraft pressurization is to reduce the possibility of DCS and hypoxia.

3. Reduced need for supplemental oxygen equipment below 10,000 feet cabin altitude. However, crewmembers are required to wear oxygen equipment during certain situations. For example, all crewmembers must wear oxygen equipment during emergencies involving loss of pressurization or emergencies involving the presence of fire, smoke or fumes.

4. Reduced expansion of gastrointestinal trapped gas

5. Controls cabin temperature, humidity, and ventilation within a desired comfort range

6. Allows the crew and passengers to move freely within large cabins unencumbered by oxygen equipment

7. Minimizes fatigue and discomfort of crew and passengers during long flights (air evacuation, troop transport, etc.).

8. Protects the sinuses and middle ears from sudden pressure increases during descents by slowly scheduling the cabin descent

Disadvantages — Aircraft pressurization has the following disadvantages:

1. Decompression. The *primary*, and most critical, disadvantage of aircraft pressurization is the potential for decompression. If decompression should occur, the aircraft occupants are immediately exposed to the inherent hazards of high altitude — hypoxia, DCS, trapped gas problems and hypothermia. Decompression will be discussed in greater detail later in this lesson.

2. Increased aircraft weight because of the additional fuselage strength required

3. Requires additional design engineering, mechanical systems, and engine power

4. Decreased performance and payload

5. Increased maintenance requirements and costs

6. Requires control of cabin air contamination from smoke, fumes, carbon monoxide, carbon dioxide, water vapor and odors

Types of Decompression

Decompressions can occur in two ways, slow or rapid. The effects of a decompression are primarily due to the rate of pressure change and the pressure differential.

Slow Decompression — can occur when a leak develops from a failing pressure seal. If unaware of the decompression, hypoxia may occur and you could be incapacitated (check cabin altitude periodically to detect a slow decompression). Other physiological consequences that can result after decompression include DCS. A pressurization loss requires descent to FL250. Remember, DCS can occur as low as FL180.

Rapid Decompression — (RD) is easily recognized and you must consider its physiological effects. Air expanding in the lungs may cause physical injury and unrestrained crewmembers may be forced through an opening in the cabin. Because time of useful consciousness (TUC) is reduced after an RD, oxygen is the most immediate requirement.

Factors Affecting Decompressions

Several factors affect the *speed* at which cabin pressure will drop to ambient pressure. The larger the cabin volume, the slower the decompression, assuming other factors remain the same. The larger the opening in the cabin, the faster the decompression.

The *initial* difference between the cabin pressure and the ambient pressure determines the *rate* and *severity* of the decompression. The larger the *pressure differential* the more severe the decompression.

The *pressure ratio*, defined as the ratio between cabin pressure and ambient pressure, determines the *time* required for decompression. The larger the ratio, the longer it takes for the two pressures to equalize.

The physiological consequences after a rapid decompression are influenced by the ambient altitude at which the decompression occurs, particularly the effects and onset of acute hypoxia. The most severe effects are produced by a decompression involving a large pressure change over a short period of time (moving from a relatively low cabin altitude to an extremely high ambient altitude in the shortest amount of time). There is little effect if a large pressure change occurs over a long period of time, or if a small pressure change occurs quickly.

Physical Indications of a Rapid Decompression

The altitude chamber RD profile is intended to train you to recognize some of the physical characteristics of an actual rapid decompression. All physical characteristics of an RD cannot be duplicated in the chamber. However, RDs in the chamber prepare you for recognition and action if an RD occurs in the aircraft.

Explosive Noise — When two different air masses collide, they cause a noise ranging from a *swoosh* to an explosive sound.

Windblast/Flying Debris — The rapid evacuation of air during an RD is strong enough to blow unsecured items out of the aircraft. These include maps, charts, flight logs and magazines. Dust and dirt will also kick up and interfere with vision for a short period of time. Even unrestrained passengers and crewmembers have been forced from aircraft by this tremendous movement of air. Therefore, you should always have your lap belts fastened during pressurized flight.

Fogging — During an RD, cockpit temperature and pressure are reduced. As a result, there is a reduction in water saturation capacity and the water vapor not held in suspension appears in the compartment as fog. The dissipation of the fog is fairly rapid in fighter aircraft, but considerably slower in multi-place aircraft. The dissipation rate is affected by the volume of the aircraft cabin.

Temperature — Cabin temperature during flight is generally maintained at a comfortable level; however, the ambient temperature reduces with altitude. If a decompression occurs, cabin temperature drops rapidly, possibly as low as -55°C. Chilling and frostbite may occur if protective clothing is not worn.

Pressure — A rapid drop in pressure occurs during an RD. The earlier you recognize the physical characteristics of a decompression, the sooner you can combat the physiological hazards.

Review Exercise JP(0)103

Complete the following review exercise by choosing the correct answer(s) or filling in the blanks. Answers are at Attachment 1.

1. During ascent (as ambient pressure decreases), gases trapped within body cavities will_________________.

2. The four areas of the body influenced by the mechanical effects of trapped gases are:

   a.

   b.

   c.

   d.

3. What is the best method of *preventing* problems with the ears and sinuses inflight?

   a. Breathe 100 percent oxygen under positive pressure.

   b. Do not fly with a cold.

   c. Perform the Valsalva maneuver frequently on descent.

4. Enter the type of DCS (1-4) beside the following symptoms:

   a. ______Deep, dull boring pain in a joint

   b. ______Deep, sharp pain centrally located under the sternum

   c. ______Difficulty with inspiration

   d. ______Visual disturbance

   e. ______Mottled and diffuse rash

   f. ______Pain may involve the muscles

   g. ______Itching sensation

   h. ______Partial paralysis, loss of speech or hearing

   i. ______Severe, persistent headache

   j. ______Vertigo, loss of orientation.

   k. ______Tingling of one arm, leg or side of the body

   l. ______Usually occurs in shoulders, knees, elbows and ankles

   1. Bends
   2. Chokes
   3. Skin manifestations
   4. Central nervous system (neurological manifestations)

5. DCS is caused by______________________coming out of solution in the tissues and blood.

6. List, in order, the corrective actions for any suspected or observed DCS.

   a. ________________oxygen.

   b. ________________the affected area.

   c. ________________as soon as practical.

   d. Obtain________________ ________________(flight surgeon).

   e. ________________therapy (if required).

7. Adequate protection against DCS can be established by________________ ________________and or________________.

8. The USAF and USN forbid flight within______________hours of a compressed air exposure for all normal flying operations.

9. ________________is a state of oxygen deficiency in the blood, cells or tissues sufficient to cause an impairment of function.

10. ________________ ________________is usually caused by exposure to low barometric pressure.

11. Enter the type of hypoxia (1-4) resulting from the following causes:

   a. ______Loss of cabin pressurization

   b. ______Cold temperatures

   c. ______Shock

   d. ______Alcohol

   e. ______Drugs

   f. ______Carbon monoxide

   g. ______Cyanide

   h. ______Hyperventilation

   i. ______Oxygen equipment malfunctions

   j. ______Improper use of oxygen equipment

   k. ______"G" forces

   l. ______Blood donation

   1. Hypoxic hypoxia
   2. Stagnant hypoxia
   3. Hypemic hypoxia
   4. Histotoxic hypoxia

12. The most dangerous characteristic of hypoxia is its________________ ________________.

13. Place a check mark beside the signs/symptoms normally associated with hypoxia.

    a. ______Bluing (cyanosis)

    b. ______Impaired vision

    c. ______Muscle ache

    d. ______Hot or cold flashes

    e. ______Dizziness

    f. ______Light headedness

    g. ______Loss of muscle coordination

    h. ______Apprehension

    i. ______Feeling of well being

    j. ______Pain on inhalation

    k. ______Tingling

    l. ______Pain

    m. ______Impaired judgment/confusion

14. The time of onset of hypoxia and the severity of symptoms are identical with all crewmembers from one day to the next.

    a. True

    b. False

15. ________________of________________ ________________is the period of time from the interruption of the oxygen supply or exposure to an oxygen poor environment, to the time when useful function is lost.

16. Which of the following factors decrease TUC?

    a. Increased physical activity

    b. Stress

    c. Sufficient oxygen supplies

    d Hypoxia (histotoxic, hypemic, stagnant)

    e. Rapid decompression

    f. Anxiety

    g. Increased altitude

17. A________________ ________________can reduce your TUC by as much as________________percent.

18. Hyperventilation is a condition in which the ________________and or ________________of breathing is abnormally increased.

19. Hyperventilation causes an excessive loss of ________________ ________________from the lungs and blood.

20. List five signs and five symptoms of hyperventilation.

Signs

a.

b.

c.

d.

e.

Symptoms

a.

b.

c.

d.

e.

21. The most frequent cause of hyperventilation in flying training is stress.

 a. True

 b. False

22. Hyperventilation can be voluntarily induced or corrected by consciously increasing or decreasing your rate and depth of breathing.

 a. True

 b. False

23. Complete the crewmember's emergency procedures for the treatment of hyperventilation and or hypoxia.

 a. ____________ oxygen under ____________

 b. Connections --

 c. Breathe at a ____________and depth slightly less than normal until symptoms ____________.

 d. Descend below ____________ feet MSL and land as soon as ____________.

24. The main reasons for aircraft pressurization are to

 a. reduce/prevent and control trapped gas expansion.

 b. eliminate pressure breathing and 100 percent oxygen.

 c. reduce/prevent decompression sickness and hypoxia.

25. List additional advantages of aircraft pressurization.

    a.

    b.

    c.

    d.

26. The primary, and most critical, disadvantage of aircraft pressurization is the potential for a ________________.

Lesson JP(0)104 — 2.0 Hours (IBT)

Vision

Objectives

1. Identify the characteristics of and limitations to the methods of vision.
2. Identify the correct scanning technique used to avoid midair collisions.
3. Identify the factors affecting daytime visual illusions.
4. Determine the visual problems encountered in low-light level and night flying environments.
5. Identify the correct technique to keep an object in sight at night or under low-light conditions.
6. Given factors causing visual illusions, identify methods to prevent the illusions.
7. Select measures you can take to ensure maximum visual acuity in both day and night flying conditions.

Goals

1. During an unaided night vision demonstration, experience dark adaptation and determine its influence on night vision.

2. During an unaided night vision demonstration, experience autokinesis and demonstrate the method used to prevent this illusion.

3. During an unaided night vision demonstration, experience flashblindness and its debilitating effects on dark adaptation.

Assignment

Read JP(0)104 in the SG and answer the review questions.

Introduction

Sight is your most valuable sensory system in the flying environment. Depth perception, visual acuity, night vision and color vision are used to gather data from inside and outside the aircraft. However, possessing these attributes does not mean the eyes will be used effectively. A crewmember with average visual capabilities, using a proper scanning technique has an advantage over the crewmember with superior vision who doesn't know how to "see."

There are also distinct physiological and perceptual limitations on the sense of vision in this environment. The human body is designed to move at roughly four miles per hour. Therefore, your sense of vision is designed to acquire, process, and react to information at that speed. However, aircraft can travel faster than the speed of sound, so you're at a disadvantage because of your limited visual and perceptual processes.

As part of this lesson, you will receive a demonstration using a night vision trainer.

Information

Anatomy and Function of the Eye

Figure 4-1 depicts a cross section of the eyes viewed from above, with the major structures labeled. The cornea and lens refract (bend) light and focus it on the retina in a manner similar to the lens of a camera. Photoreceptors in the retina are stimulated and messages are sent to the brain, via the optic nerve, where the process of perception takes place.

The Retina

The retina is the innermost layer of tissue of the eye, containing millions of photoreceptors (rods and cones) allowing you to "see" an image. The rods and cones are distributed over the entire retina, except where the optic nerve and blood vessels exit the eyeball. This sight is the optic disk or blind spot.

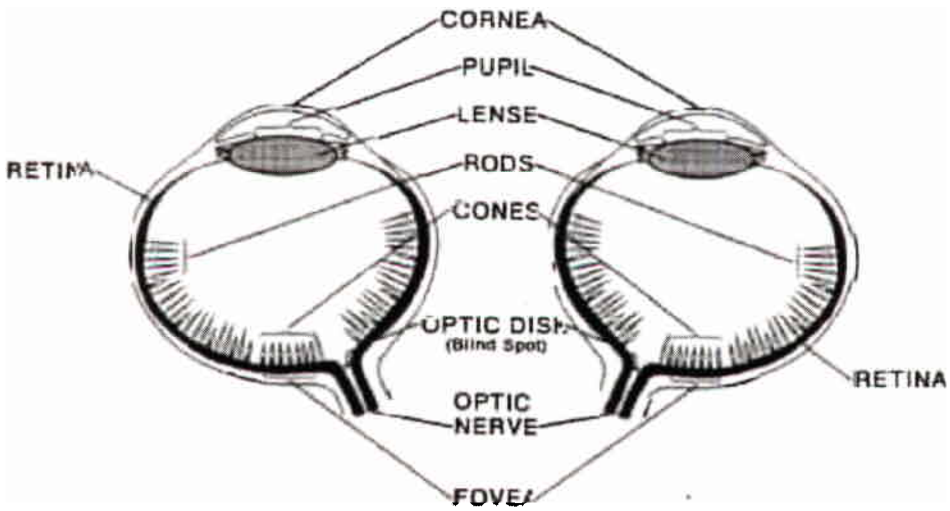


Figure 4-1 — Anatomy of the Eye

Optic Disk

Since there are no photoreceptors at this site, it is effectively an *anatomical* blind spot. However, the optic disks are located in different locations in each eye (Figure 4-1). Therefore, when the eyes are being used simultaneously, the nerve impulses from the retinas provide the brain with an image negating the effects of the blind spots. The blind spot will only be noticed when an object is being viewed with one eye. This situation can occur when one eye is obstructed by a canopy rail or bow, oxygen mask or even your nose.

Does this phenomena mean you notice a blank area in your field of vision? Unfortunately, no. The brain does an interesting thing when one of the blind spots is "active." It "fills in" the *missing* visual information caused by the blind spot with *surrounding* visual information. This process is hazardous if you are scanning for other aircraft and there is an obstruction in your field of view exposing one of the blind spots. Figure 4-2 illustrates how the optic disk/anatomical blind spot works.

The Fovea

Next to each optic disk is the fovea, another area of the retina with a specialized function. It is a tiny pit containing only cones and the natural point on the retina where the lens focuses an image. Your best color vision and maximum visual acuity are in the fovea. Also, the fovea of each eye (like the optic disk) is offset to help a person have stereoscopic depth perception to roughly 200 meters.

Because of the lack of rods at this site, the fovea is responsible for a second type of blind spot occurring during night vision. This *physiological* blind spot will be discussed during night vision.

Photoreceptors

Cones — are the photoreceptors allowing you to see the details of the world in color under bright light conditions. They are densest in the center of the retina and decrease in number toward the periphery.

There are three varieties of cones. Each type is most sensitive to one of the three primary colors of light — blue light, red light and green light. However, the "mixing" or interpretation of colors occurs in the brain, not the retina.

Cones require high light levels to function. Low light and night vision characteristics are discussed later in the lesson.

Rods — are photoreceptors most dense at the periphery of the retina and decrease in number as the center of the retina is approached. They allow you to see in gray tones under conditions of dim light and provide for our peripheral vision. Anything interfering with rod function interferes with your ability to see at night.

We're all a little blind. That's right, you may pass eye tests without a blink, have 20-20 vision, even see in the dark, but you could still miss seeing a jumbo jet at a mile and a half if the conditions are right. There's a blind spot in your eye about 30 degrees right of center when you're looking straight ahead. Your peripheral vision from the eye compensates for this "defect" because your brain normally combines the pictures from both eyes.

When the peripheral vision from one eye is obstructed, the brain can't fill in the missing part of the picture. That's really not a problem when you're walking around on the ground. But when you get inside of a machine — British racing machine, American flying machine, etc. — and look outside, things start getting in the way, like passengers, copilots, or windshield posts.

"Big deal," you say, "All I have to do is move my head." Maybe so, but try this test. Hold the picture below at arm's length and focus both eyes on the cross on the left windshield. Now, move the picture toward your face, you should be able to see the C-5 all the way in. Okay? Try it again with your left eye closed. The Galaxy will disappear and then reappear as you draw the picture closer. Ask yourself: How much airspace will my aircraft cover during the time the C-5 disappeared?

Adapted from "The MAC Flyer"

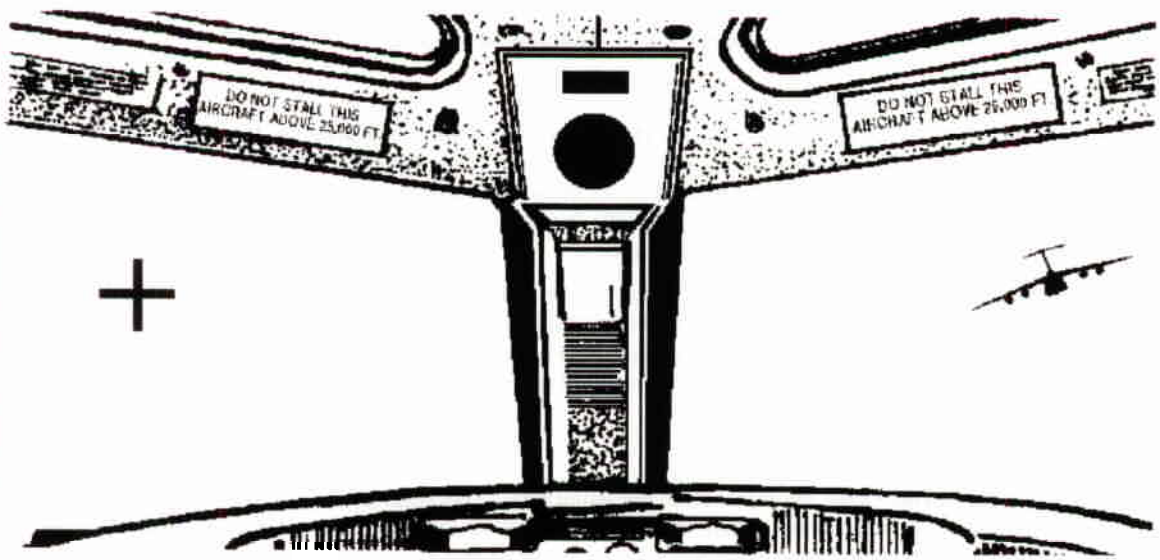


Figure 4-2 — Anatomical Blind Spot

Rods are 10,000 times more sensitive to light than cones. Their sensitivity is due to a highly photoreactive protein called rhodopsin (visual purple).

Characteristics of Vision

Objective 1 — Identify the characteristics of and limitations to the methods of vision.

Objective 2 — Identify the correct scanning technique used to avoid midair collisions.

The Visual Field

Vision can be divided into anatomical and functional systems. The total visual field is about 160° to 170°, depending on the individual. Of this total, the central 3° is used for focal vision. The remaining visual field is used for peripheral vision.

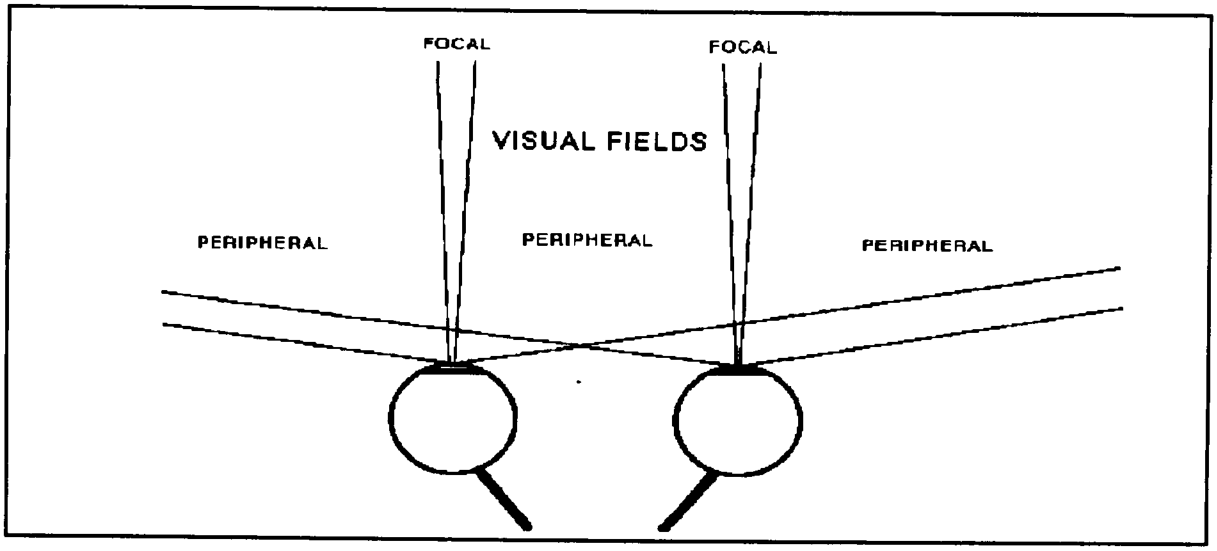


Figure 4-3 — The Total Visual Field

Focal vision is processed at a higher level of consciousness and peripheral vision is processed at a more subconscious level. Additionally, each type of vision can be categorized by the primary functions they perform. Figure 4-3 illustrates the visual field and the regions of overlap.

Focal vision — is concentrated on the fovea, constituting 3° of the total visual field. Its primary function is to recognize and identify objects, generally to answer the "what is it" question. Therefore, perceiving information with focal vision is a conscious process requiring active attention by the observer.

Focal vision orients a perceived object in space relative to the observer. It also provides maximum visual acuity and depth perception. Visual acuity decreases markedly as the image is focused away from the fovea (Figure 4-4). For example, if you have 20/20 vision and observe an object ten degrees off the fovea, your visual acuity drops to 20/100. Focal vision also requires high illumination levels because the fovea consists solely of cone cells. As a result, you don't have the same visual acuity during night or low-light operations as during the day.

Peripheral vision — is used primarily to orient oneself relative to the environment and constitutes the remainder of the visual field. Unlike focal vision, it does not require active attention on your part to process information and serves to orient you to your environment. The majority of the photoreceptors used in peripheral vision are rods. As a result, one of the main characteristics of peripheral vision is very poor visual acuity.

There is also little color vision with peripheral vision because of the decreased number of cone cells in the periphery of the retina. However, the rods used in peripheral vision allow you to see at night.

Sensing and identifying objects with peripheral vision is difficult. Peripheral vision is largely used to detect motion (real or illusory) and positional information. Orientation cues provided by the peripheral visual field are extremely powerful. These cues are processed subconsciously and are extremely difficult to overcome. An example of the power of the visual system to orient the body is the reaction people have in wide screen movie theaters where the scene on the screen is of an aircraft flying through a canyon, with its twists and turns. The audience tends to lean in the same direction

Visual Acuity (As an object is focused off the fovea)	
Degrees Focused Off the Fovea	*Visual Acuity*
0	20/20
10	20/100
20	20/200
30	20/300
40	20/400

Figure 4-4 — Decrease in Visual Acuity

the aircraft banks in order to keep themselves perpendicular to the visual horizon.

Note — A combination of these two types of vision is used at light intensities equivalent to dusk or dawn. Under these conditions the level of light is slightly below that needed for efficient cone vision and too intense for efficient rod vision. Thus, both types of sensors are operating simultaneously. Beware, since at these levels central (fovea) acuity, although functional, is only about one-half as good as in average daylight conditions and rod vision is also deficient.

You will fly both day and night missions. Understanding the different ways your eyes work in differing light conditions helps you understand your abilities and limitations in both daylight and night flying environments.

Day vision uses cones as photoreceptors due to the high light intensity. These cells adapt quickly to increases in light and give the crewmember the ability to use focal vision for detail and still maintain peripheral cues for orientation. Rods are used to some degree in the periphery but tend to become desensitized or "washed-out" in high intensity light environments.

Limitations

Limitations to day vision do exist and fall into two categories — physiological and perceptual.

Physiological limitations involve *visual contrast* of objects against their backgrounds, shapes of targets, movement of targets and environmental conditions.

Visual Contrast — helps the eye acquire the target. Objects are sensed by the differences between light and dark. Therefore, the greater the contrast of a target against its background, the easier it is to detect. For example, an aircraft painted a dark color silhouetted against a hazy sky is much easier to see than an aircraft painted gray flying against the same hazy background. This example shows why camouflage can be so effective. Camouflage attempts to blend a target into its background while breaking up the visual outline. To illustrate this concept, look at the paint schemes of some F-18 and F-16 fighters. There are two shades of gray on the aircraft with lighter shades towards the outer edges of the aircraft. The effect is to make the aircraft appear smaller and, therefore, more distant by confusing the contrast of the aircraft against the sky.

Shapes of Targets — also affect the eyes' ability to acquire them. The larger, more angular the shape of the target, the easier it is to see and is sometimes referred to as its "visual cross section." A good example is viewing an F-16 head-on versus viewing it from the side or top. It is much more difficult to see the aircraft in the head-on view.

Movement of a Target — against a background aids acquisition by the eye. A moving target is easier to detect than a stationary target. The degree of movement required also depends upon the background. An aircraft flying against a broken, irregular background, like a partly cloudy sky, requires less apparent movement to be detected than when it is flying against a featureless background, like a clear sky. As a result, a target's motion must be ten times faster in a clear sky than in a broken, cloudy sky to be perceived.

Environmental Conditions — can enhance or hamper your vision. Obviously, cloudy conditions restrict visibility but clear conditions can also cause problems. Glare is a significant problem, especially at high altitudes. For example, if you're flying at FL350 with a solid cloud deck below, you'll experience significant reflected glare (similar to being on a snow field on a sunny day). To help decrease the effects of glare, crewmembers are issued sunglasses and have visors on their helmets.

Sunglasses reduce the amount of light entering the eye, decreasing your visual acuity. The more light sunglasses eliminate, the worse the visual acuity. Military issued aircrew sunglasses eliminate 85 percent of the light entering the eye and reduce visual acuity to an average of 20/30. Commercially available sunglasses may reduce visual acuity to 20/60 or 20/65 because of the amount of light filtered out. The lenses of the sunglasses should be made of glass or polycarbonate to filter ultraviolet radiation. Additionally, the lenses should not distort color (use green or gray lenses, or lenses *certified* not to distort color) and should not be polarized, distort shapes or blur distant objects. Use issued sunglasses or buy a quality pair of sunglasses meeting or exceeding USAF/USN requirements.

Empty-Field Myopia — is caused by the tendency of the eyes to focus at approximately 3 meters in front of the face. This phenomena occurs if the eyes have nothing to focus on at infinity. You face this problem during high to medium altitude flight where there may be a featureless background or indistinct horizon. The hazards of empty-space myopia are caused by an inability to see targets outside the 3 meter focal range. Therefore, be aware of empty-space myopia and focus on a distant object (like the horizon or an object on the ground) to bring the eyes' focus out to infinity before looking for traffic.

Midair Collision Avoidance

The role of vision in midair collision (MAC) avoidance is obvious. The Federal Aviation Administration's "see and avoid" principle is founded on the crewmembers' ability to maintain visual separation from other aircraft. The speed of jet aircraft, increased air traffic density and the amount of information processed during critical phases of flight requires good vision and alertness on your part to effectively apply the "see and avoid" principle. There are additional factors affecting your ability to use this principle.

Action	Time (Seconds)
Detect and Visualize	0.4
Recognize	1.0
Decide what to do	2.0
Direct muscle movement, move, controls and change flightpath	2.5
Total Time	5.9

Figure 4-5 — Perception and Reaction Time

Perception/Reaction Time — is determined by specific physiological and perceptual limitations of what you can see and react to in a given time. Figure 4-5 lists the perception/reaction times for subjects in a laboratory environment. The times change for a variety of reasons, including type of aircraft, physical and physiological state of the crewmembers, mental state of the crewmembers, time of day and weather conditions.

Certain physiological and physical variables are under your control, including most self-imposed stresses. For example, fatigue can directly affect your ability to detect another aircraft, perceive its position in relation to your aircraft and decide how to react. However, you can minimize fatigue's effect by ensuring proper crew rest.

Visual Acquisition — of another aircraft in a MAC situation also has physiological limitations. First, because of the geometry of a MAC, you lose motion as a cue to acquire the other aircraft with your peripheral vision. When a collision occurs, the other aircraft has little or no apparent motion on the windshield. Therefore, you must acquire the target aircraft with your focal vision, which is a small portion of your total visual field. Second, depending on the size and aspect angle of the target aircraft, the physical ability to visually acquire an aircraft is also limited. For example, attempting to visually acquire a large transport aircraft, traveling in the same direction but on a converging course, is much easier than spotting a small, private aircraft (like a Cessna 150) on a head-on collision course. Therefore, in order for you to visually acquire another aircraft inflight, the target must be in your focal field of vision so it is focused on the fovea. Getting the target aircraft focused on the fovea is accomplished by using an appropriate scanning technique.

Scanning Technique — Performing a proper scan for other aircraft significantly decreases the chance of a MAC. Maximum scanning effectiveness is achieved by a series of short, regularly-spaced eye fixations. A common scanning technique is to take an area of sky (approximately 120° horizontally by 40° vertically) and divide it into sectors. Look in each sector, then scan into the next. In order to see a target, the target must fall on the fovea long enough for it to be perceived. So, let your eyes stop, focus in a sector, then continue your scan.

During flight, you must continually scan in addition to performing other flight duties. Therefore, all crewmembers are vital keys in the "see and avoid" environment. Crewmembers knowing how to correctly scan for aircraft are invaluable assets, especially in high density traffic areas.

What areas of the flight are higher risk for MACs? Usually, lower altitudes have higher density traffic and therefore a higher risk. The majority of near MACs in the United States occur below 12,500 feet MSL. Most military flights are at greater risk during the takeoff, landing and low-level phases of flight over land. During departures, you are busy establishing the aircraft on the departure path, receiving clearances from air traffic controllers, running checklists and navigating, in addition to flying the aircraft. You must also actively scan for other aircraft that may conflict with your flightpath. During the landing (terminal) phase of flights, you must fly the approach, monitor aircraft position, run approach and landing checklists, talk on the radios, *and* scan for other aircraft. Additionally, during terminal phases of flight you are more likely to be fatigued, dehydrated, and possibly hypoglycemic. These factors increase your perception/reaction time. Similar threats occur in the low-level environment.

In the low-level environment, aircraft travel faster than during terminal phases of flight and are at low altitude for longer periods of time. Consequently, your time to react is lowered by the increased aircraft speed and your exposure to the threat of a MAC increases because of the increased time spent in a low-level environment. Like terminal phases of flight, low-level flights are also task intensive, detracting from your ability to scan. Additionally, many low-level altitudes are below air traffic control radar coverage. As a result, you lose air traffic radar as an aid to MAC avoidance.

Therefore, be especially alert to MACs in addition to terrain clearance and mission accomplishment. During these critical phases of flight, it is vital that you remain keenly aware of your responsibilities and limitations.

A second MAC threat results not from other aircraft, but from birds. The majority of birdstrikes occur below 2,000 feet AGL. Unfortunately, birds are more difficult to see than aircraft and they tend to fly just beneath or just above cloud layers. So as you fly out of the clouds on final approach, don't be surprised if you must avoid birds while looking for the runway.

Another more subtle limitation (tending to increase perception/reaction time) is *expectancy*. Once you are notified of conflicting traffic, and especially if you are given the type of conflicting aircraft, you form a mental picture of your target. Unfortunately, your mental picture may not accurately reflect what you should really be seeing. For instance, your mental picture of what a C-130 looks like at 3 miles may not be accurate, leading you to misjudge your time to react.

Because of the physiological and perceptual limitations to detecting other aircraft inflight, it's critically important that the entire cockpit crew know how to correctly scan. The more crewmembers knowing how to correctly scan for aircraft means there is a greater chance of detecting and avoiding possible MACs.

Daytime Visual Illusions

Objective 3 — Identify the factors affecting daytime visual illusions.

Visual illusions are a form of spatial disorientation; you mentally *perceive* an image different than the image *seen* by the eye. Visual illusions can be caused by a variety of physical and physiological/perceptual factors. Physical factors affecting daytime visual illusions include weather, terrain, lighting and sun angles. Physiological/perceptual factors affecting daytime visual illusions include crewmember experience, expectancy and self-imposed stresses (including fatigue).

Physical Factors

The horizon is used by the peripheral visual field as a cue for orientation and balance. However, when a *perceived* horizon is not parallel to the earth's surface, you may still believe it is the *correct* horizon. Therefore, you can become disoriented and experience a false sense of orientation if you do not have a reliable visual horizon. This illusion is extremely important in conditions of marginal visibility, where the true horizon is obscured or not visible. In these cases, the eyes tend to use any straight line as a horizon.

Peripheral vision can compound the problems encountered in daytime visual illusions because it does not require conscious attention. So, in order to compensate for illusions caused by false horizons, you must use conscious thought to override the subconscious input. Doing so is difficult since it requires you to use your focal vision for orientation information, forcing you to further divide your attention between monitoring the aircraft and keeping it in the correct attitude. If you are unable to concentrate on your instruments, the subconscious input from your peripheral vision causes you to orient yourself to the false horizon. For example, flying over a sloping cloud layer where the earth's surface is not visible, you will tend to orient the aircraft so it is parallel to the cloud deck. To regain orientation, you must focus on the aircraft's artificial horizon (provided you were aware of the unusual aircraft attitude). However, if you look outside again, the horizon provided by the sloping cloud deck can cause you to reorient the aircraft parallel to the perceived horizon created by the cloud deck. Figure 4-6 illustrates this problem.

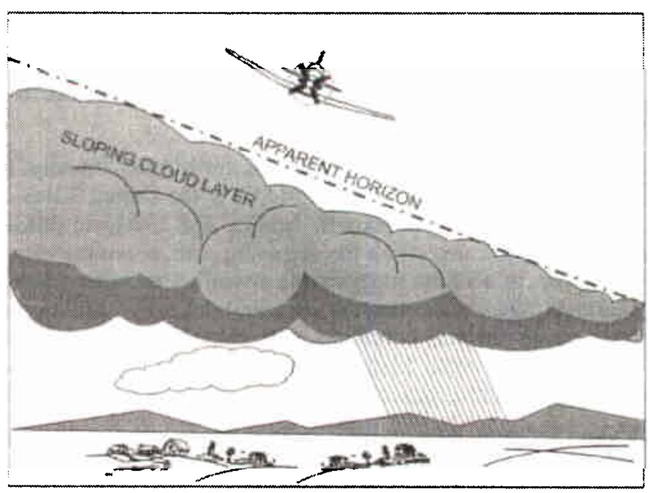


Figure 4-6 — Sloping Cloud Deck

In hazy or foggy weather, indistinct horizons can also be confusing. Critical visual cues required to safely fly approaches and landings may be missing. The decreased visibility of the runway changes your linear perspective. As a result, you may descend too early (duck-under) in order to keep more of the runway in sight, or you may shift your aim point to a visible part of the runway and land short. You may fly an approach and have adequate visual cues during the approach. But, after entering a shallow ground fog during landing, you may suddenly find these cues significantly reduced or unavailable. The fog or haze eliminates the peripheral horizon and confuses the cues you use to judge distance and depth perception. Additionally, fog or haze diffuses lights, making them appear dim and causing you to think you are farther away from an object than you really are.

Sun angle and shadows also create problems. Shadows caused by low sun angles or from the time of day can mask hazardous terrain features, particularly in the low altitude environment. This illusion is important because more and more aircraft fly low altitude missions. For example, during a low-level mission, with the Sun low on the horizon, you may see a mountain in front of you but fail to see a hill in front of the mountain because of shadows.

Sun angle and lighting of terrain can also confuse your perception of *altitude* during low-level flight. For example, flying a low-level mission over hilly terrain may cause a misperception of altitudes. The misperception can be caused by shadows and differing contrasts due to different sun angles. This situation is particularly dangerous if you are used to flying over terrain during a specific time of day and then fly the same route at a different time, with different sun angles.

Different types of terrain can also cause visual miscues and illusions. Flat, featureless terrain like valley floors, deserts or the ocean lack distinct features allowing you to visually determine your altitude above the ground. If these factors are combined with a hazy horizon, you have the larger problem of visually determining altitude *and* attitude. In these situations, a slight descent is visually imperceptible; the aircraft can impact the ground before you realize the danger.

Terrain around airfields can contribute to miscues and false perceptions of altitude during approach to landing. An airfield situated at an end of a valley with slowly rising terrain at the approach end of the runway can cause you to land your aircraft long. As you approach the airfield, you fly over the terrain and visually perceive you are lower than you should be. As a result, you may climb above the correct glideslope to compensate for your perceived low altitude. Conversely, flying an approach over terrain sloping away from the approach end of the runway may cause you to descend below the ideal flightpath to compensate for the illusion of being too high. The desired and compensated flightpaths for both rising terrain and terrain sloping away from the runway are shown in figure 4-7.

Perceptual Factors

The processing and perception of visual information by the brain is affected by a variety of variables. These variables include experience and expectancy, fatigue and other self-imposed stresses.

Experience and expectancy are major factors in visual illusions especially if you are fatigued or there are insufficient physical visual cues. Common examples of experience and expectancy problems are landing illusions caused by different runway widths and lengths. For example, if you are used to landing at your home field with a runway 300 feet wide and 13,000 feet long, you will develop a series of mental pictures of the runway at different stages of the approach. However, should you fly to another base and encounter a runway with a different width and length than your

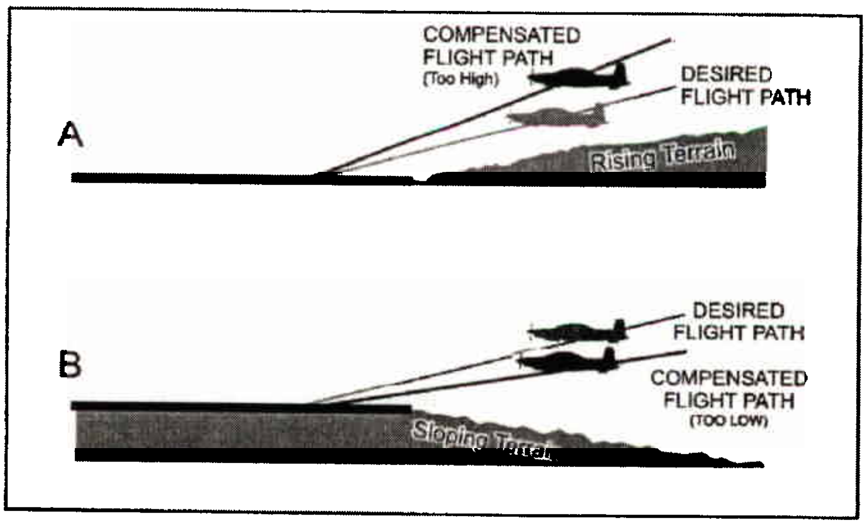


Figure 4-7 — Runway Approach Terrain

home base, you run the risk of landing short or long.

See Figure 4-8 for the following example. Your home base runway is 300 feet wide and 13,000 feet long (runway A). Consider flying into a field with a runway only 150 feet wide and 9,000 feet long (runway B). On a normal glidepath to runway B, the narrower and shorter runway appears to be farther away. You may perceive you are too high on your glideslope. Therefore, you could descend below the correct glideslope in order to make the visual image of runway B match your mental picture of what runway A should look like. As a result, you could land short of the runway. Conversely, landing at a base with a wider and longer runway (runway C) than your home field may give the perception you are lower and closer to the runway than you really are. Therefore, you may slow your descent and fly above the required glideslope in order to make the landing runway look like your preconceived mental picture. Flaring too high is a common problem in this situation.

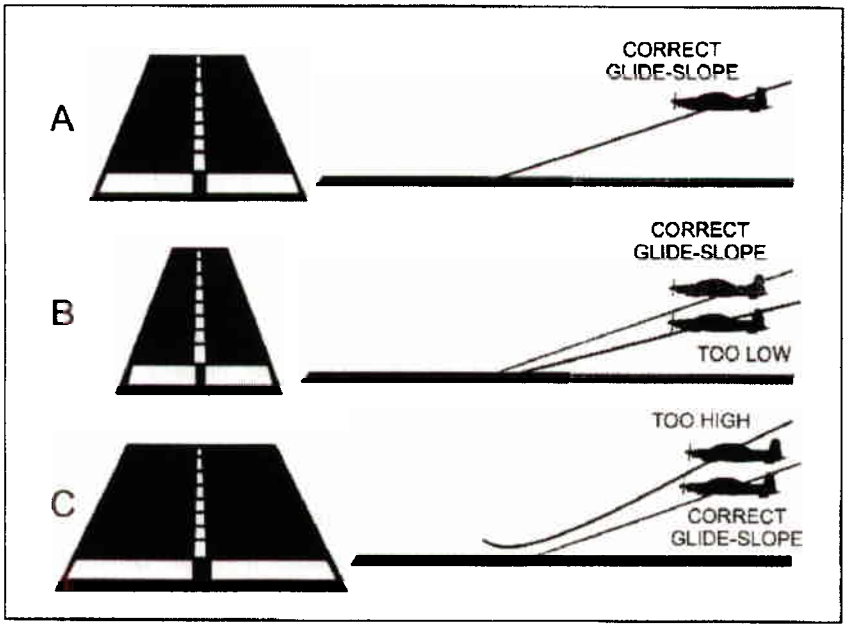


Figure 4-8 — Runway Width and Length

Unless you have experience flying approaches and landing on runways shorter or longer than what you are accustomed to, you may use your mental picture of what a runway is *supposed* to look like and adjust your visual picture to match. These illusions are increased by fatigue, when your ability to consciously prioritize information is slower and you subconsciously rely on your experience to provide cues.

Increased self-imposed stresses (dehydration, hypoglycemia, alcohol, self-medication, flying sick, etc.) decrease your eyes physical ability to capture images and increases your perception/reaction time.

Remember, a variety of techniques are available to avoid daytime visual illusions and maximize your visual acuity. First, ensure the windshield of your aircraft, your helmet visor and sunglasses are clean and not scratched. Second, use sunglasses with color neutral lenses allowing sufficient light penetration. Third, use them at high altitudes where glare may be a problem but remove them at lower altitudes when scanning for aircraft. When scanning for aircraft, focus the eyes on the horizon or distant object on the ground to eliminate the problem of empty-space myopia. Fourth, develop and use a good scanning technique. Finally, avoid or minimize exposure to self-imposed stresses that degrade your visual and perceptual performance.

It's also critically important to be aware of the illusions other crewmembers may encounter. Always review approaches and be thoroughly familiar with the approach flown and possible landing difficulties. You may be the primary backup to the pilot flying the aircraft and must always be ready to communicate unplanned flight profile deviations.

Night Vision

Objective 4 — Determine the visual problems encountered in low-light level and night flying environments.

Objective 5 — Identify the correct technique used to keep an object in sight at night or under low-light conditions.

Night vision uses different photoreceptive cells than those used during the day. Therefore, the physiological characteristics of night vision and the factors affecting it are different.

Physiology of Night Vision

The rods' ability to function in low-light environments is high but their adaptability to low-light levels is fairly slow. For example, when you walk into a dark room or building after being in the bright sunlight, a certain amount of time elapses before the eyes adapt and see images. Remember, rods are unable to distinguish color and are found primarily in the periphery of the retina. Because of their location, night vision is in the peripheral visual field and depth perception and visual acuity are severely degraded. Since night vision depends on the use of rod cells, expect to use your peripheral vision instead of focal vision.

Effect of Altitude on Night Vision
5,000 Ft Physiological Altitude (5-10% Loss of Night Vision)
10,000 Ft Physiological Altitude (15-20% Loss of Night Vision)
12,500 Ft Physiological Altitude (25-30%Loss of Night Vision)

Figure 4-9 — Loss of Visual Acuity

The rods' extreme sensitivity to changes in blood oxygen levels causes certain physiological factors to affect night visual acuity. For example, an increase in cabin altitude decreases night visual acuity. Figure 4-9 shows the drop in visual acuity at given cabin altitudes. Carbon monoxide (smoke and fumes or tobacco smoke) also decreases visual acuity at night.

Be aware of how changes in altitude and oxygen levels affect your visual acuity. If you perform activities requiring high levels of visual accuracy at night, you may want to consider breathing 100 percent oxygen to improve your vision.

The Night Blind Spot

The night blind spot is a second blind spot in the eyes, since the cones in the fovea require high light levels to function. Normally, you reflexively focus an object on the fovea in order to identify it. At night, however, there may not be enough light emanating or being reflected from a target to stimulate the cones in the fovea. If this is the case, the target is not seen if it is focused on the fovea. Therefore, the fovea is usually not useful in identifying targets at night. In order to avoid this problem, learn to focus a target about 10 to 15 degrees off the fovea so it falls on an area of the retina that contains a greater concentration of rods (night vision scanning technique). It takes conscious effort to move the focused image of the target off the fovea.

Nighttime Visual Illusions

Objective 6 — Given factors causing visual illusions, identify methods to prevent the illusions.

Nighttime visual illusions are similar to daytime illusions in that they are caused by a loss or confusion of a visual horizon and can cause problems in all phases of flight. The following section discusses illusions caused by false horizons and lack of a horizon, the perceptual mistakes made by crewmembers and what you can do to correct and avoid these mistakes.

Perceptual Errors

False Horizons — at night can be caused by any series of lights in a linear formation. For example, an aircrew flying in a rural area of the country may see a series of street lights and perceive them as the horizon. In a case occurring over the ocean, a student pilot flying a night mission saw a line of fishing boats stretched out below and misperceived them as the horizon. Fortunately, the instructor pilot noticed the aircraft was in about 15 degrees of bank and corrected.

Another cause of false horizons occurs when flying toward land after a mission over the ocean or a large body of water. If you are flying toward a populated area of land with scattered lights, the true horizon with stars will tend to blend with the scattered ground lights. This visual picture may confuse you and cause you to use the water-land boundary as the horizon.

The best preventive measure to decrease or eliminate the problem of false horizons is to ensure a good instrument cross-check.

Lack of Horizon If you are flying at night over featureless unpopulated terrain or the ocean, you may not see a visible horizon. This environment can cause you to use a false horizon (if one becomes available) or rely on your vestibular system (discussed in the Spatial Disorientation lesson) for orientation information.

The Black Hole Effect is caused by a lack of a visual horizon for the peripheral visual field to key on and use to orient the aircrew. It occurs most often during night visual approaches to airfields without surrounding city lights, or with a fairly small concentration of lights behind the runway. The pilot attempts to fly a visual approach by keeping the same visual angle on the runway. Unfortunately, the necessary peripheral visual cues are not available to provide accurate aircraft pitch information in relation to the true horizon. The pilot attempts to estimate distance, altitude and pitch information using only focal vision for input of the airfield. Therefore, a descending parabolic path to the airfield is flown although a normal descent path is perceived. As a result, the aircraft lands short of the runway. Figure 4-10 illustrates the black hole effect and depicts the flightpath flown by aircrews when they attempt to fly a visual approach in a black hole environment.

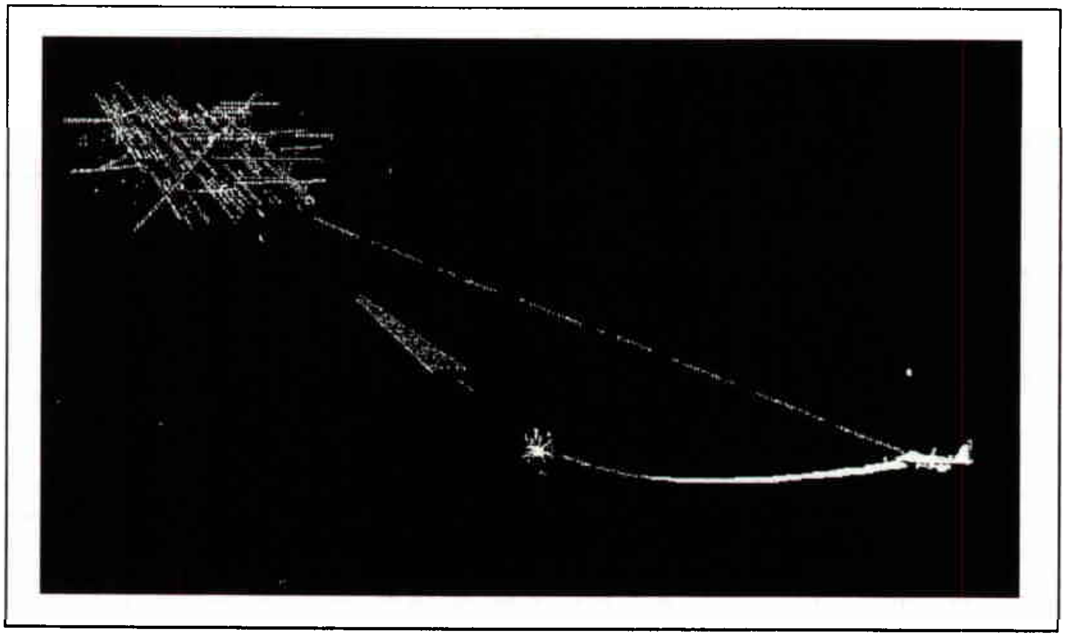


Figure 4-10 — Black Hole Effect

One solution to the black hole effect is to fly published instrument approaches, preferably an approach providing glidepath information. If a visual approach is chosen, the approach should be backed up with an instrument approach or a published approach profile to prevent a descent below a safe altitude.

Autokinesis means "self-motion." This illusion occurs by staring at a single light source against a dark background. Autokinesis can occur by fixating on a star, stationary ground lights at night, or lights from other aircraft. After staring at the light for a few moments, it appears to move randomly. The cause of the illusion is not definitely known. Generally, the larger and brighter the object, the less the autokinetic effect.

Autokinesis can be hazardous. Pilots fixating on stars or ground lights have mistaken these objects for other aircraft, sometimes taking evasive action. Also, when intercepting or following a relatively stable aircraft, it may *appear* to move erratically. Making unnecessary control inputs based on an incorrect perception can be tiring at best or hazardous at worst.

To prevent autokinesis, do not stare at the light. Use the night scanning technique and shift your gaze frequently to avoid prolonged fixation on a target. Always monitor your flight instruments to help prevent or resolve any perceptual conflicts.

Weather Factors

Nighttime visual illusions can be caused by the same types of weather that cause daytime visual illusions. Shallow ground fog, rain, snow and haze all affect your visual ability to discern altitude, attitude and distance. At night, however, there are some distinct differences in how these environmental factors affect you.

Haze and Ground Fog — tend to decrease your forward and slant range visibility just as they do during the daytime. At night, haze and ground fog tend to cause runway lights to be dimmer than usual and makes them appear farther away than they actually are. Additionally, bright flashing lights, like sequenced flashing lights found in some airfield lighting systems, can disorient you at night in foggy or hazy weather. The brightness of the flashers reflected in the weather may give you a false sense that the aircraft is nose low in relation to the horizon. You may also believe you are closer to the light source than you actually are because of the apparent size of the light. The lights appear larger because of the diffusing and scattering of the light by the fog or haze.

Rain and Snow — can cause light from aircraft landing lights to be reflected back into the cockpit. As a result, you may sense an overwhelming visual sensation of the aircraft pitching up or down. This sensation is caused by the high speed of the illuminated rain drops or snow flakes passing by the windshield. If rain or snow is encountered, in addition to lowered visibility, your ability to transition to visual flight for landing may be impaired. Deviations from the desired flightpath may occur. Therefore, keep the aircraft in a position to make a safe landing.

Improvement Measures

Objective 7 — Select measures you can take to ensure maximum visual acuity in both day and night flying conditions.

You can use a number of different techniques to maximize visual acuity in the cockpit at night. Ensure the windshield and your helmet visors are clean and scratch free. If the mission involves formation flying or visually intensive work, but does not allow for an increase in cockpit lighting levels, consider breathing 100 percent oxygen. Additionally, you can keep the cockpit lights low to allow for maximum dark adaptation. Finally, be aware that weather, expectancy and fatigue increases perception/reaction time, leaving less room for error.

Note — The problem of night visual illusions increases because you are flying at times that are usually out of alignment with your normal sleep-wake cycles and you tend to be fatigued. The problem also increases when traveling across time zones. Therefore, self-imposed stresses play a significant role in nighttime visual illusions.

Unaided Night Vision Demonstration

Goal 1 — During an unaided night vision demonstration, experience dark adaptation and determine its influence on night vision.

Goal 2 — During an unaided night vision demonstration, experience autokinesis and demonstrate the method used to prevent this illusion.

Goal 3 — During an unaided night vision demonstration, experience flashblindness and its debilitating effects on dark adaptation.

Following the classroom presentation, your class will be divided into control and experimental groups for the night vision demonstration. These groups will demonstrate the benefits of dark adaptation, experience autokinesis and experience flashblindness.

Summary

Vision is the primary means to collect information about your environment and your position in it. It can be viewed as a two-part system, the physical visual imaging part and the mental perceptual part. The cones on the retina of the eye are responsible for the ability to see color and operate most efficiently in bright light. They are scattered throughout the retina (with the greatest concentration in the fovea) and primarily used in focal vision; the area of greatest visual acuity.

Rods are found outside the fovea and in the peripheral areas of the retina. They are roughly 10,000 times more sensitive to light than cones and give you the ability to see in a low-light level environment. Rods perceive only black and white, allowing for distinction between shades of gray. They are the photoreceptors used in peripheral vision.

The retina contains two blind spots, the anatomical blind spot formed by the optic disk and the night blind spot caused by the concentration of cones in the fovea.

You must incorporate an effective scanning technique in order to see an object. The scanning technique involves taking the visual field and dividing it into sectors. Search each sector, then let your eyes stop and focus before moving on because an image is not perceived unless it is focused on the retina. This scanning technique may be used during the day or night. However, the night scan must make allowances for the night blind spot by focusing the image 10° to 15° off the fovea.

Vision and visual perception are affected by self-imposed stresses, such as fatigue, weather conditions, physiological conditions (hypoxia), and expectancy (what the eyes see is not necessarily what the mind expects to see). Be aware of these problems and be prepared to counteract them if they occur.

To maintain the high level of alertness required, ensure you are well-rested, fed, and hydrated and have thoroughly planned and briefed your mission. Be aware of the visual illusions you could encounter on your mission and how you can deal with them.

Review Exercise JP(0)104

Complete the following review exercise by choosing the correct answer(s) or filling in the blanks. Answers are at Attachment 1.

1. The retina is the innermost layer of tissue of the eye.
   a. True
   b. False

2. The rods and cones are light sensitive cells distributed over the retina.
   a. True
   b. False

3. Determine if the following are characteristics of (A) the rod cells or (B) the cone cells:
   a. Most dense at the periphery of the retina
   b. Require high light levels to function
   c. Allow you to see gray tones under conditions of dim light
   d. Densest in the center of the retina
   e. Provide for peripheral vision
   f. Allow you to see detail under bright light conditions
   g. More sensitive to light

4. What is the primary function of focal vision?
   a. To orient oneself to the environment
   b. Recognize and identify objects
   c. Monitor fluctuations in high-light levels
   d. Conscious perception of peripheral cues

5. What is the primary function of peripheral vision?
   a. Conscious perception of peripheral cues
   b. Recognize and identify objects
   c. Monitor fluctuations in low-light levels
   d. To orient oneself relative to the environment

6. An object requires less motion to be seen in a clear blue sky than an object in a partly cloudy sky.
   a. True
   b. False

7. In midair collisions, the primary peripheral visual cue of ________________ is not available. Therefore, you must acquire the target aircraft with your ________________ vision, using the scanning technique.

8. Perception/reaction time is affected by physiological and perceptual limitations.

   a. True

   b. False

9. Maximum scanning effectiveness is achieved by a series of short (long enough for the eye to focus), regularly spaced eye fixations.

   a. True

   b. False

Lesson JP(0)105 — 2.0 Hours (IBT)

Spatial Disorientation

Objectives

1. Select the correct description for each of the four sensory systems enabling orientation, equilibrium and balance.
2. Select the sensory system providing the strongest, and usually the most reliable, orientation information.
3. Identify the function of the vestibular system and its two subsystems: the semicircular canals and the otolith organs.
4. Determine the reason for the somatosensory system's unreliability inflight.
5. Select the correct physiological explanations for specific vestibular illusions.
6. Given an inflight spatial disorientation scenario, identify the probable illusion experienced by the crewmember(s).
7. Identify physical and physiological factors affecting spatial disorientation.
8. Identify five methods used to prevent spatial disorientation.
9. Identify seven procedures used to overcome spatial disorientation.

Goals

1. Using a spatial disorientation trainer, experience spatial disorientation and practice/perform methods to maintain aircraft control while disoriented.
2. Understand the physiological (sensory inputs) and psychological (self-imposed stress) causes of motion sickness.
3. Understand techniques used to prevent and overcome motion sickness in the flying environment.

Assignment

1. Read JP(0)105 in the SG and answer the review questions.
2. Read AFMAN 11-217 Vol 1, Chapter 22, *Instrument Flight Procedures.*

Introduction

As "ground dwellers," we've established a remarkable store of information about the "correctness" of two-dimensional movement within our environment. Over the years, we've relied on the accuracy of this information as input by our balance and orientation senses — the visual system, the vestibular system of the inner ear, the somatosensory system (pressure receptors of the body), and the auditory system.

When flying in visual meteorological conditions, all four sensory systems are working to provide for you spatial orientation relative to the earth's surface. During instrument meteorological conditions (IMC), at night or in the weather, the eye does not provide adequate external visual information. As a result, the vestibular, somatosensory, and auditory systems remain to process the complex motions and forces of flight. Information processed by these systems alone is unreliable because of the ease at which they automatically adjust to whatever aircraft attitude you're flying, right or wrong. Under these conditions, your brain compares the information detected by your remaining senses to the two-dimensional information you have relied on all your life. If they match, you remain oriented. However, a mismatch generates illusions capable of quickly capable of placing your senses in conflict with reality and causing spatial disorientation.

Information

Definition And Classification

Definition

Spatial disorientation (SDO) is defined as the inability to accurately orient yourself with respect to the earth's horizon. We use four sensory systems to maintain our orientation and equilibrium (balance) — the visual system, the vestibular system, the somatosensory system and the auditory system. These systems are effective when a person is on the ground, in a 1 G environment performing normal activities. Collectively, they convey an accurate message of orientation and balance. Unfortunately, when these sensory systems are used inflight, they are not reliable orientation indicators. This fact is especially evident when visual cues are lost or become confusing. Therefore, be aware of the mechanisms, functions and reactions of the sensory systems used for orientation in the flying environment.

In the following sections, types of SDO, sensory systems and their related illusions, factors affecting SDO, prevention of SDO and recovery from SDO are discussed. Additionally, the causes and preventive measures of motion sickness are discussed.

Classification

Spatial disorientation is classified into three types. Each type has different characteristics posing different threats to the crewmember.

Unrecognized Spatial Disorientation (Type I) — is the most dangerous type of SDO you can experience. Unrecognized SDO occurs when you do not realize you are disoriented. In this case, you believe the aircraft is in a normal or desired attitude (pitch, roll, and/or yaw), when in reality the aircraft is in a different or unusual attitude. Unrecognized SDO can occur while flying in clouds (no horizon) and relying on your vestibular and somatosensory systems to provide attitude information instead of the flight instruments. As a result, you think the aircraft is flying straight and level, when in reality it may be in a 30° left bank and nose low. Unrecognized SDO can lead to controlled flight into terrain (CFIT), especially in high-speed, low-altitude environments.

Recognized Spatial Disorientation (Type II) — is the least dangerous type of SDO. Once again, you become spatially disoriented. However, this time you perform effective instrument cross-checks and identify the fact you are disoriented. As a result, you are able to recover from SDO using your flight instruments.

The main purpose of SDO training is to enable you to move from unrecognized SDO to recognized SDO. Recognizing SDO allows for recovery of the aircraft or ejection (if necessary) before you are out of the ejection envelope.

Incapacitating Spatial Disorientation (Type III) — occurs when you are so disoriented that you are incapable of recovering even if it is recognized. Fortunately, this type of SDO is rarely experienced. However, there are documented cases where crewmembers realized they were disoriented, but were unable to recover because of the overwhelming sensory stimulation. In these cases, you can eject if you have the capability, or use other aids such as the autopilot or fellow crewmembers to help recover the aircraft.

Orientation Sensory Systems

Objective 1 — Select the correct description for each of the four sensory systems enabling orientation, equilibrium and balance.

Objective 2 — Select the sensory system providing the strongest, and usually the most reliable, orientation information.

Objective 3 — Identify the function of the vestibular system and its two subsystems; the semicircular canals and the otolith organs.

Objective 4 — Determine the reason for the somatosensory system's unreliability inflight.

The visual system, the vestibular system, the somatosensory system and the auditory system can all be "fooled" into believing what they sense is "true and accurate" in the flying environment.

Information from each sensory system is sent to the brain, which coordinates all the input. If the input from each system agrees with the others, the individual is "oriented." However, if there is a mismatch between the systems, three things can occur. The individual becomes disoriented, motion sick or both. Figure 5-1 depicts the different sensory

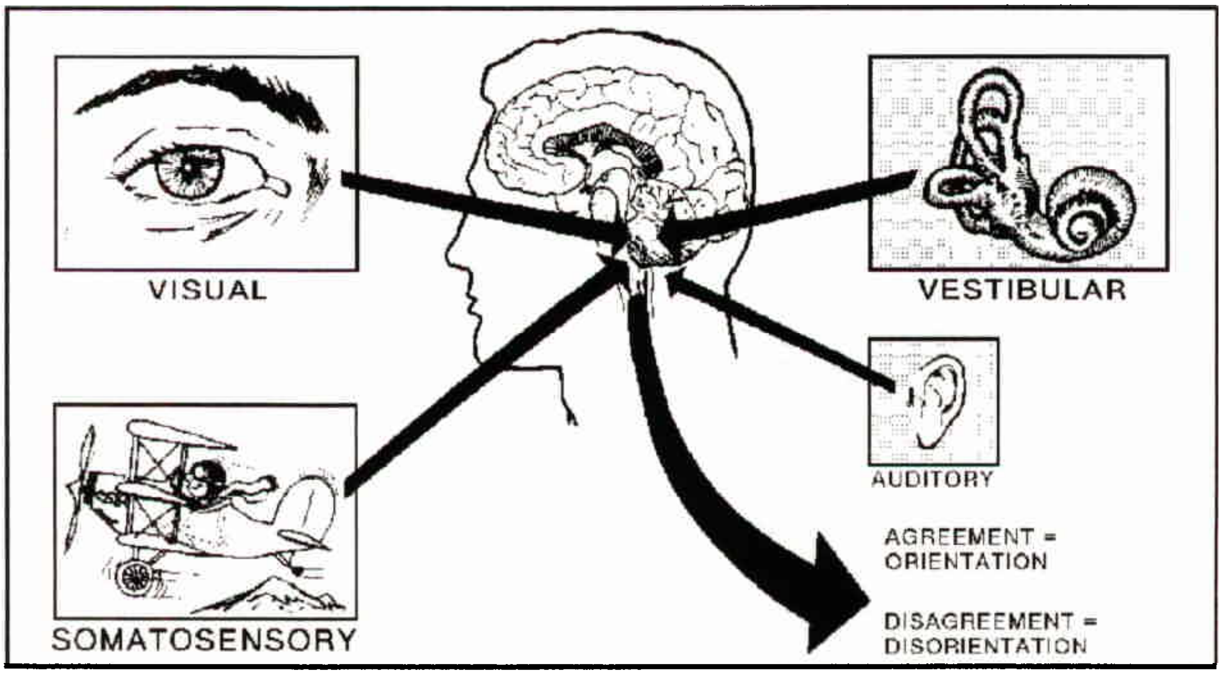


Figure 5-1 — Sensory Systems

systems and their connections to the brain. The following describes the different systems, their function and their limitations inflight.

The Visual System

The eyes provide the strongest and, usually, the most reliable orientation information during flight. Recall from the Vision lesson, peripheral vision is the primary means the visual system uses to collect orientation cues. The orientation cues provided by the eyes are strong enough to overpower all other orientation system inputs. Orientation cues from the peripheral visual field are primarily processed subconsciously, at much faster speeds than information from your focal vision. As a result, a "straight line" within the *visual field* is perceived by your *peripheral vision* as a horizon, regardless of the "straight line's" orientation to the surface of the Earth.

Most of the time, the information the eyes receive is correct. For instance, if you become disoriented flying in clouds (because of confusing vestibular input), and then fly out of the clouds and acquire an accurate horizon, the disorientation disappears almost instantly. However, when the horizon acquired is not correct, your vestibular disorientation disappears, but you may still experience visual illusions caused by the false horizon.

Visual illusions involving peripheral vision are difficult to avoid. Since information acquired by the peripheral visual fields is processed subconsciously, you must use your focal vision (requiring conscious attention) to override the peripheral input. Use your focal vision by concentrating on the flight instruments to ensure the aircraft flies correctly. Unfortunately, it's difficult to override the peripheral visual inputs and it takes practice, discipline and concentration to accomplish. If flight instruments are not used when visual horizon inputs are lost due to flying in clouds, at night or in haze, the brain reverts to the vestibular system for orientation information.

The Vestibular System

The vestibular system is located in the inner ear and consists of two subsystems — the semicircular canals and the otolith organs. Designed to work on the ground, they are responsible for two different categories of illusions inflight depending on which subsystem is stimulated. If the semicircular canals are stimulated, the illusions are categorized as somatogyral illusions. If the otolith organs are stimulated, the illusions are somatogravic illusions. Figure 5-2 illustrates the vestibular system.

The Semicircular Canals — are located in each inner ear. There are three canals in each ear, oriented at right angles to one another in the pitch (vertical), roll (lateral), and yaw (horizontal) axes. They measure angular acceleration caused

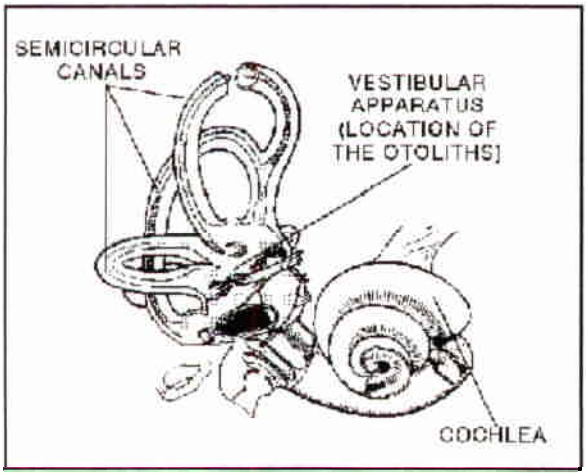


Figure 5-2 — Vestibular System Anatomy

when the head is turned or tilted. For the semicircular canals to sense angular acceleration, the acceleration must reach a threshold in the range of 0.14°/sec^2 to .5°/sec^2 actual movement.

Each semicircular canal contains a fluid called endolymph, which is stimulated into motion when the head accelerates in the axis of the canal. When the head is accelerated, the fluid in the canal lags behind because of inertia. As a result, the apparent motion of the fluid is in the opposite direction of the acceleration. This motion causes a concentration of specialized nerve cells called the *cupula* to bend in the direction of the fluid motion. The bending of the cupula sends a signal to the brain which interprets the signal as changes in position or attitude. Use Figure 5-3, A and B for the following example. If a person rotates their head to the right, the acceleration causes the displacement of the fluid to the left and the cupula bends to the right. The brain interprets the bending of the cupula to the right as angular motion to the right.

On the ground, the semicircular canals are an excellent complement to vision as an orientation system. However, inflight and without adequate visual cues, the semicircular canals have a strong and unreliable orientation input to the brain. Additionally, input from the semicircular canals can be strong enough to cause muscles to react and attempt to keep a crewmember upright.

There are maneuvers that stimulate the semicircular canals for extended periods of time. If the angular acceleration continues at a constant rate for a period of 10 to 20 seconds, the motion of the fluid in the canals equalizes with the motion of the canals. When equalization occurs, the apparent motion of the fluid is zero, the cupula are not deflected, and the brain receives a false impression that rotation has stopped (Figure 5-3, C). Therefore, in the absence of visual cues, you do not perceive you are in a bank, descent, or climb. If the motion stops or decelerates, the inertia of the endolymph causes it to continue in the original direction of acceleration. This stopping or deceleration results in the cupula being deflected in the opposite direction of the original acceleration (Figure 5-3, D). As a result, you experience the sensation of moving in the opposite direction of your original maneuver.

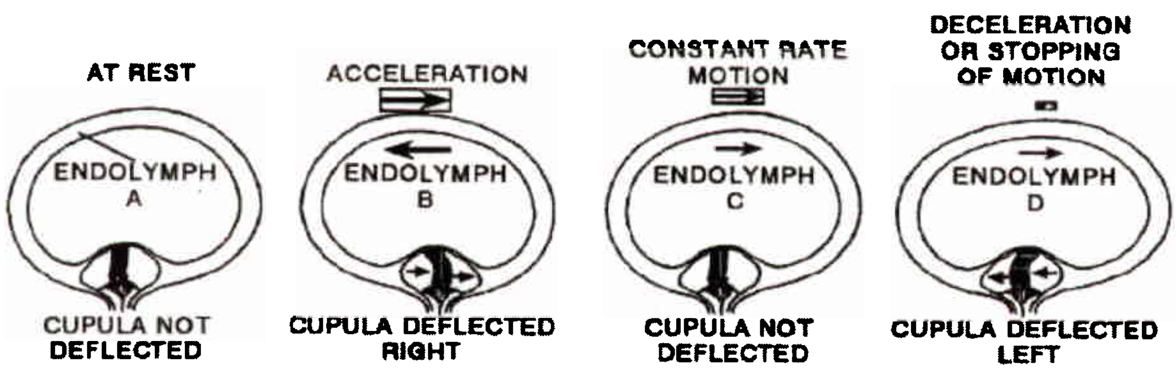


Figure 5-3 — Semicircular Canal and Angular Acceleration

An example of the effect of angular acceleration on the semicircular canals inflight occurs when you enter a holding pattern while in the weather. In this case, the absence of a visual horizon results in the semicircular canal input being used for orientation. As you enter the holding turn, you roll the aircraft to 30 degrees of right bank (stimulating the roll canal) and begin a 180-degree turn, taking two minutes. Within 10 to 20 seconds of the initiation of the turn, the endolymph equalizes and there is no physical sensation of being in a bank. When you roll out of the turn, the fluid in the canal continues to move and displaces the cupula in the opposite direction. You sense the aircraft in an opposite left bank of the same magnitude as your initial bank when in reality you are in straight-and-level flight. If you are not using your flight instruments, you may react to the sensation of being in an opposite bank by rolling into a right bank to make your head "feel right." All three semicircular canals work on the principle depicted in Figure 5-3 (response to angular acceleration) and more than one canal can be stimulated at a time.

The Otolith Organs — are located near the base of the semicircular canals in the vestibular apparatus and sense linear acceleration (refer to Figure 5-2). They consist of a base of nerve cells with hair like appendages that are embedded in a gelatinous substance containing calcium carbonate crystals. As you tilt your head forward, the crystals slide forward and the nerves signal the brain that the head is tilted forward. Conversely, if you tilt your head back, the crystals slide backwards and the nerves signal the brain that a backward tilt is occurring. Inflight, forward or backward linear accelerations cause the crystals to slide backwards or forwards respectively in response to the inertial force. For instance, if you accelerate forward, the crystals slide to the rear and, in the absence of a visual horizon, you sense the aircraft is pitching up. Conversely, a rapid deceleration causes you to sense the aircraft is pitching down. In either case, you may react by pulling back on the stick or yoke or pushing forward to compensate for the perceived change in pitch attitude. Figure 5-4 shows the function of the otolith organs in normal situations and in response to linear accelerations.

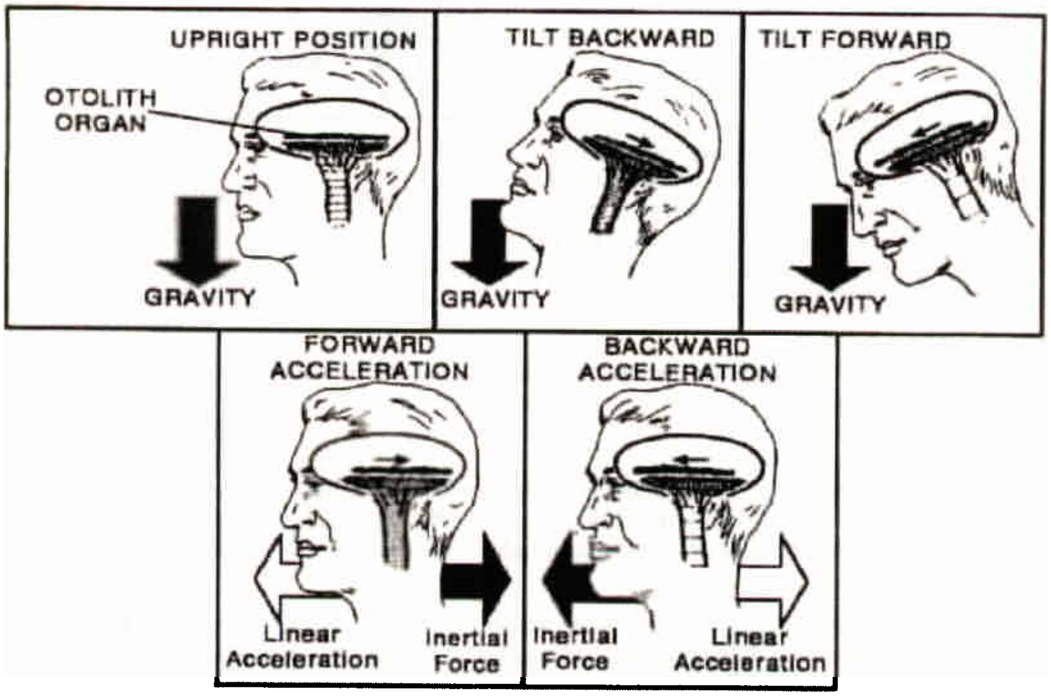


Figure 5-4 — Otolith Organs and Linear Acceleration

The Somatosensory System

The somatosensory system consists of tactile pressure receptors in the skin, muscles, tendons and joints. The pressure receptors are used to help maintain posture and balance. The somatosensory system is often called the "seat-of-the-pants" sense. Unfortunately, inflight, the somatosensory system is useless as an orientation system in the absence of correct visual cues. Because most flight maneuvers are made in the positive-G environment, there are no variations in pressure cues. Therefore, the somatosensory system does not receive adequate input to tell the somatosensory receptors if the aircraft is in a bank, nose up, nose down or inverted attitude. Figure 5-5 shows inflight forces acting on the somatosensory system.

The Auditory System

The auditory system can help maintain situational awareness and spatial orientation through feedback. This feedback is related to aircraft speed and its relationship to the noise produced by the aerodynamic forces acting upon the aircraft. For example, in IMC, increasing airstream noise may indicate an undesired nose down attitude. This auditory information should cause you to check your instruments and take corrective action, if required.

Vestibular Induced Spatial Disorientation

Objective 5 — Select the correct physiological explanations for specific vestibular illusions.

Objective 6 — Given an inflight spatial disorientation scenario, identify the probable illusion experienced by the crewmember(s).

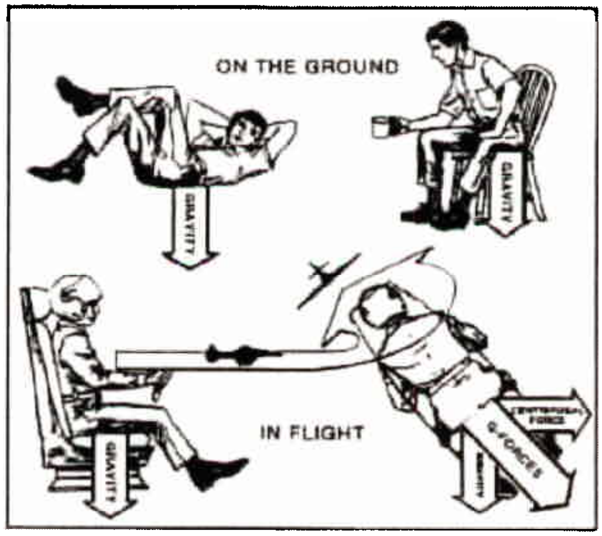


Figure 5-5 — Somatosensory System

The visual, vestibular and somatosensory systems work together to tell you where you are in relation to your environment. You can look at these three systems as a tripod, remaining stable as long as all three systems are working correctly. However, if one of these systems is not working correctly, it is like removing a leg from the tripod, which then becomes unstable. Inflight, the visual system is most likely to be lost. When loss of visual information occurs, you receive a majority of your orientation information from the vestibular system. Unfortunately, the vestibular system is very easy to corrupt and can readily provide erroneous information. The vestibular system also has a very strong input to neuromuscular pathways which, if the stimulus is strong enough, can cause you to reflexively move the aircraft controls in undesired directions. Most of the time, however, vestibular stimulation results from mild accelerations and leads to Type I/Unrecognized SDO. Remember, vestibular illusions occur primarily in the absence of peripheral visual cues.

Illusions caused by each of the vestibular systems are discussed in the following section. Illusions caused by the interface between the vestibular and visual system (vestibulo-ocular illusions) are also discussed.

Somatogyral Illusions

Somatogyral illusions are caused by the stimulation of the semicircular canals due to angular acceleration. In this illusion, after you return to straight-and-level flight, you sense the aircraft is turning or banking in the opposite direction. Three major somatogyral illusions can occur inflight — the Leans, the Graveyard spin/spiral and the Coriolis illusion.

The Leans — is the most common vestibular illusion experienced inflight. It is caused when the semicircular canal responsible for sensing acceleration in the roll axis is stimulated. If during the course of flight the aircraft is allowed to roll at a rate below the threshold, in the absence of any reliable visual cues, the roll will not be perceived. Once you realize the aircraft is in a roll or bank, however, you may correct with a roll in the opposite direction at a roll rate greater than threshold. As a result, you will perceive a bank or roll in the opposite direction even though you thought you were in a wings-level attitude. In some instances, you may find yourself physically leaning back to the opposite direction of the perceived bank, hence the term "the leans."

Additionally, if the initial roll rate is greater than the threshold, the acceleration is great enough to cause the sensation of "roll." Once the acceleration stops (motion may continue but at a constant rate), the endolymph reaches equilibrium and the cupula is not displaced. At this point, you don't perceive the aircraft is in a bank or roll. When the aircraft rolls out to a wings-level attitude, the angular momentum of the endolymph, moving in the direction of the original bank or roll, continues because of inertia. The cupula is deflected in the opposite direction of the original bank and you perceive an opposite bank or roll of the same magnitude as the original maneuver, when in reality you are wings-level. If the roll to wings-level (deceleration) is rapid enough, you may physically "lean" in the opposite direction of the perceived roll or bank (Figure 5-6).

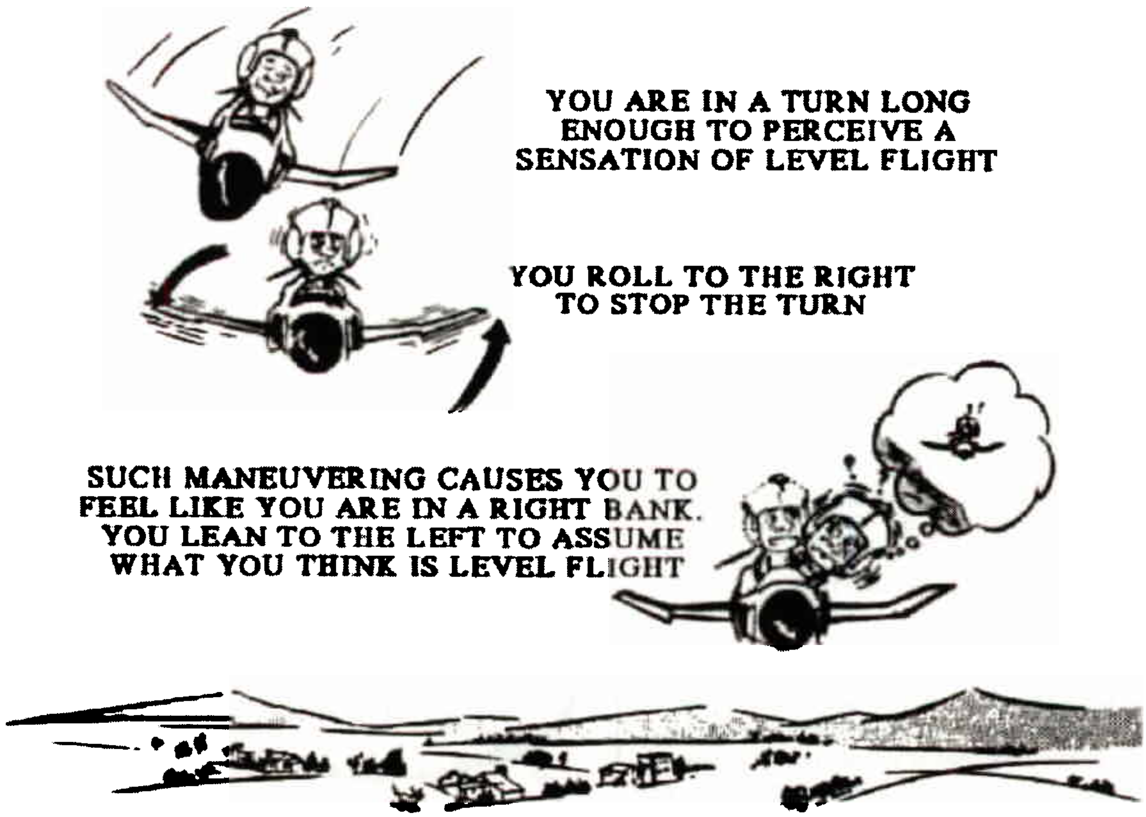


Figure 5-6 — The Leans

The Graveyard Spin/Spiral — is an example of how deadly somatogyral illusions can be when flying in conditions of reduced visibility (night or instrument weather). Because of the mechanics of the semicircular canals, you become disoriented quickly when your aircraft is placed in a spin or spiraling turn (with no distinct horizon). To help illustrate the graveyard spin or spiral, let's use a crew who unintentionally spins their T-6 (to the left) into the clouds. The crew correctly perceives the initial spin direction because the angular acceleration causes the endolymph to displace the cupula in the yaw canals. However, as the spin continues at a constant rate, the endolymph stabilizes and the cupula are no longer deflected. The crew perceives a slowing and eventual stopping of the spin. When they check their instruments, they realize they are in a spin and apply the appropriate spin recovery procedures, stopping the aircraft from spinning. Because of the angular deceleration caused by the crew's application of the correction procedures, they perceive a spin to the right even though the aircraft is no longer spinning. If they are not aware of the possibility of this illusion, they may think they have entered a right spin, apply the spin recovery procedures for a right spin, and reenter a spin in the original direction.

The graveyard spiral illusion occurs in situations where there is poor visibility and you are flying in instrument conditions. To illustrate this illusion, let's use the crew of an AC-130 gunship orbiting above a target with poor visibility at night. In this situation, the aircraft rolls into a turn with a moderate (30 degrees) amount of bank. After a number of seconds, the crew loses the sensation of turning because of the stabilization of the semicircular canals. Since the crew does not receive adequate input from their other sensory systems, they lose sensation of the increased bank. When the aircraft rolls wings-level, the crew feels they are not only turning in the opposite direction but also as if the aircraft is in an opposite bank. Unwilling to accept the sensation of making a wrong control input, the aircraft is rolled back into the original banked turn. Returning to the original banked turn satisfies the crew's sensation of straight-and-level flight, but the instruments show the aircraft is still turning and losing altitude (a banked aircraft loses lift and as a result can lose altitude). Believing the aircraft is flying straight and level but losing altitude, the crew tries to stop the descent by adding power and pulling back on the yoke (which would normally stop the descent). Unfortunately, the aircraft is in a bank and pulling back on the yoke only tightens the turn. Unless you are aware of this illusion, properly interpret and believe your instruments, and make the necessary corrections, you will continue to descend in an ever tightening spiral. Figure 5-7 illustrates the graveyard spin/spiral.

The Coriolis Illusion -- occurs when two or more of the semicircular canals are stimulated. All crewmembers are susceptible to this illusion. The crewmember perceives a tumbling sensation that can be overwhelmingly disorienting. In the aircraft, the Coriolis illusion usually occurs in situations where the aircraft is turning, rolling or changing pitch and the crewmember moves their head out of the plane of motion. For instance, a fighter crew turning their heads to look at the placement of their bombs while they are pulling off the target. The aircraft is climbing and turning when the crew turn their heads to look over their shoulders. As they turn their heads they stimulate the yaw canal and perceive the aircraft is pitching down and rolling. Their initial reaction is to pull back on the stick and roll to an attitude they think is wings-level. Unfortunately, because of the inaccuracies of the somatosensory system, they don't roll to a wings-level attitude and may impact the ground. Figure 5-8 depicts the Coriolis illusion.

The Giant-Hand Phenomenon

The giant-hand phenomenon is a subconscious reflex behavior, generated by vestibular inputs interfering with your conscious control of the aircraft. It is largely thought of as a somatogyral illusion but can be experienced as a somatogravic illusion. The giant-hand phenomenon occurs when the vestibular stimulus is so strong that you cannot physically overcome the sensation of an opposite bank or roll. As a result, you reflexively roll the aircraft back to the original bank angle to defeat the sensation of opposite bank and cannot maintain a wings-level attitude. One pilot explained the phenomenon felt like a giant hand was pressing down on the wing of his aircraft. However, it's believed the false vestibular input results in a muscular reflex causing you to return the aircraft to an attitude eliminating the sensation of pitch or bank.

To overcome this illusion, you should *momentarily* remove your hand from the aircraft controls to interrupt the reflex response from the illusion. Some pilots reported using their fingertips or knees to move the controls to keep the illusion dispelled. When they gripped the controls in the usual manner, the apparent control anomaly returned.

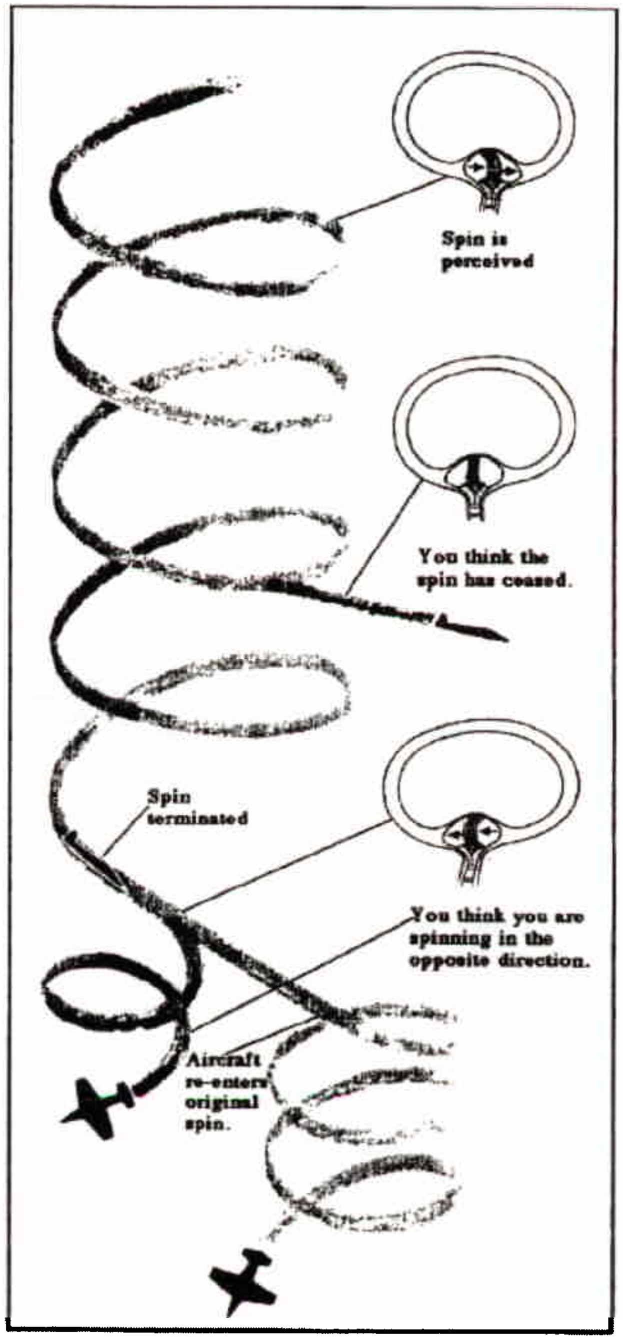


Figure 5-7 — The Graveyard Spin/Spiral

Somatogravic Illusions

Somatogravic illusions are caused by linear accelerations. The otolith organs respond to linear acceleration forces and the illusions usually involve the sensation of pitching up or down. However, there are other somatogravic illusions that are caused by Gforces and turns. The most common somatogravic illusions are the somatogravic illusion and the G-excess effect.

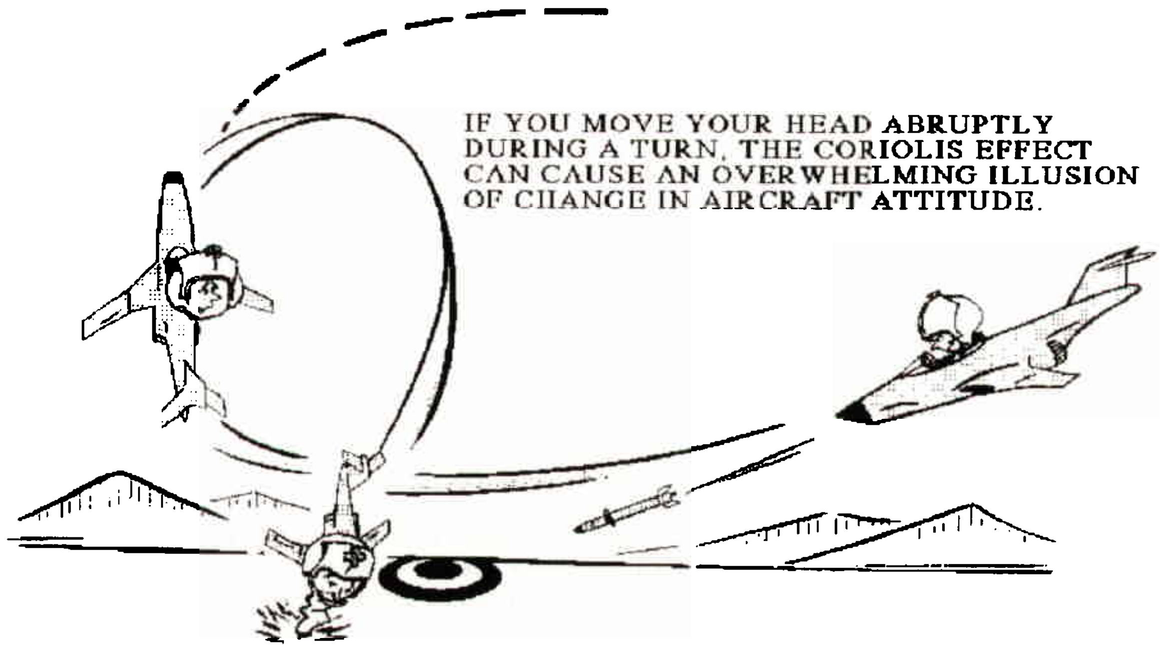


Figure 5-8 — The Coriolis Illusion

The Somatogravic Illusion — is the illusion or sensation of pitching up or down when exposed to a linear acceleration. In the absence of a visible horizon, this illusion can be dangerous. If the aircraft accelerates rapidly, you can feel a pitch up motion caused by the otoliths sliding backwards in response to the acceleration. If you are not paying attention to the instruments, you may react by pushing the nose of the aircraft over to compensate for the perceived increase in pitch. Conversely, if the aircraft decelerates rapidly, you can perceive a pitch down motion caused by the otoliths sliding forward. You may pull the nose up to compensate for the perceived nose down attitude. As a result, the aircraft could stall. Figure 5-9 illustrates the somatogravic illusion.

When the aircraft accelerates, inertial causes the otoliths to move as shown. The otolith movement results in a sensation of climbing and may cause you to overcompensate for illusory changes of attitude.

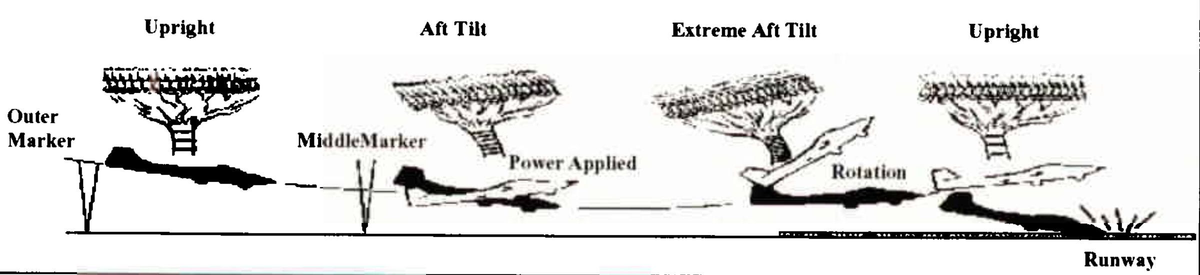


Figure 5-9 — The Somatogravic Illusion

The G-Excess Effect— occurs when the aircraft is in a turn and you are looking outside the aircraft with your head up, towards the inside of the turn, or head-down looking towards the outside of the turn. The otolith organs respond to both the tilt of the head and the G force caused by the turn. If you are looking inside the turn, your head is tilted up with respect to the axis of the aircraft and turned sideways. The G force caused by the turn causes the otolith organs to slide towards the back of the head. The sensation perceived is a decrease in the bank angle. As a result, you perceive you are not banked as much as you should be, and you increase the bank; the nose of the aircraft begins to drop below the horizon and the aircraft loses altitude. This illusion is particularly dangerous if you are operating in a low-level environment. This illusion can also be dangerous when trying to turn the aircraft immediately after take off or during approach.

Vestibulo-Ocular Illusions

Vestibulo-ocular (ocular — the eye) illusions are the result of the eye's reaction to either semicircular canal stimulation (oculogyral illusion) or otolith organ stimulation (oculogravic or elevator illusion). For example, when you turn your head, your eyes lag behind the motion and then make a quick compensatory motion to catch up. This reaction, called nystagmus, is the response of the eyes to semicircular canal stimulation. The same type reaction occurs when the otolith organs are stimulated. For example, if you suddenly accelerate upwards, your eyes reflexively look down. Depending on the type of acceleration force and the magnitude of the stimulation, you may experience either the oculogyral illusion or the elevator illusion.

The Oculogyral Illusion — occurs when the semicircular canal in the yaw plane is stimulated. When the acceleration stops, the eyes continue to "flick" back and forth because of nystagmus. As a result of the nystagmus, objects far away appear to move. However, the semicircular canal stimulus does not need to be significant enough to cause disorientation. A small input, similar to looking up and out of the cockpit, may be enough to cause nystagmus and the oculogyral illusion. For example, during a slow right turn, the instrument panel or another aircraft in formation may at first appear to be advancing through the turn faster than the observer. Following roll-out, from the sustained turn, the instrument panel, aircraft, or objects on the ground may appear to move to the left. These illusions are more severe during rapid head movements and spins. They are also more severe when external visual cues are limited as they are at night or in the weather.

The Elevator Illusion — results from upward or downward acceleration stimulating the otolith organ. If an upward linear acceleration occurs (updraft from a thunderstorm) while the aircraft is level, your eyes will reflexively look downward, giving the illusion of climbing. Most people will reflexively push the nose of the aircraft over to compensate. Conversely, if downward acceleration is experienced (downdraft in turbulence) your eyes reflexively look upward. The result is an illusion of diving and most people will pull the nose of the aircraft up to compensate.

Causes of the elevator illusion are varied. However, the most common causes are flying into weather and turbulence or an abrupt level-off after a prolonged descent or climb at night. The elevator illusion, like all other vestibular illusions, is increased when external visual cues are limited or absent.

Factors Affecting Spatial Disorientation

Objective 7 — Identify physical and physiological factors affecting spatial disorientation.

There are many factors influencing crewmembers' susceptibility to spatial disorientation (SDO). For the purposes of this course, they are divided into two major classifications, physical and physiological.

Physical Factors

Physical factors affecting spatial disorientation are those you have little or no control over. They include such things as the flight weather, type of mission, time of day of the mission and duration of the mission. Physical factors also include cockpit and aircraft design and other aircraft engineering factors you cannot influence. Knowing these factors and how they can influence your susceptibility to spatial disorientation is important for safe flight.

Weather — restricts visual cues used for orientation and can cause SDO. Being aware of the forecast weather and the possible problems that could be encountered enroute greatly increases your capability to prevent a SDO incident. If you know you are going to encounter IMC conditions, you can mentally prepare yourself for instrument flight. However, if you find yourself in an unexpected IMC situation, especially at a point in the mission where you are fatigued, you may be more susceptible to SDO. For example, you encounter expected weather at your landing base. Therefore, you are prepared for a more difficult approach and can plan accordingly. Conversely, if you unexpectedly find yourself in the weather at your landing base, you may find yourself trying to change and replan the approach into the field. If this situation occurs, there is a higher chance for errors at a critical phase of the mission. This situation is compounded if you are mentally or physically fatigued.

Type of Mission — flown can have an affect on the susceptibility to SDO. Missions requiring formation flying at night or in marginal weather are likely situations for SDO. Other types of missions, such as low-level missions or missions requiring night air refuelings, can also lead to SDO.

Time of Mission/Mission Duration — You must be prepared to fly any time of the day or night, in any weather for an extended period of time. Your ability to prepare and prevent SDO mishaps from occurring depends on your awareness of the threats, mission preparation and the physiological factors involved in SDO. The fatigue that results from disruptions in your circadian cycle greatly increases your susceptibility to SDO.

Physiological Factors

Physiological factors are those you have some control over. These factors are thoroughly discussed in the "Stress Awareness and Management" lesson. These factors are reviewed here to reinforce how influential they are in regards to SDO and include alcohol, self-medication, dehydration and fatigue.

Alcohol — The use of alcohol increases your susceptibility to SDO even though you may have stopped drinking within the time limits mandated by regulation. Alcohol produces a condition known as positional alcohol nystagmus for up to 72 hours after ingestion, depending on the amount ingested. So, for 12 to 72 hours after ingesting alcohol, you have an increased susceptibility to SDO. Additionally, the side effects of alcohol increase fatigue and dehydration, slowing your perceptual abilities and increasing your susceptibility to SDO.

Self-Medication — usually occurs when you do not feel well. Unfortunately, self-medicating increases your susceptibility to SDO by increasing fatigue levels, depressing the central nervous system, causing dehydration, and can have a synergistic effect with the illness. For example, a crewmember who is flying with a cold and taking over-the-counter cold medicines to control congestion and fever, combines the depressant effect of the cold medicine with the fatigue resulting from the cold. Therefore, they may become less alert, fail to recognize the SDO situation, possibly resulting in a mishap.

Dehydration — in the flying environment causes you to fatigue more quickly, increasing susceptibility to spatial disorientation. Your ability to recognize and correct for illusions also decreases, placing you and your crew at a disadvantage.

Fatigue — Mental or physical fatigue increases your susceptibility to SDO by decreasing your ability to react and perceive what is occurring. Additionally, when you are tired, your ability to accumulate and process information slows down. This effect means some cockpit tasks are relegated to the subconscious level. Unfortunately, the subconscious level relies on the vestibular system for orientation cues in the absence of peripheral vision cues. Therefore, if you are fatigued and find yourself in a situation where you can become disoriented, there is a greater chance the SDO will be unrecognized. Fatigue also slows your ability to analyze and overcome the SDO. It's every crewmember's responsibility to ensure they are sufficiently rested, both physically and mentally, to fly the mission.

Other Factors Affecting SDO

Several other factors can influence SDO. These factors include your experience in flying in IMC conditions, mission preparation and your recency of experience (how long ago you flew in these conditions).

Experience in IMC — The more you fly in IMC, the better able you are to cope with its specific demands. A high time IMC crewmember will probably be better able to anticipate the situations that may cause SDO (rolling out of a turn, moving your head to change a switch position, etc.) than a low time IMC crewmember. However, when SDO is involved, *there is no guarantee* a high time IMC crewmember will be less susceptible to SDO than a low time IMC crewmember.

Mission Preparation — also has a direct effect on your susceptibility to SDO. During mission planning sessions, review the portions of the mission that could present problems. Also evaluate your experience level with this type of mission. If it's a regularly flown mission, you are likely to be aware of the possible hazards. However, if the mission is flown infrequently, the hazards must be briefed accordingly. For multi-place aircraft, develop a plan and procedures to use inflight should the pilot flying the aircraft become disoriented. For example, the pilot team should have a clear plan of attack for handling SDO.

Recency of Experience — is how often, and when, you have flown a certain type of mission. A crewmember with lots of recent day, VMC low-level experience is not necessarily proficient doing night, IMC, low-level missions. Therefore, a crewmember may be more susceptible to SDO during night low-level missions since the usual day, VFR visual cues aren't available.

Good cockpit resource management is vital in situations where SDO may occur. Effective communication between crewmembers can prevent or decrease the possibility of an SDO incident by maintaining awareness of what the aircraft is doing and where it is in relation to the ground.

Prevention Of Spatial Disorientation

Objective 8 — Identify five methods used to prevent spatial disorientation.

You can prevent SDO occurrences by employing a variety of tools. The most important tools are your knowledge and awareness of SDO, its causes and what you can do to prevent an SDO mishap. You need to understand your limitations, be prepared to remedy correctable factors, properly use your capabilities, recognize high risk situations and stay alert. Figure 5-10 summarizes the methods used to prevent SDO.

Understand Limitations

Planning, training and awareness helps keep you within your limits and prevents you from finding yourself in a SDO situation you neither expected or are capable of coping with. During mission planning, identify and understand your individual limitations and your crews' collective limitations to minimize the SDO threat. Also, understand the limitations of your orientation systems and the illusions caused by the absence of clear visual cues.

Prevention of SDO
• Understand Limitations • Remedy Correctable Factors • Use Capabilities Properly • Recognize High Risk Situations • Stay Alert!

Figure 5-10 — SDO Prevention

Remedy Correctable Factors

Understanding limitations helps you identify and remedy correctable factors. For example, when was the last time you flew in instrument conditions? If you are noncurrent or have not recently flown in instrument conditions, request a simulator (if available) or fly simulated instrument conditions with an instructor. Be aware of experience levels and maintain coordination with fellow crewmembers. Thoroughly plan and brief the mission, identify those portions of the flight where SDO is a major threat, form a plan to prevent an SDO occurrence, and what actions to take if disorientation does occur.

All crewmembers must remain acutely aware of where the aircraft is in relation to the ground at all times. Every crewmember on the aircraft should know the responsibilities of other crewmembers in order to effectively back each other up, particularly in high threat situations.

Use Capabilities Properly

Use your individual and collective capabilities properly and do not overextend yourself to the point of exceeding your limits. Ensure you're aware of where the aircraft is in relation to the ground and notify fellow crewmembers of any deviation to aircraft attitude, altitude, and position. You must know the altitudes, airspeeds and rough headings to be flown. Collectively, the crewmembers must use their knowledge and awareness of the aircraft, mission and SDO to keep the aircraft within safe operating limits.

Recognize High Risk Situations

During mission planning, identify and recognize any high risk situations that may occur during the flight. For instance, if you fly a low-level route, identify factors increasing susceptibility to SDO (like a moonless night or weather hazards on the low-level route). Additionally, other situations, such as time of day of the flight and fatigue factors need to be considered. After recognizing the high risk situations, you can develop a plan to minimize or eliminate the SDO risk while still completing the mission. Furthermore, you cannot forget that you are vulnerable to SDO from take off to landing.

Stay Alert!

Finally, stay alert to the fact that SDO can be a threat at anytime during the flight. You must be aware that even though you have completed the high threat portions of the mission, SDO can still occur. For example, although the night, low-level portion of the mission is complete, the mission is not a success until the aircraft lands. And although the crew may be fatigued, everyone must remain alert. All crewmembers must actively monitor the approach airspeeds and altitudes to backup the pilot flying the aircraft. Always back each other up to ensure the mission is complete without loss of aircraft or crew.

Overcoming Spatial Disorientation

Objective 9 — Identify seven procedures used to overcome spatial disorientation.

If you become spatially disoriented, you must transition from unrecognized SDO to recognized SDO as rapidly as possible. Recognizing and correcting for SDO is vital to the safety and survival of crew and aircraft. You can ensure the crew corrects and overcomes SDO by using the following procedures (summarized in Figure 5-11).

Overcoming SDO
• Transition to Instruments • Believe the Instruments • Back-Up the Pilot Flying on Instruments • Minimize Head Movements • Fly Straight and Level • Be Prepared to Transfer/ Assume Control • Egress

Figure 5-11 — Overcoming SDO

1. Transition to Instruments

A highly disciplined instrument cross-check is the key to recovery from SDO (especially while flying at night, in the weather and in formation). Removing ambient visual cues, by leaning forward, should place any distractions from canopy glare outside your peripheral visual field. Additionally, leaning forward causes the horizon line on the attitude indicator to fill a larger area of your visual field. The longer the line, the easier it is to keep your attention.

Immediately recognize and correct unusual deviations in attitude, altitude, airspeed or position from the planned flight profile. Consciously suppress vestibular sensations by concentrating on your instruments and avoid fixating on any one thing.

2. Believe the Instruments

You must learn to ignore, overcome or control false sensations perceived from your senses. Remember, the gauges are right. If the instruments indicate you are upside down, then you *are* upside down!

Note — In some cases where the pilot flying the aircraft is severely disoriented, the copilot and/or the navigator/NFO must also transition to instruments and prepare to assume control of the aircraft or initiate an ejection.

3. Back-up the Pilot Flying on Instruments

In multiplace aircraft, the pilot not flying the aircraft or the navigator/NFO must ensure the pilot flying the aircraft takes the correct actions to recover the aircraft in a SDO situation.

4. Minimize Head Movements

Avoid excessive head movements when flying formation in weather. "Sneak-a-peek" at your gauges using your eyes only. If you feel your head is spinning, rest your head against the seat back. Doing so reduces the chance of restimulating the vestibular system and the spinning sensation should subside within seconds.

5. Fly Straight and Level

30 to 60 seconds of straight-and-level flight while concentrating on your instruments should settle your semicircular canals. When flying formation, in the weather, on the wing you can become disoriented more easily because your attention is focused on the lead aircraft's position and not on your gauges. Under these conditions, the lead aircraft is your primary attitude indicator. If you become disoriented, the lead aircraft should communicate attitude information at regular intervals. Lead should avoid abrupt accelerations and execute turns and rollouts smoothly and gently. Any unexpected attitude changes by the lead can further disorient you. Get to VMC if possible. In some fighter aircraft, the navigator can assume control and return the aircraft to straight-and-level flight if necessary.

6. Be Prepared to Transfer/Assume Control

The pilot should transfer control to the other pilot (in multi-place aircraft) or the WSO/NFO (fighter aircraft), if possible, because it is rare to have all crewmembers simultaneously disoriented. Use the autopilot to reduce task saturation and SDO, but remember to maintain a constant cross-check of the instruments. Do not allow the autopilot to fly you into the ground.

In fighters, the WSO/NFO can talk the pilot through the recovery procedures or ask for control of the aircraft.

7. Egress

If orientation cannot be reestablished, particularly during critical phases of flight, ejection or bailout may be your only chance for survival. In aircraft with ejection seats, you must be intimately familiar with your ejection seat's parameters (the ejection envelope). You must preplan how long you will attempt to recover the aircraft before ejection. *Therefore, the decision to eject is determined during mission planning and not in the air.* The loss of an aircraft because of SDO is undesirable but the preventable loss of crewmembers is unforgivable.

Formation Flights

The potential for SDO is greatest for formation flights during night or weather conditions. Crewmembers scheduled for formation flights in night/IMC should be current and proficient in instrument, night and formation flying. The flight leader in the preflight briefing should cover specific procedures to manage a disoriented wingman.

There are two essential requirements for safe formation flight in weather. One, the flight leader must be experienced, competent and smooth. Two, the wingman must be proficient in formation flying. The wingman must have total confidence in lead and concentrate primarily on maintaining a proper wing position.

If weather encountered during formation flight is either too dense or turbulent to ensure safe flight, the flight leader should separate the aircraft under controlled conditions.

The flight lead should encourage a wingman to verbalize any feelings of disorientation. A few words from lead can reassure the wingman and may help form a mental picture of the flight's position in space. If the wingman continues to have problems, lead should bring the flight to straight-and-level and advise the wingman. Maintain straight and level for at least 30 seconds (60 seconds if possible). Usually, the wingman's symptoms will subside in 30 to 60 seconds.

If the above procedures are not effective, then lead should consider transferring the flight lead position to the wingman while straight and level. Assuming the flight lead position may allow the wingman to transition to instruments and recover from the disorientation.

Spatial Disorientation Trainer

Goal 1 — Using a spatial disorientation trainer, experience spatial disorientation and practice/perform methods to maintain aircraft control while disoriented.

Your instructor will conclude classroom instruction with disorientation demonstrations in the Barany chair. Student volunteers will assist in the demonstration of various vestibular illusions. Each student will receive training in a disorientation demonstrator.

Note — In the event of maintenance difficulties precluding use of the Vista Vertigon, ASDD or MSDD the Barany chair will be used for this training.

Motion Sickness

Goal 2 — Understand the physiological (sensory inputs) and psychological (self-imposed stress) causes of motion sickness.

Goal 3 — Understand techniques used to prevent and overcome motion sickness in the flying environment.

The exact cause of motion sickness is unknown. However, the most widely accepted theory proposes motion sickness is caused by "sensory conflict." According to this theory, there is a conflict between the visual and vestibular system or between different components of the vestibular system. For example, flying with your head down in the cockpit during aerial maneuvers sets up a mismatch between the vestibular system (sensing the accelerations of the maneuvers) and the visual system (deprived of visual motion cues). The result of the mismatch is motion sickness. Susceptibility to motion sickness is increased by anxiety, fear, fatigue, dehydration, hypoglycemia and disease. Heat, lack of air flow, an inadequate visual horizon or blocked visibility are environmental factors that may also increase susceptibility to motion sickness.

Symptoms

The symptoms of motion sickness are nausea, sweating, belching, cold and clammy feeling, and headache. In some cases, active vomiting occurs and sometimes prostration (inability to remain standing). The development and intensity of these symptoms depends on individual susceptibility, previous experience, frame of mind and environmental stimuli.

Prevention

Motion sickness decreases if good outside visual references exist. However, these references are not always available, but there are other tools you can use to help prevent motion sickness.

One of the most important tools available to prevent motion sickness is your ability to *eliminate or minimize self-imposed stress*. You should be well hydrated before flight and continue to drink water during the flight. You should also ensure you are flying with some food in your stomach. Bland, starchy foods, like bread or crackers, help absorb excess acids produced by the stomach. Eliminate or severely decrease your consumption of alcohol in the 24 to 48 hours prior to flight. Finally, you should be well rested to concentrate on the mission, from beginning to end. Always remain motivated!

Treatment

Acquiring a good outside visual reference will usually remove the symptoms. Sometimes, cool air blowing across the body decreases the symptoms and breathing 100 percent oxygen also helps. If the symptoms persist, you can employ a technique known as diaphragmatic breathing to help the symptoms subside. Inhale deeply through your nose, pause, exhale out your mouth, pause, and repeat the cycle until the symptoms subside.

Post-airsickness Procedures

In the event you become airsick, you must see a flight surgeon to ensure there are no underlying physiological illnesses that caused the episode.

Summary

SDO is the inability of a person to accurately orient themselves with respect to the surface of the Earth. SDO is categorized as Type I/Unrecognized (the most dangerous), Type II/Recognized (the least dangerous) and Type III/Incapacitating (rare, but dangerous).

The visual system is the primary mode of orientation. However, when the visual cues are removed (instrument flight conditions), the vestibular system becomes the primary source of orientation information. Unfortunately, inflight, the vestibular system and somatosensory system are not only powerful but also untrustworthy.

Recognizing the physical and physiological factors affecting susceptibility to SDO helps you control them. The physical factors (those you *cannot* control) include weather, type of mission, the time of day and duration of the mission. The physiological factors (those you *can* control) include self-imposed stresses, mental and physical fatigue, emotional well-being and flight preparation.

You can help prevent SDO by knowing your limitations, remedying correctable factors, using your capabilities properly, recognizing high risk situations and staying alert. If you become disoriented, transition to instruments and believe the instruments. Basically, "GET ON THE INSTRUMENTS AND MAKE THEM READ RIGHT!" SDO is overcome by knowledge and awareness, effective crew coordination and minimized exposure to self-imposed stresses.

Review Exercise JP(0)105

Complete the following review exercise by choosing the correct answer(s) and filling in the blanks. Answers are at Attachment 1.

1. Match the categories of spatial disorientation (SDO) to the correct characteristics.

   a. Unrecognized SDO (Type I)

   b. Recognized SDO (Type II)

   c. Incapacitating SDO (Type III)

   1. The least dangerous
   2. Rarely experienced, but dangerous
   3. The most dangerous

2. List the 4 sensory systems enabling you to maintain orientation, equilibrium and balance.

   a.

   b.

   c.

   d.

3. The system primarily used for orientation is the ________________system. In the absence of ________________cues, the ________________system becomes dominant.

4. The primary means the visual system uses to collect orientation cues is________________ ________________.

5. The vestibular system's two subsystems are the ________________ ________________and the ________________ ________________.

6. The ________________ ________________detect angular accelerations and are responsible for ________________illusions.

7. The ________________ ________________detect linear accelerations and are responsible for ________________illusions.

8. The ________________system is useless as an orientation system in the absence of accurate visual cues.

9. Match the following somatogyral illusions to the correct definitions.

   a. ______The Leans

   b. ______The Graveyard Spin/Spiral

   c. ______The Coriolis Illusion

   1. Results when you move your head out of a plane of motion and perceive a tumbling sensation.
   2. Set up by a roll rate below the threshold of 0.14°/sec^2 to 0.5°/sec^2 and then correcting with a roll in the opposite direction at a roll rate greater than the threshold.
   3. Results when you correct for a spin or spiral and sense you have entered a spin in the opposite direction or are turning in the opposite direction.

10. Somatogravic illusions result from the stimulation of which organs?

    a. Semicircular canals

    b. Eustachian tubes

    c. Otolith organs

    d. Tactile pressure receptors

11. The ________________ ________________is an illusion of pitching up or down as the result of linear acceleration.

12. The ________________ ________________occurs when the aircraft is in a turn and you are head-up looking towards the inside of the turn or head-down looking towards the outside of the turn.

13. The interconnection of the vestibular system with the visual system causes ________________: a reflexive response of the eyes to stimulation of the semicircular or otolith organs.

14. Like all other vestibular illusions, the elevator illusion is increased when external visual cues are limited or absent.

    a. True

    b. False

15. Determine if the following statements refer to (A) environmental or (B) physiological factors influencing susceptibility to spatial disorientation.

    a. ______You have little or no control over

    b. ______Mental and physical fatigue

    c. ______Alcohol and self-medication

    d. ______You have some control over

    e. ______Flight weather

    f. ______Type and duration of mission

16. List three methods you can use to prevent or minimize the threat of spatial disorientation.

    a.

    b.

    c.

17. List four techniques you can use to overcome spatial disorientation.

    a.

    b.

    c.

    d.

18. Motion sickness increases if good outside visual references exist.

    a. True

    b. False

Lesson JP(0)106 — 0.5 Hours (IBT)

Noise and Vibration

Objectives

1. Identify the characteristics of sound and how they contribute to hazardous noise exposure.
2. Identify the effects of hazardous noise.
3. Identify the protective measures used to minimize hazardous noise exposure.
4. Select the symptoms or conditions that may result from prolonged exposure to aircraft vibration.

Assignment

Read JP(0)106 in the SG and answer the review questions.

Introduction

Noise is another stress you must cope with during flight and ground operations. In this lesson, the characteristics of sound, how the human perceives sound, and the effects of both short- and long-term exposure to noise will be discussed. In addition, the problems of noise-induced hearing loss and methods used to prevent hearing loss will be discussed.

Information

Noise

Objective 1 — Identify the characteristics of sound and how they contribute to hazardous noise exposure.

Exposure to high intensity noise, like that produced by jet engines, can damage hearing sensitivity, resulting in permanent or temporary deafness. There are other effects of noise exposure that can be just as harmful. For instance, sleep disturbances, mental fatigue, and stress reactions can occur from overexposure to noise. Various factors influence the degree noise affects the hearing of exposed individuals. Crewmembers exposed to noisy environments must understand the risks of noise exposure, probability of permanent hearing loss, and preventive measures to protect their hearing.

Definition and Characteristics of Noise

Noise is *unwanted* sound. The characteristics of noise of concern to you are frequency and intensity of the noise, duration of exposure to the noise, and distance from the noise source. Noise becomes hazardous as a result of these characteristics.

Frequency— Sound waves are created by the alternate compression and rarification of air, above and below atmospheric pressure respectively. The number of times each second that these oscillations occur is referred to as the frequency. By convention, one oscillation per second is termed one Hertz (Hz). Therefore, a frequency of 100 cycles per second is 100 Hz. The human ear is normally receptive to frequencies between 20 and 20,000 Hz. This is referred to as the audible range. Frequency is also referred to as pitch.

As a person becomes older, they naturally lose hearing in the higher frequencies (above 4,000 Hz). Crewmembers, however, tend to lose hearing in the upper-mid frequencies and show hearing loss in frequencies that relate to the type of aircraft they fly. For instance, crewmembers flying heavy aircraft, such as P-3s and C-130s, show frequency loss in different ranges than those crewmembers flying fighter-type aircraft.

Most noise that a crewmember is exposed to consists of many different frequencies (broad band), like an airplane at full thrust. However, there are instances where the crewmember is exposed to predominantly single-frequency noise (narrow band). In environments where there is narrow band, high intensity noise, more damage occurs to the crewmember's hearing. An example of a narrow band noise is a T-37 aircraft at idle. The majority of the sound emitted by the T-37 is at 2000 Hz. Unprotected exposure to high intensity noise at this frequency can cause permanent hearing damage within seconds.

Intensity — or loudness is the magnitude of an acoustic event and is a measure of pressure of sound waves in the ear canal. Sound pressure levels increase millions of times between the normal threshold of human hearing and the maximum safe level. To avoid the use of awkward numbers, a more convenient term, the decibel (dB), is used to measure these pressures. The decibel is a logarithmic expression of the ratio of the sound pressure being measured to the lowest sound pressure detectable by the normal human ear at 1,000 Hz. As an example of the logarithmic nature of the expression dB, the sound pressure buffeting the eardrum increases 100 times between 100 and 120 dB. Figure 6-1 illustrates several common noise situations and their corresponding intensity levels. Figures 6-2 and 6-3 provide noise intensities of various aircraft in different phases of flight.

The intensity threshold at which humans are susceptible to permanent hearing loss is 85 dB. At noise levels of 85 dB and above, hearing protection should be worn. A rule of thumb used to gauge whether certain noise levels are intense enough to require protection is the "shout test." If one has to shout to be heard at a distance of one meter, then the noise level is intense enough to require hearing protection. The threshold for pain is 130 dB and physical damage occurs at noise levels of 150 dB and above.

Loud, Louder, Loudest	
Jet engine (near)	140
Jet takeoff (100 feet), shotgun firing	130
Boom box, rock concert	120
Jackhammer, chain saw (gas)	110
Arcade game parlor, radio headset	100
Motorcycle, lawn mower (5 feet)	90
City traffic noise, hair dryer	80
Dishwasher, vacuum cleaner	70
Inside car (windows up), normal conversation	60
Quiet office	50
Refrigerator humming, living room	40
Broadcasting studio, whisper	30
Hearing test booth, rustling leaves	20
Sound just audible, normal breathing	10
Absolute threshold	0

Figure 6-1 — Common Noise Situations

Distance plays an important role in determining how hazardous a noise source may be. If noise traveled through the air efficiently (perfect conditions) there is a 6 dB decrease in intensity as distance from the source is doubled (beyond 30 meters from the source). For instance, if a jet aircraft starter unit (JASU) is emitting 100 dB at 30 meters, and you are standing 60 meters from the JASU, you are exposed to 94 dB. If you stood at 120 meters, the intensity drops to 88 dB. However, the intensity may be modified by environmental factors such as temperature and humidity.

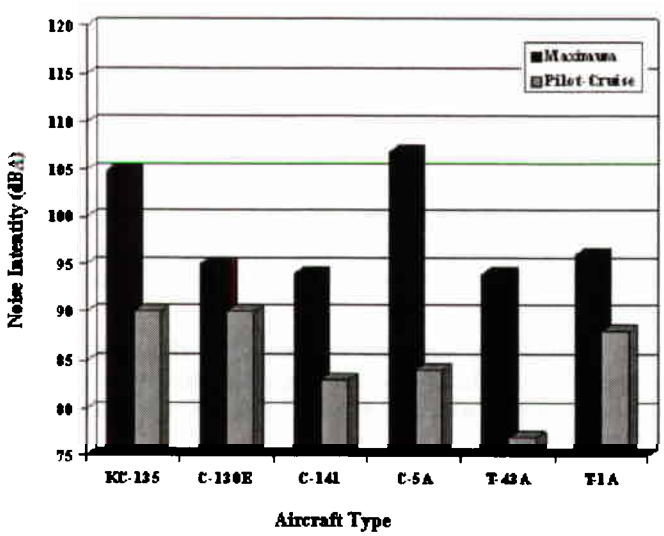


Figure 6-2 — Airlift/Tanker Noise Levels

Duration — The length of exposure to noise plays a fundamental role in determining how much irreversible damage is inflicted on your hearing. Figure 6-4 depicts the time a human can be exposed to different intensities of noise without protection. The rule for figuring exposure times is for every 3 dB increase, the time of exposure is reduced by one-half. For instance, the maximum allowable time unprotected exposure to 85 dB is eight hours. If the noise intensity is increased to 88 dB, the allowable time of exposure is four hours. At 112 dB, the maximum allowable exposure is less than one minute.

Environmental factors that affect sound transmission through the air can either increase or decrease the intensity of noise. Terrain, wind direction, wind velocity and air density significantly affect the intensity of the noise at a given distance.

Perception of Sound

The human ear is divided into three sections — the external ear, middle ear and inner ear. Figure 6-5 shows the anatomy of the human ear. For one to perceive and identify sound, the signal must be converted from the mechanical energy of sound waves to electrical energy. The electrical energy is then transmitted to the brain via the auditory nerve.

The external ear collects sound waves and directs them to the middle ear. The middle ear consists of an eardrum and three small bones (ossicles), acting to transmit sound (vibrations) from the external ear to the inner ear. The vibrations are transmitted into the spiral-shaped, fluid-filled cochlea of the inner ear. Vibrations received by the cochlea set up a fluid motion which is perceived by tiny hair cells. These hair cells are connected to the auditory nerve. Movement of the hair cells caused by fluid motion results in the production of nerve impulses. These impulses flow to the auditory center of the brain for interpretation.

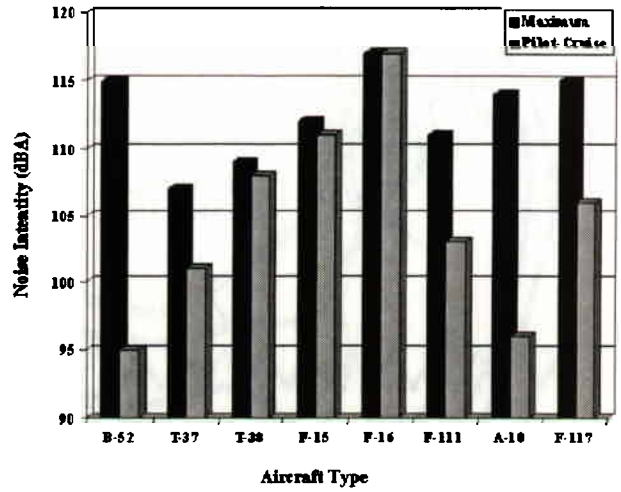


Figure 6-3 — Bomber/Fighter Noise Levels

Effects of Hazardous Noise

Objective 2 — Identify the effects of hazardous noise.

Two types of hearing loss can occur when you are exposed to high intensity noise — conductive or sensorineural (nerve-damage).

Conductive Hearing Loss — occurs when one of the parts of the ear that is designed to transmit mechanical energy fails. For instance, a ruptured eardrum cannot transmit the sound energy to the ossicles of the middle ear. Another example of conductive hearing loss is failure of one of the middle ear bones, or the joint between the bones, to vibrate correctly. Incorrect vibration causes inefficient transmission of the sound energy. Each of these examples illustrates the loss of the ability of the ear to conduct sound energy of all frequencies to the inner ear.

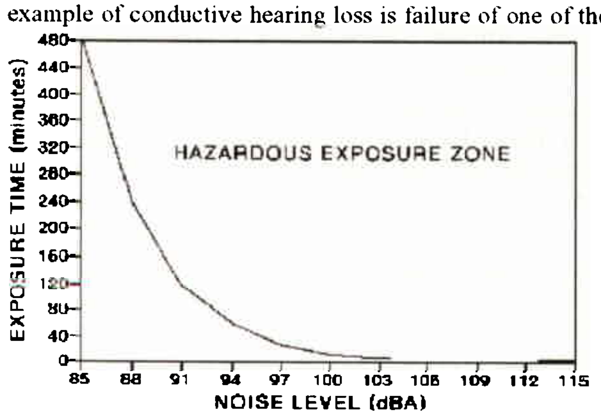


Figure 6-4 — Exposure Limits to Noise

Sensorineural Hearing Loss — occurs when the hair cells of the cochlea are damaged, destroyed, or degenerated due to overexposure to noise. When a person is exposed to loud noise, the pressure waves in the cochlea are so strong that they can cause the base membrane of the cochlear duct to vibrate excessively. The excessive vibration causes the hair cells to brush against the upper membrane of the cochlear duct with enough force to cause damage to the hair cells. If the noise is intense enough or exposure long enough, the hair cells can actually be broken off. Depending on the amount of damage to the hair cells, you may suffer from temporary or permanent sensorineural hearing loss.

1. Temporary threshold shift — is a *nonpermanent* loss of hearing in a frequency or range of frequencies after exposure to loud noise. For instance, after listening to a live band, there may be a feeling of fullness in the ears accompanied by a dullness in hearing. Additionally, there may be a ringing in the ears (tinnitus).

When a person is exposed to loud noise, the hair cells become fatigued and sometimes damaged. Fortunately, a temporary threshold shift is not permanent. If you are exposed to noise levels that can cause a temporary threshold shift, sitting in a quiet spot for a couple of hours will usually return your hearing to almost normal. However, normal or almost normal hearing levels may not return for as much as one to two days. A crewmember who has experienced a

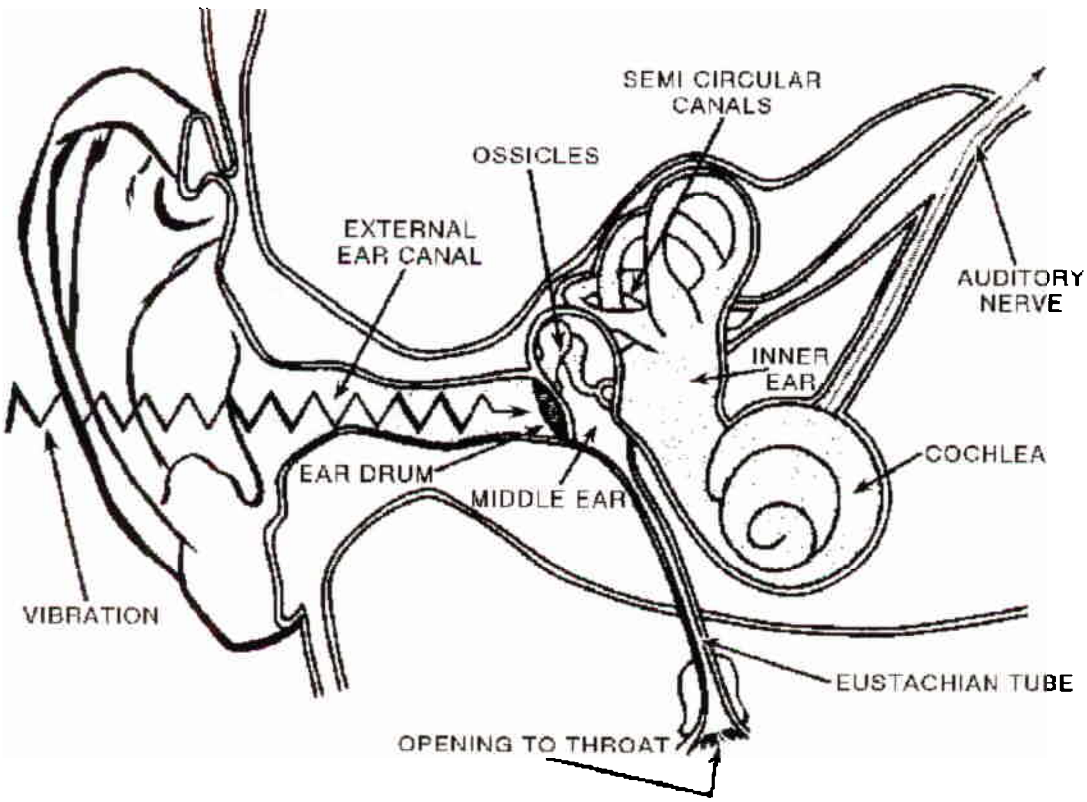


Figure 6-5 — Perception of Sound

temporary threshold shift should not expose their hearing to that particular noise environment again since hair cell damage has occurred and further damage may lead to a permanent threshold shift.

2. Permanent threshold shift — occurs when the cochlea's ability to convert a certain frequency or frequencies to electrical signals is lost because of hair cell damage. Once hair cells are destroyed or damaged to the point they are no longer functional, the ability to hear the affected frequencies is *permanently* lost. Unfortunately, crewmembers work in an environment that is very hazardous to their hearing; this environment can cause permanent damage very quickly if preventive and protective measures are not taken.

Non-Auditory Effects of Noise — on crewmembers can pose problems in the flying environment. Excessive noise masks sound entering the ear and can make speech unintelligible. Masking of other crewmember's speech can lead to misinterpretation of communication and cause the crew to make a mistake.

In addition to auditory masking, excessive noise increases stress. Excessive noise increases fatigue levels, leading to lower levels of alertness. Sleep disturbances may be encountered, leading to sleep loss and an increase in anomalies of attention. There is also an increase in crewmember irritability, distraction and uncooperativeness. In the flying environment where alertness, accuracy and attentiveness play vital roles in mission success, noise protection is important to keep the crewmember safe and effective.

Protection from Noise

Objective 3 — Identify the protective measures used to minimize hazardous noise exposure.

The aviation environment is noisy and can cause permanent hearing loss in crewmembers very quickly. Therefore, you must protect your hearing. A number of devices are available that attenuate noise and protect hearing, including earplugs, ear muffs ("Mickey Mouse ears"), headsets and flight helmets. Techniques for protecting your hearing include decreasing the time of exposure and increasing your distance from the noise source.

Earplugs — Communication in the voice range is not disrupted or degraded when using earplugs. They protect your hearing by lowering the intensity of noise reaching the cochlea and by filtering the high frequencies, making speech reception more clear and less distorted.

There are many types of earplugs available to the crewmember and are basically classified into two major categories — formable and molded plastic.

1. Molded plastic earplugs must be fitted to the ear canal by an audiologist, are reusable for long periods of time, can be washed, and are very effective at attenuating noise. The V-51R molded earplug and a similar version, the triple-flanged earplug are the most common types. Both are very effective in attenuating noise in the 2,000 Hz to 6,000 Hz range and provide from 24 to 30 dB of protection at these frequencies. However, molded earplugs provide an airtight seal in the external ear canal and can prevent equalization of pressure during descent. Therefore, because of their inaccessibility, they should not be used underneath a flight helmet. They are most often used by ground crew personnel and crewmembers who do not wear flight helmets.

2. Formable earplugs are designed to fit everyone. They are made of compressible material that expands to form-fit the external ear canal. One of the most popular types of formable earplug is the EA-R® earplug made of vinyl polymer. The E-A-R® is compressed by rolling it between the forefinger and thumb, and then inserting it into the ear. It should be held in place for approximately 20 seconds, until it has a chance to fully expand. When properly fitted, E-A-R® type earplugs provide roughly 29 dB to 35 dB protection in the 2,000 Hz to 6,000 Hz frequency range.

To ensure maximum protection with formable earplugs, they must be clean and dry. Formable earplugs can be washed but will lose some of their protective capabilities. Therefore, it's best to use a new pair of earplugs after one or two flights. E-A-R® earplugs are very popular and effective in undergraduate flying training.

Ear Defenders, Headsets and Flight Helmets — also provide noise protection. The amount and effectiveness of the protection depends on a tight seal between the earcup and the ear. Without a tight seal, sound energy can enter the ear. The effectiveness of noise protection is decreased if you wear glasses or place cloth sweat bands under the earcups. Sunglasses or eye glasses should be fitted to allow for a minimum break in the earcup seal with the ear.

The amount of noise protection is also dependent on the mass of the helmet, earplug or headset being used. The lighter and less dense the device, the less the protection.

Combination of Protective Devices — The most practical protection available to you, other than limiting or preventing exposure to noisy environments, is the use of a combination of protective devices. Using earplugs under headsets or helmets increases the protection provided to you and allows for clearer radio and interphone reception. Protective devices, used in combination, can provide 28-32 dB of protection.

Limiting Exposure — to dangerous noise levels is the best protection against hazardous noise. However, limiting exposure to noise is not always possible, especially if your aircraft is inherently noisy. Therefore, you must use protective devices to attenuate the noise. Limiting one's exposure to loud noise environments off-duty also decreases hearing loss.

Vibration

Objective 4 — Select the symptoms or conditions that may result from prolonged exposure to aircraft vibration.

Vibration is defined as the rapid movement of an object in a back and forth motion. Vibration is described with the same parameters as sound — frequency, intensity and duration.

Frequency Ranges

Vibrations occur throughout the frequency spectrum; however, vibration of very low frequency and high intensity are of most concern. The approximate range of 1 to 100 Hz is most hazardous to humans. The skull resonates at frequencies between 20 and 30 Hz and the eyeball between 60 and 90 Hz. These vibrations are distressing to the individual. Vibration energy may be passed to the body acoustically or by direct mechanical linkage. Isolation of the vibration source and restraint of the body may be necessary to provide physiological protection.

Effects on Performance

Low altitude, high speed flight in weather causes the most severe vibration exposures. Vibration can effect your ability to perform at peak levels.

Tracking — Horizontal tracking is generally not affected by vibration. However, vertical tracking is significantly impaired with vibration. Low frequency vibrations can produce tracking error up to 40 percent greater than in an environment without vibration.

Reaction Time — Studies indicate that vibration does not typically influence crewmember reaction time to tasks executed at the conscious level. However, the reaction time of executing tasks delegated to the subconscious level showed marked deterioration during vibration.

Visual Impairment — Vibration can cause blurred vision and therefore reduce your visual efficiency. Vibration in the frequency band ranges of 25 to 40 and 60 to 90 Hz are particularly degrading to visual acuity. Vibration causing blurring of the instrument panel makes accurate reading of the instruments very difficult. Proper design of visual instruments and displays and an increase in their illumination and contrast reduces the effect of the vibration.

Fatigue — Vibration contributes to fatigue, a prime factor in *decreased* crewmember performance.

Symptoms of Exposure

Symptoms which may result from exposure to harmful vibration frequencies are loss of appetite, complacency, perspiration, salivation, nausea, headache and vomiting. Severe vibration can also result in fatigue, discomfort, and actual pain. There is indication that long-term vibratory exposures can lead to chronic stiffness of articulating joints and appear to develop in much the same manner as noise-induced hearing loss.

Summary

The noise and vibration produced by the aircraft is one of the many stresses you must cope with while flying. Noise is simply defined as unwanted sound and can become a problem to you as a result of the noise's frequency, intensity or duration. The process of perceiving sound involves the conversion of the mechanical sound wave to electrical energy that can be interpreted by the brain. Proper protection from hazardous noise is most effectively accomplished through the use of a combination of devices in order to minimize the possibility of hearing loss or other non-auditory effects of noise. Finally, the hazard of vibration is greatest at a low frequency and high intensity. These hazards include effects on performance such as impaired vertical tracking, increased reaction time, visual impairment, and fatigue as well as causing physical symptoms.

Review Exercise JP(0)106

Complete the following review exercise by choosing the correct answer(s) or filling in the blanks. Answers are at Attachment 1.

1. Noise is ________________ ________________.

2. The primary characteristics of noise concerning crewmembers are ________________, ________________, and ________________.

3. The number of times (each second) compression and rarification of air occurs is ________________.

4. Noise (sound) intensity perceived by the human ear is measured in ________________.

5. The noise from a T-37 aircraft is dangerous to crewmembers because of its ________________ ________________of intensity and frequency.

6. The two types of hearing loss you can suffer are ________________hearing loss and ________________hearing loss.

7. Crewmembers on the flightline are being exposed to 97 dB of noise. Their time of maximum unprotected exposure to this noise before they must leave is ________________minutes.

8. What is the most practical method of noise protection for you?
   a. Limiting exposure
   b. Combination of protective devices
   c. Flight helmet
   d. Ear plugs

9. Select the statements describing vibration.
   a. Approximate range hazardous to humans is 1 to 100 Hz.
   b. Relaxes the crewmember.
   c. Occurs throughout the frequency spectrum.
   d. Midfrequency and intensity are of most concern.

10. Select the effects of severe vibration on crewmember performance.
    a. Low frequency vibrations can significantly impair horizontal tracking, increasing tracking error by up to 40 percent.
    b. Vibration reduces reaction time for those events/tasks executed at the conscious level.
    c. Vibration can cause blurred vision and degrade visual acuity.
    d. Vibration is a major contributor to fatigue.

Lesson JP(0)107 — 2.0 Hours (IBT)

Acceleration

Objectives

1. Select the correct definition for a specific type of G force.
2. Select the physical factors determining the effects of increased G force on a crewmember's body.
3. Identify the physiological effects of positive and negative G forces on a crewmember's body.
4. Given characteristics of G-induced loss of consciousness (G-LOC), identify the phase of incapacitation during a G-LOC incident.
5. Identify the elements of the Anti-G Straining Maneuver (AGSM) and their relation to each other.
6. Identify common errors in performing the AGSM.
7. Identify the methods used to increase a crewmember's tolerance to positive G force.

Goal

Properly demonstrate all elements of the AGSM.

Assignment

Read JP(0)107 in the SG and answer the review questions.

Introduction

As we stated before the crewmember, rather than aircraft design, is the limiting factor in military flying. You face more physiological threats of greater degree than ever before. Modern fighter aircraft routinely operate in a high-G environment — a high sortie rate and sustained operations is the "norm." Therefore, you must be in excellent physical and mental condition to perform your duties, whether in training or in combat.

An understanding of acceleration on the human body is important to your inflight performance because of its effects on the cardiovascular, pulmonary, and vestibular (orientation) systems. The ability to overcome the effects of acceleration will become more important as you are exposed to aircraft with greater maneuverability and performance. Your ability to combat the adverse effects of G forces depends directly on your level of physical condition and your ability to reduce negative life stressors.

Note — After the classroom presentation, you will demonstrate the AGSM to the satisfaction of your instructor.

Information

Before G forces are discussed in depth, we will define several terms so you can understand acceleration and how G forces are generated.

Physical Principles And Types

Physical Principles

Speed — is the rate of motion (or how far) one travels in a certain amount of time, irrespective of direction. An example is flying at 360 knots groundspeed.

Velocity — describes both a rate of motion (speed) and direction of travel. An example of velocity is 360 knots groundspeed on a heading of 180 degrees.

Acceleration — is a change in velocity per unit time and is generally expressed in feet per second per second (ft/sec^2) or meters per second per second (m/sec^2). *Acceleration is produced when either speed, direction (or both) change.*

The most familiar type of acceleration is gravity. Gravity affects anything on or near the Earth. The acceleration produced by gravity (g) is a constant with a value of 32 ft/sec^2 or 9.8 m/sec^2. Therefore, a free-falling body will increase its velocity by 32 ft/sec or 9.8 m/sec for every second it falls. The inertial force resulting from the linear acceleration of gravity acting upon a mass is termed 1 G. Therefore, when we discuss G forces in the flying environment, we are referring to the inertial force resulting from acceleration.

Types of Acceleration

Linear — acceleration is a change in speed (increase or decrease) without a change in direction. For example, linear acceleration occurs when an aircraft is on takeoff roll or landing rollout.

Radial — acceleration is a change in direction without a change in speed. Radial acceleration occurs when an aircraft pulls out of a dive, pushes over into a dive, or performs an inside or outside turn (and does not change its speed). In these examples, the aircraft's direction changes, but the airspeed remains the same.

Angular — acceleration is a simultaneous change in both speed and direction. Angular acceleration occurs during most aerial maneuvers. For instance, when an aircraft performs a split-S maneuver, the aircraft's speed and direction change simultaneously and the crew experiences angular acceleration.

G Forces

Objective 1 — Select the correct definition for a specific type of G force.

As an aircraft accelerates in one direction, inertial forces act on your body in the opposite direction of the applied force. The inertial force causes the body to experience a G force. The following section discusses the types of G forces a crewmember experiences and the physical factors influencing the effects of G forces on the body.

Types of G Forces

The direction of force determines the type of G force you experience. Three types of G forces you can experience are discussed. They are transverse G, negative G, and positive G.

Transverse G Force — is the force applied to the front ($+G_x$) or back ($-G_x$) of the body. $+G_x$ and $-G_x$ forces are normally encountered during takeoffs, acceleration in level flight, and landing. The maximum transverse G tolerable to humans is roughly 15 Gs in the $+G_x$ direction and about 8 Gs in the $-G_x$ direction. Catapult shots from a carrier deck would be a good example of $+G_x$ and Carrier landings a good example of $-G_x$.

Note — Lateral G forces (the G_y direction) are experienced during spin or roll; however, the effects are negligible.

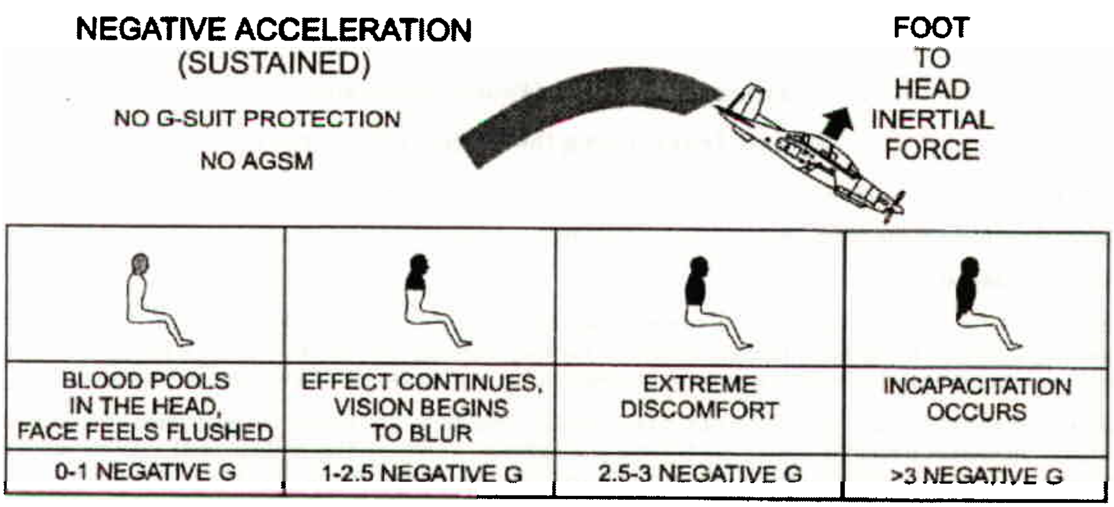


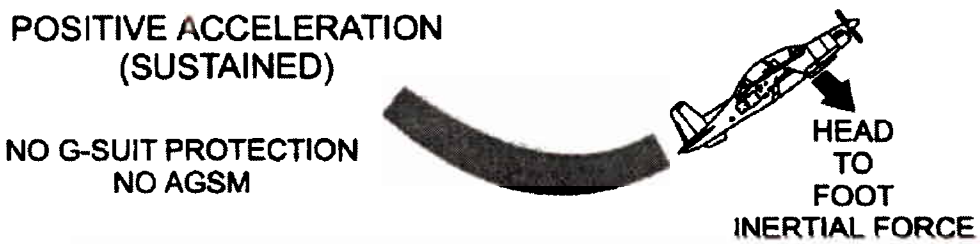
Figure 7-1 — Effects of Negative Acceleration

Negative G Force — is defined as the force being applied from the feet towards the head and is expressed as $-G_z$. Negative G force is not tolerated well by humans and is seldom experienced in high levels during normal flight. Normally, $-G_z$ is experienced when the nose of the aircraft is lowered during a "pushover" or when experiencing turbulence. Human tolerance (physical discomfort) to $-G_z$ may be as low as 3 Gs for 5 seconds.

The physical symptoms of $-G_z$ are a sense of weightlessness, congestion in the head and face, headache and visual blurring. Some flyers have reported a phenomenon called "redout," a reddening of vision during sustained negative G_z flight. The causes of *redout* are not completely understood. The progressive effects of $-G_z$ are illustrated in Figure 7-1.

There is no practical method to counteract the effects of $-G_z$. Under normal conditions, the only way to combat the effects of $-G_z$ is to reduce aircraft maneuvering and return to a 1 G environment.

Positive G Force — is a force applied from the head towards the feet. It is expressed as $+G_z$. It occurs during turns and dive recoveries and is the G force most often experienced by crewmembers. Therefore, much of the remaining information deals with the physiological effects and symptoms of $+G_z$ and methods to increase one's tolerance to $+G_z$. Crewmembers' average resting tolerance to $+G_z$ is 5.5 G. The average levels and the progressive effects of $+G_z$ are illustrated in Figure 7-2.



AS ACCELERATION STARTS, BLOOD BEGINS TO POOL	POOLING INCREASES, VISION BEGINS TO FADE (GRAYOUT)	BLACKOUT OCCURS, COMPLETE VISUAL LOSS	UNCONSCIOUSNESS OCCURS, NO BLOOD IN BRAIN
1-3 G	3-4 G	4-5 G	5-6 G

Figure 7-2 — Effects of Positive Acceleration

Factors Determining the Effects of G Forces

Objective 2 — Select the physical factors determining the effects of increased G force on a crewmember's body.

Objective 3 — Identify the physiological effects of positive and negative G forces on a crewmember's body.

Physical Considerations

The five factors (or physical considerations) determining the effects of G forces are discussed below. These factors help explain why certain G forces have different effects on the body and why the body reacts to certain types of G forces in different situations. Some of these factors are interrelated and have a combined effect on the crewmember.

Magnitude of the G Force — is the size of G force applied to the body. The greater the magnitude of acceleration and accompanying inertial force, the greater the G force. For instance, a crewmember pulling +6 G_z is being accelerated to six times the gravitational force of the Earth, or 192 ft/sec^2. Modern fighter aircraft, like the F-18 and F-16, are capable of exposing you to sustained eight to nine Gs.

Duration of Exposure to the G Force — is another determinate of the effects of the G force on the body. For example, jumping from a table one meter high results in a decelerate force of about 14 Gs for a fraction of a second, usually with no ill effects. But, being exposed to 14 Gs for over two seconds will result in significant physical and physiological effects. These effects are further discussed later in the lesson. The T-6, T-37 and T-34 do not maintain a high sustained G load due to excessive energy loss.

Rate of Application — or *G onset* directly influences the effect of a G force. Rate of G force application is expressed in G per second (G/sec). To illustrate the effect of G onset, imagine dropping a brick on someone's foot versus placing a brick of identical mass on the person's foot. The dropped brick has a greater physical effect on the foot than the brick placed, even though both bricks are identical in mass. The difference is in the rate of acceleration and the resultant inertial force.

Aircraft with long, straight, rectangular wing platforms like the T-6, T-34 and T-37 typically have rapid G onset rates. The T-37 has the highest G onset rate in the USAF inventory, 17 Gs/sec at 175 knots indicated airspeed (KIAS). For reference, the F-16 is computer-limited to 9 Gs/sec. The average time to a visual symptom (grayout) of $+G_z$ exposure is determined by the rate of G onset. The slower the onset, the longer the time to grayout in the low to moderate G ranges.

Direction of Force — defines the axis of the body the G force is applied. The G force can be applied through the X, Y or Z axis of the body (Figure 7-3). By determining the direction of the force, the type of G can be identified. For instance, a force applied from the head towards the feet is a $+G_z$ force and a force applied from the feet towards the head is a $-G_z$ force. G forces can be experienced along other axes as well, but the force applied along the +Z axis has the most significant effect on crewmember performance.

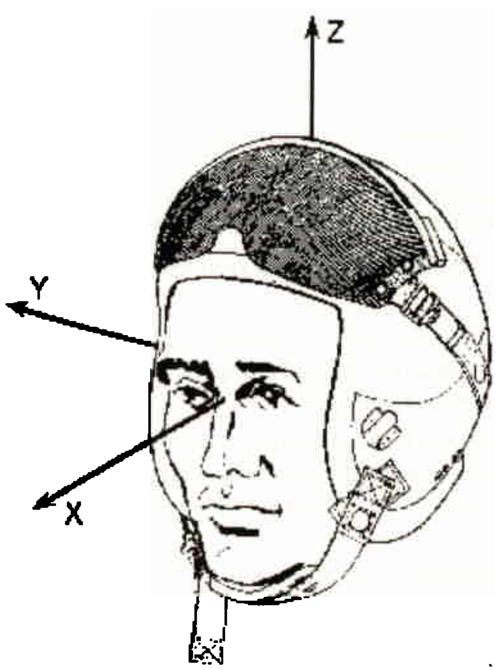


Figure 7-3 — X, Y, and Z Axes

Previous G Exposure — The Push-Pull Effect (PPE) is a phenomena of reduced $+G_z$ tolerance when preceded by exposure to Gz that is less than +1 G_z. It is thought that the less than $+1G_z$ exposure causes a cardiovascular relaxation which can affect subsequent $+G_z$ tolerance. $-G_z$ exposure for a duration of less than 2 seconds can significantly affect $+G_z$ tolerance, possibly reducing tolerance by up to 1.5 Gs (dependent upon magnitude and duration of the $-G_z$ exposure). Maneuvers that produce the PPE are found in some training aerobatics and tactics which include dive attacks, extensions, air combat maneuvering guns defense and split-s maneuvers.

Another aspect of previous G exposure is the fact that the body can be prompted to prepare for increased Gs. The G warmup is a maneuver you will fly at the beginning of most sorties. The G-warmup consists of a very controlled exposure to increased G which prepares you for the higher g- follow-on maneuvers. You will be briefed on the specific procedures of the G-warmup maneuver before your first high-G sortie.

Note — An accelerometer (G-meter) monitors G forces during flight. It displays instantaneous G, maximum positive G, and maximum negative G. The dial also indicates the maximum permissible G force the aircraft can sustain, both positive and negative.

Physiological Effects and Symptoms

Prolonged exposure to G forces affects the body in four principle ways — restricting mobility, affecting the cardiovascular system, stimulating the vestibular system, and reducing visual acuity.

Mobility — A 150 pound crewmember weighs 600 pounds when exposed to +4 G_z. This increase in weight severely restricts movement in the aircraft. For example, your head weighs about 29 pounds when wearing a helmet and oxygen mask. At +4 G_z, your head weighs approximately 116 pounds. If you are not prepared, this increased weight could force your chin into your chest when a loop is initiated. Combined with other physiological effects of $+G_z$, decreased mobility interferes with your ability to function at peak levels during high-G flight.

Cardiovascular Reflex — As $+G_z$ forces increase, blood pressure begins to decrease because of the effects of the G forces on the cardiovascular system. Each $+G_z$ drops blood pressure 22 mm Hg. The cardiovascular system attempts to compensate for the drop in blood pressure by constricting peripheral blood vessels and increasing the heart rate. This compensation is known as the *cardiovascular reflex*. The G-time tolerance curve (Figure 7-4) represents an extremely important concept regarding physiological reactions to $+G_z$. Figure 7-4 is divided into sections A, B and C.

1. Section A — The eyes and brain contain sufficient oxygen to maintain vision and consciousness for 4 to 5 seconds after blood stops flowing to the head. Therefore, a high $+G_z$ load could be applied very rapidly for a short duration without experiencing visual symptoms (i.e., snatching the stick — a very high threat area due to a lack of visual cues).

2. Section B — Between 5 and 10 seconds, when the oxygen reserve is depleted and the cardiovascular reflex has not become fully effective, a trough occurs in the curve — your G tolerance is at its lowest. Applying $+G_z$ at a moderate rate, could cause you to experience symptoms of G stress at a lower $+G_z$ level than when Gs are applied more rapidly or more slowly.

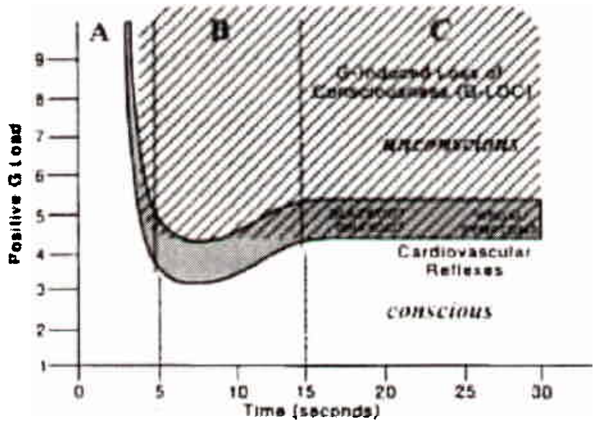


Figure 7-4 — G-Time Tolerance Curve

To reemphasize, Section A illustrates the severe danger of rapidly-applied, *sustained* G loads. The first several seconds of such a G load is symptom free because of the oxygen reserve in the eye and brain. However, as blood in the eyes and brain is depleted of the oxygen reserve, G-induced loss of consciousness (G-LOC) occurs. In this situation, there is essentially no warning from visual symptoms (grayout, tunnel vision, blackout, etc.) to indicate imminent G-LOC.

For example, crewmembers expecting to pull a rapidly-applied 9 G load until grayout (and then unload if necessary), would almost certainly experience G-LOC.

3. Section C — The cardiovascular reflexes mobilize after about 10 seconds of $+G_z$ stress. This reflex increases blood flow to the head, increasing G tolerance by about 1 G. Therefore, when the $+G_z$ load is applied slowly, this reflex helps you tolerate the Gs, and you experience visual symptoms prior to unconsciousness.

Vestibular — effects and their symptoms play a critical role in spatial disorientation and balance. The otoliths are stimulated by gravity and linear acceleration forces to provide you a sense of direction. The semicircular canals respond to angular acceleration to provide another sense of direction. If you do not rely on your instruments and visual cues, acceleration forces can provide stimuli that induce disorientation.

Visual — For blood to enter the retina, the cardiovascular system must overcome about 13-18 mm Hg of intraocular pressure. As the G forces increase and the blood pressure in the brain begins to drop, there is insufficient blood pressure to overcome the intraocular pressure. Therefore, the tissue in the eye that detects light (retina) starts losing its blood supply.

As the blood supply is decreased, peripheral vision is affected and you experience a dimming, misting, or graying of your vision referred to as *grayout* or you may experience tunnel vision, where the only vision remaining is in the center of your visual field. At this point, you must perform a more intense anti-G straining maneuver (AGSM) or unload the Gs immediately. (Exactly how you perform an effective AGSM will be discussed in subsequent paragraphs.) As the G force increases, the blood pressure drops to where it cannot overcome the intraocular pressure and all vision is lost, referred to as *blackout. It is important to note that blackout does not mean you are unconscious.* However, you are in imminent danger of G-LOC.

Note — With high G onset rates, unconsciousness can happen without any preceding visual cues, so always load up the body with an effective AGSM before you load up the aircraft.

G-Induced Loss of Consciousness

Objective 4 — Given characteristics of G-induced loss of consciousness (G-LOC), identify the phase of incapacitation during a G-LOC incident.

Trainers have much higher GLOC rates than operational aircraft. This rate is caused by student inexperience, the aircraft's high-G onset rate, crewmember inattention while flying in a dual-seat aircraft, and channelized attention on the *flying at hand* versus monitoring their AGSM and their fatigue level.

The brain has a 4 to 5 second oxygen reserve. Once blood flow ceases and the oxygen reserve is used, unconsciousness (G-LOC) results. The AGSM sustains blood flow during this critical period of G onset. The effects of GLOC are described as two phases of incapacitation — absolute and relative.

Absolute Incapacitation

In absolute incapacitation you are actually unconscious for roughly 9 to 21 seconds, with an average time of 15 seconds. When you become unconscious, you could relax your grip on the flight controls and the aircraft could return to 1 G flight. If you return to 1 G flight, the cardiovascular system is able to pump blood to the brain and consciousness is restored. However, you could also maintain your grip on the flight controls and perhaps fly the aircraft into the ground.

During the latter stages of absolute incapacitation, you may experience marked involuntary skeletal muscle contractions and spasms just before regaining consciousness. These contractions can cause your arms to flail, leave the flight controls, or hit other aircraft controls. Once you regain consciousness, you enter the second phase of incapacitation.

Relative Incapacitation

Unfortunately, when you regain consciousness, you do not instantly return to an alert and functional state. You may experience mental confusion, disorientation, stupor, apathy or memory loss. During this time, you are incapable of consciously flying the aircraft, making decisions, taking action against a threat, or communicating effectively. The time of relative incapacitation usually mirrors that of the absolute incapacitation.

Protection Against Positive G Force

Objective 5 — Identify the elements of the Anti-G Straining Maneuver (AGSM) and their relation to each other.

Objective 6 — Identify common errors in performing the AGSM.

Goal — Properly demonstrate all elements of the AGSM.

The human body has a limited ability to compensate for the effects of G force. However, there are effective artificial methods you can use to increase your G tolerance and protect against G-LOC.

Protection Methods

Anti-G Suit — sometimes referred to as a G-suit, *fast pants,* or *speed jeans* consists of a pair of pant-like covers fitting tightly over your leg and lower abdomen. Air bladders in the thigh, calf and abdomen areas of the suit are automatically inflated by an anti-G valve on the aircraft. However, the G-suit is not the primary means of G-LOC protection and used by itself, only allows for 1 to 1.5 G of protection. T-37s and T-34s are not equipped for G-suit use because of their flight envelope. Therefore, you must rely on an Anti-G Straining Maneuver (AGSM) to protect yourself from G-LOC. The T-6 is equipped with a G-suit, however it does not provide the majority of the protection from G-LOC.

Anti-G Straining Maneuver — is also referred to as the "hook" maneuver because of the sound frequently made when performing the strain. There are essentially two elements of the AGSM — muscle tensing and cyclic breathing.

1. Muscle tensing is the forceful contraction of leg, arm, and abdominal muscles to compress the blood vessels in the lower body. This skeletal muscle tensing helps prevent pooling of blood in the abdomen and lower extremities and improves the circulation of blood back to the heart (in a high $+G_z$ environment, blood will naturally pool anywhere below the heart). Muscle tensing is mandatory every time you pull Gs and the intensity should be in proportion to the G-load experienced.

In today's high performance combat aircraft and trainers, skeletal muscle tensing alone is not effective enough protection against GLOC. Therefore, a second element of *cyclic breathing* is generally used in conjunction with muscle tensing. Cyclic breathing (with skeletal muscles tensing) is used to increase chest pressure during forceful exhalation against a closed glottis (the structure separating the trachea from the esophagus). The increased chest pressure compresses the heart and blood vessels in the chest cavity and provides an artificial pumping action that, in turn, raises blood pressure in the head. As a result, blood flow to the eyes and brain is maintained during G stress.

2. Cyclic breathing begins with an initial inspiration of air filling both lungs as much as possible and trying to forcefully exhale against a closed glottis while bearing down on the diaphragm. The breath is held and the chest pressure must be maintained for approximately 3.0 (±0.5) seconds, broken only by a rapid air exchange (exhalation and inhalation) of no more than 0.5 second duration. (The initial inspiration is performed after the muscles are tensed and before the G level is increased above 1G.) From that point on cyclic breathing is performed by rapidly exhaling less than one third of the air in the lungs and inspiring a lungs-full amount of air and trying to forcefully exhale against a closed glottis while bearing down on the diaphragm. During an optimally executed AGSM, the breath and chest pressure are maintained for approximately 3.0 (±0.5) seconds before performing a rapid air exchange (about one third total lung volume) of no more than 0.5 second duration with the cycle being repeated until the aircraft returns to 1G flight.

Cyclic breathing must be accomplished simultaneously with muscle tensing. In a high G environment, failure to maintain muscle tension during the breathing element increases the amount of blood pooling in the lower extremities and deprives the heart of necessary blood pressure. The rapid air exchange reduces intrathoracic pressure and enhances venous return thereby improving cardiac output and head level blood pressure.

The muscle tensing element of the AGSM may be sufficient to maintain consciousness in the lower G environments. However, preventing blood pooling in the lower extremities and abdomen by muscle tensing can be overcome by a subtle increase in the G force. The increased G force can cause visual disturbances and/or GLOC. Therefore, crewmembers should perform both elements of the AGSM and then back off their strain as needed. It's better to strain too much then ease up, than to strain too little and not be able to catch up.

The Gtime tolerance curve in Figure 7-4 represents the average, relaxed person. Relaxed G tolerance varies from individual to individual, resulting in values below and above those indicated on the curve. A properly performed AGSM (also referred to as an L-1) can raise tolerance to G by as much as 4 Gs.

AGSM Performance

Muscle Tensing — To be totally effective and prevent GLOC, begin the AGSM *prior* to G onset. It's especially important to tense the calf, thigh, buttocks and abdominal muscles; these muscles are below the heart and have the greatest affect on preventing pooling of blood in the lower extremities. Maintain the muscle tension *until* the aircraft returns to 1 G flight.

Cyclic Breathing — Air is exchanged in 3 (±0.5) second cycles to maintain optimum chest pressure, maximize venous return to the heart and oxygen flow into the lungs. If the breathing cycle is too rapid then the chest pressure is not adequately maintained, fatigue sets in, and there is a threat of hyperventilation. Conversely, if the breathing cycle is too long then the chest pressure remains too high and venous return to the heart is restricted. This restriction decreases the blood available to be pumped by the heart to the eyes and brain. Figure 7-5 (line a) shows how blood pressure in the head responds to an effective AGSM.

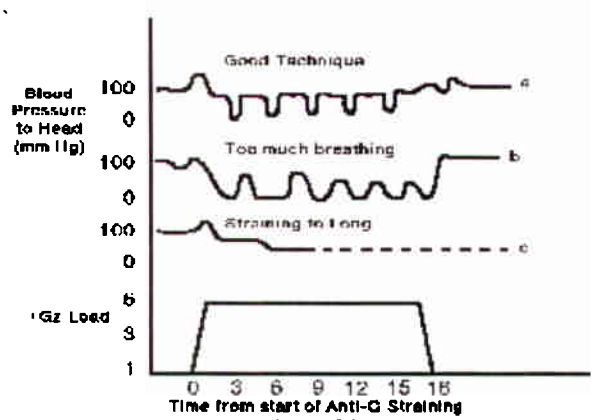


Figure 7-5 — Effective AGSM (line a)

Other keys to the AGSM are the timing of the breathing cycle and, importantly, anticipating the G forces in order to increase blood pressure in the head. With time and experience, performing the AGSM becomes easier and more natural. In the beginning, the problems crewmembers have with the AGSM mostly relate to the breathing cycle and leading the G force.

Warning *— If a crewmember experiences grayout, blackout, or any other symptom of G exposure, the pilot will be notified and the aircraft will be returned to 1 G flight, if possible. The terminology used to terminate the flight maneuver is* ***"KNOCK IT OFF."***

Common Errors of Performance

The most common cause of G-LOC is *an improperly performed AGSM*. The most common errors involve the breathing cycle, the timing of the strain, and insufficient lower body muscle tensing.

Timing — The primary timing error is starting the AGSM after the onset of the G force. Starting the strain late occurs more often if you are not at the controls of the aircraft. You may not be aware the pilot is about to perform a high-G maneuver. Experience will help overcome this disadvantage. The key to preventing this error is good crew coordination and communication. Anticipate the G onset and start the AGSM before the G force is encountered.

Note — Each preflight briefing will provide information on the sortie objectives, including the potential for G loading. During flight, the crewmember flying the aircraft should keep the other crewmember informed of aircraft maneuvers. If you are aware of potential G onset and perform an effective straining maneuver, you will decrease the chance of grayout, blackout, and most importantly G-LOC. If you are not flying the aircraft, your chance of experiencing G-LOC is greater than the crewmember flying the aircraft.

Another timing error is the failure to maintain the AGSM until the aircraft has returned to 1 G flight. Crewmembers sense the G force decreasing and relax. Unfortunately, there is still sufficient G force remaining to force the blood from the brain and cause G-LOC. Remember, maintain the AGSM until the aircraft returns to a 1 G flight environment.

Breathing — For inexperienced crewmembers, one of the more difficult aspects of the AGSM is the coordination and timing of cyclic breathing. These problems are readily corrected with practice and experience.

Common breathing errors include holding the breath too long, not holding the breath long enough (i.e., 2 second cycle), taking too much time to exchange air, exchanging too much air, and failure to exchange air at all. The primary method of correcting these errors is to practice and establish a rhythm. Your AGSM technique should be debriefed after the mission (the "Ops World" uses HUD tape audio).

Note — All students *will* practice the AGSM on the ground until fully proficient. A full AGSM should not be performed in a 1G environment unless under the supervision of an aerospace physiologist. Take the opportunity to practice the AGSM inflight.

Taking too much time to exchange the air or exchanging too much air causes the chest pressure to drop and decreases blood flow to the brain.

Failing to exchange air occurs when you have a good lung-full of air and are tensing the skeletal muscles properly, but forget to exhale and try to continue inhaling. Unfortunately, you can only put so much air into your lungs; there must be an exchange. This error eventually leads to decreased venous return to the heart and stagnant blood flow, resulting in G-LOC. The exercise of imagining to blow out a candle with a puff of air also helps to correct this error.

Other Errors — Allowing air to leak from the throat, holding the breath in the mouth instead of catching it in the back of the throat, and insufficient muscle strain are additional errors in performing the AGSM. Allowing air to leak past the glottis causes the pressure in the chest to drop. It also irritates the vocal cords and makes communication difficult. Air leakage is evidenced by a groan when you strain. Forming the sound *hook* at the back of the throat as you start the strain against the glottis helps prevent air leakage.

Note — Allowing too much air to exit the lungs in an attempt to say *hook* will decrease the amount of air in the lungs, increase required effort and increase fatigue.

Holding the breath in the mouth is another error more prevalent in inexperienced crewmembers. An inefficient strain results again from air leakage, this time from the mouth. In addition, the cheeks fatigue, decreasing your strain. The *hook* sound with the lips slightly parted helps correct this error.

Insufficient muscle strain allows too much blood into the lower extremities. This most common error of not maintaining lower body leg tension causes vision loss. Development of muscle strength and tone with an anaerobic exercise program will remedy this error. Exercise programs are discussed later in the lesson.

Waiting for the G-suit to inflate before executing the strain is another common mistake. By the time the g-suit is inflated a substantial volume of blood is pooled in the legs and will be lost to free circulation until you return to 1 G flight. You must begin the strain *before* you load up the aircraft!

Tolerance To Positive G Force

Objective 7 — Identify the methods used to increase a crewmember's tolerance to positive G force.

G tolerance changes from day to day and hour to hour based on a number of variables. Understanding the reasons for these variables helps you maximize your tolerance and minimize the threat of G-LOC. The following section describes some of the physiological factors and their effects on G tolerance.

Physiological Factors

Physical Conditioning — was mentioned previously as a method to improve muscle strain during the AGSM. Physical conditioning is also important in decreasing the fatigue levels and increasing stamina required for multiple G maneuvers. Two types of physical conditioning are encouraged — anaerobic and aerobic.

Anaerobic Conditioning — The AGSM is essentially an anaerobic maneuver. The muscles used to perform the AGSM rely upon anaerobic energy sources (energy sources not requiring oxygen). Crewmembers flying high performance aircraft are encouraged to develop a weight training program to maximize their muscle strain ability. Weight training is the primary method of anaerobic conditioning and decreases your chances of injury, particularly neck injury during high-G maneuvers.

Anaerobic conditioning increases the muscle's ability to contract and sustain the contraction throughout the G stress. Without sufficient anaerobic conditioning the muscles fatigue quickly and your AGSM loses its efficiency. However, developing a conditioning program based solely on anaerobic exercise is not complete. Aerobic conditioning must complement your anaerobic conditioning.

Aerobic Conditioning — Even though the AGSM is primarily an anaerobic maneuver, you need to be aerobically fit to combat fatigue and recover from multiple G maneuvers. Aerobic exercise programs require oxygen to produce the necessary energy. Aerobic conditioning increases stamina and resistance to fatigue. (G-LOC typically occurs towards the end of engagements during the fatigue period.)

Aerobic conditioning does increase cardiovascular fitness, leading to lower heart rates, lower blood pressure, and faster recovery times fromaerobic exercise. Unfortunately, these attributes of aerobic exercise are not entirely beneficial and may lead to problems in the high G environment. Therefore, it is not recommended for fighter aircraft crewmembers to pursue an excessive competitive aerobic exercise program.

We suggest an aerobic exercise program that does not exceed the equivalent of running twenty miles per week. Integrate your aerobic program with an anaerobic exercise program.

If you would like more information on exercise programs, particularly for G tolerance, consult an Aerospace Physiology officer.

Overall, for crewmembers who fly in high performance aircraft, a sound anaerobic training program coupled with a sensible aerobic exercise program will help maximize their G tolerance. However, exercising prior to high G flight leaves you in a pre-fatigued state and dehydrated, and is not recommended.

The Role of Self-Imposed Stress

Dehydration — Crewmembers generally drink less water than they need and are slightly dehydrated most of the time. Dehydration reduces G-tolerance markedly by depleting blood plasma volume. Aircrews must drink plenty of non-caffienated, nonalcoholic fluids (even when not thirsty) prior to (and during) flight. You suffer a 35 percent decrease in ability to do anaerobic work and a 20 percent decrease in ability to do aerobic work if you are 3 percent dehydrated. Therefore, you can only maintain an AGSM for one-half the time you normally would. For instance, if you can normally pull 9 Gs for 10 seconds, the effects of dehydration will limit you to 9 Gs for 5 seconds.

Fatigue and Sleep — Fatigue significantly decreases G tolerance. Crewmembers who are fatigued or are lacking sleep tend to experience lapses in mental function and a lower ability to maintain muscle tension during the AGSM.

Mental fatigue slows your response and anticipation of high G maneuvers. Physical fatigue lowers your capability to maintain adequate muscle strain during the AGSM and also lowers your capability to perform subsequent strains.

Take advantage of your crew rest, stay well rested and maintain good sleep patterns prior to flying.

Drugs and Self-medication — Self-medication with over-the-counter drugs decreases overall performance. You must always perform at peak levels in a high G environment. If you require medication, then you should not be flying. You are a danger to yourself and your fellow crewmembers. Do not self-medicate, report to the flight surgeon and obtain qualified medical treatment.

Alcohol/Hangover — Alcohol misuse, and the accompanying hangover, drastically reduces your G tolerance. The reduced G tolerance is primarily due to alcohol's dehydrating effects. In addition, a hangover clouds your mental capabilities, slows the thinking and decision-making process, as well as your ability to effectively judge situations.

Alcohol use should be avoided prior to flight. AFI 11-202, Volume 3 restricts crewmembers from alcohol consumption 12 hours prior to flight and OPNAVINST 3710.7Q restricts crewmembers from alcohol consumption 12 hours prior to mission planning. In addition, some detrimental aftereffects can last as long as 48 to 72 hours. Alcohol also contributes to fatigue and hypoglycemia.

Hypoglycemia and Missed Meals — Missing meals or not taking the time to eat correctly directly affects your ability to withstand increased G force. You do not have the fuel in your system to maintain high levels of activity for extended periods of time if you do not eat or you eat improperly. Take the time to eat a nutritious meal prior to flight. Your food is the fuel you must rely on to function in a high G environment.

Summary

G forces are the result of inertial forces acting on the body. G is a dimensionless number expressed as a ratio of a body's acceleration to the force of gravity (32 ft/sec^2 or 9.81 m/sec^2).

The magnitude, duration of exposure, rate of application, direction of force applied and previous G exposure are physical factors influencing the body's physiological response to a G force. These factors define the G force and can predict the effect the G force will have on you.

$+G_z$ is the force of greatest concern to you. It is regularly encountered inflight. The effects of $+G_z$ are decreased mobility, visual disturbances like grayout and blackout, and finally G-LOC. You can increase your tolerance to $+G_z$ by correctly performing the AGSM.

The AGSM is performed by tensing the skeletal muscles (particularly in the lower extremities and the abdomen), cyclic breathing, and exhaling against a closed glottis. Start the AGSM prior to G onset and do not stop the AGSM until the aircraft returns to 1 G flight.

Physiological factors will increase or decrease your G tolerance. These factors include your physical condition and self-imposed stresses (fatigue, dehydration, self-medication, alcohol use and nutrition). Staying in shape, avoiding self-imposed stresses, and performing an effective AGSM will help increase your G tolerance.

Review Exercise JP(0)107

Complete the following review exercise by choosing the correct answer(s) or filling in the blanks. Answers are at Attachment 1.

1. An F-15E crew is on takeoff roll. They accelerate to 165 KIAS in 10 seconds. They experience ________________acceleration and ________________G forces.

2. An F-18 rolls into a dive toward a target, releases weapons, and begins a pullout. He is climbing, turning, and increasing speed from 360 KIAS to 450 KIAS . This time the pilot experiences ________________acceleration.

3. A positive G_z force is defined as the force being applied from the ________________toward the ________________.

4. Define negative G_z force.

5. An aircrew is having problems figuring out the attitude of their aircraft. As the pilot makes a control input, the crew experiences congestion in their heads and lightweight feeling. What type of G force causes these symptoms?

   a. Transverse

   b. Negative

   c. Positive

6. List the five factors determining the physical effects of G forces.

   a.

   b.

   c.

   d.

   e.

7. Why would it be unadvisable to give aircraft control back to a crewmember immediately after recovering consciousness after a G-LOC incident?

8. During a dual T-6A sortie, a student pulls 5 Gs in less than a second and experiences a G-LOC. When questioned by an Aerospace Physiology Officer about symptoms, the student said grayout or blackout did not occur prior to the G-LOC. Why would the student not experience any visual cues prior to G-LOC?

9. The elements of the AGSM are

   a. ________________ ________________tensing.

   b. ________________ breathing.

10. The most common cause of GLOC is an improperly performed AGSM. What do the most common errors involve?

    a. ________________ ________________

    b. ________________ of the ________________

    c. Insufficient ________________ ________________ muscle ________________.

11. A properly performed AGSM can increase your $+G_z$ tolerance by as much as 4 Gs.

    a. True

    b. False

12. Differentiate between blackout and G-LOC.

13. You can decrease your overall G tolerance by not eating properly and/or getting insufficient rest.

    a. True

    b. False

14. Determine if the following effects of acceleration are caused by (A) $+G_z$ or (B) $-G_z$.

    a. ______ Visual loss (grayout)

    b. ______ Headache

    c. ______ Mental confusion

    d. ______ Blood pooling in lower extremities

    e. ______ Extreme feeling of congestion in the head

    f. ______ Feeling of increased weight with resultant loss of mobility

    g. ______ Blackout and possible unconsciousness

Lesson JP(0)108 — 1.0 Hours (IBT)

Stress Awareness and Management

Objectives

1. Identify the effects of drugs on the crewmember and select the effects of certain drugs.
2. Identify the residual effects of alcohol on a crewmember inflight.
3. Identify the Air Force/Navy policy concerning alcohol consumption by crewmembers.
4. Identify the hazards associated with smoking and chewing tobacco products.
5. Identify the physiological need for proper diet and nutrition.
6. Identify the adverse impact of dehydration on crewmemberperformance.
7. Select the causes of acute and chronic fatigue.
8. Select the negative effects of caffeine on crewmember's performance.
9. List methods of combating stress in the flying environment.

Assignment

Read JP(0)108 in the SG and answer the reviewquestions.

Introduction

In military aviation, roughly 85 percent of all Class A mishaps are caused by human error. The self-imposed stresses discussed in this lesson are directly linked to human errors.

Self-imposed stresses decrease your capability to function in high stress environments where physical and mental capabilities must be optimal. Figure 81 (Critical Interface Concept) illustrates the compounding effects of self-imposed stresses, attention problems, environmental stresses, and aircraft problems on an aircrew's capacity to cope with normal flight stresses. Line A of the model contains the stresses most within your control. Line B of the model

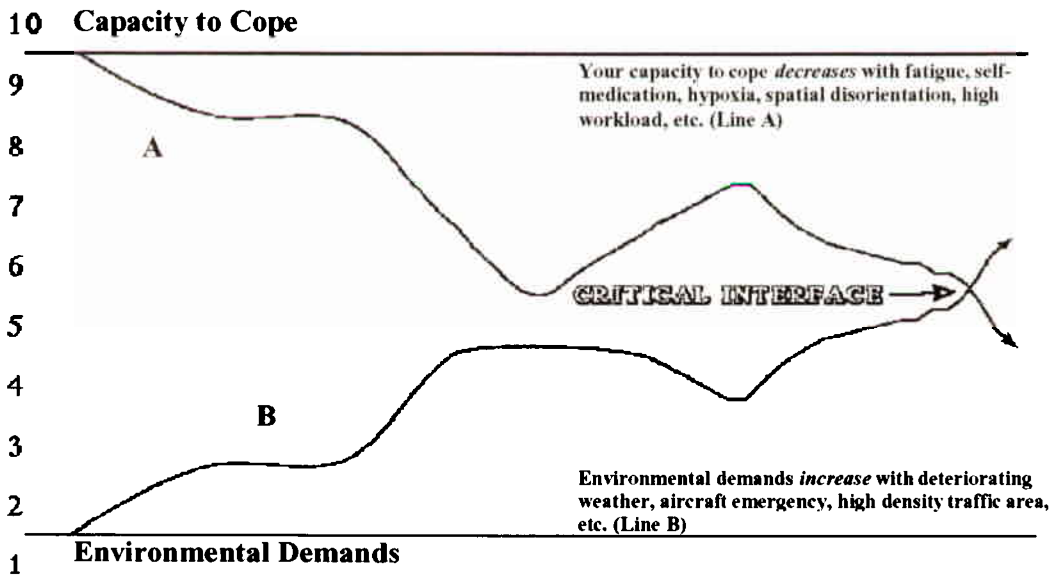


Figure 8-1 — Critical Interface Concept

depicts environmental stresses beyond the crewmember's control. For the most part, environmental stresses are based on the type of aircraft flown, time of day the mission is flown and mission profile. However, unpredictable stresses, like weather or mechanical problems, are also included in environmental stresses. The area between lines A and B represent the crewmember's capacity to cope with any unknown stress the aircraft or mission places on them.

Your capacity to cope is decreased by self-imposed stresses like alcohol misuse or self-medicating with over-the-counter (OTC) drugs. This decrease in capacity to handle stress is depicted by a dip in line A of Figure 8-1. The more stresses you subject yourself to, the more you decrease your capacity to cope. If environmental stresses increase to the point where the capacity to cope and environmental demands intersect (critical interface), you lose the capability to effectively cope with the flight situation. In most mishaps, there is seldom just one major factor causing the mishap. Instead, mishaps usually occur when many small factors add up to disrupt the crew's capacity to fly the aircraft.

Therefore, you must understand the importance of decreasing your exposure to self-imposed stress. The closer you are to 100 percent capable, the greater your ability to cope with unexpected problems or stresses arising during flight.

Self-imposed stresses result from actions taken by the crewmember. They can include the use of OTC drugs, caffeine, alcohol or tobacco. Self-imposed stresses also include nutrition, physical condition and life-style. These stresses, as well as circadian rhythm problems, can contribute to fatigue. All of these stresses strain your ability to function at an optimum level in the aircraft. Self-imposed stresses decrease your performance, impair your judgment, and decrease your tolerance to other inflight stresses.

Self-Medication

Objective 1 — Identify the effects of drugs on the crewmember and select the effects of certain drugs.

Use of Over-The-Counter (OTC) Drugs

In the civilian world, a person who catches a cold, comes down with the flu or physically feels bad, can take one of the many OTC drugs available. Crewmembers, however, are prohibited from self-medicating. Several Air Force and Navy regulations (AFI 11-202, Volume 3, *General Flight Rules*, AFI 48-123, *Medical Examination and Medical Standards* and OPNAVINST 3710.7), contain directives prohibiting the use of OTC drugs ("self-medicating") or flying while under the influence of medications.

Nonprescription medications are designed to alleviate the *symptoms* of an illness without treating the *cause* of the illness. Therefore, OTC drugs only mask the symptoms to make you feel better. The masking of symptoms may delay treatment of a medical problem. As a result of the masking effects and the side effects, OTC drugs are prohibited in the flying environment. The negative effects and the various types of OTC drugs are discussed in the following sections. Figure 8-2 lists common OTC drugs misused by crewmembers.

Effects of OTC Drugs

OTC drugs interfere with or modify normal body functions in different ways. The effects of OTC drugs are divided into *primary, side, synergistic and idiosyncratic effects.*

Primary Effect— of each type of drug is the desired (intended) effect of the drug on the individual. For instance, a person takes an OTC decongestant because they are congested. The primary effect of a decongestant is to dry up the nasal passages and sinuses.

Side Effects — are those effects known to accompany a drug but are additional to its desired effect. For example, the person who takes a decongestant to clear up their sinuses may also experience the side effects of increased heart rate and blurred vision.

Synergistic Effects — occur when the primary or side effect of a drug is modified in function or intensity when taken in combination with another drug. The effect of the combined drugs is greater than would be expected from the individual drugs (in a synergistic reaction the sum of the whole is greater than the sum of the parts, or 1+1 = 3). For example, combining a decongestant with caffeine increases the stimulant effect above the normally expected level.

Idiosyncratic Effects — are those effects on an individual that are unusual and unexpected. Just as certain individuals have unexpected allergic reactions to types of food, people may have unexpected adverse reactions to types of drugs. Although rare, a crewmember self-medicating with an OTC drug may experience an unexpected reaction to the drug.

Types of OTC Drugs

The types of OTC drugs taken by crewmembers contain chemicals falling into several broad categories. These categories are decongestants, antihistamines, vasoconstrictors, pain killers and diet pills (Figure 8-2). Some OTC drugs contain more than one type of these chemicals.

Common OTC Drugs
*Decongestants *Antihistamines *Vasoconstrictors *Pain Killers *Diet Pills

Figure 8-2 — Types of OTC Drugs

Decongestants — are normally found in "cold-remedies" and act as a stimulant. Decongestants are used to shrink inflamed mucous membranes and clear up a person's nasal passages and sinuses. OTC decongestant medications may contain only a decongestant. However, other medications may contain antihistamines and pain killers in combination with the decongestant.

The side effects of decongestants are detrimental to crewmembers. Decongestants can produce shakiness, increased heart rate, blurred vision, increased dehydration, dizziness, nausea and headaches. Therefore, self-medicating with decongestants increases your physiological stress levels and decreases your capacity to cope.

Antihistamines — are used to reduce nasal congestion due to allergies and colds. They are normally found in OTC drugs combined with other compounds such as decongestants. Common OTC cold remedy drugs contain both antihistamines and decongestants. Antihistamines relieve congestion by blocking the release of histamine — responsible for the swelling of the nasal mucous membranes in an allergic reaction. The result is a decrease in mucous production and possible relief from the itching and watering of the eyes.

Antihistamines' undesirable side effect is the depressant nature they have on the central nervous system (CNS). Drowsiness is the most common effect, but they also cause diminished alertness and increased reaction times. If alcohol or other CNS depressants are also consumed, a synergistic effect occurs, increasing the depressant effect of antihistamines. The danger of a mishap is greatly increased. This synergistic effect is particularly pronounced if you take an OTC drug high in alcohol. These OTC drugs usually contain both an antihistamine and up to 25 percent alcohol (50 proof). Idiosyncratic effects may include dizziness, muscular incoordination, nervousness and tremors.

Vasoconstrictors — are topical drugs sprayed in the nose (nasal sprays). They act to constrict blood vessels in the nose and sinuses, resulting in a reduction of inflammation and swelling. The dangers of using these drugs, without being under the supervision of a flight surgeon, are twofold. Dizziness, blurred vision, tremors and headaches may occur if a vasoconstrictor is used prior to flight. There is also the chance of the medication wearing off prior to descent and landing, allowing the tissues to swell and increasing the chance of blocked sinuses or ears. The second danger with vasoconstrictors occurs after prolonged use (roughly three days) when the nasal tissues become addicted to the drug. If vasoconstrictor use is discontinued after the tissues are addicted, the tissues increase mucous production. The resulting congestion is usually much worse than the original case of congestion. Additionally, extended use can deteriorate the nasal mucosa.

Pain Killers (Analgesics) — are used by most everyone. Primary OTC pain killers are aspirin or acetaminophen (Tylenol® or Naproxin®). Aspirin is used to relieve mild pain or headache and to relieve fever. Aspirin and acetaminophen can cause stomach irritation as a side effect. Ibuprofen is a third type of OTC pain killer. Unfortunately, the side effects are more serious than with aspirin or acetaminophen. Side effects may include dizziness, skin rash, heartburn, gastrointestinal disturbances and blurred vision. You are *not* authorized to take any medication, prescription *or* over-the-counter, without the permission of a flight surgeon.

Note — USAF regulations allow for *occasional* self-medication with aspirin or acetaminophen for minor headache or minor muscle pain. USN regulations do not allow any use of painkillers without flight surgeon approval.

Diet Pills — contain the same medications found in decongestants. They are stimulants with unwanted side effects. Including nervousness, tremors, increased blood pressure and heart rate, dehydration due to increased sweating, and sleep disturbances. There is a significant synergistic effect when diet pills are used in conjunction with caffeine. This effect includes a marked increase in blood pressure and increased dehydration.

If you feel a need to lose weight, you can do so without diet pills. A sensible diet and a regular exercise program is a much healthier and safer alternative for losing weight.

In summary, do not self medicate. If you are ill, consult a flight surgeon and don't fly.

Alcohol and Tobacco Use

Objective 2 — Identify the residual effects of alcohol on a crewmember inflight.

Objective 3 — Identify the Air Force/Navy policy concerning alcohol consumption by crewmembers.

Objective 4 — Identify the hazards associated with smoking and chewing tobacco products.

Alcohol

Perhaps the oldest drug known to man, alcohol is a legal drug having toxic effects on the body. It is a central nervous system depressant. Alcohol is absorbed through the stomach and upper tract of the small intestine and distributed throughout the body by the circulatory system. The concentration of alcohol in the brain and nervous tissues rapidly approaches the same concentration as in the blood because of the extensive blood flow through these tissues. As the alcohol reaches the tissues, it's absorbed by the cells and causes histotoxic hypoxia by disrupting cellular metabolism.

Short-Term Effects — As a result of the histotoxic effects of alcohol on the brain and nervous tissues, higher brain function is impaired. Marked psychological reactions are experienced, the most common being the impairment of judgment and performance, reduction of inhibitions, abnormal behavioral shifts, and a bolstered sense of immortality. Physiologically, the crewmember becomes anesthetized, suffers degraded sensory and motor skills, decreased visual acuity, degraded communication ability and loss of balance. Figure 8-3 summarizes the common psychological and physiological reactions to alcohol.

Psychological
*Impairment of Judgment and Performance *Reduced Inhibitions *Abnormal Behavior Shifts *Pain Killers *Bolstered Sense of Immortality
Physiological
*Anesthesia *Degraded Sensory and Motor Skills *Decreased Visual Acuity *Degraded Communication Ability *Loss of Balance

Figure 8-3 — Reactions to Alcohol

Alcohol has other effects on the body that are of particular concern to crewmembers. Alcohol affects the fluid in the inner ear that is used for orientation. This effect may contribute to spatial disorientation and airsickness. Additionally, small amounts of alcohol are sufficient to significantly disrupt sleep patterns, leading to mental and physical fatigue. Alcohol, being a sedative, deprives the body from receiving the necessary mental restorative sleep called Rapid Eye Movement (REM) sleep. Failure to achieve REM sleep leads to attention problems and decreases your ability to cope with inflight stresses.

Residual Effects — of alcohol on the crewmember depend on the amount of alcohol ingested. The body metabolizes pure alcohol at a constant rate of one ounce in 3 hours. Therefore, if you drink a six-pack of beer (72 oz.), six glasses of wine (18 oz.) or six shots of whiskey (6 oz.), you ingest approximately three ounces of alcohol (0.5 ounces of alcohol per 12 oz. beer, 3 oz. of wine or 1 oz. of distilled spirits). In this situation, it will take your body at least 9 hours to metabolize the alcohol.

AFI 11-202 Volume 3, *"A person must not act as a crewmember of an aircraft while under the influence of alcohol or its after effects." and "Aircrew shall not consume alcoholic beverages during the 12 hour period prior to takeoff."*

OPNAVINST 3710.7, *"Consumption of any type of alcohol is prohibited within 12 hours of flight planning."*

Therefore, you can calculate the amount of alcohol you drink, stop drinking twelve hours prior to takeoff/flight planning, and be legal and safe, right? Unfortunately, no, it is not that simple. Remember, AFI 11-202 states *"... while under the influence of alcohol or its aftereffects."* And OPNAVINST 3710.7 states *"Flight crews shall ensure that they are free of hangover effects prior to flight."* These statements mean that if you are suffering a hangover, or even a headache as the result of alcohol, you are not legal to fly. The bigger picture, however, is not one of legality but safety. You may be legal after 12 hours, but are you safe?

The effects of alcohol consumption can manifest themselves for longer than 12 hours after drinking is stopped. Some of these residual effects are known as a hangover and include dehydration, headache and nausea.

When alcohol is consumed, it disrupts the body's ability to regulate water and leads to dehydration. The production of antidiuretic hormone (ADH) decreases, causing the body to think there is more water in the system than required. Therefore, water is lost through increased urination. When this excessive urination happens, water is lost from the spaces between cells (interstitial spaces) and tissues shrink, creating abnormal tension on body organs. This abnormality is particularly prevalent in the tissues surrounding the brain, resulting in a painful headache. Additionally, your body is hypoglycemic, hypoxic (histotoxic hypoxia), fatigued and telling you that you must rest and recuperate. Unfortunately, the only cure for a hangover is time, rest, drinking plenty of nonalcoholic fluids (preferably water), and eating a balanced diet.

The best method to avoid the dilemma of suffering a hangover and the residual effects of alcohol is *abstinence*. If this option is unrealistic or undesirable, moderation of alcohol intake, drinking plenty of water with the alcoholic drink, and not drinking 24 hours prior to flight increases your ability to successfully complete the mission.

Hazards Associated with Tobacco Products

Each year, roughly 390,000 Americans die as a result of smoking. That's more than all the American military fatalities in World War I, World War II and Vietnam combined. In addition, 3,800 people die of lung cancer because of secondhand smoke. Also, an unknown number of lives are lost and ruined because of cancer and other diseases caused by dipping, chewing or inhaling tobacco.

The primary problems of tobacco and tobacco products are the effects of nicotine and the effects of carbon monoxide. Crewmembers are usually exposed to nicotine through smoking, chewing, dipping or inhaling (snuff) tobacco products. If you smoke cigarettes or other tobacco products, you also expose yourself to carbon monoxide (CO) and other toxic by-products of the burning tobacco.

Nicotine — is classified as a drug of abuse because of its addictive characteristics. Nicotine is also a highly toxic drug. For example, if 60 milligrams (mg) of nicotine (an amount approximately one-half the size of a match head) is ingested it is sufficient to cause death in humans within minutes. The amount of nicotine contained in three average cigarettes can cause death if injected intravenously.

Smoking is the primary means by which Americans expose themselves to nicotine. Nicotine is readily absorbed in the lungs and reaches the brain within 8 seconds after inhalation. The acute effects of nicotine on a person, who has not developed a tolerance to the drug, includes increased blood pressure, heart rate, hand tremors, nausea, salivation, vomiting, cold sweat, headache, dizziness, disturbed vision and hearing, mental confusion, and marked weakness. Nicotine acts primarily as a CNS depressant but, if combined with caffeine, it has the opposite effect (stimulant). People eventually develop a tolerance to nicotine, become dependent on the drug, and do not readily show the adverse effects of nicotine. However, even chronic smokers experience increased blood pressure, heart rate, and hand tremors after one or two cigarettes.

With the increased social stigma attached to smoking and the increased awareness of the health hazards associated with it, many people think that switching to "smokeless tobacco" is a favorable alternative. "Dipping" and "chewing" involves placing tobacco in the mouth, either between the cheek and gum or chewing leaf tobacco. Nicotine is not absorbed well in the mouth and if swallowed causes severe gastric upset and vomiting. Unfortunately, chewing or dipping tobacco increases the incidence of mouth, gum, tongue and cheek cancers.

When tobacco burns there are roughly 4,000 chemical compounds given off and inhaled by the smoker. Tobacco smoke can be separated into gaseous and particulate phases. The gaseous components contain CO, ammonia, hydrogen cyanide (HCN), volatile hydrocarbons, and other toxic agents. The particulate components of tobacco smoke are water, nicotine, and numerous documented cancer causing agents. The particulate phase also contains several radioactive compounds, like polonium 210, contributing to the cancer causing effects of other compounds.

Carbon Monoxide — is one of the major by-products of tobacco smoke. The danger to you from carbon monoxide (CO) is its effect on the oxygen carrying capacity of the blood (hypemic hypoxia). CO binds to the red blood cells roughly 200 to 250 times greater than oxygen. Smoking three cigarettes is sufficient to raise the body's physiological altitude 5,000 to 7,000 feet because of the increased amount of carbon monoxide in the blood. Your visual acuity is decreased because of decreased oxygen transport to the eye. There are other problems caused by a combination of the CO and other combustion by-products.

The effects of smoking on the crewmember are decreased resistance to hypoxia because of the CO load on the red blood cells and the HCN inhaled. Motor skills may also be affected because of the effect of nicotine on the nervous tissues and peripheral blood vessels. The long-term effects of smoking include increased stress on the respiratory system due to lung damage, increased cardiovascular disease due to increased atherosclerosis (blocking and hardening of the arteries), increased threat of forming blood clots, and the danger of cancer and other long term diseases caused by tobacco smoke by-products.

In summary, the use of tobacco will reduce a crewmember's tolerance to other flight stress and can decrease performance.

Nutrition

Objective 5 — Identify the physiological need for proper diet and nutrition.

In order for the human body to function, it must have fuel to burn. The fuel the human body uses is a sugar called glucose. When you eat, the glucose liberated during the digestion process enters the blood stream and is transported to the organs and tissues needing it, or taken to the liver where it is stored as glycogen.

Nervous tissue (the nerves and brain) and retinal tissue (photoreceptive tissue in the back of the eye) are both dependent on blood sugar levels to function. When glucose levels in the blood fall below levels adequate to supply these tissues, the liver converts glycogen to glucose and releases it into the blood stream.

Hypoglycemia

Hypoglycemia results when the glycogen stores in the liver are depleted and there is not enough glucose in the blood stream. Hypoglycemia means "low blood sugar" and has a variety of causes. The most common cause is skipping meals or eating foods that are predominantly simple sugars. Other causes of hypoglycemia are high protein/low carbohydrate diets and diets where a crewmember does not eat for extended periods of time (fasts or starvation diets).

Short-Term Symptoms — of hypoglycemia are shakiness, decreased mental ability, physical weakness, irritability, fatigue and sleepiness. These symptoms arise within 4 to 6 hours after your last meal. However, if you had a meal of complex carbohydrates, like pasta, potatoes, or whole wheat breads, hypoglycemia does not occur as quickly. If your last meal consisted of simple carbohydrates, like those found in candy and soft drinks, then hypoglycemia occurs much more quickly because of the rapid digestion and rapid metabolism of the simple sugars.

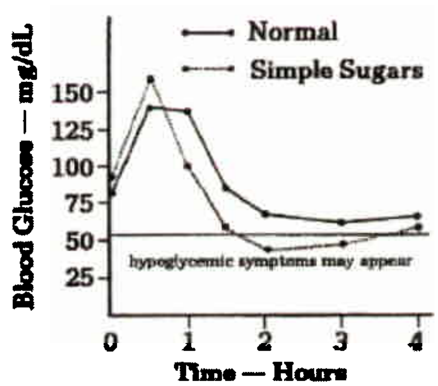


Figure 8-4 — **Blood Sugar Levels**

Complex carbohydrates, proteins and fat require more time for digestion and utilization. Their glucose is slowly released into the blood and stored in the liver over a period of time, avoiding erratic shifts in metabolism. Simple carbohydrates are absorbed into the blood quickly, causing the blood sugar level to rise dramatically. As the blood sugar rises, the brain senses there is too much glucose in the blood and signals the pancreas to release insulin into the blood stream which acts to remove glucose from the blood and take it to the liver. Unfortunately, if the blood sugar levels are high, insulin removes most of the sugar, leaving a blood sugar level that is lower than before the candy was eaten. Figure 8-4 shows a hypothetical time line of blood sugar levels for a crewmember flying while following a diet consisting of simple sugars. As clearly shown in Figure 8-4, relying on a typical "Coke and candy" meal sets you up for hypoglycemia.

Complex Carbohydrates
*Bagels
*Pretzels
*Fig or Fruit Bars
*Granola Bars (low in sugar)
*Yogurt
*Milk
*Fresh Fruits and Vegetables

Figure 8-5 — **Recommended Snacks**

Long-Term Symptoms — of hypoglycemia can include convulsions and fainting, usually occurring as a result of large swings in blood sugar levels. One of the major effects of hypoglycemia is a lapse in mental processes. When the brain cannot get the glucose it needs from the blood, it begins to slow down. For a crewmember, common symptoms are math errors, checklist errors, and decreased attention span which cause missed-communication errors and perception errors.

Prevention of Hypoglycemia— Eat regularly. When meals are missed, snacks of complex carbohydrates are more beneficial than candy and soft drinks. Figure 8-5 lists some snacks designed to keep the amount of sugar in the blood at a constant level.

The bottom line on nutrition and flying is to eat sensible meals containing complex carbohydrates low in fat, at regular intervals. If you are accustomed to eating three meals a day, then try not to skip a meal since the glycogen stores in your liver may become depleted. Avoid fad diets or high protein/low carbohydrate diets designed to build bulk. Furthermore, protein is an inefficient source of energy and is primarily used to build muscle and bone. Carbohydrates, however, are efficient sources of energy and are easily converted to glucose.

Dehydration (Thermal Stress)

Objective 6 — Identify the adverse impact of dehydration on crewmember performance.

Dehydration, like hypoglycemia, is a major contributor to fatigue. There are varying degrees of dehydration, with different symptoms. Unfortunately, most people are constantly in a slightly dehydrated condition. When dehydration is combined with the flying environment, you fatigue quickly and are at a higher risk of experiencing decompression sickness, spatial disorientation, visual illusions, airsickness, and loss of situational awareness.

The first common indication of dehydration is a sensation of thirst. At this point, you are about 2 percent dehydrated or about 1.5 quarts (1.6 liters) low on water. If you are flying in a pressurized cockpit while 2 percent dehydrated, the level of dehydration increases rapidly. In an aircraft pressurized to 8,000 ft MSL, the cockpit air is about 9 percent to 11 percent humidity, causing water loss as you breathe. Combine this water loss with the diuretic effects of caffienated drinks (coffee, colas) and you can quickly become 3 percent or more dehydrated.

At a dehydration level of 3 percent, you may experience sleepiness, nausea, mental impairment, and mental and physical fatigue. If you fly after a night of drinking alcoholic beverages, you will reach the 3 percent dehydration level more quickly than other crewmembers because of the diuretic effects of alcohol. In addition to mental impairment, dehydration decreases your ability to do physical work (performing an anti-G straining maneuver for example).

The best method to prevent the problems of dehydration in the aircraft is to drink plenty of water before, during and after a flight. If water is unappealing or unpalatable, drinks that are low in sugar, nonalcoholic, and decaffeinated can be substituted. Many crewmembers prefer "sports drinks" like Gatorade®. These drinks are fine but some contain higher amounts of salt the body normally needs. In addition, some of the drinks are heavily sugared. Usually, you don't lose enough salts or electrolytes during normal activity to warrant the use of these types of drinks. However, if you prefer sports drinks to water, then drink whatever you like best providing it is not alcoholic, caffienated or heavily sugared. Staying hydrated before, during and after flying has a pronounced positive effect on how well you perform flight duties.

Fatigue

Objective 7 — Select the causes of acute and chronic fatigue.

Fatigue is defined as a state of diminished mental and physical efficiency. Unfortunately, fatigue is an insidious stressor because crewmembers usually becomes mentally fatigued before they become physically fatigued. If you self-medicate and fly when you are sick, suffer from a hangover, are dehydrated, hypoglycemic, or any combination of these stresses, you increase fatigue's effect on your ability to safely accomplish the mission. Therefore, all the self-imposed stresses discussed previously have a direct effect on your fatigue levels.

Fatigue is normally caused by the common day-to-day activities a crewmember performs. However, problems also arise when the crewmember fails to gain adequate rest and short-term fatigue evolves into long-term fatigue.

Fatigue is divided into two categories, acute fatigue and chronic fatigue. Acute fatigue is short-term fatigue caused by the normal daily activities of the crewmember. It's remedied with a good night's sleep and rest. Unfortunately, if you fail to remedy acute fatigue, then you begin to suffer from chronic fatigue. Chronic fatigue is long-term fatigue and is caused by a variety of factors. For instance, when you fail to get adequate rest and sleep for several days, you become chronically fatigued. Other major causes of chronic fatigue in crewmembers include interrupted or poor sleep patterns, circadian rhythm shifts, illness, successive long missions with minimal recuperation time, and succumbing to self-imposed stresses.

Circadian Rhythm

Everyone has a circadian (circa = about, dian = a day) rhythm or "body clock", which is roughly a 23-26 hour cycle of body functions. These cyclic body functions include endocrine gland function (hormones, etc.), metabolic processes, and body temperatures. These functions help control sleep-wake cycles and directly affect your alertness and performance. This cycle is repetitive day in and day out with little change. When your circadian rhythm is disrupted, chronic fatigue can become a major factor in your performance. There are two basic types of circadian rhythm problems: sleep cycle disruptions and circadian desynchronization due to rapid time zone changes.

Sleep Cycle Disruptions — occur when you must fly during hours you would normally be sleeping. Examples are night or early morning (0100 hours to 0600 hours) flights. Additionally, crewmembers involved with war games or exercises (remaining on duty for extended periods of time) suffer sleep cycle disruptions. If you're forced to wake-up early over a long period of time, 7 to 10 days for instance, then you lose a part of your sleep cycle that is vital to mental alertness. You can experience mental fatigue resulting in decreased attention span, concentration, and an increase in thinking and perceptual errors. Additionally, you fall asleep much easier and can experience "microsleeps" in which the brain briefly slips into dream activity. Fortunately, microsleeps only last a few seconds but are insidious and indicate that you are very fatigued. You can attempt to minimize or eliminate sleep cycle disruptions by adjusting the time you go to bed. This adjustment compensates, to a degree, for the early morning wake ups and your circadian rhythm eventually adapts to getting up early. Circadian rhythm desynchronization, however, is much more involved and difficult to remedy.

Circadian Rhythm Desynchronization — occurs when you cross time zones (transmeridian travel). This problem is commonly known as "jet lag." For the crewmember, jet lag is a serious problem that can jeopardize safety of flight. Physiologically, the body requires 24 hours to completely recover from every one hour shift in time zone. To a non-flying officer arriving in Germany on a permanent duty assignment, this time zone shift is not a problem since they stay in one location and do not need to fly. However, it *is* a problem for crewmembers landing in England after an 8 hour (and eight time zone change) flight from the U.S. They may not be able to take the required time to completely recover from the time shift, since operational demands rarely permit crewmembers 8 days off to resynchronize.

For crewmembers who do not remain in one time zone for more than 24 hours, the problem of circadian desynchronization is compounded. The negative effects of circadian desynchronization, and subsequent sleep loss, on a crewmember's ability to function mentally and physically are critical. Most of the problems relate to decreased mental information processing abilities, decreased mental agility, impaired judgment/decision making skills, decreased communication and problem solving skills, and increased irritability. Unfortunately, there are no set rules or procedures to follow regarding adaptation to changes in time zone. However, there are some techniques that you can use in an attempt to deal with time zone changes and circadian desynchronization.

When you change time zones, you basically have four options at your disposal. First, you can attempt to stay on home time. Second, you can slowly adapt to the new time zone naturally. Third, you can force your routine and conform to the local time in order to rapidly adapt to the new time zone. Finally, you can combine aspects from the first three options. In any case, the decision should be based on your personal judgment but also should consider the following variables.

Variables Affecting Circadian Rhythm

Direction of Travel — Transmeridian flight involves traveling east or west across different time zones. If you travel eastbound, you are essentially traveling ahead in time. For example, if you leave the west coast and fly directly to Rhein-Main AB in Germany, you experience a time shift that is 10 hours ahead of your local time. If you depart the west coast at 0800 hours Pacific Standard Time (PST) and fly for 12 hours to Rhein-Main AB, Germany, you land at 0600 hours (the following day) local German time (Takeoff 0800 + 12 hour flight + 10 hour time zone change = Land at 0600). Unfortunately, your body clock is set to PST. So physiologically, you are landing at 2000 hours. Your body is preparing for rest and sleep while the local population is just waking up. You probably experience one good nights rest the evening you arrive because of the acute fatigue but start having sleep-cycle problems on the second day and night.

Aircrews experiencing an eastbound circadian shift experience trouble falling asleep at local times, trouble rising at normal local times, and lose mentally restorative sleep. These problems are similar to those associated with westbound travel with one major problem added. Because their body clock is slow to respond naturally to the new time zone (24 hours to adapt to a one hour change in time), they do not obtain the sleep necessary to correct for fatigue.

The body has an easier time adjusting to westbound travel. Circadian desynchronization is still evident but the physiological signs are not as severe as eastbound travel. The primary reason westbound travel is easier on the crew is that the crew is traveling backward in time. A crew taking off from San Antonio, Texas and flying to Hickam AFB, Hawaii (an 8 hour flight) experiences a 7 hour time shift. If the crew takes off at 0800 Central Standard Time (CST), they land at 0900 hours Hawaiian time (Hawaii's local time is 7 hours behind CST.) The effect on the crew is that they become tired and sleepy earlier in the day and wake up earlier in the morning. The result is the crew is mentally efficient in the mornings but their capabilities decrease more rapidly towards the afternoon. It still takes the crewmember 7 days to naturally adapt to their new time zone but they can tolerate the physiological changes better than eastbound travelers.

Magnitude of Time Zone Change — You need to consider how many time zone changes you are experiencing. The number of changes gives you an idea of the degree of jet lag you are going to encounter and helps you decide how to deal with its effects. If a crew flies eastward and only crosses three time zones, they may not experience serious circadian desynchronization. However, if they are flying to Saudi Arabia (11 hours ahead of a west coast base) they may experience serious performance decrements within a day or two of their arrival.

Interval Between Arrival and Departure of Next Flight — This variable requires consideration to estimate the possible negative effects circadian desynchronization has on follow-on flight activity. How long you stay in one time zone impacts the methods you use to cope with circadian rhythm disruption. If the time between landing and your next flight is short (13-24 hours), you need to plan your rest periods differently than if you have a longer time between flights.

The shorter the time interval between landing and the next flight, the more you need to maintain your home-time rest and sleep habits. If the duration between landing and flight is long, then you should adjust your rest and sleep cycles in an attempt to adjust your circadian rhythms to local time and gain the rest needed before flight.

Relative Difficulty of Next Flight — is a major consideration. Many times a crew experiences new flying environments that have different local procedures than their home base. If they fly in a foreign country, the terminology used by controllers could be different and cause confusion in the cockpit. If the crew is fatigued, their ability to adapt to new flying environments and demands is decreased.

Additionally, aspects of the flight itself need to be considered. Are there portions of the flight requiring above average alertness on the part of the crew? For instance, are low-level flight, aerial refueling, ordinance delivery, or other high attention related tasks required? Is weather likely to be a factor? For example, is there icing, thunderstorms, visibility restrictions caused by rain, snow, or fog? Is the mission scheduled as a day or night sortie? How are the crew's circadian desynchronization and the timing of the flight likely to affect their performance? Finally, what is the experience level of the crew for the type of mission scheduled? Experience not only includes the crew's overall flying experience but their recency of experience (when was the last time they flew a mission of this sort?) and specificity of experience (have they flown this type of mission before?). Consideration of this particular variable guides the crew in forming a plan to cope with fatigue. Additionally, it increases their awareness of the fatigue factor during the later stages of the flight.

Availability of Dining Facilities — In addition to rest, the body needs nourishment to provide energy. One of the ways to help adapt to a new time zone is a good diet. However, if the local dining facilities are closed when you land, then you need to consider adjusting your schedule prior to their next scheduled duty period to include time for eating a good meal. If dining facilities are unavailable, you should make plans to take "combat snacks" (nonperishables consisting of complex carbohydrates). Also, starting a weight loss diet on the road is not wise. Most common weight loss diets (low calorie intake) are an added stressor the body must cope with in addition to circadian desynchronization.

Direction of Next Destination — If you are not going to stay in one location for an appreciable length of time, but are going to travel on, you need to consider the direction (east or west) of your next destination and the effect it has on your circadian rhythm. If the direction of travel is north or south, the time zone does not change and there isn't any affect on circadian rhythm. If you travel east or west, circadian disruption can worsen or improve depending on the direction of travel in relation to your home base.

Adapting to a New Time Zone — There are no hard and fast rules or effective procedures on how to adapt to a new time zone. Regardless of whether or not you decide to adapt to the new time zones, there are techniques that can guide you on dealing with circadian desynchronization.

If you decide to rapidly adapt to the new time zone, you should force yourself into the local routine. Use your willpower and alarm clock to force yourself to wake up at normal local times in the morning. To help go to sleep at night, try mild to moderate exercise and a relaxing shower or bath (if available). Above all, moderation or elimination of alcohol and caffeine helps. Alcohol or sleep inducing drugs must not be used. These drugs severely disrupt and decrease your quality of sleep, *increasing* fatigue.

Decreasing the Effects of Fatigue

Prior to Flight — There are many ways crewmembers can try to compensate for the effects of fatigue. First, always start your scheduled flights well rested, especially when scheduled for extended missions or transcontinental travel. This proper rest often requires cooperation from family members. Naps (not longer than two hours) are strongly recommended prior to night flights or continuing an extended trip. You should minimize the use of tobacco and alcohol, and ensure you are well hydrated.

You can also use diet to reduce the effects of fatigue. Avoid high fat, high carbohydrate meals to reduce drowsiness. Instead, emphasize a meal moderately high in protein with moderate carbohydrates. Additionally, avoid eating large, filling meals prior to flight to reduce the chance of drowsiness. It's more beneficial, in this instance, to eat several smaller meals (snacks) rather than a full meal at a single seating.

To help maintain an adequate diet, you can carry "emergency rations" or "combat snacks." This option is invaluable if you are not fond of box lunches. You can take a supply of canned fruit, canned meat (tuna, ham, chicken), beef jerky, trail mix or other complex carbohydrate and protein rich foods with you. This food is also a benefit should you sleep through the dining facility hours.

During the Flight — you can reduce the effects of fatigue by staying active. If possible, get up and move around periodically. The cockpit lights can be turned up inflight and turned down again 30 minutes prior to landing to restore night vision. An augmented crew should plan ahead and take advantage of inflight naps. When a crew is fatigued, it is important to increase your awareness of coordinated critical flight functions, such as approach, landing or low-level operations. Be aware of the potential for increased errors due to fatigue and cross-check fellow crewmember activities.

As one can see, the problem of circadian rhythm desynchronization is complex and has many variables to take into account during mission planning. Between sorties, ensure you and your crew are able to get adequate crew rest along with nutrition. Allow either the aircraft commander or your supervisor know when you feel you are to fatigued to fly. Remember, as long as you are aware of your options, including Air Force and major command (MAJCOM) policy, you should be able to form a plan to reduce the effect circadian rhythm shifts have on your performance.

One of the major U.S. Air Force policies on fatigue and crew rest is in AFI 11-202, Volume 3, Chapter 9, Crew Rest and Flight Duty Limitations. Paragraph 9.2.2.4, states: *"Aircraft commanders must terminate a mission or mission leg if safety may be compromised by fatigue factors, regardless of authorized flight duty periods."*

AFI 11-202, Volume 3 also specifies minimum crew rest requirements and maximum flight duty periods for aircrew. Paragraph 9.6, Minimum Crew Rest Period, specifies, *"The minimum crew rest period is 12 hours.*

Paragraph 9.4.5, defines crew rest period as, *"...the non-duty period before the flight duty period begins......Air Force aircrews require at least eight hours of uninterrupted rest during the twelve hours immediately prior to the beginning of the flight duty period. These eight hours of uninterrupted rest must be continuous. When an aircrew member remains at the airfield after flying duties to perform official duties, the crew rest period begins after termination of these duties."* This paragraph also defines crew rest interruptions and aircrew responsibilities when faced with interruptions.

Each MAJCOM or Navy type commander supplements AFI 11-202, Volume 3, or OPNAVINST 3710.7 with their own policies. These policies are usually more restrictive. You must be aware of these policies if you are to develop a positive plan to help combat the effects of fatigue and circadian rhythm disruptions.

Caffeine Use

Objective 8 — Select the negative effects of caffeine on a crewmember's performance.

Caffeine is a tasteless substance occurring naturally in plants and found in a variety of beverages, medicines and foods. Coffee is the most popular source of caffeine in the American diet. Crewmembers can also receive significant amounts of caffeine from carbonated beverages, tea, OTC drugs and chocolate.

Caffeine acts as a powerful CNS stimulant. Caffeine's popularity is due to its ability to elevate mood, mask feelings of fatigue and increase the capacity for work. In low doses, caffeine may not be harmful. However, ingestion of high levels of caffeine may be related to a variety of acute and chronic ailments.

Effects of Caffeine
*Dehydration *Restlessness *Nervousness *Faulty Thinking *Disturbed Sleep
Withdrawal Symptoms
*Headaches *Restlessness *Sense of Disquiet *Anguish *Aching Joints & Muscles

Figure 8-6 — Caffeine Effects/Symptoms

Most people regard caffeine as a safe stimulant and do not actively monitor their intake. As they consume caffeine-loaded products, they remain unaware of the potential negative side effects of caffeine. Figure 8-6 illustrates the effects of too much caffeine and associated withdrawal symptoms.

Addiction — Caffeine *is* addicting. A person requiring 400 mg of caffeine in a 24 hour period to function is considered addicted to caffeine. OPNAVINST 3710.7 states *"Caffeine intake should be limited to not more that 450 mg. per day, or 3 to 4 cups of coffee."* Figure 8-7 shows the amount of caffeine present in common food/beverages and OTC drugs. If you ingest too much caffeine, you can experience the effects depicted in Figure 8-6. However, you can also develop sensitivity to the drug. If a person is addicted to caffeine, they can experience some withdrawal symptoms when, and if, they decide to quit. The withdrawal symptoms commonly include headaches but can be as severe as muscle cramps, nausea, aches in joints and muscles, and psychological feelings of anxiety, dread, and irritation. If you are addicted to caffeine, it is advisable to reduce intake gradually instead of quitting altogether.

Food/Beverage	mg/Serv
*Coffee	110 - 140
*Tea	10 - 50
*Soft Drinks	30 - 60
*Cocoa	10 - 40
*Chocolate	5 - 20
OTC Drugs	**mg/Dose**
*No-Doz®	100
*Anacin®	64
*Excedrin®	130
*Coryban-D®	30
*Dristan®	32
*Triaminicin®	30
*Dexatrim®	200
*Prolamine®	280

Figure 8-7 — Caffeine Amounts

Caffeine has synergistic effects when used in combination with other drugs. Its stimulant effect on the body is significantly increased when used in combination with decongestants or nicotine. An example of the deliberate use of caffeine as a synergistic drug is its use in OTC diet pills. Until recently, diet pill manufacturers combined caffeine with decongestants in order to increase the body's metabolic rate. Unfortunately, the negative side effects of this combination, sweating, increased blood pressure and heart rate, sleep disturbances, and shakiness or tremor, are not desirable in crewmembers. Dehydration is another, more common, synergistic effect of caffeine.

Dehydration — If you drink caffeinated beverages during flight, ensure you also drink water. The combination of a pressurized cabin (humidity below 9 to 11 percent increases water lost during respiration) and the diuretic (makes one urinate more often) effect of caffeine causes an increased dehydration rate. The result is increased mental and physical fatigue and decreased performance. Drinking water, or other non-caffeinated beverages, during flight helps offset the negative effects of caffeine.

Combating Stress

Objective 9 — List methods of combating stress in the flying environment.

Psychological Stress

Overload — has deservedly received much attention as an important stressor. In overload the demands are such as to exceed the individuals ability to meet them.

An example of overload is role conflict. This can be viewed as a situation in which a person finds, in essence, opposed demand being made on him. A person may often be asked to work on one assignment when he/she already has some other assignment. That person may have to stop what he/she is doing at that time. When the issue concerns merely the sum total of work that must be done irrespective of its difficulty, we talk about quantitative overload. The person has more work than can be done in a given period of time. That person may be fully competent in the work but time restrictions are what elicits the stress reaction. Quantitative overload could involve working for long hours without appropriate rest periods.

When the work is overloading because it requires skills, abilities and knowledge beyond what the person has, then we talk about qualitative overload. The work may demand continuous concentration, innovation and meaningful decision. An important factor contributing to qualitative overload is job complexity. The higher the inherent difficulty of the work, the more stressful the job.

In some job situations there is a combination of both quantitative and qualitative overload; this is frequently encountered in aviators, particularly student aviators.

Underload — may also create stress. A job may fail to provide meaningful stimulation or adequate reinforcement. Thus, jobs which involve dehumanizing monotony, no opportunity to use acquired skills and expertise, an absence of any intellectual involvement and repetitive performance provide instances of underload. Boredom can result from too high a degree of specialization. This is a rare occurrence in student aviators.

Stress Management

Each crewmember is a successful competitor or would never have been selected for a military flight program. Competition is usually a healthy environment in which to function but can also be a source of stress. Constantly trying to succeed in a pressure environment, impressing your instructor, and outperforming your peers provide a continual source of stress.

Stress can be both positive and negative. How you manage it is important to you in both your personal and professional life. To be an effective crewmember, you must learn to manage the stresses that are part of your everyday life. To begin managing stress, you have to first understand what it is and what it does — how it affects you physically and mentally.

Stress — is the normal reaction to any demand placed on you, either physically or mentally. You need stress because it serves as a motivator and an indicator (increased heart rate, respiration, perspiration, etc.) which helps prepare you to respond. If there is too little stress, you are under-aroused and inattentive. On the other hand, if there is too much stress you are limited in your ability to perform.

Inherent in man is a biological response to a crisis situation. For example, when suddenly confronted by a crisis situation, an involuntary physiological process begins. Adrenaline is produced, causing the eyes to dilate, increasing heart rate, stopping digestion, directing blood to the large muscle groups, and increasing perspiration. These responses prepare you to confront the crisis or run away from it (a response known as "fight or flight").

Financial, family, professional and social responsibilities are a few of the stresses which may confront you. Many of these are self-imposed. Even if these stresses are not self-imposed (stresses you are personally responsible for), they may lead to negative behavior associated with self-imposed stress.

Aviators live in a success oriented and competitive society and are often placed in stressful environments. For example, it's obvious that an inflight emergency evokes stress, but a checkride is also a form of stress. Both elicit the same physiological response of fight or flight. Stress is useful if you control it. If you don't control it, it will control you. Therefore, effective methods for controlling or relieving stress are necessary.

Place Demands into Perspective — Doing well in flying training, living comfortably, and being a good parent are all worthwhile aspirations, but they are not life threatening situations. You can't control the reflexive physiological process that activates in a crisis situation, but you can control what you perceive as a crisis situation — so don't over react. Keep your supervisor or flight commander informed. They may be able to help you deal with some of these stresses.

Maintain a Healthy Diversity in Your Life — Entertainment and hobbies provide a healthy balance to life. You need to save some of your energy for yourself. A healthy balance will make the energy you expend on your job and your family more effective or meaningful. The flying environment, particularly flying training, is a demanding one, constantly changing and requiring a total mental and physical commitment from you, the crewmember. Any factor or condition that bothers you — distracting you from your work — is important and must be given adequate attention.

Eliminate Self-Imposed Stress — Smoking, excessive drinking of alcohol, self-medicating, poor nutrition and lack of exercise are stressful in themselves, and make it more difficult to deal with other stresses. Avoiding these behaviors eliminates their effect on the crewmember, minimizing self-imposed stress.

Exercise

Studies demonstrate that certain life-style factors directly contribute to health and well-being. Many life-style factors such as diet, alcohol use, rest, self-medication, stress management, and exercise are under your control. Self-imposed stresses such as fatigue and hypoglycemia are reduced by taking proper care of your body. Two tools you can use to increase your performance in the aircraft and increase your resistance to fatigue are *exercise* and *proper diet*. This section discusses the benefits of an exercise program to help minimize the effects of fatigue. A well-rounded exercise program should incorporate both aerobic and anaerobic exercise.

Aerobic Exercise — is defined as the type of exercise in which the muscles use oxygen along with fat and glucose to produce energy. Aerobic exercises include activities like running, swimming, bicycling and walking. There are many benefits of aerobic exercise. A person who is in good aerobic condition has a higher basal metabolic rate (BMR) than an aerobically unfit person, less body fat, lower blood pressure, greater stamina, more energy, and their heart and lungs (cardiovascular system) are in better condition. In the flying environment, aerobically fit crewmembers have greater resistance to fatigue.

Anaerobic Exercise — is defined as a type of exercise in which the muscles produce energy without the use of oxygen. The muscles still use glucose for fuel; however, they don't completely metabolize it and lactic acid is formed. Lactic acid is the substance that is associated with the characteristic "burn" sensation when working out with weights. Anaerobic activities are weightlifting, sprinting, sit-ups, push-ups and pull-ups. These activities train the muscles to burn fuel without oxygen and tend to increase their mass and strength. A person who is in good anaerobic condition can contract and maintain greater muscle force for longer periods of time than anaerobically unfit people. In the flying environment, muscle contractions are important in the performance of the Anti-G Straining Maneuver (AGSM) used when pulling positive Gs.

Anaerobic vs. Aerobic Conditioning — Exercise causes a cardiopulmonary (CP) system reaction. For instance, after jogging for a few minutes, an individual starts to breath faster and deeper, starts to perspire, and their heart rate increases. Conversely, anaerobic training does not necessarily cause as extensive a systemic CP reaction but tends to isolate muscle groups and work them at a high intensity. For example, performing arm curls with 50 pounds of weight causes the muscles in the arms to work anaerobically, fatigue and "burn." However, the individual does not experience the level of systemic response to the exercise that jogging for five minutes would cause. Therefore, aerobic and anaerobic conditioning are used to achieve different parts of a total fitness program. Additionally, regardless of the type of exercise program you develop, you experience an added benefit of decreased mental fatigue and stress. Finally, exercise helps to release the psychological stresses encountered in day-to-day activities.

Balanced Programs — Regardless of the type of aircraft you fly, your physical condition (aerobic and anaerobic) affects your performance. For example, if you fly fighters, your physical condition directly affects your ability to pull Gs, perform the AGSM, and your ability to fly multiple missions in one day. If you fly heavy aircraft, then your physical condition directly affects your ability to handle long, sometimes stressful and tedious flights.

A balance between aerobic and anaerobic conditioning is important. You can, however, emphasize certain areas as you develop your own workout. For example, if you are going to fly fighters, you should place more emphasis on anaerobic conditioning over aerobic conditioning. On the other hand, if you are going to fly heavy aircraft, placing emphasis on one type of exercise over the other is not necessary. In this case, an equal balance between aerobic and anaerobic workouts is beneficial.

Finally, OPNAVINST 3710.7 states, *"Due consideration must be given to avoiding contact sports, skiing, etc. Adequate rest periods must be provided for aviators before flying following participation in competitive or particularly tiring sports activity. Twelve hours should normally be adequate"*

Conditioning Techniques and Developing Programs

When determining the type of conditioning program to develop, you can help yourself plan by using the acronym **FITT**. This acronym is useful in planning both aerobic and anaerobic conditioning programs. **FITT** is

1. **F** — Frequency.
2. **I** — Intensity.
3. **T** — Type of exercise.
4. **T** — Time (duration).

Aerobic Exercise — increases your BMR, decreases body fat, increases CP efficiency, and decreases susceptibility to fatigue and other inflight stresses. As the muscles work during aerobic exercise, respiration and heart rate increase to maintain the supply of oxygen to the muscles. If exercise intensity increases to the point where the heart cannot keep up with the muscles' demand for oxygen, the exercise becomes anaerobic. Caution —At extreme levels of aerobic fitness, your ability to perform the AGSM may be reduced.

Using the FITT acronym to develop guidelines for an aerobic conditioning program, you can achieve the level of fitness required to improve and maintain your performance in the aircraft.

1. Frequency — Plan on working out a minimum of 3 days and a maximum of 6 days a week. Studies indicate that a minimum of 3 days per week of aerobic workouts are required to benefit the CP system. If you wish to workout more frequently, you can workout up to a recommended 6 days per week but need to consider the risk of injury. If you alternate aerobic activities, for instance, run on certain days and bicycle or walk on others, you lessen the chances of injury caused by over working certain joints and muscle groups. You must also consider the time it takes to rest and recover, especially if you are just starting an aerobic workout program. A day of rest to let the body rebuild is beneficial.

Note — If you combine anaerobic and aerobic training, you can work out 7 days a week if you prefer.

2. Intensity — Exercise at an intensity sufficient to cause the CP system to work. However, you should not work at an intensity that is beyond the ability of your CP system to supply oxygen to the muscles. Therefore, there are guidelines to help maintain exercise intensity within your CP system's capabilities.

The best method of judging the intensity level of exercise is to measure heart rate. Work out at an intensity sufficient enough to raise your heart rate into a target zone (your *target hear rate* or THR).

One method to determine your THR, is to first determine your *maximum heart rate* (MHR) in beats per minute by subtracting your age from 220. Secondly, the THR is calculated by multiplying the MHR by 65 to 80 percent.

MHR = 220 - age

THR = MHR x 65 percent to 80 percent

Using this formula, you can periodically check whether or not you're at your THR. If your pulse is too high, then you should slow down: if your heart rate is too low, then increase the intensity.

3. Type of exercise — For aerobic exercise, choose a type of exercise sufficient enough to cause your heart rate to increase to a target range for a certain period of time. Exercises involving the large muscle groups, like the buttocks and legs (approximately 40 percent of the body's muscle mass), increase heart and respiration rates more efficiently than using smaller groups like the arms and shoulders. Additionally, choose an exercise that is continuous and rhythmic. For instance, running, bicycling, and walking involve large muscle groups (the legs and buttocks), are continuous and rhythmic, and if performed with sufficient intensity, cause the cardiopulmonary system to work.

4. Time — Plan to workout for a specified length of time or duration to maximize the benefits. The time spent working out depends on the exercise chosen. For instance, if you run, you need only run for 20 minutes. However, if you choose to walk, you must walk 40 minutes to achieve the same results as if you ran for 20 minutes. The exercises are both aerobic, yet their intensity and level are different. Studies show that running for 20 to 30 minutes is beneficial; however, increasing the time above 30 minutes increases the chance of injury and pain, especially for those who are just starting aerobic programs.

If you are not in good aerobic condition and just starting an exercise program, pay careful attention to the above steps and do not overexert yourself. If you overexert yourself on the first or second workout and are in pain, the chances of continuing the exercise program is less than 50 percent. Therefore, start with an easy program and increase the difficulty as you increase your fitness level. Additionally, you must warm-up and then stretch before beginning the workout. A warm-up and stretching period before strenuous exercise increases blood flow and loosens muscles, decreasing the chance of injury. Cool-down and stretch for 2-10 minutes after your workout. A cool-down and stretch decreases post-workout muscle stiffness and soreness. Above all, pick an exercise you can enjoy and start working out gradually to avoid the possibility of injury.

Anaerobic Exercise — increases muscle mass and tone, along with your ability to contract and sustain muscular contractions. The most common form of anaerobic exercise is weight lifting. Other types are isometric exercises (fixed-resistance, like pushing against a wall) or exercises requiring short, intense bursts of energy, like sprinting, sit-ups, pull-ups, or push-ups. The FITT model is also useful when developing an anaerobic workout program.

1. Frequency — Anaerobic exercise, particularly weight lifting, requires the body to rest and recuperate. Therefore, consider performing your anaerobic exercise program roughly every other day. Anaerobic conditioning every other day conveniently fits into combining an aerobic program with an anaerobic program. Aerobic exercise is performed one day and anaerobic exercise performed the next. If, however, you wish to lift weights every day, then you should work specific muscle groups each day. For example, perform exercises that isolate the shoulders and arms one day, the chest and back the next day, the legs and buttocks the day after, and so forth. This schedule allows the muscle group worked the day before to recuperate prior to working out again.

2. Intensity — The intensity of anaerobic training should not leave you feeling as if you are crippled. A lot of individuals pick an intensity level higher than their capabilities and either injure themselves or are so sore after the workout, they cannot continue with the exercise. Being unable to continue is particularly true with weightlifting. Therefore, if you do not lift weights on a regular basis, or have not lifted weights at all, use extreme caution when starting out.

Free-weights require the individual to not only lift against resistance but also balance the weight. Consider starting out with extremely light weight loads to condition your muscles. If you can bench-press 200 pounds one time (one maximum repetition or 1 RM), start working out at 50 to 60 percent of that weight or 100 to 120 pounds. Lift three sets of 10 repetitions apiece. Once your muscles are used to working anaerobically (about 2 to 3 weeks of working out 2 to 3 times a week), then you can increase the weight gradually until you are working at roughly 85 percent of 1 RM. As your strength increases, then your 1 RM weight increases and your workout weight increases. Also consider the type of weight training to pursue. Are you going to develop muscle mass (bulk) and strength or do you want strength and endurance? To develop bulk and strength, the workout should consist of heavier weight and less repetitions per set. If you wish to develop strength and endurance, then the workout should consist of less weight and more repetitions per set. As with any other form of exercise, warming-up followed by stretching prior to lifting weights is essential.

3. Type of exercise — For anaerobic exercises, choose an exercise that isolates a specific muscle group. The exercise should cause the muscle group to work against a form of resistance and fatigue quickly. For example, use barbells or dumbbells to isolate the muscles in the front of the arms (biceps) and force these muscles to work against resistance. This exercise also forces the muscle to develop energy sources without immediately relying on oxygen.

4. Time — Unlike aerobic exercise, where the training goal is to maintain a target heart rate for a specified period of time, anaerobic training works the muscle to fatigue and failure. By working the muscle to the point it is fatigued and can no longer work, the muscle is becoming conditioned. Therefore, there isn't a set rule about elapsed time of exercise in anaerobic training, even though some training programs have the individual perform as many repetitions as possible in a certain amount of time. However, there are some guidelines on how much time the individual should rest the muscle before beginning another set of repetitions. As a guide, if it takes 10 seconds to accomplish ten repetitions, then rest 30 seconds prior to starting another set.

Like aerobic training, if you are not used to lifting weights, it's highly recommended you start with very light weight and gradually work into a program. Again, a pre-workout warm-up and stretching period and the post-workout cool-down and stretch is important in preventing injury and soreness from exercise.

Unfortunately, it's beyond the scope of this course to prescribe workout programs. If you wish to start a program, consult the base gym staff for advice and guidance. The key to remember is that a solid exercise program including both aerobic and anaerobic workouts increases your resistance to fatigue and decreases your susceptibility to other inflight stresses. Additionally, a solid exercise program decreases the effects of psychological stress.

Summary

Roughly 85 percent of military aircraft mishaps are caused by aircrew error. Some of the major contributors to aircrew error are self-imposed stresses that decrease the crew's capacity to cope with unforeseen environmental or aircraft stresses.

The major self-imposed stresses are self-medication with OTC drugs, alcohol and tobacco use, hypoglycemia and dehydration. Each of these contribute to fatigue, which is the crucible from which increased susceptibility to stresses such as spatial disorientation, visual illusions, and G-induced loss of consciousness arise. Fatigue is also a result of sleep cycle disruption and circadian rhythm shifts caused by transmeridian travel.

Overall, you can ensure your flights are safe and productive by eliminating or minimizing self-imposed stresses. Flying sick, with a hangover, dehydrated, or on OTC drugs are invitations to a miserable flight at the least and the loss of life at the worst.

Unnecessary stress can be controlled or avoided with observance of crew duty day, rest regulations, adequate recreation, good living quarters, and attention to morale factors. The demands of flying are in no way compatible with emotional stresses. Recognition, treatment, or better yet, avoidance of emotional stress is essential for maintaining situational awareness and ultimately safety. Resolution of the problems prior to flight is the only way to prevent them from adversely affecting you and your mission. If individual efforts to resolve these stresses are unsuccessful, seeking professional help is essential.

You can increase your capacity to cope by eliminating or minimizing exposure to self-imposed stresses. However, stresses such as fatigue are not always controllable. Therefore, your awareness of the causes and effects of fatigue is key to decreasing the negative manifestations. Develop plans to cope with situations where fatigue, like circadian rhythm desynchronization, is a threat. The best way to cope with fatigue is to minimize or eliminate self-imposed stresses and ensure you are in good physical shape.

Exercise is one of the best methods to increase your tolerance to not only fatigue, but also spatial disorientation, positive Gs, and visual illusions. You must be both aerobically and anaerobically fit.

Aerobic exercises are those causing the muscles to use oxygen to produce energy. They are activities such as running, bicycling, walking, and swimming. Activities causing an increase in respiration, heart rate, and sweating are also aerobic. Stay in your aerobic training zone by monitoring your heart rate.

Anaerobic training isolates muscle groups and forces them to produce energy without immediately relying on oxygen. Weightlifting, sprinting, sit-ups, pull-ups, and push-ups are examples of anaerobic exercises. If you are just starting a weightlifting program, you should start gradually and build up to reduce the chance of injury.

Review Exercise JP(0)108

Complete the following review exercise by choosing the correct answer(s) or filling in the blanks. Answers are at Attachment 1.

1. Match the type of OTC drug with its undesirable side effects.

   a. ______Decongestants

   b. ______Antihistamines

   c. ______Vasoconstrictors

   d. ______Pain killers

   e. ______Diet pills

   1. Stomach irritation, dizziness, skin rashes, heartburn, blurred vision
   2. Nervousness, tremors, increased blood pressure and heart rate, dehydration due to increased sweating, sleep disturbances
   3. Shakiness, increased heart rate, blurred vision, increased dehydration, dizziness, nausea, headaches
   4. Dizziness, blurred vision, tremors, headaches
   5. Drowsiness, diminished alertness, increased reaction times

2a. Air Force policy does not allow crewmembers to fly within ________ hours after consuming alcoholic beverages. Furthermore, you must not act as a crewmember of an aircraft while under the influence of alcohol or its __________________ .

2b. Navy Policy is ________ hours from bottle to __________.

3. What is the *best* way to avoid the effects alcohol has on your performance as a crewmember?

   a. Do not fly within 24 hours after consuming alcoholic beverages.

   b. Drink only beer; it has a lower alcohol content.

   c. Practice abstinence.

   d. Eat plenty of food before you drink alcohol and drink plenty of coffee the next day.

4. What is the immediate danger of carbon monoxide from cigarette smoke?

   a. It inhibits the body's ability to remove nitrogen during denitrogenation.

   b. It inhibits the blood's oxygen carrying capacity.

   c. It increases your chance of mouth and gum cancer.

   d. It acts as a depressant on the central nervous system.

5. Bagels, pretzels, granola bars, fresh fruits, vegetables, etc. are recommended snacks containing complex carbohydrates. What is the advantage of these foods over a coke and a candy bar?

6. List five signs and symptoms of dehydration.

   a.

   b.

   c.

   d.

   e.

7. Chronic fatigue is caused by the normal daily activities of a crewmember and is remedied with a good night's sleep and rest.

   a. True

   b. False

8. Caffeinated beverages can increase your dehydration rate. As a result, your ________ and ________ fatigue increases and your ________ decreases as you become dehydrated.

9. Identify four methods of combating stress in the flying environment.

   a.

   b.

   c.

   d.

Lesson JP(0)109 — 4.0 Hours (IBT)

Descent and Landing Techniques

Goals

1. Using the suspended ring and harness or virtual reality (VR) trainer, demonstrate and practice the following parachute harness suspension manipulations:
   a. Proper body position for parachute opening shock
   b. Methods of parachute control and correction of parachute malfunctions
   c. Proper body position for descent and landing over land and over water
2. Using two-foot and four-foot elevated platforms, execute proper parachute landing falls (PLFs).
3. Using a parachute harness, demonstrate proper recovery and release from the parachute during a simulated drag situation.
4. Using the Swing Landing Trainer/Lateral Drift Trainer (SLT/LDT), execute proper PLFs.

Assignment

Read JP(0)109 in the SG.

Introduction

During this period of instruction you will demonstrate proficiency in parachute harness and canopy manipulations, PLFs from elevated platforms, recovery and release from the parachute during a drag situation, and PLFs from the SLT/LDT. You will be expected to perform all of the demonstrations to the satisfaction of your instructor(s). This training is designed to prepare you for parachute familiarization training and a possible bailout situation from your aircraft.

We recommend bringing an extra flight suit to change into after training is complete. Bring your gloves for the training. All leather flight boots are required in order to provide support to the ankles. Remove jewelry and any objects from the uniform that could cause injury (i.e. pens, keys, cell phones, etc). Do not participate in the training if you are ill or have any joint or muscle injury (ankle, knee, back, shoulder, etc.). If you are in doubt, inform the instructor. You will participate in approximately 10 minutes of warm-up exercises prior to beginning training. The exercises will be those considered best for the prevention of joint and muscle injuries.

Information

Your class may be divided into groups with instructors for each group. After the initial instructor demonstrations, each group will report to separate training areas with their instructors. Everyone completes the training by performing PLFs from the SLT/LDT. Your responsibility is to complete the training in a safe effective manner.

Suspended Ring and Harness Trainer

Goal 1 — Using the suspended ring and harness or virtual reality (VR) trainer, demonstrate and practice the following parachute harness suspension manipulations:

a. Proper body position for parachute opening shock
b. Methods of parachute control and correction of parachute malfunctions
c. Proper body position for descent and landing over land and over water

This device is designed to demonstrate/perform proper body position for opening shock (military free-fall position), canopy manipulation, and descent and landing techniques. Your instructors will assist you in hooking up to the trainer and proceed through the demonstrations procedure by procedure. You will be expected to perform these techniques and procedures to the satisfaction of your instructor(s).

PLFs, Practice Area

Goal 2 — Using two-foot and four-foot elevated platforms, execute proper parachute landing falls (PLFs).

Practice of the PLFs will start at ground level. You will begin by maintaining the feet and knees together and making contact with the ground on all *five* points of contact. You will practice left, right, front and rear PLFs. When proficiency is demonstrated at ground level, you will continue to the two- and four-foot elevated platforms and perform the PLFs to the satisfaction of your instructor(s).

Parachute Drag Recovery

Goal 3 — Using a parachute harness, demonstrate proper recovery and release from the parachute during a simulated drag situation.

Parachute drag recovery is performed in the event you are unable to release from the parachute immediately after completing the PLF. You must release and recover as soon as possible to eliminate any further injury. However, do not release from the *training device* until the instructor has checked your procedures and body position and given the command "RELEASE." If training with an NB6/8 parachute, do not roll out of the parachute during this training evolution until your instructor has checked your procedures and body position and has given you the "ROLL OUT" command.

PLFs from the SLT/LDT

Goal 4 — Using the Swing Landing Trainer/Lateral Drift Trainer (SLT/LDT), execute proper PLFs.

The SLT will simulate motion under parachute canopy. You will be expected to perform left, right, front and rear PLFs to the satisfaction of your instructor(s). Always remember to keep the feet and knees together, your eyes on the horizon. You must be able to perform PLFs from the SLT/LDT in order to continue on to parachute familiarization training (parasail).

Lesson JP(0)110 — 4.0 Hours (IBT)

Parachute Familiarization Training (PFT)

Goal

Using a parasail, develop confidence in the ability to survive a parachute descent, control the parachute during descent, and correctly execute a parachute landing fall (PLF).

Assignment

Read JP(0)110 in the SG.

Introduction

After completing lesson JP0109 and an aircraft specific parachuting lesson, you will be briefed on procedures to follow during Parachute Familiarization Training (PFT). PFT provides you the opportunity to demonstrate your proficiency at canopy control and your ability to perform a PLF. Again, you may want to bring an extra flight suit to change in to after training is complete. Bring your gloves for the training. All leather flight boots are required in order to provide support to the ankles. Remove jewelry and any objects from the uniform that could cause injury (i.e. pens, keys, cell phones, etc).Do not participate in the training if you are ill or have any joint or muscle injury (ankle, knee, back, shoulder, etc.). If you are in doubt, inform the instructor. You will participate in approximately 10 minutes of warm-up exercises and you will also perform refresher PLF training prior to PFT (parasail).

Information

Training Method

Parasail training is a confidence-building program designed to prevent injury during actual aircraft bailout and to practice the proper and safe use of a parachute. After the procedures have been demonstrated/performed during Descent and Landing Techniques. The parasail canopy is an ascending/gliding parachute that facilitates forward travel by a series of ports or slots that exhaust air and establish a lifting angle of attack. By using the parasail, it is possible to tow you to altitude over land or water and to release you for unrestrained parachute descent. With the parasail, you can perform turns, execute PLFs, and perform equipment releases and anti-drag procedures, if required. Procedures will only be performed under the direct supervision and instruction of aerospace physiology parasail crewmembers. Pay close and careful attention to your instructors.

Operational Procedures

Goal — Using a parasail, develop confidence in the ability to survive a parachute descent, control the parachute during descent and correctly execute a parachute landing fall (PLF).

Prior to each parasail launch, you will be fitted with a parachute harness (with the parasail canopy attached) and a protective helmet. One-way communication, from the instructors to the students, is maintained by radio or by megaphone. Listen to the instructors. On your first ascent (Figure 10-1) and slow descent, you will remain attached to the tow vehicle. This tow up and tow down should alleviate any apprehension you may have had and prepare you for subsequent tows.

On the subsequent tows, you will be released from the tow vehicle for a free parachute descent to practice parachute steering and to execute a parachute landing fall. The descent and turns are very similar to a parachute descent with the four-line jettison modification.

Note — Do not perform any turns when you are attached to the tow vehicle. When you perform turns during the free descents, perform the turns by pulling down on the appropriate rear riser. The parasail does not incorporate the red lanyards found in the parachute.

Figure 10-1 — Tow-Up

Lesson JP(0)115 — 6.0 Hours (IBT)

Altitude Chamber Flight and Rapid Decompression

Goals

1. Identify the proper techniques for pressure breathing
2. Conduct preflight and inflight checks of oxygen equipment
3. Conduct the procedures to treat hypoxia
4. Conduct the procedures to prevent trapped gas disorders inflight
5. Identify the proper use of emergency oxygen systems and portable oxygen equipment
6. Identify visual problems resulting from decreased oxygen during night flying conditions
7. Conduct the procedures to prevent hypoxia, trapped gas, and evolved gas disorders after a rapid decompression
8. Identify the physical signs of a rapid decompression
9. Identify the physiological effects of a rapid decompression

Assignment

Read JP(0)115 in the SG.

Introduction

The Type 2A chamber flight provides practical experience in, and confirms the effects of, barometric pressure change. Figure 11-1 provides the Type 2A flight profile. Remember, the altitude chamber is an extension of the classroom and the chamber flight is intended to enhance your learning experience. A rapid decompression chamber flight is part of the Type 2A.

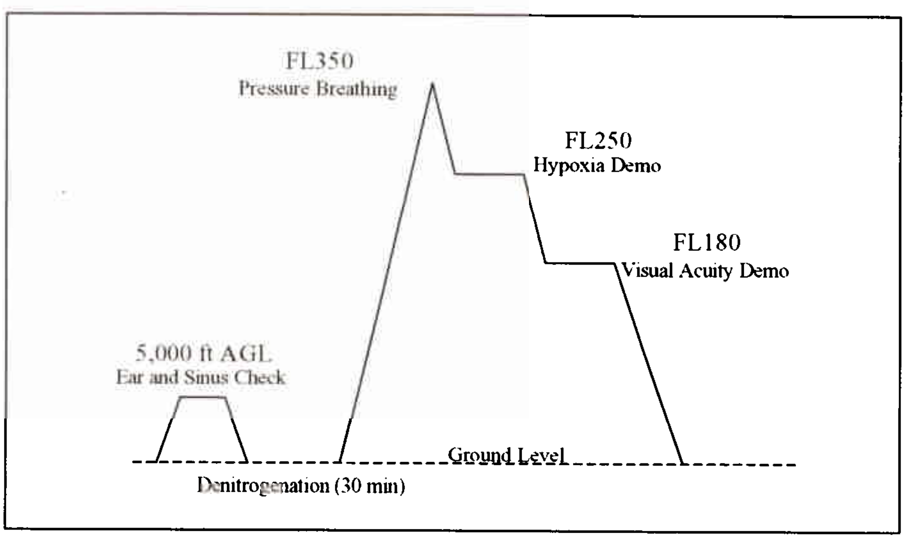


Figure 11-1 — Type 2A Flight Profile

Information

Preflight Briefing

A preflight briefing is conducted to ensure safe and efficient operation and completion of the chamber flight. You will be briefed on the flight profile, purpose and procedure. You will also receive a medical briefing to determine your immediate physical status (colds, headache, abdominal pain, medication, etc.) If you answer yes to any of the questions asked by the instructor or are in doubt, notify the instructor. At the conclusion of the preflight briefing, you will be given an altitude chamber seat number and directed to the chamber. The main purpose of the chamber flight is to reinforce the principles and procedures learned in class.

Type 2A Chamber Flight

Enter the altitude chamber and sit in your preassigned seat. The chamber crew personnel will assist you in performing a PRICE check to guarantee the integrity of your oxygen equipment. Denitrogenation time (30 minutes) begins after all students and inside observers have completed a PRICE check and are breathing 100 percent oxygen. A communications check is conducted after all students and crew personnel are in position. An ear and sinus check is conducted to identify any potential difficulties. The Valsalva maneuver is necessary only on descent. After the ear and sinus check is completed, the remainder of the denitrogenation time is used to review the PRICE check and practice pressure breathing.

During ascent to FL350, you will demonstrate and practice using your oxygen equipment, discuss the value of frequent equipment/intercommunication checks and discuss decompression phenomena.

Safety pressure is delivered to your mask by the narrow panel regulator at about FL280. Monitor your rate and depth of breathing. Remember, passive inhalation and active (forceful) exhalation, with a pause between, will help prevent hyperventilation. Your chief observer will have you place the EMERGENCY lever into EMERGENCY around FL320 to allow you to experience pressure breathing as it would be at the maximum safe altitude of the system (FL430). The chief observer may ask for a communications check during final ascent to FL350; break your words up into syllables and forcefully speak against the pressure. The combined affects of pressure breathing and gas expansion at FL350 makes it very difficult to perform flight tasks proficiently.

A rapid descent to FL250 begins almost immediately after reaching FL350. The pressure change during descent is not as great at the higher altitudes, but it is still important to perform the Valsalva maneuver as required. At FL250, a hypoxia demonstration is conducted to allow you to experience the objective and subjective symptoms of hypoxia.

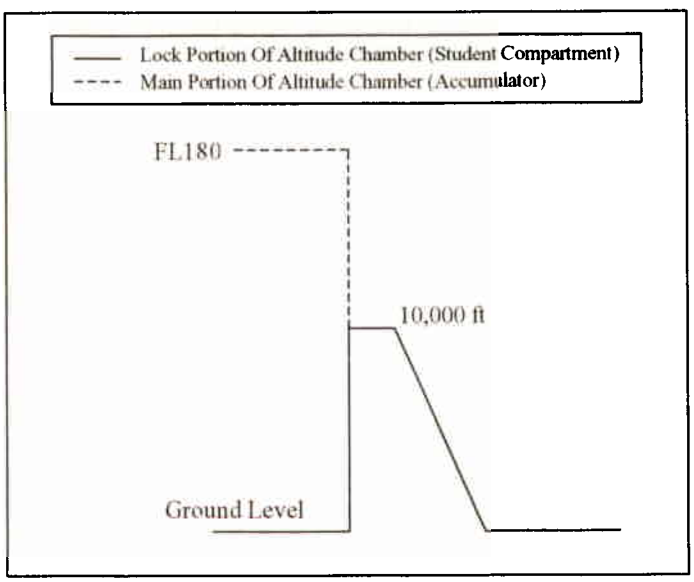


Figure 11-2 — Rapid Decompression Flight Profile

A final hypoxia demonstration will be conducted at FL180 to show the effects of (mild) hypoxia on vision at lower altitudes.

Equalizing the pressure in the middle ears and sinuses is your main concern during the final descent to ground level. The remaining two demonstrations of the Type 2A chamber flight are with the emergency oxygen cylinder and the narrow panel regulator. Remember your pressure breathing technique as you use the emergency oxygen cylinder; do not overbreathe the system. Once ground level is reached, do not disconnect from the regulator hose or the communication cord until instructed to do so.

Rapid Decompression

As part of the Type 2A altitude chamber flight, you are assigned to a group (with one Inside Observer (IO)) for the rapid decompression chamber flight. Figure 11-2 provides the rapid decompression flight profile. Enter the lock portion of the altitude chamber and follow the instructions of your IO. A preflight check of your oxygen equipment and an intercom check are conducted after your group and the IO are in position. The door is closed and you will be briefed on the phenomena of a rapid decompression. After the briefing is complete, a rapid decompression will occur without prior notice. The decompression causes an ascent from ground level to about 10,000 feet in approximately two seconds. The final altitude will be determined by the field elevation, but will be around 10,000 feet. Your responsibilities are to *not* hold your breath, gangload your regulator and check your connections.

Final descent begins after everyone recovers, a communications check is completed, and the emergency lever is returned to NORMAL. Equalizing the pressure in the middle ears and the sinuses is your main concern during descent. Your chief observer will discuss the physiological affects and physical characteristics of a rapid decompression, pointing out their significance to an actual event on an aircraft. Once ground level is reached, do not disconnect from the regulator hose or the communication cord until instructed by the IO.

Post Flight Briefing

The postflight briefing reviews the chamber flight and emphasizes the learning outcomes. You are given instructions to follow in the event of a delayed reaction and restrictions you must adhere to following the chamber flight.

Because nitrogen in body tissue comes out of solution during exposure to low barometric pressure, you are restricted from strenuous activity and from flying as a crewmember for 12 hours following the chamber flight. These precautions help prevent postflight DCS.

There is also the possibility of experiencing a postflight ear block (delayed reaction) after breathing 100 percent oxygen for an extended period of time. As the 100 percent oxygen diffuses out of the middle ear space into the surrounding tissues, a relative low pressure area results. The low pressure area allows the now greater ambient pressure on the exterior surface of the ear drum to deflect the ear drum inward, dulling the hearing and producing pain. So, continue to perform the Valsalva maneuver as necessary following the chamber flight.

Lesson JP(0)190 — 2.0 Hours (IBT)

Examination and Critique

Goals

1. Complete the examination in the allotted time and within the academic standard.
2. Critique all errors on the examination to 100 percent.

Assignment

Review lessons JP(0)101 through JP(0)115 in the Aerospace Physiology Student Guide.

Introduction

The examination and critique are administered IAW AETCI 36-2205, *Formal Aircrew Training and Management* and AETCI 36-2220, *Academic Training*.

Information

Aerospace Physiology Examination

Goal 1 — Complete the examination in the allotted time and within the academic standard.

"Open book" material will not be used during this examination. Remove all material from your examination area. No. 2 pencils will be provided.

Aerospace Physiology Examination Critique

Goal 2 — Critique all errors on the examination to 100 percent.

Note — Individual course critiques will be distributed for completion after the examination.

Attachment 1

Answers to Review Exercises

Review Exercise JP(0)101

1. a
2. b
3. d
4. b
5. b
6. a
7. d
8. a. B
   b. D
   c. E
   d. A
   e. C

Review Exercise JP(0)102

1. oxygen, carbon dioxide
2. c
3. c
4. a
5. b

Review Exercise JP(0)103

1. expand
2. a. ears
   b. sinuses
   c. G. I. tract
   d. teeth
3. b
4. a. 1
   b. 2
   c. 2
   d. 4
   e. 3
   f. 1
   g. 3
   h. 4
   i. 4
   j. 4
   k. 4
   l. 1
5. nitrogen
6. a. 100% or maximum
   b. immobilize
   c. land
   d. medical assistance
   e. hyperbaric
7. cabin pressure, denitrogenation
8. 24
9. Hypoxia
10. Hypoxic hypoxia
11. a. 1
    b. 2
    c. 2
    d. 4
    e. 4
    f. 3
    g. 4
    h. 2
    i. 1
    j. 1
    k. 2
    l. 3
12. insidious onset
13. a, b, d, e, f, g, h, i, k, l, m
14. b
15. time, useful consciousness
16. a, b, d, e, f, g
17. rapid decompression, 50%
18. rate, depth
19. carbon dioxide
20. **signs**
    a. muscle tightness/spasms
    b. increased rate/depth of breathing
    c. paleness
    d. cold, clammy skin
    e. unconsciousness
    symptoms
    a. dizziness
    b. faintness
    c. slight nausea
    d. numbness
    e. tingling
    f. coolness
    g. muscle tremors
21. a
22. a
23. a. maximum, pressure
    b. Check security
    c. rate, disappear
    d. 10,000, possible
24. c
25. a. reduced need for supplemental oxygen
    b. reduced expansion of G.I. gas
    c. control temperature and humidity
    d. move with encumbrance of oxygen equipment
    e. minimize fatigue
    f. protect ears/sinuses from rapid pressure change
26. decompression

Review Exercise JP(0)104

1. a
2. a
3. a A
   b. B
   c. A
   d. B
   e. A
   f. B
   g. A
4. b
5. d
6. b
7. motion, central
8. a
9. a

Review Exercise JP(0)105

1. a 3
   b. 1
   c. 2
2. a. visual
   b. vestibular
   c. seat-of-the-pants
   d. auditory
3. visual, visual, vestibular
4. peripheral vision
5. semicircular canals, otolith organs
6. semicircular canal, somatogyral
7. otolith organs, somatogravic
8. somatosensory
9. a. 2
   b. 3
   c. 1
10. c
11. elevator illusion
12. G-excess effect
13. nystagmus
14. a
15. a. A
    b. B
    c. B
    d. B
    e. A
    f. A
16. a. understand limitations
    b. remedy correctable factors
    c. use capabilities properly
    d. recognize high-risk situations
    e. stay alert!
17. a. transition to instruments
    b. believe the instruments
    c. back-up the pilot flying on instruments
    d. minimize head movements
    e. fly straight and level
    f. be prepared to transfer/assume control
    g. egress
18. b

Review Exercise JP(0)106

1. unwanted sound
2. intensity, frequency, duration
3. hertz
4. decibels
5. narrow band
6. conductive, sensorineural
7. 40
8. b
9. a, c
10. c, d

Review Exercise JP(0)107

1. linear, transverse
2. angular
3. head, feet
4. force acting from feet to head
5. b
6. a. magnitude
   b. rate
   c. duration
   d. direction
   e. previous exposure
7. G-LOC victims may be disoriented for some time after regaining consciousness
8. Rapid G-onset rate gives little or no visual warning prior to G-LOC
9. a. skeletal muscle
   b. cyclic
10. a. breathing cycle
    b. timing, strain
    c. lower body, tensing
11. a
12. G-LOC results in unconsciousness whereas blackout results in vision loss only
13. a
14. a. A.
    b. B
    c. B
    d. A
    e. B
    f. A
    g. A

Review Exercise JP(0)108

1. a. 3
   b. 5
   c. 4
   d. 1
   e. 2

2a. 12, aftereffects

2b. 12, mission plan (brief)

3. c
4. b
5. avoids hypoglycemia
6. a. thirst
   b. sleepiness
   c. nausea
   d. mental impairment
   e. fatigue
7. b
8. mental, physical, performance
9. a. place demands into perspective
   b. maintain a healthy diversity in you life
   c. eliminate self-imposed stress
   d. exercise