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ABSTRACT

This publication provides guidelines for teachers using the textbook entitled "Aerospace Environment," published in the Aerospace Education I series. Major categories included in each chapter are objectives, behavioral objectives, suggested outline, orientation, suggested key points, instructional aids, projects, and further reading. Background materials for major concepts stressed are included. Page references corresponding to the textbook are given where appropriate. A blank sheet is included after each chapter for recording teacher ideas. (PS)

SEPTEMBER 1972

AE-I

THE AEROSPACE ENVIRONMENT

INSTRUCTIONAL UNIT OBJECTIVES — Each student should:

a. Be familiar with the dimensions and characteristics of the space environment.

b. Be familiar with the contributions of the space program to man's knowledge of the universe.

c. Know the scientific basis for the existence of plant and animal life on the earth's surface.

d. Be familiar with the natural forces and events that produce weather.

e. Be familiar with the sources of information for weather forecasting and with the methods of forecasting the weather.

PHASES IN INSTRUCTIONAL UNIT:

PHASE I — FROM THE GROUND UP — A SURVEY OF AEROSPACE

The first phase of this study provides a broad survey of the aerospace environment as an introduction to a more detailed examination of the earth's atmosphere and the universe in later chapters. The first half of Chapter 1 describes how the density and pressure of the earth's atmosphere changes with increases in altitude. The latter half of the chapter introduces the student to the vast dimensions of the universe and to the units of measurement designed by man to represent these dimensions.

1. PHASES I OBJECTIVES — Each student should:

   a. Know what happens in the earth's atmosphere as men and machines climb to higher altitudes.

   b. Know the divisions of the space environment and the immense distances represented by each division.

   c. Be familiar with the units of measurement used by scientists to indicate interplanetary, interstellar, and intergalactic distances.

   d. Know the requirements for life support elsewhere in the universe.

2. BEHAVIORAL OBJECTIVES — Each student should be able to:

   a. Explain why air-breathing flight becomes more difficult at high altitudes.

   b. Explain why a satellite orbiting the earth at less than 100 miles altitude will not remain aloft as long as a satellite in orbit at 300 miles.

   c. Cite examples illustrating the vast distances of the universe.

   d. Define the astronomical unit, the light year, and the parsec as units for measuring interplanetary, interstellar, and intergalactic distances.

   e. State the principal reason why scientists believe that intelligent life may exist elsewhere in the universe but not within the solar system.

3. SUGGESTED OUTLINE:

   a. Nature of the atmosphere

      (1) Air and air pressure

(2) Air movement, moisture, and temperature (weather).

(3) Effect of decreasing air pressure on individuals and air-breathing machines with increases in altitude.

b. The boundary between air and space

(1) Definition of the boundary

(2) Effect of variations in altitude on orbiting satellites

(3) Evidence that space is not an empty vacuum.

c. Dimensions of the space environment

(1) Cislunar distances — the present limit of human travel

(2) Distances traveled by unmanned space vehicles to reach earth's next-door neighbors in the solar system

(3) Overall design of the solar system

(4) Gravitational control of planetary orbits

d. Units for computing distances in space

(1) The astronomical unit

(2) The light year

(3) Heliocentric parallax (parsec)

(4) The solar system in relation to the Milky Way Galaxy

(5) Intergalactic distances

e. Theories concerning life in outer space

4. ORIENTATION:

a. As a survey of the earth's atmosphere and the boundaries of the space environment, the purpose of this initial chapter is to stimulate the student's interest in the nature of the atmosphere and the vastness of the universe. It begins with a discussion of the earth's atmosphere at sea level and describes how atmospheric pressure decreases at various altitudes. It then discusses the flight of vehicles through the airlessness of space and explains how flight is prolonged because of the absence of air molecules. The discussion of distances in space should lead the student to an appreciation of the almost incomprehensible vastness of the universe.

5. SUGGESTED KEY POINTS:

a. The realm of aerospace begins with the invisible film of gas called atmosphere surrounding the earth and extends outward from the earth to infinity. At sea level, dense molecules of air exert a tremendous pressure of 14.7 pounds per square inch. The movement and changes in the moisture content and temperature of the air near the earth's surface constitute what is known as weather. At higher altitudes, the film of gas or atmosphere thins, and man and his machines find it increasingly difficult to breathe. At altitudes of 7 to 10 miles, molecules of air become so thin that neither life nor weather exist as it is known on the earth.

**(J-9003) pp 13-16
***(J-9096) pp 81-85
**(J-9107) pp 1-3, 9-15
***(J-9156) pp 198-204

b. According to one definition, space begins approximately 100 miles above the earth's surface. Another definition sets the boundary of space at 600 miles above the earth. Numerous other definitions range from 60 to 20,000 miles. At these altitudes, man-made satellites can orbit the earth at speeds greater than 17,000 miles per hour because air molecules are too thin to slow them down. The orbiting life of satellites varies according to their altitude. Satellites boosted no higher than 100 miles remain aloft for only a few months because air molecules are sufficiently dense to slow them down. At altitudes of 600 miles or more, air molecules are so thin that satellites can remain aloft for years and not lose their speed. Space is not an empty vacuum as witnessed by the stars, the Van Allen radiation belts, the solar winds, and other phenomena.

c. The space environment can be divided into four immense realms - cislunar space, interplanetary space, interstellar space, and intergalactic space. Cislunar space is a reference to any space within 250,000 miles of the earth and is the present limit of manned space travel. Interplanetary space includes the Sun, the planets, and smaller bodies within the influence of the Sun's force of gravity. Unmanned space vehicles have either closely approached or visited Venus and Mars at their nearest approach to the earth, 26,000,000 and 34,500,000 miles, respectively. The planets vary in weight from Mercury's one-twentieth that of the earth to Jupiter's 318 times that of the earth. The solar system is shaped like a giant platter 7.35 billion miles across.

d. Astronomers use three basic units to measure distances in space: the astronomical unit, the light year, and the parsec. The astronomical unit is the basic unit for measuring distances within the solar system and is based on the average distance from the Sun to the orbiting earth, or 93 million miles. For measuring interstellar space and beyond, astronomers use the light year and the parsec. The light year measures interstellar

***(J-9003) pp 7-33, 49-55, 65-76
***(J-9033) pp 765-6, 792-3
***(J-9146) pp 61-67

distances according to the speed of light, 186,000 miles per second. Thus, an observer on the earth sees the Moon as it was 1.3 seconds ago, and, on an average, the Sun is roughly eight light minutes away from the earth. One light year equals 5,878 billion miles or approximately 66,000 astronomical units. To the far edge of the Milky Way is a distance of 80,000 light years. The parsec is a short term for <u>parallax of one second of arc</u> as a star is viewed from the earth as it swings to opposite sides of its orbit around the Sun. One second of arc is 1/1,296,000 of a circle or 1/3,600 of a degree. One parsec equals 3.26 light years. By this measurement, the nearest star to the earth, Alpha Centauri, is 1.3 parsecs away.

**(J-9083) pp 159 - 168

e. Our Sun and all the other visible stars belong to the Milky Way Galaxy, a flat, pancake-shaped formation of stars. Inhabitants of the earth are approximately 30,000 light years from the center of the Milky Way, which has a total diameter of approximately 100,000 light years. A larger, neighboring galaxy to the Milky Way is seen as a tiny blob of light in the center of the constellation Andromeda. This galaxy is 130,000 light years in diameter and is approximately 2 million light years away from the earth. Astronomers estimate the number of galaxies in the universe in the hundreds of millions; the most remote galaxy ever observed is estimated to be 5 billion light years away.

***(J-9146) pp 177 - 179
***(J-9023N) pp 36 - 57
pp 83-92

f. Scientists generally agree that life could exist elsewhere in the universe. It may not have the same appearance as earth-based life, but it may perform certain functions that are basic for all forms of life. Because the whole universe seems to be constructed of the same elements and because these elements interact in the same manner wherever they are found, it is highly possible that some form of life could exist in other star systems similar to our solar system. What are the conditions necessary for life? Some of the conditions are: a proper temperature (ranges from -75° to +140°), an energy source (light or some other type of electromagnetic radiation or some chemical compounds containing stored energy), a suitable environment (usually an atmosphere containing water vapor, oxygen, and carbon dioxide).

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

Number of Academic Periods per Week	Recommended Number of Periods for this Phase				
	1	2	3	4	5
2	X				
3	X				
4		X			

b. This phase is especially adapted to the lecture-discussion approach and to the use of a guest lecturer. In teaching the first half of the chapter, you might find it helpful to use a prepared illustration or a chalkboard demonstration showing how air pressure and density decrease at various levels of the atmosphere. A guest lecturer, possibly a science or physics instructor, might be used to discuss and explain the dimensions of space. However, he should understand that this phase is intended primarily as an introduction to a more detailed study in later chapters. Therefore, he should focus on clarifying for the students the units for measuring distances in space and on presenting a broad picture that will enable the students to appreciate the vastness of the universe.

c. Since this phase is mainly descriptive, visual aids can be very helpful in the presentation of key ideas. Thus, models of our solar system showing the positions and orbits of the planets, asteroids, and Van Allen radiation belts in relation to the Sun may help your students understand the size and distance relationships within the solar system. Another model of the universe showing our solar system in relation to the Milky Way and the Milky Way in relation to millions of other galaxies can impress the students with the physical insignificance of the earth in terms of other planets and other star systems. You might be able to borrow some of the needed equipment, charts, and models from science instructors. Overhead transparencies (both those provided by the Air Force and those which you make) and handout sheets might also be effective classroom aids. Transparency T-34 is especially appropriate for this block of instruction.

7. INSTRUCTIONAL AIDS:

a. 35mm Slides

(1) SVA-41 Military Space Environment

b. NASA Films, general series

(1) HQ 163 - View of the Sky, 28 min., Color, 1967

(2) HQ 164 - Universe on a Scratchpad, 28 min., B&W, 1967

c. Transparencies

(1) T-34 - Division of Space

8. PROJECTS:

a. Develop local projects based on your students' interests.

9. FURTHER READING:

a. Hoyle, Fred. The Nature of the Universe. New York: The New American Library of World Literature, Inc., 1960.

b. Moffat, Samuel and Shneour, Elie. Life Beyond the Earth. New York: Scholastic Book Services, 1965.

c. Motz, Lloyd. This is Outer Space. New York: The New American. Library of World Literature, Inc., 1962.

PLEASE NOTE ANY SUGGESTIONS FOR IMPROVEMENT OR EFFECTIVE TEACHING METHODS ON THE BLANK SHEET AT THE END OF THIS PHASE!

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTORS GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE

PHASE II - EARTH AND ATMOSPHERE

This phase reviews the chemical and physical nature of the atmosphere and its support of life on the earth. It introduces the student to the properties of the dry atmosphere, the role of the oxygen cycle in sustaining life, and the importance of water and dust in maintaining the earth's ecological balance. After reviewing the properties of the atmosphere, the chapter considers the atmosphere in motion, including heat transfer, the layers of the atmosphere, and the effect of these layers on weather. Also, included is a description of the earth and atmosphere as a giant weather machine, global weather cycles, and the effect of air masses on the earth's weather.

1. PHASE II OBJECTIVES -- Each student should:

    a. Know how the atmosphere and the earth provide a balanced environment for the support of life.

    b. Understand how the various movements and layers of the atmosphere contribute to the phenomenon known as weather.

    c. Understand how the earth's rotation and revolution, terrain, and air masses contribute to global weather patterns.

2. BEHAVIORAL OBJECTIVES -- Each student should be able to:

    a. Name the components of the earth's atmosphere and describe the contributions of each toward the support of life on the earth.

    b. Demonstrate four methods of heat transfer and explain which two of these methods are characteristic of the atmosphere.

    c. Identify and describe the nature of the major air masses that affect the United States.

3. SUGGESTED OUTLINE:

    a. Composition of the dry atmosphere

        (1) Chemical properties of air

            (a) Nitrogen and oxygen

            (b) Carbon dioxide

            (c) Water

        (2) Physical properties of air

            (a) Air as a fluid

(b) Reaction to heat, cold, and movement

(c) An insulator to the earth

(d) The nitrogen and oxygen cycle

(e) The role of water and dust

(f) Precipitation

b. The atmosphere in motion

(1) Principals of heat transfer

(a) Radiation and conduction

(b) Convection and advection

(2) Levels of the atmosphere

(a) Troposphere

(b) Tropopause

(c) Stratosphere

c. Global weather patterns

(1) Effect of the earth's revolution around the Sun and the earth's rotation on its axis

(2) The fluid effect of the atmosphere

(3) Effect of the Sun's heat on the atmosphere

(4) Effect of the earth's terrain

(5) Air masses

(a) Maritime tropical air masses

(b) Continental polar air masses

(c) Maritime polar air masses

(d) Collisions of air masses

4. ORIENTATION:

a. Whether we like it or not, all of us are confronted daily with weather. This is especially true when we think in terms of aerospace, whether it is commercial aviation, military aviation, or spaceflight. This is the first of two phases in our study of the earth's atmosphere and the natural forces that produce weather. The purpose of this phase is to show how the atmosphere and the earth provide an environment that supports and protects life. The next phase deals with more specific weather phenomena and various conditions on the earth's surface and in the atmosphere that produce such phenomena.

5. SUGGESTED KEY POINTS:

**(J-9005) pp 89-92
**(J-9018) pp 65-184
**(J-9033) pp 240-241
*(J-9047) pp 16-19
*(J-9065) pp 104-105
***(J-9156) pp 198-199

a. The atmosphere is a gaseous mixture composed of such chemical elements as nitrogen and oxygen and chemical compounds like water vapor and carbon dioxide. Under the proper conditions, different chemicals react with each other and form new compounds or release new elements. Although the chemical substances in the air do not undergo the same type of chemical reaction as gasoline or other chemical mixtures, the air is not a dead mixture of inert chemicals.

***(J-9107) pp 2-3
***(J-9156) pp 212-217

b. Like any other gas, air has physical properties. Heating the air causes air molecules to become more active and create pressure. Cooling the air causes the pressure to drop. Atmospheric pressure and temperature constantly vary from place to place and at any one place. Despite these variations, the chemical mixture of gases in the atmosphere almost always remain constant, with the exception of one, water vapor, which varies widely in warm and cool areas. Proper amounts of both nitrogen and oxygen are vitally important in the life cycle of all plants and animals. Although humans and other breathing creatures use nitrogen in their lungs only to dilute their supply of oxygen, it nourishes plants and creates proteins necessary to sustain the food supply for humans and animals.

c. Human beings, other breathing creatures, and machines depend on the oxygen cycle to live and function. Carbon and hydrogen in different compounds provide energy for living beings or machines in the carbohydrates of food or the hydrocarbons, which are the energy-giving compounds of coal and petroleum products. Carbon dioxide is a waste product of combustion in man and machine and is, in turn, consumed by plants. Plants replenish the world's oxygen supply through the miracle of photosynthesis by which they convert sunlight to food energy. In the process, they draw carbon dioxide from the air and release oxygen. All sources of food or fuel on or within the earth can be traced to plant photosynthesis and the sun's energy. Life depends upon a basic chemical balance in air, water, and living things, of which carbon, hydrogen, oxygen, and nitrogen in various proportions and combinations are the prime elements.

**(J-9005) pp 90-92
**(J-9107) pp 29-34
***(J-9156) pp 212 - 214

d. Water and dust are basic factors in the ecological balance. Clear air contains water in its invisible form known as water vapor. The amount of this invisible vapor that a given quantity of air can hold varies with the air temperature. The warmer the air, the more water molecules that it can hold. When the air reaches its limit, it becomes saturated and condensation causes the formation of water droplets. A single droplet is almost invisible, but large numbers of droplets can be seen in the atmosphere as fog or clouds. The temperature at which saturation occurs is called the dew point.

**(J-9005) pp 90-92
***(J-9107) pp 30-34
***(J-9156) pp 212 - 214

e. Various forms of precipitation occur, depending upon the temperature at which saturation occurs. Dew forms on the ground and other surfaces when the temperature at ground level is at or below the dew point. Frost occurs when the temperature at ground level is below freezing. When cloud or fog droplets become too heavy to float, they settle toward the ground in the form of mist or drizzle. Heavier drops are called rain. Snow is produced by the freezing of moisture around an ice crystal. A dust particle usually forms the nucleus of a raindrop.

**(J-9005) p 93
**(J-9065) pp 104 - 117
***(J-9107) pp 19-52

f. In addition to the properties of the atmosphere discussed above, the atmosphere has the characteristic of motion as a means of transferring heat. Since air is a fluid, it flows from place to place as it seeks some sort of balance. Heated air rises, and more air rushes in to fill the vacuum left by rising air. Cool air descends and displaces other air. The vertical motions in this cycle -- updrafts and downdrafts -- are called convection. The horizontal motions, sensed as wind, are called advection. A local circulation pattern of air that occurs over a woodlot and cornfield on a summer afternoon involves more convection than advection, but there is always a certain degree of horizontal movement. Larger circulation patterns involve long-range advection from the tropics or the poles toward middle latitudes or from the oceans toward interior plains, but convection is a part of these cycles, also.

g. Scientists divide the atmosphere into levels or "spheres" of different heights above the earth's surface. The lowest level is the troposphere, varying from about 5 miles at the poles to 10 miles at the equator and averaging about 7 miles over the United States. The main source of heat in the troposphere is the sun-warmed earth. The next level is a narrow border zone known as the tropopause. Immediately above the tropopause is the stratosphere where temperatures fall as low as 100° below F but also where where mild temperatures above zero have been reported. Insofar as the earth's weather is concerned, the troposphere is the most significant level of the atmosphere. At this level are found 80 percent of the air molecules and almost 100 percent of the water molecules. This is the zone where all weather begins -- billowing clouds, shifting winds, turbulence, rain, snow, lightning, hail -- all caused by heat from the earth and the cold of the troposphere.

**(J-9005) p 89
***(J-9107) pp 1-2

h. The earth's revolution around the sun once every 365 days and its tilt on its axis produce the seasons, and its rotation once every 24 hours insures a fairly constant and equal distribution of heat and light. Since the atmosphere acts as a fluid, the surface features of the earth keep the atmosphere constantly in motion as it seeks equilibrium. Various features of the earth's surface do not heat at an even rate and, when they do heat, they do not cool at an even rate. In this process, the air alternately heats, expands, rises, cools, and descends to the earth in a regular cycle called the three-cell pattern. As it proceeds through this pattern, it produces the so-called trade winds in the subtropic belts of latitude above and below the equator and the Coriolis force in the middle latitudes. As the air travels along the earth's surface, it constantly exchanges heat and moisture with the earth below it in the process that we call weather.

**(J-9005) p 90
***(J-9107) pp 19-28, 42-45

i. A large body of air with uniform characteristics is called an air mass. An air mass has the characteristics of the area over which it forms. A mass of air that originates over cold land areas is cold and dry, and one that originates over a tropical ocean is warm and contains much moisture. As air masses move from place to place, they carry these characteristics with them and affect the weather over the areas which they cross. When two air masses meet, the normal result is a change in the weather. The three most important air masses in the United States are maritime tropical, continental polar, and maritime polar. Maritime tropical air masses originate over a distant tropical sea and provide the United States with much of its warmth and rainfall. Continental polar air masses originate over cold land areas and produce relatively dry and extremely cold weather in the United States. Maritime polar air masses originate over oceans in the northern hemisphere and produce snowstorms in the United States.

***(J-9107) pp 62-72
***(J-9156) pp 225 - 233

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

Number of Academic Periods per Week	Recommended Number of Periods for this Phase				
	1	2	3	4	5
2			X		
3				X	
4					X

b. Guided discussion is probably the most appropriate teaching method for this and other phases in this unit. The text material is fairly familiar to most students, interest should be high, and many areas are appropriate for maximum student participation.

c. This phase is closely related to the general science area, and most of the students have had some experience with this subject area even at the junior high school level. All of the key points can be covered through guided discussion and further expanded with special student projects and other activities.

d. Weather instruments are usually available from the science or physics department, and teachers in these departments can also be very helpful in providing resource materials and presenting lectures in specialized areas. The TV weather report is also a very valuable and helpful source of information.

7. INSTRUCTIONAL AIDS:

a. FAA Films

(1) FAN-101 - Fog and Low Ceiling Clouds - Advection Fog and Ground Fog, 23 min., Color, 1962

(2) FAN-102 - Fog and Low Ceiling Clouds - Upslope Fog and Frontal Fog, 10 min., Color, 1962

(3) FA-608 - A New Look at Fog, 13 min., Color, 1967

b. USAF Films

(1) TF-1-5388a - Air Masses and Fronts, 12 min., Color, 1962

(2) TF-5532 - The Aerospace Meteorological Challenge, 19 min., Color, 1963

c. NASA Film

(1) HQ 148 - The Challenge of Unanswered Questions, 15 1/2 min., Color 1968

d. TRANSPARENCIES:

(1) Milliken Weather Book, Nos. 1-2

(2) T-13 - Weather Map

(3) T-17 - Cross Section of a Thunderstorm

(4) T-22A - Global Air Flow - High Low Pressure Areas of Wind Circulation

(5) T-35 - Regions of the Atmosphere

8. PROJECTS:

a. With available weather instruments, have students make readings and recordings throughout this unit.

b. Conduct a field trip to a weather station (FAA or military), if one is available in your local area.

c. Have selected students give daily weather reports and forecasts. The students might even try their hand at forecasting as they gain more knowledge in the subject.

d. Assign research projects to selected students and ask them to make reports to the class on how the weather affects health, communications, politics, transportation, sports events, agriculture, and flying.

e. Most of these projects can be scheduled throughout this unit.

9. FURTHER READING:

a. Check your school and community library.

PLEASE NOTE ANY SUGGESTIONS FOR IMPROVEMENT OR EFFECTIVE TEACHING METHODS ON THE BLANK SHEET AT THE END OF THIS PHASE!

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTORS GUIDE AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS PHASE

PHASE III - MORE ABOUT THE WEATHER

This phase describes fronts, clouds, types of clouds, and their effects on local weather. Another area considers terrain as a contributing factor in weather changes. The student is also introduced to modern methods of observing and forecasting weather, common weather hazards to aviation, and some of the forecaster's capabilities and limitations.

1. PHASE III OBJECTIVES - Each student should:

   a. <u>Know</u> the weather typically associated with various types of fronts.

   b. <u>Know</u> the kinds of weather produced by various cloud types and by the earth's surface features.

   c. <u>Understand</u> the instruments and techniques used by forecasters to observe and report weather conditions.

   d. <u>Know</u> some of the major weather hazards to aviation and their causes.

   e. <u>Understand</u> the capabilities and limitations of the weather forecaster.

2. BEHAVIORAL OBJECTIVES -- Each student should be able to:

   a. Explain the causes of warm and cold fronts and describe at least two weather situations that result from each type of front.

   b. Identify the weather situations that result from various cloud formations and irregularities in the earth's surface.

   c. Read a modern weather map and interpret weather information from at least two other sources used by weather forecasters.

   d. Describe the kinds of weather that are hazards to flying and indicate how a forecaster might help a flyer to avoid them.

   e. Discuss specific capabilities and limitations of weather forecasters and explain the basis for their limitations.

3. SUGGESTED OUTLINE:

   a. Weather fronts as manufacturers of weather

      (1) Cold fronts

      (2) Warm fronts

(3) Occluded fronts

b. Other weather makers

(1) Convectional thunderstorms

(2) Types of cloud formations

(a) High clouds

(b) Middle clouds

(c) Low clouds

(d) Clouds that develop vertically

(3) Terrain

c. Weather observing and forecasting

(1) Features of the atmosphere that contribute to weather making

(2) Instruments used in surface observation

(a) Barometer

(b) Thermometer

(c) Hygrometer

(d) Psychrometer

(e) Weathervanes and anemometers

(3) Extensions of man's weather knowledge

(a) National Weather Service

(b) Air Weather Service

(c) Weather maps

(d) Teletypewriter

(e) Facsimile transmission

(f) Radar

(g) Upper air observation

(h) Satellites

(i) Climatology

d. Weather hazards to flying and the forecaster's role

(1) Turbulence

(2) Icing

(3) Reduced visibility

(4) Thunderstorms

(5) The forecaster's capability

(6) Unsolved problems of forecasting

4. ORIENTATION:

a. This phase involves the student in a more detailed study of weather phenomena. It deals with some of the specific conditions and factors that generate various kinds of weather, and it follows in a logical sequence with the preceding phase. The introductory material in Phase II should provide the student with a background that will assist him in understanding some of the more technical information in this phase. During your study of this phase, you should reinforce the point that weather does not just happen. There are reasons for every weather condition, and this characteristic enables weathermen to predict (forecast) weather. However, you should also point out that weathermen frequently make erroneous predictions because there are so many variables that determine the weather and their predictions are merely estimates based on probabilities.

5. SUGGESTED KEY POINTS:

*(J-9005) p 93
*(J-9047) p 56
**(J-9065 pp 123-126
***(J-9107) p 78
***(J-9156) pp 232 - 241

a. When cold air advances and replaces warmer air, the leading edge of the cold air is called a cold front. The cold air advances when the wind within it blows toward the front. A cold front usually moves faster than a warm front because the cold front is oriented so that the cold, dense air is directed more perpendicularly to the front. Friction between the moving air and the ground changes the shape of the frontal surface by retarding the layer of air near the ground. This causes the frontal slope to be steeper than a warm front, particularly near the ground. Behind a cold front, the cold air near the ground is usually warmed and moistened from below, causing unstable air and rough flying weather.

*(J-9047) p 55
***(J-9107) p 81
***(J-9156) pp 235 - 237

b. When a moving mass of warm air displaces cold air at the surface, the leading edge of the warm air mass is called a warm front. The cold air, being heavier, ordinarily retreats only when the warm air blows against it with some force. As the warm (usually moist) air is forced upward, condensation occurs. The area affected by an active warm front may be very large.

c. When a cold front overtakes a warm front or a warm front overtakes a cold front, the overtaken front is forced aloft and becomes what is known as an occluded front. Some of our most severe weather occurs in an occluded front, usually a combination of weather associated with both cold and warm fronts.

*(J-9047) p 58
***(J-9107) p 83
***(J-9156) pp 237 - 239

d. The thunderstorm is a local weather condition invariably produced by a cumulonimbus cloud and is usually accompanied by thunder and lightning. The thunderstorm represents atmospheric convection at its strongest. Unstable air and high moisture content are the necessary ingredients for the formation of thunderstorms. Thunderstorms are extremely dangerous to flyers because they are usually accompanied by strong winds, up and down drafts, and severe turbulence.

*(J-9005) pp 95-96
*(J-9018) p 129
*(J-9047) pp 26-30
***(J-9107) p 92
***(J-9156) pp 239 - 246

e. Clouds are both the cause and the result of weather conditions. Various types of clouds fall into three height categories -- high clouds, middle clouds, and low clouds. Common types of high clouds are cirrus and cirrostratus. Cirrus clouds are feathery or mare's tail clouds that may indicate the arrival of a warm front. Cirrostratus clouds are thin sheets of clouds that give the sky a pale blue or milky appearance and may indicate the approach of rainy weather. Middle clouds may range from smooth, gray altostratus to patterned rows of small altostratus to patterned rows of small altocumulus, sometimes called mackerel sky. Low clouds range from puffy white fair weather cumulus clouds to dark gray stratus clouds that bring prolonged rain or stormy weather. Cumulus clouds become cumulonimus when their tops reach freezing levels and fan out into characteristic anvil shapes indicative of a thunderstorm.

*(J-9005) p 92
*(J-9018) pp 108 - 126
*(J-9047) pp 41-48
*(J-9065) pp 93-100
***(J-9107) p 53
***(J-9156) pp 223 - 232

f. Since is is a product of heat energy and a fluid atmosphere, weather behaves according to some very well-defined laws. Air is a fluid and reacts like any other fluid. Heat exchange in the atmosphere can be measured as can the moisture content of air because it can hold only so much water vapor. And the energies involved in weather behave according to the laws of energy-conservation. Thus, the weather forecaster's job becomes increasingly more efficient as his instruments improve. The most common instruments used by the forecaster are the barometer for measuring atmospheric pressure, the thermometer for measuring temperature, the hygrometer for determining the moisture content of the air, the psychrometer for measuring the amount of water vapor dissolved in the air, the weathervane for indicating wind direction, and the anemometer for measuring wind speed.

**(J-9075) pp 3-22

g. In addition to the radio and telegraph, a number of modern inventions provide increased weather coverage, speed up the collection and distribution of weather data, and extend weather observation into the upper atmosphere and space. Practically all weather information begins with the National Weather Service.

**(J-9047) pp 37-41
***(J-9107) pp 141 - 157,

151 - 152,
206, 210 -
211, 214 - 216
*(J-9133) pp 1 - 2

The weather map is the most useful basis for predicting weather because it tells where the weather has been and how far it has moved since the last map. Other indispensable aids to the weather forecaster are interconnected weather stations, the teletypewriter, the facsimile machine, and radar.

**(J-9075) pp 5 - 13
***(J-9107) p 182

h. Weather observations made above the earth's surface are usually known as upper air observations. A primary method for obtaining upper air information is the rawinsonde system, consisting of a miniature weather instrument that contains radio and radar for transmitting information on wind, temperature, pressure, and humidity. In areas without rawinsonde stations, aircraft take weather soundings by dropsonde, a system that uses the same kind of weather instruments dropped by parachute from a high altitude. The newest and most amazing electronic device used in weather forecasting is the weather satellite, which takes photographs of weather and cloud formations on a global scale and relays them to ground stations for evaluation. The two most outstanding weather satellites are TIROS and NIMBUS.

*(J-9005) pp 94-97
**(J-9065) pp 101-102
***(J-9107) pp 42-48
114, 128-138
***(J-9156) pp 217 -
222,
246-253

i. The three most severe weather hazards encountered by flyers are turbulence, icing, and poor visibility. Turbulence is a reference to up-and-down air currents, which may range from mild to violent and cause structural damage to aircraft. The most violent turbulence usually occurs in thunderstorms, but it may occur in any cloud with vertical development. Conditions are most favorable for ice formation inside a cloud where air air is saturated with water droplets and the temperature is below freezing. With the shock of an airplane passing through the cloud, these droplets quickly turn to ice on the airfoil surfaces, propeller blades, or intake systems. Fog and low stratus clouds are the most frequent causes of reduced visibility, but modern navigational aids make it possible for pilots to fly despite poor visibility. However, even the best pilots prefer to see where they are headed. Thunderstorms are a "triple threat" because they may contain all three weather hazards in addition to such side effects as rain, snow, lightning, and hail.

**(J-9033) pp 240 -
241
**(J-9065) pp 118 -
137
***(J-9107) pp 144 -
148, 197 - 217
***(J-9156) pp 250 -
258

j. Despite spectacular progress in recent years, weather forecasting is not yet an exact science. This does not mean that the weather forecaster cannot be of vital assistance to the aircraft pilot. The pilot must understand the forecaster's capabilities and limitations and accept the forecaster's advice as expert opinion rather than absolute truth. He must realize that weather continually changes and that the older the forecast, the greater its chances of being wrong.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

Number of Academic Periods per Week	Recommended Number of Periods for this Phase					
	1	2	3	4	5	6
2			X			
3					X	
4						X

b. You probably will find it desirable to continue the guided discussion used in the preceding phase. For this type of material, maximum student participation is an excellent approach. If time permits, you might invite the students to relate some of their personal experiences with weather. A daily weather map in the newspaper or the daily TV weather report can be used to emphasize some of the key points in this phase, such as fronts, clouds, thunderstorms, etc.

c. As the students become more knowledgeable about weather, you might select certain individuals to present weather briefings and forecasts. You might even extend the weather briefings to role playing by the entire class. The class could pretend to be a group of pilots and aircrew members, with one or more students playing the role of weather officers whose job is to brief the class on weather conditions which they can expect on an imaginary flight.

d. Electronic equipment now plays an important part in weather observing and forecasting. Many students will be interested in this aspect of the weather service.

e. Another interesting possibility is to approach the study of weather from a pilot's viewpoint. Invite a pilot to talk to the class or request a student to make a report on a pilot's activities regarding weather before, during, and after a long cross-country flight.

7. INSTRUCTIONAL AIDS:

a. FAA Films

(1) FAN - 103 - The Cold Front, 9 min., Color, 1962

(2) FAN - 104 - The Warm Front, 18 min., Color, 1962

b. USAF Films

(1) FR-1054 - Fog Dispersel and Its Value to Military Operations, 12 min., Color, 1971

(2) ***SFP-1359 - The Air Weather Service, 14 min., Color, 1966

(3) ***TF-1-5259 - The Unchained Goddess, 56 min., Color, 1958

(4) ***(TF-1-5388 a, b, c, d - Air Masses and Fronts, 51 min., Color 1962

(5) **TF-5532 - Aerospace Meteorological Challenge, 19 min., Color, 1963

(6) **TF-1-5598 - Meteorological Satellites, 20 min., Color, 1964

(7) **TF-6139 - Air Force Global Weather Central, 14 min., Color, 1971

c. NASA Film

(1) HQ-178 - A New Look at an Old Planet, 26 min., Color, 1969

d. TRANSPARENCIES:

(1) T-12 - Vertical Air Currents

(2) T-13 - Weather Map

(3) T-14 - Teletypewriter Weather Reports

(4) T-14B - Weather Station Symbols

(5) T-17 - Cross Section of a Thunderstorm

(6) T-18 - Mountain Waves

(7) T-22 - High Low Pressure Areas of Wind Circulation

(8) T-23 - Cross Section of a Cold Front

(9) T-24 - Weather Map and Weather Report

(10) T-25 - Cross Section of a Warm Front

(11) Milliken Weather Book, Nos. 3-12

e. TRANSPARENCIES OF NEWSPAPER WEATHER MAPS

8. PROJECTS:

a. Continue readings and recordings. With the added information included in this phase, the weather observations can now include cloud coverage, types of clouds, and future weather possibilities indicated by types of clouds.

b. Ask the students to collect articles and stories from newspapers and magazines on "man-made" weather. Modern weather satellites and current interest in this area make this a significant subject for the future.

c. Old weather maps and facsimile maps should be available from a weather station. This will illustrate some of the materials used by weather forecasters and pilots in observing the weather. Ask your students to explain one or more of these maps to the class.

9. FURTHER READING: Check your school and community library.

PLEASE NOTE ANY SUGGESTIONS FOR IMPROVEMENT OR EFFECTIVE TEACHING METHODS ON THE BLANK SHEET AT THE END OF THIS PHASE!

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTORS GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE

PHASE IV - FROM THE EARTH TO THE MOON

This phase takes the student into the upper reaches of the earth's atmosphere and examines some of the characteristics of the ionosphere, a strange region that acts as a reflector of electromagnetic waves from one part of the earth to the other. From the ionosphere, the chapter advances to the magnetosphere and considers the structure and composition of the Van Allen radiation belts. The last half of the chapter deals with the surface characteristics of the Moon, theories concerning its origin, and recent findings by the Apollo astronauts.

1. PHASE IV OBJECTIVES - Each student should:

   a. Know the chief characteristics of the ionosphere and the circumstances that led to its discovery.

   b. Understand the structure and composition of the Van Allen radiation belts (the magnetosphere).

   c. Understand the astronomical and surface characteristics of the Moon.

   d. Know some of the theories concerning the origin and history of the Moon.

2. BEHAVIORAL OBJECTIVES -- Each student should be able to:

   a. Discuss the characteristics of the ionosphere and the conductive layers within the ionosphere.

   b. Explain the hazards to manned vehicles orbiting within or across the Van Allen radiation belts.

   c. Describe the surface and astronomical features of the Moon, giving special attention to recent discoveries by manned and unmanned spacecraft.

   d. Compare various theories concerning the origin of the Moon,

3. SUGGESTED OUTLINE:

   a. Discovery of the ionosphere

      (1) Guglielmo Marconi's radio experiments

      (2) A. E. Kennelly and Oliver Heaviside's theories

      (3) Discovery of reflecting layers in the ionosphere

b. Characteristics of the ionosphere

(1) Ionospheric activities

(2) Ionized atoms and their causes

c. Outer zones of radiation (the Van Allen radiation belts)

(1) Causes and behavior

(2) Structure and nature

d. Astronomical characteristics of the Moon

(1) Orbital behavior

(2) Mass and gravitation

(3) Celestial mechanics

e. Surface characteristics of the Moon

(1) Absence of atmosphere

(2) Lunar topography

(3) Moon dust

f. Origin and history of the Moon

(1) Evidence of age

(2) Moon-separation theory

(3) Hot gas theory

(4) Accretion theories

(5) Orbital capture theories

4. ORIENTATION:

a. This phase begins with a discussion of the upper atmosphere, which ranges in height from 60 to 600 miles above the earth's surface and marks the fringes of space. This area includes both the ionosphere and the magnetosphere. Our purpose in discussing these two zones is to describe the activities of magnetic forces which surround the earth and to point out the nature of the radiation hazard presented by the Van Allen belts to space travelers. From this point, the student continues his journey through cislunar space to the Moon, an earth satellite smaller than the planet Mercury. Since the Moon has many characteristics similar to the planets, scientists believe that studies of these characteristics will yield valuable information about the origin of the entire solar system and, even possibly, the universe. You should make every effort to explain to your students the importance of lunar studies both in terms of future planetary exploration and the increased scientific knowledge about the universe that may result from these studies.

5. SUGGESTED KEY POINTS:

a. Discovery of the ionosphere, a zone of electrically-conductive layers in the upper atmosphere, came as a result of Guglielmo Marconi's invention of the radio and his broadcast of a radio message across the Atlantic Ocean. Prior to Marconi's feat, scientists believed that electromagnetic waves could not be transmitted beyond the curve of the earth. An American and a British physicist, A. E. Kennelly and Oliver Heaviside, advanced theories of a conductive layer in the upper atmosphere that acted as both shield and mirror to prevent the escape of of electromagnetic waves into space and to reflect them to the earth. Four separate reflecting layers have been discovered: the D layer, at 31 miles altitude; the E layer, at approximately 62 miles; and the Appleton Region, containing the F_1 and F_2 layers at 186 and 248 miles, respectively.

***(J-9023D) pp 55-56, 66, 130-131
***(J-9033) pp 401-440, 535-542
***(J-9081) pp 55-61, 101-106
** (J-9145) pp 54-72
*(J-9146) pp 174-175

b. The term ionosphere is a reference to the electrical characteristics of the zones of the upper atmosphere. These zones contain numerous ionized atoms, together with hordes of free electrons and other charged subatomic particles. The principal causes of ionization are ultra high frequency cosmic rays from the stars in outer space and ultraviolet radiation from the Sun. Sunspots, solar flares, and other disturbances on the Sun's surface produce fluctuations in the output of the Sun's rays. These fluctuations produce sudden ionospheric disturbances (SIDs) and other variations in the behavior of the ionosphere. For example, excess electrons, produced by SIDs, absorb radio waves and produce fadeouts on the sunlit side of the earth. Other influences on the behavior of the ionosphere are the normal rhythm of earth nights and days and the earth's magnetic forces.

***(J-9033) pp 401-440, 535-542
*(J-9083) pp 14-15, 83-84
**(J-9145) pp 54-72

c. Like the ionosphere, the Van Allen radiation belts are filled with charged particles, which result from interaction between radiations from the Sun and the magnetism of the earth. Because of this interaction, the particles are trapped into the Van Allen belt pattern. Within the belts, they whirl back and forth in a spiral course around the earth as they travel from points above one magnetic pole to points above the other pole. In their travel, their speeds vary from 60 to 186,000 miles per second (the speed of light).

**(J-9023J) pp 142-147
**(J-9051) pp 156-161
*(J-9083) p 88
***(J-9145) pp 16-18, 57-59, 66-67

d. The Van Allen radiation belts are shaped somewhat like inner and outer doughnuts surrounding the earth over the equator and middle latitudes. There are radiation-free zones approximately within the circles of 70° latitude north and south, corresponding to the hole in the outer doughnut. The inner doughnut begins at altitudes varying from 250 to 600 miles and extends outward to to approximately 40,000 miles. Radiation tends to be heavy and constant in the inner doughnut but varies greatly from day to day and hour to hour in the outer doughnut. The most dangerous concentration for manned spacecraft lies over the earth's equator at an altitude of approximately 1,500 miles..

**(J-9023J) pp 142 - 147
**(J-9051) pp 156 - 161
***(J-9145) pp 16-18, 57-59, 66-67

e. The Moon is an earth satellite that orbits the earth in an elliptical path at an average distance of 238,000 miles. The Moon makes its trip around the earth in 27 days, 7 hours, and 53 minutes at an average speed of 2,300 miles per hour and rotates on its axis during a similar period. Because of its elliptical orbit and variations in its speed of travel, observers at different times can see approximately 59 percent of the Moon's surface. The diameter of the Moon is slightly more than one-fourth that of the earth, 2,162 miles. Its volume is approximately 1/50 that of the earth and its mass, 1/81. The force of gravity on the Moon is only 1/6 that of the earth, meaning that a 150-pound man on the earth weighs only 25 pounds on the Moon. The earth attracts the Moon as the Moon attracts the earth, and the Moon is constantly "falling" toward the earth. However, the Moon moves forward at such a speed that it falls <u>around</u> the earth rather than <u>into</u> it (Kepler's laws of interplanetary motion and celestial mechanics).

***(J-9023D) pp 69-88
**(J-9026) Entire Book
**(J-9083) pp 101 - 117
**(J-9094) Entire Book
***(J-9113) Entire Book
**(J-9145) pp 118 - 137
***(J-9146) pp 83 - 107

f. The absence of atmosphere on the Moon affects the visibility of the Moon, its temperature, and its topography. Without the diffusion of light caused by atmosphere, mountains on the Moon appear higher and craters deeper than they actually are when observed from the earth. An astronaut's space suit must provide the proper atmospheric pressure and serve as insulation against temperature extremes, ranging above 250° F during the daytime and -250° F at night. The Moon's rugged surface features are due in part to the absence of erosion caused by wind and water, which are produced by atmosphere. The Moon's surface features a profusion of craters of all sizes, large flat areas called maria, rugged mountains, and long irregular troughs known as rilles.

**(J-9008) pp 7-10, 81-83, 96-105
*(J-9023C) pp 106 - 125
***(J-9023D) pp 69-88
***(J-9033) pp 602 - 663
**(J-9132) pp 261 - 283
***(J-9146) pp 83 - 107

g. Samples of Moon dust brought to the earth by the Apollo astronauts reveal interesting physical and chemical properties. Without air molecules between them, the dust particles cling together like damp sand and form a firm base capable of supporting several pounds per square inch. In the absence of gravity

**(J-9023D) pp 69-88
***(J-9146) pp 83 - 107

and atmosphere, the Apollo 12 landing vehicle propelled dust particles across the Moon's surface at an estimated speed of 155 miles per hour. Experiments with a core sample of sub-surface dust indicated that it had a sterilizing effect almost as strong as that of a typical mouthwash. Surface samples did not produce this effect. In other experiments, a variety of plants grew more rapidly and became healthier with the addition of Moon dust.

***(J-9033) pp 578 - 579, 636-645
**(J-9116) pp 68-73
***(J-9146) pp 86-87, 85-89, 90-93

h. There are several theories regarding the Moon's age and origin. Most samples from the Moon have an estimated age of 3.5 billion years, and one sample returned by the Apollo 12 astronauts has an estimated age of 4.6 billion years. According to the Moon-separation theory, the Moon was once a part of the earth. The earth was a spinning sphere of molten rock, and the gravitational pull of the Sun, combined with centrifugal force, caused a portion of the earth to separate and form the Moon. Various hot gas theories hold that the earth, Moon, and other planets formed from hot gaseous matter, which liquified and condensed after a collision between the Sun and another star. Another group of scientists believe that the earth, Moon, and other planets began as small chunks of matter like meteoroids and grew with the accumulation of solid particles of matter, much like snowballs. Others believe that the Moon was once a small planet traveling in its own orbit around the Sun until it wandered near the earth's force of gravity and became a satellite of the earth.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

Number of Academic Periods per Week	Recommended Number of Periods for this Phase				
	1	2	3	4	5
2		X			
3			X		
4				X	

b. The lecture-discussion method is one suggested approach to teaching this phase. This method not only enables the instructor to emphasize certain basic ideas in the text material but also requires the student to develop his own background in the subject area in order to make meaningful contributions to the class. The instructor might introduce the class with challenging questions that require more than simple repetitions of facts, such as the following: What would happen to the earth without the ionosphere? What would be the nature of an average day on the Moon? What would we as a class need to do in preparation for an excursion to the Moon?

c. It is particularly important that the instructor use as many aids as possible to illustrate the material contained in this phase. Photographs of the lunar surface, taken by Lunar Orbiter, Surveyor, and the Apollo astronauts, should help the students to understand the characteristics of the Moon's surface. (These can be obtained from the NASA information office.) In addition to photographs, charts, and other visual aids, demonstrations by the instructor or by a science teacher can help the students to understand certain underlying principles, especially those regarding the material on the ionosphere and the Van Allen radiation belts.

d. Such projects as the construction of a lunar landscape might be developed from photographs and other descriptive materials available from NASA, Hughes Aircraft Company, and other participants in lunar projects. Complete maps of the Moon's surface (front and rear) can be obtained from the Air University Library's Cartographic Section. This section also has detailed surface maps showing enlarged selected areas on the front of the Moon.

7. INSTRUCTIONAL AIDS:

a. NASA Films

(1) HQ 188 - Debrief: Apollo 8, 28 min., Color, 1969

(2) HQ 194 - Eagle Has Landed - The Flight of Apollo 11, 28 1/2 min., Color 1969

(3) ** HQa 197 - Apollo 12: Pinpoint for Science, 28 min., Color, 1969

(4) HQ 211 - Apollo 14: Mission to Fra Mauro, 28 min, Color, 1971

(5) HQ 217 - Apollo 15: In the Mountains of the Moon, Color, 1971

b. Hughes Aircraft Company

(1) Next . . . . . the Men, 17 1/2 min., Color, 1966

8. PROJECTS:

a. Develop local projects based on your students' interests.

9. FURTHER READING:

a. Alter, Dinsmore. Pictorial Guide to the Moon. New York: Thomas Y. Crowell Co. 1967.

b. Brantley, Franklyn. Explotation of the Moon. Garden City, New York: The Natural History Press. 1964.

c. Callaway, Vincent de. Atlas of the Moon. New York: St. Martin's Press. 1962.

d. Kopal, Zdenek. The Moon. New York: Academic Press Inc., Publishers. 1964.

e. Lewin, Ellis, Viele, Donald, and Eldrenkamp, Lowell. "The Lunar Orbiter Mission to the Moon," Scientific American, May 1968, pp 59-78.

f. Maisak, Lawrence. Survival on the Moon. New York: The Macmillan Co. 1966.

PLEASE NOTE ANY SUGGESTIONS FOR IMPROVEMENT OR EFFECTIVE TEACHING METHODS ON THE BLANK SHEET AT THE END OF THIS PHASE!

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTORS GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE

PHASE V -- THE WORLD OF OUTER SPACE

This chapter takes the student beyond the Moon and into the realms of interplanetary, interstellar, and intergalactic space. The subject matter may be divided roughly into three broad areas. The first area includes an examination and description of the instruments used by astronomers to study the universe. The second area is a somewhat detailed view of the solar system and some recent discoveries concerning the Sun and the planets by man-made satellites. The last area describes how scientists use interstellar and intergalactic measurements to determine distances in deep space and to study the formation of galaxies. Also included is a description of the universe beyond the Milky Way and Einstein's theory of relativity as it applies to future excursions by man in intergalactic space.

1. PHASE V OBJECTIVES -- Each student should:

   a. Be familiar with some of the most common instruments used by astronomers in their study of the space environment.

   b. Know the characteristics of the Sun and the distinguishing features of each of the nine planets in the solar system.

   c. Understand how scientists use interstellar and intergalactic distances in deep space and to study the formation of galaxies.

   d. Understand the nature of the universe beyond the Milky Way.

2. BEHAVIORAL OBJECTIVES -- Each student should be able to:

   a. Name and describe the major instruments used by astronomers to learn about the space environment.

   b. Describe the distinguishing features of the Sun and each of the nine planets.

   c. Explain interstellar and intergalactic measurements and the formation of galaxies.

   d. Describe the composition and nature of the universe beyond the Milky Way.

3. SUGGESTED OUTLINE:

   a. The instruments of astronomy

      (1) Optical telescopes

         (a) Refracting telescopes

(b) Reflecting telescopes

(2) Radio telescopes

(3) Auxiliary instruments

(a) Filters

(b) Coronagraph

(c) Spectroscopes and spectrographs

b. The solar system

(1) Sun

(2) The inner planets

(3) Asteroids

(4) The outer planets

c. Interstellar and intergalactic space

(1) Measurement of distances

(2) Galaxy formation and structure

(3) Beyond the Milky Way

(a) Magellanic clouds

(b) Island universes

(c) "Peculiar" galaxies and quasars

(d) Expanding universe

(4) The passing of time in deep space

4. ORIENTATION:

a. This final chapter on the environment of space deals with the vastness and the overall design of the universe. After reviewing the astronomer's tools, the chapter introduces the student to the basic organization and composition of the solar system. It begins with the Sun and then considers the four planets, besides the earth, nearest the Sun. It then moves farther outward in space within the 342,200,000-mile gap between the orbits of Jupiter and Mars to a group of minor planets known as the asteroids. From this point, it proceeds to the outer planets -- Jupiter, Saturn, Uranus, and Neptune. These planets and the Sun are members of the Milky Way Galaxy, a star system representing almost incomprehensible distances. But, beyond the Milky Way, however, we are only at the beginning of a journey covering billions of miles into a world of infinity. Your objective in this chapter should be to impress your students not only with the design of the universe but also with the infinite distances that confront man-made machines beyond our solar system.

5. SUGGESTED KEY POINTS:

*(J-9023c) pp 139 - 162
*(J-9023d) pp 7-51
*(J-9102) pp 27-34, 43-46
**(J-9132) pp 179 - 203
***(J-9146) pp 61-81

a. For centuries, astronomers have depended upon ground-based instruments of various kinds for knowledge of the universe. One of the oldest of the astronomer's tools is the optical telescope, first invented by Hans Lippershey. Galileo used a similar telescope to discover craters on the Moon, the rings around Saturn, and the sunspots. Isaac Newton devised the first reflecting telescope with the use of a curved mirror in the place of a lens. Two types of optical telescopes in use by astronomers are the refracting telescope and the reflecting telescope. Refracting telescopes bend or refract rays of light and cause them to come to a point of focus where an image is magnified for direct viewing. Both the curve of the lens surface and the hardness of the glass within the different lens elements affect the degree to which the light rays are bent. The two largest refracting telescopes ever built were the 36-inch telescope at the Lick Observatory in California and the 40-inch telescope at the Yerkes Observatory in Wisconsin. Reflecting telescopes usually apply one of three different types of focusing devices: the Newtonian focus, the Cassegrainian focus, and the Coudé focus. After years of tedious grinding and polishing to acquire the proper curve, the primary mirror of reflecting telescopes is coated with a microscopically thin reflecting layer of aluminum, which is brighter and less subject to tarnish than silver. The entire aluminum coating of the world's largest reflecting telescope, the Hale, weighs only one ounce.

*(J-9023c) pp 139 - 162
*(J-9023d) pp 7-51
*(J-9102) pp 27-34, 43-46
**(J-9132) pp 179 - 203
***(J-9146) pp 61-81

b. Another type of telescope used by astronomers is the radio telescope, which collects radio emissions from stars in the farthest reaches of space and brings them into focus just as optical telescopes intensify the physical images of stars. Radio emissions from deep space reveal the locations of stars and distant galaxies and even indicate electronic activity in interstellar space. Other astronomical instruments include filters for reducing the intensity of the Sun's rays, the coronagraph for blotting out the Sun's disc and making the Sun's corona visible, spectroscopes for breaking down light beams into band-shaped spectrums, and spectrographs for recording and classifying each light source.

**J-9033) pp 375 - 401
*(J-9083) pp 9-16
**(J-9116) pp 17-19, 62, 98-99
**(J-9132) pp 319-321
*(J-9145) pp 62-63
**(J-9156) pp 539 - 541

c. The solar system is composed of four types of celestial bodies: stars, planets, asteroids, and satellites (moons). The Sun is a medium-sized star that produces a relatively large amount of radiation. The steadiness of this source of energy is a particularly important feature since men and other forms of life on the earth depend upon it. The planets revolve around the Sun and all of them have a greater density than the Sun. Each of the planets have an enveloping atmospheric region. They do not produce the same amount of energy as the Sun and therefore rely upon the Sun for their energy. The asteroids are quite small in comparison with other celestial bodies. Most of the asteroids rotate in an orbit between Mars and Jupiter, and most of them have no atmosphere. The planetary satellites or moons revolve around the various planets rather than in an elliptical orbit about the Sun as the planets do. Most of these satellites are no larger than the earth's moon and, like the earth's moon, have no atmosphere.

*(J-9003) pp 56-64
**(J-9023D) pp 52-59, 89-117
***(J-9033) pp 664 - 763
**(J-9083) pp 118 - 139
**(J-9102) pp 13-21
**(J-9116) pp 90-107
***(J-9132) pp 321-333
***(J-9146) pp 109 - 177, 180-184, 193-194
***(J-9156) pp 532 - 539

d. Each planet has some unique characteristics of its own and some that resemble the other planets. (Basic resemblances of all the planets were listed in key point "a" above.) The planets may be grouped according to two principal types. The inner or terrestrial type includes Mercury, Venus, Earth, and Mars, and the outer or gas-giant type includes Jupiter, Saturn, Uranus, and Neptune. Pluto is probably an in-between type, with a solid core that may consist of frozen gases similar to those on the gas giants. As the planet nearest the Sun, Mercury probably has the highest temperature of all the planets. Venus has a heavy lemon-yellow cloud cover and is the brightest of all the planets in the evening sky. Earth's prominent land masses surrounded by bodies of water are particularly striking characteristics. Mars is a reddish brown color with telescopically visible markings called canali. Jupiter has 12 large moons and a giant red spot that drifts about in its rapidly moving gas envelope. Saturn's major distinguishing characteristic is its three thin rings encircling it. Uranus is unusual because the tilt of its axis lies almost in the plane of its orbit. Neptune has the highest content of methane gas, is greenish in color, and is the only major planet that cannot be seen without a telescope.

*(J-9003) pp 82-87
**(J-9023D) pp 60-68
***(J-9033) pp 292 - 374
*(J-9102) pp 5-6
**(J-9132) pp 286 - 303

e. The Sun is the most important member of the entire solar system. Without the Sun, there would be no source of energy to provide heat and other types of radiation to the planets. It is particularly important in this respect for the earth, since life could never have originated nor continued to exist without the Sun's energy. Every source of energy that man uses is derived from the Sun, with the exception of nuclear energy, and the Sun's influence has partly determined the composition of the planets. If the Sun's output of energy were larger or smaller, tremendous changes would occur in the composition of each planet's atmosphere, surface features, and living matter. The Sun is also important because of its gravitational attraction, which keeps each planet revolving in its special orbit. Since the Sun comprises 99.8 percent of the total mass of the solar system, it also exercises a tremendous influence on the smaller celestial bodies. Each directly or indirectly, the Sun also affects the members of the solar system in a number of other ways, such as the influence of the solar wind on earth-based life and its constant source of energy.

***(J-9023D) pp 140 - 149
*(J-9102) pp 9-10

f. Our solar system occupies only a tiny spot in the Milky Way Galaxy, and the Sun is only an average star in size and brightness, compared with millions of other stars. The Milky Way is a vast pancake-shaped disc about 100,000 light years in diameter, composed of something like 100 billion stars. It is so vast that light traveling at a speed of 670 million miles per hour requires 100,000 years to reach from rim to rim. Only in recent decades have scientists found accurate means of computing the distances and movements of stars. One of the most direct ways of determining the distance of a star is to measure its parallax, but this method is accurate to a limit of only 400 light years. Other methods are necessary for computing interstellar and intergalactic distances.

**(J-9003) pp 65-81, 76-105
***(J-9023D) pp 50, 94, 135-136, 144-145, 146-147, 152
*(J-9102) pp 7-8, 40
*(J-9146) pp 113

g. Prior to their use of parallax measurements, scientists believed that a star's magnitude determined its distance from the earth, and, by measuring its visible brightness (apparent magnitude), they could determine its distance. More recently, they discovered that stars have wide variations in their output of energy (absolute magnitude). However, they also discovered that certain classes of stars do indicate their distances according to their magnitude. One such class includes Cepheid variables, which are fluctuating stars that grow alternately dimmer and brighter in regular cycles. Another means of measuring stellar distances is to compute the speed at which stars move about in the sky, known by scientists as their proper motions. Still another means of measuring the movement of stars is to determine their speed directly toward or away from the earth according to shifts in the color spectrum, known as the "Doppler effect."

***(J-9023D) pp 140 - 149
*(J-9102) pp 9-14, 37

h. When viewed from the side, the Milky Way shows two principal populations of stars. The outer envelope, known as the galactic plane, contains a majority of the stars, vast quantities of dust and gases, and great spiral arms, which include our solar system. The Sun and the other stars in these arms follow orbits around the galactic center and form a "Population I" class of stars. The great mass of stars at the galactic nucleus constitute "Population II" stars.

Scientists refer to the huge clouds of dust and gas in the Milky Way as nebulae, and they believe that these nebulae are the remains of unstable stars. Sometime, when a star explodes, it may glow at many times its former intensity and may appear in the sky as a new star or "nova stella."

**(J-9102) pp 38-42
*(J-9116) pp 50-53
**(J-9146) pp 168 - 190

i. Despite the vast interplanetary distances within the Milky Way Galaxy, scientists now know that the Milky Way is only one among millions of other galaxies that inhabit the universe. The only two other galaxies observable with the unaided eye beyond the Milky Way are the Magellanic Clouds. At Mount Wilson Observatory in 1925, Edwin Hubble concluded that the universe contains almost as many galaxies as there are stars in the Milky Way. With even more powerful telescopes, modern astronomers believe that galaxies outnumber stars by about six to one. Hubble distinguished three classifications of families of galaxies according to their shape -- spirals, ellipticals, and irregulars. In addition to these families of galaxies, scientists have observed so-called "peculiar galaxies," some of which spin side by side, while others send forth giant flares. One of their most puzzling characteristics is that they produce radio waves millions of times more powerful than a normal spiral galaxy. Even more puzzling are quasars, tiny starlike objects in deep space that radiate more energy at radio frequencies than the most powerful galaxies.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

Number of Academic Periods per Week	Recommended Number of Periods for this Phase				
	1	2	3	4	5
2		X			
3			X		
4				X	

b. The lecture-discussion method, combined with the use of a guest speaker or lecturer, is a good approach to teaching this phase. Since this phase is an extension of the points developed in Phase I, the instructor will probably find it appropriate to use the same teaching approaches suggested for the first chapter.

c. A field trip to the planetarium would be an excellent way to stimulate interest in this block of instruction.

7. INSTRUCTIONAL AIDS:

a. NASA Films

(1) HQ 163 - View of the Sky, 28 min., Color, 1967

(2) HQ 164 - Universe on a Scratch Pad, 28 min., B&W, 1967

b. SLIDES:

(1) S-41 - Military Space Environment

8. PROJECTS:

a. Develop local projects based on your students' interests.

9. FURTHER READING:

a. Bergaust, Erik. Mars: Planet for Conquest. New York: G. P. Putnam's Sons, 1967.

b. Brantley, Franklyn M. The Nine Planets. New York: Thomas Y. Crowell Co., 1966.

c. Chamberlain, Joseph M. and Nicholson, Thomas D. Planets, Stars and Space. Mankato, Minn.: Creative Educational Society, 1967.

d. Fanning, A. E. Planets, Stars, and Galaxies. New York: Dover Publications, Inc., 1966.

e. Hoyle, Fred. The Nature of the Universe. New York: The New American Library of World Literature, Inc., 1960.

f. Moffat, Samuel and Shneour, Elie. Life Beyond the Earth. New York: Scholastic Book Services, 1965.

g. Motz, Lloyd. This is Outer Space. New York: The New American Library of World Literature, Inc., 1962.

PLEASE NOTE ANY SUGGESTIONS FOR IMPROVEMENT OR EFFECTIVE TEACHING METHODS ON THE BLANK SHEET AT THE END OF THIS PHASE!

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTORS GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE

PLEASE COMPILE THE COMMENTS FOR EACH PHASE AND FORWARD TO AFROTC/EDH, MAXWELL AFB, ALABAMA 36112. THESE WILL BE USED FOR FUTURE REVISIONS. (IF TIME IS CRITICAL, PLEASE REMOVE THE INDIVIDUAL PHASE COMMENT SHEETS AND FORWARD THOSE).