DOCUMENT RESUME

ED 111 630 SE 017 467

TITLE The Aerospace Age. Aerospace Education I. Instructional Unit II.
INSTITUTION Air Univ., Maxwell AFB, Ala. Junior Reserve Office Training Corps.
PUB DATE [71]
NOTE 73p.; For the accompanying textbook, see ED 068 286

EDRS PRICE MF-$0.76 HC-$3.32 Plus Postage
DESCRIPTORS *Aerospace Education; *Aerospace Technology; Course Organization; Curriculum Guides; Development; History; *Instructional Materials; Resource Materials; *Science History; Secondary Education; Teaching Guides; Unit Plan
IDENTIFIERS *Air Force Junior ROTC

ABSTRACT

This curriculum guide is prepared for the textbook entitled "The Aerospace Age," published in the Aerospace Education I series. The guide is organized by objectives, behavioral objectives, textbook outline, orientation, suggested key points, suggestions for teaching, instructional aids, projects, and further reading. Major points stressed in the textbook are briefly explained in the guide. Some background information is also included on each chapter. Page references corresponding to the textbook are given. (PS)

ED111630

INSTRUCTIONAL UNIT II

THE AEROSPACE AGE

INSTRUCTIONAL UNIT OBJECTIVES - Each student should:

a. Understand the technological achievements symbolized by the modern aerospace environment.

b. Be familiar with man's early attempts to fly.

c. Know the developmental sequence of the major technical events that led to the Aerospace Age.

d. Be familiar with possible future developments in aerospace.

PHASES IN INSTRUCTIONAL UNIT II:

I. AN INTRODUCTION

II. AN AGE-OLD DREAM

III. WINGED FLIGHT: A REALITY

IV. AVIATION COMES OF AGE

V. THE AEROSPACE THRESHOLD

VI. THE MODERN AGE

SE 017 467

THE AEROSPACE AGE

PHASE I - AN INTRODUCTION

This section presents a brief overview of the modern Aerospace Age and the impact of rapid technological change on modern transportation systems. It shows how, in a relatively short period, man not only gained mastery of the air with winged aircraft but also developed space vehicles that took him to the moon. It discusses some of the latest developments in winged flight and space exploration.

1. PHASE I OBJECTIVES - Each student should:

   a. Understand how powered flight revolutionized man's transportation systems.

   b. Be familiar with major achievements in winged flight since the late 1950s.

   c. Know some of man's achievements in the space environment.

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

   a. Give two examples why the airplane is the most revolutionary transportation medium in man's history.

   b. Identify three significant technological improvements represented by military and commercial aircraft currently in operation.

   c. Cite specific engineering accomplishments that make the US manned space program the high point of aerospace technology.

3. TEXTBOOK OUTLINE:

   a. The impact of aviation on transportation systems.
   b. Comparison of modern aircraft with the Wright Flyer.
   c. Major advances in aviation since the late 1950s.
      (1) C-133 Cargomaster
      (2) C-5 Galaxy
      (3) F-111A
      (4) Boeing 747
      (5) Other modern aircraft

d. Beginning of the Space Age
   (1) Sputnik I and II
   (2) Explorer I
e. Manned space program
   (1) Significance of manned spaceflight
   (2) The first manned spaceflights
   (3) Project Gemini
   (4) Project Apollo

4. ORIENTATION:

a. The purpose of this first learning phase is to set the stage for studying the technical evolution of powered flight. Major emphasis in this phase focuses on the airplane as the symbol of rapid technological progress during the twentieth century. For thousands of years, man could transport himself only on the surface of the earth at average speeds no greater than 35 to 40 miles per hour. And then, with the discovery of powered flight in the early twentieth century, he not only surmounted physical barriers that had restricted his movements but also increased his capacity to move at speeds greater than 4,000 miles per hour in winged aircraft and up to 25,000 miles per hour in manned spacecraft. Of even greater significance is the fact that he achieved these speeds in an unbelievably short period of slightly more than 60 years. This means that modern man lives in a period when rapid and profound change is the rule rather than the exception.

b. You probably will find it worthwhile in this phase to use the text material as a vehicle for developing an awareness and interest on the part of your students concerning the modern technological environment. Air and space travel has become so common within the past 10 or 15 years that the young man of today may tend to take it for granted. The machines comprising the modern aerospace environment represent fantastic technological achievements. But the evolution of human flight from the days when man could only gaze at birds and dream of flying to the modern age when he journeyed to the moon is itself a fantastic story of human ingenuity and resourcefulness that only the airplane can tell.

5. SUGGESTED KEY POINTS:

(J-5) pp 1-9**
(J-12) pp 11-78, 113-189*
(J-148) pp 13-29*

a. During a period of roughly a half million years, man lived at the bottom of a vast ocean of air and had no other use for it except to breathe. Even after he improved his mobility with mechanical conveyances, he was limited for about 50,000 years to surface movement at speeds no greater than 35 miles per hour. Suddenly, in the span of about three-fourths of a century, he became able to move unrestricted over surface barriers at fantastic speeds. When the Wright brothers introduced the Aerospace Age in 1903, they not only provided man with an almost unlimited medium for reaching the most remote spots on the earth's surface and, ultimately, the moon. They also ushered in a period of bursting technology and rapid change that continues unabated even as this is written.

(J-1) Part 1, pp 2-54**
(J-5) pp 1-9*
(J-24) pp 293-346**
(J-25) pp 12-158**
(J-49) pp 26-48***

b. It took less than 100 years for the airplane to advance from the design of the Wright Flyer to the numerous designs that comprise the modern aerospace environment. The most rapid advances have occurred during the past two decades. An Air Force C-133 Cargomaster made a record-setting flight in 1958 by carrying 117,000 pounds of cargo to an altitude of 10,000 feet. Just 10 years later, the C-5 Galaxy became operational with the capacity to carry 265,000 pounds of cargo for distances of 2,700 nautical miles. In 1954, the Boeing 707 commercial jet revolutionized air-passenger transportation with its speed, safety, and comfort, but, in 1968, this airliner faded into the background when the Boeing 747 jumbo jet took to the air as the world's largest and fastest airliner to fly below the speed of sound. The same period saw the flights of supersonic bombers and fighters capable of speeds greater than three times the speed of sound. The Soviet Union launched the world's first supersonic airliner capable of carrying 120 passengers at a speed of 1,550 miles per hour. Numerous other modern aircraft, such as one-man helicopters, two-passenger private planes, 25-passenger airliners, and others, have distinguishing features that make them adaptable for almost any type of travel.

(J-1) Part 6, pp 4-65**
(J-5) pp 138-147*
(J-25) pp 160-249**
(J-28A, B, C, D, E, F, G, H- 8 Vols.)***
<u>Aeroscience</u>, pp 558-602***
(J-105) pp 30-77**
(J-145) pp 144-194**

c. As miraculous as were the advances made by the airplane in the past 10 or so years, some of the most electrifying developments in the technology of flight came with the launching of Sputnik I and the Space Age in 1957. Quickly on the heels of the Sputniks in 1958, the United States launched its first orbiting satellite, Explorer I, and, in slightly over 10 years, placed more than 240 space vehicles in orbit. The most dramatic achievements came with the Apollo flights when man demonstrated that he could design a machine that would carry him to the moon across 233,000 miles of space at speeds as high as 25,000 miles per hour. In little more than a decade, he advanced from the technology of Explorer I, a tiny satellite the size of a grapefruit, to the technology of Apollo, a towering giant 36 stories high weighing millions of pounds. With its Saturn 5 booster and 3.5 million parts, the Apollo is the capstone of engineering and manufacturing achievements in the twentieth century. In addition to the engineering complexities of the Apollo spacecraft, the ground facilities necessary to support the Apollo stagger the imagination with their enormous size. Various stages of the spacecraft are mounted on a launch platform the size of a baseball diamond inside a building 50 stories high. To transport the spacecraft to the launch site three and one-half miles away, a giant caterpillar with tracks 10 feet high and 40 feet long moved with the spacecraft, a launch tower, and the platform over a road wider than an eight-lane freeway.

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. Although the needs and capabilities of your students will vary from group to group, you will probably want to use the initial phase of this instructional unit to stimulate interest in the modern aerospace environment. You should not consider interest in the modern environment as an end in itself, however. In your discussion of air and space travel, you should find the proper moment to direct the students' attention to the evolution of aerospace vehicles with such questions as, "How did we reach this point in aviation technology? How many of you know when the age of the airplane began?" or "What basic principles had to be applied before the first man-made machine became airborne?"

c. One approach to this instructional unit might begin with a discussion of the role played by various forms of surface transportation at different stages in the development of civilized society. As different modes of transportation are discussed, you might list them on the chalkboard, beginning with the crudest and progressing to the more advanced forms, such as steam locomotive, the automobile, and the ocean liner. After developing a complete list, you might ask what common restriction limited each of these modes? Opposite the list of surface transportation media, you might write the word, airplane, and discuss with the class the third dimension provided by the airplane to man's ability to move from place to place. The discussion might then advance to the advantage of speed which the airplane provides and the impact of rapid increases in speed on human relationships.

d. Another approach might be to ask how many of your students have traveled on a modern commercial airliner or have observed missiles or spacecraft in flight. If you have pictures or slides of modern commercial and military aircraft, you might ask your students to identify them by name and give some significant bit of information about each. This will give you an opportunity to conduct an informal discussion of modern aircraft and air travel as compared with early aircraft and other modes of transportation.

e. After you have introduced this instructional phase, you might find it desirable to invite a guest speaker from a nearby Air Force base or from a local aerospace industry. This person should be sufficiently informed to discuss with your students some of the most significant developments in aerospace in recent years. At the same time, he should be able to provide interesting comparisons of modern aerospace vehicles with early aircraft and other early modes of transportation. Primary attention should be directed to the impact of aerospace on man's transportation systems. Since your first concern is to acquaint the student with the modern aerospace environment and stimulate his interest in the progress of aviation, you should request the speaker to concentrate on the major achievements of the modern age and the changes which these achievements have brought.

f. In preparing for this instructional phase, your students, of course, should read and study the text material on the appropriate pages in the textbook, and this material can be assigned as a written exercise or used as points of discussion to emphasize your teaching objectives with the class.

7. INSTRUCTIONAL AIDS:

If you have access to pictures, models, films, or slides of early aircraft and modern aerospacecraft, you might use them as motivational devices. You should be careful, however, to use them in the comparative sense; that is, to show how rapidly man has advanced in his ability to transport himself.

a. FILMS:

(1) SFP 501, Air Power--The Early Days, 26 min., B&W, 1957.

(2) SFP 1534, It's Everybody's Business, 22 min., Color, 1953.

(3) SFP 1240, From Kitty Hawk to Aerospace, 21 min., Color, 1965.

b. SLIDES:

CAP-1 The Challenge of the Aerospace Age.

8. PROJECTS:

A field trip to a modern airport or Air Force base might be used to reinforce your discussion of the modern aerospace environment. If you are located near a museum, you may find replicas or models of early aircraft for comparison with modern aerospace achievements.

9. FURTHER READING:

a. Becker, Beril. Dreams and Realities of the Conquest of the Skies. West Hanover, Massachusetts: Halliday Lithograph Corporation, 1967.

b. Cook, Alfred D. (ed.) Where Do We Go From the Moon? New York: Fairchild Publications, Inc., 1967.

c. Gibbs-Smith, Charles H. The Aeroplane. (A Historical Survey of Its Origins and Development). London: Her Majesty's Stationary Office, 1960.

d. Miller, Ronald and Sawers, David. The Technical Development of Modern Aviation. London: Routledge and Kegan Paul, 1968.

e. NASA. Significant Achievements in Space Applications, 1965. Washington, D. C.: Office of Technical Utilization, NASA, 1966.

f. Space: The New Frontier. Washington, D. C.: Superintendent of Documents, US Government Printing Office, 1967.

g. Von Braun, Wernher. History of Rocketry and Space Travel. New York: Thomas Y. Crowell Company, 1966.

PHASE II - AN AGE-OLD DREAM

This section contains a review of ancient legends of flight and man's earliest attempts to fly by imitating the flight of birds. It traces the evolution of lighter-than-air flight from the first free-floating balloons of the Montgolfier brothers to the controlled flights of giant dirigibles that carried man on his first scheduled passenger flights. This learning phase introduces the student to some of the pioneers in lighter-than-air flight and describes the airship designs that enabled them to achieve man's age-old dream.

1. PHASE I OBJECTIVES - Each student should:

   a. Know some of the ancient expressions of man's undying urge to fly.

   b. Understand the theory of lighter-than-air flight.

   c. Know the significant events in lighter-than-air flight that encouraged men to pursue their desire to fly.

   d. Know some of the contributions of early pioneers to the evolution of controlled flight.

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

   a. State two ideas that indicate that civilized man dreamed of flying for thousands of years before he discovered the secret of powered flight.

   b. Explain the theory underlying lighter-than-air flight.

   c. Trace the events and observations which convinced early experimenters that human flight was possible.

   d. Identify the technical contributions of six men to the evolution of the rigid airship and controlled lighter-than-air flight.

3. TEXTBOOK OUTLINE:

   a. Early myths and legends of flight

b. Tower jumpers and wing flappers
c. The first practical flights
   (1) Montgolfiers' hot-air balloon
   (2) Charles' hydrogen balloon
   (3) Crossing of the English Channel by Jeffries and Blanchard
   (4) The first live parachute drop
   (5) Experimental balloons
   (6) Military uses of balloons
d. Features that improved balloon flight
   (1) Meusnier's ellipsoidal balloon and his design for sustained flight
   (2) Giffard's controlled balloon
   (3) Engine development--Hanlein, Renard, Krebs, and Schwarz
e. Nonrigid and rigid dirigibles
   (1) Forerunners of the dirigible
   (2) Santos-Dumont's nonrigid airship
   (3) Zeppelin's rigid dirigibles
   (4) The decline of buoyant flight

4. ORIENTATION:

a. Your discussion of the modern aerospace environment in Phase I should serve as the springboard for a backward look at the events which led to the creation of this environment. Phase II is an important section of this instructional unit because, in this phase, you must shift your teaching techniques from the modern age to the ancient age when men only dreamed of flying. Emphasis in this phase should center on the fact that, although man always had the resources necessary for flight at his disposal, he tried for centuries without success to fly simply by imitating the flight of birds. Not until less than 200 years ago did he achieve his first sustained flight--and then only with the aid of lighter-than-air craft. You should use the early accounts of man's interest in flying to show how, through trial and error, a few courageous adventurers began to uncover the secrets of human flight.

b. Beginning with the Archimedian principle of specific gravity, you should show how the discovery and application of scientific principles enabled man to make his first flights in lighter-than-air craft.

Although the Montgolfier and Charles balloons and the Zeppelin dirigibles at first seemed to point in the direction of controlled flight in winged aircraft, they were not the final answer in man's search for a practical flying machine. They only stimulated further interest in flying to the point that man directed his efforts to heavier-than-air flight. Although this phase stresses early achievements in lighter-than-air flight, you should observe that such men as Leonardo da Vinci and others also pointed the way to the creation of the airplane through their experiments with gliders and ornithopters.

5. SUGGESTED KEY POINTS:

(J-2) pp 1, 4*
(J-5) pp 11-12*
(J-14) pp 10-37, 40-44, 47-49***
(J-17) pp 13-22*
(J-24) pp 9-10*
(Aeroscience) pp 625-630**
(J-140) pp 320-323**

a. Although the early legends of human flight and the activities of the tower jumpers are interesting narratives, their primary importance in this unit is the evidence which they present concerning man's age-old desire to fly. Despite centuries of superstition, disappointment, and misplaced experimentation, this desire led to a knowledge of scientific principles and theories which man had to acquire as a prerequisite for practical flight. Da Vinci's experiments, Archimedes' theory of specific gravity, and the Montgolfier balloons were necessary preludes to practical human flight. Archimedes proposed a theory that he could not apply, but the Montgolfier brothers capitalized on his idea with the first flight of a man-made balloon. After observing that smoke rises into the air under its own power, they found a way to collect this "hot air" in a simple bag or balloon which also would rise into the atmosphere. Their success with the flight of hot-air balloons renewed and reinforced man's interest in the possibility of flying.

b. Following the Montgolfier flights, a number of significant developments occurred in balloon design and flight.

(J-2) pp 4-8*
(J-14) pp 40-44, 51-55, 64-65, 74-76***
(Aeroscience) pp 630-637**

(1) J. A. C. Charles designed a manned hydrogen balloon that remained airborne for as long as two hours and traveled greater distances with only a minimum of effort from the crew. Charles could control his balloon by throwing sand ballast overboard or by releasing hydrogen to increase or decrease his altitude. The first intercontinental flight of a man-made balloon came with the crossing of the English Channel from Great Britain to France by Dr. Jeffries and Pierre Blanchard.

(2) Charles Green inflated a giant balloon of 85,000 cubic feet with coal gas and used a trailing guide rope as a kind of automatic ballast to regulate lift and warn of rising terrain. The largest balloon of the period, Le Geant, carried a large two-story car with a capacity for 13 passengers. An American, John Wise, invented a ripping panel for rapid deflation after landing, and a French aeronaut, Andre-Jacques Garnerin, made the first live parachute drop from a balloon flying at an altitude of more than 3,000 feet.

(3) In addition to exhibition flights, a number of men began using balloons for the conduct of scientific experiments. Professor Charles studied air temperature and barometric pressure at various heights, and Jeffries and Blanchard carried meteorological instruments on their flight. On one flight, a British scientist, James Glaisher, lost consciousness at an altitude of 25,000 feet. When he recovered 13 minutes later, he estimated that he had reached an altitude of 37,000 feet, the highest that man had ever risen into the atmosphere.

(4) Balloons played a variety of military roles, beginning in the mid-1800s and continuing through World War II. In 1849, they were used as bomb-carrying devices for the first time. During the Civil War, the Franco-Prussian War, and the two world wars, balloons were used extensively for observation and reconnaissance.

(J-2) p 8*
(J-14) pp 45, 60-69***
(J-17) p 22*
(J-24) p 10*
(J-140) pp 323-324*

c. Two Frenchmen, Jean Meusnier and Henri Giffard, made important contributions to balloon technology. Meusnier took the first step toward the streamlined dirigible with his design for an ellipsoidal balloon to reduce air resistance. For sustained flight, he also proposed compartmentalizing the gasbag with several cells, some containing hydrogen and others air which could be pumped in or out as necessary. This design would maintain the rigidity of the balloon at different altitudes even though the hydrogen gas might expand or contract. Giffard improved Meusnier's design with the addition of a steam propulsion unit which enabled him to steer his balloon at a speed of 5 miles per hour for a distance of 17 miles. Giffard's balloon was a direct forerunner of the dirigible, an airship that could be directed, controlled, and steered from takeoff to landing.

(J-14) pp 45, 67-77***

d. Further advances in balloon technology came almost 100 years after Meusnier and Giffard when a German engineer, Paul Hanlein, replaced Giffard's steam engine with a light-weight gasoline engine, the first known internal combustion engine used in an airship. Hanlein's engine generated 3.6 horsepower and achieved an airspeed of 10 miles per hour. Two other Frenchmen, C. Renard and A. C. Krebs, operated their airship, La France, with a 9-horsepower electric motor, and, although the weight of its batteries limited sustained flight, it propelled La France through the air at speeds of 14 miles per hour. David Schwarz developed the first rigid airship when he covered a balloon envelope with sheet aluminum secured to a tubular aluminum frame. He equipped his airship with a 12-horsepower gasoline motor that drove two aluminum propellers. Schwarz reached a speed of 16 miles per hour, but his engine, like other engines of the day, generated insufficient power for its weight and size.

(J-2) pp 8-9**
(J-14) pp 45, 70-71, 124-125, 136-137, 170-171***
(J-17) pp 22-23*
(J-24) p 26*
(Aeroscience) pp 637-640, 675-677, 701-702, 711-712***

e. As a practical flying machine, the dirigible made its most noteworthy advances with the contributions of Alberto Santos-Dumont and Count Ferdinand von Zeppelin. Although von Zeppelin perfected the dirigible for public use, Santos-Dumont introduced the era of the powered gas bag with a nonrigid airship 82 feet long, driven by a 3-horsepower gasoline motor. He became the idol of Paris in 1901 when he piloted a blimp driven by a 12-horsepower motor a distance of nine miles from St. Cloud around the Eiffel Tower. Zeppelin introduced one of the most significant innovations with the development of the rigid airship known as the dirigible. One of the most successful rigid dirigibles was the Graf Zeppelin, equipped with five 530-horsepower engines which drove the airship at a top speed of 80 miles per hour. It established a world airship record, unbroken to this day, for a distance in a straight line without landing when it made a return trip from Lakehurst, New Jersey, to Friedrichshafen, Germany, in three days. The world's largest dirigible was the Hindenburg, 803 feet long and 135 feet in diameter. After making a transatlantic crossing with 97 passengers in 1937, it burst into flames while approaching its moorage at Lakehurst, New Jersey. The destruction of the Hindenburg brought an end to the era of passenger-carrying dirigibles.

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. In general, you should avoid teaching this phase strictly as a history of aviation in the sense that you focus your instruction on a simple recitation of historical facts and events. Certainly, you should keep the sequence of events in the evolution of powered flight in their proper perspective, but you should also develop the hows and whys of each event as it contributed to man's ability to fly. Your purpose, of course, is not to make historians of your students, but you should make them aware that history, particularly the technical history of the airplane, provides the basis for understanding some of the technical achievements of the modern age. The what, where, when, and why of an event in the growth of aviation, for example, can save much time and effort. One way to prove this point is to present a problem such as the following: "Observe smoke and pieces of ash rising from a pile of burning leaves. Based on this phenomenon alone, describe how to devise a machine that will take advantage of the principles under consideration." After presenting this clue, you might ask the students to describe how they would make this machine, what materials are needed, and how the machine will work. You could assign a student to act as a recorder at the chalkboard while you and the class discuss the problem. Some main headings which the recorder might list are: steps in making this machine, a materials list, and operation and control of the machine. After the students have designed what appears to be a workable model, you might be able to obtain some materials and permit them to implement their project ideas. Throughout the discussion of this problem, you should keep the class focussed on the text material by periodically referring to the development of the balloon by the Montgolfier brothers. An alternate approach might be to propose this problem near the end of the class period. A listing similar to that developed above on the chalkboard can be partially prepared. You can then ask the students to think over the problem as they read their assignment about the early history of ballooning. During class the next day, you can complete the discussion and then conduct the experiment listed below under "Projects" or design one of your own.

c. Another effective teaching approach is to lead your students from something which they already know to something unfamiliar or unknown to them. For example, you might ask how many of your students have ever seen a rigid dirigible or have ever taken a ride on a blimp such as those often seen at football games or parades. Then you might follow the discussion of this question with such questions as, "What do you think early balloons looked like?" "Have you ever considered why men wanted to fly?" or "What steps would I take to construct a machine that will fly?" Such questions as these might lead to a problem-solving discussion which, in reality, will be an examination of basic ideas and events in the evolution of human flight. You could then point out to your students that, in the process of answering the questions, they have been playing limited roles as historians in their search for information concerning the who, what, where, wher, how, and why of man's early experiments in flying.

d. Interest generated by the above discussion might be channeled into student research projects or brief oral reports on a particular problem or area of interest. Again, the students would serve in the role of historians probing and analyzing the background of various events in the evolution of flight. Possible research projects might deal with such projects as the following: (1) Early balloonists who increased interest in aviation in the United States; (2) Various types of military operations conducted by balloons; (3) Results of some early attempts to add power plants to balloons; (4) More detailed reports on the text material stories of men and events and their contributions to advancing aeronautics.

e. As preparation for this learning phase, the students should read and study the appropriate pages of the text. You might use the textbook questions as written assignments or as starting points for class discussion. You should not feel that you are required to assign these questions for written answers or that the questions are the only questions available to support this unit. Above all, you should not consider these questions as adequate testing devices to evaluate student accomplishment.

7. INSTRUCTIONAL AIDS:

Bring to class any pictures, models, or even stuffed birds that will help the student relate the apparent simplicity of bird or insect flight to man's difficulties in learning to fly.

8. PROJECTS:

A project involving the construction of a medium-size hot-air balloon to support the material in this learning phase is described on pages 252-254 of Introduction to Aerospace Education by Strickler, Mervin L. (J-148).

9. FURTHER READING:

a. Air Force ROTC, Air University. History of the USAF. Maxwell AFB: Air University, 1965.

b. Haydon, F. Stansbury. Aeronautics of the Union and Confederate Armies, Vol 1. Baltimore: Johns Hopkins Press, 1941.

c. Morgan, Len. "The Day the Balloon Went Up." Air Force, 37:12, December 1954, pp 71-79.

d. Parkinson, Russel J. "United States Signal Corps Balloons, 1871-1902." Military Affairs. Spring-Winter 1960-61, pp 189-202.

e. Shaw, Russell B. "Ballooning and Its History." National Aeronautic Association Review, 3:3, March 1925, pp 34-36.

f. USAF Historical Division. The United States Army Air Arm (April 1861 to April 1917). Maxwell AFB: USAF Historical Division. 1958, pp 1-19.

PHASE III - WINGED FLIGHT - A REALITY

This learning phase shows how the powered aircraft emerged from glider experiments to become a reliable mode of transportation. It first discusses the basic principles of heavier-than-air flight and then traces the development of gliders and the aerodynamic innovations that led to controlled flight. In this phase, you have the opportunity to appeal to the imagination and skill of your students in the construction of models based on early aircraft design. In addition to studying the technical evolution of the airplane from the Wright brothers' Flyer through World War I, you can explore in broad terms with your students the forces of lift and drag, other important elements of flight, and the function of the major components of an aircraft.

1. PHASE III OBJECTIVES - Each student should:

a. Know how the application of the principles of flight to gliders contributed to the development of powered flight.

b. Know some of the attempts of early pioneers to overcome design deficiencies by adding major components to the basic aircraft.

c. Be familiar with how the elementary principles of flight determined the functional design of major aircraft components.

d. Know some of the significant innovations in aircraft design contributed by American and European air enthusiasts from the first flights of the Wright brothers through World War I.

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

a. Tell how the application of three principles of flight in glider experiments contributed to the development of powered aircraft.

b. List the sequence of events that led to the development of four major structural components of early powered aircraft.

c. Identify three elementary principles of flight that determined the functional design of major aircraft components.

d. Describe major changes that occurred in aircraft design just prior to World War I and during the war.

3. TEXTBOOK OUTLINE:

a. Early developments in heavier-than-air flight influenced by the flight of birds.
   (1) Basic theories related to heavier-than-air flight.
   (2) Contributions of early air pioneers, such as Cayley, Lilienthal, Montgomery, Chanute, and others.
b. Aviation developments influenced by the design of kites.
   (1) The fixed-wing glider.
   (2) Powered flight.
c. Efforts to create stability in flight.
   (1) Partial yaw and pitch control in Cayley's glider.
   (2) The experiments of Henson, Stringfellow, Wenham, and Penaud.
   (3) Lilienthal's fixed tailplane control device.
   (4) Chanute's design for inherent stability in the biplane glider.
   (5) Wright brothers' inherently unstable designs with devices to control aircraft flight.
d. Addition of power to fixed-wing aircraft.
   (1) Early attempts by Ader, Maxim, and Langley.
   (2) The Wright brothers.
      (a) Glider control by "wing warping."
      (b) Three early glider designs.
      (c) Motor and propeller design.
      (d) The first power controlled flights of Flyer No. 1 and Flyer No. 2.
      (e) Flyer No. 3--the world's first practical powered airplane.
   (3) European contributions to powered flight.
e. The early growth of aviation.
   (1) Award of first Government contract for aircraft construction--Samuel P. Langley.
   (2) Award of Government contract to the Wright brothers.

(3) Lilienthal's fixed tailplane control device.
(4) Movable control surfaces.
(5) Shock absorption.
(6) Increased speed and climbing ability.
(7) The synchronized machine gun.
(8) Improved engine power.
(9) The all-metal monoplane with cantilevered wing.
(10) Advant of multiengine airplanes.

4. ORIENTATION

a. A basic question to be answered in this unit is: How did man's achievement of controlled flight lead to the first practical powered airplane? In terms of the technical evolution of the airplane, this is an extension of the theme developed in the previous learning unit.

b. Many of the early pioneers in aviation attempted to build a controllable flying machine, but only a few succeeded. Those who achieved partial control of their craft added only scant information for others to use in their attempts to build a more efficient airplane. Significant advances in aviation did not occur until the Wright brothers reexamined some of the old theories of flight through their own system of laboratory and model testing. One of their most significant contributions to aviation was their design for an inherently unstable glider that could be controlled only by a skilled pilot. Their subsequent addition of a power source was perhaps less difficult than the problem of learning how to control a machine in flight.

c. Only a few years after the initial flights of the Wright brothers, aviation activities increased both in Europe and in the United States, and air enthusiasts experimented with a number of airplane designs. In addition to the achievements of the Wright brothers, this learning phase includes some of the highlights in the evolution of the airplane from the Wright brothers' Flyer through World War I. Major emphasis is given to changes in the design of the airplane during the years prior to World War I and to the impact of war on aircraft design.

5. SUGGESTED KEY POINTS:

**(J-2) pp 1-3
***(J-14) pp 11-13, 16-27, 32-36, 82-83, 97-101
**(J-17) pp 13-28
*(Aeroscience) pp 640
*(J-157) pp 9-10

a. One of man's first lessons in learning to fly was that he required more equipment than simple birdlike wings. Some of the early would-be aviators designed wings similar to those of birds and attempted to imitate the flapping motion of birds in flight. Few seemed to realize that birds not only flap their wings but also hold them in a fixed position to glide. Later studies revealed that the outer primary feathers on birds' wings act as small propellers when birds move their wings up and down. (See ** p 2, J-2.) Also, when gliding, birds control the shape of their wings to provide lift on takeoff and in flight and to brake their speed in landing. Man achieved heavier-than-air flight only when he applied certain basic aeronautical principles to his glider designs.

*(J-2) p 10
*(J-5) pp 11-12
***(J-14) pp 80-81, 88-89, 110
**(Aeroscience) p 641
***(J-122) pp 1-13
**(J-157) pp 10-11

b. Another route to human flight came by way of the kite which, in many respects, proved to be more successful than mere imitations of birds in flight. As early as the seventeenth century, the Chinese used kites to lift men for aerial reconnaissance, and George Cayley used the kite in one of his early glider designs. This glider used a diamond-shaped kite as a wing mounted on a long stick (the fuselage) with a tail assembly attached to a swivel joint at the opposite end. Cayley's important contribution to aviation was his modern airplane design, consisting of fixed wings, fuselage, tail unit of elevator and rudder, and an independent propulsion system.

c. Otto Lilienthal took another step toward controlled flight with his tailplane device. He achieved control of his

*(J-2) pp 11-12
**(J-14) pp 83, 103
*(J-17) pp 23-24
*(Aeroscience) pp 643-644
***(J-122) pp 23-26
**(J-157) pp 12-13

first gliders by swinging his body from the center section of the wing framework. With his forearms in armlets attached to this framework, he could move his body in different directions and shift the center of gravity as necessary to maintain control and stability. Just prior to his death in a glider accident, Lilienthal had designed a glider with a body-harness type of elevator control. By means of a headband which connected him with the tailplane, he could lower his chin and cause the glider to rise or lift his chin and cause the craft to descend. Lilienthal's technical writings on aviation and photographs of his glider flights provided convincing proof to other advocates of winged flight that the air would support fixed-wing flight, with or without engine power.

*(J-2) p 12
**(J-14) pp 83-84 102-103, 113-115, 119
*(Aeroscience) pp 642-643
***(J-122) pp 28-30 54-59
*(J-157) p 13

d. The next forward steps in the evolution of the airplane came with the experiments of John J. Montgomery and Octave Chanute. Although Montgomery based the design of his gliders on flapping wing flight proposed by Cayley, he introduced a new idea when he used flaps on the wing tips of his glider to restore its equilibrium during wind gusts. Chanute not only pointed the glider in the direction of powered flight but also exercised a great deal of influence on the aviation movement in both the United States (the Wrights) and Europe (Ferber, the Voisins, Farman, and others). His primary concern was the development of a glider with inherent stability by using movable wings to adjust to sudden changes in air pressure. Although he never completely achieved this goal, he created a fixed tail unit with spring attachments that acted as gust dampers. His major technical contribution to the advancement of aviation was his bridge-truss method of wing-rigging for his biplane glider. He not only offered technical advice and financial assistance to the Wright brothers but also initiated the aviation movement in Europe with illustrated lectures on the Wright brothers' achievements.

**(J-2) pp 13-15
*(J-5) pp 12-13
***(J-14) pp 84-87 106-109, 114-115, 118-125, 128-129, 152-153
**(J-17) pp 27-28 127
*(Aeroscience) pp 645-647
***(J-122) pp 13-14 20-22, 34-36, 37-50, 188-190 222-227, 304-307 344-346
***(J-157) pp 14-29

e. Following the contributions of such early pioneers as Cayley, Lilienthal, Chanute, Langley, and others, the Wright brothers exerted the most significant influence on the aviation movement when they achieved man's first sustained powered flight. They succeeded primarily because they understood that controlled flight was a prerequisite to powered flight, and they applied this idea in the development of a practical aircraft. Largely through their own efforts, they mastered both the theory and practice of aviation, airplane construction and flight control, and, what is even more amazing, created their own practical propellers and engines. Clement Ader almost achieved powered flight with a lightweight steam engine, but he was unable to develop an effective wing design or control mechanism in his airplanes. Hiram Maxim's giant biplane moved only a few feet under its own power before it broke loose from its mooring and crashed. Samuel P. Langley accepted a Government contract to build a power-driven airplane capable of carrying a man, but, in flight tests, the tailplane collapsed and the airplane crashed in the Potomac River. Even if the tailplane had remained intact, the Langley Aerodrome was too frail for controlled flight.

f. The Wright brothers claim certain specific achievements in gaining control of an airplane in flight. Their first step was to develop an inherently stable

***(J-14) pp 85-86, 114-115
***(J-122) pp 34-42 308-311, 344-346

airplane, making built-in controls unnecessary. When they discovered the process of wing warping, they held the key to three areas of control. Wing warping enabled the operator to bank the airframe without shifting his weight. But, in the process of wing warping, another problem of control occurred when their glider began to yaw. To counteract this problem, the Wrights added a rudder to the rear of the glider to be operated in conjunction with the wing warping control device. Another addition to the glider was a forward stabilizer-elevator which permitted the operator to control the pitch of the aircraft. The Wrights then built a modified glider and fitted it with an engine and propellers of their own design. Mounted in a pusher position, the propellers rotated in opposite directions to counteract torque. On their second powered test, the Wrights controlled their aircraft by using a hip saddle which enabled them to control both the wing warping and rudder devices simultaneously when they shifted the weight of their bodies to the right or to the left.

g. Although Wilbur and Orville Wright flew constantly during a period of about five years, the public and the press viewed their achievements as the work of eccentric upstarts. After much delay, they finally received a patent on their aircraft but refused to give a public demonstration without a guarantee of purchase. Finally, with Wilbur's assistance, the US Army drafted the first public specifications for an aircraft. These specifications called for an aircraft that could carry a pilot, a passenger, and fuel for a 125-mile trip, fly at least 36 miles per hour, and take off and land in any war zone without damage. In a series of flight tests at Fort Myers, Virginia, Orville Wright gave a brilliant demonstration of his new two-seater biplane in almost effortless banks, turns, circles, and figure eights. On the last day of the test series, the biplane crashed, causing the death of Lt Thomas Selfridge, the first pilot to die in the crash of a powered aircraft.

***(J-14) pp 119-157
**(Aeroscience) pp 647-652
***(J-122) pp 51-66 84-200, 210-219

h. In Europe, the prospects of achieving powered flight in a controlled airplane were almost nonexistent during the early 1900s. Most European air pioneers misunderstood the Wright concept of inherent instability and concentrated their efforts on inherent stability in their aircraft. Such men as Ferdinand Ferber, Louis Bleriot, Gabriel Voisin, Henri Farman, and others made a few short flights, but they were crude in comparison with the Wright achievements. One of the most significant developments in European aircraft design came in 1907 when Blériot began experimenting with powered monoplanes. Not until Wilbur Wright demonstrated his mastery of flight control and the improved thrust provided by geared-down propellers did the pace of aviation progress quicken in Europe. The first major contribution to European aviation in terms of distance flying came in 1909 when Bleriot crossed the English Channel in a monoplane equipped with rear elevator and rudder controls. Bleriot's achievement gave the aviation movement a technical stimulus that reached worldwide proportions. Shortly after the Bleriot flight came the world's first international air meet at Reims, France, and increasing numbers of young aviators made record-breaking flights in airplanes featuring the latest aerodynamic improvements.

***(J-14) pp 118-157
***(J-122) pp 51-66, 84-200, 210-219

i. In a comparatively short period of 11 years preceding the outbreak of war in 1914, a number of important changes occurred in the original configuration of the airplane. The most obvious developments were the enclosed monocoque fuselage, the monoplane with thin mid-mounted wings, streamlined landing gear, and more powerful engines. Other significant changes occurred in the airplane's control surfaces, which moved to the rear of the wings and the propeller. Ailerons replaced wing warping for lateral control, and hydraulic shock absorbers replaced rubber absorbers. Engineers began experimenting with all-metal frames and internally braced wings. They designed air-cooled radial engines to reduce the weight required by water cooling and simplified control by means of employing one control stick for all control surfaces. They placed horizontal stabilizers on the rear of the airplane to prevent pitching, hinged an elevator to the wing to control the tail unit and the angle of the wings, and added a vertical fin to control the direction of flight. Thanks to Lawrence Sperry's work with the gyroscope, a Curtiss plane flew under the control of the world's first automatic pilot.

***(J-14) pp 160-195
***(Aeroscience) pp 658-677
**(J-147) pp 67-87

j. With the outbreak of war, the airplane developed according to the duties expected of it as the war progressed. At first, the demand was for slow, stable aircraft to allow time for observation and reconnaissance. For months after the war began, aircraft armament was in the form of rifles, hand revolvers, and even shotguns. The addition of the synchronized (able to fire between propeller blades) machine gun revolutionized air warfare and made the airplane a maneuverable piece of artillery. An outstanding fighter of the war was the British S.E. 5, which reached a speed of 132 miles per hour and climbed at the rate of 765 feet per minute. Hugo Junkers introduced one of the most far-reaching innovations of the war with his all-metal, cantilevered monoplane. Other smaller, but no less significant, innovations included the first workable air brakes or spoilers, bubble cockpit covers, superchargers, and two-pitch propellers. Famous engines to come out of the war were the 12-cylinder 360 horse-power Rolls Royce Eagle VIII, the 8-cylinder 240-horsepower Mercedes, and the 12-cylinder 400-horsepower American Liberty. Light and heavy bombers, forerunners of the transport plane, evolved from the slow reconnaissance planes used early in the war. The end of the war saw the appearance of large multiengine bombers capable of delivering 7,500 pounds of bombs in a radius of 1,300 miles.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

Number of Academic Periods per Week	Recommended Number of Periods for Each Phase					
	1	2	3	4	5	6
2			x			
3					x	
4						x

b. You might begin this learning phase by relating it to the preceding phase with a statement such as the following: "In our last discussion, we learned that man has always desired to fly and that his continuing efforts led first to a hot-air balloon, then to a hydrogen balloon, and finally to a motorized rigid airship. In this phase, we will examine another series of developments that eventually led to winged flight. Instead of balloon flight, which is somewhat artificial in comparison with the flight of birds, another group of air pioneers searched for the secret of flight in experiments with the fixed-wing glider. Although a fixed-wing could not fly as high as the balloon, it could fly further for short periods in a horizontal direction. With the addition of a power source, the glider could stay off the ground longer, thus enabling it to fly longer distances." At this point, you might either show a balsa wood glider or a folded paper plane to the class or ask each member to construct a model glider. (See J-148, pp 248-250.) You might then begin a discussion on how to change the glider to provide better control and performance. You can then briefly discuss modern aircraft control surfaces as compared with methods of control on early gliders. This could lead naturally to a discussion of significant developments in the evolution of powered flight. A major point of emphasis may be the manner by which the Wright brothers first achieved controlled flight as a prerequisite to powered flight.

c. You may find it desirable to use a film at this point to show some of the early flight experiments and their results. The high point in these experiments came when the Wrights flew the first heavier-than-air craft. One or more of the following films might be useful as an introduction to this phase, as reinforcement during the study of early aviation developments, or as a conclusion to the study: SFP 355, We Saw It Happen; SFP 501, Air Power--The Early Days; SFP 1240, From Kitty Hawk to Aerospace. You might use one of these films to summarize the events leading to the Wright brothers' achievements and then introduce the next phase by showing later changes that occurred in aircraft design.

d. Your "J" series reference library contains three excellent references for use in this learning phase: J-14, History of Flight; J-122, The Invention of the Aeroplane; and J-157, Flight. Another useful reference, which we do not include in the J series, is The Wright Brothers by C. H. Gibbs-Smith. This booklet can be obtained from the Air Force Museum at Dayton, Ohio, for approximately $.50. It is also available from British Information Services, 845 Third Avenue, New York, New York 10022.

e. Although a discussion of the Wright brothers and their role in aviation progress may appear to be "old hat," a thorough examination of their achievements in comparison with the achievements of others can show just how brilliant their achievements were. Such a comparison may well be a means of stimulating your students to learn more about this phase in the evolution of the airplane. Challenge them to determine who made the most significant accomplishments in the early days of the airplane or ask them to suggest what might have been the result if the Wright brothers had made their first flights 10 years later. Would the attitude of the public have changed during an additional 10-year period to the extent that people would have been more enthusiastic about the airplane as a transportation medium?

f. This phase examines in a step by step manner the major developments that led to the heavier-than-air craft and its subsequent refinement. Many interesting events and personal experiences of early pioneers have been deliberately omitted for the sake of brevity. You might suggest or assign research projects that will enable students to learn more of the details concerning the growth of aviation or the technical evolution of the airplane.

g. Student assignment: Read the appropriate pages in the text.

7. INSTRUCTIONAL AIDS:

a. FILMS:

(1) SFP 355, We Saw It Happen, 58 min., 2 reels, B&W, 1954

(2) SFP 501, Air Power--The Early Days, 26 min., B&W, 1957.

(3) SFP 1240, From Kitty Hawk to Aerospace, 21 min., Color, 1965.

b. Other:

Aircraft models, paper for folded gliders, or pictures of early airplanes.

8. PROJECTS:

a. Construct model aircraft of some of the early gliders and airplanes.

b. A model of the Wright Flyer can be obtained from Monogram Models, #PA30.

9. FURTHER READING:

a. Air University. History of the USAF. Maxwell AFB: Air University, 1965, pp 1-1 to 1-4.

b. Chandler, Charles deForest, Col, US Army. How Our Army Grew Wings (Airmen and Aircraft Before 1914). New York: The Ronald Press Company, 1943, pp 124-178.

c. Gibbs-Smith, Charles H. The Aeroplane (Historical Survey of Its Origins and Development). London: Her Majesty's Stationary Office, 1960.

d. Gibbs-Smith, C. H. The Wright Brothers (A brief account of their work 1899-1911). London: Her Majesty's Stationary Office, 1963.

e. Sunderman, James F., Maj, USAF. Early Air Pioneers 1862-1935). New York: Franklin Watts, Inc., 1961.

f. USAF Historical Division. The United States Army Air Arm (April 1861 to April 1917). Maxwell AFB: USAF Historical Division, 1958, pp 20-152.

PHASE IV - AVIATION COMES OF AGE

During its first 20 years, the airplane advanced from an idea to an effective weapon of war. But some of the more spectacular advancements came during a 25-year period following World War II. This learning phase covers some of the major events in the evolution of the airplane, beginning in 1920 and ending in 1945. It recounts some of the feats of early aviators and famous pioneer flights during a period that became known as the "Golden Age of Aviation." Also included is a brief discussion of commercial aviation and its impact on the evolution of the airplane. A concluding section reviews some of the major changes in the design and structure of the airplane just prior to World War II.

1. PHASE IV OBJECTIVES - Each student should:

   a. Understand how the barnstorming era and the famous pioneer flights brought the world into the "Golden Age of Aviation."

   b. Understand how the early development of commercial aviation had an impact on the evolution of the airplane.

   c. Know some of the major changes that occurred in the design and structure of the airplane during the 25 years between World War I and World War II.

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

   a. Discuss how the feats of the barnstormers and the long-distance flights of the twenties and thirties showed to the public that aviation was coming of age.

   b. Discuss the beginnings of commercial aviation in the United States and the growing public demands for comfort and safety in air travel.

   c. Identify the major innovations that occurred in airplane design and the names of early planes that featured these innovations.

   d. Discuss the design characteristics that made the DC-3 so attractive for commercial and military use.

3. TEXTBOOK OUTLINE:

a. The status of aviation following World War I.
   (1) Influence of the barnstormers.
   (2) Famous pioneer flights and their influence.
b. The airplane and the public.
   (1) Airmail delivery.
      (a) The Army Air Service.
      (b) Government recognition of commercial aviation.
   (2) Growth of commercial airlines.
c. Two phases of commercial airline development.
   (1) European - 1920 to 1933.
   (2) United States - 1933 to the present.
d. Major changes in airplane design.
   (1) Civil aircraft production in the United States.
      (a) Ryan monoplane.
      (b) Lockheed Vega.
      (c) Northrop Alpha.
      (d) Boeing Monomail.
      (e) Boeing 247.
      (f) Douglas "DC" series.
   (2) The shape of the airplane.
      (a) Nieuport monoplane of 1910.
      (b) Junkers cantilever monoplane.
      (c) Application of streamlining by American and British designers.
      (d) Changes introduced by the Northrop Alpha and the Boeing Monomail.
   (3) Improved propellers and wing design.
      (a) Reduction gearing.
      (b) The first metal propeller.
      (c) Introduction of the variable-pitch propeller.
      (d) Wing flaps.
   (4) Improved engines and fuel.
      (a) Early engine problems.
      (b) Advent of the radial engine.
      (c) Development of fuels with higher octane ratings.
   (5) Other innovations.
      (a) Navigational instruments.
      (b) The automatic pilot and inertial navigation.
      (c) The pressurized cabin.
      (d) Retractable tricycle undercarriage.
e. The DC-3.
   (1) Military and civilian uses.
   (2) Its technical characteristics.
   (3) Improved maintenance features.
   (4) Its wartime achievements.

4. ORIENTATION:

As in the preceding phase, this phase continues our examination of major events in the growth of aviation and the technical evolution of the airplane. Until the airplane entered World War I, its development came largely from the work of a few private enterprises and individuals who were determined to make it a recognized mode of transportation. Events included in this phase occurred in a period of 25 years between two major wars and brought universal acceptance of the airplane as a third dimension in human transportation.

The feats of the barnstormers and the first record-setting long-distance flights will probably generate a great deal of student interest. You should capitalize on this interest to show how technical improvements enabled veteran aviators to restore public faith in the future of the airplane. Major emphasis throughout this learning phase should center on the innovations in design and structure that were pointing the airplane toward the modern aerospace age.

5. SUGGESTED KEY POINTS:

*(J-2) pp 17-18
*(J-5) pp 13-15
*(J-12) pp 293-304
***(J-14) pp 196, 198-199, 207-218, 232
**(J-19) pp 27-37
**(J-24) pp 78-180
**(Aeroscience) pp 677-725

a. Immediately following World War I, aviation progress faltered while aviation and pilots adjusted to peacetime conditions. Neither private business nor the public accepted the airplane as a reliable transportation medium. Consequently, there was only a limited demand for large numbers of surplus warplanes which the US Government placed on sale for civilian use. The most popular plane of the day was the JN-4 Curtiss "Jenny" training plane. Many veteran aviators who were unable to find employment elsewhere bought surplus "Jennies" and made their living as barnstormers. Without realizing it, these "flying gypsies" publicized the capabilities of the airplane and restored faith in the future of aviation. In addition to the activities of the barnstormers, a number of historic long-distance flights, including Charles A. Lindbergh's solo flight from New York to Paris, showed the public that the airplane was rapidly coming of age.

b. Air transportation as a commercial enterprise had its beginning in the United States with the delivery of the mail. During the war, Army pilots became the first flying mailmen on scheduled runs between Washington, Philadelphia, and New York. With $100,000 granted by Congress and the help of Army pilots, the Post Office Department opened an airmail route between Washington and New York in 1918 and continued to provide airmail service until 1925. In response to growing demands during the twenties and thirties for the Government to contract with private airlines for airmail delivery, Congress passed four significant legislative acts to encourage commercial aviation and authorize the Postmaster General to make private airmail contracts: the Kelly Act of 1925, the Air Commerce Act of 1926, the McNary-Watres Act of 1930, and the Civil Aeronautics Act of 1939. By 1933, the Boeing Aircraft Company had introduced the Boeing 247, an all-metal monoplane that reached speeds of 170 miles per hour. In the same year, the Douglas Aircraft Company introduced the DC-2, a twin-engine, all metal monoplane with soundproof cabins, retractable landing gear, a galley for hot meals, and other major improvements. The DC-2 was followed by the DC-3 which featured the latest innovations in aircraft design.

*(J-2) pp 17-18
*(J-5) pp 14-15
***(J-14) pp 199 202-203, 229, 243-246
**(Aeroscience) pp 655-657, 677, 681-684
***(J-147) pp 91-202

c. Following World War I, commercial aviation passed through two well-defined phases, the first dominated by European airlines until 1933 and the second by the United States from 1933 to the present. The first completely enclosed cabin appeared in 1919 on a converted French Goliath bomber with two 260-horsepower engines and "trousered" undercarriage legs. The first major postwar improvement in the airplane came in Europe with the introduction of the Junkers, Rohrbach, and Fokker monoplanes. The first semblance of an

***(J-14) pp 203-205, 216, 232, 234, 243-245, 269
**(J-24) pp 78-213
**(Aeroscience) pp 679-691
*(Climb to Greatness) pp 58-76

airliner in the United States was the Ford trimotor monoplane based on the Junkers and Fokker design. The United States assumed a leading role in commercial aircraft design with the introduction of the Boeing 247.

*(J-2) p 18
**(J-14) pp 198-205, 242-249

d. As a result of increased public interest in aviation and with the availability of radial air-cooled engines, American manufacturers initiated a process of improvement that made the United States a world leader in commercial aircraft design. The Ryan monoplane appeared in 1927 as the best streamlined plane of the day, and, in the same year, an even more advanced design appeared in the Lockheed Vega, a cantilever monoplane that closely resembled modern aircraft. The first all-metal low-wing monoplanes in the United States were the Northrop Alpha and the Boeing Monomail, also one of the first airplanes in the world to feature a retractable undercarriage. The Boeing 247 was a twin-engine transport that evolved from the Monomail through the Boeing B-9 bomber and featured the same improvements found on smaller single-engine planes. The DC-3 series featured major aerodynamic and propulsive improvements, including cantilever monoplane wings, better streamlining, variable-pitch propellers, more efficient engines, and the efficient utilization of higher quality fuels.

*(J-2) p 18
**(J-14) pp 198-205, 242-249

e. The twenties and thirties saw major improvements in the shape of the airplane and in propeller and wing design. Demands for increased efficiency brought efforts to reduce drag by streamlining the fuselage and other vital parts of the airplane, including engine cowlings, stressed-skin all-metal construction, wing fillets, and engines mounted on the leading edge of the wing. Propellers advanced from simple wooden designs to the fixed-pitch metal propeller to the variable-pitch constant-speed type. These propellers automatically change their pitch to match the rotational speed of the engine. British designers first used flaps hinged upward at the rear center section of the wing to brake the flow of air during landing. Later developments brought the use of flaps hinged downward on the trailing edge of the wing to increase lift rather than drag. The most significant developments in the evolution of wing flaps came with the invention of the slotted flap, the split flap, the Fowler flap, the double- and triple-slotted flap, and the leading-edge flap.

**(J-5) pp 38-39
**(J-13) pp 119, 136-156
***(J-14) pp 81-85, 90-95, 104-105, 111, 120-122, 153, 164, 203, 204, 243-246, 254-256, 266, 371-376
*(J-47) pp 113, 114, 115-116
***(Aeroscience) pp 63-67
**(J-86) pp 15, 18, 22, 29, 31, 33, 35, 37, 43, 44, 50, 52, 53, 54, 55, 59, 65, 80, 89, 91, 94-95, 106, 114, 117, 120, 135, 137, 138, 142, 143, 145, 162, 166
***(Flight) pp 77-82

f. Of all the improvements in airplane design between World War I and World War II, the most far-reaching came with the creation of more powerful engines. A common problem with early engines was a loss of power from inadequate cooling. The rotary engine solved this problem until 1914, but this engine could not satisfy wartime demands for more power. The problem of engine power was solved by the radial air-cooled engine with a crankshaft rotating within the crankcase and cylinders. The period from the early thirties to the outbreak of World War II saw the steady advance of air- and liquid-cooled engines to power levels as high as 1,500 horsepower, almost three times the power of engines in use at the end of World War I. A striking feature of these advances in engine power was that engineers obtained more power without increasing engine weight. This was possible because of higher compression ratios and pressure increases provided by superchargers permitted the use of improved fuels.

***(J-5) pp 71-87
***(Flight) pp 123-130, 90, 101-102, 106

g. Other innovations in aircraft design came with major improvements in navigational systems, the pressurized cabin, and the addition of the retractable tricycle undercarriage. An airplane presents unique navigational problems because of its capacity for vertical movement and much higher speeds in comparison with surface vehicles. In the early days of flying, pilots depended on land markings to serve as visual guides over unfamiliar territory. The period of the twenties and thirties saw a number of additions to the airplane's instrument panel, including the directional gyroscope, the "artificial horizon," the radio beam, airspeed indicator, rate-of-climb indicator, and others. Some of the most important advances of the period was the introduction of the automatic pilot, and later, a more complete system known as inertial navigation. Another important development was the pressurized cabin, which enabled the airplane to fly higher and faster. Still another change in airplane design came with the addition of a tricycle undercarriage that retracted into the wings. This feature made landing and taking off easier for pilots and more comfortable for passengers.

**(J-14) pp 245, 269, 370
***(J-78) Complete text
***(J-79) Complete text

h. The DC-3 was the most famous airliner ever built primarily because of its unmatched reliability and economy of operation. It served both as a military transport under such names as SKYTRAIN, SKYTROOPER, DAKOTA, and more commonly "Gooney Bird," and as the foremost commercial airliner of its day. In addition to two 850-horsepower radial supercharged engines which gave it a cruising speed of 190 miles per hour, it featured all the latest technical advances--all-metal monocoque construction, retractable landing gear, engines mounted on the wings, variable-pitch propellers, wing flaps, and cockpit instruments that permitted all-weather and night flying. One of its most attractive features was its greatly reduced cost of maintenance. As outstanding as were its achievements as a commercial airliner, its achievements in war were even more spectacular. From all corners of the earth came such fantastic stories of its endurance and reliability in emergency flights that even Douglas engineers could not believe them.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

Number of Academic Periods per Week	Recommended Number of Periods for Each Phase					
	1	2	3	4	5	6
2		x				
3			x			
4				x		

b. The initial section of this learning phase can be used to arouse the interest of your students in the growing popularity of the airplane following World War I. You might introduce the phase by directing a question to the students, such as: "What were some of the factors that led to the rapid expansion of aviation after World War I?" Point out that progress in aviation faltered following World War I primarily because the public and private business viewed the airplane as a weapon of war and not as a reliable carrier of passengers and cargo. Consequently, the US Government came out of the war with a surplus of warplanes and no ready commercial market. The barnstormers bought surplus Curtiss "Jennies" either for economic reasons or for the adventure of performing in air shows before the public. They unwittingly became the ambassadors of aviation in their demonstrations before a skeptical public. You might also bring out that the American free enterprise system provided the environment for early flyers to exploit their "pioneering spirit" and advance the airplane to new heights of achievement.

c. The development of air transportation as a commercial enterprise can be the subject of an interesting discussion if you point out some of the perils faced by early aviators in delivering the mail. The early airmail flights were, in many respects, the technical version of the "Pony Express" of America's frontier days. A discussion of these early airmail flights can lead to a discussion of Government incentives for private contracts and the impact of commercial competition on demands for improving the airplane.

d. So popular did the airplane become between World War I and World War II that the period became known as the "Golden Age of Aviation." Flying activities ranged from daredevil shows at county fairs and the like to the heroic feats of daring aviators in mad dashes across continents, oceans, and even the polar regions. Heroes and world records came in rapid order as the pioneers of flight sought to prove that the airplane was coming of age. Since there are so many names and events associated with this early period, films could be used at this point to present personalities and their achievements to your classes. Later, when you discuss these early pioneers, scenes from the movies may stimulate certain students to contribute worthwhile ideas or to read further into the history of the immediate postwar years.

e. Also, in the early sections of this phase, you may find it desirable to assign student research projects. Reference books and other sources of information in most libraries provide good background information which the students can use to prepare interesting oral reports. Encourage the students to develop unique methods of presenting their talks. One effective technique used by some units is to assign a student the role of one of the heroes discussed in this chapter. He could prepare a brief talk (five minutes) on his exploits as an early pilot and then answer questions from his classmates for another five-minute period. For this technique to be effective, the student should play the role as if he had actually gone through the experiences.

f. One interesting approach to the study of major changes in aircraft design and structure is to compare the configuration of postwar airplanes with the airplanes developed during the first 10 years of powered flight. You might call attention to pictures of postwar airplane designs in the text and compare them with the earlier Wright, Junkers, Fokker, and Bleriot airplanes. Another approach might be to list on the chalkboard major innovations in airplane design during the 25 years between world wars. In discussing the DC-3, make sure to point out the fact that this airplane incorporated all the most recent technical innovations of the day. In addition to the stories of the DC-3 included in the text, you may have interesting anecdotes or experiences of your own concerning the DC-3's characteristics.

7. INSTRUCTIONAL AIDS:

a. FILMS:

(1) SFP 263-1, The Air Force Story--The Beginning, 15 min., B&W, 1953.

(2) SFP 263-1, The Air Force Story--After the War (1918-1923), 14 min., B&W, 1953.

(3) SFP 263-3, The Air Force Story--Struggle for Recognition (1924-1930), 14 min., B&W, 1953.

(4) SFP, 263-4, The Air Force Story--Between Wars (1930-1935), 13 min., B&W, 1953.

(5) SFP 506, Air Power--Fools, Daredevils, and Geniuses, 27 min., B&W, 1957.

(6) SFP 556, Air Force Scrapbook, 28½ min., B&W, 1957.

(7) SFP 1240, From Kitty Hawk to Aerospace, 21 min., Color, 1965.

8. PROJECTS:

The construction and display of various aircraft models from this period might provide the student with a better understanding of the events. Seeing a model of Lindbergh's plane or of Amelia Earhart's plane might give them a better idea of the "state of the art" at that time and stimulate them to ask questions about the design and performance of these aircraft that enabled them to accomplish such outstanding feats.

9. FURTHER READING:

a. Becker, Beril. Dreams and Realities of the Conquest of the Skies. West Hanover, Massachusetts: Halliday Lithograph Corporation, 1967.

b. Caidin, Martin. Barnstorming. New York: Duell, Sloan, and Pierce, 1965.

c. Ellis, E. H., and Ellis, E. M. Atlantic Air Conquest. London: William Kimber, 1963.

d. Hurley, Alfred F., Major, USA. Billy Mitchell. New York: Franklin Watts, Inc., 1964.

e. Lindbergh, Charles A. We. New York: G. P. Putnam's Sons, 1927.

f. Miller, Ronald and Sawers, David. The Technical Development of the Airplane. London: Routledge and Kegan Paul, 1968.

g. Scamehorn, Howard L. Balloons to Jets. Chicago: Henry Regnery Company, 1957.

h. Sunderman, James F., Major, USAF. Early Air Pioneers (1862-1935). New York: Franklin Watts, Inc., 1961.

PHASE V - THE AEROSPACE THRESHOLD

As spectacular as were the advances of the airplane during the period of the twenties and thirties, even further momentous developments came with the application of jet propulsion and rocketry to the flying machine. This learning phase covers the beginnings of jet propulsion and the application of the jet principle to the airplane. Also included is a discussion of rocketry and its implications for space travel.

In contrast to its status in World War I, the airplane evolved to the point that it was a dominant part of military operations in World War II. Momentous changes in design not only led to unprecedented improvements in the airplane's speed, performance, and endurance, but these changes also enabled the airplane to carry man to the outer fringes of space. The chapter includes a discussion of these improvements and their impact on military and commercial aircraft at the conclusion of World War II. By 1945, large numbers of people were flying in multiengine transports over ranges of more than 3,000 miles at speeds above 300 miles per hour. Smaller planes were approaching the sound barrier at speeds over 500 miles per hour. The chapter ends with man preparing to cross the threshold into the Aerospace Age.

1. PHASE V OBJECTIVES - Each student should:

a. Understand some of the experiments that led to the creation of the jet engine, rockets, and guided missiles.

b. Know some of the technological improvements brought to aviation by some of the outstanding military aircraft of World War II.

c. Understand the impact of guided missiles and jet aircraft on the conduct of war.

d. Know the contributions of Leonardo da Vinci, Juan de la Cierva, and Igor Sikorsky to the evolution of the helicopter.

e. Know some of the technological characteristics of outstanding airliners to emerge from World War II.

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

a. Discuss the significant events that led to the creation of practical jet engines, rockets, and guided missiles.

b. List the outstanding military aircraft of World War II and the technological improvements which they brought to aviation.

c. Explain some of the technical capabilities of guided missiles and jet aircraft and their significance in the conduct of war.

d. Describe how the early contributions of Leonardo da Vinci, Juan de la Cierva, and Igor Sikorsky led to the modern helicopter design.

e. Trace the development of modern commercial airliners and their technical contribution to aircraft design.

3. TEXTBOOK OUTLINE:

a. Jet propulsion and rocketry.
   (1) Early history of jet propulsion and rocketry.
   (2) Experiments in turbojet propulsion.
      (a) Sanford A. Moss.
      (b) Frank Whittle.
      (c) Ernst Heinkel.
      (d) Hans von Chain.
      (e) The first practical jet aircraft.
   (3) The modern era of rocketry.
      (a) The work of Eduardovitch Tsiolkovsky.
      (b) Robert Goddard and practical rocketry.
      (c) Hermann Oberth and Wernher von Braun.

b. The airplane and World War II.
   (1) Outstanding fighter planes of World War II and their technical characteristics.
   (2) Technical improvements represented by medium and heavy bombers.
   (3) V-1 and V-2 missiles.
   (4) The first operational jet fighters and bombers.
      (a) Messerschmitt ME-262 Schwalbe.
      (b) Heinkel HE 162 Salamander.
      (c) Messerschmitt ME-163 Komet.
      (d) P-38 Shooting Star.

(5) The practical helicopter.
   (a) Leonardo da Vinci's design.
   (b) Juan de la Cierva's autogiro.
   (c) The Focke-Achgelis FW-61 and the Focke-Achgelis FA-223.
   (d) The Sikorsky R-4B.
   (e) The modern helicopter.

c. Civil transport aircraft.
   (1) The China Clipper and the Yankee Clipper.
   (2) Douglas DC-4 Skymaster.
   (3) Lockheed Constellation.
   (4) Boeing Stratocruiser.
   (5) Improvements in navigational and landing facilities.

4. ORIENTATION:

This learning phase contains two major blocks of subject matter: (1) the advent of practical jet propulsion and rocketry and (2) the impact of war on aircraft design and structure. Your major concern, therefore, is to focus on the implications of jet propulsion and rocketry for the future of human flight and to point how technical innovations in the airplane during wartime brought man to the threshold of the Aerospace Age. This phase, of course, marks the decline of the propeller-driven aircraft and the introduction of jet- and rocket-propelled vehicles. The chapter concludes with the idea that, even with the unprecedented wartime improvements in the airplane, man was still only in the initial stages of vast new dimensions in air power.

5. SUGGESTED KEY POINTS:

**(J-4) pp 9-58
**(J-5) pp 123-125
**(J-10) pp 6-10
***(J-111) pp 2-39

a. As the period of the twenties and thirties drew to a close, the propeller-driven airplane was rapidly reaching the peak of its capacity in speed, climbing ability, and range. But with the application of jet propulsion and rocketry, the airplane would achieve almost unlimited dimensions of power. As early as 400 B.C., Archytas of Tarentum applied the jet principle to a flying wooden pigeon. Some 300 years later, Hero of Alexander designed an aeolipile, which, unknown to Hero, demonstrated the action-reaction principle underlying both the jet engine and the rocket. The Chinese were probably the first to use rockets in warfare during the Chinese-Mongolian wars in 1232 A.D. Historians report numerous rocket experiments in Europe from the thirteenth to the fifteenth centuries. Roger Bacon experimented with rockets in England; Lehan Freissart discovered the principle of the bazooka in France almost 50 years before Columbus was born; and an Italian designed a rocket-propelled torpedo. In the nineteenth century, Francis Scott Key spoke of rockets in the "Star Spangled Banner." But rocketry and jet propulsion did not become a practical reality for human flight until the 1920s and 1930s.

**(J-2) pp 200-217
*(J-5) p 31
*(J-13) pp 132-136
**(J-14) pp 371-376
**(J-19) pp 47-69
*(J-25) pp 34-49
**(Flight) pp 82-86

b. Sanford A. Moss first pointed in the direction of a modern turbojet engine in 1900 when he wrote a thesis on turbine machinery and in 1902 when he experimented with a gas turbine. In 1928, Frank Whittle suggested that a gas turbine was the only logical means of propelling the airplane at speeds above 500 miles per hour. His invention of the gas turbine paved the way for a British aircraft company to produce a jet aircraft in the early forties. In Germany during the same period, however, Ernst Heinkel underwrote two lines of propulsive research that brought Germany to the forefront in propulsion technology--Wernher von Braun's creation of liquid fuel rockets and Hans von Chain's development of the first practical jet fighter, the Heinkel HE-178. Toward the end of World War II, Germany developed a limited number of jet fighters that could fly 50 miles per hour faster than Allied piston-engine fighters and 100 miles per hour faster than Allied bombers.

c. The modern era of rocketry began with the work of Eduardovitch Tsiolkovsky

**(J-4) pp 9-58
*(J-5) pp 123-126
*(J-10) pp 11-18
***(J-23A) pp 62-97
***(J-28A) pp 23-46, 90-110, 133-155
**(J-44) pp 9-16, 31-41, 53-57, 62-73
*(J-46) pp 13-21
**(J-83) pp 17-30
***(J-111) pp 40-119

who developed a theory that liquid propellants could be used in rockets to achieve spaceflight. He suggested step or multistage rockets to generate the thrust necessary for flights into space. He also proposed space stations as a means of launching probes into distant parts of the universe. Robert Goddard became the first modern space pioneer in his experiments with both solid and liquid propellants. He fired the world's first rocket with a liquid-propellant system in 1926 and, by 1935, had developed gyroscopically stabilized rockets that achieved speeds faster than the speed of sound. Few people in the United States could foresee the vast military potential of the rocket at the beginning of World War II. Germany developed the technique for long-range ballistic rocketry with the work of Hermann Oberth and Wernher von Braun. Like Goddard, Oberth wrote detailed technical reports describing the requirements for space travel. In a little-known place called Peenemunde, Oberth, von Braun, and other German rocket scientists experimented with high-thrust, ballistic rockets that led to pilotless, guided missiles used during World War II.

*(J-2) pp 18-19
**(J-14) pp 288-295, 301, 317, 322-323, 324-325, 328-335, 336
*(Aeroscience)pp 728-735, 747-751

d. In World War I, the airplane was still something of a novelty unproven as a weapon of war, but, in World War II, major improvements in design and structure enabled it to play a decisive role in military operations. With engines of 1,000- to 2,000-horsepower, the airplane not only reached speeds above 400 miles per hour but also increased its range and climbing ability. At the beginning of World War II, the British Spitfire, the German Messerschmitt ME-109, and the British Hawker Hurricane were outstanding single-seat, single-engine, propeller-driven fighters with normal speeds of 350 miles per hour. Improvements in design and engine power enabled the Spitfire to reach speeds above 440 miles per hour before the end of the war. Two outstanding American fighter planes were the P-51 Mustang and the Thunderbolt. The Mustang was an all-metal, stressed-skin monoplane that reached a maximum speed of 390 miles per hour at 8,000 feet on its initial flight, but later versions with improved engines reached a top speed of 442 miles per hour at 24,000 feet and climbed to 20,000 feet in 10 minutes. The Spitfire and the Mustang were the fastest piston-engine fighters in service at the end of the war. The Thunderbolt was the first 2,000-horsepower, single-engine fighter built in the United States. It reached a top speed of 427 miles per hour and served as an escort plane for B-17 and B-29 bombers in raids over Europe. Toward the end of the war, such fighter planes as the P-38 Lightning flew at altitudes of 40,000 feet and climbed at a rate of 5,000 feet per minute.

*(J-2) pp 18-19
**(J-14) pp 288-295, 301, 317, 322-323, 324-325, 328-335, 336
*(Aeroscience) pp 728-735, 747-751

e. At the beginning of World War II, such medium bombers as the Blenheim, Beaufort, and Junkers JU-88, carried approximately 1,500 pounds of bombs at speeds of 270 miles per hour over a radius of 1,000 miles. Heavy bombers, such as the Heinkel 111 and the Wellington carried 4,500 pounds of bombs at speeds of 250 miles per hour over a radius of 1,250 miles. By the end of the war, the American medium bomber, the B-25 Mitchell, carried 2,000 pounds of bombs at 300 miles per hour over a 500-mile radius. Another American medium bomber, the Marauder, carried 4,000 pounds of bombs at speeds of 287 miles per hour. Some of the most significant innovations in aircraft design came with the introduction of heavy four-engine bombers. The B-17 Flying Fortress carried 13 machine guns in revolving turrets and flew at altitudes up to 35,000 feet with bombloads of as much as 20,800 pounds. It had a top speed of 295 miles per hour over a radius of 2,500 miles. An advanced version of the B-17, the B-29 Superfortress, had a top speed of more than 350 miles per hour and a range of 8,400 miles. An advanced version of the B-29, the B-50, appeared with a top speed of 400 miles per hour and a range of 6,000 miles with 10,000 pounds of bombs. As impressive as were these armored battleships of the sky, they became highly vulnerable targets as fighter plane speeds increased.

*(J-14) pp 334
**(J-23A) pp 94-97
***(J-44) pp 53-62
***(J-57) Entire Book
***(J-111) pp 65, 71, 72-73, 100, 104-105, 115-121, 122

f. Germany's introduction of guided missiles and long-range rockets added a new dimension to the conduct of war. Here for the first time was a weapon that could be delivered to enemy territory without an airplane to carry it. It represented the first practical application of the jet principle to a weapon of war. The first such weapon was the V-1, a pilotless monoplane equipped with low, swept-back wings, and a pulse-jet engine. It carried about 2,000 pounds of explosive for 150 miles at a speed of 400 miles per hour. The most significant development in guided missilery came with the V-2, a pilotless missile propelled by a liquid-fuel rocket. This missile could fly at a maximum altitude over 300,000 feet, a range of 200 miles, and had a top speed of 3,500 miles per hour.

*(J-14) pp 334, 371, 376
**(J-24) 216-219, 240-241

g. With the successful test flights of the Heinkel HE-178, Germany introduced one of the war's most spectacular airplanes, the Messerschmitt ME-262 Schwalbe which was the world's first operational jet fighter. Two axial-flow Jumo engines gave the ME-262 a speed above 500 miles per hour and a ceiling of 40,000 feet. Another noteworthy German jet fighter was the Heinkel HE-162 Salamander which became operational in 1945 at a speed of

520 miles per hour. Germany also introduced the world's first heavy jet bomber, the Junkers JU-287, which reached a speed over 500 miles per hour with 8,800 pounds of bombs. Another spectacular German production was the world's first rocket-jet airplane, the Messerschmitt ME-163 Komet fighter. Equipped with swept-back wings and a liquid-fuel rocket motor, it could fly at the rate of 590 miles per hour and climb to 30,000 feet in 2½ minutes. The US response to the flight of German jet-propelled aircraft was the P-80 Shooting Star, a sleek, single-engine jet with a speed of 575 miles per hour.

**(J-2) pp 382-396
*(J-5) pp 5-6
**(J-13) pp 656-684
**(J-25) pp 126-144
**(J-53) pp 92-102

h. Men confronted the problem of space required for winged aircraft to take off and land long before the advent of the modern high-speed airplane. For years, flying enthusiasts toyed with the idea of raising a conventional aircraft vertically with a horizontally rotating propeller. They needed a vehicle capable of taking off and landing in small areas, traveling at low speeds, hovering in the air, and moving backward and sideways. The obvious solution was the helicopter. Leonardo da Vinci made the first recorded sketch of a helicopter, and George Cayley built a toy helicopter. But the first semblance of a practical helicopter was Juan de la Cierva's autogiro. This machine, an ordinary airplane with a huge windmill motor instead of wings, could rise vertically to a height of 20 to 30 feet before it began its forward flight. The Focke-Achgelis FW 61 built by German engineers in 1936 was the first fully operational helicopter. With a standard propeller on the front and a metal framework topped by rotors on each side, it could climb to an altitude of 11,240 feet and fly at a speed of 75 miles per hour. The Focke-Achgelis FA-223 was the first production helicopter in the history of aviation.

Igor Sikorsky built the first practical and controllable helicopter in the R-4B, a machine that had a three-blade main rotor 38 feet in diameter and a three-blade controllable-pitch rotor 8 feet in diameter. The modern helicopter is an indispensable element of the Aerospace Age, both in military and civilian uses.

**(J-14) pp 266-269
**(J-19) Entire Book
**(J-53) pp 133-144

i. Although a number of international civil air routes were established by 1939, only token efforts had been made for scheduled transoceanic services by the Pan American Airways <u>China Clipper</u> and <u>Yankee Clipper</u>. The DC-3 was the backbone of civil transport aircraft throughout World War II. The most significant development in commercial transport came with the appearance of four-engine bombers. These aircraft, particularly the B-29 <u>Superfortress</u>, made a routine performance of transoceanic and transcontinental travel and convinced the public that the whole world was at last within the practical range of the airplane. This achievement led to a whole new series of four-engine transports--the Douglas DC-4 <u>Skymaster</u>, the Lockheed <u>Constellation</u>, and the Boeing <u>Stratocruiser</u>. These aircraft flew at speeds of more than 200 miles per hour over ranges of 1,500 to 3,500 miles. In addition to revolutionary changes in civil transport design, speed, and range, the war brought vast improvements in navigational and landing facilities, including radio and radar communications systems and more efficient lighting systems.

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. One possible approach for presenting this learning phase to your class might be to determine the exact role of your community, city, and state in aerospace activities. It might also be helpful for you to know the names of local citizens who contribute to this role. This preliminary discussion should generate interest on the part of your students in the background of the jet engine, the rocket, guided missiles, helicopters, and commercial airliners. Models, diagrams, or colorful illustrations of these aerospace vehicles could be used to reinforce your discussion.

c. For your study of rockets, you might find it possible to fire a small rocket on your school campus to illustrate some of the difficulties faced by early rocket pioneers.

d. Another approach is to divide the class into small groups and assign one student to play the role of a scientist in modern rocketry or jet propulsion and another to play the role of a news reporter. Still another student could present a narrative explanation of events covered in the interview. You might appoint another member of the class to demonstrate models or point out specific objects or events on illustrated posters. Such assignments should be given well in advance to allow time for the students to prepare properly. This type of group activity can also be adapted to other material in this learning phase.

e. You might assign individual students to play the role of Goddard, Whittle, Chain, von Braun, or others. The assignment could cover the periods in these men's lives when they were experimenting with rockets and jet engines. In a question and answer period, the student would answer questions as if he were the scientist being studied. The role-playing student, the class, and the instructor must be well prepared for this type of class activity to be worthwhile.

f. Some of the material in this learning phase can be presented by guest lecturers. You might invite a science teacher, a social studies teacher, or a local aerospace official to lecture in an area of his interest or specialty. The material can also be adapted to the team teaching approach. For this approach, you could enlist the services of teachers, local government officials, aerospace officials, and others who have specialized knowledge in a given area.

g. Transparencies listed for instructional aids should be used only for introductory purposes and not for a comprehensive coverage of a given subject.

7. INSTRUCTIONAL AIDS:

a. FILMS:

(1) USAF

(a) SFP 595, Road to the Stars, 27 min., Color, 1958.

(b) SFP 660, The Widest Horizon, 28 min., Color, 1958.

(c) TF 5622, Space in Perspective, 27 min., Color, 1965.

(2) NASA

HQa 54 Father of the Space Age, 18 min., B&W, 1961.

b. TRANSPARENCIES:

(1) T-35 Regions of the Atmosphere

(2) T-34 Division of Space

(3) T-33 Liquid Propellant Rocket

(4) T-39 Rocket Engines

8. PROJECTS:

a. Students can build various models of helicopters, jets, commercial aircraft, and rockets.

b. If school and local policies will permit, conduct an experiment in launching a small rocket. (Write for a free Centuri Model Rocket Products Catalog from the Centuri Engineering Company, P. O. Box 1988, Phoenix, Arizona, 85001, and a Model Rocketry Catalog from Estes Industries, Inc., Box 227, Penrose, Colorado 81240.)

c. If you live in an area near an aerospace activity, you might conduct a field trip to observe jet aircraft rockets, or helicopters firsthand. Such a project should be a well planned activity with a responsible assignment for each student.

9. FURTHER READING:

a. Davies, R. E. G. A History of the World's Airlines. New York: Oxford University Press, 1964.

b. Loening, Grover. Takeoff into Greatness. New York: G. P. Putnam's Sons, 1968.

c. Miller, Ronald and Sawers, David. The Technical Development of Modern Aviation. London: Routledge and Kegan Paul, 1968.

PHASE VI - THE MODERN AGE

This learning phase focuses on major developments in aviation and spaceflight since World War II. Following a brief examination of significant aerodynamic and structural improvements in aircraft design brought by the jet engine, the chapter describes the impact of these improvements on military and commercial aircraft and cites examples of outstanding aircraft to show how far the airplane has advanced since the first glider flights of the Wright brothers. It then traces postwar advances in rocket technology, ballistic missilery, and the beginnings of space exploration. It concludes with the idea that, despite unprecedented technological advancement, man has only just begun to realize the ultimate possibilities of mechanical flight.

1. PHASE VI OBJECTIVES - Each student should:

   a. Know why the term "aerospace" has replaced the term "aviation" as a reference to modern space vehicles.

   b. Be familiar with the impact of the jet engine on aircraft design.

   c. Understand some of the characteristics of the outstanding military and commercial aircraft that developed in the period following World War II.

   d. Know the events that brought the United States into the long-distance missile field and space exploration.

   e. Know some of the possible future developments in winged flight and space exploration.

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

   a. State why the term "aerospace" is a more logical reference to the modern generation of flight vehicles.

   b. Identify specific aerodynamic and structural innovations in aircraft design that came with the practical application of the jet engine.

   c. Discuss the technical characteristics of outstanding military and commercial aircraft of the post-World War II period, giving particular attention to modern jet aircraft.

d. Trace the development of intercontinental ballistic missiles in the United States and the events leading to space exploration.

e. Give examples to illustrate some of the future possibilities in winged flight and space exploration.

3. TEXTBOOK OUTLINE:

a. The new flight environment.
   (1) Limitations of the term "aviation."
   (2) The context of aerospace.
   (3) Symbolic events of the Aerospace Age.
b. Aerodynamic and structural innovations in aircraft since 1945.
   (1) Problems faced by engineers in the immediate postwar years.
   (2) Innovations that overcame the sonic barrier.
   (3) The problem of temperature and stress at supersonic speeds.
   (4) Improvements in engine design.
      (a) Turbofan
      (b) Ramjet
      (c) Turboprop
      (d) Rocket.
   (5) The instrument panel.
c. Military aviation.
   (1) Early American military jet aircraft.
      (a) Fighters--F-80 Shooting Star, F-84 Thunderjet, F-86 Sabre, F-89 Scorpion, F-94 Starfire, F-84F Thunderstreak, F9F Cougar.
      (b) Bombers--B-36, B-45 Tornado, XB-48, B-47 Stratojet, B-57 Canberra.
   (2) Supersonic aircraft
      (a) F-100 Supersabre
      (b) F-101 Voodoo
      (c) F-102 Deuce
      (d) F-104 Starfighter
      (e) F-105 Thunderchief
      (f) F-106 Delta Dart
      (g) F-4 Phantom
      (h) F-111
      (i) B-58 Hustler
      (j) FB-111
      (k) F-14
      (l) F-15
      (m) YF-12A

(3) Cargo and transport aircraft
   (a) C-47
   (b) C-110 Flying Boxcar
   (c) C-124 Globemaster
   (d) C-130 Hercules
   (e) C-133 Cargomaster
   (f) KC-135 Stratotanker
   (g) C-141 Starlifter
   (h) C-5 Galaxy

d. Commercial aviation
   (1) Modern commercial airline flight
   (2) Outstanding airliners of the post-World War II period
      (a) Douglas DC-6 and -7 series
      (b) Boeing 377 Stratocruiser
      (c) Lockheed Constellation
      (d) Super Constellation
   (3) Jet airliners and freighters
      (a) De Havilland Comet
      (b) Lockheed Electra
      (c) Boeing 707
      (d) Boeing 727 and 737 series
      (e) DC-8 and DC-9
      (f) Boeing 747 and 747F
      (g) The supersonic transport

e. Beginnings of the Space Age
   (1) Early Air Force long-distance missiles
      (a) JB series
      (b) Snark and Matador
      (c) Mace
      (d) Navaho
   (2) The Hermes program
   (3) Operation Bumper
   (4) The Redstone and Jupiter missiles
   (5) Sounding rockets
   (6) Unmanned spacecraft
      (a) The Sputniks
      (b) The Explorers
      (c) Meteorological and communications satellites
   (7) Interplanetary probes
      (a) Luna and Ranger spacecraft
      (b) Lunar Orbiter
      (c) The Pioneer and Mariner series
   (8) Manned spacecraft
      (a) Mercury
      (b) Gemini
      (c) Apollo

f. Future aerospace developments
   (1) Winged flight
      (a) Improved subsonic airliners
      (b) A new generation of vertical flight aircraft
      (c) Private aircraft
   (2) Space exploration
      (a) Skylab--Orbital Workshop
      (b) Permanent space station
      (c) The space shuttle

4. ORIENTATION:

This learning phase presents a brief review of major developments in the aerospace environment since World War II. No attempt is made to present a detailed examination of technological and scientific breakthroughs that brought unprecedented changes in winged flight and the beginnings of space exploration. Instead, the chapter is designed to serve a twofold purpose: (1) provide the reader with a capsule description of the advanced technology represented by modern aerospace vehicles and (2) show how mechanical flight in comparison with other transportation media developed as a result of rapid technological change. You should use this phase to show your students how rapidly the airplane has advanced since the first sustained flights of the Wright brothers, how it revolutionized man's transportation systems, and how it provided man with the technical background to extend his domain beyond the upper atmosphere into space.

5. SUGGESTED KEY POINTS:

***(J-148) pp 13-31

a. The piston-engine airplane freed man from the limitations of surface travel by land and water, but it ultimately confronted an invisible barrier which limited it to the upper boundaries of the earth's atmosphere. But man had already developed new and revolutionary sources of power which enabled him to create a whole new generation of flight vehicles. With jet and rocket engines, he not only achieved unprecedented speeds within the earth's atmosphere but also boosted his flight beyond the earth's atmosphere into space. These achievements forced piston-engine aircraft into obsolescence and, at the same time, made the term "aviation" an inadequate reference to the modern generation of flight vehicles. Modern man views flight in the context of aerospace, a total area that encompasses both the earth's atmosphere and outer space.

** (J-14) pp 370-405
*** (Flight) pp 176-191

b. In less than 70 years since the Wright brothers made their first sustained flight, rapid improvements in aerodynamics, engine technology, and metallurgy produced fantastic increases in the airplane's speed. These increases, in turn, required a number of significant innovations in aircraft design. As the airplane reached speeds of 600 miles per hour, engineers added hydraulic controls, special ejection seats, pressurized cockpits, refrigeration systems, and numerous automatic controls. At speeds above 650 miles per hour (the speed of sound), the airplane confronted a cone-shaped wave of compressed air known as the sonic barrier. To overcome this barrier, it took the shape of a giant 50-caliber bullet and added swept-back wings. At supersonic speeds up to 2,000 miles per hour, a boundary layer of air increased the temperature of the airplane's outer aluminum surface to a dangerous level. Engineers are solving this problem with methods such as applying thin coatings of heat-resistant titanium. High speeds also caused the stressed-skin structures of conventional aircraft to buckle. This problem led to wings of thicker metal sheets and the use of honeycomb material of steel and ceramic to provide a smooth skin and protect aircraft fuel from extreme temperatures.

**(J-13) pp 156-167, 171-172 176-184, 185-233
**(J-14) pp 373-399
**(J-25) pp 34-49

c. Continuing advances in engine power was a major contributing factor in these innovations. The most significant improvement in the pure gas turbine engine came with the turbofan engine which provides a greater thrust with less fuel. In comparison with the thrust range of 1,000 to 1,100 pounds of early turbojet engines, modern turbojets have thrust ratings as high as 40,000 pounds. But as the power of the turbojet increased, the rapid compression of air thrust into its intake ducts created dangerous increases in air temperature. To solve this problem, engineers created the simplest and most modern jet engine design yet known--the ramjet, which has neither compressor nor turbine. Commercial airlines first considered the turbojet engine too expensive for civilian transportation and used the turboprop until improvements in the turbojet engine made it economically practical. Although the rocket engine can be used for jet-assisted takeoff, it is used primarily as a booster for missiles and spacecraft. Numerous other improvements in materials, construction, and design make the modern jet airplane unbelievably complex. One of the most obvious evidences of its growing complexity is the pilot's instrument panel, consisting of more than 150 dials and controls and built-in computer readouts.

d. Most of the innovations in airplane design during the 1930s first appeared on commercial airliners, but the military used the jet engine for almost 10 years before the commercial airlines accepted it. The military made fantastic advances in the application of jet propulsion to fighter and

**(J-14) pp 373-399
*(J-21A) pp R-21, R-24, R-38, R-44-45, R-49, R-62, 69, 71, 76-80, 88
**(J-24) pp 250-346
**(J-25) pp 98-99, 105-106, 108, 110-112, 121-123

bomber aircraft in the immediate postwar years. Since speed was more important than range and early jet engines consumed too much fuel for use on large bombers and transport planes, the military first used jet engines on fighter aircraft. Outstanding early American jet fighters were the F-80 Shooting Star, F-84 Thunderjet, F-86 Sabre, F-94 Starfire, F-89 Scorpion, and the F9F Cougar. These planes reached speeds of 550 to 700 miles per hour. In 1946, the Convair B-36 became the first American jet bomber when it added four turbojet engines for takeoff and combat. The first modern jet-propelled bomber came in 1947 with the flights of the XB-46, XB-48, and the six-engine B-47 Stratojet. These aircraft reached speeds over 600 miles per hour. The period from 1950 to 1960 saw the introduction of such supersonic jet fighters and bombers as the F-100 Supersabre, F-101 Voodoo, F-102 Deuce, F-104 Starfighter, F-105 Thunderchief, F-106 Delta Dart, and the F-4 Phantom. One revolutionary development in fighter aircraft was the F-111 with variable-sweep wings that can be adjusted during flight. This aircraft has two turbofan engines capable of speeds from 100 to 1,850 miles per hour. Our newest fighters, the F-14 and F-15, employ many new concepts also. The B-52 Stratofortress was an intercontinental jet that reached a maximum speed just below the sonic range. The first American supersonic bomber was the B-58 Hustler, capable of a maximum speed of 1,360 miles per hour at 35,000 feet. The latest American bomber is the swing-wing FB-111. Outstanding military transports to enter service between 1945 and 1971 were the C-110 Flying Boxcar, the C-124 Globemaster, C-130 Hercules, C-133 Cargomaster, KC-135 Stratotanker, C-141 Starlifter, and the C-5 Galaxy.

*(J-13) pp 22-40
*(J-21A) pp R-21-R-24, R-39-40
**(J-25) pp 84-86, 88-96

e. The modern commercial airliner represents the ultimate in passenger comfort. Passengers on early airliners endured the smell of aviation fuel, the roar of propellers, overcrowded seating arrangements. Transoceanic flights were unknown 40 years ago. Today, airline passengers cross the Atlantic Ocean in about six hours. A single airliner on one transcontinental flight can carry more people than made the same trip during the entire first year that transcontinental service was available. For almost 10 years following World War II, the United States dominated the world airline market with such outstanding airliners as the Douglas DC-6 and -7 series, the Boeing 377 Stratocruiser, the Lockheed Constellation, and the Super Constellation. The first jet airliner to enter commercial service was the De Havilland Comet in 1952. American designers compromised with the foremost turboprop aircraft of the day--the Lockheed Electra. The Boeing 707 was the first pure jet airliner to enter service in the United States. In later years, this airliner served as the basic design for a series of medium- and short-range jet airliners, such as the 727 and 737 series. Another revolutionary development in civil air transportation was the introduction of the so-called jumbo jet, the Boeing 747, which is the largest plane ever built entirely for commercial service. Great Britain, France, and the Soviet Union have concluded flight tests with supersonic transports capable of speeds above mach 2.

f. The modern rocket developed as the practical answer to a military need.

*(J-14) pp 396-397
**(J-21A) pp R-100-139
***(J-23A) pp 100-120
**(J-25) pp 160-183
*(J-44) pp 42-49
***(J-111) pp 116-201

The Air Force entered the long-distance missile field in 1944 with the JB jet-propelled guided bomb series modelled after the German V-1 used in World War II. These were subsonic winged missiles with slow cruising speeds. Other subsonic missiles in service between 1944 and 1960 were the Snark, Matador, and Mace. The next step in the development of American ICBMs was the Navaho, which provided the technological basis for such missiles as the Jupiter, Thor, Atlas, Hound Dog, and Minuteman. Further developments in ballistic missilery came with the assignment of Werner von Braun to the Hermes program and Operation Bumper, which led directly to the Redstone and Jupiter missiles. These missiles set the stage for an entire arsenal of short-, medium, and long-range missiles capable of carrying warheads to any point on the earth.

g. In addition to its use as a military weapon, the rocket has furnished power for magnificant achievements in the exploration of space. As a prelude to entering the space environment, scientists used sounding rockets to obtain information on the upper reaches of the earth's atmosphere and outer space. The Space Age began on 4 October 1957 when the Soviet Union launched the world's first artificial satellite, Sputnik I, followed in quick succession by Sputniks 2 and 3. The first orbiting US satellites were Explorer 1 and 2 launched in 1958. Following these initial flights, the United States achieved outstanding successes with a series of meteorological and communications satellites which transmitted pictures and scientific data millions of miles through

**(J-5) pp 133-147
**(J-8) pp 11-105
***(J-23A) pp 120-207
**(J-25) pp 186-247
*(J-44) pp 42-49, 74-145
***(J-105) pp 4-11 16-55, 56-71
***(J-111) pp 202-220

space to the earth. With more powerful rockets and sophisticated guidance systems, both the United States and the Soviet Union launched a series of interplanetary probes with unmanned spacecraft under the names of Luna, Ranger, Surveyor, Lunar Orbiter, Pioneer, and Mariner. From V-2 rockets to ballistic missiles, to sounding rockets, to unmanned spacecraft, the rocket advanced in power to the point that manned spaceflight became a reality. Manned spaceflight in the United States began with the organization of Project Mercury in 1958 and continued through a period of about 12 years with the Gemini experiments and finally the Apollo moon landings.

**(J-2) pp 398-404, 405-406
***(Flight) pp 145-176

h. In view of almost unlimited sources of engine and propulsive power, modern scientists recognize no absolute barriers to the further development of any type of flight. Even with the outstanding technological achievements represented by the X-15, the C-5 Galaxy, and the Boeing 747, an entire new generation of winged aircraft will probably become operational during the decade of the seventies. Improvements in turbojet propulsion systems now make it possible to build a family of relatively small subsonic airliners that will fly short hops of 200 to 1,000 miles in a period of one hour or less. In the not too distant duture, people may travel from city to city on a new generation of vertical flight aircraft that will take off and land (VTOL) like the helicopter. This aircraft will fly at a cruising speed between 350 and 500 miles per hour and then slow down and descend vertically. Private planes also will undergo revolutionary changes in power and design. It may be a small compact aircraft shaped like a thumbnail and powered with turbine engines. Capable of making short takeoffs or hovering near the ground, it could operate from small fields, downtown airports, or highways.

**(J-2) pp 409-412
**(J-8) pp 106-124
**(J-25) pp 214-249
*(J-44) pp 48-50, 146-178
**(J-64) pp 160-293
**(J-105) pp 72-77
***(J-111) pp 221-222

i. Space exploration offers almost infinite future possibilities. The decade of the seventies may see a shift in emphasis from experimental spaceflight control to the scientist and the laboratory. This will require a permanent space station in earth orbit capable of sustaining people for prolonged periods. The launching of a Skylab or Orbital Workshop will be the first step toward such a permanent station. Alternate crews of three men each will occupy the workshop during three different periods of 56 days each. From this program, scientists hope to obtain further information about man's physiological and psychological responses to the space environment and his ability to work in space. The ultimate goal is a permanent space station that will remain in orbit for 10 or more years. Such a station could serve as a national research center, a center for certain commercial activities, a base for launching missions to the moon and deeper space, and a supply, transfer, and assembly facility. To reach the station, space scientists and technicians will depend on a space shuttle between the earth and the station. With its capacity to takeoff, fly through the atmosphere, go into orbit, return to earth, and make a conventional landing, the space shuttle will be the first true aerospace vehicle. One design for the space shuttle system includes a rocket plane consisting of an orbiter and booster united piggy-back style.

The booster will separate from the orbiter at a height of about 40 miles above the earth and then return to earth and make a conventional landing. The orbiter will circle the earth for periods up to 30 days, return to earth and also make a conventional landing.

6. SUGGESTIONS FOR TEACHING:

a. You might find it desirable to introduce this learning phase with a comparison of modern aircraft with early aircraft, including the Wright Flyer, the Bleriot monoplane, the British Sopwith Camel, the Junkers and others. A display on one side of the classroom showing pictures of early aircraft and, on the other side, pictures of modern aircraft would be desirable. On the chalkboard, list the names of early aircraft and, under each aircraft, indicate the component or components that were added to make the aircraft more flyable. On another chalkboard, list the names of modern military and commercial aircraft and list or call attention to the components which have been added to the airplane since the early days. This will provide an opportunity not only to review aircraft innovations included in intervening chapters but also to discuss major aerodynamic and structural improvements in aircraft design since 1945. This approach can lead to a detailed discussion of outstanding military and commercial aircraft of the post-World War II period, the beginnings of the Space Age, present achievements in aviation and space, and future possibilities in aerospace.

b. For your most effective coverage of this learning phase, you will find it most helpful to make an extensive use of pictures (the more the better) of early airplanes and modern aerospace vehicles. You can arrange attractive displays on flannel boards, on bulletin boards, or across the top of chalkboards. You should not attempt to study modern aerospace vehicles in too much detail in this phase because other units provide comprehensive information in this area.

c. This learning phase provides an excellent opportunity to use resource speakers, such as space officials, airport employees, commercial airline pilots, military pilots, and others. Before their presentation, however, you should outline your objectives with them and indicate the desired scope of their lecture.

7. INSTRUCTIONAL AIDS:

a. SLIDES:

AFROTC 20 series - Revolution in Airlift: C-5A

AFROTC 22 series - USAF Aircraft

AFROTC 23 series - United States Missiles

AFROTC 46 series - Spaceflight

b. FILMS:

SFP 1215 Sonic Boom, 14 min., Color, 1963

SFP 1534 It's Everybody's Business, 22 min., Color, 1953

SFP 1697 The B-52: Vietnam, 38 min., Color, 1969

SFP 1768 C-5 Galaxy, 28 min., Color, 1969

AFIF 194 The Eagle Has Landed, 28 min., Color, 1969

TF-6177c F-111 Weapons System, 1971

FR-1234 The C-5 - What It Is, What It Does, 1971

McDonnell Douglas, St. Louis. "The Challenge," 1971.

8. PROJECTS:

If you are located near a modern airport or space facility, arrange a visit to observe modern aerospace vehicles in operation. Use the field trip to identify some of the latest additions and innovations in aircraft design, such as the engine, wings, fuselage, landing gear, etc.

9. FURTHER READING:

a. Becker, Beril. Dreams and Realities of the Conquest of the Skies. West Hanover, Massachusetts: Halliday Lithograph Corporation, 1967.

b. Cook, Alfred D. (ed.) Where Do We Go From the Moon? New York: Fairchild Publications, Inc., 1967, pp 123-162 (Paperback).

c. Davies, R. E. G. A History of the World's Airlines. New York: Oxford University Press, 1964.

d. Leinwoll, Stanley. Space Communications. New York: John F. Rider, Inc., 1964 (Paperback).

e. Miller, Ronald and Sawers, David. The Technical Development of Modern Aviation. London: Routledge and Kegan Paul, 1968.