DOCUMENT RESUME

ED 111 629 SE 017 466

TITLE Aircraft of Today. [Aerospace Education I. Instructor Handbook.]
INSTITUTION Air Univ., Maxwell AFB, Ala. Junior Reserve Office Training Corps.
PUB DATE [71]
NOTE 74p.; For the accompanying textbook, see ED 068 287

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

ABSTRACT

This publication is prepared to accompany the textbook entitled "Aircraft of Today," published in the Aerospace Education I series. The curriculum guide provides guidelines for teachers in terms of various concepts stressed in each chapter and suggested methodology for instruction. The subdivisions in the guidebook for each chapter include objectives, behavioral objectives, textbook outline, orientation, suggested key points, suggestions for teaching, instructional aids, projects, and further reading. Page references corresponding to the textbook are given where appropriate. (PS)

AIRCRAFT OF TODAY

PHASE I - FROM GOONEY BIRD TO GALAXY

This phase provides a historical approach to the field of military air transport, from the Douglas DC-3 or C-47 down to today's mammoth Lockheed C-5 Galaxy. Through this means, an attempt is made to arouse student interest in the values of functional aircraft design. Various aircraft are described and the functions and roles of each discussed in some detail. The concept of functional design is reinforced in the new revision by addition of a section on "performance and trade-offs."

1. PHASE I OBJECTIVES - Each student should:

   a. Be familiar with the history of the C-47 and its advantages for transport duty.

   b. Know in terms of payload, performance, and special uses some of the current military transports.

   c. Understand the principle of "payload" as it applies to military and commercial aircraft.

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

   a. Identify at least three characteristics which made the C-47 an effective transport during its long history of service.

   b. Compare the payloads of at least four modern military transport aircraft with the C-47.

   c. Explain the civilian and military definition of the term "payload."

3. TEXTBOOK OUTLINE:

   a. The C-47 Gooney Bird
      (1) First impact as airliner
      (2) Career as military transport
         (a) During WW II
         (b) Varied uses in modern times
      (3) Characteristics
   b. Postwar military air transport

(1) Some interim designs
    (a) C-119 Flying Boxcar
    (b) C-124 Globemaster
    (c) C-133 Cargomaster
    (d) CL-44
    (e) Guppy series
    (f) C-123 Provider
    (g) C-130 Hercules
(2) The Big Jets of the Military Airlift Command
    (a) C-135 Stratolifter
    (b) C-141 Starlifter
    (c) C-5A Galaxy

c. Performance and "trade offs"
   (1) In aircraft design
   (2) In flight planning

d. Definition of "payload"
   (1) Commercial
   (2) General aviation
   (3) Military

4. ORIENTATION:

a. Your first few classes are probably the most important student contact periods of all your years of teaching Aerospace Education. A dynamic, highly-motivational beginning is a must if you want to avoid losing student interest. The students' first impressions of the course and particularly of you as instructor and real-life person hang on the slender thread of what you say and what you do these first few hours. So treat each student as a partner in this serious business of cooperative learning. Let each youngster in your class know that you have a sincere interest in his success and in his personal and social needs and take the time to let him know what the course is all about, what he will see, and what will be expected of him. It may be worth your while to spend your first class period in a motivational discussion that will answer the students' questions, put them at ease with you, and develop feeling within each student's mind that he picked a winner when he signed up for Aerospace Education.

b. You may wonder why this unit begins by talking about a specific aircraft type instead of more basic concepts such as the principles of flight and basic aircraft parts (the subjects of Phases II and III). Writers since ancient times have felt that the best way to begin a story or play is in medias res--"in the middle of things"--then go back and explain, if necessary, what took place earlier. The same principle can apply to a course of instruction. Students, like audiences prefer to be "drawn in" to a subject. Before Chapter I ends, the student should be drawn from the specifics of transport airplanes to more basic concepts--functional design, "trade-offs" to achieve functional design, and payload. Perhaps this will make him more receptive to the still more basic concepts of the phases that follow.

5. SUGGESTED KEY POINTS:

a. Since the mid-1930's the Douglas DC-3 Skytrain or C-47 Gooney Bird has had a career of dependable service down to the present day.

*(J-77) pp 396-403
***(J-78) entire book

(1) The earliest commercial DC-3s carried 21 passengers and cruised at 170 mph. They were the ultimate in size, speed, and luxury for their day. More than any other single model of commercial airplane, they revolutionized aviation by getting the traveling public accustomed to air travel.

(2) As the C-47, the airplane also made history as a military transport in World War II, the Berlin airlift, and in numerous special tasks since then.

(3) Despite lack of speed and payload capacity, compared to modern cargo airplanes, old Gooney Birds keep flying because of their high-lift characteristics (due in great measure to a long wingspan), short takeoff abilities, and exceptional ruggedness and dependability.

*(J-11) pp 57-60
76-77, 81, 83,
88-89, 105-109

b. During and since WWII we have had a steady stream of new and improved transport airplanes, in the Air Force or serving Government missions.

(1) The C-119 was the first airplane designed as a military cargo plane, not an adaptation of a passenger airliner. It has a low-slung fuselage for easier loading, unloading and parachute exit, but still has the disadvantage of side-door loading.

(2) Giant reciprocating-engine and turboprop transports include the C-124 Globemaster, C-133 Cargomaster, CL-44 (Canadian), and the Guppy series flying missiles and boosters for NASA. All feature not only great interior volume but also large special door designs such as clamshell (C-124), rear ramp (C-133), swing tail (CL-44 and "Pregnant Guppy"), and swing nose ("Super Guppy").

(3) Medium-sized transports capable of negotiating short, rough landing fields and also equipped with rear-ramp loading are highly useful as tactical transports, serving the Army in and near battle zones. The C-123 Provider has seen much service in Vietnam as has the larger C-130 Hercules. These can unload by parachute extraction without landing. The C-130E, with extra fuel capacity, has long-distance capability.

c. Within the past decade, overseas US military airlift, the mission of the Military Airlift Command, has been almost completely converted to large jet aircraft.

(1) The C-135 Stratolifter, patterned after the commercial Boeing 707, served as interim general airlifter and still serves in special jobs such as the KC-135 tanker and the EC-135 command ship.

(2) The C-141 Starlifter has become the backbone of the MAC global

airlift fleet. It is a 500 mph turbofan with a low-slung rear-loading fuselage like that of the C-130.

(3) Newest and largest US military airlifter, largest airplane in the world, is the Lockheed C-5 Galaxy, which weighs 728,000 pounds fully loaded and can carry 265,000 pounds a distance of 2,875 miles or 100,000 pounds over 6,325 miles. Teaming with the C-141, a fleet of C-5s could airlift a whole army division to any point on the globe in a few days' time. The C-5 is a 500 mph jet with both front and rear loading ramps.

*(J-13) pp 82-113

d. What should be obvious from the descriptions of different transport aircraft is that improvements in aircraft design can only be "improvements" for a given purpose and are often achieved at the expense of reducing some other capability--such as sacrificing speed for payload capacity or vice versa. This is the principle of the "trade-off" (familiar to all fields of design engineering as well as aviation).

*(J-13) pp 82-88
*(J-89) pp 48-50

e. A definition of "payload" (boxed on page 17 of the textbook) in both commercial, general aviation, and military aviation, is desirable for understanding of other principles discussed in this chapter.

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. Pictures and models to stimulate interest and questions should be available. A model building project is another way of beginning with a high level of interest. It is best to start this project a week ahead of time and end it on the day you start the phase. Whatever the method of showing the class a given aircraft type--models, slides, or flat pictures--an old-fashioned session on aircraft recognition might be diverting. Flash the image before the class briefly to see who can be first to identify the aircraft. But remember that aircraft recognition alone is of little value in terms of the purposes of this unit. When a student can quickly distinguish between, for example, a C-119 and a C-123, then it is time to be sure that he knows the reasons why a C-123 looks different from a C-119. An insight into the principles of functional design is provided in such a way.

c. Comparison of large transport aircraft payloads with those of surface transportation will be constructive. Ships, trains, trucks, and river barges still move more goods cheaper, but airlift grows steadily more competitive.

d. The concept of functional design and the "trade offs" by which one capability is reduced for the sake of improving another is introduced here, but the student is not ready for technicalities yet. Later on he will learn, for example, that aspect ratio, camber, and sweepback of wings are related to the problem of speed versus lift. Here he need only be generally aware that there is a conflict in speed versus lift or speed versus shorter takeoff capability.

e. Student assignment: Read pages 1-17.

7. INSTRUCTIONAL AIDS:

a. SLIDES:

(1) SVA-20 Evolution in Airlift, C-5A

(2) SVA-22 USAF Aircraft

b. FILMS:

(1) FR 764 Impact of the C-5A on Logistics, 22 min., B&W, 1967

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

(3) SFP 1797 The Indispensables: KC-135 Air Refueling, 24 min., Color, 1970

(4) TF 6350 C-47 Armed Transport, 20 min., Color, 1970.

c. Aircraft models such as plastic models by Revel.

d. Pictures and charts of aircraft, trains, trucks, and ships showing load carrying capacity.

8. PROJECTS:

Model aircraft building contest. Pictures and aircraft models for room display.

9. FURTHER READING:

a. Taylor, John W. R. (Ed.) Jane's All the World's Aircraft, 1971-72. New York: McGraw-Hill. 1971 (or latest available edition; back numbers also useful for descriptions of older than currently manufactured aircraft).

b. Glines, Carroll V., and Mosely, Wendell F. The DC-3, The Story of a Fabulous Airplane. New York: J. B. Lippincott Co. 1965.

c. Check your school and community libraries.

PHASE II - SOME BASIC PRINCIPLES OF FLIGHT

This phase introduces simple, nontechnical aerodynamic principles related to flight and demonstrates how these principles relate to the functional design of aircraft. In the current revision, the discussion advances into certain aircraft performance factors and what they mean, introducing such concepts as cruising speed and service ceiling, and the special terminology applying to supersonic flight.

1. PHASE II OBJECTIVES - Each student should:

a. Know four forces that act upon an aircraft moving through the air.

b. Be familiar with the parts of an aircraft designed to react against air.

c. Be familiar with some of the principles of streamlining.

d. Know the meaning of "maximum cruising speed" and "service ceiling."

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

a. Define at least ~~three~~ forces that act upon an object in flight.

b. Identify the functions of two different airfoils.

c. Identify at least three different methods utilized in streamlining portions of a modern aircraft.

d. Define the terms cruising speed and service ceiling.

3. TEXTBOOK OUTLINE:

a. Thrust, weight, drag, and lift
   (1) Thrust--any force that moves an object through air or space
   (2) Drag--any force opposing thrust, more specifically, air pressure in front and partial vacuum behind
   (3) Weight--effect of gravity
   (4) Lift--upward force produced by action against airfoils

(5) Need for balance of the forces
(6) Relation to trade-off in aircraft design

b. Airfoils and aerodynamic forces
   (1) Wings for lift
   (2) Smaller airfoils for control
   (3) All operate by Newtonian principle of reaction
   (4) Airspeed related to relative wind
   (5) Lift according to Bernoulli's Law
   (6) Drag and principles of streamlining
      (a) Essential teardrop shape
      (b) Value of eliminating external structures
      (c) Special problems of high speed flight

c. Aircraft performance factors
   (1) Cruising speed, 75 percent or less of available horsepower
   (2) Ceiling and high-altitude performance
      (a) Value of high ceiling
      (b) Engine factors
      (c) Human factors (breathing equipment)

4. ORIENTATION:

After a first phase which plunges directly into a discussion of aircraft by types, this phase backtracks into basic concepts. It concerns the laws of aerodynamics that apply to all objects that move through the air. It should be used only as an introduction, because this subject is covered in more detail in AE-II. In this context of this unit, however, the introduction is not so much to a further study of aerodynamics as to a further study of aircraft types. Familiarity with the terminology and principles given here will make the study of aircraft types, both civil and military, more meaningful to the student. That is why a new section on aircraft performance factors has been added. In a later chapter, for example, the student will learn that two almost-identical general aviation aircraft can differ greatly in price because one has turbosupercharged engines and a cabin oxygen system, which the other lacks. Here the meaning of high-altitude capability <u>per se</u> is explained.

5. SUGGESTED KEY POINTS:

a. There are four forces which act upon an object moving through the air.

To put it simply, these are four directions--forward, backward, up, and down; more technically, respectively--thrust, drag, lift, and weight (or gravity).

(1) We have deliberately chosen a baseball as an example rather than one with airfoil surfaces, to make the point that all objects moving through air are subject to these forces, not merely those designed to take advantage of them.

(2) The four forces compensate for each other. It is wrong to think of thrust and lift as aiding flight and drag and gravity as opposing it. The four forces in balance keep an aircraft flying straight and level, at a constant rate of speed.

b. The parts of an aircraft designed to react against the forces of air (aerodynamic forces) are called airfoils--flat but gently curved surfaces, both fixed and movable, that provide the lift, stability, and control necessary for flight.

(1) Airfoils work on the Newtonian principle that for every action there is an equal and opposite reaction. The powerful rush of "relative wind" is needed to react against an airplane's airfoils. (Yet the gentle relative wind encountered by kites, gliders, and birds is also effective.)

(2) Because of the importance of understanding the effect of relative wind, it is also important to understand the concept of airspeed--the speed of an aircraft relative to air and the direction the latter is moving, not relative to the ground, which is groundspeed.

(a) Airspeed is a measure not only of movement but of aerodynamic forces acting on an aircraft.

(b) The Air Force prefers to measure airspeed in nautical miles per hour or "knots." Supersonic speeds are calculated in mach numbers (see box in text, p. 24, for other terms related to supersonic flight).

(3) Another very basic concept of aerodynamics is that of Bernoulli's Law--the faster the flow of a fluid, the lower its pressure. Wind flows faster over the curved upper surface of a wing than over its flat under surface, hence creating the dual effect of vacuum from above and impact pressure from below, both producing lift.

(4) Angle of attack is the angle of the wing with respect to relative wind. Another component of lift is the thrust of an aircraft engine aimed upward.

(5) The first principle of streamlining is that the less surface an object has to oppose movement through a fluid, the more easily a body moves.

(a) Aerodynamic design must compromise between keeping forms slender and permitting them enough bulk to function as airfoils or carriers. The teardrop shape is the most basic of such compromises.

(b) External structures such as struts, landing gear, exposed engines, etc. are permissible on light, low-performance aircraft but must be enclosed within streamlined pods or fairings or retracted entirely within the fuselage in higher-performance aircraft.

(c) In high speed jets, little things count. Rivet heads must be flushed; surfaces highly polished; heat-resistant metals used.

c. In considering descriptions of aircraft as presented later in this unit, certain aircraft performance factors and standards must be understood. Two which can be explained at this point are cruising speed and ceiling.

(1) Cruising speeds are those speeds at which an aircraft flies with reasonable efficiency. Maximum cruising speed is that speed at which the aircraft engine uses about 75 percent of available horsepower.

(2) An aircraft's absolute ceiling is the highest altitude at which it can fly at all. Its service ceiling is the highest at which it can climb still higher at a rate of 100 feet per minute. Three main factors govern the height of an aircraft ceiling.

(a) Aerodynamic design of the aircraft.

(b) Engine type and power--since engine breathes air.

(c) Whether or not the aircraft has oxygen breathing apparatus or cabin pressurization to permit human occupants to breathe at high altitudes.

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. Although aerodynamics is a big subject, and the smattering offered here hardly scratches the surface, a deeper penetration is not advised at this point. Keep the discussion oriented toward the application of aerodynamic principles to the design of aircraft. This subject will get fuller treatment in forthcoming phases of this unit, not to mention AE II. Keep it simple.

c. This material lends itself very well to lecture-discussion. After a lecture on the four forces affecting flight and their action on control surfaces, hopefully questions will arise spontaneously. If not, the teacher should devise his own questions to bring out the principles of flight.

d. This discussion lends itself to simple demonstrations. Those described in "Things to Do" on page 31 of the text can be accomplished with no more elaborate props than a few pieces of paper. Lightweight tissue, such as is used for typing carbons, works better than heavier grade paper for demonstrations 1 and 2. A heavier grade is preferred for paper airplanes. If more advanced or substantial models are to be used, try to motivate students to supply them. Some can make wooden gliders; others may own radi-controlled model airplanes.

e. In setting forth principles of streamlining, remember that these principles apply to cars, boats, and other vehicles with which the student may be more familiar then with airplanes. Transfer from the familiar to the unfamiliar wherever possible.

f. Student assignment: Read pages 19-31.

7. INSTRUCTIONAL AIDS:

a. FILMS: 191 FTA Basic Aircraft Control, 7 min, B&W, 1961.

b. OVERHEAD PROJECTOR TRANSPARENCIES:

(1) T-2 C-1, Gravity.

(2) T-3 A-4, Wing Structure.

(3) T-4 B-2, Tail Structure.

(4) T-5 A-6, Lift.

c. Models at discretion of instructor.

d. Paper airplane to demonstrate principles of flight.

8. PROJECTS:

Paper, wooden, or plastic aircraft model construction contest. The winner is the student whose design best demonstrates the basic forces that act upon an object in flight.

9. FURTHER READING:

Check your school and community libraries.

PHASE III - BASIC AIRCRAFT STRUCTURE, PARTS, AND SYSTEMS

This phase acquaints the student with the structural components, control systems, and instruments that are common to most types of aircraft. First, it identifies the major parts of an airplane and explains their position and function. Next, in a section that receives strong emphasis, it compares wing designs and explains the functional purpose of the designs. Hydraulic systems, electric power, and instruments and their functions are then treated.

I. PHASE III OBJECTIVES - Each student should:

a. Be familiar with the major structural parts of an aircraft.

b. Know the relationship between wing design and aircraft performance.

c. Understand some of the main uses of the hydraulic and electrical systems of an aircraft.

d. Understand the flight control instruments used on aircraft.

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

a. Identify and locate at least ten of the main structural parts of a fixed-wing aircraft.

b. Describe at least two wing shapes and explain how they affect aircraft performance.

c. Discuss at least two uses of electrical and hydraulic power in aircraft operations.

d. Give examples of the uses of at least three aircraft instruments.

3. TEXTBOOK OUTLINE:

a. Major Parts of an Airplane:
   (1) Miscellaneous (all parts other than flight-control airfoils):
      (a) Propeller.
      (b) Engine Cowl (or nacelle)..
      (c) Firewall.
      (d) Landing gear.
      (e) Wing Struts.
      (f) Wings (see below).
      (g) Fuselage

(2) Flight Control Airfoils:
  (a) Ailerons.
  (b) Empennage (including horizontal and vertical stabilizers, rudder, and elevators).
  (c) Auxiliary flight-control members (including landing flaps, trim tabs, spoilers, and speedbrakes).
(3) Wings:
  (a) Nature of crop-duster's wings--high aspect ratio.
  (b) Nature of supersonic wings--sweepback, low aspect ratio.
  (c) Wing design terms and factors--chord, camber, sweepback, aspect ratio.
  (d) The variable-sweep wing--F-111 and other airplanes.
  (e) The transonic zone and the supercritical wing--"critical mach," sound barrier (a new section in this revision).
(4) Control Systems and Instruments:
  (a) Hydraulic pressure.
  (b) Electric power.
  (c) Aircraft instruments.

4. ORIENTATION

a. This phase continues a general introduction to the aircraft, this time looking at its component parts. It follows very closely the theme of the preceding phase, especially in its discussions of airfoils and wings, which act according to the principles of flight previously discussed. This phase can be used as an introduction to material that will be covered in detail in AE-II. One more phase, on motors or propulsion units, will complete the orientation needed for further description of aircraft types.

5. SUGGESTED KEY POINTS:

**(J-47) Chap 6
***(J-13) PP 82-106
*(J-118) ~~PP~~ 139-174

a. An "exploded" diagram of a simple light airplane (textbook Fig. 15, p. 34) can serve the purpose of identifying the major parts of all airplanes, even advanced jets which bear little resemblance to the picture.

***(J-156) Chaps 4 and 5

b. The category "miscellaneous" can be used to include all parts of an airplane other than flight-control airfoils and wings. These include:

(1) Propeller (further discussed in next phase).
(2) Engine Cowl in front and firewall behind, housing the engine in a forward position on a typical single-engine airplane. Engines of multi-engine airplanes are housed in "nacelles."
(3) Landing gear to provide means of landing or takeoff run and absorb shock of touchdown. These are retractable on higher-performance aircraft.
(4) Wing struts--external supports for wings, found only on light, lower-performance airplanes.
(5) Fuselage, main body of the aircraft. The three basic types of construction are truss, using a framework of tubes or bars; monocoque, depending on outer shell or stressed skin; and semi-monocoque, in which the stressed skin is reinforced by longerons, stringers, and bulkheads, etc.

*(J-156) PP 14-15

c. Flight control airfoils serve to change or stabilize the <u>attitude</u> of an aircraft in flight. (In aerodynamic flight, a change of <u>attitude</u> means a change in <u>direction</u> of flight. This point is not made in this unit, but instructor should be aware of it; in space flight, attitude can be independent of direction. Do not mention this confusing fact unless a student brings it up.)

(1) Ailerons, on trailing edges of wings, provide a means of turning.
(2) Other flight control airfoils are usually grouped on the tail assembly or "empennage." These include:
   (a) Horizontal and vertical stabilizers.
   (b) Rudder to provide coordination during a turn.
   (c) Elevators are the main climb and descent airfoils.
   (d) Other flight control airfoils or combinations, not necessarily located on the empennage, can serve the same functions as the above. For example: ailerons on delta wings also functioning as

elevators (elevons), butterfly empennage in which elevator and rudder functions are combined; stabilators combining stabilizers and elevators.

(3) Auxiliary flight-control members include landing flaps, trim tabs, spoilers and occasionally speedbrakers.

d. Modern aircraft reflect the wide variety of their functions in the variety of shapes of their wings.

***(J-156) PP 44-45, 763-765

(1) The crop duster must fly slowly at low altitude and needs the utmost in lift for the sake of control. Its wing design deliberately strives for high lift and slow speed-maximum use of Bernoulli effect. Therefore, the wings are long and straight, and have thick camber (see below).

(2) Interceptor and other fighter-type aircraft, to achieve supersonic speed, have stubby or delta-shaped wings with low aspect ratio.

(3) Terms to understand for an understanding of wing design include:

(a) Chord--cross-sectional measurement front to rear. A tapering wing has a mean chord.

(b) Camber--ratio between chord and measurement of upper surface, reflecting amount of curve or bulge in a wing.

(c) Sweepback--backward slant of a wing, another streamlining factor decreasing both drag and lift.

(d) Aspect ratio--ratio between square of wingspan and area of wing. Long, narrow wings have a high aspect ratio (and high lift).

(4) Wing design provides the most striking example of the principle of "trade off" discussed in Phase 1.

(5) The variable-sweep wing is designed to provide one aircraft with both slow takeoff-and-landing and supersonic flight by changing the positions of the wings from straight out to full sweepback.

(a) The Air Force's F-111 and FB-111 employ this design concept.

(b) The Soviets have also developed swing-wing fighters, as have the French (mirage G). A West European fighter with this feature is under development. The Navy's carrier-borne F-14 fighter also has swing wings.

(6) Another new concept in wing design is the supercritical wing, under development by NASA. It is designed to ease the transition from subsonic to supersonic flight by reducing behind-the-wing turbulence. A flat wing top with a downward curve at the rear is the main feature of this design. <u>(This subject is new in the current revision.)</u>

e. Control systems and instruments, along with the hydraulic and electric power systems that operate them, are other essential systems in aircraft.

(J-156)

(1) Hydraulic principles are based on Blaise Pascal's discoveries on the effect of liquid pressure and how its force can be multiplied. In aircraft, this permits operation of movable airfoils and other controls by human muscle against the force of relative wind.

(2) Electricity produced by engine driven generators can also assist the pilot of operating controls, sometimes in conjunction with hydraulic systems. Other uses of electric power apply to engine operation and instruments.

**(J-13) PP 185-233
**(J-118) PP 244-280
***(J-156) PP 144-165

(3) Depending upon the size or complexity of an aircraft, instruments can be few or many. Instruments can be used to indicate engine conditions, flight conditions, or as a means of guidance of navigation. If they operate by transmitting or receiving automatic signals, they are called avionics.

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 students can attain the learning objective of this phase through a guided discussion. Many of them will be familiar, to a degree, with aircraft structure and parts and probably to a lesser degree with the hydraulic and electric systems and aircraft instruments. The discussion could lead from the less complicated light general aviation airplane like the Piper Cub or Comanche to the latest jet aircraft. Emphasize basic resemblances between these aircraft rather than differences. A model with movable controls would be helpful. Another possibility would be a large and clear chart or exploded diagram similar to Fig. 15 in the textbook but with the parts unlabeled. If such is not available, you can draw one or have a student with artistic ability draw one, on the chalkboard, or with "Magic Marker" on a large sheet of paper. This unlabeled diagram could be the basis of a fast oral part-recognition, similar to aircraft-recognition, session.

c. The comparison in the text between automobile instruments and aircraft instruments is good and can be elaborated on so that the student may gain a sound understanding of the importance of aircraft instruments to safe and efficient flight.

d. Student assignment: Read Pages 33-51.

7. INSTRUCTIONAL AIDS:

a. TRANSPARENCIES:

(1) T-1 Airplane Components.

(2) T-3 Wing Structure.

(3) T-4 Tail Structure.

(4) T-8 Airplane Roll, Pitch, and Yaw Axes.

(5) T-9 Operation of Elevators.

(6) T-10 Pilot Static System.

(7) T-11 Flight Instruments.

b. FILMS:

(1) TF 5688, RF-4C Familiarization, 14 min, color, 1966.

(2) SFP 1590, The F-111, 15 min, color, 1966.

(3) FR 982, B-52 Flaps Up Landing, 10 min, color, 1968.

8. PROJECTS:

Select a student or perhaps a group of students and have them make a study of the changing shape of aircraft wings from the Wright Brothers to the present time. Study should include reasons for changes, pictures, and diagrams.

9. FURTHER READING:

John W. R. Taylor, (ed.), Jane's All the World's Aircraft, New York: McGraw-Hill, latest available edition.

Check your school and community library.

PHASE IV - PROPULSION UNITS

This phase is an extension of the preceding phase. After considering the other components of an aircraft, the student now turns to the highly important component, the power unit--what makes it go--certainly deserving of separate treatment. Before specific engine types are considered, certain elemental propulsion principles are presented--the Newtonian principle of action and reaction, and the principle of internal combustion. Then propellers, reciprocating engines, jet engines, turboprops, and rocket engines are taken up in that order. The section on the rocket motor is expanded in this revision, not so much because of its importance to aviation as to provide an interesting base of comparison for a better understanding of air-breathing engines.

1. PHASE IV OBJECTIVES - Each student should:

   a. Be familiar with how Newton's Third Law applies to the production of thrust by aircraft propulsion units.

   b. Understand the operational cycle and cylinder arrangements of four-stroke reciprocating engines.

   c. Know the four parts of one operational cycle of a turbojet engine and understand their analogy to those of a reciprocating engine.

   d. Understand the advantages and disadvantages of rocket propulsion in aerospace.

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

   a. Given diagrams of reciprocating and turbojet engines, identify the two common factors that operate to provide thrust.

   b. Given a diagram of the four parts of an operational cycle of a reciprocating engine, explain the operation of each cycle.

   c. In the same manner, explain the operational cycle of a turbojet engine.

d. Explain at least two advantages and two disadvantages of rocket propulsion in aerospace.

3. TEXTBOOK OUTLINE:

a. Definition of "propulsion unit"--engine plus means of propulsion
b. Common Propulsion Principles
   (1) Newton's third law of motion
   (2) Internal combustion
c. Operation of propellers
   (1) Blade angle or pitch
   (2) Subsonic performance limits
d. Reciprocating engines
   (1) Principles of operation
      (a) Four cycles: intake, compression, ignition, and exhaust
      (b) Translation into turning motion, or torque
   (2) Types of reciprocating engine
      (a) Radial
      (b) In-line
      (c) Horizontally-opposed
   (3) Superchargers to increase altitude capability (new data)
e. Jet propulsion units
   (1) Basic principle of operation--same four cycles
      (a) Ramjet--no compressor, highest speed potential
      (b) Pulse jet--WWII "buzz bomb"
      (c) Turbojet types (with afterburner; turbofan)
   (3) Power rating by thrust pounds rather than hp
f. Turboprop propulsion units
   (1) Principles of operation
   (2) Uses in aviation
g. Rocket Motor--the X-15
   (1) Rocket applications to aviation
      (a) JATO
      (b) X-24
      (c) X-15
   (2) Principles of rocket motor operation
      (a) Contained oxidizer (no air)
      (b) Advantages and disadvantages

4. ORIENTATION

This is the last of the phases in this unit dealing with the basics of aircraft flight and aircraft components.

All students will know beforehand the essential differences between propeller-driven and jet aircraft in modern aviation. More insight on how these propulsion units function and their comparative advantages and disadvantages for different aviation tasks is provided in this phase. A former brief notation on rocket motors has been expanded in this revision to underscore by comparison the functions and advantages of air-breathing engines in general.

5. SUGGESTED KEY POINTS:

a. An aircraft unit includes an engine together with the means of propulsion. Reciprocating or turboprop engine plus propeller, for example; or jet engine plus rear nozzle for producing reactive forces.

b. All aircraft propulsion units have two things in common:

(1) Operation according to Newton's Third Law--action equals reaction, whether the unit is a jet directly hurling a mass of gas rearward creating equal forward thrust, or a propeller unit hurling the ambient air rearward for the same effect.

(2) Internal combustion. All thrust is generated by heating and expansion of gas <u>inside</u> the engine, due to combustion of fuel and oxygen, whether inside the cylinder of a reciprocating engine or the combustion chamber of a jet engine, or a rocket engine (in which case the oxygen is carried internally and not drawn in from the outside).

c. A propeller is a curved airfoil, acting in the air somewhat like a screw.

(1) Except for the simplest types, propellers function differently

according to the way their pitch is adjusted, pitch being the angle at which the blade attacks the air.

(2) Performance limits of propeller-driven aircraft are determined by the fact that the blade tip cannot move at supersonic speed, hence airspeed must be still lower. Theoretical speed limits are under 500 mph. Altitude limits are also lower than those of jets.

d. Reciprocating engines work "back and forth" (Latin, reciprocus)--the action of piston in cylinder as it revolves.

***(J-2) pp 169-199
**(J-5) pp 38-45
***(J-131) pp 3-15
**(J-156) pp 63-67, 74

(1) Most aviation engines have four cycle engines, going through four basic movements or strokes:

(a) Intake--piston pulls back and draws in air and fuel vapor.

(b) Compression--piston pushes forward and squeezes gas-vapor mixture.

(c) Power--mixture is ignited and expands with force to push piston back.

(d) Exhaust--piston pushes forward again to clear cylinder of waste gas.

(2) Types of reciprocating engines include--

(a) Radial--odd number of cylinders arranged in circle around crankshaft. Majority of transports, bombers, and other high-performance aircraft during heyday of reciprocating engine had this type. Up to 3,800 horsepower.

(b) In-line engines were featured in high-speed fighters of WWII like Mustang and Spitfire. These engines adapt well to streamlining.

(c) Horizontally opposed engines are light and economical--tye type favored today since modern reciprocating engines are best suited for lighter aviation in under-500 hp class.

(3) Reciprocating engines have a limited ceiling, which can be extended by use of a device called a "supercharger" (most efficient type is "turbo-supercharger," which increases air intake.

***(J-2) pp 200-219
**(J-5) pp 45-51
**(J-23F) pp 7-27
***(J-131) pp 405-476
*(J-156) pp 93, 101-105

e. Jet propulsion units really have the same four cycles as reciprocating engines--intake, compression, combustion, and exhaust. The difference is that they take place in four different parts of the engine, and the exhaust provides the main thrusting force.

(1) The ramjet engine is the simplest because it has no compression mechanism. It achieves air/fuel compression by scooping in air on the run; therefore, it cannot be used on takeoff or launch because the vehicle must be already moving by other means before the ramjet can operate.

(a) Ramjets nevertheless achieve great speed and efficiency at high speed and high altitude. Used on Bomarc missile, can achieve 100,000 feet at mach 3.

(b) Future ramjets or scramjets (supersonic combustion ramjets) might be key to ultraspeed transportation in aerospace.

(2) The pulse jet is an historical curiosity, the propulsion means of the German V-1 "buzz bomb" of World War II. It achieved intake and compression by alternate opening and closing of a shutter.

(3). The turbojet engine is the basic jet engine of today. It achieves compression by means of a turbine, which can be started and run up by electricity, then turned by the engine itself once it gets going. Thrust is purely by hot exhaust from the combustion chamber. Variants are:

(a) Turbojet with afterburner, providing extra thrust by injecting and igniting fuel in exhaust channel behind main combustion chamber.

(b) Turbofan--preferred today on most airliners and other heavier jet aircraft, and some fighters. An additional turbine turns a powerful ducted fan which provides thrust from air not going through combustion. Somewhat similar in principle to turboprop but fan is enclosed.

(4) Engineers prefer to rate jet engine power in pounds of thrust rather than horsepower. This accounts for variations in efficiency with speed. Horsepower equals pounds of thrust at one speed--375 mph. An F-4c fighter weighing 58,000 pounds has a total thrust of 34,000 pounds and can achieve more than mach 2 speed. A C-5A Galaxy has a power plant totaling 165,000 pounds of thrust and, at lower speed, can lift 728,000 pounds.

*(J-156) pp 106-07

f. Turboprop propulsion units use a turbine engine similar to a jet engine to turn a propeller.

(1) Reduction gears around the drive shaft hold the propeller tips to subsonic speed.

(2) Most of the energy is used up turning the propeller. Very little is left for jet propulsion.

(3) Turboprops are especially efficient for cargo aircraft.

***(J-156) pp 542-49

g. Rockets can be mentioned in an aviation context because of certain applications (also because points of comparison with air-breathing engines may be instructive).

(1) Aviation applications include JATO (jet-assist takeoff) to shorten takeoff run of conventional airplanes by providing additional thrust; the X-24 lifting body for research into controlled landing of spacecraft; and the recently-retired X-15 program for varied scientific research. The rocket-powered X-15 reached altitude of 67 miles and a speed of 4,543 mph.

(2) Rocket motors differ from jet engines in that they use no oxygen from the surrounding atmosphere. This permits operation in space. On the other hand, it requires a great increase in weight, since the required weight of oxygen is much greater than that of the fuel. Another disadvantage for aviation purposes is the rapid expenditure of propellants needed to achieve rocket thrust. For the present, air-breathing engines will serve the needs of aviation best.

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 material in this phase can be covered briefly but adequately by using the lecture method. This is introductory material for the subject of the AE-II unit, Propulsion Systems for Aircraft, but in this unit it sets the stage for consideration of aircraft types. The very next phase, on general aviation aircraft, will include reciprocating, turboprop, and jet types.

c. Simple points that are persistently difficult for some students should be stressed in discussion. One is Newton's third law, since many think of jet action as that of escaping gas "pushing" against outside air. This is one good reason for getting ahead of the story and mentioning rocket engines in space, where the engine has nothing to push against. A reciprocating engine, too, operates on the expansion of a "mass of gas" moving within a cylinder against piston walls and a piston.

d. Any model or instructional aid available will be helpful. We suggest the use of all available transparencies on aircraft engines and rocket engines.

7. INSTRUCTIONAL AIDS:

a. FILMS:

(1) TF 1-5364 An Introduction to Jet Engines, 13 min., Color, 1960.

(2) NASA: HQ 79 Research Project X-15, 27 min., Color, 1966.

(3) NASA: HQ 175 Flight Without Wings (lifting body), 14½ min., Color, 1969.

b. TRANSPARENCIES:

(1) T-20 Engine Cylinder Piston Diagram

(2) T-38 Turbojet and Ramjet Engines

(3) T-39 Rocket Engines.

8. PROJECTS

a. For a special project or independent study, a student or a group of students can compare the operation of a four-stroke reciprocating engine to a particular type of jet propulsion unit. This can take the form of either a research paper or oral report.

b. See "Things to Do," textbook page 73.

9. FURTHER READING

a. Taylor, John W. R. (Ed.) Jane's All the World's Aircraft (see separate section on engines--by nation). McGraw-Hill, latest available edition.

b. Check your school and community libraries.

PHASE V - GENERAL AVIATION AIRCRAFT

"General aviation" is a broad category which includes practically all aviation other than military or airline aviation. This chapter is an introduction, then, to the world of civilian flying and the simpler types of airplanes. General and statistical facts about the field of general aviation--production, airport availability, and training requirements--before taking up specific aircraft types from single-engine two-passenger up to turboprop and jet corporation planes.

This phase is brief but somewhat expanded in comparison with the discussion of general aviation in previous editions of this unit. It includes only general aviation where the previous Phase V included both general and commercial aviation.

1. PHASE V OBJECTIVES - Each student should:

a. Understand the size and relationships of the various aspects of general aviation.

b. Know the various types of aircraft used in general aviation in the United States.

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

a. Construct a table on general aviation, showing such items as: number of aircraft in use; number of qualified pilots; number of available airports (different classes); annual aircraft production and average price. Add to this table your estimates for a period 10 years from now.

b. Describe at least four examples of general aviation aircraft showing how they vary in size, equipment, and price.

3. TEXTBOOK OUTLINE

a. Introduction--definition of "general aviation"
b. Some Facts, Figures, and Trends
  (1) Number of pilot licenses, AOPA members, and aircraft

(2) Aircraft production and prices
(3) Airport availability
(a) Number of airports of different sizes in U.S.
(b) Relation to convenience of private vs. commercial-airline flying
(c) Relation to takeoff and landing performance of aircraft of different weights
(4) Training requirements
(a) For visual flying
(b) For instrument flying
(c) Trend toward instrument flying

c. Some Representative Types
(1) Single reciprocating-engine airplanes. Examples:
(a) Piper Cherokee
(b) Beechcraft Bonanza
(2) Twin reciprocating-engine airplanes: Examples:
(a) Cessna Skymaster (O-2 Air Force version)
(b) Piper Turbo-Aztec
(3) Heavier general aviation aircraft
(a) Uses: light cargo; "flying conference room"
(b) Reciprocating engine types
(c) Turboprop types. Examples: Beechcraft King Air 100
(d) Jet. Examples: Learjet, Beechcraft-Hawker 125

4. ORIENTATION

a. Consideration of aircraft by types picks up from Phase I. Here the lightest and simplest airplanes are considered, and study of preceding phases should prepare the student to evaluate them in terms of performance. This is the only phase in which aircraft types are listed with price tags, for comparative purposes, so student will know something about relation to performance. For example, instead of thinking of the comparative costs of such-and-such features on an aircraft, such as twin engines, turbosuperchargers, and breathing apparatus or pressurization; the student should consider the need for reliability (twin engines), the desirability of a service ceiling of 30,000 feet (avoiding bad weather), the means of achieving a service ceiling of 30,000 feet (turbosuperchargers), and the minimal need for breathing tanks as well as the comfort factor in pressurization. All these factors tie in with previous phases.

b. Broad statements about general aviation provide another important insight of this unit--function and employment rather than mere identification of different types of aircraft.

5. SUGGESTED KEY POINTS

**(J-156) pp 754-66
*(J-21 C) pp 245-46

a. General aviation is a term meaning practically all aviation other than airline and military aviation. As a class of aircraft types, it includes civil aircraft smaller and lighter than commercial passenger or cargo planes.

b. General aviation aircraft constitute the heavy majority of aircraft flown by licensed pilots in the United States (500,000 including students). There are about 100,000 general aviation aircraft in the nation, 50,000 of which are classed as "personal."

(1) Annual production of aircraft rose from 7,000 in 1960 to over 12,000 in 1969. Average price in this period rose from $19,000 to $47,000 (due to emphasis on business more than sport flying, rather than merely inflation).

(2) There are 10,000 airports available to light general aviation aircraft as compared to fewer than 50 capable of taking major airliners.

(a) This fact indicates an advantage for private flying. The slower airspeeds are offset by convenience of one's own scheduling, direct routing, and freedom from surface and air congestion.

(b) The matter of airport availability is directly related to the superior STOL capability of lighter aircraft.

(3) Modern private flying, however, demands increasing skill of the pilot. The emphasis is on business rather than pleasure flying and this entails a need for all-weather capability and a pilot's mastery of instruments.

**(J-21 C)
**(J-13) pp 286-375

c. Although general aviation includes many special-purpose aircraft, representative types here are limited to enclosed-cabin passenger monoplanes of varying weights and performance capabilities. Prices as of 1970 are quoted for a general idea of how cost relates to capacity and performance.

(1) Single reciprocating engine

(a) Piper Cherokee 140, 2-3 passenger, 150 hp, 142 mph, service ceiling 14,300 ft, useful load 937 pounds, $10,400.

(b) Beechcraft A-36 Bonanza, 285 hp 4-6 passenger, useful load 1,580 pounds, cruise 167-195 mph; 16,000 ft ceiling. $45,550.

(2) Twin reciprocating engine

(a) Cessna Skymaster (Air Force 0-2 observation plane), 2/210 hp engines, cruise 190 mph, ceiling 19,500, takeoff over 50 foot obstacle 1,545 feet; useful load (civ.), 1,745 pounds. $50,000.

(b) Piper Turbo-Aztec. Twin turbo-supercharged 250 hp each; 6 seats, useful load 2,145 pounds, takeoff over 50 feet in 1,250 feet, cruise at 230 mph plus, ceiling 30,000 feet. Oxygen tanks, $75,000.

(c) Cessna Golden Eagle and Beechcraft Duke have similar capabilities but have pressurized cabins, raising price to more than $150,000.

(3) Heavier general aviation (over 2,000 pounds useful load; some have separate crew compartments).

(a) Reciprocating powered models are best for economy, have good takeoff and landing capability.

(b) Turboprops have more speed and lifting power while retaining good STOL capability. Example is Beechcraft King Air 100, 250 mph, seats up to 15, pressurized cabin, $600,000.

(c) Jets provide over 500 mph speed. Eight or more passengers, prices from $800,000 to over a million. Some corporations buy private airliners at higher cost.

UPDATE DATA. (no mention in text) Cessna Citation is an 8-passenger jet for only $600,000--competitively priced because limited performance, 400 mph top speed!

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d. There are almost 3,000 specimens of home-built aircraft flying in the United States. An extremely light single seater with a 40 hp Volkswagen engine and a speed of 70 mph can be built for $1,000. Four seaters of greater performance may cost in excess of $4,000 to build. Time required for the project runs from 500 to 1,000 man-hours. Home built or club built gliders and sailplanes are also popular.

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. This phase can be presented in class adequately by the lecture method. The material should be presented as an introduction to general aviation, to be further developed in this course in the unit The Aerospace Age and next year in Civil Aviation and Facilities. The background is still desirable here as an understanding of the functions of the aircraft types described.

c. Since available slides, transparencies, and films give little support to this phase, teacher and students will have to dig up their own illustrative materials. This should be easy. Current aviation magazines, both advertising and editorial matter, abound in pictures of the current crop of general aviation aircraft. Brochures from manufacturers are also useful. Flashing pictures at the class for rapid identification of general types and features of aircraft should provide a lively interlude. (Do not expect the class to identify aircraft by make and model. Engine recognition, introduced in Phase V, is more to the point.)

d. Both teacher and students should be especially alert to find examples of new aircraft or new modifications since the unit textbook was published.

e. Student assignment: read pages 75-85.

7. INSTRUCTIONAL AIDS:

a. Charts, posters, etc., of related information from aircraft companies. Some aviation magazines carry performance charts on new general-aviation aircraft.

8. PROJECTS:

a. A group of students can visit a local airport and report on its role in general aviation. In a large metropolitan area there will be airports devoted entirely to general aviation and others at which both general aviation and airlines will share the facilities. Both types are of interest; although a more elaborate project would be more appropriate for the forthcoming unit, The Aerospace Age, or next year's unit, Civil Aviation and Facilities. This one should be kept simple.

b. General aviation as a career field is a good, motivational topic for a student report. References accompanying key points, above, are helpful.

c. Invite an experienced general-aviation charter pilot, instructor, or businessman-pilot to speak on the advantages and problems of flying. There may also be an amateur aircraft builder in your area worth hearing from.

9. FURTHER READING:

a. Taylor, John W. R. (Ed.) Jane's All the World's Aircraft. McGraw-Hill, latest available edition.

b. Check your school and community libraries.

PHASE VI - COMMERCIAL AIRLINE AIRCRAFT

This phase takes up aircraft used in commercial aviation. Although it begins with a brief section on commercial cargo aircraft, the emphasis is on jet passenger liners, which have taken over the great majority of intercity as well as long distance passenger air traffic. Greatly expanded over the previous treatment of this subject (formerly included in phase V but now a phase in itself), the discussion includes three main types of jet passenger airplanes, designed for different segments of the passenger trade. A concluding section discusses the future of the supersonic transport and some of its problems.

1. PHASE VI OBJECTIVES - Each student should:

   a. Understand the service that cargo type aircraft can offer the civil market.

   b. Know the current types of passenger jet aircraft.

   c. Know some of the characteristics of supersonic transport aircraft.

   d. Know some of the problems connected with SST development.

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

   a. Explain how aircraft especially designed for cargo rather than passenger carrying can serve the civil market.

   b. List at least three current types of passenger jet aircraft and the principal functions of each.

   c. Describe the British-French and American versions of the SST.

   d. State at least two of the problems connected with SST development.

3. TEXTBOOK OUTLINE:

   a. Commercial cargo aircraft

(1) If specially adapted, follow military designs
(2) Large types for outsize cargo ability
(3) Smaller types with STOL for point-to-point service

b. Commercial Passenger Aircraft
(1) Currently made by 10 companies
(2) Standard Large, Long-Range
(a) Boeing 707
(b) McDonnell Douglas DC-8
(c) Foreign types (British BAC VC-10 Comet; Soviet Ilyushin IL-62)
(3) Standard Medium-to-Short Range
(a) Importance in service to smaller communities
(b) Foreign makes: Fokker, Hawker-Siddeley, Sud Aviation; Dassault, Tupolev
(c) Douglas DC-9 (C-9)
(d) Boeing 727, 737, and stretched 727
(4) Jumbojets and Airbuses
(a) Long-range and short-range service
(b) Boeing 747
(c) McDonnell-Douglas DC-10
(d) Lockheed Tri-Star L-1011
(e) Sud Aviation-Deutsche Airbus A-300

c. The Supersonic Transport (SST) Controversy
(1) Status in different countries
(a) British-French Concorde
(b) Soviet TU-144
(c) Boeing SST (projected specifications, cancellation)
(2) Development Problems and Achievements
(a) Military fighters--supersonic "dash"
(b) B-58 and XB-70--toward supersonic cruise
(3) Pros and Cons
(a) Con arguments: lack of real need, sonic boom, pollution
(b) Pro arguments: Competitive advantage, national morale, national aerospace capability
(4) The Sonic Boom
(a) Factors, especially altitude
(b) Effect of minimum-altitude regulations

4. ORIENTATION:

a. With separate phases devoted to general aviation and commercial aviation, the civil side of aviation gets proper emphasis in this revised and expanded unit. Other units such as The Aerospace Age and next year's Civil Aviation and Facilities will expand upon the subject. Note, however, that in this discussion we again try to do more than consider airplanes as hardware but point out the social impact of their employment. The lighter passenger jets, for example, have brought jet air transportation to smaller cities. Jumbojets in their "airbus" configuration may help solve inter-city traffic problems and also lower fares on international and other long-distance routes.

5. SUGGESTED KEY POINTS:

a. Commercial cargo aircraft are essentially no different from military transport aircraft discussed in Chapter 1, or are adapted from passenger models. Civil versions of military airlifters such as C-130 have good cargo-handling capability. Civil versions of C-141 and C-5 (L-500) are expected in future. Outsize cargo capability of "Guppy" series is finding many commercial uses. Smaller freighters of good STOL capability are desired for direct deliveries to factories, mines, and construction sites.

b. Commercial passenger aircraft still include many propeller-driven types, but here we shall consider three main types of jet passenger liners. Currently there are 10 private or government firms in the world that make them: 1-3--Boeing, Lockheed, and McDonnell-Douglas of US; 4-5--BAC and Hawker-Siddeley in UK; 6--Fokker of Netherlands; 7-8--Dassault and Sud Aviation of France; 9-10--Ilyushin and Tupolev of Soviet Union. The three types are:

(1) Standard large, long-range

(a) Boeing 707 (707-320B), (Air Force VC-137), 120 passengers in mixed class, maximum weight 312,000 pounds, 72,000-tp turbofan power plant, 600 mph.

same general dimensions and capabilities as 707. Trader model has movable bulkhead dividing passenger-freight compartments.

(c) Foreign types include BAC's VC-10 Comet, somewhat larger and more powerful than 707; Soviet's IL-62 is also somewhat larger.

(2) Standard Medium- to Short-Range

(a) This type, seating less than 100 passengers, has seem much growth in recent years, opening up more and more airports of smaller cities to jet traffic.

(b) Foreign firms are heavy competitors in this class. Types include Fokker of Netherlands F-28 Fellowship; Hawker-Siddeley's Trident; Sud Aviation's Caravelle; Dassault Mercure; Tupolev Tu-124.

(c) US models are McDonnell-Douglas DC-9, seating 80 to 90, with a maximum takeoff weight of 108,000 pounds, (AF uses C-9 hospital plane version); Boeing 727, somewhat larger tri-jet, carries 94 in mixed class seating, 134 all coach. A stretched 727 really belongs in large class; 737 is a smaller twin jet.

(3) Jumbojets and Airbuses--new class of giants

(a) Boeing 747 is largest commercial plane and second largest and heaviest plane after C-5 Galaxy. It seats over 300 in mixed class and up to 495 all economy.

(b) Other large jumbojet or "airbus" types flying or under development are: McDonell-Douglas DC-10; Lockheed Tri-Star L-1011, and the European Sud Aviation and Deutsche Airbus A-300. All will have engines of 40,000 or more pounds of thrust each.

(c) The new class of giant aircraft will provide two types of transportation--as roomy, luxurious transoceanic liners, and as "airbuses" of large passenger capacity in all-economy class. The latter will provide low-cost transoceanic flying and also serve on short high-density city-to-city runs.

c. The Supersonic transport (SST) has been a matter of hot controversy in recent times. The US version by Boeing is cancelled* but the British-French Concorde and the Soviet Tupolev-144 are nearing operational status.

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*Update note: Textbook footnote on p. 101 notes Congressional rejection of SST funding in March 1971. Since then, fate of SST was virtually sealed when Boeing officials themselves demurred another effort by friendly congressmen to revive the project, stating that cost of reestablishing the project after cancellation would far exceed the amount offered.

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(1) Foreign versions of SST are smaller and slower (120 passengers, mach 2) than Boeing ~~SST~~ as planned.

(2) Plans for Boeing SST were: length 280 ft.; wingspan, 142 ft.; capacity 350 passengers; cruise at mach 2.7 (1800 mph). Four engines of 67,000

pounds each would add up to most powerful engines and greatest total power plant in aviation history.

(3) Supersonic development in past has been all military

(a) Military supersonic planes have been light and have been short-range "supersonic dash" capability (long-range cruise, if at all, is subsonic).

(b) B-58 flew oceans supersonically with refueling. XB-70 had supersonic cruise but, despite 500,000 pound maximum takeoff weight, lacked payload capacity.

(4) Three presidents--Kennedy, Johnson, and Nixon, have backed the SST, but have had to fight opposition all the way.

(a) Arguments against it include question of need for this luxury in terms of general economy, as indicated by lack of industry's ability to foot the bill itself; sonic boom, pollution, airport noise, and other atmospheric disturbances.

(b) Pro arguments are that SST will lead competition on basis of passenger preference regardless of "need;" foreign SSTs will profit if we don't; nation's leadership in aerospace technology will suffer from lack of support.

(5) Question of sonic boom deserves special attention. Regulations forcing SSTs to fly at high altitude would probably alleviate problem,

but question of economy and convenience of requiring SSTs to hold to subsonic speed before reaching required altitude is still unsettled. There is also question of engine noise at airports. Is it worse than that of present-day subsonic jumbojets?

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. This phase lends itself well to the lecture-discussion technique. Indeed, it has more meat for discussion than other phases because it deals with controversial topics. A classroom debate is a natural for the SST topic. Note above, behavioral objective b. There are other controversial topics suggested by topics in this phase. The textbook does not explore these, but the instructor need not feel squamish about bringing them up or at least letting students bring them up. Teacher should, of course, maintain his own objectivity and let students explore the pro's and con's of issues concerning commercial aviation. The alert teacher can serve as referee and should be capable of bringing the discussion back to the facts if it strays too far from them. Aside from the SST, such issues include the financial troubles surrounding the Lockheed L-1011 and its Rolls Royce engines, and the problems of declining passenger traffic in the face of new airbus development.

c. Students can present written or oral reports on either airline or aircraft companies. The press is full of details on new developments in the field. Brochures and other literature can be obtained through public-relations or advertising divisions of companies.

d. Student assignment, read pp. 89-107.

7. INSTRUCTIONAL AIDS:

a. Maps, charts, posters, etc., of relevant information from airline companies and aircraft industries.

8. PROJECTS:

a. Another group airport visit (see Projects, Phase V) can be made, this time with emphasis on commercial aviation and facilities.

b. Invite a representative of commercial aviation to speak on the relative merits of jet passenger aircraft of different types.

9. FURTHER READING:

a. Taylor, John W. R. (Ed.) Jane's All the World's Aircraft. McGraw-Hill, latest available edition.

b. Check your school and community libraries.

PHASE VII - AIR FORCE AIRCRAFT

This phase acquaints the student with the variety of tasks which aircraft perform in the Air Force, and some of the design features which adapt aircraft to these tasks. Some of these aircraft have been mentioned in previous phases. Here the emphasis is on function in terms of commands and their missions. A section is devoted to each of five Air Force commands which are principal aircraft users, and describes the particular aircraft it uses.

1. PHASE VII OBJECTIVES - Each student should:

a. Know the Air Force commands that are the principal users of aircraft.

b. Know the relationship between the design of principal Air Force aircraft types and the missions of the commands which employ them.

c. Understand the categories and designation codes of military aircraft.

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

a. Name at least four Air Force commands that are principal users of military aircraft.

b. Outline the mission of at least three Air Force commands that are principal users of military aircraft.

c. Explain the letter and number designations of at least five Air Force aircraft.

3. TEXTBOOK OUTLINE:

a. Functional character of Air Force aviation
   (1) "Systems" rather than "aircraft
   (2) Adapted to missions of five primary using commands
b. ATC Trainers
   (1) Undergraduate Pilot Training (UPT) program
      (a) Primary Cessna T-41 (propeller)
      (b) Basic jet Cessna T-37 (subsonic)
      (c) Advanced jet Northrop T-38 (supersonic)

(2) Navigation training (T-29 Flying Classroom)

c. Tactical Warriors
  (1) Theater nature of tactical warfare
  (2) Missions of tactical airpower
    (a) Counterair
    (b) Interdiction
    (c) Close support
    (d) Reconnaissance and observation
    (e) Airlift

d. Supersonic fighter and reconnaissance aircraft
  (1) Definition of "fighter"--air-to-air capability and supersonic speed
  (2) Fighter types: F-100, F-105, F-4, F-111, F-15
  (3) Reconnaissance airplanes adapted from fighter (RF-4)
  (4) Subsonic attack, observation, special
    (a) Subsonic jets: A-7D, A-37, EB-66, B-57, A-X
    (b) Propeller-driven: A-1E, AC-47, AC-130, AC-119, O-1, O-2, U-10, OV-10

e. ADC Interceptor and Warning aircraft
  (1) Mission of ADC
  (2) Fighter interceptors
    (a) Types--the F-106, YF-12
    (b) Fighter operations (value of manned interceptor)
  (3) Early Warning and AWACS
    (a) C-131 Warning Star and operations
    (b) AWACS concept and operations

f. The SAC Global Fleet
  (1) Bombers
    (a) B-52
    (b) FB-111
    (c) B-1 concept and operations
  (2) Other SAC aircraft
    (a) SR-71 reconnaissance
    (b) KC-135, tanker and command post

g. MAC Technical Specialists
  (1) Hospital ships--C-141 and C-9
  (2) ARRS aircraft
    (a) Helicopters--HH-3 and HH-53
    (b) Fixed-wing--HC-97, U-16, HC-130
  (3) Photomapping--RC-130
  (4) Weather--WB-57, WC-135, WC-130

h. Designator codes (box on p. 138).

4. ORIENTATION:

a. This phase is tied directly to the first phase of this unit, which deals with military air transport. It also is related to parts of another unit, The Aerospace Age. In next year's curriculum, the unit Military Aerospace will provide more detailed coverage of the employment of aircraft in war, which is introduced in this phase. The theme reiterated throughout this unit is especially stressed in this phase--that aircraft design follows aircraft function and aircraft function follows command mission.

5. SUGGESTED KEY POINTS:

**(J-156) pp 739-43
**(J-25) pp 97-124
*(J-24) pp 319-46
*(J-76) pp 187-309
***(J-21 C)

a. The most advanced aviation technology is in the field of military aviation. Each aircraft is designed for its mission in every respect; hence the term "system" is preferred to "aircraft" to describe the aircraft and all its weapons and controls. Virtually all types are found in the aircraft systems used by five principal using Air Force commands.

b. The Air Training Command (ATC) is the principal user of training aircraft.

(1) In the Undergraduate Pilot Training Program (UPT), three aircraft are used.

(a) Only 30 hours are spent behind a propeller in a simple Cessna T-41.

(b) The Cessna T-37 is a light twin jet with a speed of 350 mph; the trainee has 90 hours in this aircraft.

(c) The Northrop T-38 provides 120 hours of UPT. It can reach 55,000 feet or a speed of 850 mph (mach 1.2).

(2) Navigation training is provided in the T-29, a propeller-driven transport fitted with multiple sets of navigation instruments.

c. The Tactical Air Command (TAC), along with overseas commands, uses a wide variety of aircraft for limited warfare in a geographic zone of action called a "theater."

(1) The five missions of tactical airpower are:

(a) Counterair--including both air defense and efforts to destroy enemy airpower on the ground.

(b) Interdiction--deep strikes behind enemy lines to cut off supply and communication lines to the battlefield. Both counterair and interdiction missions call for supersonic fighters because targets are well defended and enemy fighters may be encountered.

(c) Close support--backing up the firepower of ground forces at request of latter. Both fighter and subsonic attack aircraft, including Army helicopters, used.

(d) Reconnaissance and observation. Deep missions behind enemy lines require fighter-type (RF) aircraft. Visual observation and direction of close-support and ground fire done from light airplanes like O-2 by Forward Air Controller (FAC).

(e) Airlift--already discussed in Phase I. Mission shared with Army helicopters. Good STOL capability preferred.

*(J-156) pp 496-509 (2) Supersonic aircraft are used as fighters and reconnaissance ships. A "fighter" is defined as an aircraft with air-to-air capability, even though it may be used mainly against ground targets.

(a) Fighter types include F-100 Supersabre (mach 1) sometimes used as Super FAC plane; F-105 Thunderchief, up to 6 tons ordnance, mach 2.25; F-4 Phantom II, armament 7 tons, mach 2.5, ceiling above 66,000 feet; F-111 with swing wings, largest and heaviest--all-weather avionics; F-5 Freedom Fighter (used by allies) modeled after T-38 trainer; F-15 projected air-to-air fighter, mach 2.5, high maneuverability.

(b) Reconnaissance planes for deep missions must carry heavy load of equipment, fly unarmed. Fighter flight capabilities needed. Example is RF-4.

(3) Subsonic attack, Observation and Special aircraft include:

(a) Subsonic jets--LTV A7D Corsair II, heavy armament, advanced avionics for low-level flight; A-37 based on T-37 trainer, can carry over 5,000 pounds of weapons; aging bombers now used for special missions like EB-66 or B-57, RB-57. A new attack airplane, the A-X, with twin turbofan engines, is planned.

(b) Propeller-driven attack and special aircraft have many uses, especially in theater like SE Asia. A-1 Skyraider has advantage of great maneuverability.. Converted cargo-attack planes have huge weapon payloads but need backup of fighters for performing their role. These include AC-47, AC-199, AC-130--all armed with fast-firing miniguns or Vulcan cannons. Light observation and utility craft include 0-1 Birddog, 0-2 Skymaster, Helio U-10 Courier (excellent STOL), OV-10 is advanced turboprop STOL type.

d. The Aerospace Defense Command uses aircraft for the mission of defense of United States against manned bombers.

(1) Fighter interceptors are like tactical fighters but designed primarily for air-to-air combat. The F-106 has high speed (mach 2), special armament, and close ground-control avionics.

(a) The F-15.

(b) One possible improvement is F-106X.

(c) Another possibility is YF-12A, a mach 3 high altitude aircraft which could operate independently of ground control.

(2) Early warning and airborne command-and-control systems are also useful in air defense.

(a) EC-121 provides early warning surveillance.

(b) Airborne warning and control system (AWACS), will provide surveillance plus command-and-control to take the place of present-day ground-based systems.

e. SAC maintains a fleet of manned aircraft to deter aggression by means of their global range.

(1) Huge subsonic jets like B-52 have great payload and flexibility, but more modern bombers are needed.

(a) FB-111 employs the swing-wing principle, has supersonic dash capability but a payload smaller than B-52.

(b) The proposed B-1 would combine B-52 payload with supersonic capability. It will also have swing wings.

(2) Other SAC aircraft include SR-71, based on YF-12A, long range supersonic reconnaissance aircraft. Boeing KC-135 tanker serves not only SAC but other commands. Other C-135 versions include RC-135 and EC-135 for radar reconnaissance and flying command posts.

f. MAC airlifters were discussed in Phase I, but MAC also flies various special aircraft worthy of mention:

(1) Airlift fleet includes airevac hospital ships C-141s for trans-oceanic airlift and specially-designed converted DC-9 airliners (see Phase VI), the C-9, for domestic airevac.

(2) ARRS uses or trains men in use of:

(a) Helicopters like HH-3 and HH-53 (see Phase VIII).

(b) Fixed wing like U-16 Albatross flying boat, HC-97 and HC-130.

(3) Also photomapping, RC-130; and weather service, WB-57, WC-135, WC-130.

g. A letter and numerical code can be used to identify all aircraft used in the armed services (text p. 138).

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. Since this phase is greatly expanded over Phase VI of previous year's unit, greater classroom time allotment is called for. However, the instructor should avoid the temptation to overdo it. There will be more penetration of the roles and missions of commands in next year's Military Aerospace unit. Here treat this subject no more deeply than necessary to explain differences in aircraft design. For example, why are certain design features desired in "F" or "fighter" planes and others in "A" or "attack" planes? For another example, note behavioral objective c above. More can be learned from a specific comparison between the F-106 and the F-4--two supersonic fighters adapted to the missions of different commands--than from a more general discussion of the roles of the two commands.

c. Lecture-and-discussion method recommended. Audio-visual resources are particularly rich for this phase (as compared to poverty for other phases). Note especially slides, which can be flashed on screen while making a classroom "game" of aircraft recognition.

d. Students ought to master the letter-and-number code for designating military aircraft. A quiz should be used to reinforce this section.

e. The instructor may want to review military airlift aircraft as discussed in Phase I.

f. Student assignment: read pages 109-141.

7. INSTRUCTIONAL AIDS:

a. SLIDES:

(1) Series 22, USAF Aircraft

(2) Series 73, Tactical Air Command

(3) Series 77, Strategic Air Command

(4) Series 78, Aerospace Defense Command

b. FILMS:

(1) FR 881 SAC in the Western Pacific, 10 min., Color, 1967

(2) FR 643 Air Power in Action, 13 min., Color, 1966.

(3) SFP 1187 TAC on Target, 14 min., B&W, 1962.

(4) FR-1234 The C-5--What It Is, What It Does. 1971

(5) TF-6172C F-111 Weapons System--Flight Characteristics, FB-111. 1971.

8. PROJECTS:

Develop local projects based on your students' interest.

9. FURTHER READING:

a. Air University, History of the USAF, Air University: Air Force ROTC, 1965, pp. 11-2 to 15-8.

b. Air Force Magazine, latest almanac issue.

c. Taylor, John W. R. (Ed.) Jane's All the World's Aircraft. McGraw-Hill, latest available edition.

PHASE VIII - ROTARY WING, STOL, AND VTOL AIRCRAFT

With increasing problems of land costs, geographic location, and space requirements for landings and takeoffs, both military and civil aviation circles are becoming increasingly interested in development of aircraft with vertical and/or short takeoff and landing capability. This phase takes a historical approach to the problem, discussing the evolution of autogiro and conventional helicopter to modern advanced helicopter concepts. Current experimentation has led to the development of airplanes with STOL and VTOL capability. One fighter VSTOL type is already operational; other aircraft are still in the experimental state, having experienced both successes and failures. As with the SST, we strive for an honest and objective appraisal of the problem and its possible solutions.

1. PHASE VIII OBJECTIVES - Each student should:

   a. Know the general development and performance characteristics of rotary-wing aircraft.

   b. Understand the meaning of VTOL and STOL and know the Air Force standards regarding STOL performance.

   c. Know some of the special features of VTOL and STOL aircraft.

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

   a. Trace the development of a particular helicopter and describe its performance limits.

   b. Define VTOL and STOL in official Air Force terms.

   c. Identify at least two VTOL or STOL aircraft and discuss a special feature of their design and function.

3. TEXTBOOK OUTLINE

   a. Problem of land areas needed for conventional takeoffs and landings.
      (1) Civil
      (2) Military
   b. Rotary-Wing Aircraft
      (1) The autogiro

(a) Preceded the helicopter
(b) Unpowered windmilling rotor

(2) Helicopter Characteristics
(a) Principles of powered rotor for VTOL
(b) Drawbacks: high cost, limited speed, limited payload, limited range

(3) Compound and Hybrid Helicopters
(a) Compound helicopter adds conventional forward thrust
(b) Hybrid helicopter uses various modifications of rotor itself: stowable rotor, proprotor, and delta-wing rotor

c. STOL Airplanes
(1) STOL defined (50 ft. obstacle, 1500 ft.)
(2) Value of STOL (in comparison with VTOL)
(a) Lower cost
(b) Less encroachment on speed, payload, and range
(c) Many suitable landing sites

(3) Some STOL Characteristics and Problems
(a) Basic characteristics: high-aspect-ration wings, extra airfoils and flap area, high thrust-to-weight
(b) Deflected slipstream, and other means of increasing Bernoulli effect at slow takeoff and landing speed
(c) Safety problem and rules to prevent too slow speed
(d) Sudden takeoff acceleration: JATO and carrier catapult

(4) Representative STOL types
(a) Propeller models: De Haviland series--U-1, C-7 and C-8, Breguet 941 (McDonnell-Douglas 188)
(b) Soviet jet-lift STOL fighters

d. Rotary VTOL and VSTOL Aircraft
(1) Turboprop VSTOL concepts
(a) X-19, X-22
(b) XC-142

(2) Jet VSTOL concepts
(a) Pivoting engine (VJ-101C)
(b) Fan in Wing (XV-5A)
(c) Combination including shifting duct (XV-4)
(d) Swiveling nozzle (XV-6A Kestrel or P.1157 Harrier)

4. ORIENTATION:

This is the final phase of the unit Aircraft of Today. It takes its departure from the subject by dealing with current problems and future solutions by means of new advances in aircraft design. Academically speaking, this is also an "advanced" topic. The student is not prepared for it without study of the preceding phases. Not only does this phase tie in with preceding phases on aircraft types, but a review of basic principles of aircraft construction and principles of flight is also necessary to understand how these same principles work in design of STOL/VSTOL aircraft--and also how they create obstacles and problems which designers and flyers must overcome. The student, now ready to address himself to other units in the curriculum, may not be an expert on modern aircraft, but those he sees flying about him will make sense to him, and discussions of aircraft and aviation in current printed and broadcast media can be understood with the intelligence of an informed citizen.

5. SUGGESTED KEY POINTS:

a. A serious and growing problem for modern aviation, either civil or military, is the excessive amounts of land areas needed for takeoffs and landings. Both remote areas and congested urban areas have this same problem in different forms.

**(J-2) pp 382-405
***(J-14) pp 11, 12, 13, 26, 80, 97, 135, 215, 270, 381, 394-5

b. Rotary wing aircraft are one answer to this problem, but there is a need for aircraft that can combine the helicopter's VTOL ability with high performance.

(1) Predecessor of the modern helicopter was the autogiro, developed in the 1920s. It achieved near-VTOL capability by means of a free-windmilling rotor.

**(J-21 C)

(2) Helicopters, developed since World War II, use rotors both for lift and propulsion, using a swimming or "flapping" motion of rotors. Their limitations are as follows:

(a) Cost, more expensive than airplanes of comparable size.

(b) Speed mostly under 150 mph, but certain advanced models now exceed 200.

(c) Payload--heavier models compare to lighter transports--9 to 11 tons.

(d) Range--usual radius 100 miles or less but rescue helicopters like Jolly Green Giant and Super Jolly can achieve 575 or more.

(3) Advanced helicopter designs and concepts include:

(a) Compound helicopter, notably the AH-51 Cheyenne, recently considered, but not adopted by the Army. Compound helicopter includes conventional rotor plus forward thrust. Cheyenne has rigid rotor plus horizontal control rotor.

(b) Hybrid helicopters change rotor position or design for more efficient forward flight. Examples are German type with stowable rotor; proprotor in which rotor converts to forward-thrusting propeller; delta-wing rotor in which triangular rotor stops to become delta wing.

**(J-21 C)

c. Short takeoff and landing (STOL) is a relative term. Air Force defines it as ability to clear 50 foot obstacle 1500 feet from start of takeoff run--easy for a light airplane but requires advanced technology for heavier or faster aircraft.

(1) Despite the fact that, compared to VTOL, STOL performance is inadequate

for some purposes (especially military), STOL is of great advantage in many military and civil situations.

(a) Short fields and STOLport sites can be found in many areas.

(b) STOL airplanes can be built more cheaply and with less sacrifice of performance than most VTOL aircraft, in the present state of the art.

(2) Certain design features provide STOL capability, but there are attendant problems:

(a) Wings of high aspect ratio, extra airfoil areas, slots, flaps, and fences are found in airframe STOL designs. Reciprocating engines or turboprop engines of high thrust-to-weight ratio are effective.

(b) Deflected slipstream, channel wing, and other devices, increase Bernoulli effect at slow landing and takeoff speeds, but too slow landing and takeoff speeds are a stall hazard and regulations demand minimum speeds.

(c) On the contrary, there are fast STOL takeoff methods, employing auxiliary rockets or jet engines. The Navy method of using catapults and arresting gear on carriers is used on dry land by equipped landing fields called SATS, by Marines.

(3) Representative STOL types include both propeller models and a Soviet jet-lift fighter design.

(a) Notable examples of propeller-driven types are the DeHaviland series used in US armed forces:

U-1 Otter, a light transport; C-7 Caribou, reciprocating, medium-light; C-8 Buffalo, heavier turboprop; Breguet 941 (also in American 188 version) 56-passenger turboprop with deflected slipstream.

(b) Certain Soviet fighters have downward-aimed jets to provide STOL assist, permit supersonic performance.

*(J-21 C)
*(J-2) p. 406

d. The most advanced aircraft are fixed-wing aircraft which also have VTOL capability (usually both VTOL and STOL or VSTOL capability).

(1) Turboprop VSTOL designs include:

(a) X-19 (central engine, tilting propeller nacelles)

(b) X-22 (tilting engine-propeller units in ducts, fixed wings)

(c) XC-142 and Canadian Dynavert--wings and propulsion units tilt together. XC-142 experimental project scratched because of instability but performed many successful flights.

(2) Jet VSTOL designs include:

(a) West German VJ-101C, with vertically-pivoting engines, supersonic speed.

(b) Ryan XV-5A, with flat lift fans in wings, operated by jet exhaust.

(c) Lockheed XV-4 Hummingbird project, with six jet engines using a variety of lift principles.

(d) XV-6A Kestrel, now a British operational fighter, the P.1127 Harrier, with swiveling-nozzle Pegasus engines, capable of lift or thrust.

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 lecture-discussion method seems to be about the best way to accomplish the objectives.

c. After the instructor has given the basic information to the students, there are several ways to get good student discussion and participation. One way is to have students prepare, before class, a list of jobs that the helicopter could perform. During class in discussion a master list could be made and put on the blackboard. This type of discussion is sometimes called "brainstorming" and should result in many more ideas than the students originally had on their papers, as ideas usually will generate new ideas.

d. Areas of the phase can be assigned to individual students or small groups of students for oral reporting. Helicopters, STOL airplanes, and VTOL or VSTOL airplanes are three such areas.

e. A guest lecturer with competence in one of the subject areas of this phase should be of great interest. Expertise in advanced STOL/VTOL concepts may be hard to find in your locality, but there may be a civil, Air Force, or Army helicopter pilot or crewman available. Perhaps an Air Force pilot qualified in the C-7 Caribou or OV-10 Bronco may be available. He can provide some insights into flying of STOL-capable aircraft.

7. INSTRUCTIONAL AIDS:

a. FILMS:

(1) TF-1-3677 The Story of the Helicopter, 21 min., B&W, 1944.

(2) TF-1-5181 Helicopter Orientation--Introduction to Rotary Wing Flight, 27 min., B&W, 1952.

(3) TF 6279 C-79 Operations, 20 min., Color, 1969.

(4) TF 6262 Air Force Helicopter UH-1 Tactical Operations, 20 min., Color, 1970.

b. SLIDES:

(1) From series 17 (US Army Weapons): 17-22, 17-23, 17-24, 17-25, 17-26, 17-27, 17-28, 17-29 (Army helicopters or STOL airplanes)

(2) From series 21 (advanced manned systems): 21-15, 21-16, 21-17 (XC-142), 21-18 (OV-10A)

(3) From series 22, USAF Aircraft. 22-8 (UH-1F helicopter), 22-9, (C-7A Caribou) 22-34--22-37 (various USAF helicopters) 22-54 (U-10 Courier).

8. PROJECTS:

Develop local projects based on your students' interests.

9. FURTHER READING:

a. Federal Aviation Agency. The Helicopter and Other VSTOL Aircraft, Growth to Date and Forecasted Growth.

b. Taylor, John W. R. (Ed.) Jane's All the World's Aircraft. McGraw-Hill, latest available edition.

c. Air Force Magazine, latest almanac issue. Also consult index for relevant articles in other issues.

FILMS FOR <u>AIRCRAFT OF TODAY</u>

1. PHASE I:

a. USAF

p. 155*	1.	FR 764	Impact of the C-5A on Logistics, 22 minutes, B&W, 1967.
p. 497	2.	SFP 1768	C-5 Galaxy, 28 minutes, Color, 1969.
p. 497	3.	SFP 1797	The Indispensables: KC-135 Air Refueling, 24 minutes, Color, 1970.
p. 506	4.	TF 6350	C-47 Armed Transport, 20 minutes, Color, 1970.

b. LOCKHEED-GEORGIA COMPANY

1. C-5 Galaxy Status Report, 10 minutes, 1969.

This film shows some of the main events in the production and flight testing of the C-5.

2. Thirty Minutes to Go, 17½ minutes, 1968.

This film describes the quick turnaround of the Lockheed 500 (L-500), off-loading and reloading.

3. Cast a Giant Shadow, 24 minutes, Color, 1968.

This film presents a detailed look at the C-5 transport. It shows its basic mission and corollary applications with a brief account of the manufacturing process and dramatic view of its first flight.

4. Command Performance, 14½ minutes, Color, 1965.

This film was designed to introduce the C-141 to the military forces and general public. The main features of this plane are illustrated and explained.

5. On Deck With Hercules, 6½ minutes, Color, 1964.

This film is a documentation of the United States Navy uses of the C-130. It includes the Ski-130 in Antarctica, in-flight refueling of jet fighters; Navy tests of landings and take-offs on board an aircraft carrier.

* This is the page number in AFM 95-2, vol 1, dated 11 March 1970, including changes 1-4 on which the narrative for the film can be found.

6. Starlifter: A Biography, 20 minutes, Color, not dated.

This film shows the development, testing and production of the C-141 accenting program management, test simulators and assembly of the first plane.

7. Starlifter: A New Dimension in Airlift, 11 minutes, Color, 1964.

This film presents a documentation of airlift capabilities of the C-141 and broad global logistics role it will play for the USAF around the world.

8. Starlifter: Patterned for Performance, 12 minutes, Color, 1965.

This film shows the testing and development program for the C-141 to meet military specifications and civil air regulations as well.

9. Talk About Speed--Plus, 13 minutes, Color, 1965.

It is a sales film which points up the effectiveness of the C-140 as a multipurpose support aircraft. After emphasizing the necessity for speed--jet speed--other factors such as versatility, safety, reliability, and economy are examined.

2. PHASE II:

a. USAF

p. 191 FTA 503 Basic Aircraft Control, 7 minutes, B&W, 1961.

b. McDONNELL DOUGLAS CORPORATION

Control is a Greek Named Alpha, 20 minutes, Color, 1966.

This film presents McDonnell Test Pilot Mr. Jack Krings, who discusses angle of attack from the pilot's point of view. It presents a simplified explanation of angle of attack and its effect on control.

c. FAA

FAA 703 How Airplanes Fly, 18 minutes.

What makes an airplane get off the ground and stay aloft? An easy-to-understand film which combines animation and live sequences to explain basic aerodynamics for general aviation pilots and high school science students alike. Forces of lift, weight, thrust, and drag are shown in relation to flight.

d. SHELL FILM LIBRARY

1. Approaching the Speed of Sound, 27½ minutes, Color, 1958.

This film provides an introduction to high speed flight. It clearly describes and explains how sound travels through air and why the speed of sound affects high speed aircraft. Special photographic techniques give striking views of shock waves building up.

2. Beyond the Speed of Sound, 19 minutes, Color, not dated.

This film discusses the behavior of supersonic airflow and shows how problems of supersonic flight are being overcome through advanced design techniques and innovations such as vertical take-off and movable wings. It is part of a series that includes: "Approaching the Speed of Sound," and "Transonic Flight."

3. Transonic Flight, 20 minutes, Color, 1959.

This film gives an analysis of technical problems in the transonic range--those speeds at which airflow around a plane is part subsonic and part supersonic. It shows how designers have solved the problems and made transonic flight smooth and safe.

3. PHASE III:

USAF

p. 359 a. TF 5688 RF-4C Familiarization, 14 minutes, Color, 1966.

p. 261 b. SFP 1590 The F-111, 15 minutes, Color, 1966.
p. 162 c. FR 982 B-52 Flaps Up Landing, 10 minutes, Color, 1968.

4. PHASE IV:

a. USAF

p. 327 TF 1-5364 An Introduction to Jet Engines, 13 minutes, Color, 1960.

b. MCDONNELL DOUGLAS CORPORATION

Toward the Unexplored, 26 minutes, Color, 1967.

The thrilling performance of the United States Navy's Blue Angel Flight Demonstration Team is included, along with highlights of the endless practice and preparation that precede the appearance of the Blues at airports across the country.

c. NASA.

Hq 79 Research Project X-15, 27 minutes, Color, 1966.

5. PHASE V:

a. USAF. None.

b. FAA

1. FA-612 Path to Safety, 20 minutes, Color, 1967.

More accidents are caused by human error than by any other factor. Cliff Robertson stars in this film as a flight instructor briefing a class of student pilots on dramatic incidents occurring as a result of misjudgment.

2. FA-807 Plane Sense, 20 minutes, Color, 1968.

The buyer beware, warns this film--especially first-time purchasers of used aircraft. The movie offers safety hints to the prospective pilot and airplane owner, outlines his responsibilities in maintaining the aircraft, and shows him how to keep abreast of pertinent FAA regulations concerning the operation and maintenance of his plane.

c. LOCKHEED-GEORGIA COMPANY

Wings at Work, 28 minutes, Color, 1965.

Tells the story of one of the most inspiring chapters of American business--the story of business aviation, from its birth shortly after the Wright brothers' historic flight, through a cow-pasture and baling-wire infancy to the achievements of today's Gulfstreams, Sabreliners, Lear-Jets and Jet Stars.

d. MONTANA AERONAUTICS COMMISSION

1. Montana and Its Aircraft, 28 minutes, Color, 1968.

This is a lively presentation of aviation in Montana. Airports, from the large all carrier stops with their thunderous jets, to the small peaceful backwoods recreational strips, are covered showing that a man may fly quickly to any part of the nation or spend a few days fishing in some remote area. (Montana Aeronautics Commission)

2. Montana and the Sky, 18 minutes, Color, 1953.

It is about the people of Montana and shows how these people make use of the airplane. It depicts the airplane as an important and frequently used tool in the development of a modern frontier. (Montana Aeronautics Commission)

e. PIPER AIRCRAFT CORPORATION

1. Don't Tell My Wife, 19 minutes, Color, 1965.

Tells the story of a man and his wife who are both learning to fly without the knowledge of the other. The Piper Cherokee 235 and Cherokee Six are used for the flights and the film includes scenery of mid-state New York. (Piper Aircraft Corporation)

2. Flight of the Bluebird II, 26 minutes, Color, 1968.

It tells the story of a flight into adventure that any competent pilot can make in today's modern aircraft. It is a story of the progress in general aviation that makes it possible for average people to experience the wonders of travel. (Piper Aircraft Corporation)

3. The Sky is Yours, 26½ minutes, Color, 1968.

Shows the types of people from all walks of life who fly for business or for pleasure, to go farther, to see more, and to have a more interesting life. It also shows the planes they fly, the equipment they use--new, old, large, small, expensive, inexpensive--from two-place trainers and utility aircrafts to business jets that are larger, faster, and more expensive than some airliners.

6. PHASE IV

a. USAF. None.

b. THE BOEING COMPANY

1. New Dimensions, 13 minutes, Color, not dated.

This film shows the first flight of the huge Boeing 747 jet airliner. Flashbacks to the early program stages explain how the facilities and the first airframes were constructed almost simultaneously.

2. You and Me and the SST, 12½ minutes, Color, not dated.

This film tells of the financial impact of the United States Supersonic Transport, especially the effect on balance of payments. National benefits of the program are explored, and effects of the Russian and Anglo-French SST aircraft are noted. The first flight films of the Boeing 747 and the Concorde SST are included. (The availability of this film is limited; also, this film can be obtained from FAA.)

c. FAA

1. A Plane is Born, 27 minutes, Color, 1968.

Describes how FAA works with manufacturers in the design, manufacture, and certification of new aircraft. Featured are wind tunnel experiments, manufacturing processes and test flights of the Douglas DC-9 and the Boeing 727. (FAA)

2. FAC-133, You and Me and the SST, 13 minutes, Color, 1969.

This country's first commercial supersonic transport (the SST) will be the largest and fastest commercial airplane flying during the next two decades. This film, produced by The Boeing Company and narrated by the noted commentator Bob Considine, explains what the SST is, how it is being developed through a government/industry partnership, how the government's investment will be repaid, the potential market and its effect on the balance of payments, and how the SST will contribute to America's economic, social, and technological prosperity. The film also includes interesting film clips of the European and Russian versions of the SST.

3. FA-811, Sonic Boom and You, 10 minutes, Color, 1969.

A sonic boom occurs when the speed of an aircraft exceeds the speed of sound. This film was produced as part of FAA's supersonic transport development program to describe the phenomenon of sonic boom and its cause.

7. PHASE VII:

a. USAF

p. 146 1. FR 564 Hq SAC Commander-in-Chief: General John D. Ryan, 4 minutes, B&W, 1964.

p. 150 2. FR 643 Air Power in Action: The United States Air Force in Vietnam, 13 minutes, Color, 1966.

p. 161 3. FR 881 SAC in the Western Pacific, 10 minutes, Color, 1967.

p. 491 4. FR 908 Strategic Air Command Semiannual Report: August 1968-January 1969, 22 minutes, Color, 1969.

p. 491 5. FR 909 Strategic Air Command Semiannual Report: January 1969-January 1970, 20 minutes, Color, 1970.

p. 232 6. SFP 1049 Skywatch, 28 minutes, Color, 1960.

p. 239 7. SFP 1187 TAC on Target, 14 minutes, Color, 1962.

p. 243 8. SFP 1243 Strategy For Peace, 28 minutes, B&W, 1965.

p. 251 9. SFP 1390 Assignment TAC, 32 minutes, Color, 1965.

p. 261 10. SFP 1597 Tactical Air Power, 20 minutes, Color, 1967.

p. 496 11. SFP 1697 The B-52: Vietnam, 38 minutes, Color, 1969.

p. 500 12. SFP 2062 Lifeline, 24 minutes, Color, 1969.

p. 193 13. FTA 567 Interdiction, 11½ minutes, B&W, 1961.

p. 502 14. TF 6122 Tactical Air Employment, 24 minutes, Color, 1969.

b. GENERAL DYNAMICS

The Versatile F-111, 10 minutes, Color, 1969.

This is an up-to-date report on the F-111, the world's first operational variable-sweep-wing airplane, which is now in production in several versions for the United States Air Force and the Royal Australian Air Force.

c. LOCKHEED GEORGIA COMPANY

Lifeline, 25 minutes, Color, 1968.

This is a broad portrayal of the USAF Aerospace Rescue and Recovery Service's role around the world and the part played by the HC-130H Hercules.

d. McDONNELL DOUGLAS CORPORATION

The F-4, 14½ minutes, Color, 1966.

It shows Phantom II aircrews as they perform a typical mission of the Navy, Marines, and Air Force. Operational units of the three services are featured and full sound effects are employed to give the impression of actual presence at the scene. (McDonnell Douglas Corporation)

e. SIKORSKY AIRCRAFT

No Man Expendable, 11½ minutes, Color, not dated.

It tells the story of the Aerospace Rescue and Recovery Service of the United States Air Force, from Cape Kennedy to Vietnam. It features the Sikorsky/US Air Force HH-3E Jolly Green Giant helicopter. Sikorsky Aircraft or Association Films, Inc.

8. PHASE VIII:

a. USAF

p. 165 1. FR 1010 Combat and Support Activities, SEA-May 1968 - C-7A-Operations in South Vietnam, 9 minutes, Color, 1968.

p. 278 2. TF1-3677 The Story of the Helicopter, 21 minutes, B&W, 1944.

p. 282 3. TF1-4129 The Sikorsky Helicopter, 25 minutes, B&W, 1944.

p. 309 4. TF1-5052 Shipboard Helicopter Operations - Landings and Take-Offs at Sea, 7½ minutes, Color, 1954.

p. 315 5. TF1-5181 Helicopter Orientation - Introduction to Rotary Wing Flight, 27 minutes, B&W, 1952.

p. 324 6. TF1-5333 Helicopter Rescue Operations, 34 minutes Color, 1959.

p. 504 7. TF 6262 Air Force Helicopter UH-1 Tactical Operations, 20 minutes, Color, 1970.

p. 504 8. TF 6279 C-7A Operations, 20 minutes, Color, 1969.

p. 251 9. SFP 1385 Toward the Unexplored, 26 minutes, Color, 1967.

b. FAA

FA-709 A Place to Land, 20 minutes, Color, 1968.

It demonstrates the ability of V/STOL aircraft and helicopters to provide air access and logistic support to a metropolitan center-city area in time of emergency. It contains scenes of aircraft taking off and landing on streets, docks, and parks, demonstrating the unique characteristics of helicopters and the V/STOL aircraft. (FAA)

c. NASA

Hq 168 Flight to Tomorrow, 28 minutes, Color, 1967.

Illustrates various types of research on future aircraft by comparison with present day jet flight. It includes supersonic and hypersonic planes, vertical take off and landing craft, stability of light aircraft, jet noise reduction and advances in aircraft safety.

d. SIKORSKY AIRCRAFT

1. Big, Tough and Fast, 7 minutes, Color, not dated.

Shows the work-horse helicopter performing some of the missions in Vietnam, and describes the grueling stateside tests that the aircraft went through to prove itself prior to its introduction to combat.

2. Copters in Combat, 12½ minutes, Color, not dated.

It shows the Army Sikorsky H-37 and H-34 helicopters in field exercises of the 4th Transportation Company at Fort Benning, Georgia. The helicopters, which do not have to use roads and are not restricted by such surface obstacles as rivers, swamps, and ridges, reach the battle objectives in minutes rather than in hours.

3. No Runway Needed, 12 minutes, Color, not dated.

It shows how helicopters are operated in scheduled airline service over the crowded city streets and over the roadless wastes of frozen Greenland. The film describes these operations and tells how the helicopter is helping to solve transportation problems of differing types.

4. Flying Crane in Vietnam, 7 minutes, Color, not dated.

This film compiled from combat footage, shows the Flying Cranes in action airlifting bulldozers, road graders, artillery pieces, fuel cells, and supplies. The big copters are also shown recovering other helicopters and airplanes which have been downed by mechanical trouble or enemy action.

5. Skycrane and Containership, 7 minutes, Color, not dated.

Shows that Skycrane helicopters could shuttle cargo from containership anchored offshore direct to its destination, or to a central distribution point. Containerized loads up to ten tons can be airlifted by these helicopters.

6. Skycrane, 26 minutes, Color, not dated.

It presents the Sikorsky S-64 Skycrane, the giant new aerial tool for industry. It shows it in action in the heavy construction, petroleum, transmission tower, and shipping industries in the United States and South America. It also scans the future size and missions of the Skycrane with forecasts by Igor I. Sikorsky.

7. Versatility Unlimited, 16 minutes, Color, not dated.

It presents the Sikorsky S-61 helicopter, one of the most advanced of the turbine-powered helicopters. It shows its performance in military and commercial applications, which were filmed at Cape Kennedy, Gulf of Mexico, German Alps, Atlantic Ocean, New York World's Fair, San Francisco, and Great Britain.