DOCUMENT RESUME

ED 111 612 SE 017 449

TITLE Spacecraft and Their Boosters. Aerospace Education I. Instructor Handbook.
INSTITUTION Air Univ., Maxwell AFB, Ala. Junior Reserve Office Training Corps.
PUB DATE Sep 72
NOTE 62p.; For the accompanying textbook, see SE 017 448

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

ABSTRACT

This curriculum guide is prepared for the textbook entitled "Spacecraft and their Boosters," published in the Aerospace Education I series. Specific guidelines are provided for teachers on each chapter included in the textbook. The guidelines are organized in nine categories: 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 for major concepts stressed. (PS)

SEPTEMBER 1972

INSTRUCTIONAL UNIT IV

SPACECRAFT AND THEIR BOOSTERS

INSTRUCTIONAL UNIT OBJECTIVES - Each student should:

a. Be familiar with the great variety of spacecraft.

b. Understand the principles behind the operation of the rocket engine.

c. Know the characteristics of a booster.

d. Know how a spacecraft is put into its orbit or trajectory.

e. Know the major objectives of both manned and unmanned spacecraft.

f. Understand how future spacecraft and boosters can be used to advance man's knowledge of space.

PHASES IN INSTRUCTIONAL UNIT IV:

PHASE I - WHAT IS A SPACECRAFT?

This phase introduces space operations by defining a spacecraft as a vehicle that does not simply move through space but that is orbited and follows the laws of celestial mechanics, just as the earth, the moon, and other natural bodies do. This definition provides a point of departure for explaining that spacecraft are different from aircraft and that spacecraft are characterized by their great variety: in shape, size, form, materials of which constructed, and purposes served. The purposes for which spacecraft are launched are outlined during the unit according to the two large classes of spacecraft: unmanned and manned.

1. PHASE I OBJECTIVES - Each student should:

   a. Know that spacecraft are orbited by rocket boosters and follow the laws of celestial mechanics.

   b. Be familiar with the ways in which spacecraft are different from aircraft.

   c. Know about the great variety of spacecraft.

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

   a. Define a spacecraft.

   b. Explain at least three ways in which spacecraft are different from aircraft.

   c. Tell how spacecraft get their power at launch.

   d. Name the two large classes of spacecraft.

3. TEXTBOOK OUTLINE:

   a. Definition of a spacecraft: a vehicle designed to operate in space.

      (1) Orbited by a rocket booster.

      (2) Follows the laws of celestial mechanics.

   b. Great variety in spacecraft.

      (1) No set shape.

(2) No set size but the weight of the spacecraft must not exceed the weight that can be lifted by the booster selected for launching.

(3) Many kinds of materials used in construction: aluminum steel, and fiberglass and other plastics.

c. Two classes: unmanned and manned; many purposes.

4. ORIENTATION:

a. Some introduction to space operations has already been given during the unit The Aerospace Age. The first phase of this unit should be limited to a brief introduction to spacecraft. You will need to give the students some idea of the great variety of spacecraft and of the characteristics that all present-day spacecraft have in common.

b. Although this phase must of necessity be brief, it will be important. It should give you an opportunity to find out what the students already know about space operations and what their special interests are. This information will be valuable to you in judging the level at which you should present the subject and what you can do to motivate students.

5. SUGGESTED KEY POINTS:

a. Experimental rocket aircraft like the X-15 traveled to the fringes of space, and some sounding rockets have gone to altitudes higher than those at which the early manned spacecraft orbited. But these rocket aircraft and sounding rockets were not designed to operate in space for any length of time. They were not orbited. Spacecraft designed to operate in space are orbited by rocket boosters and follow the laws of celestial mechanics.

***(J-9008) pp 19-21
**(J-9083) pp 55-69

b. Since spacecraft do not depend upon the aerodynamic lift forces for their flight, they do not have to be shaped with wings and airfoils, as aircraft are. Spacecraft are designed in a great variety of shapes (globes, hexagonal or many-sided figures, cones, cut-off cones or bell shapes, etc.). But since spacecraft must travel through the atmosphere at launch, they must be protected against aerodynamic drag forces as much as possible. Protruding parts are folded back or retracted at launch, and the spacecraft is usually protected with a cover, or shroud.

c. Besides having great variety in shape and form, spacecraft also have great variety in their size, materials of which they are constructed, and the purposes they serve. Spacecraft vary in size from the tiny research satellites to the large Apollo manned spacecraft. The size of each kind of spacecraft must, however, come within strict weight limitations so that it can be launched by the booster selected for that purpose. Spacecraft are constructed of a wide variety of materials. A search is constantly being made for materials that will survive frictional heating and be reliable in space. Special paints and coatings are used to control temperature and to cut down frictional heating caused by the air molecules that are to be found at the lower orbital altitudes. The many purposes served by spacecraft will be described during the unit according to the two large classes of spacecraft.

d. There are two large classes of spacecraft: unmanned and manned. When the United States has a space station in earth orbit, there will be less of a distinction made between the two classes. Unmanned spacecraft can then be launched and controlled from earth orbit, and they can be manned for a part of the time. Manned spacecraft are generally larger and more complex than unmanned spacecraft because they must carry large quantities of life-support supplies and equipment to keep astronauts alive in the hostile environment of space. Before describing the different kinds of unmanned and manned spacecraft, it would be well to learn more about the way spacecraft are launched by rocket boosters (Phase II) and the way they are injected into orbit and travel in orbit (Phase III).

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

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

b. In order to give the general discussion of spacecraft some objective reality for the students, you may wish to use as a point of departure a recent space launch or a future launch that may be especially interesting for them. But do not allow the class to get into a detailed discussion of any one launch or any one spacecraft at this point. Move quickly on to a discussion of the characteristics of all spacecraft.

c. The main idea that you want to leave with the students is that vehicles designed to travel in space are orbited by rocket boosters and travel according to the laws of celestial mechanics. Do not try to go too deeply into the reasons behind the definition of a spacecraft. If the students raise questions that are too difficult to answer in the introductory lesson, reserve these questions until later. Have the students record the questions in their notebooks or write them on the blackboard and keep them there. Questions that the students themselves raise are excellent means of motivation.

d. Another idea you will want to leave with students is the great variety of spacecraft. Most students will know something about the manned spacecraft and about the communications and weather satellites. Let the students pool their knowledge. You will want them to realize there are many other kinds of research satellites and other applications satellites. Stimulate them to ask further question and explain that their questions will be answered in later classes.

e. Student assignment: Read entire Chapter 1.

7. INSTRUCTIONAL AIDS:

a. You will probably not want to take time out to show a film during this brief introductory phase.

b. Wall charts, diagrams, models, and photographs will be helpful in giving students a good idea of the variety of spacecraft and of their relative size and weight. This material will need to be carefully planned and prepared in advance.

8. PROJECTS:

There will not be time for special reports during this phase, but you may wish to take a few minutes of the class time to to assign future individual and class projects. See suggestions in textbook at the end of the chapter.

9. FURTHER READING:

a. NASA Educational Publications:

(1) EP-22. This Is NASA. 20 pp. 45 cents.

(2) EP-54. NASA Spacecraft. 26 pp. 50 cents.

b. See list in the back of the textbook.

c. Recent copies of Aviation Week and Space Technology.

PHASE II - ROCKET BOOSTERS

This phase covers the entire rocket booster assembly that orbits spacecraft but concentrates on the basic principle behind the operation of the rocket engine. Since this is the only kind of engine that will operate in space, it is also used in the spacecraft, but in this phase emphasis is placed on the engines that power the booster. During this phase your students are to learn how different rocket engines use either a liquid or a solid chemical propellant and how propellants vary in their measure of efficiency (specific impulse). Next the phase considers some of the exotic kinds of propellants that might be used in the future, with emphasis on the nuclear rocket, which is likely to be the first put to use. Then the phase takes up the staging principle, the methods of assembling rocket engines in the booster, and the standard families of boosters with the upper stages that are sometimes added. The phase concludes with a description of the system for guiding and controlling the booster during flight and the procedures followed in launching boosters.

1. PHASE II OBJECTIVES - Each student should:

   a. Know that rocket power is the key to spacecraft operations.

   b. Understand the basic principle behind the operation of the rocket engine.

   c. Be familiar with different kinds of rocket propellants, the staging principles, families of standard boosters, booster control and guidance systems, and launch procedures.

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

   a. Name the principal parts of the space booster.

   b. Explain the basic principle upon which the rocket engine operates.

   c. Name the two principal kinds of propellants used in present-day space boosters.

   d. Explain why space boosters must be staged.

   e. Name two kinds of guidance systems and two kinds of control systems used in space boosters.

f. Describe gantry operations and countdown before launch.

3. TEXTBOOK OUTLINE:

a. Rocket power as the key to space operations.

(1) Konstantin E. Tsiolkovsky: calculations and theory for liquid-fueled rocket engines to propel vehicle into space.

(2) Robert H. Goddard: calculations and actual experiments with liquid-fueled rocket engines.

(3) Hermann Oberth: theories about space travel made possible by rocket engines.

(4) German rocket experts: V-2 rockets.

b. Parts of a space booster.

(1) Rocket engines: propellant, nozzle, combustion chamber, and plumbing.

(2) Airframe.

(3) Explosive bolts.

(4) Guidance system.

(5) Control system.

c. Principle of the rocket engine.

(1) Principle demonstrated by simple gunpowder rocket.

(2) Based on Newton's third law of motion: For every action there is an equal and opposite reaction.

(a) Heat energy converted to kinetic energy to create reaction force.

(b) Other examples of Newton's law.

(3) Means of increasing thrust of rocket engine.

(a) Producing a larger jet of exhaust gases.

(b) Using a pinched (convergent-divergent) nozzle.

(4) Ways of expressing thrust of space booster.

(a) Total thrust of all engines in first stage.

(b) Number of pounds lifted to a specified orbit.

(5) High thrust-to-weight ratio of space boosters.

d. Propellants for rocket engines.

(1) Parts of propellant: fuel and oxidizer.

(2) Two kinds of chemical propellants: liquid and solid.

(3) Specific impulse: measure of efficiency.

(a) Expressed in seconds.

(b) Greater efficiency, larger number of seconds.

(4) Liquid chemical propellants

(a) Hypergolic--unite upon contact.

(b) Two kinds of liquid systems: pressure-fed and pump-fed.

(c) Difficulties in handling and storing.

(d) Use of liquid oxygen and liquid hydrogen.

(5) Solid chemical propellants.

(a) Complex mixtures of solid chemicals.

(b) Advantage: ease of storage.

(c) Disadvantage: lower specific impulse.

(6) New kinds of propellants.

(a) Nuclear rockets: NERVA.

(b) Photon rockets.

(c) Electric (ion) rockets.

e. Assembling rocket engines in the booster.

(1) Step principle, or staging; needed to generate sufficient power.

(2) Clustering; can be used to increase power within a stage.

(3) Adding solid-fueled strap-on engines; done to increase total thrust of booster.

f. Families of boosters.

(1) Development from basic booster: improving design or using devices to increase thrust, or adding upper stages (Burner II, Agena, or Centaur).

(2) Standard families: Scout, Thor-Agena, Atlas, Titan, and Saturn.

g. Guidance and control systems.

(1) Kinds of guidance systems.

(a) Inertial guidance system: accelerometers, gyroscopes, and autopilot.

(b) Radio command (radar) guidance system.

(2) Kinds of control systems.

(a) Movable jet vanes.

(b) Jet thrusters.

(c) Gimbaled engine.

h. Countdown and launch.

(1) Countdown: roll call of all systems and facilities.

(2) Launch manager's position in blockhouse.

(3) Holding or scubbing a launch.

(4) Gantry for supporting and servicing space booster; unbilicals for attachment to booster.

(5) Launch pad.

4. ORIENTATION:

a. If you have taken some time to explain the operation of the rocket engine in the unit Aircraft of Today, you might begin this phase by referring back to what was learned in the earlier unit. Otherwise, it would be advisable to spend some time describing the operation of the rocket engine and emphasizing its importance in space operations. Without the modern rocket engine there would be no space operations.

b. In AE-III further work is done on the rocket engine and their guidance and control systems. This phase provides a foundation for this later work and for all units dealing with space operations.

5. SUGGESTED KEY POINTS:

**(J-9004) pp 9-32
**(J-9023A) pp 84-97, 105-110
***(J-9028A) pp 23-46, 90-110, 133-155
*(J-9028H) pp 31-34
**(J-9033) pp 11-31
**(J-9038) pp 28-57

a. Only the rocket engine can furnish the tremendous power required in a space booster, and only the rocket engine can generate power in the vacuum of space. All present-day spacecraft ride into space on top of a booster powered by rocket engines. The launch of the first spacecraft into orbit had to await development of the modern liquid-fueled rocket engine. Important pioneer developments were made by Tsiolkovsky, Goddard, Oberth, and the early German rocket experts, who produced the V-2 rockets. The first Soviet and American space boosters were developed from intercontinental ballistic missiles (ICBMs).

*(J-9046) pp 7-10, 12-21
*(J-9057) pp 7-112
**(J-9083) pp 16-20
***(J-9111) pp 40-149
*(J-9145) pp 46-53
***(J-9158) pp 60-85

b. Since no single rocket engine is powerful enough to boost a spacecraft into orbit by itself, two or more engines are used, and these are assembled in stages. A space booster is made up of two or more rocket stages. A booster consists of rocket engines, each with its propellant, combustion chamber, nozzle, and plumbing. The shell of the booster is called the airframe. The separate stages of the booster are held in place by explosive bolts, which are fired to release the stage and allow it to fall and be jettisoned after burnout. To keep a booster on course, it must have a guidance system and a control system.

**(J-9033) pp 96-110
**(J-9008) pp 30-31
**(J-9072) pp 11-20
**(J-9083) pp 20-30
**(J-9132) pp 424-427
**(J-9140) pp 169-171
*(J-9156) p 542
***(J-9158) pp 52-54

c. The rocket engine operates on the reaction principle stated in Newton's third law of motion: For every action there is an equal and opposite reaction. The law can be illustrated in many common occurrences, such as in the lurching of a boat as one jumps from the boat to the shore. In the rocket engine the heat energy produced in the combustion chamber is converted into kinetic energy in the jet of exhaust gases. This jet of exhaust gases produces a reaction force, which propels the rocket forward (upward). It is this reaction force, not the pressure of the exhaust gases against the launch pad or the atmosphere, that makes the booster lift off the pad. Actually the atmosphere hinders rather than helps liftoff. A rocket engine operates most efficiently in space. The principle of the rocket engine operates in its simplest form in the firecracker rocket or the gunpowder rocket.

d. To increase the amount of thrust, or pounds of power, produced by modern rocket engines, it is necessary to increase the size of the jet of exhaust gases. Another way to increase thrust is to increase the velocity of the exhaust gases. This is done by using a pinched (convergent-divergent) nozzle in the rocket engine.

e. To overcome the earth's gravitational pull and the drag force of the atmosphere, a space booster must produce a tremendous burst of power by burning large quantities of propellant within a short time. Space boosters have a high thrust-to-weight ratio.

f. A rocket engine can operate in the vacuum of space because it takes its own oxygen with it in the propellant. A rocket propellant is made up of two parts: fuel and oxidizer. A large part of the weight of a space booster at launch is made up of the weight of the propellant. The airframe is little more than a thin shell for holding the propellant.

**(J-9005) pp 124 - 126
**(J-9008) pp 31-33
*(J-9033) pp 110 - 116
**(J-9132) pp 435 - 439
*(J-9140) pp 258 - 259
**(J-9156) pp 543, 546-547

g. Present-day propellants for rocket engines are chemical propellants. They may be either liquid or solid chemicals. The liquid chemical propellants were developed first to make the modern rocket engine possible. After scientists and engineers developed the liquid chemical propellants, they were able to produce solid propellants for modern rocket engines. The liquid-fueled engines are still the mainstay for space boosters, and they are generally used in the first stage of the booster. Solid-fueled engines are used in the upper stages or for strap-on motors for augmenting the thrust of the booster.

**(J-9156) pp 543 - 545

h. Specific impulse, the measure of the efficiency of the propellant used in a rocket engine, is expressed in seconds. The larger the number of seconds, the greater the efficiency of the propellant. Liquid propellants have a higher specific impulse than solid propellants, but solid propellants are more easily stored.

i. Liquid rocket propellants are highly volatile, corrosive, and have to be kept at extremely low temperatures. They are difficult to store and handle, but they are the most efficient propellants in use. Systems for handling liquid propellants are either pressure-fed or pump-fed. Liquid hydrogen and liquid oxygen are used as a propellant in some of the most recently developed rocket engines.

j. In the future, new kinds of propellants are likely to be developed. All that it is necessary to have is some kind of material that can be rapidly expelled from the nozzle of

***(J-9033) pp 137 - 149
*(J-9064) pp 163 - 216
*(J-9072) pp 32-39
**(J-9132) pp 439 - 442
**(J-9156) pp 547 - 549

of the rocket engine to create a reaction force. Nuclear rockets, photon (light-energy) rockets, and electric (ion) rockets are likely to be developed in the future. A large nuclear rocket engine (NERVA) has already undergone static tests, but work on the rocket has been halted. The technology developed for this large nuclear engine may be used in developing smaller nuclear rockets. The new exotic materials have great potential in terms of specific impulse, but the machinery in the rockets that use such propellants will have to be quite heavy. Therefore, such propellants cannot be used for the rocket engines that must lift a spacecraft off the earth and counter the strong gravitational pull of the earth. They can be used only in the upper stages of the space booster or in the spacecraft after it is in space.

**(J-9008) p 34
*(J-9072) pp 18-19

k. All rockets for launching spacecraft must be staged, or developed according to the step principle: The heaviest and largest stage is placed on the bottom of the stack, the second largest next, and so on. Usually a booster is limited to two or three stages.

l. The power of a space booster may be increased by clustering rocket engines within a single stage or by adding solid-fueled strap-on motors.

*(J-9008) pp 59-68
**(J-9140) pp 198 - 202
**(J-9156) pp 587 - 588

m. NASA uses standard families of space boosters. A family of boosters is developed from a basic booster in either of two directions: by increasing the thrust of the booster or by adding upper stages. There are five standard families of boosters: Scout, Thor-Delta, Atlas, Titan, and the Saturn boosters. Burner II, Agena, and Centaur are the upper stages most commonly used.

**(J-9008) pp 36-40
**(J-9033) pp 174 - 206
**(J-9123) pp 451 - 454

n. To keep a booster on the highly accurate path needed for orbiting a spacecraft, each booster must have a guidance system and a control system. The guidance system senses the corrections needed in the flight path and notifies an autopilot, or control center. The control system actually makes the changes required. The guidance system may be an inertial or a radio command (radar) system. The control system may consist of movable jet vanes, jet thrusters, or a gimbaled (swiveling) engine.

*(J-9051) pp 13-97

o. A booster is assembled on a gantry for servicing and launch. All procedures at launch are controlled by an orderly countdown, or roll call of systems and facilities. The launch manager is stationed in the blockhouse. After launch, the range safety officer takes over. The booster lifts off from the launch pad. All operations are carefully coordinated and controlled to make a successful launch. Teamwork is the keynote.

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. The way in which you teach this phase will be determined largely by the time allowed and the knowledge that the students already have on the subject. If the students know nothing about the space booster, you will need to concentrate on the principle of the rocket engine, the staging of rockets, and the parts of the space booster. If you are able to enlarge your instruction, you can explain more about propellants, the guidance and control systems, the standard families of boosters, and launch procedures. You can draw upon the students' knowledge of actual launches to enrich the instruction.

c. Use blackboard diagrams and other visual aids for explaining the principle of the rocket engine. There are many excellent visual aids available to aid in explaining Newton's Laws and rocket engines. If they are available, transparencies T-30, T-31, T-33, T-39, T-40 and the first transparency from the Milliken Space Travel book all support this phase of instruction. The Teacher's Data Sheets supplied with the GAF transparencies provide an additional source of background material (GAF transparencies are not supplied to units activated after 1971). However, you will want to evaluate these aids carefully as you may prefer to use them in support of a later phase of instruction. The crossword puzzle in Space Travel can be used to add variety to your classes.

d. No matter how limited your time is, it would be well to devote some time to demonstrating the operation of the rocket engine by using the model engine. It would also be well to show a short film of an actual launch. You can use the excitement of a launch to motivate interest. Launching your model rocket jointly with AE-III classes may be an excellent approach. The key to the whole launch is rocket power. This gives you a point of departure for your instruction.

e. Student assignment: read entire Chapter 2. If you must limit your instruction, have the students read the first two sections of the chapter and other selected sections.

7. INSTRUCTIONAL AIDS:

a. Estes model rocket, catalog, and pamphlet Aerospace Education and Model Rocketry; also Estes film T Minus One and Counting, 11 1/2 min. (film could be used in support of a class project on model rocket building).

b. Air Force film:

*** TF 5621. Rocket Propulsion. 1964. 30 min. (best for AE-III).

c. NASA films, general series:

HQk 125. The Dream That Wouldn't Down (Robert Goddard). 1965. Black and white. 27 min.

HQ 152. Nuclear Propulsion in Space. 1968. Color. 24 min.

HQa 170. The Big Challenge (Kennedy Space Center). 1967. Color. 28 min.

HQa 171. Doorway to Tomorrow (Kennedy Moonport). 1967. Color. 28 min.

HQ 210. Spaceport U.S.A. 1970. Color. 23 min.

d. NASA films, special interest series (1969):

AD-9 Powering Apollo. 4:50 min.

AD-10. Saturn First Stage. 5:15 min.

AD-11. Saturn Second Stage. 4:30 min.

AD-12. Saturn Third Stage. 5:20 min.

AD-13. The Instrument Unit. 4:30 min.

AD-14. The First Short Step. 7:00 min.

AD-15. Launch of the Saturn V. 3:40 min.

AD-16. Canaveral to Kennedy. Short history. 7:30 min.

AD-17. Launch Site to the Moon. 3:20 min.

AD-18. Minus Three Miles (movement of rocket to launch pad). 6:50 min.

AD-19. Assembling Apollo (assembly of Saturn V stages). 5:40 min.

AD-20. Launch Control Center. 5:00 min.

AD-21. Testing Apollo (rocket and spacecraft testing). 5:00 min.

e. NASA Fact Sheets:

NF-8 Launch Vehicles. 8 pp. 10 cents.

NF-20. U.S. Launch Vehicles for Peaceful Exploration of Space. Color supplement to NF-8. Wall display sheet. 25 cents.

NF-33. Saturn V. Color wall sheet. 25 cents.

f. 35 mm slides:

SVA-42 - last three slides

g. Transparencies:

T-30, T-31, T-33, T-39, and T-40 (not furnished to units activated after 1971.)

Milliken Space Travel book Nos. 1 and 3.

8. PROJECTS:

a. If you are located in an area where there are rocket facilities, it might be worthwhile to arrange a field trip for the class.

b. Have the students construct and launch the model rocket.

c. See suggestions in textbook.

9. FURTHER READING:

a. See list in back of textbook.

b. Check your school and community libraries for other references.

PHASE III - ORBITING AND TRACKING SPACECRAFT

This phase is designed to explain how a spacecraft becomes an artificial satellite of the earth (or other body being orbited) and how it is tracked and controlled to enable it to perform its mission. The phase introduces Newton's theory of an artificial satellite and then applies this theory to spacecraft orbited with modern rocket boosters. During this phase the students should learn the principal kinds of orbits and trajectories. They should also come to understand that the movements of a spacecraft follow the laws of celestial mechanics, as defined by Kepler, and they should see how the flight paths of spacecraft are related to the sections of a cone. Next the phase takes up the special orbits and trajectories that spacecraft follow to perform different kinds of missions. The phase concludes with the explanation of the means used to track spacecraft and of the way in which unmanned spacecraft are controlled and stabilized and manned spacecraft are navigated.

1. PHASE III OBJECTIVES - Each student should:

   a. Understand the three conditions that must be met for orbiting a spacecraft.

   b. Be familiar with the elliptical path of an earth satellite and its points of perigee and apogee.

   c. Know how spacecraft are tracked.

   d. Be familiar with the means used for controlling a spacecraft in orbit.

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

   a. Tell the three conditions that must be met for orbiting a spacecraft.

   b. Explain the difference between an orbit and a trajectory.

   c. Draw the elliptical orbit of an earth satellite and show the points of perigee and apogee.

   d. Explain the different use made of the large propulsion engine and the small thrusters in a spacecraft.

3. TEXTBOOK OUTLINE:

a. A spacecraft as an artificial satellite.

(1) Follows basic laws of motion and gravity as formulated by Newton.

(2) Newton's theory of an artificial satellite: modern rocket power can be substituted for the giant cannon and the very high mountain.

(3) Three conditions must be met: spacecraft must be orbited above the earth's atmosphere, spacecraft must be propelled fast enough to counteract the earth's gravitational pull, and it must travel in a path parallel to the curvature of the earth.

(4) Balance of gravitational pull and centrifugal force: condition of weightlessness.

(5) Earth's gravitational pull overbalanced: escape from the earth.

b. Orbits and trajectories.

(1) Inaccuracies in flight path corrected (midcourse correction).

(2) Difference between <u>orbit</u> and <u>trajectory</u>: orbit, a closed path; trajectory, an open path.

(a) Orbits: circular, elliptical.

(b) Trajectories: escape trajectories.

(3) Kepler's laws applied to spacecraft as to natural bodies.

(a) Period of spacecraft predicted according to Kepler's law; related to distance from body being orbited.

(b) Most satellites' orbits elliptical; two foci; for earth satellite, point in orbit closest to earth, perigee; point in orbit farthest from earth, apogee.

(c) Earth synchronous orbit, an equatorial orbit 22,300 miles above earth.

c. Special orbits and trajectories.

(1) Relation to earth's (or other body's) equator: equatorial, inclined, or polar orbits.

(2) Relation to altitude above earth (or other body): synchronous orbit; for earth, an equatorial orbit at an altitude of 22,300 miles.

(3) Orbits used for travel to and from moon.

(a) Preliminary parking orbit around the earth.

(b) Direct earth-moon trajectory.

(c) Free-return trajectory.

(d) Flyby trajectory.

d. Tracking spacecraft

(1) NASA network of tracking stations worldwide; equipped with large radio antennas.

(2) Four means of tracking spacecraft: visual, special cameras, radar, and radio.

(a) Telemetry: system of sensing and measuring and then transmitting information by coded radio signals; television pictures also transmitted by telemetry.

(b) Extra large antennas used in NASA Deep Space Network; stations at Goldstone, Madrid, and Canberra.

e. Stabilization and navigation of spacecraft.

(1) Stabilization of unmanned spacecraft: radio commands to cause equipment to operate.

(2) Navigation of manned spacecraft.

(a) Rendezvous: searching for and meeting with another spacecraft.

(b) Docking: linking together of spacecraft.

(c) Change of trajectory; requirement for large propulsion engine.

(d) Adjustment of spacecraft's attitude in orbit; use of small thrusters.

(e) Retrorockets for braking spacecraft and causing it to fall out of orbit.

(3) Guidance for spacecraft: same as for boosters and star tracking.

(4) Power for spacecraft: fuel cells, nuclear power plants, and solar cells (exposed in large quantities on paddle-wheels).

4. ORIENTATION:

a. This phase of the unit is closely related to the preceding one and should be planned in relation to it. Phase II covers the liftoff of the rocket boosters. Phase III completes the launch and the orbiting of the spacecraft and the action taken to guide and control it on its pathway.

b. Further work on guidance and control of spacecraft is included in AE-III. Instruction in this phase should be planned with the later work in mind and should serve as an introduction to it.

5. SUGGESTED KEY POINTS:

a. A spacecraft is unique because it is orbited and follows the laws of celestial mechanics, traveling along a pathway just as the natural bodies like the earth and the planets do. More than a thousand spacecraft had been successfully orbited by all countries at the beginning of the 1970s.

**(J-9033) pp 72-73
*(J-9083) pp 14-16, 31-41
***(J-9158) pp 86-89

b. Man was unable to orbit a spacecraft until he could generate the tremendous amount of rocket power that could counteract the pull of the earth's gravity and allow the vehicle to travel high above the earth's atmosphere, where aerodynamic drag is negligible. Besides the rocket power, a guidance system was required to keep the spacecraft on its planned course. By the time man had produced the gigantic rocket-powered ICBMs, he had also produced guidance systems that were accurate enough to keep the booster on course and enable it to orbit a spacecraft. For orbiting a spacecraft, three conditions must be met: the spacecraft must be lifted above the earth's atmosphere, it must be propelled fast enough to counteract the earth's gravitational pull, and it must travel along a path parallel to the curvature of the earth.

c. The world's first artificial satellite was Soviet Sputnik 1, orbited in October 1957. The first US artificial satellite was Explorer 1, orbited in January 1958.

**(J-9056) pp 22-26, 28-31
**(J-9140) pp 174 - 175

d. The laws for explaining an artifical satellite and for predicting its course were formulated long before man was able to launch an artificial satellite. Satellites, or spacecraft, in orbit follow the fundamental laws of gravity and motion formulated by Isaac Newton and Johannes Kepler centuries before.

***(J-9158) pp 93-97
***(J-9132) pp 100 - 119
*(J-9156) p 553
***(J-9158) pp 22-26

e. Newton expounded the theory of an artificial satellite of the earth in the 17th century. He did this to explain why the earth's natural satellite, the moon, travels in an orbit about the earth. If one were to substitute a modern rocket booster for Newton's giant cannon and very high mountain, he would have a theory for explaining why artificial satellites orbit the earth and remain in space.

***(J-9008) pp 22-27
*(J-9033) pp 32-38, 41-44, 61-62
**(J-9072) pp 21-22

f. A spacecraft orbiting the earth travels at an altitude of at least 100 miles and at a speed of about 17,500 mph.

g. When a spacecraft is in orbit above the earth (or other body), its centrifugal (inertial) force tends to keep in balance with the gravitational pull of the earth (or other body) upon the spacecraft, producing a condition of weightlessness.

**(J-9140) pp 170 - 172
**(J-9156) pp 554 - 555

h. If the centrifugal (inertial) force of the spacecraft becomes so large as to overbalance the gravitational pull, then the spacecraft escapes from the body it is orbiting and goes into the gravitational field of another body.

**(J-9008) pp 28-29
***(J-9132) pp 449 - 451
**(J-9140) pp 172-173
**(J-9156) pp 556 - 557

i. The gravitational pull of any body on a spacecraft can be computed according to Newton's law of universal gravitation: Every body in the universe attracts every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

j. Space travel is essentially travel along an orbit or trajectory. Space launches are carefully planned and timed so that a spacecraft arrives at a designated point along its orbit or trajectory at a specified time.

k. An <u>orbit</u> is a closed path, a <u>trajectory</u> an open path. All orbits and trajectories can be located as sections of a cone. Most orbits are elliptical; a circular orbit is a special case. Escape trajectories can be located at different points on a cone.

***(J-9005) pp 127 - 128
***(J-9158) pp 89-91

l. A spacecraft escapes from the earth when it is traveling at a velocity of about 25,000 mph. Such a spacecraft would escape to the vicinity of the moon. Spacecraft traveling at much greater velocities would escape to the planets.

*(J-9003) pp 43-47
***(J-9123) pp 108 - 109

m. Most spacecraft traveling in an orbit around the earth follow an elliptical orbit with the earth as one of the two foci. The point on the orbit closest to the earth is the perigee, the point farthest from the earth is apogee.

**(J-9156) pp 555-556

n. A satellite orbiting the earth at the minimum altitude has a period of about 90 minutes. Satellites orbiting at higher altitudes have longer periods. The period of a satellite in an equatorial orbit about 22,300 miles above the earth has the same period as the earth's rotation period; it is said to be in an earth synchronous orbit. The period of the moon is slightly longer than 27 days.

**(J-9158) p 92

o. A spacecraft is usually launched due east of Cape Kennedy to take advantage of the earth's rotation. Such a satellite is inclined about 29 degrees north and south of the earth's equator; it is said to be in an inclined orbit. A satellite launched so that its orbit is directly above the earth's equator is in an equatorial orbit; one in an orbit directly above the earth's poles is in a polar orbit.

p. A spacecraft traveling in an earth synchronous orbit remains in a fixed position above the earth (stationery orbit). Communications satellites are placed in such an orbit.

**(J-9072) pp 23-31

q. In travel to and from the moon spacecraft use different orbits and trajectories. A spacecraft is usually put into a preliminary parking orbit around the earth. A spacecraft could be sent on a direct earth-moon trajectory if there is adequate power and accurate direction. An Apollo spacecraft begins its journey to the moon on a free-return trajectory. Some of the early Pioneer probes of the moon were put on a flyby trajectory. All Mariner probes to the planets launched during the 1960s were put on a flyby trajectory of the planet.

**(J-9033) pp 217 - 239
*(J-9123) pp 192 - 197, 455-458
**(J-9140) pp 232 - 233
***(J-9156) pp 550 - 552
***(J-9158) pp 98-102

r. There are four means of tracking satellites, or spacecraft: visual observation, special cameras, radar, and radio. Of these means, radio is the most reliable. NASA has a network of stations worldwide equipped to send radio communications and receive radio signals from spacecraft. Telemetry, which means measuring from afar, is a system of sensing and measuring and then transmitting the data by means of radio code, which is received and processed at a ground station. Television pictures are also telemetered to the earth. Data gathered by telemetry can be stored in the spacecraft to be released upon radio command from a ground station. For communicating with spacecraft in the vicinity of the moon and beyond, NASA makes use of its Deep Space Network. This consists of three stations equipped with extra large dish antennas, which are located at Goldstone, Madrid, and Canberra.

**(J-9140) pp 231 - 232

s. Spacecraft tend to tumble about in orbit, much as a boat does when adrift upon the water. Unmanned spacecraft that have special missions to perform must be stabilized in orbit and have instruments oriented in a certain direction. Spacecraft are stabilized by firing small thrusters or by spinning, much as a toy top is. Manned spacecraft are navigated along their orbits and trajectories. By using a powerful propulsion engine in the spacecraft, astronauts can change orbit, and they can rendezvous and dock with another spacecraft especially designed for linkup. Retrorockets are fired to brake a spacecraft and cause it to fall out of orbit.

**(J-9008) pp 118 - 119
***(J-9140) pp 228 - 231

t. Spacecraft receive electric power for operating their instruments and equipment from fuel cells, conventional batteries, solar cells, or nuclear power plants. Solar cells, which are exposed on paddlewheels, make use of the pure sunlight available in space.

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. As with Phase II, this phase will have to be adjusted to what the students already know, and this phase is also basic to understanding space operations. If the students do not know much about space operations, concentrate on teaching the basic concept of the artificial satellite of the earth and explain that all true spacecraft are artificial satellites. Keep the discussion general, reserving the study of specific satellites or spacecraft for Phases IV and V.

c. To keep the classwork from becoming too abstract, illustrate everything with diagrams. Use blackboard drawings of orbits and trajectories. Prepare a large paper cone to cut in sections if you think this will help in describing different kinds of orbits and trajectories.

d. Concentrate on the elliptical orbit for an earth satellite, showing perigee and apogee. The concept of an ellipse may be new to some of the students, but it should not be too difficult to grasp if they can picture it as a slightly squashed circle.

e. Student assignment: Read Chapter 3. Concentrate especially on the first section of the chapter.

7. INSTRUCTIONAL AIDS:

   a. Probably the best aids for this phase will be those you plan and make for yourself. The orbiting satellite device is an outstanding aid in helping to explain why and how satellites stay in orbit. Plans are found on page 16 of VCS, Visual Communications Systems by William Reynolds.

   b. NASA films:

      HQ 116. Space Navigation. 1967. Color. 21 min.

      HQa 174. The Vital Link (NASA's worldwide tracking and communications network). 1967. Color. 28 1/2 min.

      AD-22. Mission Control (Houston). 1969. 6:30 min.

      AD-23. Guidance and Navigation. 1969. 6:30 min.

      AD-24. Apollo Communications. 1969. 6:30 min.

      AD-29. Lunar Receiving Lab. 1969. 7:45 min.

   c. AF Films:

      *** TF1-8194. G-Forces. 1962. 30 min.

   d. 35 mm Slides:

      SVA 42 - Keplers Laws

   e. Transparencies:

      T-26, T-27, and T-32 (not furnished to units activated after 1971).

8. PROJECTS:

   a. Any project that would lead to a good understanding of an earth satellite and of the orbit of such a satellite would be helpful.

   b. See suggestions in textbook.

9. FURTHER READING:

   a. NASA publications:

      EP-55. Spacecraft Tracking. 18 pp. 40 cents.

EP-56. Linking Man and Spacecraft. 18 pp. 40 cents.

EP-59. Spacecraft Power. 18 pp. 35 cents.

NF-37. Space Navigation. 10 cents.

NF-38. Electric Power Generation in Space. 10 cents.

S-2. Spacecraft Tracking and Communication (simplified). 5 cents.

S-6. Solar Cells. 5 cents.

S-7. Orbits and Revolution. 10 cents.

b. Articles in Aviation Week and Space Technology.

c. See list at back of textbook.

PHASE IV - UNMANNED SPACECRAFT

This phase covers the different kinds of missions performed by the two large classes of unmanned spacecraft: research satellites and applications satellites. During the phase your class will study the three kinds of research satellites: (1) those investigating the space environment and the earth, (2) those probing the moon, and (3) those probing the planets. In your study of the research satellites, you should name the most important series of each kind of research satellite and describe some of the most significant discoveries made possible by research satellites. The phase next takes up the four kinds of applications satellites: (1) communications satellites, (2) weather satellites, (3) navigation satellites, and (4) survey satellites. During the study of the applications satellites, you should describe one or more series of each kind of applications satellite, summarize the progress made with each kind, and point out significant developments likely to be made in the future.

1. PHASE IV OBJECTIVES - Each student should:

   a. Know the three kinds of research satellites and the four kinds of applications satellites.

   b. Be familiar with at least one series of each kind of research and applications satellite.

   c. Know some of the significant discoveries made possible by research satellites.

   d. Be familiar with some of the potential uses of applications satellites in the future.

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

   a. Describe three kinds of research satellites and name at least one series of each kind.

   b. Name at least two significant discoveries made possible by research satellites.

   c. Name the four kinds of applications satellites and give at least one series of satellites of each kind.

d. Describe two significant uses that are likely to be made of applications satellites in the future.

3. TEXTBOOK OUTLINE:

a. Unmanned satellites.

(1) About 96 percent of all U.S. satellites unmanned.

(2) Important role of earth satellites.

(3) Satellites sent to moon and planets: hard-landers, soft-landers, and flybys.

(4) Two large classes of unmanned satellites: research and applications satellites.

b. Research satellites.

(1) Satellites investigating cislunar space and the earth

(a) Investigations of earth's magnetic field (magnetosphere), cosmic rays, solar wind, and the earth's radiation belts.

(b) Explorer and Pioneer satellites: discovery of Van Allen radiation belts and solar wind.

(c) Discovery that earth is slightly pear-shaped (Vanguard 1).

(d) Orbiting Observatories; Orbiting Geophysical Observatory (OGO), Orbiting Solar Observatory (OSO), and Orbiting Astronomical Observatory (OAO).

(e) Openness of space, allowing investigation of all electromagnetic wavelengths by satellites; in atmosphere only three openings, or "windows": for visible light, for the shorter radio waves, and for narrow bands of infrared waves.

(2) Lunar probes.

(a) Rangers: success of 7, 8, and 9; hard landings and closeup pictures.

(b) Surveyor soft-landers: five of seven successful; tested bearing strength of moon's surface, took pictures at surface of moon, and made chemical tests of surface materials. Also tested methods for descent to moon and landing on moon.

(c) Lunar Orbiter: all five successful; carried instruments and took pictures for detailed mapping of moon; wiggles in orbits called attention to presence of mascons (mass concentrations of matter).

(3) Planetary probes.

(a) Mariner spacecraft modified for different planetary mission.

(b) All flybys before 1971.

(c) Favorable opportunities: planet and earth aligned in their orbits to permit passage on a trajectory with rocket power available; Mars, every two years; Venus, once every 19 months.

(d) Nine Mariner spacecraft launched and six successful; two successful U.S. probes of Venus and four of Mars; Mariner 9 to Mars (1971), first planetary orbiter took photographs for detailed mapping of planet.

c. Applications satellites.

(1) United States a pioneer in this kind of satellite.

(2) Four kinds of applications satellites: communications, weather, navigation, and survey satellites.

(3) Communications satellites (comsats)

(a) Efforts to increase channel capacity.

(b) Placement in synchronous orbit.

(c) Ability to relay radio signals from one ground station to another beyond line-of-sight distance.

(d) Clarke's theory: three communications satellites in synchronous orbit for covering the earth.

(e) Developments: bouncing radar signal off moon, Project Score (tape recorder in orbit for transmitting radio signals to earth), bouncing radio signals off Echo satellites, and Courier satellites (first active communications satellites--transmitter for rebroadcasting radio signals from earth).

(f) Syncom and Relay satellites.

(g) Telestar, Intelsat, and other satellites for giving commercial communications service.

(h) Further tests of communications with Applications Technology Satellite (ATS)--direct broadcast.

(4) Weather satellites.

(a) Need to obtain weather information from all portions of earth and information about movement of large air masses above the earth.

(b) Tiros satellites, experimental; ten in number; pictures of cloud coverage over the earth.

(c) Nimbus satellites; beginning with Nimbus 3, infrared cameras to take pictures at night and in bad weather; also improved instruments; satellites operational.

(d) Improved Tiros Operational Satellites (ITOS); together with Nimbus satellites, used to obtain data for regular weather service.

(5) Navigation satellites.

(a) Artificial "star" for steering ships.

(b) Transit navigation satellites; polar orbit.

(c) Navy system of navigation with satellites; need for special navigation tables, computer on board ship, and series of ground stations; information about system released for general use.

(d) Possible use in the future for widespread air and ship navigation and traffic control.

(6) Survey satellites.

(a) Military reconnaissance satellites; Midas satellites; polar orbit.

(b) Widespread use for making surveys of earth resources; in experimental stage.

(c) Earth Resources Technology Satellites (ERTS), one scheduled for launch in 1972 and one for 1973;

intended to make observations to find out what survey satellites can do; need to develop system for processing information received from satellites.

(d) Principal uses of earth survey satellites: discovery of new resources, improving the management of present resources, and spotting trouble zones that require remedial action.

4. ORIENTATION:

a. You may have introduced the subject of unmanned satellites in the unit on The Aerospace Age. If so, you will want to refer back to what was said in this unit to introduce this phase of instruction.

b. If you have not made specific reference to unmanned satellites in the earlier unit, this phase will introduce the subject, which is taken up again in AE-III in the unit on Space Exploration. This phase should be planned with the later work in mind. Probably the best plan is to take up a more complete study of unmanned satellites in this phase and reserve the later study for a brief review of unmanned satellites and a more detailed study of the most recent developments in this field. You may wish to vary the plan to suit your requirements.

5. SUGGESTED KEY POINTS:

a. Although the public knows most about the flights of the manned spacecraft, these have made up only about 4 percent of all US spacecraft launched. Most of the spacecraft are unmanned, and some of these unmanned spacecraft are controlled from the earth after launch. Unmanned spacecraft that orbit the earth are able to perform unique tasks because of their position at a great distance from the earth. Unmanned spacecraft are not confined to earth orbits, however. They have also been sent out to the moon and to the two neighboring planets, Venus and Mars. One spacecraft, Pioneer 10, is at present on its way to make a flyby of Jupiter in December 1973.

b. US spacecraft have made hard landings and soft landings on the moon, they have been sent to make flybys of the moon and the planets, and they have orbited the moon. One US spacecraft (Mariner 9) has become an orbiter of Mars.

c. Unmanned spacecraft are of two large classes: research satellites and applications satellites. The first class is especially designed to gather data to contribute to the sum total of scientific knowledge, the second to apply information obtained in order to perform useful tasks.

d. The first US spacecraft were research satellites. Explorer 1, launched in January 1958, was the first U.S. artificial satellite. Research satellites are of three kinds: satellites investigating cislunar space and the earth, probes of the moon, and probes of the planets.

**(J-9004) pp 59-65
**(J-9008) pp 75-81
**(J-9028A) pp 111 - 132
*(J-9038) pp 53-63, 65
***(J-9056) pp 26-83
*(J-9111) pp 183-184, 186-188
*(J-9145) pp 12-17, 108-110
*(J-9132) pp 74-75
**(J-9140) pp 182 - 185
*(J-9146) p 36
**(J-9156) pp 558-562
***(J-9158) p 47, 103 - 109

e. Explorer 1 discovered the Van Allen radiation belts surrounding the earth. Later Explorer satellites and Pioneer satellites made further discoveries about the radiation belts and the extent of the earth's magnetosphere. They also investigated the solar wind and cosmic rays in the region between the earth and the moon. Later, the Pioneer satellites were sent beyond the moon to explore the space between the earth and the orbits of Mars and Jupiter. Explorer satellites continue to be used to investigate space closer to the earth. Research satellites were responsible for the discovery of the Van Allen radiation belts and the solar wind. Vanguard 1 led to the discovery that the earth is slightly pear-shaped. After three Vanguard satellites were orbited, the Vanguard program was absorbed with that of the Explorer satellites. Larger and more complex research satellites operating in the area between the earth and the moon are the Orbiting Observatories. These are of three kinds: the Orbiting Geophysical Observatory (OGO), for studying the earth; the Orbiting Solar Observatory (OSO), for studying the sun; and the Orbiting Astronomical Observatory (OAO), for studying the stars. Research satellites, orbiting in open space, are able to make readings in any wavelength of the electromagnetic spectrum. The earth's atmosphere has only three openings, or "windows," for admitting electromagnetic waves of: visible light, the shorter radio waves, and narrow bands of infrared rays.

*(J-9008) pp 81-83
**(J-9140) pp 185-188
**(J-9156) pp 566-572
***(J-9158) pp 145-173

f. The Apollo landings on the moon were made possible by preliminary unmanned probes of the moon. The first US lunar probes were made by the early Pioneer spacecraft. Although these were not particularly successful as probes of the moon, they sent back valuable information about the region of space between the earth and the moon. Later probes of the moon were made by the Ranger hard-landers, the Surveyor soft-landers, and the Lunar Orbiters. Three Rangers were successful: Rangers 7, 8, and 9. These spacecraft telemetered back to the earth a series of photographs of three sites on the moon before impacting on the moon. Five of the seven Surveyor soft-landers were successful, testing the bearing strength of the moon's surface, and taking pictures on the moon; and two of the Surveyors made chemical tests of surface materials. All five Lunar Orbiters were successful, taking photographs for detailed mapping of the moon and supplying additional scientific data about the moon. Irregularities in the paths of the Lunar Orbiters led to the discovery of the mascons (mass concentrations of matter) on the moon.

*(J-9008) pp 83-84
**(J-9072) pp 40-47
**(J-9083) pp 42-54
*(J-9140) p 188
*(J-9145) pp 114-117
*(J-9156) pp 572-578
***(J-9158) pp 180-197

g. The Mariner spacecraft has been modified to make different kinds of planetary flybys. Up to November 1971 all US planetary probes had been flybys. In May 1971, Mariner 9, designed as an orbiter, was sent to Mars and began to orbit that planet in November 1971. Of the first nine Mariner spacecraft launched, six were successful. Of these six, two were sent to Venus and four to Mars. Mariner spacecraft have now returned thousands of detailed photographs of the surface of Mars. Mariner 9 has taken photographs of the entire surface, and these photographs will be used in preparing a detailed map of the planet. The Mariner spacecraft have not been able to photograph Venus up to the present time, and no scientists have seen the surface of this planet in their telescopes, since it is covered by a dense atmosphere. Mariner spacecraft sent to Venus have shown its atmosphere to be 75 to 100 times as dense at that of the earth. Temperature readings made near the surface have been higher than that of melted lead, indicating that life cannot be expected to survive on this planet. In time scientists intend to obtain more information about the solar system by making probes of all the planets. They can then compare data obtained from the different planets. Probes to the planets cannot be made at any time, only when the planets are favorably aligned, or a favorable opportunity exists. For Mars, this is every two years, for Venus once in a 19-month interval.

h. The United States has made rapid advances with applications satellites. By 1960, two years after its first artificial satellite was launched, this country had orbited at least one of each kind of applications satellites. There are four kinds of applications satellites: communications satellites (comsats), weather satellites, navigation satellites, and survey satellites.

**(J-9033) pp 262-282
**(J-9056) pp 119-150
**(J-9140) pp 188-190, 195-196
*(J-9145) pp 92-98
**(J-9156) pp 562-565
***(J-9158) pp 117-123

i. Communications satellites have great value in relaying radio signals between ground stations that are beyond line-of-sight distances. In 1945 Arthur C. Clarke pointed out that three communications satellites placed in the stationery orbit (equatorial orbit 22,300 miles above the earth) could provide radio coverage of the whole earth. It was some time before this theory could be proved. First the United States bounced a radar signal off the moon and next bounced radio signals from Echo satellites. The first active communications satellites were the Courier satellites, which contained transmitters for rebroadcasting radio signals from the earth.

Syncom satellites tested the synchronous orbit, and Relay satellites were put in lower orbits, allowing the signals to be picked up by different satellites as the earth rotated. The early experimental communications satellites were followed by Telstar and the Intelsat communications satellites, which are used for providing commercial communications service. An international semicommercial communications organization, the Intelsat organization, controls international communications services. What is needed now are more and better communications satellites to increase channel capacity. The Applications Technology Satellite (ATS) is to be used for testing direct broadcast from a satellite to a receiver on the ground without the necessity of first going through a broadcast station.

**(J-9033) pp 240-261
**(J-9056) pp 151-167
***(J-9140) pp 190-194, 291-299
*(J-9145) pp 98-107
*(J-9156) p 565
*(J-9158) p 115

j. Weather satellites have great value in covering the areas over the world's oceans and uninhabited regions, and they can show the movement of large air masses above the earth. The first Tiros weather satellites, which took pictures of cloud coverage, detected the movement of storms and provided other data about the weather. Beginning with Nimbus 3, weather satellites have been equipped with infrared cameras, which are able to take pictures at night and in bad weather. The present Nimbus satellites and the Improved Tiros Operational Satellites (ITOS) take pictures and provide data for regular weather coverage. The newer weather satellites also have improved instruments. Satellite coverage is now an important part of the service provided by the National Oceanographic and Atmospheric Administration of the US Department of Commerce, of which the National Weather Service is a part.

**(J-9033) pp 282-287
**(J-9056) pp 168-179
**(J-9140) pp 194-195
*(J-9156) p 565

k. Navigation satellites, which are put into a polar orbit, provide an artificial "star" for guiding ships at sea. The first navigation satellites were the Transit satellites. The Navy now has an operational system, based on satellites, that it uses for navigating its ships and submarines worldwide. The navigator of a US Navy ship can check his position by sending a radio signal and receiving a reply from a navigation satellite. Use of the system requires special equipment and navigation tables. The navigator uses the Tables and a computer to correct his position, making it highly accurate. The Navy has released information on the satellite system so that it can be used by other ships. In time all air and sea traffic is likely to be navigated and controlled by means of satellites.

**(J-9056) pp 180-183

l. Survey satellites, also placed in polar orbit, are satellites that make observations over the earth as it rotates below them. The United States has already used survey satellites for military reconnaissance. The first of such satellites were known as the Midas satellites. Survey satellites have a great potential for use in surveying earth resources. The thousands of pictures taken by astronauts and by unmanned satellites show the great possibilities of a system of survey satellites, since visibility of the earth from space is much greater than was previously believed possible. Two earth survey satellites, called Earth Resources Technology Satellites (ERTSs) are scheduled for orbit, one in 1972 and one in 1973. These satellites are to explore the possibilities of using satellites for earth surveys. One requirement for making such systems practicable is to develop ground stations that can efficiently process and distribute the data collected by the satellites. Earth survey satellites have possibilities for three kinds of uses: (1) discover new resources, (2) help improve the management of present resources, and (3) spot trouble zones that require remedial action. Now that pollution of the environment and waste of our great natural resources have become serious national problems, we can look to space technology to provide some solutions to these problems.

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. If your time for teaching this phase is limited, you will want to concentrate on giving the students some idea of the large proportion of the spacecraft launched that are unmanned and of the wide variety of unmanned spacecraft and the range of purposes they serve. Most students know something about the flights made by the astronauts, but they are not likely to have an understanding of the many kinds of tasks assigned to unmanned satellites. As you take up the different kinds of unmanned satellites, it is a good plan to make the students acquainted with as many names of satellite series as possible. This will enable them to identify these satellites when they read and hear about them later. Be on the alert to note and tell your students about significant developments made with applications satellites. Look especially for reports on the two Earth Resources Technology Satellites (ERTSs). You may want to introduce the concept that ERTS satellites can be beneficial in improving our ecology.

c. Even if your time is limited, it would be a good plan to show a film of either a planetary probe, an applications satellite, or a research satellite, or have some kind of individual or class project for this phase. You might also study one of the lunar probes, but interest in these probes waned once the astronauts landed on the moon. To give the student an insight into space operations, it is necessary for him to understand some of the remarkable things that an unmanned spacecraft is capable of doing.

d. Student assignment: Read the entire Chapter 4. If the time is limited, the students should read the chapter rapidly. It is better to cover the entire chapter rather than concentrate on special sections, since you want the student to reach an understanding of the wide variety of unmanned satellites.

7. INSTRUCTIONAL AIDS:

a. NASA films:

HQa 82. The Clouds of Venus. 1963. Color. 30 min.

HQa 95. Orbiting Solar Observatory. 1962. Color. 25 min.

HQ 123. Trial Balance (research satellites). 1965. Color. 27 min.

HQa 135. Seas of Infinity (Orbiting Astronomical Observatory). 1969. Color. 14 1/2 min.

HQ 149. Men Encounter Mars. 1965. Color. 28 1/2 min.

HQa 159. Log of Mariner IV (Mars). 1966. Color. 27 min.

HQ 167. Assignment: Shoot the Moon. 1969. Color. 28 min.

HQ 178. A New Look at an Old Planet. 1969. Color. 28 min.

HQa 192. A Mission for Mariner (Venus). 1969. Color. 14 1/2 min.

HQ 193. Satellite Astronomy - Progress and Promise. 1969. Color. 17 min.

HQ 195. The Martian Investigators. 1969. Color. 28 min.

**HQ 196. Seeds of Discovery. 1969. Color. 28 min.

*HQ 204. Space Down to Earth (applications satellites. 1970. Color. 27 1/2 min.

HQ 207. Space in the 70s -- The Knowledge Bank. 1971. Color. 25 min.

**HQ 208. Mariner-Mars '69. 1971. Color. 21 min.

b. 35 mm Slides:

SVA 41-10 Van Allen Belts

c. Transparencies:

Milliken Space Travel - Nos. 4 and 11.

8. PROJECTS:

   a. Concentrate on the applications satellites undergoing most development at the present time.

   b. See suggestions in textbook.

9. FURTHER READING:

   a. NASA publications:

      EP-39. <u>Report from Mars</u>. 52 pp. 50 cents.

      EP-51. <u>Space Physics and Astronomy</u>. 22 pp. 45 cents.

      EP-52. <u>Exploring the Moon and Planets</u>. 26 pp. 50 cents.

      EP-53. <u>Putting Satellites to Work</u>. 26 pp. 50 cents.

      EP-71. "In This Decade. . ." Mission to the Moon. Color. 48 pp. $1.25.

      EP-79. <u>Weather in Motion</u>. 8 pp plus Xograph. 50 cents.

      EP-83. <u>Earth Orbital Science</u>. Color. 28 pp. $1.00.

      EP-90. <u>Two Over Mars</u>. 40 pp. 50 cents.

      NF-25. <u>Explorer XXIX (The Geodetic Explorer)</u>. 8 pp. 10 cents.

      NF-32. <u>Lunar Orbiter</u>. 20 cents.

   b. See list in back of textbook.

PHASE V - MANNED SPACECRAFT

This phase covers the three series of manned spacecraft (Mercury, Gemini, and Apollo) that the United States developed in advancing toward the moon and landing upon it, as well as the modified Apollo command and service modules that are to be used to take astronauts to the experimental space station, the Skylab. During this phase the students are to learn how the single-module Mercury spacecraft was used for Step 1 in the advance toward the moon. The phase includes a description of the module, the selection and training of astronauts for spaceflight, the first US suborbital and orbital flights, and the results of the Mercury flights. Next the phase takes up the Gemini spacecraft, which was made up of two modules and was used for Step 2. Students are to learn how the Gemini astronauts extended time in space, performed rendezvous and docking, and engaged in extravehicular activity (EVA). The phase next takes up the three-module Apollo spacecraft, which was used for Step 3, the final step in reaching the moon and landing. In this third part of the phase, students are to learn how the Apollo spacecraft is constructed and how it operates on the trip to the moon and upon landing. They take up the flights leading to the moon landing, the world's first moon landing, and the later scientific flights to the moon. The phase concludes by considering how the modified Apollo command and service modules will be used to take astronauts to the Skylab and return them to the earth.

1. PHASE I OBJECTIVES - Each student should:

   a. Know the principal advances made with US manned spacecraft in each of the three steps toward the moon landing.

   b. Understand how the Mercury capsule (Gemini reentry module or Apollo command module) reentered the atmosphere and was recovered.

   c. Be familiar with the three historic US spaceflights: first suborbital flight, first orbital flight, and first moon landing.

   d. Be familiar with the general flight plan for a trip to the moon and return to the earth.

   e. Know how the Apollo command and service modules will be used to take astronauts to the Skylab.

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

a. Name the manned spacecraft used for the three steps toward the moon landing.

b. Tell at least two important developments in manned spaceflight made during each of the three steps.

c. Explain how the Apollo astronauts are recovered after a moon landing.

d. Identify the three most significant US spaceflights from the standpoint of history, explain your choice, and name the astronaut or astronauts participating in each flight.

e. Tell the principal purpose of the Skylab and explain how astronauts will reach the Skylab and be returned to the earth.

3. TEXTBOOK OUTLINE:

a. Early Soviet efforts: stimulus to US objective for moon landing.

(1) Experiments with dogs on Soviet Sputniks.

(2) Flight of first man into orbit: Soviet Cosmonaut Yuri Gagarin, 12 April 1961.

(3) First US suborbital flight, 5 May 1961.

(4) US goal of moon landing set by President Kennedy on 26 May 1961.

b. Mercury spacecraft: Step 1.

(1) One-module spacecraft; form-fitting couch for astronaut; thrusters for attitude control; space suit and life-support equipment; heat shield with ablation cooling at reentry.

(2) Selection and training of astronauts.

(a) Rigid tests for selection.

(b) Seven original astronauts selected.

(c) Practice by simulated spaceflights.

(d) Survival training.

(e) Jet training.

(f) Academic subjects: astronomy, lunar geology, etc.

(g) Highly coordinated teamwork.

(h) Flying weightless trajectories.

(i) Workouts on centrifuges to help in withstanding greatly increased G-forces.

(3) Mercury flights: two suborbital and four orbital flights by a single astronaut.

(a) Suborbital--first made by Alan Shepard on 5 May 1961; flight repeated by the late Virgil I. Grissom.

(b) First US orbital flight by John Glenn on 20 February 1962; alarm signal indicating possible loss of heat shield; manual firing of thrusters.

(c) Orbital flight repeated three times, and flight time gradually extended; flights by Scott Carpenter, Walter Schirra, and Gordon Cooper; last flight extended to day and a half.

(d) Results: showed man had a place as pilot in spaceflight; no harmful effects from greatly increased G-forces and from weightlessness; all astronauts recovered fully after return to earth.

c. Gemini spacecraft: Step 2.

(1) Two-module spacecraft: adapter and reentry modules.

(a) Large propulsion thrusters for making orbital changes.

(b) Rendezvous with target vehicle.

(c) Docking, or linkup, with target vehicle.

(d) Extravehicular activity (EVA); extra heavy space suit for EVA.

(2) Targets for rendezvous and docking.

(a) Practice targets: Augmented Target Docking Adapter (ATDA) and Radar Evaluation Pod (REP); REP had no docking collar.

(b) Actual target vehicle: Agena target vehicle; systems to be connected with those of the Gemini spacecraft; additional fuel stored in Agena for making large orbital changes.

(3) Goals for Project Gemini.

(a) Geared to Lunar Orbit Rendezvous (LOR) plan for Project Apollo.

(b) Three major goals: extend time in spaceflight up to two weeks; be able to rendezvous and dock the Gemini spacecraft with the Agena target vehicle and refire Agena engine; and perform extended EVA in space, including so-called space walks and useful work in space.

(4) Gemini flights: 10 manned flights made in rapid succession; two astronauts.

(a) Extending time in space: telemetered medical data; Gemini 4, four days; Gemini 5, eight days; and Gemini 7, fourteen days; Gemini 7 still holds American record but Soviet cosmonauts have exceeded; astronauts on the Gemini 7 flight wore lightweight space suit and space coveralls for first time.

(b) Rendezvous and docking: orbit change made according to laws of celestial mechanics; rendezvous practice with REP; world's first rendezvous made between Gemini 7 and Gemini 6; first docking on Gemini 8 and then emergency recovery; further practice of rendezvous and docking on remaining flights.

(c) Extravehicular activity (EVA): first US space walk by the late Edward White on Gemini-4 flight; heavy EVA suit and maneuvering gun and chest pack; de pressurization of cabin in preparation for EVA; return to EVA practice on Gemini 9A and later flights; all space work completed by Astronaut Edwin Aldrin on final flight (Gemini 12).

(d) All goals met in preparation for Project Apollo.

d. Apollo spacecraft: Step 3.

(1) New maneuvers and new flight territory; first earth-moon trajectory for manned spacecraft.

(2) Tragedy: fire at Cape Kennedy in January 1967 and death of three astronauts; new dedication.

(3) Three-module spacecraft.

(a) Three modules: command module, service module, and lunar module; purpose of each.

(b) For moon journey, assembly on Saturn V; complete stack, 364 feet high; Apollo spacecraft about 82 feet high.

(4) Apollo flights: 10 manned flights by April 1972; last flight (Apollo 17) scheduled for December 1972.

(a) Tests of three modules and other flight equipment; preparation for first moon landing (Apollo 7, 8, 9, and 10); Apollo 7, earth orbit; Apollo 8, lunar orbit; Apollo 9, earth or landing.

(b) First lunar landing, Apollo 11; Astronauts Neil Armstrong, Edwin Aldrin, and Michael Collins; landing made in July 1969; goal for lunar landing achieved before end of decade; landing on Sea of Tranquility; test of moon suit and Portable Life Support System (PLSS); quarantine of astronauts after recovery; return of rock samples.

(c) Later flights: landings on Apollo 12, 14, 15, and 16; emplacement of experiments and return of rock samples; no landing on Apollo 13 because of explosion in service module but safe return of astronauts after using lunar module for lifeboat; use of powered lunar rover on Apollo 15 and subsequent flights.

(d) Apollo 17 scheduled for landing in Taurus-Littrow area, a highland area; both highland and lowlands (lunar seas) have been investigated.

e. Skylab and modules for visiting it.

(1) Skylab: forerunner of first space station, an experimental space station to be used as a laboratory for performing extended experiments in orbit.

(2) Three visits to Skylab by three astronauts: first visit, 28 days; second and third visits, 56 days.

(3) Modified Apollo command-service modules to be used for taking astronauts to Skylab; will rendezvous and dock with Skylab; at end of visit the astronauts will return to the earth in the command-service modules; command module is to be recovered in ocean, just as after the Apollo flights.

4. ORIENTATION:

a. You have probably mentioned the Apollo flights during the AE-I unit, The Aerospace Age. You will want to refer back to your earlier remarks, as well as review something about the most recent Apollo or Skylab flight to motivate the students for this phase. Most of the students will know something about the astronauts' flights, but in this phase you want them to come to an understanding of the essential difference between an unmanned spacecraft and one that supports man. This phase of instruction is intended to give students an understanding of why man requires continuous life support to survive in the hostile environment of space.

b. This phase of instruction is intended to provide a foundation for two units in AE-III, Space Exploration and the unit on Man and Flight (Human Factors of Flight). It would be well to plan this phase with the two later units in mind. This phase should cover the basic elements of survival in space. In the AE-III unit on Space Exploration, you might review the most recent spaceflight operations and then concentrate on exploration on the moon or, later, on the experiments performed in the Skylab or the training for flying the space shuttle. The AE-III unit on Man and Flight (Human Factors) would concentrate on the more specialized biological and medical aspects of spaceflight and flight in high-performance aircraft. Since there is so much subject matter on manned spaceflight, it is advisable to select content for this phase carefully so that it will be oriented toward introducing subject matter to be taken up in AE-III.

5. SUGGESTED KEY POINTS:

a. Now that American astronauts are in training for the last Apollo flight to the moon (Apollo 17), we realize how rapidly manned spaceflight has progressed in a little less than a dozen years. The flights of the Apollo astronauts to the moon are about as different from the flights of the first Mercury astronauts as the flights of pilots in present-day high-performance jets are different from the flights of the Wright Brothers. But the Apollo flights would never have been possible if it had not been for the Mercury and Gemini flights. US flights of manned spacecraft have progressed gradually from simple to more difficult flights.

**(J-9145)pp 8-11
***(J-9158)pp 124-135

b. At first the Soviets made rapid advances in space. They orbited the first artificial satellite, and Soviet Cosmonaut Yuri Gagarin was the first man to make an orbital flight (12 April 1961). Astronaut Alan Shepard did not make the first suborbital flight until 5 May 1961. The United States had vast resources and talent, but this country did not at the outset seem able to bring together its resources and organize them for advancing space operations. Then on 26 May 1961 President Kennedy set the goal for a US moon landing before the end of the 1960s. With a long-range goal clearly set, this country began to organize its efforts and advance rapidly in all space operations, but especially in manned spaceflight.

c. Because there was a great gap between the kind of simple orbital flights that could be made with the Mercury spaceflight and the flights to the moon, a middle project was set up, which was known as Project Gemini. US astronauts made the progress to the moon in three steps, or stages: Project Mercury, Project Gemini, and Project Apollo. The Mercury spacecraft was made up of one module, the Gemini of two modules, and the Apollo of three modules.

**(J-9008)pp 53-54

d. The cut-off cone shape of the Mercury spacecraft was chosen because it was believed that it was the shape best suited for resisting the aerodynamic forces at liftoff. The cone-shaped module could be turned in orbit and braked so that it would present the large blunt end to the atmosphere when it descended through the atmosphere for recovery. The same general shape has been used in the recovery module of the Gemini spacecraft and for the command module of the Apollo spacecraft.

**(J-9008)pp 49-53
**(J-9072)pp 48-57
*(J-9111) pp 205-207
**(J-9123) pp 458-464, 471-481
*(J-9140) pp 241-242
**(J-9156) pp 580-581
*(J-9033) pp 860-866

e. In the Mercury spacecraft the astronaut was protected against greatly increased G-forces by reclining on a form-fitting couch. The astronaut wore a space suit, and the sealed cabin of the spacecraft was pressurized with pure oxygen for breathing and for counterpressure against his body. The principles for providing life support for the Mercury astronaut have in general been followed in the Gemini and Apollo spacecraft. The heat shield on the Mercury spacecraft covered only the large blunt end. That on the Apollo command module (the portion of the Apollo spacecraft that is returned to the earth) covers the entire module. Cooling of the module is accomplished by means of ablation, or melting of the surface materials, which collect the heat and keep the module relatively cool inside. An air-conditioning system helps with the cooling process.

**(J-9004) pp 95-115
*(J-9008) pp 123-124

f. The first astronauts were chosen by a rigid selection process. The original seven astronauts were accomplished jet pilots who had some knowledge of engineering and were capable of withstanding the great pressures of spaceflight. They were able to assist in developing the Mercury spacecraft, and with their knowledge of engineering, they were able to do some trouble-shooting once they were in spaceflight. All the original seven astronauts except Donald Slayton made one spaceflight in the Mercury. Slayton became chief of astronaut training and then Director of Flight Crew Operations at the Manned Spacecraft Center. He has recently (1972) been cleared for spaceflight but is not likely to be assigned as a crew member, since all crew positions have already been assigned through the Skylab flights.

*(J-9033) pp 866-867
***(J-9038) pp 66-85
**(J-9123) pp 472-476
**(J-9145) pp 76-91

g. The first seven astronauts (and all astronauts) underwent rigid training for spaceflight. The Mercury astronauts made simulated spaceflights, took survival training, kept up jet training, studied academic subjects like astronomy and celestial mechanics, practiced on centrifuges to gain greater tolerance to increased G-forces, and flew weightless trajectories to accustom themselves to weightlessness during orbital flight.

***(J-9023A) pp 163 - 174
**(J-9046) pp 50-73

h. Astronaut Alan Shepard made the historic first suborbital flight on 5 May 1961. This was followed by a second suborbital flight by Virgil I. Grissom.

*(J-9056) pp 208 - 212
*(J-9145) pp 18-21
*(J-9023A) p 175
**(J-9026) pp 32-50
**(J-9046) pp 96-121
***(J-9038) pp 102-125
*(J-9056) pp 213-219

i. Astronaut John Glenn was chosen to make the historic first orbital flight on 20 February 1962. John Glenn successfully fired the thrusters to stabilize the spacecraft in orbit. An alarm signaled warning that the heat shield might be lost. Possible loss of the heat shield was prevented by keeping the retrorocket package in place after firing. The alarm proved false, and the spacecraft made a safe reentry and was recovered.

*(J-9145) pp 22-23, 146-149
*(J-9023A) pp 176 - 177
**(J-9046) pp 123-193
***(J-9038) pp 126-141

j. John Glenn's flight was followed by three other orbital flights in the Mercury spacecraft. Time in flight was gradually increased to one day and a half on the last Mercury flight, that by Gordon Cooper.

**(J-9056) pp 220 - 242
**(J-9140) pp 175-177
***(J-9156) pp 578 - 579, 581-582

k. The Mercury flights showed that man could survive orbital flight without injury and that man has a definite place as a pilot in a spacecraft. All Mercury astronauts fully recovered from any ill effects of spaceflight after they returned to earth.

**(J-9026) pp 73-89
*(J-9033) pp 867-869
*(J-9056) pp 243-250
**(J-9111) pp 211-213
***(J-9156) pp 582 - 583

l. The Gemini spacecraft was a larger and better organized spacecraft than the Mercury. The Gemini spacecraft consisted of two modules and was equipped for two astronauts, for longer flights, and for some maneuvering. Large thrusters in the Gemini could be fired to cause the spacecraft to change orbit.

*(J-9033) pp 872 - 875

m. The goals of Project Gemini were keyed to the requirements for the moon landing. By the time the Gemini flights were planned, it was known that the moon landing would be made by means of lunar orbit rendezvous (LOR). Project Gemini, keyed to LOR, had three principal goals: increasing time in spaceflight to about 14 days; developing and then practicing rendezvous and docking of the Gemini spacecraft with the Agena target vehicle, which would permit the docked spacecraft to go to much higher altitudes; and practicing EVA, including both the so-called space walks and performing useful work in space.

n. Ten manned flights were made with the Gemini spacecraft in rapid succession. All goals set were accomplished, and the Gemini astronauts gained valuable experience for the forthcoming Apollo flights. On the Gemini flights, time in space was increased from 4 to 8 days, and then finally to 14 days on the Gemini-7 flight. This is still the American record for spaceflight, but Soviet cosmonauts have exceeded this time. The world's first rendezvous was made between the Gemini 6 and the Gemini 7 in December 1965. The first docking took place on the Gemini-8 flight, which was forced to make an emergency landing. The first US space walk was made by the late Astronaut Edward White on the Gemini-4 flight. Then EVA practice was postponed until Gemini 9A and subsequent flights. On the final flight (Gemini 12) all space work assigned was completed.

**(J-9008) pp 85-93
**(J-9026) pp 90-110
*(J-9033) pp 869-870
**(J-9140) pp 177-181
*(J-9145) pp 150-159
**(J-9156) pp 583-584
**(J-9158) pp 136-144

o. The Apollo flights make up Step 3, or the final step, in the moon landing program. Once the first moon landing was made, the goal for Project Apollo was met, but the capabilities of the Apollo spacecraft were used afterwards to make scientific explorations on the moon. The eleventh and last Apollo flight (Apollo 17) is scheduled for December 1972.

p. The Apollo spacecraft is made up of three modules: the command module, the service module, and the lunar module. The command and service modules remain linked during flight. The lunar module, which rests in the adapter at the bottom of the spacecraft during takeoff, breaks out of the adapter and is docked with the command-service modules, which turn through 180 degrees, on the trajectory to the moon. The service module carries reserve supplies of oxygen and the large service engine, which is fired to make midcourse corrections and to put the spacecraft on the return trajectory to the earth.

***(J-9156) pp 585-587, 590-591
***(J-9158) pp 174-179

q. The first four Apollo manned flights (Apollo 7, 8, 9, and 10) were made alternately in earth orbit and lunar orbit to test the modules and flight equipment. Apollo 8 was the first flight in lunar orbit. Apollo 9, in earth orbit, tested the lunar module. Apollo 10 was a dress rehearsal of the lunar landing.

***(J-9156) pp 588-592

r. The world's first landing of men on the moon was made in July 1969 on the Apollo-11 flight. Astronauts Neil Armstrong

and Edwin Aldrin made the first landing, and Astronaut Michael Collins piloted the command-service modules in lunar orbit while the other two astronauts were on the moon. The landing was televised worldwide, and President Nixon talked with the astronauts by telephone from the White House. The United States stressed the fact that the astronauts made
(J-9156) pp 595-602 the trip to the moon in the interests of peace and as representatives of all mankind. Scientific experiments were emplaced, and rock samples were returned. The astronauts were quarantined after the landing, as was done after the two subsequent landings.

s. The first landing was followed by landings on Apollo 12, 14, 15, and 16. After Apollo 12, the astronauts landed at sites in highland areas. Beginning with the Apollo-15 flight the astronauts made use of a powered lunar rover. Almost all the scientific experiments have been successful, and the astronauts have been able to visit a wide range of sites. Only one landing remains to be made, that scheduled for December 1972 in the Taurus-Littrow highland area. On the Apollo-13 flight, an explosion in the service module kept the astronauts from making a moon landing, but they were able to bring the Apollo spacecraft back to the earth by using the lunar module as a lifeboat. The astronauts were safely recovered.

t. In the Spring of 1973, the United States will orbit the Skylab, an experimental space station made from the empty shell of the third stage of the Saturn V booster. The Skylab will be used for conducting extended experiments in earth orbit. Three visits are to be made to the Skylab, the first scheduled for 28 days and the second and third visits for 56 days. Three astronauts have been assigned for each visit. Making the trip to the Skylab in the modified Apollo command-service modules, the astronauts will rendezvous and then dock with the Skylab. After their tour of duty in the Skylab is over, the three astronauts will return to the earth in the same spacecraft, and they will be recovered in the command module, as the astronauts were after the Apollo flights.

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. There is much material that can be used in this phase, but you should select from the offering only what you can adequately cover in the time allowed. Counting the Skylab visits, there are four steps, or stages, to US manned spaceflight. You might summarize the four stages and select a few significant flights to present in some detail instead of trying to cover every flight. By making a few flights realistic and vivid for the students, you will increase their interest in space.

c. In this phase of instruction you need to build up a background for later work. The better the students understand the principles of manned spaceflight, the more interesting and challenging the later work will be for them. To motivate students, it is probably a good plan to begin with the most recent Apollo or Skylab flight and then say that this flight was made possible by many earlier flights. During this introductory phase, stress the first stages in manned spaceflight and the most important historic flights. Try to make the students see some of the big problems that existed in the beginning and the way in which these problems were solved. When you do this, the students will gain a better understanding of principles, and they will be better able to interpret for themeslves the happenings on later flights.

d. Even if time is limited, you will want to show one or two brief films so that the students get a better idea of manned spacecraft and spaceflight operations. If you show one film of a recent flight, you might go back and show a Mercury or a Gemini flight to make clear basic recovery techniques or maneuvers.

e. Student assignment: Read the entire Chapter 5. If time is too limited to do this, you might ask the students to look over all the illustrations and the tables recording flights, and then concentrate on specific sections covering basic principles and the historic flights.

7. INSTRUCTIONAL AIDS:

a. NASA films, regular series:

HQ 9. The Mastery of Space (Project Mercury). 1962. Color. 58 min.

HQa 51. Freedom 7 (Alan Shepard's suborbital flight). 1961. Color. 28 1/2 min.

HQa 59. Friendship 7 (John Glenn's orbital flight). 1962. Color. 58 min.

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

HQa 101. The Flight of Faith 7 (Gordon Cooper's orbital flight). 1963. Color. 28 min.

*HQ A,B,C Living in Space series

HQa 134. The Four Days of Gemini 4 (first US space walk). 1965. Color. 27 1/2 min.

HQ 160. Legacy of Gemini. 1967. Color. 27 1/2 min.

HQ 187. The Flight of Apollo 7. 1968. Color. 14 min.

HQ 188. Debrief: Apollo 8. 1969. Color. 28 min.

HQ 189. Apollo 9: The Space Duet of Gumdrop and Spider. 1969. Color. 28 1/2 min.

HQ 190. Apollo 10: Green Light for a Lunar Landing. 1969. Color. 28 1/2 min.

HQ 191. Within This Decade: America in Space. 1969. Color. 28 min.

HQ 194. Eagle Has Landed: The Flight of Apollo 11. 1969. Color. 28 1/2 min.

**HQ 197. Apollo 12: Pinpoint for Science. 1969. Color. 28 min.

***HQ 200. Apollo 13: "Houston. . .We've Got a Problem." 1970. Color. 28 min.

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

HQ 212. Apollo 14: Mission to Fra Mauro. 1971. Color. 28 min.

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

b. NASA films, special interest (1969):

AD-4. Astronaut Training. 7:30 min.

AD-5. Spacecraft for Apollo. 6:00 min.

AD-6. The Command Module. 6:00 min.

AD-7. The Lunar Module. 5:00 min.

AD-8. The Service Module. 5:00 min.

AD-25. Living in Space. 8:00 min.

AD-26. Space Suit. 5:00 min.

AD-28. Apollo Recovery. 7:00 min.

c. NASA picture sets and posters:

Picture Set No. 1. Apollo--"In the Beginning . . ." Apollo 8, 9, and 10. $1.25 per set.

Picture Set No. 2. Men of Apollo. Portraits of the crews of Apollo 7, 8, 9, 10, and 11. $1.00 per set.

Picture Set No. 3. Eyewitness to Space. Paintings of space program scenes. $2.75 per set.

Picture Set No. 4. First Manned Lunar Landing. $1.75 per set.

Picture Set No. 5. Man on the Moon. The first step on the moon. $1.00 per copy.

Picture Set No. 6. Apollo 12--Pinpoint Landing on the Moon. $1.50 per set.

Apollo Program Wall Posters. Ten 30-inch X 40-inch wall posters in full color. $4.75 per set.

NF-40. Journey to the Moon. Wall sheet in color. 30 cents.

d. 35 mm Slides:

NASA 1, Apollo Slide Set

e. Transparencies:

T-36, G-Force and Weightlessness

Millikin Space Travel Nos. 2, 5, 6, 7, 8, 9, and 10.

8. PROJECTS:

a. If you have an opportunity, arrange for the students to see models of the Apollo spacecraft modules, or have models of these on display in the classroom. Add the Gemini and Mercury spacecraft models.

b. See additional suggestions in the textbook.

9. FURTHER READINGS:

a. NASA publications:

EP-57. Man in Space. 30 pp. 55 cents.

EP-66. Apollo 8: Man Around the Moon. 24 pp. 50 cents.

EP-68. Code Name: Spider (Apollo 9). 16 pp. 40 cents.

EP-70. Mission Report/Apollo 10. 12 pp. 35 cents.

EP-71. "In This Decade. . ." Mission to the Moon. Color. 48 pp. $1.25.

EP-72. Log of Apollo 11. 12 pp. 35 cents.

EP-73. The First Lunar Landing/As Told by the Astronauts. 24 pp. 75 cents.

EP-74. Apollo 12/A New Vista for Lunar Science. 20 pp. 65 cents.

EP-76. Apollo 13. "Houston, We've Got a Problem." 25 pp. 75 cents.

EP-91. Apollo 14: Science at Fra Mauro. 48 pp. $1.25.

NF-27. Living in Space. 12 pp. 15 cents.

NF-36. Simulators. 8 pp. 10 cents.

NF-41. Food for Space Flight. 20 cents.

b. See list in back of textbook.

PHASE VI - SPACECRAFT OF THE FUTURE

During this final phase of the unit the class will take a glimpse into the future to make some predictions about the spacecraft of tomorrow, based upon plans now being made by NASA. One major goal of the United States is to have a permanent space station in earth orbit and reusable space vehicles to service it. This phase describes the first of these reusable vehicles, the space shuttle, which is now being developed, as well as other vehicles that might follow. Next the phase takes up plans for future planetary probes and the spacecraft that are to be used for these probes. The phase concludes with some speculation about manned flights to the planets and the kind of spacecraft that might be used for such flights.

1. PHASE VI OBJECTIVES - Each student should:

   a. Know how the presence of a space station in earth orbit would affect the operation of future spacecraft.

   b. Be familiar with US plans for developing a space shuttle and other reusable space vehicles.

   c. Be familiar with US plans for future planetary probes.

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

   a. Describe the way in which spacecraft are likely to be launched when the United States has a permanent space station in earth orbit.

   b. Explain how the US space shuttle is expected to operate.

   c. Name at least two planetary probes planned for the future and tell what spacecraft will be used for the probes.

   d. Tell why you believe (or do not believe) that the United States will be making manned flights to Mars before the end of the century. If you think such flights are possible, describe the kind of spacecraft that will be used for the flights.

3. TEXTBOOK OUTLINE:

   a. Space station and reusable space vehicles.

(1) Space station, place for conducting extended experiments in orbit; important experiments in life sciences to learn more about man's ability to live and work in space.

(2) New space transportation system.

(a) Reusable vehicles; return to earth or space station after use; great reduction in cost of orbiting pound of payload.

(b) Space shuttle: two parts, booster and orbiter; crew of two and two passengers; solid-fueled rocket engines in booster portion and liquid-fueled (hydrogen and oxygen) engines in orbiter portion.

(c) Space tug, orbit-to-orbit shuttle.

(d) More powerful shuttles later.

(3) New kinds of space operations.

(a) Control of unmanned satellites removed from earth to space station.

(b) Launch of unmanned satellites from space station; power to be supplied for orbital changes.

(c) Shuttling between earth and space station.

(4) US plans: one large space station in earth orbit; size of station to be gradually increased until it can accommodate 100 persons.

(5) Possibility of space stations in different orbits much later.

(a) Potentials of an earth synchronous orbit.

(b) Potentials of a polar orbit above the moon.

(6) Vehicles for going from earth orbit to scientific station on moon.

(7) Possible breakthrough in developing new space vehicles.

(a) New materials, such as carbon and boron composites.

(b) Use of oxygen from atmosphere for part of oxidizer in rocket engine.

(c) Nuclear rocket engines, likely soon.

(d) Other kinds of rocket engines: ion and photon engines, mentioned earlier (Chapter 2).

b. Spacecraft for planetary exploration.

(1) Pioneer probes to Jupiter.

(a) First one launched in March 1972; must pass through asteroid belt; due to make flyby of Jupiter in December 1973.

(b) Second Pioneer probe scheduled later (1973).

(2) Mariner spacecraft to Venus and Mercury in 1973.

(a) Scheduled to swing around Venus; will carry special television camera with lens for piercing through Venusian atmosphere and taking pictures of surface of planet.

(b) Flyby of Mercury later; first probe of this planet closest to sun.

(3) Viking spacecraft to Mars in 1976.

(a) A combined orbiter-lander.

(b) Search for answers to question about presence of life on planet.

(4) Possibility of manned flights to Mars.

(a) Future US plans made with this goal implied.

(b) Spacecraft to be used is likely to resemble modules of space station.

(c) Statements of President Nixon and former NASA Administrator Thomas O. Paine.

(d) Predictions of Tsiolkovsky and Kepler.

4. ORIENTATION:

a. This is the only phase in the unit that covers future spacecraft. Although some projection into the future is made in tracing each kind of development in spacecraft, this introductory unit is planned with the intent of stressing principles and developments that have alreayd been made rather than developments that might be expected in the future. Work in AE-III should be projected more into the future. This phase points toward the work to be done in AE-III.

b. To keep this phase of instruction up to date, you will need to keep up with the latest plans projected by NASA and the most recent policy decisions made. For example, early in 1972, NASA plans for the Grand Tours (multiple probes of the outer planets) were dropped to make more funds available for developing the space shuttle. Then, too, as preliminary designs studies for the shuttle were completed, new decisions about the shuttle were made. When you make use of earlier material published about the shuttle, you will need to evaluate it to see how much still applies.

c. You will want to cover as many meaningful predictions about future spacecraft as possible, but it is a good plan to orient your instruction in this phase toward the future developments that are of the most significance at this time. These may be returns expected from planetary probes, or they may be recent developments made with the space shuttle or with space station modules.

5. SUGGESTED KEY POINTS:

a. In your study of manned spacecraft you learned how the United States gradually developed more complex spacecraft and larger and more powerful boosters for launching them. With the Saturn V booster and the Apollo spacecraft, the United States has probably reached its peak of development with expendable boosters and spacecraft. The upper stages of the Saturn V may have their power augmented, or a nuclear stage might be used, but this country is not likely to develop a more gigantic booster. We now plan to take a new line of development. The United States is now designing and will develop a new series of reusable space vehicles, which are to make up the new space transportation system.

b. Reusable space vehicles should make spaceflight less hazardous, and they should reduce the cost of orbiting payloads in space. Explorer 1 was orbited at the enormous cost of about $100,000 per pound of payload. With Saturn V, the cost was reduced to about $500 per pound of payload. With the space shuttle, the first reusable space vehicle to be developed, the cost of orbiting a pound of payload should be reduced to $100 or even less. When boosters and orbiters are recovered and used repeatedly, the cost of space operations should be cut considerably, and the United States will be able to make long-range plans for space projects on a continuing basis.

c. At the same time that the space shuttle is being developed, plans are going forward to develop modules for the first permanent space station in earth orbit. The shuttle will probably travel back and forth between the space station and the earth. When the space station and the shuttle are in operation, the nature of space operations will change. Control of unmanned spacecraft will then shift from the earth to earth orbit. Most unmanned spacecraft will no longer be launched from the earth but from earth orbit. Satellites can be powered to allow them to be launched from the orbit of the space station into other orbits. The space shuttle will be able to take satellites to orbit, return them from orbit, make in-orbit repairs, service satellites, and conduct short-duration science and applications missions with self-contained experiments in low earth orbit.

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d. President Nixon gave approval for the development of the space shuttle in January 1972. The shuttle is to consist of two parts: booster and orbiter. The booster is to be powered by solid rocket motors in a parallel-burn configuration. The orbiter stage will use rocket engines burning liquid hydrogen and liquid oxygen, much like the engines used in the upper stages of the Saturn V booster. The rockets in the booster portion of the space shuttle will detach at an altitude of about 25 miles and fall into the ocean to be recovered and reused. The orbiter portion, traveling under its own power, will continue into a low earth orbit. The orbiter stage will have delta wings and will be much like an airplane landing on conventional runways. After landing, the orbiter will be serviced and prepared for another mission. It is to be designed for reuse more than 100 times. The orbiter is to have a cargo compartment measuring about 60 feet in length and about 15 feet in diameter. It should be able to place about 65,000 pounds into a 100-nautical-mile orbit. The orbiter will carry four persons: a pilot, copilot, and two specialists.

e. The space shuttle will be developed over the next six years, The first test flights are to begin in 1976, and the manned orbital flights in 1978. The completed space shuttle is to be in operation before 1980.

f. While the space shuttle is undergoing development, other reusable space vehicles may be planned. One under design is the space tug, or the orbit-to-orbit shuttle, which is to be used for hauling freight. The first space shuttle will be followed by more powerful shuttles. One will probably have nuclear rocket engines in the orbiter portion.

g. US plans for a space station call for eventually having one large space station in earth orbit. The station might start with one or two small modules. The size and complexity of the space station could be increased by the addition of modules until the space station was large enough to accommodate 100 persons at one time.

h. Some space scientists believe that the Soviet Union and the United States will eventually have space stations in many different orbits to perform different missions. One potential orbit would be an earth synchronous orbit. A space station in such an orbit would remain continuously above one portion of the earth. Another orbit for a space station might be a polar orbit above the moon. A station placed in such an orbit could make continuous observations of the surface of the moon. In time, a permanent scientific station is likely to be established on the moon. When we have such a station we would need spacecraft for shuttling between earth orbit and the moon.

i. Because the United States is concentrating effort on developing a space shuttle and a space station in earth orbit does not mean that we are no longer interested in moving father out into space. On the contrary, a space station in earth orbit can be used as a way station to the moon and the planets. With the new extra large (210-foot) dish-shaped antennas in the NASA Deep Space Network, scientists will be able to send and receive radio signals throughout the solar system.

j. Scientists have recommended that this country not concentrate all its effort on probes of the two neighboring planets, Venus and Mars, but gradually obtain some information about all the planets. By comparing data from different planets, it will be possible to learn more about the earth and all planets in the solar system. Pioneer 10 is already on its way (launched March 1972) to make a flyby of Jupiter in December 1973. Another Pioneer probe is to be launched toward Jupiter in 1973. Also, in 1973, a Mariner spacecraft is to be launched to swing around Venus and go inward to Mercury, the planet closest to the sun. The Mariner will be equipped with a special television camera with lens designed to pierce the Venusian atmosphere and take pictures of the surface of the planet. In 1976, the United States is to launch a new spacecraft, the Viking orbiter-lander, to Mars. The orbiter portion will go into orbit around the planet while the other portion makes a soft landing to obtain data that should tell us whether or not life exists on the planet.

k. The United States at present has no plans projected for manned flights to Mars, but this goal is implicit in present planning. Former NASA Administrator Thomas O. Paine said that the lunar landing was a prelude to manned flights to the planets. President Nixon expressed the belief that astronauts would one day go to Mars. A space module like those being designed for the space station might be used for making the trip to Mars. Before trips are made beyond the moon, we are likely to make important breakthroughs in materials and means of powering spacecraft.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time

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

b. You will want to direct the teaching of this phase especially toward the needs of the class. This phase should create interest by allowing the students to apply what they have learned in this unit and give them a chance to use their imagination.

c. You want to encourage the students to project their thinking into the future but insist that they begin with the plans that NASA now has in the making. If some of the students are especially interested in spacecraft designs, you might have them draw sketches, or make models, of future spacecraft or space station modules and have these ready in advance.

d. Remind the students that they will be taking up future developments later in their work during AE-III. In the meantime, they should be alert and watch the progress of space launches and new developments.

e. Student assignment: Read the entire Chapter 6 and try to find a newspaper or television report on a future spacecraft.

7. INSTRUCTIONAL AIDS:

a. NASA films:

HQ 175. Flight Without Wings (lifting bodies; future space shuttles). 1969. Color. 14 1/2 min.

HQ 196. Seeds of Discovery (future research satellites and planetary probes). 1970. Color. 28 min.

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

***HQ 212. Space in the 70s--Exploration of the Planets. 1971. Color. 25 min.

b. Air Force film:

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

c. Transparencies

Millikin Space Travel No. 12.

8. PROJECTS:

a. Have students draw sketches of future spacecraft or space station modules.

b. See further suggestions in textbook.

9. FURTHER READING:

a. Aerospace Magazine reprint: "The Space Shuttle."

b. NASA publications:

EP-75. Space Station, Key to the Future. 40 pp. 45 cents.

EP-77. Space Shuttle. 8 pp. 25 cents.

EP-81. Man in Space. 28 pp. $1.00.

EP-83. Earth Orbital Science. 28 pp. $1.00.

c. See list at the back of the textbook.

d. Recent articles in Aviation Week and Space Technology.