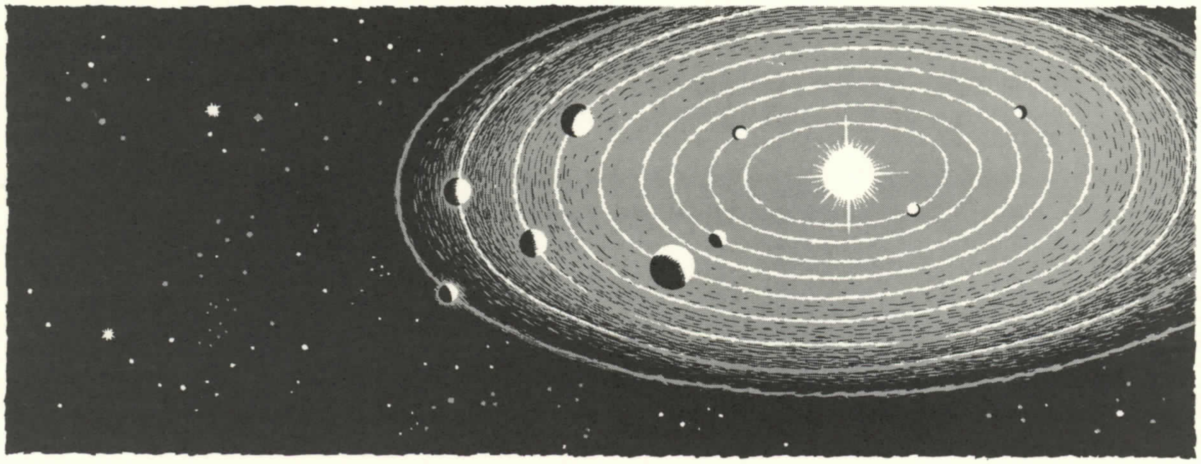

ASTRONOMY ACTIVITIES

BY

R. Lynn Bondurant, Jr.

SCIENCE EDUCATION SPECIALIST
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

PREFACE

This booklet contains information and suggested activities in Astronomy for teachers attending a NASA supported Aerospace Education Workshop.

It is not intended that it provide all the background information necessary to complete all of the activities. This is done by the instructor during the workshop-seminar.

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INTRODUCTION

What must have been truly mystifying to the ancient astronomers about planetary motions can now be easily explained. No doubt, difficult to these early scientists were questions like the following. Why do some of the planets appear in the evening sky tonight, and later appear only in the morning sky? Why do the planets which appear to move eastward among the stars suddenly stop, and then move westward for a time only to stop again, and reverse their motion toward the east? Even the answer to the question of whether the earth revolved around the sun or the sun about the earth was not known to these early astronomers.

It is almost inconceivable to have any feeling for how difficult it must have been to solve these questions. However, the answers to these and other questions about orbits have been learned through careful observations of the planetary motions. A great deal of credit should be given to Johannes Kepler for solving the mysteries of planetary motion. He was able to formulate three laws of planetary motion 50 years before Newton announced his Law of Gravitation. Kepler discovered that the orbits of the planets were ellipses rather than circular, as supposed by others. He also found out that when the planets approach the sun they move faster in their orbits than when they are farther from the sun. This information, in addition to the sun-centered solar system of Copernicus, and Newton's Law of Gravitation, enabled the scientists to begin development of a very accurate model of the solar system.

A NASA satellite orbiting around the earth obeys the same laws that a planet does orbiting the sun, and the determination of satellite orbits is very important to NASA scientists. Satellite orbits have to be precisely known, so that the space scientists will know from which part of their orbit the satellites are collecting their data. In addition, all of the meteorological satellites are placed in circular or near circular orbits so that the scale will be the same on all of the cloud cover photographs of the earth. This saves a great deal of time in reading the photographs.

If a NASA satellite is launched toward the east, and revolves around the earth faster than the earth rotates on its axis, the satellite will appear to rise above the western horizon and set in the east. Whereas, a satellite which revolves around the earth in the same amount of time that it takes for the earth to rotate on its axis will seem to stay in one position in the sky. This is known as a synchronous orbit, and the satellite is approximately 22,300 miles above the earth's equator. The moon, which is 240,000 miles from the earth and revolves around the earth in an eastward direction, appears to rise in the east and set in the west each day. This is because it takes the moon longer to orbit the earth than it does for the earth to rotate on its axis. Thus, the earth "catches up" to the moon. Since the earth rotates on its axis from west to east, the moon will appear to rise in the east.

The following activities are included to aid in the understanding of planetary and NASA satellite orbits.

PLOTTING A SATELLITE'S ORBIT AROUND THE EARTH

Often it is difficult for a student to understand why a satellite orbit resembles an "S" when drawn on a flat world map in a textbook. Everyone knows that a satellite's orbit about the earth is circular or elliptical. On television during the coverage of a manned space flight, lights appear to flash along a "wavy" line, more properly termed a sine curve, which locate the successive positions of the spacecraft in its orbit around the earth.

The following activity will help to clarify this point.

ACTIVITY

You are to launch a satellite from Cape Kennedy to orbit the earth. String wrapped around a globe can represent the satellite's orbit. You are to then draw this orbit on a flat projection world map and note its path.

Materials Needed:

a) earth globe
b) string
c) map of the world - flat projection

Directions:

1. Wrap a piece of string around the equator on the globe. Note its length.

2. Tie the string at the proper length so it will fit tightly around the globe at its equator.

3. Place the string around the globe so that it passes through Cape Kennedy. Carefully adjust the string so that half of the orbit is below the equator while the other half is above.

   (Check the position of the string on the globe by noting the greatest distance above the equator in the Northern Hemisphere and the greatest distance below in the Southern Hemisphere. They should be equal).

4. Draw the orbit accurately on the map in Figure 1, making sure that the drawings on the map correspond to the string's location on the globe.

Start at Cape Kennedy. Mark a dot or an "X" on the map at this point. Moving east (toward Africa) locate the point at which the string crosses the equator. Mark this position on the map. Next, note where the string crosses the west coast of Africa. Mark this point on the map. Continue to locate easily recognizable locations on the globe until at least fifteen points have been plotted on the map. Connect all the points with a smooth curved line.

WHAT IS THE SHAPE OF THE ORBIT?

THE POSITION OF A SATELLITE IN ORBIT

A NASA satellite, such as Echo or Pageos, is passing across the sky. Let us assume the NASA scientists need your help in determining how far the satellite is above the earth's surface and its distance from your observation point. You make your observation from a location at 25° North Latitude. To determine these distances, another person must make an observation at the same time you do but from a different latitude. A friend of yours, who lives at 40° North Latitude, has agreed to help you solve the problem. At 11:30 P.M., on March 29, you both observe the same satellite and record your observations. With an instrument, such as the astrolabe, you find that the satellite is 20° from the zenith in a northerly direction. Your friend observes the satellite at 35° from the zenith in a southerly direction. Using these two observations and a scale drawing, you can now solve the problem.

Directions: (Refer to diagram in Figure 2)

1. Draw a quarter of a circle to represent a portion of the earth's surface. Draw the circle with a 4-inch radius. One inch on the scale drawing will, therefore, correspond to 1,000 miles.

2. Measure an angle of 25° from the radius line at the center of the circle. Extend the line OA beyond the circle. This extension represents the observer's zenith or the point overhead for a latitude of 25°.

3. Repeat step 2 for an angle of 40°. Points A and B represent the locations where the observations were made—at latitudes of 25° and 40° North Latitude.

4. From the earth's surface, at point A, measure an angle of 20° from the zenith line toward the north. Draw the line. This line represents the direction of the satellite as observed from point A.

5. Repeat step 4 using the observation made at 40° North Latitude. Measure an angle of 35° from point B towards the south. The intersection of the lines at point C is the observed position of the satellite.

6. With a ruler measure the length of the line AC. Remember 1" = 1,000 miles. Line AC represents the distance from the satellite to the observer at A.

7. Measure the line BC, the distance from the observer at B.

8. Measure the line CD, the height above the earth's surface.

Many volunteers using this technique furnished information which was used to determine satellite positions during the early years of space exploration. Although present day tracking stations employ modern radar systems and computers, the principle of determining satellite positions has not changed.

MAKING A SCALE MODEL OF THE ORBITS OF MERCURY, VENUS AND THE EARTH

Tycho Brahe made many very accurate observations of the positions of Mercury and Venus in relation to the sun as seen from the earth. Brahe found that Venus never appeared more than 48° from the sun, while Mercury's orbit was observed to be only 24° away.

Using Brahe's observations, Johannes Kepler made a scale model to show the orbits of Mercury, Venus and the earth around the sun. Kepler was also able to calculate from this model the distance of Mercury and Venus from the sun in terms of astronomical units.

The following activity is provided to demonstrate how Kepler made his scale model of the orbits of the first three planets of the solar system. It will also permit you to determine the distance from the sun of Mercury and Venus in terms of astronomical units.

ACTIVITY

Materials Needed:

a) ruler
b) compass
c) protractor
d) paper

Directions:

1. Draw a circle with a four-inch radius. Let the center of the circle represent the sun, and the circle the earth's orbit about the sun.

2. Place a point on the earth's orbit to represent the earth.

3. Connect the earth and sun with a straight line. Let us refer to the distance from the earth to the sun as Kepler did, and call it one astronomical unit.

4. From the earth and the earth-sun line draw an angle of 48° to represent Venus' greatest angular distance from the sun. Direct this angle toward the sun inside the earth's orbit.

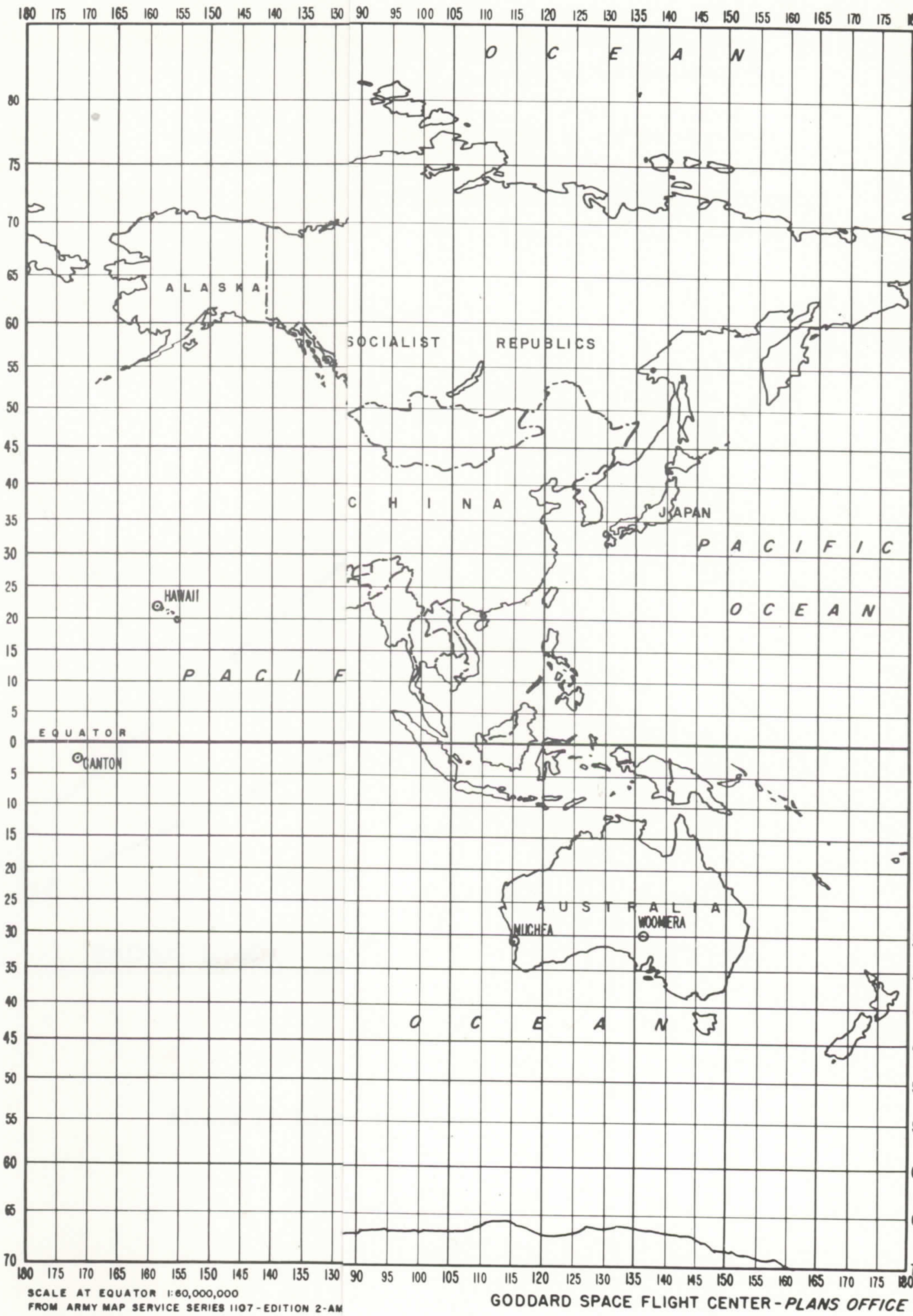
5. With the sun as the center, take a compass and draw the largest possible circle that will touch the 48° angle line, but will not cross it. This circle represents the orbit of Venus.

6. Repeat steps 4 and 5 to determine Mercury's orbit; however, this time measure an angle of 24° from the earth. The circle drawn in this step represents Mercury's orbit.

7. With a ruler determine the distance from the sun to the orbits of Mercury and Venus along the earth-sun line in terms of astronomical units. One inch on your scale drawing corresponds to 1/4 of an astronomical unit.

What is the distance from the sun to Mercury and Venus in astronomical units?

One astronomical unit is equal to 93,000,000 miles. By multiplying your answers above by 93,000,000 miles, determine the two planets' distance from the sun in miles. The correct answer should be approximately 35,960,000 miles for Mercury, and 67,200,000 miles for Venus.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SOCIALIST
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GODDARD SPACE FLIGHT CENTER-*PLANS OFFICE*

Figure 1

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SCALE AT EQUATOR 1:60,000,000
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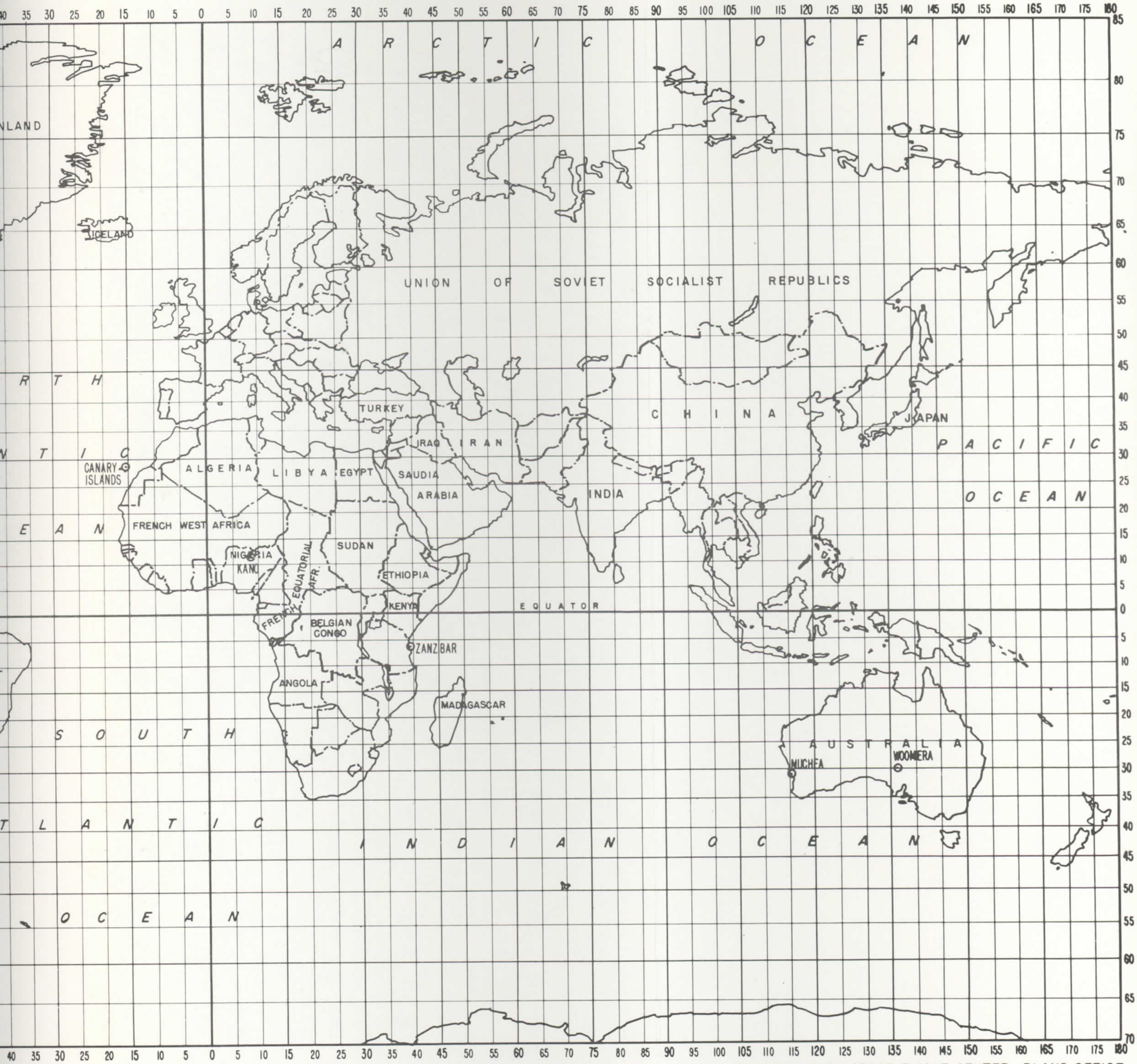

GODDARD SPACE FLIGHT CENTER - *PLANS OFFICE*

Figure 1

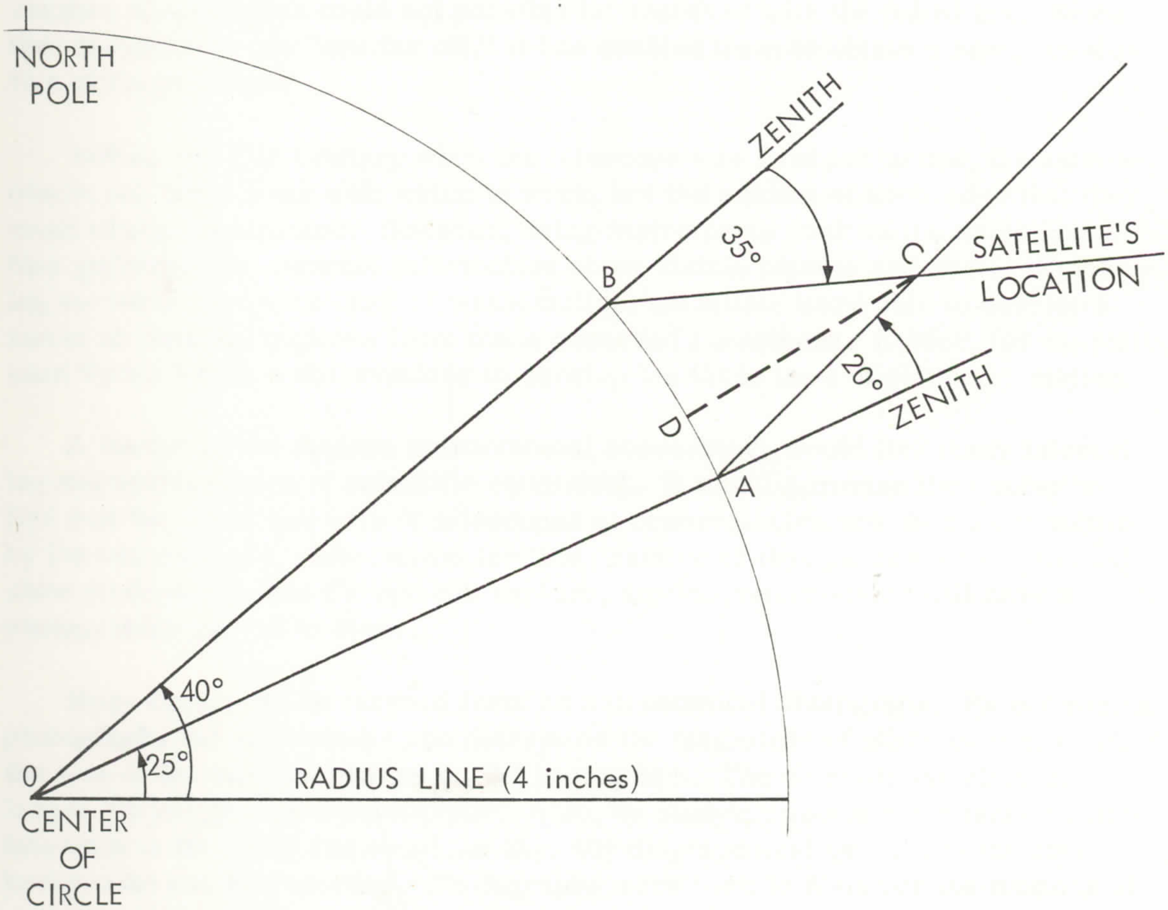

Figure 2. Locating a Satellite.

THE TOOLS OF THE ASTRONOMER

A modern astronomical observatory has many instruments which can be used to gather information and make measurements about the universe. Telescope is a familiar word to everyone. Translated from Greek it means "to see far off." This is precisely what it has been doing since the 17th Century. This "optic tube" has permitted the astronomers to discover objects in the distant reaches of space that could not possibly be observed with the naked eye. Since the astronomers can "see far off," it has enabled them to obtain a new perspective of the universe.

Before the 17th Century when the telescope was first put to use, the astronomers had other tools with which to work, but the amount of knowledge that they could obtain was limited. However, using instruments such as the astrolabe, they gathered very precise information about visible planets and stars. Employing the advances in the field of mathematics, scientists were able to develop a model of celestial motions from these observed phenomena. Kepler, for example, used Tycho Brahe's observations to develop his three laws of planetary motion.

A visitor to the modern astronomical observatory would find many interesting and useful pieces of scientific equipment. It might surprise the visitor to find that the great majority of telescopes at observatories are used as cameras by the astronomers. The reason for this practice is that the developed film will show more detail than the eye can capture, and the astronomers will have a photographic record to study.

Many things can be learned from an astronomical photograph. By examining photographs the astronomer can determine the magnitude of stars by comparing the size of the various images on the photograph. The brighter the star, the larger the image on the photograph. Also, by studying photographs taken at time intervals in the same region of the sky, any displacement or shift in the star background can be recorded. Photographs were used to discover the motions of comets, and to measure the distance of stars from the earth. Pluto, discovered in the 1930's, was first located on a photograph.

Of special importance in an observatory is the spectroscope. This instrument can be used to "finger print" the universe. By looking at the light from a star, such as the sun, its chemical composition can be identified. A galaxy's motion in space relative to the earth can also be ascertained from the galaxy's spectrum.

A photometer is also used in many observatories to measure the light intensity of stars. A comparison of the light received from star "X" with one whose magnitude is known allows the astronomer to determine the amount of light that is received from star "X".

The interferometer can be used to determine the angular diameter of stars. Once the star's angular diameter is known, and this data is coupled with information concerning its distance from the earth, the star's size can be determined.

Radio telescopes are used to study electromagnetic radiation not visible to the human eye. The 200-inch optical telescope at Mt. Palomar is 40 million times the length of the light waves it detects. To obtain the same level of sensitivity with a radio telescope, it would need an antenna 60 miles in diameter. This gigantic proportion has not yet been achieved, but the radio telescope nevertheless is adding greatly to our knowledge about the universe. It can "see" things in space which are not visible to the optical telescope. As an example, the Great Spiral Galaxy in Andromeda appears to be surrounded by a shell of energy which makes the dimensions of this galaxy much larger than it appears visually or when photographed.

The NASA satellites have or will incorporate much of the instrumentation already discussed. In addition, they will have packaged Geiger Counters to study cosmic rays, or magnetometers to study the magnetic fields in space. All of these instruments will "see" and study areas of the electromagnetic spectrum and gather other information that is invisible on the earth's surface due to our protective atmosphere.

THE SPECTROSCOPE

The spectroscope is an instrument which is really a "sorting out" device. The spectroscope takes light which is composed of numerous different colors and sorts out the various colors in the order of their wavelength. In visible light, the colors range from red light with a very long wavelength, to violet with a very short wavelength. All of the other colors fall in between these two, and they tend to blend into each other.

The spectroscope has many uses. One of the most important for the astronomer, however, is the spectroscope's ability to identify chemical elements. Through the use of this "finger-printing machine," astronomers have been able to determine the composition of the sun, stars, and the atmospheres of several planets. Because of its usefulness, the spectroscope will be placed in space often to aid in analyzing the chemical composition of the areas visited by the NASA spacecraft.

CONSTRUCTION OF A SHOE BOX SPECTROSCOPE

Materials Needed:

a) masking tape, 3/4-1 inch wide
b) shoe box with its top
c) 1 single edged razor blade
d) 1 double edged razor blade
e) transmission diffraction grating
(This can be purchased from Edmund Scientific Company, Barrington, New Jersey, Catalog Number 50,180. The price is $6.95 for a six-foot roll.)

Directions:

1. Locate the center of each end of the shoe box. The easiest and quickest way is to draw two diagonals. The intersection of these lines is the center of the shoe box.

2. At the center on one end of the shoe box, draw a circle, using a compass, with a 1/2 inch radius.

3. Cut the circle out with a single edged razor blade. This will be the eyehole.

4. Exactly opposite the eyehole, cut a narrow vertical slit with the single edged razor blade. The slit should be approximately 1" x 1/4". Therefore, the slit should extend 1/2" above and below the point already determined to be the center.

5. Break in half the double edged razor blade. (Break blade with wrapper still around it).

6. Tape the two halves of the razor blade to the inside of the box over the slit. The sharp edges should form an opening between 1/16 and 1/32 of an inch.

7. On the inside of the box, over the eyehole, tape the transmission diffraction grating so that the fine lines on the grating run parallel to the slit.

8. Place the lid back on the shoe box, and tape it around the edges to keep out unwanted light.

ACTIVITIES

1. Look at the light from an ordinary light bulb with your spectroscope. While looking at the light, you should observe the following colors through your spectroscope — violet, green, blue, red, yellow, indigo and orange. Arrange the colors in the order you see them in your spectroscope from left to right.

   This is an example of a continuous spectrum. The spectrum from the light bulb is very similar to the sun's spectrum. NEVER LOOK AT THE SUN DIRECTLY. IF YOU WANT TO SEE THE SUN'S SPECTRUM, LOOK AT SUNLIGHT REFLECTED OFF A WHITE PIECE OF PAPER.

2. Look at a flourescent light with your spectroscope. Do you see the bright lines? In which section of the spectrum are they located? Make a drawing of the spectrum and draw in the bright lines. The type of spectrum that you have just observed is called an emission-line spectrum.

3. The flame from a bunsen burner, candle, or alcohol lamp can be used to observe the emission-line spectra of other elements. Take some table salt (NaCl) and add just enough water to dampen it. With a piece of cotton soak up as much salt as you can on the cotton. Then with a pair of forceps (being careful not to get burned) hold the piece of cotton over the

flame. Record the spectral lines observed. Are the bright lines in the same location as those observed in the fluorescent light in step 2?

OPTIONAL

Repeat the observations in step 3 with one modification. This time, place an ordinary light bulb so that its light will shine through the flame. Burn the table salt again, and observe the flame with the light in the background. Do you see the black lines? Where are they located? (The black lines will be observed to be in the same position as the bright lines of sodium were when it was burned with no light present in the background.) The spectrum where the lines appear dark rather than bright is known as the absorption-line spectrum. Observe other materials to see their absorption-line spectra.

SUGGESTED READINGS:

Baker, Robert H. ASTRONOMY. D. Van Nostrand Company, Inc., Princeton, New Jersey, 1964.

Brinton, Henry. MEASURING THE UNIVERSE. Roy Publishers, New York, 1962.

Ronan, Colin A. OPTICAL ASTRONOMY. Roy Publishers, New York, 1964.

MEASURING THE ALTITUDES OF STARS

Today, astronomers know very accurately the positions of all the stars that can be observed at night. This is the result of the many observations made through the ages. Since the celestial positions are accurately known, they can be used for locating the observer's position on the earth. Therefore, the stars, including the sun, have been used for navigation purposes since antiquity.

With manned space flights under way, and the future trips to the moon and Mars a reality, celestial navigation, using the stars to determine the astronauts' location in space, is most important. The Apollo Optical Navigation Unit will be used to determine location in space just as the early sea explorers, such as Magellan, used the quadrant to determine their positions at sea.

The astrolabe, the forerunner of the quadrant, is a simple astronomical device for determining the height of the stars above the horizon. The astrolabe seems to have originated in antiquity. It was used by Arab and European astronomers as well as astrologers. The astrolabe could be used to tell time by measuring the sun's angle above the horizon in a vertical position, or could be placed horizontally to determine the positions and coordinates of the heavenly bodies.

CONSTRUCTION OF ASTROLABE

Materials Needed:

a) 1 paper clip
b) 1 brass paper fastener
c) 1 sheet of Polar Co-ordinate Graph Paper
d) 2 cardboard sheets as rigid as possible
e) rubber cement
f) 2 needles
g) 1 single edged razor blade
h) ruler

Directions:

1. Take a sheet of Polar Co-ordinate Graph Paper, and cut out a circle of desired size (Example — 7-inch diameter).

2. Place rubber cement on back of circle that you have cut out and allow to dry.

3. On a sheet of rigid cardboard cover with rubber cement an area large enough to fit the circle and allow to dry.

4. Affix circle to cardboard sheet.

5. Using a single edged razor blade, cut out circle.

6. Take a second sheet of cardboard, and cover with rubber cement an area large enough to fit circle from number 5. Allow to dry.

7. Cover cardboard back of circle from number 5 with rubber cement, and let dry.

8. Mount cardboard and circle together. Mounting will look like the one in Figure 1.

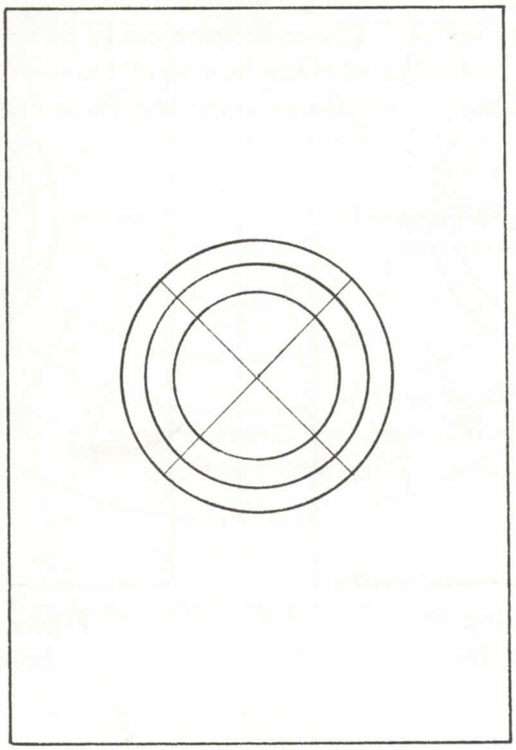

Figure 1. Mounted Polar Co-ordinate Graph Paper.