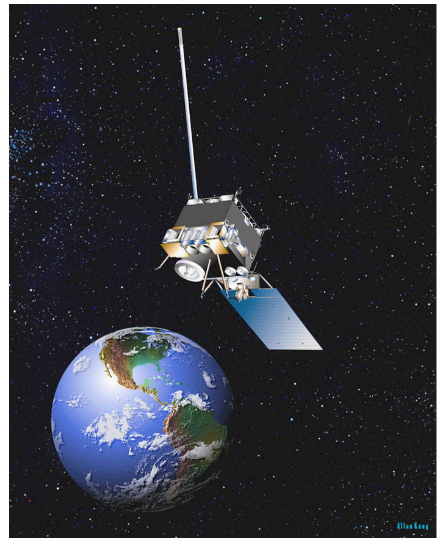
# Where Is That Satellite?

*Lots of stuff orbits the Earth. Do you know where they are? This activity will help your students better understand the size and scale of the various satellites in space that they use everyday.*



**Materials Needed**

- A 12 inch diameter earth globe
- Rulers, tape measures, and meter sticks
- Calculators

**What To Do:**

- Show student the 12-inch (30 cm) diameter Earth globe. Remind the students that the Earth has a diameter of about 12,700 km. So we are going to be working with a scale where

$$12{,}700 \text{ km}/ 30 \text{ cm} = X/1 \text{ cm}$$

$$X = 12700 \text{ km } (1\text{cm}/30\text{cm})$$

$$X = 12{,}700 \text{ km}/30$$

$$X = 423 \text{ km}$$

$$X \sim 400 \text{ km}$$

So, in this activity, where the Earth is the size of the globe, 1 cm = 400 km.

- The table below describes the orbits of several satellites. Assign groups of students to one of the orbiting satellites and pass out the flash card attached. Their task will be to show, using the globe, where the satellite orbits (or, in the case of Sputnik 1, used to orbit) the earth.

| Satellite | Distance From Earth's SURFACE | #Orbits in 24 hrs | Orbit Type/Notes |
|---|---|---|---|
| Sputnik 1 | 130 km –600 km | 15.0 | Was in a **low earth, elliptical orbit** with an eccentricity of 0.05 |
| International Space Station | 350 km | 15.8 | In **low earth, circular orbit** with eccentricity of 0. |
| Hubble Space Telescope | 600 km | 14.8 | In **low earth, circular orbit** with eccentricity of 0. |
| Satcom 1 | 36,000 km | 1.0 | In **geostationary orbit**; responsible for the broadcast of cable television. Launched in 1975. Eccentricity = 0. |
| RadioStat | 24,000 km – 47,000 km | 1.0 | In highly elliptical **tundra orbit**; broadcasts "Sirius Satellite Radio"; Eccentricity = 0.27 |
| Molniya 1-4 | 1500 km – 40,000 km | 2.0 | In highly elliptical **molniya** orbit. Responsible for military and television communication in Russia. Eccentricity = 0.70 |
| Geostationary Operational Environmental Satellite (GOES) | 36,000 km | 1.0 | In **geostationary orbit**; weather satellite used by the National Weather Service for imaging, data collection, and meteorological research. Eccentricity = 0. |

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- Once student teams have determined the scaled distance that their satellite orbits above the surface of the earth globe, have each group show the rest of the class where the satellite is located in space.

## What Else Can You Do?

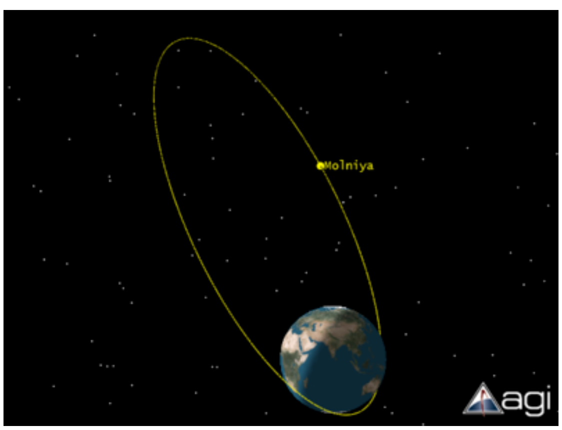
- The table also lists the eccentricities of the orbits of these satellites. Some orbits are very elliptical (oval shaped with eccentricities near 1.0) while some are circular (eccentricities = 0). Have students draw the shapes of these orbits, placing the earth at one of the foci of the ellipse (see attached handout, "*Orbits of the Planets and Satellites*")

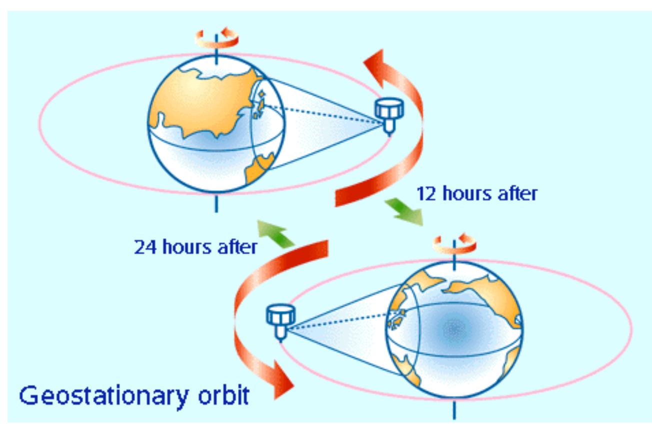
- Have student groups conduct research on the satellites they were assigned. Have groups write reports, develop multimedia presentations, or create poster boards that describe the history of the satellite, its purpose, and its orbital characteristics.

## What's Going On?

Students may be surprised by three things after doing this activity: (1) that some satellites orbit very close to the earth's surface while others orbit very far, (2) that satellite orbits are not always circular; some are noticeably elliptical, and (3) some satellites orbit once every 24 hours along the equator (hovering above one geographical location on the earth). How a satellite orbits the earth has everything to do with its purpose. For example, weather satellites that take films of the planet's cloud cover need to hover above a fixed point on the earth. These satellites need to have a geosynchronous orbit parallel to the earth's equator.

Communications satellites that service extreme northern latitudes, like Russia, do not function well in geosynchronous orbits that would place them very low in the Russian sky where signal interference would be a problem. Instead, Russians place their satellites in very elliptical orbits, called "Molniya" orbits. Their satellites pass close to the earth (where they travel at high speeds) and travel far from the earth (where they travel at very slow speeds). For eight out of the 12 hours that it takes these satellites to complete one orbit, these objects are in a nearly stationary position above Russian land; the other four hours are spent whipping past the earth. Three Molniya Satellites, taking turns at farthest approach, are used to cover communications in a 24-hour period. The figure below shows a Molniya orbit and a geosynchronous (also called a geostationary) orbit.




## So What?

Source: http://sattechnology.wordpress.com/

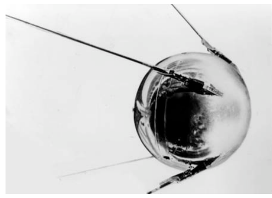
"A satellite can be defined as any object, either manmade or naturally occurring, that orbits around something else. For example, the moon orbits around Earth and is thus a satellite. The Earth orbits around the sun and is a satellite of the sun. Other examples of naturally occurring satellites include comets, stars, asteroids, and other planets.

Most are more familiar with the term satellite in relationship to the many satellites that circulate the earth. Sputnik was the first artificial satellite, launched in 1957 by the Soviet Union. The launching of Sputnik is almost analogous for the beginning of the Space Race that followed between the US and the USSR. In today's climate, however, many countries have found that a cooperative effort is more successful in space exploration and studies. The International Space Station, a satellite that orbits earth, is currently the largest manmade satellite in Space, and represents the cooperative effort of numerous countries.

Manmade satellites are classified by types, and there are over ten types. Some of the main types of satellite used today include astronomical satellites, communication satellites, earth observation satellites, weather satellites and space stations. Other types of satellites include those used to monitor earth from a military standpoint, and biosatellites, which may carry animals or other lifeforms for the purpose of research on earth lifeforms in space. Navigational satellites are now popular and form a vital part of the global positioning system (GPS) now available in many cars. A manmade satellite can serve many purposes. We currently use many different types of satellite systems to track things like weather, to make our cell phones work, to find out how to get somewhere and to gather more information about earth, and about the galaxy.

About 5000 manmade satellites currently orbit earth, and on clear dark nights, it's often possible to see one in the night sky. Of course, viewing a planet, the stars, or comets is also viewing a satellite. We also must remember, we live on a satellite, and are not stationary in the sky."

### Sputnik

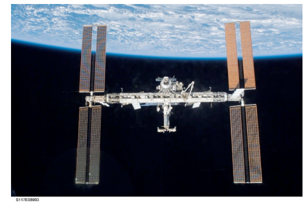


Distance from
Earth's Surface = 130km - 600km

# Orbits in 24 hours = 15

Was in a **low earth, elliptical orbit** with an eccentricity of 0.05

### International Space Station



Distance from
Earth's Surface = 350km

# Orbits in 24 hours = 15.8

In **low earth, circular orbit** with eccentricity = 0.

### Hubble Space Telescope

Distance from Earth's Surface = 600km

# Orbits in 24 hours = 14.8

Was in a **low earth, elliptical orbit** with an eccentricity of 0.

### Satcom 1

Distance from
Earth's Surface = 36000km

# Orbits in 24 hours = 1

In **geostationary orbit**; responsible for the broadcast of cable television. Launched in 1975. Eccentricity = 0.

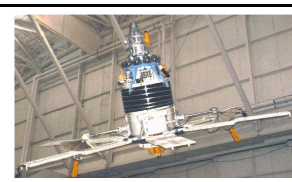
### Radiostat

Distance from Earth's Surface = 24000km - 47000km

# Orbits in 24 hours = 1

In highly elliptical **tundra orbit**; broadcasts "Sirius Satellite Radio"; Eccentricity = 0.27

### Molniya 1-4

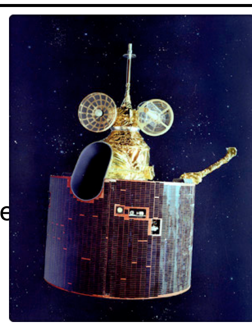


Distance from
Earth's Surface = 1500 km – 40,000 km

# Orbits in 24 hours = 2

In highly elliptical **molniya** orbit. Responsible for military and television communication in Russia. Eccentricity = 0.70

### Geostationary Operational Environmental Satellite (GOES)



Distance from Earth's Surface = 36000km

# Orbits in 24 hours = 1

In **geostationary orbit**; weather satellite used by the National Weather Service for imaging, data collection, and meteorological research. Eccentricity = 0.

# Orbits of the Planets and Satellites

*Think the orbits of the planets are cigar shaped ellipses? Think satellite orbits are always circular? Think again.*

## Materials Needed (for every student)

- push pins
- thread or thin string
- butcher paper (or other large sheet)
- ruler
- pencil or pen
- Styrofoam board or thick cardboard

## Background

What is an ellipse? *An ellipse is a curve for which the sum of the distances from any point along the curve to each foci inside the ellipse are always equal.* **Figure 1** below shows the geometry of an ellipse. Note that ellipses have two *foci*, a *semi-major axis* (a), and a *major axis* (2a). The *eccentricity* (e) of an ellipse is the ratio of the distance between the two foci and the length of the major axis.

e = (Distance between the foci) ÷ (Length of the major axis)

We will use this information to investigate the eccentricity (e) of orbits of objects in our solar system.

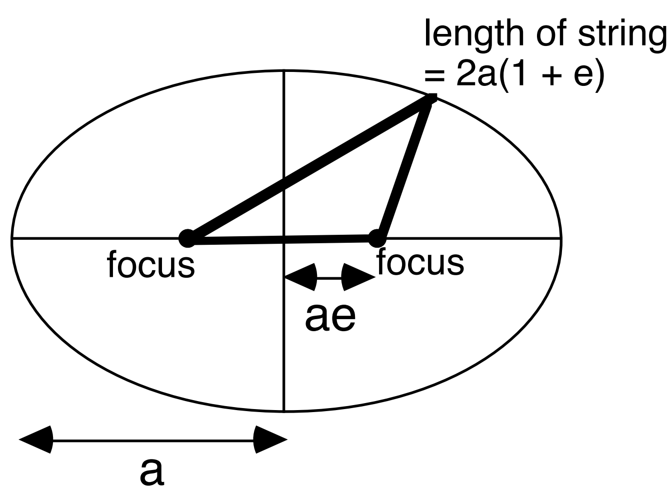



Figure 1

## What To Do

- Pick one of the planets, comets, or satellites listed in Table 1.
- Note that the table lists some of the dimensions in astronomical units. One astronomical unit equals the average distance between the earth and the sun. If you try to draw your ellipse to scale, you will have a problem finding enough paper. So, you should choose a scale so that you can easily fit your ellipse on a piece of butcher paper. You can try 10 cm = 1 A.U. for the inner planets (Mercury to Mars). For the outer planets and the comets (Jupiter to Pluto) you might want to try 1 cm = 1 A.U.
- The satellite dimensions are given in kilometers. For these objects you might want to pick a scale where 1cm = 1000km.
- Place a sheet of butcher paper on the Styrofoam board. Using the information supplied below for your planet/comet and the scaling factor you chose, place pins a distance of 2ae apart and cut a length of string equal to 2a + 2ae.

- Put the loop around the pins. Using a pencil as shown in **Figure 2**, sketch out the shape of the orbit.

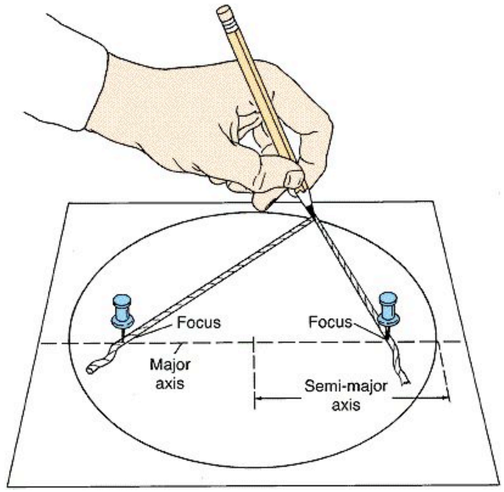



**Figure 2**

- Compare the orbit of your planet/comet to the other orbits drawn by pother members of the class. How elliptical is your orbit? Is it cigar shaped? An oval? Or is your orbit nearly circular? Are you surprised?

**What's Going On?**
Because of misleading diagrams often seen in books other astronomy reference materials, most people believe that the orbits of the planets are highly elliptical – almost cigar shaped. In fact, the orbits of the planets are very nearly circular.

The problem with this misconception about planetary orbits is that it leads many students to erroneously believe that the cause of the earth's seasons has something to do with changing distance to the sun. After all, if the earth's orbit were as elliptical as these students believe, we would in fact be much closer to the sun during certain times of the year and much further away at other times.

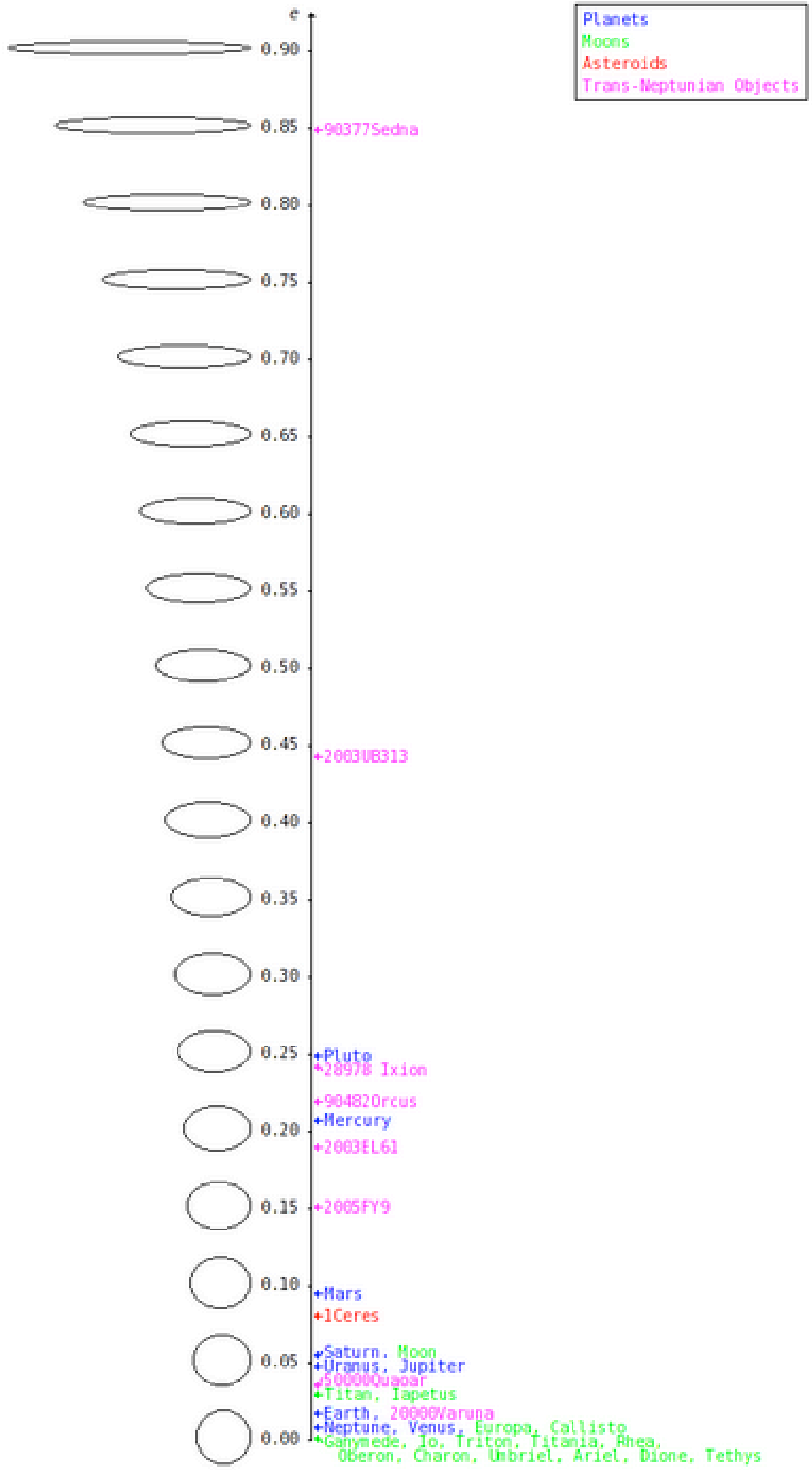
The fact is that the earth's orbit is very close to being circular. At our closest approach to the sun, we are 147,000,000 kilometers away. At farthest approach to the sun, we are 152,000,000 kilometers away. Our distance from the sun varies by only 3% – not enough to account for changes in how the earth is heated by the sun during the year.

Another misconception held by some students is that all man-made satellites (e.g. those used for communications or science research) have circular orbits around the earth. Some do, but many do not. Some satellites need to hover above the exact same geographical point above the surface of the Earth, for example the satellites used by the National Weather Service to image the Earth. These satellites are in *geosynchronous orbit*, meaning that the orbital periods are equal to (or "in synch") with the earth's spin (it takes these satellites 24 hours to complete one orbit around the earth). Satellites in geosynchronous orbit have circular orbits with eccentricities = 0. Examples of satellites in geosynchronous orbit include SATCOM 1 (used to broadcast cable television), and Geostationary Operational Environmental Satellite (GOES).

Some satellites take advantage of the orbital properties of highly elliptical orbits to hover above a certain region of the earth. When a satellite orbits in an elliptical orbit, it's speed will be slowest when the satellite is furthest from the focus (the earth); fastest when the satellite is closest to earth. The higher the eccentricity, the flatter the ellipse and larger the differences in orbital speed. Russian Molniya Satellites (used in communications) orbit in these kinds of highly elliptical orbits. They pass very close to the earth (where they travel at high speeds) and travel very far from the earth (where they travel at very slow speeds). About 8-hours of these 12-hour orbits are spent far from the earth in nearly stationary positions above Russian land; the other 4-hours are spent whipping past the earth. Three Molniya Satellites, taking turns at farthest approach, are used to cover communications in a 24-hour period.

*Table 1: Orbital dimensions of some objects in our solar system*

| Name of Body | e eccentricity | a (A.U.) | 2ae = dist between foci (A.U.) | 2a+2ae = string length (A.U.) |
|---|---|---|---|---|
| OBJECTS ORBITING SUN | | | | |
| Mercury | 0.200 | 0.38 | 0.150 | 0.91 |
| Venus | 0.001 | 0.72 | 0.001 | 1.44 |
| Earth | 0.017 | 1.00 | 0.034 | 2.03 |
| Mars | 0.093 | 1.52 | 0.283 | 3.32 |
| Asteroid Apollo | 0.56 | 1.47 | 1.65 | 4.59 |
| Asteroid Eros | 0.22 | 1.46 | 0.64 | 3.56 |
| Jupiter | 0.048 | 5.20 | 0.499 | 10.90 |
| Saturn | 0.056 | 9.54 | 1.068 | 20.15 |
| Uranus | 0.047 | 19.18 | 1.803 | 40.16 |
| Neptune | 0.008 | 30.06 | 0.481 | 60.60 |
| Halley's Comet | 0.97 | 17.90 | 34.73 | 70.53 |
| Pluto | 0.250 | 39.44 | 19.72 | 98.60 |
| OBJECTS ORBITING EARTH | e eccentricity | a (km) | 2ae = dist between foci (km) | 2a+2ae = string length (km) |
| Sputnik 1 | 0.05 | 7000 | 700 | 14700 |
| International Space Station | 0 | 6700 | 0 | 13400 |
| Hubble Space Telescope | 0 | 6700 | 0 | 13400 |
| Satcom 1 | 0 | 42000 | 0 | 84000 |
| RadioStat 1-4 | 0.27 | 42000 | 22680 | 77000 |
| Molniya 1-4 | 0.70 | 27000 | 38000 | 92000 |
| GOES | 0 | 42000 | 0 | 84000 |


e
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Planets
Moons
Asteroids
Trans-Neptunian Objects
90377Sedna
2003UB313
Pluto
28978 Ixion
90482Orcus
Mercury
2003EL61
2005FY9
Mars
1Ceres
Saturn, Moon
Uranus, Jupiter
50000Quaoar
Titan, Iapetus
Earth, 20000Varuna
Neptune, Venus, Europa, Callisto
Ganymede, Io, Triton, Titania, Rhea,
Oberon, Charon, Umbriel, Ariel, Dione, Tethys