Our Corner of the Universe
AST 101, Fall 2007
ORBITING EARTH LAB
Week of October 2

PRE-LAB PREPARATION

We will be making use of two formulae:

$$(1) \quad \upsilon = \sqrt{\frac{GM}{r}} \qquad\qquad (2) \quad \upsilon = \frac{2\pi r}{P}$$

Equation (1) relates the velocity of a satellite around the Earth to the mass, *M*, of the Earth and *r*, the distance of the satellite from the **center** of the Earth. *G* is Newton's constant.

Equation (2) relates the velocity to *r*, and *P*, the period (or time it takes for the satellite to complete one orbit). Putting these two equations together we can relate *P*, the period of the orbit, to the distance from the center of the Earth.

$$(3) \quad P = \left(\frac{4\pi^2 r^3}{GM}\right)^{1/2}$$

Or we can solve 3 for r and find the needed radius to achieve a given period

$$(4) \quad r = \left(\frac{P^2 GM}{4\pi^2}\right)^{1/3}$$

The motion of a satellite, the relationship between its orbital period and its height, is completely determined by Newton's Laws and the law of gravity! Orbits just above the atmosphere are called low Earth orbits or LEO. We need to be high enough to minimize friction with the atmosphere or drag. A height of about 130 km is the minimum practical height of a satellite.

Q. How long does it take a satellite this height to complete an orbit (use eq. 3)? If the satellite were 250 km high, what would its period be? Notice that there is little difference in time. All LEO have essentially the same period.

Q. Using equation (4) find the radius of an orbit that would cause a satellite to orbit Earth with a period of one sidereal day, 23 hours and 56 minutes. Equation (3) and this period yield a radius of 42,200 km. A satellite on orbit at that radius would be 35,800 km above Earth's surface.

LAB

A satellite on an equatorial orbit at 35,800 km above Earth traveling east, is in a **geostationary** or **geosynchronous orbit**, often called **geosynch**. Many communications and weather satellites are on **geosynch**. From vantage points on Earth, these satellites appear fixed in the sky. "Satellite" dishes aimed at these points may receive microwave signals from the satellites 24 hours a day. From the satellite's viewpoint, its transmitter can send signals to, and its cameras can see, nearly one-third of Earth's surface, although it cannot effectively reach high (north or south) latitudes. Geosynch is an example of a high orbit.

An ideal location for a spaceport would be the top of the highest mountain on Earth's equator. This would allow satellites to achieve orbit with the minimum expenditure of rocket fuel. Launching eastward takes advantage of Earth's rotation, which provides a velocity of 1670 km/hr eastward at the equator. The Kennedy Space Center, at Cape Canaveral, Florida, is the primary launch facility of the United States space program. The location was chosen to take advantage of year-round warm weather, the availability of then undeveloped land, of being relatively close to Earth's equator in then "secure" US territory, and also to be on the eastern seaboard. Being on the eastern seaboard places rockets that fail early during their launches over the Atlantic Ocean, where there are no cities to be damaged by the falling debris.

PROCEDURES

Apparatus: Globe of Earth, rolls of removable tape, drawing compass, millimeter scale, and meter stick.

A. Drawing Orbits to Scale

1. Use a drawing compass and draw as accurately as possible a circle to represent Earth, at the scale of 1.00 cm = 1000 km. Then, using the same center and scale, draw a circle to represent the orbit of a satellite 130 km above Earth.

2. Use a drawing compass to draw another circle to represent Earth at the scale of 1.00 cm = 5000 km. Then, using the same center and scale, draw a circle to represent the orbit of a satellite at geosynch.

3. Draw free hand, as accurately as possible, a circle to represent Earth at the scale of 1.00 cm = 50,000 km. Do this by placing two small marks a distance apart to represent the diameter of Earth, and then sketch a circle of that diameter. Then, using the center of that circle, and the same scale, draw a circle with a drawing compass to represent the orbit of the Moon.

4. On the drawing showing the orbit of the Moon around Earth, add to scale as accurately as possible a low Earth orbit and a geostationary orbit.

5. Comment on the difficulty of accurately showing these three orbits on the same drawing.

B. Orbits With a Globe

1. Measure and record the diameter of your globe in cm. Compute the scale factor for your globe (a ratio which will convert cm to km for your globe). Most of the Earth's atmosphere is below 6 km. How many cm above the globe is this? How many cm above the globe is a satellite in LEO? Calculate the number of centimeters from the globe's surface a satellite would be on geosynch.

2. Position a meter stick perpendicular to the surface with one end on the equator of your globe, and place your head against the meter stick so one eye is at the equivalent of the geosynch distance from the globe. Look at the globe from that point, and make a list of which continents can be seen as the globe is rotated. Can all continents be seen? Which can not? What are the highest and lowest latitudes that can be seen?

3. What longitude (on the equator) would be the best location for a communications satellite on geosynch to serve both USA and Europe? The USA and Japan? Japan and Australia? Is it possible for a communications satellite to serve USA, Japan and Australia at the same time?

4. If you wanted to broadcast TV from a geosynch satellite to the U.S., where would it be? What direction would you aim your satellite dish from Syracuse to pick up this signal? Check this out the next time you pass someone's satellite dish.