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Determining the Altitude of Iridium Flares

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Audience: Earth science students in middle school and high school. Math required; beginning trigonometry.

Background: If you have a clear night and you're somewhat removed from city lights, many satellites are fairly easy objects to see. They look like faint stars (occasionally bright stars) gliding across the night sky. Sometimes satellites look like airplanes, but airplanes have blinking lights that are usually colored. What's interesting about Iridium satellites, from a star gazing point of view, is that they can suddenly brighten and may easily outshine every star or planet in the sky. Such dramatic "flaring" is a result of the special composition and configuration of the antenna on these satellites. I suspect that a number of future UFO sightings will be attributed to these things. You may be curious about how high Iridium satellites are as they wander across the sky. With just a little information, we can calculate the altitude of the Iridium satellites and the altitudes of other satellites as well.

Iridium flares have nothing to do with the element iridium. The name comes from the telecommunications-company that has been launching satellites into low, near-polar orbits for use in a new type of wireless phone and paging service. Two years ago, the first of 77 originally proposed Iridium satellites (77 is the atomic number of iridium) was launched. The flotilla of satellites has now been scaled-down to 66.

Because both the Sun's and the satellite's position are known, it is possible to predict just where and when these flares will occur. Heavens Above has a Web site that helps you figure out the best viewing times for your particular location and the expected brightness of the flares. Click on to (http://www.heavens-above.com). Scroll down the "Welcome to Heavens Above" page to where it says "entering coordinates manually" or "selecting from huge data base." This is where you plug in the latitude and longitude of your hometown. You can get this from an atlas or right from the program if your hometown is listed in their index of cities. Once you've done this, information about viewing various satellites will appear. Make a selection under "iridium flares." The program will show you the dates when the flares are visible for the next seven days, the local time when you can observe the flare, the flare intensity, its elevation above the horizon, its azimuth (this is basically the direction from due north measured clockwise in degrees), the distance and direction you would have to travel in order for the flare to be at its brightest, and the satellite number. Give it a try, and for best results wait for a clear, moonless night

Exercise: How far overhead are the Iridium satellites? On a warm spring evening, you witness the predicted brightening of the Iridium satellite known as Iridium 29. The flare has a magnitude of –7, and you're able to track it over a portion of the sky that's about the length of your thumb when held at arm's length, until it dies out. In the clear, moonless sky, it takes 8.5 seconds (according to the stopwatch you have with you) from when you first notice the flaring until you can no longer see it. The minimum velocity needed for a satellite to orbit the Earth is about 17,500 miles per hour (28,000 km per hour), and the Iridium satellites travel a bit faster than this – approximately 18,000 miles per hour (28,800 km per hour). You know that the flare is 60 degrees above the horizon, in a due east direction. How far away is this satellite?

Needed Information: This is a simple trigonometry problem. To determine the height of the triangle, you need to know the length of one of its sides and the size of one of its angles. We're working with a right triangle – the base is inverted so that it's represented by the flare distance. Ten degrees of sky is the angular distance of the sky covered by your fist when held at arm's length, and 5 degrees is the amount of sky covered by your thumb at arm's length. From one horizon to the opposite horizon the angular distance is 180 degrees, and thus the angular distance directly overhead (zenith) from the horizon is 90 degrees. You don't really know if the satellite is moving toward you, away from you or laterally (neither toward you or away from you), but for the purposes of this exercise, we'll say that it's moving laterally to your position.

Solution: Since you know that the velocity of the satellite is 18,000 mph and that it's visible for about 8.5 seconds during the time it moves across 5 degrees of sky, the distance the satellite travels in that time is 42.5 miles or 68 km (18,000/60 minutes = 300/60 seconds, 5 x 8.5 = 42.5). Set up a right triangle with a base of 42.5 miles. The observer is at point C, so side c is the base (42.5). See the accompanying diagram. Because you know that the width of the flare is 5 degrees, the remaining angle (CBA) must be 85 degrees. Thus angle CAB = 90 degrees, angle CBA = 85 degrees, and angle BCA = 5 degrees. Length of side c is 42.5 miles, and we need to find either the length of side a or side b. At such a small angle (5 degrees), the distance of lengths b and a will be nearly the same. We'll choose to determine the length of side b. We can solve this using the tangent function. The tangent of 5 degrees (angle BCA) is equal to c, which we know is 42.5 miles, divided by b ($\tan 5^\circ = c/b$). So b is equal to c divided by the tangent of 5 degrees ($b = 42.5 \tan 5^\circ$). Using a calculator, the tangent of 5 degrees is 0.0875. Thus, b is equal to 42.5 divided by 0.0875, which equals 485.7 miles (782 km). We can round this off to two significant digits (490). In fact, satellite Iridium 29 is approximately 483 miles (778 km) above the Earth's surface.

Discussion: The Iridium satellites will flare up for five seconds to as long as twenty seconds, and then they'll quickly seem to turn off. Astronomers use an apparent brightness magnitude scale to determine how bright one object is compared to another. The brighter the object, the more negative the magnitude. Each increase in magnitude, from –1 to –2, for instance, is 2.51 times brighter. On this scale, the faintest stars that we can see with the unaided eye have a magnitude of about 5. The brightest star in the Northern Hemisphere, Sirius, has a magnitude of –1.4, Venus at its brightest can reach a magnitude of about –5, and the full moon is approximately –12. Iridium flares can attain a magnitude of –8. A magnitude of –7.4 would be about 250 times brighter than Sirius! Some observers have mentioned that when the satellite "flares," it looks like a headlight beam shining in the darkness.

Why is it that these particular satellites suddenly become so bright? The source of the flaring is sunlight bouncing off the satellite and then reflecting back towards Earth. They're best seen after dusk or before dawn when the Earth is darkened, but the satellite is still illuminated by the

Sun. Satellite glint is a common occurrence with most all satellites, but the construction of these Iridium birds accentuates the light that's reflected. The main mission antenna is where most of the glint is coming from. The satellite itself is about 10 ft (3 m) long and 3 ft (.92 m) wide, and there are 3 antennae, each of which is about 3 ft (.92 m) wide by 6 ft (1.92 m) long. These antennae are flat aluminum plates treated with silver-coated teflon for thermal control. Since the principal axis of the satellite is constantly oriented vertical to the Earth's surface (another axis is aligned in the direction of flight), the antennas are aligned in such a way that they can direct a specular (mirror-like) reflection of the Sun's disk toward the surface, if a certain set of unique geometric conditions exist. The spot in the sky where flaring can occur shifts from day to day as the Sun-satellite-observer geometry changes. Because the position of the Sun relative to the satellite position changes daily, it's likely that even if you observe a –7 flare from Iridium 29 one night, at the same elevation and azimuth the next night, no reflection will occur in your viewing direction. From the Earth's surface, the reflections from one Iridium satellite may be viewed only from a narrow, approximately north to south swath, which is on the order of twenty or thirty miles (about 32 to 48 km) in width.