Launching Satellites to Orbit

One of the systems of any object that is set to be launched into space including satellites is the structural sub-system. The structural sub-system of a satellite is mostly a very strong and rugged frame. You may ask, why a satellite would need a very strong frame when it will exist most of its life in space where the environment around it is relatively very quite and relatively low gravitational forces act on it (the environment of weightlessness). The answer is that the strong frame is not needed for space but is needed for the launching process as it is a very violent process that shakes the satellite violently until the satellite reaches its orbit. You would not want a satellite to reach orbit with some broken or deformed parts that may force it to function improperly or even not function at all.

Pre-Launch Testing

After the satellite is built and before it is launched, it is subjected to a test called "shake and bake" where it is literally put into an oven that heats its components up and is shaken severely to make sure that all the electronics survive the high and cold temperatures that exist in space. Note that on Earth, things that heat up as a result of being exposed to sun beams usually get cooled by 1 of several methods: conduction (transfer of heat by contact of two objects), radiation (transfer of heat by infrared radiation), and convection (transfer of heat by Brownian motion of fluids). Conduction passing colder air around them. Since air does not exist in space, a satellite that is exposed to the sun will heat up to high temperatures of around will heating satellite cool down

To learn more about the temperatures often observed in space, read
http://www.nasa.gov/pdf/379068main_Temperature_of_Space.pdf

Launching Cost

Let us do a little bit of math. Let us compare the amount of fuel different vehicles use to carry cargo:

- Let us say that an average small car that carrier 5 people with luggage (something like 5*70 kg + 100 kg = 450 kg) travels approximately 10 km for each 1 letter of fuel. Since the lowest grade of fuel costs SR 0.45/letter in our country, this means that it costs approximately SR 0.45 to carry 450 kg a distance of 10 km, which is equivalent to costing SR 0.0001 to carry 1 kg a distance of 1 km. Assume that you had a highway along Earth's equator (40,000 km) that you were driving over. Therefore, it would cost approximately SR 4 to take 1 kg around the world (a distance of 40,000 km).

- A Boeing 747 is capable of carrying approximately 500 people with their luggage (500*70 kg + 10,000 kg = 45,000 kg) a distance of 1 km using approximately 10 letters of fuel. Assuming the jet fuel is the same price as gasoline (that is, SR 0.45 / letter), this would be equivalent to SR 4.5 to carry 45,000 kg a distance of 1 km, or SR 0.0001 to carry 1 kg a distance of 1 km. Again, this would be roughly equivalent to SR 4 to carry 1 kg around the world (or 40,000 km)

- Comparing the above with taking cargo to space, it costs approximately SR 100,000 to carry 1 kg to a GEO orbit. WOW. That is so expensive.

The point here is that this comparison is unfair. Remember that an airplane or a car carry you horizontally, while a rocket carries you vertically, so you would need much more fuel to travel the roughly 35,000 km upwards than you would need to travel horizontally. In addition, carrying the same weight using an airplane or a car again would consume the same amount of money each time, while it costs money to launch a piece of cargo to space during the launch but it almost costs nothing to keep the cargo traveling in space at a particular orbit at the speed of several km per second.

Launch Vehicles

Now, how would you launch an object into space? The answer is using something with a rocket engine. Remember that there is no oxygen above approximately 20 km above sea level so a jet engine would not be able to operate. The answer is to carry both rocket fuel and an oxidizer with you in tanks on your rocket.

The important question is this: Why are rockets designed such that they have stages?

The answer is simple. If you designed your rocket such that it is a single stage, this means that even when the fuel tank is almost empty, you rocket engine would be forced to carry the whole weight of the rocket in addition to the cargo. This is clearly inefficient. The ideal thing would be to have an infinite-stage rocket where the rocket throws away infinitesimally small fuel tanks as the fuel held in each tank is consumed. However, this is also not practical, so they usually design rockets to have two or more stages.

Several private and governmental entities specialize in the business of satellite launching:

http://www.satellitedish.org/blog/2011/7-companies-that-launch-satellites-and-why/

GSLV: India: Active

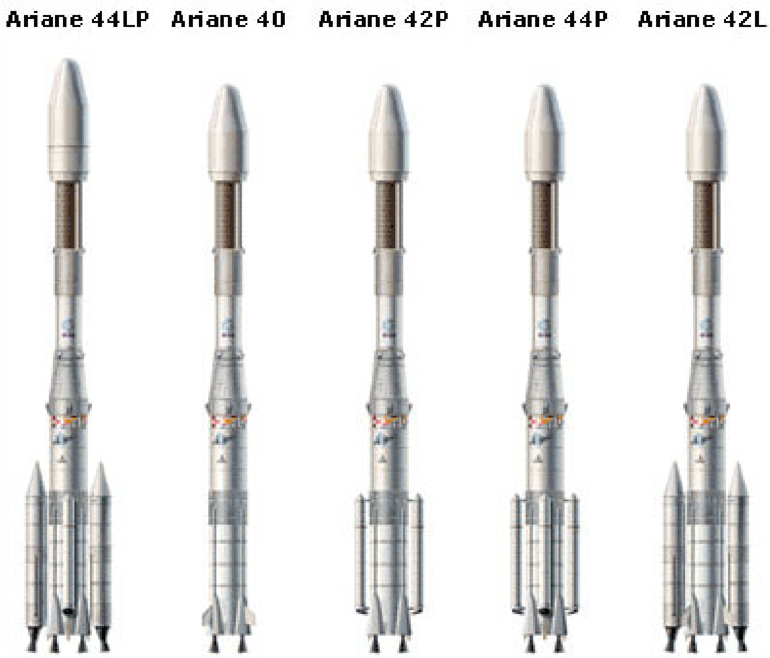
First launch in 2001:   Total of 7 launches: 2 successes, 5 failures.

Total payload weight 2,000 – 2,500 kg to GTO.

Number of Stages: 3 + Boosters, Fuel: N_2O_4

http://en.wikipedia.org/wiki/Geosynchronous_Satellite_Launch_Vehicle

Ariane 4: Europe: Retired



First launch in 1988, Total Launches: 116: 113 successes, 3 failures.

Total payload weight: 5,000 – 7,600 kg to GTO.

Number of Stages: 3 + Boosters

http://en.wikipedia.org/wiki/Ariane_4

Soyuz-U: Russia: Active

First launch in 1973, Total Launches: 745:
724 successes, 21 failures.

Total payload weight: 6,700 kg to LEO.

Number of Stages: ?

http://en.wikipedia.org/wiki/Soyuz-U

Delta II: USA: Active

First launch in 1973, Total Launches: 150:
? successes, ? failures.

Total payload weight: 900 - 2,170 kg to GTO.

Number of Stages: 3 + Boosters

http://en.wikipedia.org/wiki/Soyuz-U

Falcon 9: USA: Active

First launch in 2010, Total Launches: 2:
2 successes, 0 failures.

Total payload weight: 4,540 kg to GTO.

Number of Stages: 2 possibly with Boosters

http://en.wikipedia.org/wiki/Soyuz-U

Space Shuttle: USA: Retired (few months ago)

First launch in 1981, Total Launches: 135:
133 successes, 2 failures.

Total payload weight: 3,810 kg to GTO.

Number of Stages: 2 + Boosters

http://en.wikipedia.org/wiki/Space_shuttle

http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=14554&media_id=112757481

http://www.youtube.com/watch?v=4FROxZ5i67k

http://www.youtube.com/watch?v=OqTmSFkBqkg&feature=related

http://www.youtube.com/watch?v=h9R131hl4zI&feature=related

Rocket Fuel

Some rockets use airplane fuel (kerosene). However, other types of fuel are often used. Several types of fuel are used in rockets including:

Solid Propellants

In the 1950s and 1960s, the US developed what is considered now to be the standard high-energy solid rocket fuel, Ammonium Perchlorate Composite Propellant (APCP). This mixture is primarily ammonium perchlorate powder (an oxidizer), combined with fine aluminium powder (a fuel), held together in a rubber-like material. This fuel is composed as a liquid mixture, and then it is casted into the correct shape and solidify into a rubbery solid

Liquid Propellants

The most common liquid propellants in use today:

- Liquid Oxygen and kerosene: Used for the lower stages of most Russian and Chinese boosters, the first stages of the Saturn V and Atlas V, and all stages of Falcon 1 and Falcon 9. This is considered as the most practical fuel for boosters that lift off at ground level and therefore must operate at full atmospheric pressure.

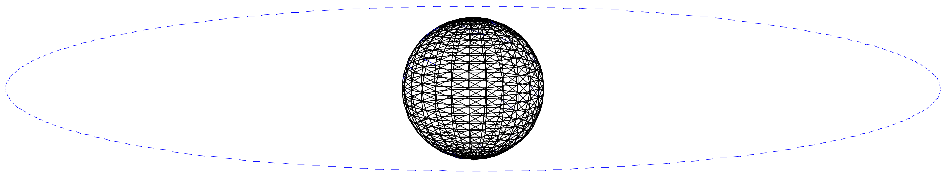
- Liquid Oxygen and liquid hydrogen: used in the Space Shuttle orbiter, the upper stage of the Atlas V, Saturn V upper stages, the newer Delta IV rocket, the H-IIA rocket, and most stages of the European Ariane rockets.

- Nitrogen tetroxide (N_2O_4) and hydrazine (N_2H_4): Used in military, orbital, and deep space rockets because both liquids are storable for long periods at reasonable temperatures and pressures. N_2O_4 is the main fuel for the Proton rocket. These combinations is attractive for its simple ignition sequences. The major inconvenience is that these propellants are highly toxic, hence they require careful handling.

- Monopropellants such as hydrogen peroxide, hydrazine, and nitrous oxide: are primarily used for spacecraft station-keeping (keeping a satellite in its specific orbit or position) where their long-term storability, simplicity of use, and ability to provide the tiny impulses needed, outweighs their lower specific impulse as compared to bipropellants.

GEO Orbit Launching Process

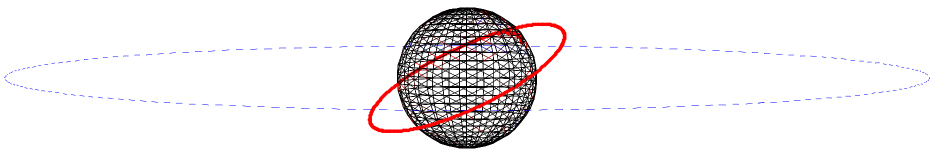
Launching a satellite into a low earth orbit is done as a single step process, where the launching vehicle would raise the satellite to its proper altitude and gives it the speed necessary to maintain that orbit. Launching a GEO satellite, however, is a multi-step process.



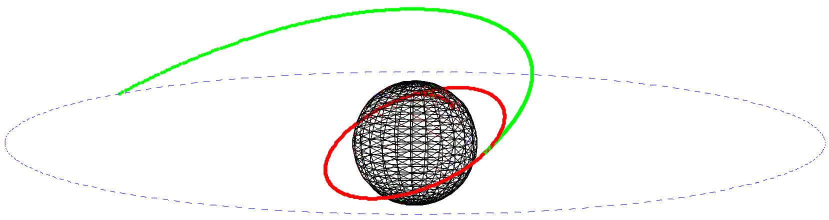
The process of launching a GEO satellite is described by the following steps:

where the satellite is:

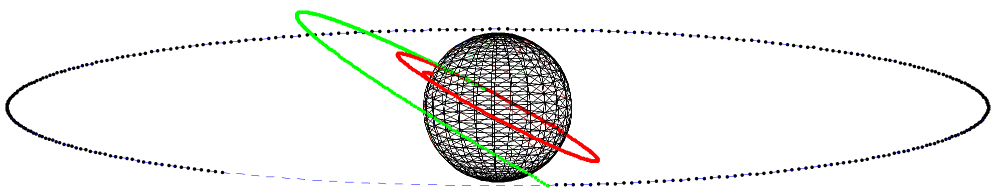
1. Launched to a LEO orbit using a rocket with 1 or more stages. The satellite is checked at the low earth orbit for problems before it is raised to a higher orbit.



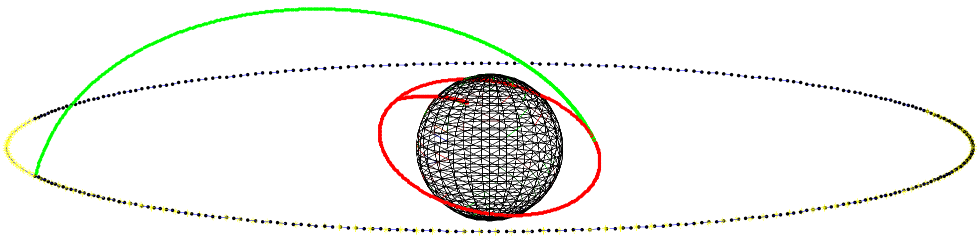
2. When the satellite passes the test, the last rocket stage puts it in an orbit that takes it from the LEO orbit to the GEO orbit known as the Geostationary Transfer Orbit (GTO). This GTO is an elliptical orbit with the perigee on the LEO orbit and the apogee of the orbit on the GEO orbit.



3. If the satellite is launched from a point not on the equator, its LEO, GTO, and HEO orbits will be inclined. Since a GEO orbit has an inclination of 0, the satellite must correct its inclination to get into the proper GEO orbit.



4. The last step would be to drift in the GEO ring until the right position is reached where the satellite would adjust its speed to remain in the position.



The whole process of launching a satellite into a GEO orbit takes several hours, afterwards, the satellite control is handed to the owning company (you can download the Matlab file and run it to see the different steps one by one).

The following clips show some rocket launch failures

http://www.youtube.com/watch?v=CEFNjL86y9c&NR=1

http://www.satelliteonthenet.co.uk/index.php/launch-schedule

Satellite Launching Locations

You may ask, where is the best place to launch a satellite. The answer is: it depends on what orbit would you like the satellite to have. The location from which a satellite is launched may have a significant effect on the life duration of a satellite because a satellite that is launched from the "wrong" place would have to use small or possibly large amounts of its fuel to correct its path to place itself in the right orbit. This used fuel reduces the amount of fuel that remains for orbit maneuvers, and therefore, reduce the life of a satellite.

Let us understand one important point. Launching a satellite from a location that has Latitude L° that is non-zero will result in an inclined orbit with inclination of at least L°. A higher inclination may be achieved but lower inclinations can only be achieved by further use of some rocket fuel to correct for the inclination of the orbit. Let us now consider different orbits one at a time:

GEO: The best place to launch a GEO satellite would be from a point on Earth's equator. This has two reasons:

1. Launching from a location on the equator places both the LEO and GTO in the same plane of the equator, and therefore the launching rocket or launched satellite does not need to spend some of its fuel to correct the inclination of its original launch orbit to 0, which is needed for a GEO satellite.
2. Earth rotates around its axis. Because Earth is a sphere, the speed at which different points on its surface rotate is a function of the distance of each point from the rotation axis. Therefore, points on the equator rotate at the highest speed. Given this, it makes sense to launch a GEO satellite from a point on the equator because this additional speed it gets from the rotation of Earth itself reduces the consumed fuel of the satellite, and hence extending its life. This may increase the life of a satellite by several months or a year.

Effect of Sun on Satellite Operation

Previously, we discussed that the Sun's gravity has an effect on the orbit of satellites. However, we are interested here on other effects of the Sun. The two effects here are on the power system and on signal reception from satellites.

1. Satellites get their power from the Sun using solar cells. There is plenty of sun in space however depending on satellite orbits, a satellite may be in the shadow of Earth during part of its period and may not. If a satellite passes through the shadow of Earth, it cannot use solar cells to power itself but will have to depend on power stored in batteries that were charged during the period of solar cell illumination. Sometimes the period over which a satellite will remain in the shadow of Earth may be relatively long for batteries to power the operation of the satellite for that whole period (for example, a communication satellite that use from 10 kWatts of power). In this case, part of the satellite that contains non-essential components may be shut down until the satellite comes out of the region of Earth's shadow.
    a. A LEO satellite will pass through Earth's shadow almost in each orbit and will remain in Earth's shadow for almost half of its period each time (around 40 minuets of the 90 minutes). Therefore, the use of batteries is extremely important.
    b. A GEO satellite will pass through Earht's shadow only during some parts of the year. During the periods around the equinoxes (Fall and Spring) where the Sun becomes perpendicular on the equator, a GEO satellite will pass through Earth's shadow for periods of time that are less than around 70 minutes per period (or 24 hours). Before and after the equinoxes, the period over which a GEO satellite will be less than this 70 minutes. Far away from these equinoxes, a GEO satellite will be illuminated by the sun for the orbital period.
2. The satellite sometimes may pass exactly between the Sun and Earth (relative to a specific point on Earth). That is, the Sun may appear exactly behind a satellite from a specific point on Earth. In this case, the signal received from the satellite by an Earth station will be accompanied by a huge amount of noise that orbiginates from the Sun that causes the satellite signal to become useless. This is called SUN OUTAGE. This will happen to different locations receiving from the same satellite at different times of the year of different times of the day depending on the relative latitudes and longitudes of the locations.