

The Capabilities and Limitations of Orbiting Satellites

Ballistic Trajectories

In order to propel an object to a great distance it is necessary to overcome the forces of gravity and of air resistance. This can be achieved by continuous exertion of thrust throughout the flight, as is done by the engines of an aircraft, or by sudden acceleration to high velocity, followed by un-powered coasting in a ballistic trajectory, as is done with a shell fired from a gun. A disadvantage of a gun is that both it and its projectile must be very strongly built in order to withstand the forces needed to accelerate the projectile to high velocity in a very short period of time (no more than a few thousandths of a second). Intermediate between these extremes is rocket propulsion, by which the projectile is accelerated comparatively gently over a period of seconds or even a few minutes, thus reaching high velocity without having to withstand great stress.

A disadvantage of very long range rockets is that the original vehicle must include a large rocket motor containing plenty of fuel, attached to the payload that is to be sent to a great distance. Much of the fuel will be consumed in accelerating unburnt fuel and the motor. However, rocket propulsion permits very high velocities to be attained, especially when multiple motors are employed in successive stages, so that the first (and largest) stages can be separated after they have burned up their own fuel, leaving the later stages to propel only the ever-lighter remaining portions (including the payload). Burn-out velocities above three kilometres per second are sufficient to propel a rocket to altitudes at which air resistance becomes negligible, and beyond this the force of gravity itself becomes somewhat reduced.

In the case of an intercontinental ballistic missile, for which burnout velocity needs to be about 6.4 km per second, the elliptical trajectory curves downward only a little faster than the surface of the earth underneath it, so that it continues far beyond the horizon of the launching site before it falls back to the earth. See the trajectory labelled with burn out velocity 6.4 km per second in the upper diagram of Figure 5.