ORBITAL VEHICLE OPERATIONS HANDBOOK

2016.08.17

ZLSA DESIGN

OCCUPANT PROTECTION

SEAT BELTS

Seat belts are a vital safety feature built into your spacecraft. Spacecraft are subjected to extreme acceleration, occasionally off-axis, during launch and reentry, as well as in a launch abort situation. It is critical to safely secure yourself in your seat during these times.

During launch and reentry, you should keep both of your feet on the footrests and your arms on the armrests. Failure to do so could result in personal injury after unexpected spacecraft motions.

CARGO STRAPS

It is the pilot's responsibility to ensure all onboard pressurized cargo is secured before flight. Unsecured or improperly secured cargo may break loose and hinder on-orbit operations or damage spacecraft components. The cargo area of your spacecraft should have tie-down hooks; use spaceflight-certified straps to tie down your cargo before liftoff.

Make sure you are using properly-sized straps for the cargo size and mass. Secure large cargo bags with multiple straps, and make sure the cargo bags cannot slide out from underneath the straps.

LAUNCH PROFILE

PRELAUNCH OPERATIONS

Months before the launch of your spacecraft, mission planners will begin to plan out your mission. If your mission is to a space station such as the International Space Station, the mission planners will need to secure approval for a visiting spacecraft as well as preparing for the rendezvous procedure.

Your mission planners will formulate a mission plan. This includes:

- ➔ Cargo manifest and center of mass calculations
- ➔ Astronaut scheduling
- ➔ Launch profile and orbital trajectory
- ➔ Space station approach, rendezvous, and docking
- ➔ Space station undocking and departure
- ➔ Deorbit planning and entry trajectory
- ➔ Recovery vessel positioning

While your mission is being prepared by the mission planners, you and your crew will train for spacecraft operations and zero-g movement, in addition to whatever specialized training your mission may require. Crew training is considered one of the more strenuous and difficult parts of being an astronaut, but just remember: what you learn in crew training will possibly save your life in the future.

LAUNCH OPERATIONS

The spacecraft will arrive at the launch site integration hangar a few weeks before launch. During this time, it is loaded with cargo, with the exception of late-load cargo. Checks are done on the spacecraft, and it's integrated to the launch vehicle and readied for rollout and erection.

The launch vehicle is usually rolled out to the launchpad a few days in advance of T-0. Different launch providers have different launch vehicle designs, and hence have different rollout and erection schedules and guidelines.

You and your crew will board the spacecraft only a few hours before launch, before fueling has occurred. Typically, you will board the spacecraft via the crew arm, which is swung away after ground crew have strapped you into your seats and closed the spacecraft ground door.

After the launchpad is cleared of all personnel and the command is given, launch vehicle fueling will begin. Once again, precise timing depends on the launch provider's choice of vehicle.

If your mission includes rendezvous with a space station, the launch window is very short or instantaneous. If the launch occurs too far from the optimal launch time, the spacecraft will need to perform an expensive on-orbit inclination change. Most spacecraft do not have enough onboard delta-v to perform this maneuver themselves.

ORBITAL MECHANICS

DELTA-V

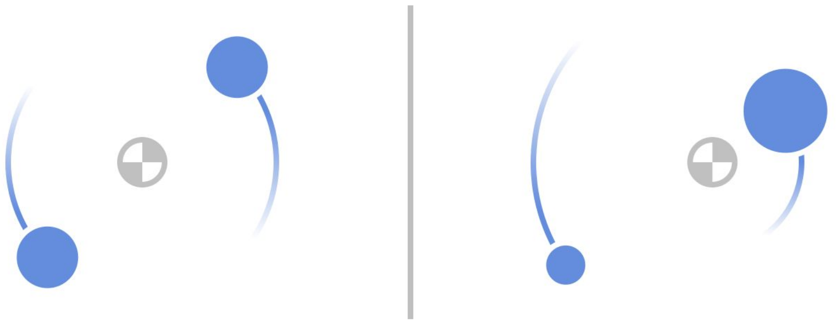
Delta-v, dV, or Δv (short for **delta velocity)**, is simply the difference in velocity between two states. For example, imagine your spacecraft is floating in space, with no other bodies to affect it; to quantifiably measure Δv, a piece of your ship is separated from it. Because of Newton's first law, it will simply coast along with your ship; the current Δv is 0 meters per second.

Now imagine a rocket engine on the spacecraft is started. Your spacecraft will start to fly away from the piece of your ship. When the engine is shut down, the Δv of the burn is simply the difference in velocity between the piece of your ship (which is equivalent to the velocity of your ship *before* the burn) and your ship *after* the burn. Δv is almost always measured in meters per second.

BASIC ORBITAL MECHANICS

TWO-BODY SYSTEMS

The path that a body traces through space while under the gravitational influence of another body is called an **orbit**. In an ideal two-body system, both of the bodies will orbit around their common **barycenter**. This is because both bodies are affecting each other; no matter how heavy one is and how light the other is, the bodies will have a barycenter. As one body gets heavier and the other gets lighter, the barycenter will move towards the heavier body; however, unless the lighter body has zero mass, the heavier body will always be orbiting the shared barycenter.



Despite this, in an ideal two-body system featuring a planet (such as the Earth or Mars) and a spacecraft, it can usually be simulated as a fixed, nonmoving body and a spacecraft that orbits around it. For example, in an ideal two-body system with a typical crewed spacecraft orbiting the Earth, the barycenter of the pair is only one 50,000th of an atom away from the Earth's center of mass (**CoM**). Realistically, the barycenter can be ignored when planning for most missions.

MULTI-BODY SYSTEMS

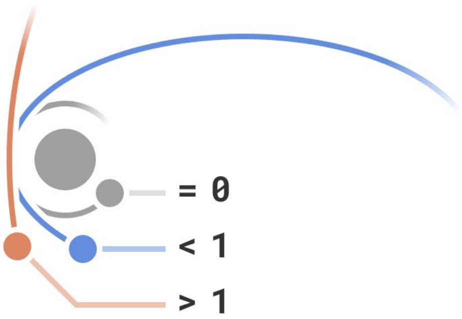
The above information is only correct for an idealized two-body system. In reality, while your spacecraft may only be orbiting a single planet, that planet is orbiting another body, which may have dozens of bodies orbiting it, all of which also have other orbiting bodies.

During Earth operations on-orbit, the strongest gravitational influences are the Earth, the Moon, the Sun, and Jupiter. The Earth and the Moon are high on the list for obvious reasons, as is the sun. Jupiter is also on the list because it's an exceptionally heavy planet (over three times heavier than Saturn, the next heaviest planet). Despite being so far away, it exerts a measurable influence on satellites orbiting the Earth, and it must be taken into account during the mission planning phase.

When a spacecraft is affected by bodies other than the body it's orbiting, the orbital trajectory includes **perturbations**. These manifest as slight drifts and wobble during an otherwise ideal orbit; the spacecraft may need to perform correction burns as a result of perturbations from bodies other than the one it's orbiting. The Earth's moon, in particular, is very large relative to the Earth for a planetary moon; its effects on orbiting spacecraft is marked, and special care must be taken during mission planning for lunar perturbations.

ECCENTRICITY

So far, we have only investigated perfectly circular orbits. In reality, no orbit is perfectly circular; such an ideal orbit has an **eccentricity** of zero. The more elliptical an orbit is, the higher its eccentricity; an orbit with an eccentricity of one is a **parabolic escape trajectory**; and an orbit with an eccentricity greater than one is a **hyperbolic trajectory**.



When a body is orbiting around its parent with a parabolic escape trajectory, its speed is the absolute minimum required to escape the gravitational influence of its parent; if its speed were any lower, the eccentricity would be less than one, and it would remain in orbit instead of being flung out.

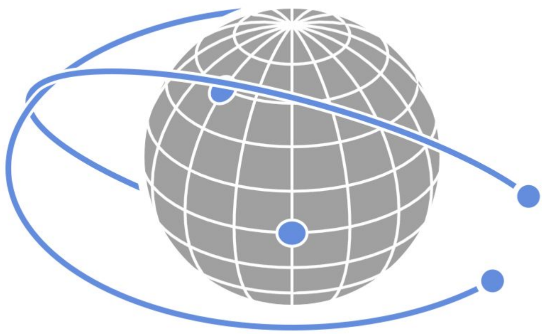
A hyperbolic trajectory is simply a parabolic escape trajectory, but with a higher velocity. In reality, any spacecraft traveling between two bodies will use a hyperbolic trajectory, both when departing the first body and when arriving at the second.

INCLINATION

Unlike these beautiful orbital diagrams, reality is not two-dimensional. Spacecraft must deal with a third dimension: inclination.

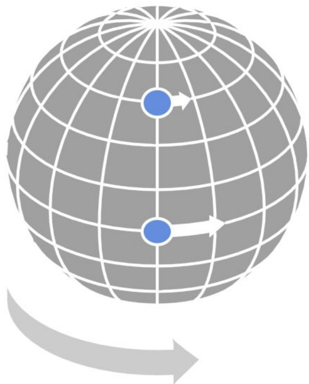
When launching from an ideal equatorial launch site, the inclination of the resulting orbit will be zero. The ground track of a zero-inclination orbit would follow along the equator; if you mounted a camera onboard the spacecraft and aimed it at the Earth, the equator would always be in the center of the frame.

However, no launch sites currently in operation are situated on the equator. Cape Canaveral is at 28 degrees north of the equator, while Russia's Baikonur Cosmodrome is nearly 46 degrees north of the equator. When a spacecraft is launched into orbit, the minimum inclination is the same as that of its launch site. This is a large part of the decision to build the ISS at 51.6 degrees inclination, since Russia's launch site is located at 46 degrees north; if the inclination of the ISS was lower than 46 degrees, Russia would not be



able to easily launch their spacecraft to the ISS.

There's another factor that must be taken into consideration in conjunction with orbital inclination, and that's the velocity of the planet's surface at the launch site. Since the Earth spins along its axis once every 23 hours and 56 minutes (one sidereal day), some velocity can be taken from the Earth's rotation when launching spacecraft. At the equator, the Earth's surface velocity (relative to the Sun and Earth's center of mass) is 464 meters per second (m/s). The further the launch site is from the equator, the less surface velocity is present. To launch into orbit from a high inclination launch site requires more energy from the launch vehicle as compared to an equatorial launch site.



This is why most launch sites are located as close as possible to the Earth's equator: the closer you are to the equator, the less fuel your launch vehicle will need to reach Earth orbit (and beyond).

LAST UPDATE

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