Astronautical Glossary

Chapter 1

Introduction

In this document I attempt to define the technical terms I use in Jonathan's Space Report and associated material (the General Catalog of Artificial Space Objects, the Deep Space Catalog, etc.).

Some of these definitions reference GCAT (the General Catalog of Artificial Space Objects, (See https://planet4589.org/space/gcat/)

People have strong feelings about the meaning and usage of words, and I am sure some readers will disagree with my choices. Here I am expressing what *I* mean by the words in question, in particular when I use them in these JSR documents. This document is an excuse for me to indulge my tendency for pedantry to a previously unprecedented degree. I have concentrated particulary on including terms which tend to be (in my opinion) misused, or which have multiple senses. I have added extra detail in cases where everyone else is wrong and I'm right (funny how that happens...). You may find the inclusion (or exclusion) of terms to be idiosyncratic. I am happy to consider suggestions for additional terms, but I make no promises.

Words in English often have multiple senses. A word may have a narrow and broad sense (see here 'satellite'). Words may be homographs or homonyms, with the same spelling but unrelated meanings ('row', 'bat', 'down', etc.) I attempt to be explicit about these multiple senses.

I am a dual US-Brit (My parents were UK citizens born in Belfast who moved to England; I was born in Atlanta, Georgia, moved to the UK as a baby, was brought up mainly in England but a bit in the US too, and with one toe in France.) Therefore, my idiolect can legitimately swap between UK and US spellings in the course of a single sentence - you have been warned.

With that, let's proceed - I hope someone finds this useful.

Chapter 2

Glossary A-Z

- **Abort**
  - **Sense 1 (general)** An abort is the (relatively) immediate and premature cessation of an activity currently in progress - for example, a docking may be aborted if the vehicle is approaching its target too quickly, in which case the abort may involve an evasive manouevre. In this general sense, an abort does not necessarily preclude a later try at the same activity.
  - **Sense 2 (launch)** An abort is the termination of a launch attempt after the engines have ignited. The most benign type of abort is a pad abort, when the rocket has not actually yet lifted off and the engines can be safely shut down, with another attempt possible at a later date. (For termination of a countdown prior to engine ignition, see Scrub).

    Once the rocket has lifted off, an abort is usually fatal to the rocket and may involve remote-commanded destruction of the rocket.

    In human spaceflight, a launch abort will usually involve the use of a preplanned strategy to return the crew safely to Earth, for example with the use of a launch escape tower, or just by separating the spaceship into a ballistic trajectory as was done on Soyuz MS-10.

    The Space Shuttle had a number of predefined abort strategies, which included:
    * Abort to Orbit (ATO) - limp into lower than planned orbit on remaining engines, and possibly continue mission.
    * Abort Once Around (AOA) - make almost one orbit, possibly landing back at the launch site after circling the Earth.
    * Transatlantic Abort (TAL) - a very fast trip from Florida to emergency runways at places like Dakar (Senegal), Moron (Spain), or Ben Guerir (Morocco).

        * Return to Launch Site (RTLS) - drop the SRBs, make a U-turn with the Shuttle main engines and, if the wings have not fallen off the Orbiter, drop the ET and glide back to the runway at the launch site.
        * Contingency abort - a term of art, but arguably a euphemism, for jumping out of the spaceship as it smashes into the ocean.

- **Aerobraking**
    - The use of orbital decay (qv) to deliberately change an orbit with minimal use of propellant. The spacecraft, in an elliptical orbit, executes a maneuver to lower its periapsis into the atmosphere to increase drag and slow the spacecraft periapsis velocity. This causes the apoapsis to decrease. Once the apoapsis has reached its desired value, another maneouvre is made to raise periapsis again and stop the aerobraking.

      A related concept is aerocapture, in which aerobraking is used to turn a hyperbolic orbit into a bound elliptical one.

- **Altitude**
    - See Height (and do not confuse with Attitude).

- **Apoapsis**
    - **Sense 1 (location):** Furthest point from the central body in an orbit. Opposite of periapsis, the closest point to the central body in the orbit.
    - **Sense 2 (height):** The apoapsis height; the height above the central body surface (of radius R) at the apoapsis point. Opposed to the periapsis height.

      Let the Keplerian elements (q.v.) include semi-major axis a and eccentricity e. Then we define

        * **Periapsis height** Hp, defined as

          Hp = a (1-e) - R
        * **Apoapsis height** Ha, defined as

          Ha = a (1+e) -R
    - The specific terms for the periapsis and apoapsis for an Earth orbit are perigee and apogee. Analogous terms (peri/aphelion, peri/apojove, etc.) exist for other central bodies.

      Some have pointed out that the formation of the generic words is inconsistent with those of the specific: the apsis is the end of the orbital radius, not the body center. The word 'apoapsis' must be read as 'furthest apsis', while 'apogee' is 'furthest *from* the Earth'. Writers who find this inconsistency problematic advocate the uglier 'apocenter' and 'pericenter'. I am not one of them; see <A HREF="periapsis.txt">my 2006 rant on the subject</A>

See the GCAT discussion of (See the Friends of Perigee and Apogee.)

In a hyperbolic orbit, with e greater than 1, the semimajor axis a is negative and doesn't have the same simple geometrical interpretation. Since 1-e is also negative, the formal periapsis radius a(1-e) remains positive, and indeed the perapsis height does retain its usual interpretation as the mimimum height in the orbit. The apoapsis height, however, is negative; we treat it as a formal value without geometric meaning.

- **Apogee**
  - See Apoapsis
- **Apogee Kick Motor (AKM)**
  - To reach a high circular orbit, the earliest technique used was to have the launch vehicle place the satellite in a highly elliptical orbit. After several hours coasting in that orbit, the satellite would reach apogee and fire an internal rocket motor to change its velocity by the amount needed to change the orbit to a circular one - giving the satellite a 'kick in the apogee'. The term apogee boost motor (ABM, but note that that can also stand for anti-ballistic missile) is equivalent.

    If the satellite is spin-stablized and the rocket injects the satellite at perigee of the transfer orbit with its 'top' in the direction of motion, you don't need to orient the satellite further. Just wait half an orbit with a timer, and the satellite will be at apogee with the 'top' now facing opposite the direction of motion (same direction as before in inertial space). So if you put the rocket nozzle sticking out the top of the satellite, just fire it and you'll get the right result without the need for an attitude control sensor or maneuver. That was a pretty neat trick in the late 1950s; nowadays accuracy standards are too high to rely on it.
- **Argument of periapsis** (or of perigee, etc.)
  - see Keplerian Elements
- **Ascent Point**
  - See Launch Origin
- **Ascent Site**

- See Launch Origin

- **Astronaut**
  - **Sense 1 (narrow)** Space crew; driver of a spaceship: crewmember as opposed to passenger.
  - **Sense 2 (broader)** space traveller; Any person who has flown in space.
  - **Sense 3 (specialized)** Job title; e.g. member of the NASA astronaut office, even if they have not yet flown.
  - **Sense 4 (idiotic)** A space traveller specifically from the United States only.
  - The most widespread use is sense 2. Recently there has been some pushback on that, with some objecting to space tourists getting the 'astronaut' designation. I propose to keep using this broader sense, and use 'space crew(member)' or 'spacer' (as popularized by Heinlein) to specifically denote the non-passenger astronauts.

    I consider all humans who have flown above 80 km to be astronauts (see 'space', sense 2.) Arguably also other primates who have done so.
  - The use of sense 4, and the corresponding use of 'cosmonaut', an anglicized version the Russian word for astronaut ('kosmonavt') for Soviet astronauts, is in my opinion ridiculous. The extension of this historical anomaly to invent words like 'taikonaut' (Chinese astronaut) is both ludicrous and ultimately untenable. Note that in Russian, the same word ('kosmonavt') was used for both US and Soviet/Russian astronauts for most of the space age. Until relatively recently there was no Russian-language equivalent of this unnecessary distinction, but alas ' ' has now come into use as they have been infected by the same stupidity.

    We don't have separate words in English for French or Russian or Japanese butchers, bakers or candlestick makers, and we don't need separate ones for astronauts of different nations. Let's just use "astronaut", and consign 'cosmonaut' to the dustbin of linguistic history. (And Russian friends, please do the complement: use and jettison)

- **Astronautics**
  - Astronautics is the study of space travel, including rockets, spacecraft, debris, orbits and orbital mechanics, human and robotic spaceflight, among other topics. It does not generally treat the natural bodies in space, which is the province of astronomy; however there is obviously some overlap.

- **Attitude**
  - The attitude of a space object is its orientation (pointing direction) in 3-dimensional space: whether the (arbitrarily defined) X axis of the spacecraft is pointing at the Earth, the Sun, or in some other direction. ‘attitude control’ is the system that changes or maintains the attitude, and can involve rocket thrusters, magnetorquers, gravity gradient booms, reaction wheels or some other system.

    An attitude maneuver changes which way the satellite is pointing as it follows its orbit; it does not change the orbit itself.

- **Attitude and orbit control system (AOCS)**
  - An AOCS is a satellite subsystem - a propulsion system - that allows the satellite to change both its attitude (q.v.) and its orbit. Some satellites only have an ACS (attitude control system) without the ability to change the orbit. See also Maneuver.

- **Ballistic Coefficient**
  - The ballistic coefficient B of a space object tells you how easily it is affected by a given amount of atmospheric drag. Its dimensions are area per unit mass. (Warning: some authors define a ballistic coefficient that is the inverse of this one). The drag force on the object is one-half B m * rho * (v squared), where m and v are the object mass and its velocity relative to the ambient gas of density rho. Typical values of B for space objects range from 0.005 to 0.05 square metres per kilogram, with 0.01 sq m/kg a good reference value for a typical satellite.

- **Ballistic Missile**
  - A ballistic missile is a missile that follows a ballistic trajectory for most of its flight. A ballistic trajectory just means that the missile is freely travelling under gravity, with no propulsion system operating; in other words it is in (suborbital) orbit. An example of a missile that is not ballistic is a cruise missile, which flies in the atmosphere and has a continuously operating jet engine which is needed to keep it aloft.

    A ballistic missile weapons system many consist of some or all of the following components:

    * the missile itself, a single or multi-stage rocket
    * a nose fairing to protect the reentry vehicle(s), especially if there is more than one RV

  * a ‘post boost system’ and ‘dispenser’, with a low thrust engine, which aims and releases the RVs one at a time
  * the reentry vehicles (RVs, q.v.)

  For test launches, the RVs usually contain test instrumentation; when used in war they will instead contain warheads, possibly nuclear.

  The US military has an elaborate classification of ballistic missiles based on their range. (Note that other counties may not share the same definitions).

Abbreviation	Name	Range
SRBM	Short Range Ballistic Misisle	Less than 1000 km
MRBM	Medium Range Ballistic Missile	1000 to 3000 km
IRBM	Intermediate Range Ballistic Missile	3000 to 5500 km
ICBM	Intercontintental Ballistic Missile	above 5500 km
	Looser groupings	
TBM	Tactical Ballistic Missile	Less than 300 km?
TBM	Theatre Ballistic Missile	Less than 3500 km

- **Barycenter (Barycentre)**
  - Barycenter is a fancy word for ‘centre of gravity’. The barycentre of a system of bodies is the centre around which the bodies orbit.
- **Beginning of Life (BOL)**
  - BOL refers to the beginning of the operational phase of a satellite’s life. It is particularly used for geostationary satellites, to denote the state of the spacecraft (for example, its mass) after launch and orbit raising, once the satellite is at its initial geostationary position. In this sense it is as opposed to the state of the spacecraft at launch, launch vehicle separation, and end of life (EOL, q.v.).
- **Berthing**
  - see Docking.
- **Body, central body**
  - I use the term body to refer to an astronomical body, in particular **central body** as the thing as a spacecraft is orbiting. A body is often a world (q.v.) but sometimes instead is a **small body,** a natural freely orbiting object smaller than a world (e.g. small moon, asteroid or comet).

    The Outer Space Treaty uses the term ‘celestial body’ which means the same thing EXCEPT that the Earth is not considered a ‘celestial body’ by the OST, but I do consider it to be one.

The term 'primary' is often used in astronomy as a synonym for 'central body', particulary in the context of multiple-star systems.

A special case is when objects are in the vicinity of one of the Lagrange Points (q.v.) of two bodies. The motion of the objects can then be thought of as being 'orbits' around the Lagrange Point, considered as a fictitious body, instead of around an actual massive body. Such orbits are strongly non-Keplerian.

- **Booster**

  - **Sense 1:** A small rocket stage provding high acceleration for a short time, giving the main rocket a 'boost' off the launch pad. Many early rockets were two stage vehicles consisting of a short, stocky 'booster' first stage and a long, thin 'sustainer' second stage, the latter with a much longer burn time but lower thrust. The booster was required to get the sustainer up to high speed quickly so that it could fly stably. The booster would be discarded a few seconds after launch, after reaching an altitude of a kilometer or less, and would fall near the launch site.
  - **Sense 2: (strap-on booster).** Later vehicles, including modern ones, would have multiple booster stages strapped to the side of a much larger core stage. They provided the same function of providing high initial acceleration and quick jettison of the associated booster dry mass.
  - **Sense 3: first stage.** In space launch vehicles of the mid 1960s and later, the first stage was no longer short in size or burn time - indeed it was usually larger in size than the upper stages. It still had higher thrust than those stages, and so was still occasionally called the 'booster'.
  - **Sense 4: entire vehicle (informal)** Especially in the 1960s, some people would refer to the entire vehicle as the 'booster', as opposed to the payload. This was common in the Apollo/Saturn program. This usage is rare or absent today.
  - **Sense 5: Atlas booster (specific).** The Atlas rocket had an unusual design. Three engines were fed from the main Atlas stage. But the outer two engines were packaged in a jettisonable module (the 'booster') that was discarded after about two to three minutes of flight, while the central ('sustainer') engine continued firing.

  Note the common acronyms BECO, SECO, MECO: Booster/Sustainer (or Second Stage)/Main Engine Cutoff.

- **Bus**

- A spacecraft bus is its overall structure and systems. We use the term loosely to mean the 'model' of the satellite, especially if it uses a common design. We say for example that 'their last satellite used the Boeing 601HP bus' in the same way that I might say 'my last car was a Honda Civic'.

  Note that the term 'satellite bus' means something different to spacecraft electrical engineers: the electronics and wiring system that sends information and power around the satellite. I never use the term in this sense.

- **Celestial body**
  - see Body
- **Cislunar space**
  - **Sense 1 (broad):** Space this side of lunar orbit; between the Earth and the Moon. See also translunar.
  - **Sense 2 (narrow):** Space immediately this side of lunar orbit; between about 300,000 km from Earth and 384,400 km. (used for orbital category in GCAT). The parts of cislunar space (sense 1) not covered by other orbital categories.
- **Conjunction**
  - **Sense 1 (astronomy):** an event in which two astronomical objects appear close to each other in the sky from the vantage point of a particular observer.
  - **Sense 2 (satellites and SSA):** an event in which two space objects are predicted to pass sufficiently close to each other such that, within the uncertainties, a collision cannot be excluded.
- **Control Center (Centre)**
  - Satellites often have two control centres: the spacecraft operations control centre (SOC) - also sometimes called mission operations centre (MOC) - which monitors the state of health of the spacecraft systems and commands orbital maneuvers; and the payload operations control center (POC) which monitors and commands the payload instruments (for example, adjusts camera settings and commands a particular image exposure). The SOC and the POC are often operated by different organizations. Usually the data flows from the spacecraft to a ground station (q.v.) to the SOC and then from there a subset is sent to the POC.

    For science satellites, the POC is sometimes called a Science Operations Center (confusingly, SOC).

- **Constellation**

  - **Sense 1 (astronomy):** A constellation is a 2-dimensional region on the celestial sphere. The brightest stars in the constellation are used to define an asterism (pattern of stars) that gives the constellation its name; thus, the brightest stars in the constellation of Aquila are deemed to look like an eagle (latin: aquila), although you could have fooled me. The reader should remember that the stars in a constellation are usually not physically related to one another, as although they lie in roughly the same direction, they are at very different distances. The patterns would look entirely different when seen from another star system.

    The sky is divided into 88 constellations, whose boundaries were fixed in 1926 by the International Astronomical Union.

  - **Sense 2 (astronautics):** A constellation is a group of related satellites, usually but not always of similar or identical design. For most constellations the aim is to use many satellites to provide frequent or continuous coverage of the whole Earth surface (whether for imaging, navigation, communications or some other purpose.) This means that you would like the satellites to be reasonably evenly spaced. This may be done conveniently by dividing the constellation into some number N of equally spaced orbital planes, with M satellites in each plane at different nodal angles, for a total of M * N satellites. For example, a constellation might have 3 orbital planes spaced 60 degrees apart, with 8 satellites in each plane separated by 45 degrees of nodal angle.

- **Cosmonaut**

  - Stupid word for an astronaut from Russia or the USSR. Avoid. See 'astronaut', sense 4.

- **Debris, orbital**

  - **Sense 1 (broad, formal)** Orbital debris means any artificial space object that is not an actively operating satellite. This includes defunct payloads, rocket stages, discarded components and fragments from satellite breakups.

  - **Sense 2 (narrow, informal)** Sometimes we use the term debris just to mean the smaller breakup fragments in contrast to dead payloads and rocket stages.

    Orbital debris is also informally referred to as 'space junk'.

- **Decommissioning**

Decommissioning a spacecraft is the process of turning it off safely when its mission is done. It includes end of life tests, possibly moving the spacecraft to a retirement orbit, depleting propellants and switching off transmitters. See also End of Life and Passivation.

A 2020 web article from the Space Data Association described the destruction of the FY-1C and USA 193 satellties with antisatellite weapons as decommissioning them. However, this kind of 'decommissioning with extreme prejudice' is not normally included within the concept.

- **Deep Space**
  - **Sense 1 (general):** Parts of space far from Earth, excluding 'near Earth space'. Not well defined, but usually considered to beging beyond the GEO distance. NASA's Deep Space Network is used to communicate with lunar and planetary probes, but also supports spacecraft like Chandra which have Earth orbits well beyond GEO.
  - **Sense 2 (SGP4):** The SGP4 model used to propagate Earth satellite orbits refers to orbits with periods above 225 minutes (semi major axis height more than 5876 km above Earth surface) as deep space and uses different algorithms to treat those orbits. I haven't seen this usage outside the SGP4 code.
  - **Sense 3 (GCAT):** In McDowell (2018, Acta Astronautica 151, 668) and McDowell (2020, Proceedings of the IISL, in press) I proposed a deep space boundary at the EL1:4 resonance, where an Earth satellite has an orbital period one-quarter that of the Moon's. This works out to a geocentric radius of 152066 km. This is the value I use in my work (GCAT, Deepcat, etc.)
- **Deorbit**
  - **Sense 1** (correct): Actively remove a satellite from orbit. 'The satellite was deorbited over the Pacific Ocean'. Deorbiting involves firing a rocket engine to lower the orbital perigee within the atmosphere, causing reentry within one orbit. Deorbits may be destructive (the satellite may burn up and be destroyed) or they may be a precusors to controlled reentry and landing.

    The advent of the Starlink constellation has introduced a qualitatively new kind of deorbit. The Starlink satellites are retired by continuously lowering their orbit with electric propulsion. Reentry occurs in a way similar to uncontrolled reentry - eventually the satellite is low enough and the ambient density is high enough that the vehicle heats, breaks up and is destroyed. The crucial point here is that the *location* of the breakup on the Earth is unpredictable and uncontrolled, in contrast to an impulsive deorbit where the rapid elliptical-orbit descent from a relatively high apogee means that reentry location is determined relatively precisely by the orbital parameters. These Starlink retirements should perhaps be termed 'propulsion-assisted orbital decay' - they are more like normal orbital decay but speeded up by the thrusters.

  – **Sense 2** (incorrect, to be avoided): In recent years some in the US aerospace community have begun to use 'deorbit' to mean 'move a satellite from its operational orbit to a retirement orbit'. The satellite is only removed from its original orbit, not from orbit entirely. This is completely different from the original meaning of the word and it causes endless confusion. I strongly deprecate its use.

    I have also seen 'reorbit' for this second use: that's better, but I still don't like it - it sounds like the sat landed and took off again. I prefer to use a handful of extra words and say 'the satellite was moved to a retirement (or graveyard) orbit'. (See Graveyard Orbit).

    See also Reentry.

- **Diameter**

  – The diameter, together with the length, characterize the approximate size of the main body of a space object excluding appendages. Many space objects are cylindrical or spherical, in which case the diameter has its obvious meaning. For space objects with box-shaped main bodies, the length is the longest dimension and the diameter is the next longest dimension.

    For most box-shaped spacecraft, the two smaller axes are approximately equal in size (i.e. the box has a square cross-section). Rarely, however, all three axes are distinctly different in size. Similarly, a quasi-cylindrical spacecraft might have an elliptical cross section (although I can't think of an example right now). I will use the term 'thickness' for this.

    Other sources use the terms height/width/depth to describe the spacecraft main body dimensions. The correspondence is:

Usual term	GCAT term
height	length
width	diameter
depth	thickness

- **Deploy**

  – **Sense 1: Unfold.** Deployment of appendages (booms, antennae, solar sail) of a space object involves unfurling or unfolding them from the compact form in which they were packaged for launch (e.g. to fit wihin the launch vehicle fairing).

  - **Sense 2: Eject in a controlled way.** Deployment of a subsatellite from a satellite, or of a satellite payload from the launch vehicle upper stage, just means the object's physical separation from its parent. This is usually done by firing explosive bolts, releasing clamps, and/or using springs. The distinction between 'eject' and 'deploy' is that the latter implies the ejection is performed in a controlled way, with the separation direction, separation rate and rotational state of the ejected object predetermined.

- **Docking**

  - Attachment of one space object to another, with a direct attachment between the two objects (as opposed to a tether or a robotic arm). Current usage distinguishes docking from 'grapple', in which an articulated robotic arm on one object captures a target on the other. (To be honest, I find it difficult to see the difference - why does it matter that the robotic arm method involves an articulated connection? I'd rather just call it all 'docking', but for once I bow to the collective standard).

    All early dockings involved a docking between two pressurized vehicles, and most had a docking aperture with a hatch system allowing internal transfer of crew or cargo between the vehicles once docked. Use of the term 'docking' does not require this: for example, the attachment of the MEV-1 satellite to the Intelsat 901 satellite in 2020 was referred to as a docking, even though the satellites were unpressurized and there were no hatches.

    Grapple is used when a robotic arm captures another space object.

    Berthing refers to a docking between two objects A and B mediated by a robotic arm. First the robotic arm on object A grapples a fixture on object B. Then the arm is used to move the docking aperture on B next to that on A and joins them together; systems on the docking apertures then complete the connection (just as on a normal docking) and the robotic arm can then ungrapple the fixture on B.

- **Domain**

  - **Sense 1: function theory.** The domain of a function is the set over which it is defined. For example, the real function f(x) = sin(x) has the entire real line as its domain (and it has a complex analog which is defined over the space of all complex numbers.). But the function that maps Shuttle flight numbers to satellite catalog numbers is defined over the domain of integers 1 to 135. See also Range (sense 4).

By extension, space (sense 2) is the domain of the subject of astronautics. More quantitatively, the number of satellites and space objects per unit volume is defined over the domain of space (sense 2).

  - **Sense 2: military terminology.** In contrast, the US (and European?) military use domain, and in particular 'space domain', in a sense that seems to be closer to the word 'dominate', and as a shorthand for 'war-fighting domain'. Therefore, I advise some caution in using this term.
  - (For the purposes of this glossary I'll skip the sense in 'internet domain name'.)

- **Dry mass**
  - The mass of the satellite before adding propellants and other consumables; or, when all propellants and consumables have been used up or jettisoned. This mass is useful to know for space debris studies, and is usually close to the satellite mass at end of life.

- **Eccentricity**
  - see Keplerian Elements

- **Elset**
  - Short for Element Set. A dataset giving the orbital elements for a space object at a given epoch. Usually a TLE, although not necessarily.

- **End of Life (EOL)**
  - EOL refers to the end of the operational life of a satellite. For example, specifications may describe the power output and remaining propellant of a spacecraft at EOL. Following EOL, the spacecraft may be used for 'EOL tests' to perform evaluation of compoments, or investigation of previous anomalies, that were considered too high-risk during the operational mission. Following EOL, the satellite may be deorbited (q.v.) or moved to a graveyard orbit, and then be passivated (see Passivation).

- **Endoatmospheric**
  - (Entirely) within the atmosphere (usually, the Earth's atmosphere). As opposed to 'exoatmospheric' (in space).

- **Engine, rocket**

  - See rocket (sense 1).

- **Entry (atmospheric)**

  - Atmospheric entry is the passage of an object from space to the lower part of a body's atmosphere. This normally happens at speeds comparable to or greather than the local Keplerian orbital velocity. As the object passes deeper into the atmosphere, shock heating envelops the object in a region of hot plasma which, unless the object has an appropriate heat shield, may cause the object to melt and break up. Depending on the details of the object's construction, the timescale for complete destruction may be less then or greater than the time to slow the debris to low velocities, and this will determine whether anything reaches the body's surface.

    Entry may occur because of a deorbit burn (q.v.), because of natural orbital decay (q.v.), or because the object was already approaching the body on a hyperbolic entry trajectory.

    If the object was originally launched from the same body, the term **reentry** is used to emphasise that the object is returning to its origin. (Actually, the term reentry is occasionally used - sloppily - even if the object has never been to that world before.)

- **Event**

  - **(GCAT):** In GCAT I use the word event to mean a significant change in state of a space object (especially a change in which other object it is attached to). An event triggers the end of one phase and the beginning of another. See: Phase.

- **Exoatmospheric**

  - Outside the atmosphere. As opposed to endoatmospheric. For the 80 km atmosphere boundary, see Space (sense 2 and 3).

- **Fairing**

  - **Sense 1 (broad)** Any aerodynamically shaped cover, sometimes removable or jettisonable, that protects a non-aerodynamically-shaped part of the rocket or space object from airflow during atmospheric ascent or entry.
  - **Sense 2 (narrow)** The nose fairing of a launch vehicle, protecting the payloads (and sometimes the upper stage of the rocket) from the atmosphere during the early stages of ascent. Fairings are usually constructed out of two or three segments which are separated using small explosives so that they peel off the launch vehicle and fall away

without hitting it, after the vehicle has left the dense part of the atmosphere. In all but exceptional cases the fairings are suborbital and fall to Earth after jettison.

- **Fragment**
  - A piece of orbital debris. Not necessarily the result of a breakup - traditionally the word fragment has been used for any debris object, including a deliberately ejected intact component.

    The word 'fragmentation' is, however, generally synonmous with 'breakup' and implies some kind of disruption of the object, usually with many debris objects resulting.

- **Geoid**
  - **Sense 1 (accurate)**
    The gravitational equipotential surface that approximates the Earth's surface. The EGM96 geoid is approximately an ellipsoid, but with detailed deviation up to 100 metres due to density variations in the Earth.
  - **Sense 2 (approximate)**
    The oblate reference ellipsoid used to approximate the Earth's surface. The Earth is flattened at the poles - polar radius 6356.8 km compared to equatorial radius 6378.1 km. Heights may be quoted above the geoid or above the standard fictional spherical Earth of radius 6378.1 km. The latter is convenient for studying orbital properties, but not for knowing how high above the ground you actually are.

- **Geostationary Earth Orbit (GEO) and Geosynchronous Earth Orbit**
  - The higher your orbit, the longer its period (the time it takes to go round the Earth). At a height above the equator of 35786 km, it takes exactly 23h 56min to orbit - the same time it takes the Earth to spin round once relative to the stars (one sidereal day). As a GEO satellite orbits, the Earth spins beneath it at the same rate and so it remains above the same geographic location.

    To be in GEO, you must have a circular (apogee and perigee both close to 35786 km) equatorial (inclination close to 0.0 degrees) orbit.

    If the inclination is nonzero, the satellite's ground track will trace out a figure-eight around the equator. If the eccentricity is nonzero, the track will move in an east-west cycle each day. In these cases the orbit is called 'geosynchronous' rather than geostationary. If the orbital height is slightly too low or too high, the satellite will drift east or west - hence, a small height adjustment can be used to relocate the satellite.

GCAT's orbital classification defines several sub-cases, but the important distinction is between synchronous (24 hour period) and strictly stationary (circular equatorial as well).

Analogous synchronous orbits are of course possible around other worlds.

- **Grapple**
  - see Docking.
- **Graveyard orbit**
  - An orbit, or range of orbital parameters, reserved for disposal of dead spacecraft, suitably distant from the operational orbits used by spacecraft. Particulary, the GEO Graveyard, which begins 300 km above GEO.
- **Ground Station**
  - A ground station is an installation on the Earth (or, potentially on an airborne platform, despite the misnomer) which receives data from a spacecraft, and in some cases transmits commands and/or data to the spacecraft.

    The ground station is often more or less a relay point, sending and recieving data from a control center (q.v.) elsewhere - but sometimes it can be colocated with the control center or carry out some of those functions.

    Sometimes the ground station is not associated with the satellite owner/operator and is just intercepting data from the satellite, hopefully with the owner's permission. Satellite television receivers and your phone (if it has GPS capability) are examples, although by today's standards we wouldn't really consider them ground stations. Usually we restrict the term ground station to mean a dedicated facility, possibly part of a larger network.
- **Height**
  - **Sense 1: true orbital height** We often refer to the height of a space object above the surface of the body it is orbiting, or the perigee and apogee heights of its orbit. Height in this sense is the object's distance from the body centre minus the distance beween the body surface

and the body center (e.g. geocentric distance of satellite minus geoid radius at the sub-satellite point).

The body-centred radial distance (e.g. geocentric distance) is the more fundamental parameter, but being aware of your satellite's orbital height (and keeping it strictly positive) is important if you are to avoid inadvertent lithobraking (among other reasons).

- **Sense 2: conventional orbital height**

  For reasons elaborated in GCAT's (See Orbital Parameters and Coordinate Frames) section, it is conventional in US and European astronautics to quote periapsis and apoapsis heights relative to a (fictitious) spherical central body with radius equal to the actual body's equatorial radius, i.e. ignoring the existence of polar flattening. So if you see that the ISS is quoted as being in a 417 x 420 km orbit today (as I write this), that is relative to the 6738 km fictitious sphere; actual heights at perigee and apogee today are 424 x 438 km. These values (the Sense 1 figures) are always larger than the quoted (i.e. Sense 2) figures, because the Earth's radius at a given latitude is always less than or equal to the equatorial one.

- **Sense 3: space object height.** We consider most space objects to consist of a central main object (with large volume filling factor) and appendages (with low volume filling factor). Appendages include solar array wings, antenna booms, deployable dish antennas, etc. For payloads, the central object may reflect the launch vehicle fairing size, with the appendages folded up for launch and deployed after separation from the launch vehicle.

  I characterize the shape of the central object by its length, diameter, and sometimes 'minor diameter'. In this context (there is no 'up' in space) the length is synonymous with 'height', since for most spacecraft and rocket stages the long axis of the object is vertical at the time of launch (when 'vertical' still has meaning).

• **Highly Elliptical Orbit (HEO)**

- **Sense 1 (Broad):** Highly Elliptical (sometimes called Highly Eccentric) orbit is a concept that is usually only vaguely defined. Typically a HEO orbit would have perigee in the LEO region and apogee of at least 10,000 km.
- **Sense 2 (GCAT):** The HEO classification in GCAT is for orbits with orbital period less than 23 hours and eccentricity greater than 0.5. Orbits with orbital periods between 23 and 25 hours and high eccentricity are called 'synchronous' with classification GEO/T. Orbits with periods more than 25 hours and apogees lesss than 145688 km are classified as VHEO (Very High Earth Orbit - note the E stands for

something different here) regardless of eccentricity. Orbits beyond that are considered to be in 'deep space' (q.v.)

Orbits with inclinations between 62 and 64 degrees and periods from 11.5 to 12.5 hours are a special case, classified as HEO/M (Molniya orbit, q.v.).

- **Hill Sphere**
  - The region within which a particular body's gravity dominates the effects on an object's orbit. For example, the radius of the Sun-Earth Hill sphere is about 1.5 million km centered on the Earth. The radius of the Earth-Moon Hill sphere is about 66,000 km centred on the Moon, and therefore is entirely within the Sun-Earth sphere.

    The Hill Sphere is also called the 'gravitational sphere of influence' of the body. An alternative concept, the Laplace sphere, is also termed a graviational sphere of influence, but I prefer to use the Hill sphere.

    For further discusson see the GCAT explanation: (See Hill Sphere)
- **Human spaceflight**
  - Space travel involving humans; see also Spaceship. 'Crewed spaceflight' is uglier and less generally applicable but is also acceptable. 'Piloted' or 'Crewed' or even 'inhabited' spacecraft is acceptable, but I prefer 'spaceship'. The gendered term 'Manned' has been obsolete (and deprecated by agencies such as NASA) for decades, and you should have caught up by now.
- **Inclination**
  - see Keplerian Elements
- **Julian Date**
  - see Time
- **Karman Line**
  - The Karman line is the height above the Earth at which, for an object moving at orbital velocity, gravitational forces exceed aerodynamic ones. It is used as the proposed boundary of outer space. In a 2018 paper (McDowell 2018, Acta Astronautica 151, 668) I showed that this line is close to 80 km, and not 100 km as had been conventionally assumed.
- **Keplerian Elements**

- Keplerian elements describe a conic-section orbit around a central body relative to a given coordinate system whose origin is coincident with the central body. The 6 classical elements are associated with a time **(epoch)** at which they are valid. There are a number of different but equivalent sets of elements that can be used.
- **Form 1: with true anomaly**

  The orbit is an ellipse or hyperbola which lies in a flat plane, the orbital plane. The orbital plane intersects the coordinate system's equatorial plane in a line called the **line of nodes** (of course, the line is not well-defined in the degenerate case of zero inclination where the orbital plane and the equatorial plane are the same).

  Two elements describe the orientation of the orbital plane:

  * **Inclination** i, the inclination of the orbital plane to the coordinate system equator.

    Inclination is zero if you orbit the equator eastwards (same direction Earth turns), between 0 and 90 if you are moving roughly eastwards, 90 for pure polar, and 180 for a westward equatorial orbit.
  * **Longitude of Ascending Node,** Ω - the angle between the line of nodes and the X-axis of the coordinate system.

    The longitude in an ICRS or TEME geocentric coordinate system is the right ascension; for a heliocentric ecliptic system it is the ecliptic longitude.

  Two elements describe the shape of the ellipse or hyperbola:

  * **Semi-major axis,** a, describes the size of the orbit. For an ellipse, this is half the length of the long axis of the ellipse.
  * **Eccentricity** e. This describes how elongated the orbit is; e = 0 is a circle; ellipses have e beween 0 and 1, hyperbolae have e greater than 1.

  One element specifies the rotation of the ellipse within the orbital plane:

  * **Argument of periapsis** ω is the angle between the line of nodes and the periapsis position.

  One final element specifies the position of the object within the orbit at the moment specified by the epoch.

  * **True anomaly** ν is the angle between the periapsis position and the position of the object at the epoch.
- **Form 2: with mean anomaly**

  This form is the same as form 1, but instead of the true anomaly, we use

    * **Mean anomaly** M, the time since last periapsis as a fraction of the orbital period, expressed as an angle. M is related to the true anomaly via Kepler's equation.
- **Form 3: with apsis heights or radii.**
  In this form we replace a and e with the perapsis and apoapsis radii q and Q or heights Hp and Ha defined relative to the equatorial central body radius R. (Note the difference from the actual height above the geoid. See Geoid and Height).
    * **Periapsis radius** q, defined as

      q = a(1-e)
    * **Apoapsis radius** Q, defined as

      Q = a(1+e)
    * **Periapsis height** Hp, defined as

      Hp = q - R
    * **Apoapsis height** Ha, defined as

      Ha = Q -R

  See also Apoapsis.
- **Form 4: with periapsis radius instead of semi-major axis.**
  Instead of a and e, you can use q and e (periapsis radius and eccentricity). This is actually more generally robust, since in the case of a parabola (e =1), a is infinite while q remains finite. For cometary orbits, a is often quite uncertain while q is well determined. Therefore, there is an argument for always using q instead of a.
- **Form 5: with time of periapsis instead of mean anomaly.**
  It may be convenient to require that M = 0 (zero mean anomaly corresponds to periapsis passage) and give the orbital elements at an epoch equal to the time of a periapsis. Then you only need 5 numbers plus the epoch instead of 6 plus the epoch.
- **Other useful elements**
    * **the longitude of periapsis** $\varpi = \Omega + \omega$ is the sum of the longitude of ascending node and the argument of periapsis. It has the advantage that this sum is defined when the inclination is zero even though the two contributors are not. The disadvantage is that since the two angles are in different planes, the sum has no good geometrical interpretation when the inclination is not zero.
    * **the nodal angle** $\theta = \nu + \omega$ - the sum of the true anomaly and the argument of periapsis, giving the angle from the ascending node to the object. This element has the advantage that it is well-defined when the eccentricity is zero, while the two contributing angles are not.

- **Lagrange Point**
  - Consider two bodies A and B with B in a circular orbit around the more massive A, and an object C moving in their combined gravitational field. The Lagrange Points are locations where the gravitational effects of A and B on C's orbit are in balance, so that C can (in an appropriate coordinate system rotating with the A-B line) remain approximately stationary.

    There are five Lagrange Points in any such system, denoted L1 to L5. Frequently encountered cases have special names: the points in the Sun-Earth system are denoted SEL1 to SEL5, and in the Earth-Moon system EML1 to EML5.

    L1, L2 and L3 are on the line joining A and B. L1 is between A and B, L2 is beyond B, and L3 is beyond A. These points are unstable, but a spacecraft can remain there with minimal propellant use.

    L4 and L5 lie in the A-B orbital plane and each make an equatorial triangle with A and B. They are formally stable, but in the real universe there are other gravitating objects D, E, F..... which will perturb their positions.

    In astronautics, the SEL1 and SEL2 points have been the most used to date. The L3 point rarely comes up in practical situations in astronomy or astronautics, although I think it's vaguely relevant to some of the co-orbital satellites of Saturn.

    Lagrange points are sometimes referred to as libration points; this is reasonably correct for L4 and L5, since objects near them librate (oscillate back and forth) around the points, but I don't think it's correct for L1 to L3.

- **Launch**
  - **Sense 1 (usual)** A launch is the flight of a rocket or launch vehicle. The launch begins when the vehicle departs the ascent site (launch pad or carrier plane). It is usually considered to end when the payload, if any, separates from the final stage of the launch vehicle.

    A pad abort (when the engines ignite but the vehicle does not leave the pad) or a pad explosion (when the vehicle does not leave the pad in an intact state) are not considered to be launches.

    Launches are broadly characterized as endoatmospheric, suborbital, orbital, or deep-space; we also treat specially orbital launch failures (launches that were intended to be orbital but ended up not being so).

There is no consensus on the exact definition for the start time of air launches. In an air launch, the rocket is dropped from a carrier aircraft, falls for several seconds, and then ignites the first stage rocket motor to begin its ascent. There are three obvious candidates to define the launch time: (1) the aircraft takeoff from the runway, (2) the moment of drop from the aircraft, and (3) the first stage ignition. I adopt (2), while some others adopt (3). (My reasoning is that the ignition of a rocket is not fundamental to putting something in space - one could imagine an EM linear accelerator, or - on a low gravity world - a very big trampoline. So ‘first motion’ is the more extensible definition.)

  - **Sense 2 (narrow)** Personnel associated with launch sites (especially at Cape Canaveral) sometimes restrict the meaning of ‘launch’ to the early stages of flight until the rocket clears the launch pad area, or even to the fact of there being a liftoff at all. Thus, they may report ‘there was a successful launch’ even if the rocket blows up during a later stage of powered flight. What they mean is that once it clears the shore line and is out over the ocean, it’s not their problem anymore. Everyone else follows the rule that you don’t call the launch complete, much less successful, until all payloads have separated from the vehicle and are ‘power positive’ (are getting electricity from their solar arrays or batteries). I recommend that use of Sense 2 be avoided.

- **Launch Failure**

  - I will focus on orbital launches here. In the early years of the space program, a launch might be considered a success or at least a partial success even if it exploded not far above the launch pad, as long as good data was obtained on the performance of the main engine. These days, the usual standard is that the vehicle delivers all the payloads accurately to their intended orbits and successfully separates them without damaging them.

    There are various complications. The main one is the division of responsibilities between the launch vehicle provider and the payload owner, which may differ from mission to mission. In some cases the launch vehicle may deliver the payload to a suborbital trajectory, and an insertion stage considered to be part of the payload completes the rocket firings needed to reach orbit - in this case the launch may be considered a success (as far as launch vehicle reliability is concerned) even if the payload falls in the ocean. Another relevant example is the ZUMA launch in 2018. In that case the launch vehicle entered orbit, but the payload adapter failed to operate. The payload adapter is a device that connects the payload to the launch vehicle; it is usually part of the launch vehicle, but in this case it was operated by the payload owner. The launch vehicle upper stage then performed a deorbit burn, with the payload still attached. This was considered a successful launch for the launch vehicle, although obviously a failed mission for the payload.

If the rocket delivers the payloads to the wrong orbit, a successful mission may still be possible. How far off the orbit can be to allow this depends on the payload.

In 2012 I introduced the launch success fraction definition that is now used in GCAT. See GCAT's section on (See Launch Success Fractions) for details.

- **Launch Origin**
  - I introduced this term in GCAT as a generalization of the concept of a launch site. The Launch Origin comprises several components:
    * the **Platform** (optional): either a ship or an airplane from which the rocket is launched.
    * the **Launch Pad** or **Launch Point** (LP for short, unifying the two terms) where the rocket ignition occurs; LPs are always associated with
    * a **Launch Site** which groups together related LPs.
      However, for an air launch, we consider **two** Launch Site/LP pairs: the location of the departure runway where the aircraft takes off, and the location where the rocket drops from the plane and ignites. This latter pair we call:
    * the **Ascent Site** and
    * the **Ascent Point.** For other launches we consider the Ascent Site and Ascent Point to be identical with the Launch Site and Launch Point. (Ideally, for sea launches one would track the ship port departure point and distinguish it from the launch itself in the same way, but usually that information is not known).

  For further details see the (See Space Launch Origins Catalog.)

- **Launch Pad**
  - See Launch Origin
- **Launch Site**
  - See Launch Origin
- **Launch Vehicle**

  - A launch vehicle is anything that causes a space object to move from the surface of a body to free flight above its atmosphere. Launch vehicles which place objects in bound or escape orbits may be referred to as satellite launch vehicles or space launch vehicles, as opposed to suborbital launch vehicles.

    At the present time all launch vehicles are rockets, although gun launch systems have been used for suborbital launches in the past and other possibilities have been envisaged.

    See also Rocket (sense 3).

- **Length**

  - The length of the space object is defined as the longest dimension of the main body, excluding appendages. An exception: for cylindrical objects the length is that of the axis of symmetry, even if it is smaller than the diameter.

    I haven't been entirely rigorous about defining the difference between a main body and an appendage; for example, antennae that are closely packed on the end of the main body are sometimes considered to be part of it. The idea is that the product of length and diameter give an approximate minimum (lower limit) cross section for the space object (with an upper limit provided from the span, q.v.).

    See also Diameter and Span.

- **Lithobraking**

  - Like aerobraking, but the periapsis is lowered too far. From 'lithos' (Greek) - stone, rock. Aerobraking reduces the apoapsis height slowly over many revolutions. Lithobraking reduces the apoapsis height to zero instantly, but with the unfortunate side effect that the spacecraft does not survive. Originally a whimsical euphemism, but increasingly a standard term. Example: 'because of a units error, Mars Climate Orbiter's attempt at aerobraking became lithobraking instead'. If the initial orbit is hyperbolic, lithobraking would properly be termed lithocapture.

- **Longitude of Ascending Node (or of periapsis)**

  - see Keplerian Elements

- **Low Earth Orbit (LEO)**

  - **Sense 1 - region of space:** Low Earth Orbit, usually referred to simply as LEO, is a region of space in which satellites in a circular orbit can satisfy the conditions for LEO in Sense 2. Note that a space object can be in the LEO region without being in a low Earth orbit - a suborbital ballistic missile, as one of many examples, passes through this region but is not in LEO in sense 2.
  - **Sense 2- orbital classification, broad:** The height distribution of geocentric satellite orbits shows a broad lower peak between about 300 km and 1000 to 2000 km, above which there are few satellites until you get to the popular regions at about 19000 km (12 hour orbits) and 35000 km (24 hour orbits). The upper cutoff of this lower peak is mostly set by the intense part of the trapped radiation (Van Allen) belts which satellites would prefer to avoid.
  - **Sense 3 - orbital classification, narrow:** There is no universal agreement on the exact boundaries of LEO. The lower boundary is set by the lowest possible orbits; in the GCAT scheme we consider this to be 80 km, although circular orbits are not possible below about 120 km. Two popular choices for the upper boundary are 2000 km and 1681 km (the latter is the height corresponding to a two hour orbital period). For GCAT I have adopted the latter, although in retrospect I regret that choice.
  - **Sense 4 - orbital classification, GCAT:** In GCAT, I distinguish between upper LEO (LEO proper) and lower LEO (LLEO), with a boundary between them at 600 km. Objects in LLEO typically reenter naturally via orbital decay within about 25 years, while orbits in upper LEO tend to remain in orbit for centuries. See McDowell (2020, Astrophys. J. Letters, 892, L36) for further discussion.

  Note that sun-synchronous orbit (SSO; GCAT orbital categories LEO/S and LLEO/S) is a subset of LEO.

- **Maneuver [US], Manoeuvre [UK]**

  - We use the term manouevre to denote a deliberate change in the state or attitude of a space object. We distinguish between attitude maneuvers, which rotate the object around its center of gravity, and trajectory correction maneuvers (or orbit adjust maneuvers), which change the momentum of the centre of gravity and thus alter the orbit of the object.

    I am a dual UK-US, and alternate the two spellings arbitrarily.

- **Mean anomaly**

  - see Keplerian Elements

- **Medium Earth Orbit (MEO)**

  - MEO is a loosely defined category for satellites that are above LEO but not in GEO. GPS satellites are in MEO. In GCAT I classify MEO satellites as those with orbital periods between 2 and 23 hours and orbital eccentricity less than 0.5. See also Highly Elliptical Orbit and Molniya orbit.

- **Mesonaut**

  - By analogy with astronaut: a person who has flown in the mesosphere (above 50 km) but not in space (above 80 km). I coined this word in the early 1990s in correspondence with M. O. Thompson, who at the time was the only living mesonaut. He seemed to like it, as his reply was proudly signed 'Milt Thompson, NASA Mesonaut'.

- **Microgravity**

  - The term microgravity has largely replaced the older 'zero gravity', since small perturbations from a variety of sources make it extremly hard to remove all sources of acceleration. The enviroment in a quiescent LEO spacecraft, in a coordinate system moving with the spacecraft centre of gravity, is typically in the milli-g to micro-g range.

    The reader should be very careful about the interpretation of 'microgravity' and 'zero gravity'. In accordance with general relativity, choosing an accelerated coordinate frame whose origin is the center of gravity of the freely falling space object allows one to have zero gravity at that point (gravity and acceleration are fungible *at a point* by change of coordinate frame). But this coordinate frame is not an inertial one, and counter-intuitive things (apparent ficitious forces) will happen when you are not at the centre of gravity.

    In particular, do not be fooled into thinking that the lack of gravity is because you are 'too far' from Earth and that the gravity is 'weak' there. In an inertial coordinate system or in a geocentric coordinate system rotating with the Earth, the strength of gravity on (for definiteness, let us pick:) the ISS is only 13 percent less than that on the Earth's surface. In other words, the acceleration due to gravity is 8.67 meters per second squared instead of 9.81, and you weigh only 13 percent less than you did on the ground. The apparent lack of gravity is exactly the same as that experienced in a falling elevator, or by jumping off a tall building: you will be 'weightless' and feel no gravity in your personal coordinate frame - until the moment you hit the ground, which will not be friendly.

- **Minor Planet**

  - 'Minor planet' is the technical name for what is colloquially called an asteroid. A minor planet is any rocky (non-cometary) celestial body in heliocentric orbit that is not one of the eight major planets. The larger minor planets, such as Eris and Pluto, are also categorized as dwarf planets. The lower boundary between a small minor planet and a meteoroid is unclear (I think a 1 metre diameter boundary would be sensible, although there's no *physical* motivation for a distinction).

There are millions of minor planets in the solar system; ones with well determined orbits are given numbers ('numbered minor planets') and are eligible to be named by the discoverer (or failing that by the IAU Minor Planet Center). I will note that numbered minor planet (4589) was named McDowell in 1993.

- **Missile**
  - **Sense 1 (broadest):** A guided or aimed projectile of any kind. (A thrown stone can be referred to as a missile). Especially, a guided rocket-propelled projectile weapon ('guided missile'), but also 'cruise missiles', which are usually propelled by air-breathing jet engines.
  - **Sense 2:** ballistic missile. A rocket vehicle whose propulsion ends early in flight, with most of the remainder of the flight occuring under the momentum of the vehicle (i.e. following its orbit under gravity, or 'ballistic flight').
  - **Sense 3: (narrower)** ballistic missile weapon; a ballistic missile with a (real or simulated) warhead.

  - Although usually when we talk about ballistic missiles we mean weapons (Sense 3), sometimes the term is used for related vehicles used for test, research or even space launch (sense 2). (It was common in the 1960s to talk about the Atlas first stage of the Atlas Centaur rocket as 'the missile', even when it had been custom-built for a space launch vehicle.)

    See also Rocket. When talking about 'rockets and missiles' (a common juxtaposition), some writers mean 'rockets (small unguided projectile weapons) and missiles (larger but still small guided weapons)', e.g. MLRS M26 vs Sidewinder, while others mean 'rockets (huge space launch vehicles) and missiles (smaller but still huge ballistic missile weapons)', e.g. Saturn V vs Minuteman 3. Caveat lector.

- **Molniya Orbit**
  - The Molniya orbit is a special highly elliptical orbit first used by the USSR's Molniya communications satellites. For GCAT, I classify an orbit as Molniya if its orbital period is between 11.5 and 12.5 hours, its inclination is from 62 to 64 degrees, and its orbital eccentricity is more than 0.5.

One effect of Earth's oblateness is that an elliptical orbit rotates slowly in the orbital plane, so that if the perigee starts off at southern latitudes it will at a later time be in northern ones. The rate of this rotation is proportional to a function which is zero if (sin i) squared is 0.8, corresponding to i = 63.43 degrees. Satellites with this inclination will have the latitude of perigee locked instead of rotating, useful for a number of applications.

- **Moon**
  - **Sense 1 (specific):** The Moon. Earth's satellite, or arguably companion world if you consider us a binary planet. Frequently (especially by me) called Luna, to distinguish it from moon (sense 2).
  - **Sense 2 (general):** A moon is a natural satellite of a celestial body. See also World.
- **Motor, rocket**
  - See rocket (sense 1).
- **Nominal**
  - **Sense 1** (regular English) - In name only; Miminally acceptable. 'He left a nominal tip' means an insultingly small one.
  - **Sense 2** (aerospace) - Equal to the predefined expected value; perfect; normal. 'What is a nominal tip in this country?' asks what the default amount is. 'The orbital parameters were nominal' - the actual orbital parameters were in agreement with the pre-specified values.

  The jokey use of 'norminal' as a replacement for 'nominal' in this context appears to have originated as a slip of the tongue by highly-respected SpaceX engineer John Insprucker during a launch commentary. I fully support and endorse the widespread usage of 'norminal'.
- **Object (or Space object)**
  - **Sense 1** - artificial objects in space. I usually use the word 'object' to mean an artificial space object, as distinguished from a natural astronomical object or 'body'. Objects include suborbital rockets, artifical satellites, space probes, and space debris (including artificial debris in interplanetary space).
  - **Sense 2:** - objects, but not space objects. In GCAT the word 'object' is slightly more general as it is also used for launch vehicle parts that are not space objects (because they do not reach space). This applies to the objects in the endoatmospheric object catalog (lcat) and some of the objects in the orbital launch failure catalog (ftocat). Here 'object' just means 'identifiable artifact in propulsive or free flight'.

- **Sense 3** - orbital space object. The term ‘space object’ is used in the field of space law (and in the Outer Space Treaty). It is there usually understood to mean objects in orbit (sense 2) around the Earth, or objects in deep space. In other words, suborbital objects are not generally thought to be covered by the term in this context.

- **Orbit**

  - **Sense 1:** (broad). An orbit is the trajectory (position and velocity as a function of time) of an object freely falling in the ambient gravitational field (or if not perfectly freely falling, on which forces other than gravity may be neglected for short periods and to first order.) ‘the probe’s orbit through the Jovian system was perturbed..’

    In some cases the ambient gravitational field is dominated by a single pointlike massive body (or, deviations from this ideal are small enough to be neglected). In this case the orbit of an object is a conic section: an ellipse or a hyperbola. (I will omit discussion of the rare special cases of a parabola and a rectilinear orbit, although we do use parabolic orbits as an approximation to the trajectory of some comets.) Further, the motion of the object along this conic section is described by Kepler’s laws. Such an orbit is called a **Keplerian orbit.** It is described by seven parameters - the six classical **Keplerian elements** (q.v., also known as orbital elements) and the epoch (time) at which they apply. In a perfect Keplerian orbit, six of these parameters are constant and one (the mean anomaly) increases linearly with time; the elements at one epoch describe the motion of the object at all past and future times.

    When the orbit isn’t perfectly Keplerian, deviations are often small enough that we can approximate it as a Keplerian orbit whose orbital elements change with time. At any moment, for a given central body mass, the state vector (position and velocity at a given time) is sufficient to define a unique set of Keplerian orbital elements - the orbit the object would have if all forces other than the central body were suddenly switched off. These elements are known as the **osculating elements** with respect to that central body at the given epoch.

    When we consider an object to be in a gravitational field dominated by a single body, we say that it is ‘in orbit around’ that body, even if we are not explicitly calculating its orbital elements. This usage is valid even if the orbit is hyperbolic, or if the object’s orbit intersects the body surface.

    One of the orbital elements is the **eccentricity.** If the eccentricity is less than one, the orbit is elliptical; we also say that it is ‘bound’ (remains a finite distance from the central body). If e is more than one, the orbit is a hyperbola, and we can also say it is 'unbound' (the object will head off to infinity).

 - **Sense 2:** (narrow): in a bound orbit fully outside the central body's atmosphere, if any. Example: 'the satellite is now in orbit around the Earth' (see "In Orbit"). We usually mean by this that the satellite's orbital elements with respect to the Earth imply a perigee height that is not only positive, but in space (i.e. above 80 km, see Space sense 2.), and an eccentricity that is less than 1, so bound (elliptical).

   However, note that even if the object is suborbital or escaping, the example sentence would still be valid using sense 1. See further discussion in GCAT's section (See Space and Orbit.)

- **In Orbit**

  - We say that 'Hubble is in orbit around the Earth'. (or: 'the Moon is in orbit around the Earth', 'Mariner 9 is in orbit around Mars'). We can also equivalently say 'Hubble is in Earth orbit'.

    Strictly speaking, Hubble and the Earth are orbiting *each other* around their common center of gravity (barycenter). However, since the Earth is 540,000,000,000,000,000,000 times more massive than Hubble, that barycenter is less than one atom-size away from the geocenter, and we usually ignore this technicality. (for Earth and Moon, the issue is more important to address correctly.

    Usually when we say "A is in orbit around B", we are using the narrow sense 2 (above) of orbit, with positive periapsis, except in rare technical usages where we are asking if the relevant central body should be B rather than C. "Did it reach orbit?" usally means "did it reach an orbit with a perigee outside the planet's atmosphere?".

    Confusingly, "in B's orbit" and "in B orbit" have very different meanings: "B's orbit around something" vs "something's orbit around B". This is a frequent source of mistakes by those outside the field. **"Earth's orbit"** is shorthand for "Earth's orbit around the Sun", while **"Earth orbit"** refers to an object in orbit around the Earth. Be very careful of this one. Examples:

    "The asteroid belt is outside Earth's orbit" (more precise: outside the orbit of Earth [around the Sun]).
    versus

    "The satellite is in Earth orbit" (more precise: is in an orbit around the Earth").

- **On Orbit**

  - In American aerospace usage, one encounters both the phrases ”in orbit” and ”on orbit”, although the former is usually considered more correct in normal English.

    The term ”in orbit” is much older, and was used in astronomy well prior to the space age. I started to hear ”on orbit” in the 1980s in astronautical engineering contexts.

    My personal, prescriptive, opinion is that ‘on orbit’ is a misuse of the preposition ‘on’, makes no grammatical sense, and should be eschewed. Use ‘in orbit’ instead in all cases. Nevertheless I describe here the nuance between ‘in orbit’ and ‘on orbit’ that I observe in its usage.

    Examples: ”the satellite has been in orbit for three years”; ”the satellite deployed its antenna once on orbit”. ”On orbit” is used to indicate ”the state of being in orbit”, ”the operational phase of orbital operations” (as opposed, for example, to ”during launch”). I don’t think you would say ”the Moon is on orbit”, or talk about debris objects being on orbit - the phrase implies not only the dynamical state of being in orbit, but also a state of activity.

- **Orbital Decay**

  - Orbital decay is the natural shrinking of an orbit around a body with an atmosphere due to atmospheric drag - the fact that the space object is passing at high relative speed through the tenuous outer atmosphere of a body.

    For an elliptical orbit, the vast majority of the drag is experienced at periapsis, where the atmosphere is densest. Drag has the effect of slowing down the satellite, reducing the periapsis velocity. This has the consequence that the next apoapsis is lower than it would have been, and thus the semimajor axis is reduced. The counter-intuitive result is that the average velocity of the space object is increased rather than decreased (because the lower semimajor axis has a shorter orbital period and a higher Keplerian velocity).

    Another effect of the drag is to make the orbit more circular (the periapsis stays about the same while the apoapsis shrinks). The orbit continues to shrink while circular, until the height is low enough and atmospheric density high enough that the satellite heats up sufficiently to break up and melt: see Entry.

    In contrast to active deorbit (see Deorbit) where the final orbit is relatively elliptical and the entry point is therefore easy to accurately predict, the circular final orbit of a satellite undergoing orbital decay makes the location of reentry uncertain. A small change in atmospheric density (e.g. caused by solar activity) or in the orientation of the satellite (changing its effective ballistic coefficient and thus how much drag affects it) can change the reentry time by hours or days. Even on the day of reentry, an uncertainty of many hours is common. During that period the space object circles the Earth several times. Thus, the *location* of reentry is completely unpredictable, the uncertainty region covering multiple continents and oceans - possibly even after reentry has occurred. Sometimes the breakup is detected by infrared sensors on satellites, but on other occasions all we know is that it was seen by radars on one orbit and not on another pass a few orbits later, with reentry having occurred somewhere in between.

- **Orbital Plane**
  - An object's orbit lies in a flat plane with a fixed inclination to the equator. On short timescales (or for a perfectly spherical central body) the plane is fixed in inertial space; it crosses the equator at two points called the nodes, and the celestial longitude (right ascension) of these nodes is fixed. On longer timescales, perturbations cause the plane to rotate with time. The rotation rate depends on the orbit altitude and the inclination, but not (to reasonably high accuracy) on the longitude. Thus, all orbital planes with the same inclination and altitude rotate at the same rate and so keep their relative spacing. See also Constellation (sense 2) and Keplerian Elements.

- **Organization**
  - In GCAT, I use the term 'organization' in a broad sense to identify country of origin, owner/operator organization, and/or manufacturer of an object. In this sense an organization can be any named and spacetime-localized entity including
    - A world or a region on a world - an 'astronomical polity'
    - A country (nation-state) or autonomous political region
    - An intergovernmental organization, used as if it were a country
    - An academic or non-profit organization
    - A business entity, a corporation, company, or operating location thereof
    - A civilian or military/defense government agency, base, or group

    See the description of the (See Space Organizations Catalog) for more details.

- **Outer Space**
  - see Space.

- **Outer Space Treaty**
  - The foundational treaty of space law. It includes the following principles:
    - the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind;
    - outer space shall be free for exploration and use by all States;
    - outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;
    - States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner;
    - the Moon and other celestial bodies shall be used exclusively for peaceful purposes;
    - astronauts shall be regarded as the envoys of mankind;
    - States shall be responsible for national space activities whether carried out by governmental or non-governmental entities;
    - States shall be liable for damage caused by their space objects; and
    - States shall avoid harmful contamination of space and celestial bodies.

    See the UN OOSA page for the text of the treaty in various languages: (See https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html)

- **Passivation**
  - At end of life, spacecraft are ‘passivated’, i.e. made passive rather than active. This involves discharging batteries, venting remaining propellants, disabling radio transmitters, and generally eliminating the presence of sources of energy that might cause debris generation or other kinds of interference with other space users.

- **Payload**
  - **Sense 1** A payload is an artifical satellite (sense 5) or space probe; i.e. an artificial space object which is (or was, or was designed to be) active in the sense that it has internal power, sensors or other operating equipment, as opposed to objects not designed to operate separately in orbit after the launch phase of an orbital launch. In this sense the payload is the entire space object, not just the bits that are carrying out the payload function.

    A rocket stage may contain instrumentation that sends data to the ground during the first few hours after launch, but this is not usually considered a payload (except if the instrumentation is integrated as a separate package to qualify new technology of some kind).

A special case is that of passive calibration satellites (radar calibration spheres, Lageos, etc) which are considered payloads despite being inert, because they are the 'purpose' of the launch. Similarly, ballast dummy payloads on test launches of new launch vehicles are counted as payloads.

  - **Sense 2** An individual instrument or subsystem on a spacecraft: a science instrument, a communications system, an Earth imaging camera, etc. In this sense a single satellite may have many payloads. I usually use 'instrument' or 'experiment' for this sense, although in general those words can be misnomers. In this sense the payload of a space station ferry or cargo ship is its crew and/or cargo.
  - **Sense 3.** In a launch (especially an orbital launch), the vehicle is considered to be divided into 'launch vehicle' (LV) and 'payload' (PL). You might think that the propulsive stages of the rocket are the LV and everything on top of that is the PL, but that's not always the case. The distinction is actually one of responsiblity - between the launch vehicle owner/operator and the launch vehicle customer. There may be propulsive stages associated with the payload and considered to be part of it in this sense. If these stages fail, it is not a launch failure but a payload failure.

    Usually in my work, I use 'payload' in sense 1: a satellite that isn't (or wasn't at one point) space junk.

- **Periapsis**
  - See Apoapsis
- **Perigee**
  - See Apoapsis
- **Phase**
  - This is my own concept, introduced for GCAT. Each time an object transitions to another state (undocks, is attached to something, reenters, changes which body it is orbiting, etc.) marks the beginning or end of a phase. Most objects in GCAT have only a single phase - they separate from an object (launch vehicle) and then are either still in free flight or have reentered. However, some objects go through many phases.

    For more details, see the definition of (See Phases) in GCAT.
- **Platform**

  - I use this term in GCAT to specify a ship, sub or plane from which a rocket is launched.

    Some space launches are carried out from mobile structures which don't have a fixed geographical location. I thus distinguish between the 'platform' (the vehicle used as a launch platform) and the 'site' (the geographical location at which the platform was located when the rocket separated from it).

    Platforms which have been used to launch rockets include surface ships, submarines and aircraft. (I also include the KSC pad 39 mobile launch platforms, just because I want to record which one was used for which launch and it's a useful database field to stash that particular information.)

    See also Launch Origin, and see the discussion in GCAT on (See Launch Platforms.)

- **Primary**
  - Synonym of 'central body'. The body we are orbiting, and usually the center of the coordinate system we are using.

- **Propellant**
  - Terrestrial vehicles and aircraft carry fuel which they burn in the ambient air. Space rockets, in contrast, must bring their 'air' with them. The fuel combusts with an 'oxidizer', which is any chemical that lets the fuel burn. So rocket stages usually have two tanks, a fuel tank and an oxidizer tank. It's often useful to refer to fuel and oxidizer collectively - the term for that is 'propellant'.

    Sometimes, however, the fuel contains its own oxidizer; it is a 'monopropellant'. Often, as with the monopropellant hydrazine, a catalyst allows the reaction to proceed.

- **Radioisotope Heater Unit (RHU)**
  - An RHU is a small heater unit that makes use of the heat of radioactive decay of a few grams of Pu-238 or Po-210 to generate of order 1 watt of heat, and is used on planetary probes, rovers and landers. Unlike an RTG, it does not generate electricity.

- **Radioisotope Thermoelectric Generator (RTG)**
  - An RTG is a 'battery' using the heat of radioactive decay to generate electricity using thermocouples. US RTGs usually use plutonium Pu-238 as fuel, while some Russian ones use polonium Po-210. See also

RHU. Note that an RTG is NOT a nuclear reactor, and there is not enough radioactive material to achieve criticality; they are in that respect comparatively safe, but are nevertheless usually launched in protective casings that can survive a launch vehicle failure to lower the risk of releasing even a small amount of radioactive material into the enviroment.

- **Range**
  - **Sense 1, Surface range:** The distance along the (curved) Earth surface from a rocket's launch point to its descent (impact, landing) point.
  - **Sense 2, Distance from observer:** The radial (geodesic, straight line) distance from the observer or other origin being discussed to a space object. 'We last contacted the Mars probe when its range (to the antenna) was 2 million km'.

    In this sense, we also use 'range rate' to mean the rate of change of the range, i.e. the radial component of its velocity relative to you. Positive rates mean the object is getting further away.
  - **Sense 3, Instrumented launch corridor:** To launch a large rocket or space vehicle you need not just a launch site, but an entire range. The rocket is launched on a given azimuth and flies in that direction , with lower stages impacting the surface at a variety of ranges (sense 1) from the pad. You need the the ability to track the rocket along its flight path, and to control access to the surface (e.g. ocean) under the flight path at least to the extent of issuing warning notices, and possibly recovering debris in case of a failure. This imaginary corridor along which the rocket flies, with instrumentation and tracking stations strewn along it, is the range. (The tracking stations are becoming less necessary in the days of onboard GPS).

    For example, the Eastern Test Range in the early 1960s included the Cape Canaveral launch site and stations on Caribbean islands such as Grand Turk and Antigua, out to the Ascension Island tracking station and missile impact zone in the middle of the South Atlantic.

    Associated with this sense are several additional terms:
    * Range Safety Officer (RSO): the official whose responsibility it is to destroy the rocket or terminate its flight if it goes badly off course.
    * Rangehead: the start of the range, where the launch pads are. (This terms seems to be more used in UK and Australian sources, but I might be wrong about that).
    * Uprange and Downrange: Uprange is closer to the rangehead, downrange is further from the rangehead in the direction of flight.

  - **4, function theory:** The range of a function is the set of values it can take. For example, the range of the real function sin(x) (with domain the real line) is the real line subset [-1,1].

- **Reaction Control System (RCS)**
  - Term for a (usually secondary) set of rocket thrusters used to make attitude changes or small orbit adjustments. Usually as opposed to the spacecraft's main propulsion system. It's a bit of an odd name; reaction is of course the key to Newton's third law and thus to rocket propulsion, so it's not wrong per se, but a bit unhelpful.

- **Reentry**
  - See Entry (atmospheric).

- **Reentry Vehicle**
  - A reentry vehicle (or 'entry vehicle' if for planetary atmosphere entry) is any space object which is designed to survive atmospheric entry (q.v.). Some reentry vehicles are conical in shape and have a blunt end with thermal protection systems; others have the pointy end forward, and others have quite different shapes. Some are 'lifting' reentry vehicles as opposed to 'ballisitic'; their trajectory is altered by the aerodynamic properties of the vehicle. The Space Shuttle Orbiter is an example of an unconventionally shaped lifting reentry vehicle.

    The term reentry vehicle (RV) is particularly associated, however, with ballistic missiles. In an operational ballistic missile weapon, the RV contains an explosive warhead (in some cases a nuclear weapon). However, in test launches the warhead is replaced by test instrumentation: for example, when the US test-launches a Minuteman missile from Vandenberg to Kwajalein, or North Korea tests a Hwasong 15 flying it over Japan into the Pacific, the reentry vehicles do not contain warheads. (I emphasize this because the terms reentry vehicle and warhead are often conflated and confused in popular descriptions of missiles).

- **Registration Convention**
  - The UN (See Convention on Registration of Objects Launched into Outer Space) (1976) requires (Article IV) that states provide certain information to the UN, to be made public (Article III), about each space object that it launches, as soon as practicable (Article IV). This is an important foundation for the transparency of activities in space. Compliance with the convention has been imperfect, as noted by the author and colleagues in Jakhu, Jasani and McDowell (2018, Acta Astronautica, 143, 406).

- **Ripley Line**
  - It is well known that in space, no one can hear you scream (Scott, R. et al 1979.) Following by a suggestion by Mark Harrison (twitter.com/meh130), I proposed in Jul 2021 that this defines an alternative boundary of space which I call the Ripley Line: space starts at the altitude at which the loudest possible scream becomes inaudible. Using the US Standard Atmosphere 1976, and the absolute hearing sound threshold of 20 micropascals, and assuming that the loudest possible sound wave is of order the total air density, the Ripley Line is at about 250 km altitude.

- **Robot arm**
  - An informal term for a teleoperated (robotic) articulated manipulator system. Robot arms typically end in a grapple device used to lock on to fixtures on another space object so that they can be moved around.

- **Robotic spacecraft**
  - This is the preferred term for a spacecraft or satellite without humans aboard. The slightly uglier alternative 'uncrewed spacecraft', is also preferable to the older gendered term that we don't use any more.

- **Rocket**
  - **Sense 1 - rocket motor.** A rocket is a device that produces thrust by heating of propellant in a chamber with a narrow exit; the escaping propellant particles (molecules, solid propellant lumps, ions or whatever) carry momentum in one direction, causing the rocket (and whatever it is attached to) to go in the other direction by Newton's Third. A device of this kind is more specifically a rocket engine or rocket motor. ('engine' is used usually for liquid propellant, and 'motor' typically for solid propellant.)
  - **Sense 2 - rocket stage.** A rocket is a self-contained system which contains propellant tanks and a rocket engine/motor. A rocket in this sense is usually referred to as a rocket stage.
  - **Sense 3 - launch vehicle** A rocket consists of one or more stages, as well as, typically, a payload and a nose fairing to protect the payload during atmospheric flight. Each stage is propelled by a rocket engine/motor. 'The rocket was launched from Cape Canaveral on Tuesday'. Large rockets with non-weapon payloads are also called launch vehicles. A small endoatmospheric rocket with an explosive warhead would not normally be called a launch vehicle (see sense 4).

  Sense 3 is the most common usage today.

- **Sense 4 - unguided rocket weapon.** In some military contexts, the term ‘rocket’ refers to a small vehicle with a rocket motor that is unguided; the term is used in opposition to ‘missile’ which is used to mean a rocket weapon with a guidance system. This distinction is not generally made in the space context, and I do not used the word in this sense.

- **Rapid Unplanned Disassembly (RUD)**
  - Sarcastic expression meaning: rocket went bang into lots of small pieces. ‘they had a successful first flight, but on the second flight they had a RUD’.

    Similar but less common expressions include IOBM (In Ocean By Mistake) and SWLC (Salt Water Leak Check). Also known as ‘having a bad day’.

- **Satellite**
  - **Sense 1** (broad) Anything in a bound (closed) orbit around a body. Satellites in this sense may be artificial satellites, spacecraft of any kind, or natural satellites (moons).
  - **Sense 2 (narrow)** Natural satellite. A natural celestial body in closed orbit around a nonstellar object of larger mass; a ”natural satellite”: ”Phobos is a satellite of Mars”. All known examples to date are rocky bodies, but one could imagine a Neptune orbiting a super-Jovian... the boundary between ’satellite and primary’ and ’binary world’ is fuzzy, as has been pointed out in the case of the Earth-Moon and Pluto-Charon systems.
  - **Sense 3** (narrower) Artificial satellite; artificial (human - or alien! - made) object in bound orbit around a body (usually the Earth). (The Russian term is ‘iskusstvenniy sputnik zemli’, artificial satellite of the Earth.) This sense includes space debris and human-carrying spaceships, rocket stages, ejected components. ‘Cassini is an artificial satellite of Saturn’ is correct in this sense. The satellite’s motion must be gravitationally dominated: it must be in the Hill sphere of the object it is orbiting. This usually implies that the central object must be a natural body: when Atlantis makes a flyaround of the ISS, it is not a satellite of the ISS. But possibly Luke’s X-wing fighter, if his engines go out, is a satellite of the Death Star, even though the Death Star is artificial....
  - **Sense 4** (narrower) As sense 3, but restricted to objects orbiting the Earth. Still includes debris, rocket stages, etc. ‘The spacewalker’s tool bag floated off and is now a separate artificial satellite’ is correct usage in this sense.

Spacecraft beyond Earth orbit, including artificial satellites of the Sun and of other worlds (Moon, Mars, etc.) are usually called space probes rather than satellites. The phrases 'satellites and space probes' is often used in the sense of 'artificial satellites of the Earth and interplanetary spacecraft, respectively'.

  - **Sense 5** (narrow). Artificial satellite payload. A satellite carrying a functionally useful payload (set of instruments, experiments, crew, transmitters, etc.) as opposed to a rocket stage or inert piece of space debris; however, also includes previously active payloads that are now defunct. 'The satellite separated from the launch vehicle final stage'.
  - **Sense 6** (narrow). Active artificial satellite payload. A satellite carrying an active payload that is still working. Often the questioner asking 'how many satellites are there orbiting the Earth right now' wants to know just about still working ones.
  - **Sense 7** (too narrow). An artificial satellite payload that does not include design provisions for carrying humans (i.e. is not a 'spaceship'), propulsion intended to send it onto a hyperbolic orbit after a brief stay in parking orbit (i.e. is not a 'space probe'), or aerosurfaces intended to provide controlled reentry and landing (i.e. is not a 'spaceplane'). Some authors consider the word satellite to exclude human spaceflight vehicles such as the ISS, the Space Shuttle, and even cargo ships such as Progress. I don't see these exclusions as justified - those objects are 'more than' satellites, but they are indeed still satellites (in the same sense that humans are indeed apes.)

    When I use the word satellite, I usually mean Sense 4 or, occasionally, Sense 5. However instead of Sense 5 I prefer to use the word 'payload'. I never mean Sense 7. Senses 3 and 4 are both in wide use and are quite different; therefore, you should be careful to be clear which one you mean (e.g. in questions like 'how many satellites are in orbit?')

    See also Small satellite

- **Scrub**
  - When a rocket launch is postponed after the start of the formal countdown (which can be up to 2 days or so before the launch time) but before ignition of the rocket engines. See also Abort.
- **Semi-major axis**
  - see Keplerian Elements
- **Small Satellite (Smallsat)**
  - A small satellite or smallsat is a satellite whose launch mass is 500 kg or less. Several subcategories are defined:

Term	Mass range
Minisatellite	100 to 500 kg
Microsatellite	10 to 100 kg
Nanosatellite	1 to 10 kg
Picosatellite	0.1 to 1 kg
Femtosatellite	Less than 0.1 kg.

Note that despite the use of SI prefixes, the words micro, nano, pico and femto do not have their usual (3-orders-of-magnitude) SI meanings.

- **Space**
  - **Sense 1** (broad): The universe at a fixed time; any 3-dimensional spacelike slice of the space-time manifold. In this broad sense, the Earth is in space, and so are you.
  - **Sense 2** (narrower): The universe, except for Earth and its lower atmosphere. This is probably the most commonly used sense. I consider space in this sense to begin at 80 km above the geoid surface (McDowell, J., Acta Astronautica 151, 668 (2018)). Yes, the atmosphere does extend beyond 80 km, but for the reasons laid out in the cited paper I treat everything above that point as 'space'.
  - **Sense 3:** (narrow): The airless spatial regions between worlds. In this sense, if you are within the Martian atmosphere you are not in space. For worlds with atmospheres, the Karman line argument can be used to define the boundary of space.

    For airless worlds it's a bit tricky: if you are standing on the lunar surface, are you in space? What if you jump a few centimetres, are you in space then? I like to think of a future lunar space traffic control distinguishing between local traffic and long range traffic at some altitude like 1 km, but I'd be interested to hear other suggestions.
  - **Sense 4:** (narrow): The spatial regions in which orbital travel around some body is possible (practical). For worlds with an atmosphere, this is close to Sense 3. For airless worlds, it could be defined by an altitude at which any circular orbit will not intersect topography even when perturbed by some specified amount (possibly the maximum one-orbit perturbation due to mass concentrations, and the maximum solar radiation pressure perturbation for some reasonable ballistic coefficient). This value would be of order 20 km on the Moon. A definition like this would avoid recording each 1-meter jump by a lunar astronaut as a separate space launch. However, a precise and general definition along these lines needs to be proposed.

    I will sometimes specify 'outer space' to distinguish from other English usages of the word ('inner' psychological space, living and personal space, hit the space (ASCII 0x20) key...) as well as mathematical ones (vector space, topological space, parameter space).

- **Space Probe**
  - A space probe is an artifical object sent to deep space, as opposed to an artificial Earth satellite in relatively low orbit. Although usually the term is used for lunar or planetary probes, traditionally (especially early in the history of space exploration) highly elliptical Earth orbiting satellites such as Explorer 10 are included. (That traditional usage maps surprisingly well to my Deep Space boundary definition of about 150,000 km).
- **Space Situational Awareness (SSA)**
  - Space Situational Awareness is the term used to describe the process of tracking, cataloging and understanding the space object population. One of the main goals of SSA in the early 21st century is to provide timely warning of conjunctions (q.v.). SSA is distinguished from Space Traffic Management in which instructions to satellite operators, rather than just warnings, are envisaged, and Space Domain Awareness, a term recently introduced by the US DoD which seems to emphasise a more militaristic view of the problem.
- **Space Station**
  - **Sense 1** (human spaceflight) A space station is a spacecraft with a pressurized interior and at least one docking or berthing port, which is intended for long term use with one or more visiting crews who arrive and depart in a separate spacecraft.

    To date, space stations have been launched without anyone aboard, but I don't think that's a requirement of the definition as long as other crews are meant to arrive later.

    The docking of Gemini ships with Agena target vehicles could be seen as the creation of a temporary space station. The Agena did not have a pressurized interior, however, and we do not usually regard the Gemini/TDA/Agena complex as a space station.

    The docking of Soyuz 4 with Soyuz 5, with the transfer of crew between the two, is also close to being a temporary station but is not regarded as such. The Apollo CSM/LM complex is equivalent.

    DOS 1 (Salyut 1) is regarded as the first space station. It was launched without a crew. Two Soyuz crew ferry spaceships docked with the station, although only one succeeded in entering it and living aboard it for a period of time.

Almaz 1 (Salyut 2) and DOS 3 (Kosmos-557) are regarded as space stations, even though they both failed before crews could be sent to them.

Skylab was the first space station which was successfully boarded by multiple visiting crews, which arrived and departed in Apollo CSM spaceships.

Space stations may be made up of multiple modules assembled in orbit (but are not required to be). The difference between a docked module and a visting cargo ship is fuzzy; Kosmos-1267 was docked to Salyut 6 and remained attached for the rest of its life. One can regard it as a large cargo ship or as part of the first two-module station. Salyut-7 also had temporary attached modules, but Mir was the first station with modules designed to be permanent parts of the station.

Some writers assert that stations have to be large, and that smaller examples such as DOS 1 and China's Tiangong 1 should be instead called 'space laboratories' or spacelabs, rather than full space stations. I reject this interpretation.

The NASA/ESA Spacelab was a space laboratory carried within the Shuttle payload bay. As it did not fly separately from the spaceship it was aboard, and could not receive multiple ferry spaceships, it does not meet the definition of a space station.

Several organizations have proposed to develop 'human-tended' space laboratories which would not normally carry a crew but which could be visited by a crew for maintenance. Typical proposals of this kind would meet the definition of space station as laid out above, including having a pressurized interior section, and I would consider them as such. In contrast, the Hubble Space Telescope, although human-tended, has no pressurized cabin.

  - **Sense 2** (telecom law) In licensing documents for communication satellite transmissions (e.g. with the ITU or the US FCC) a communications satellite is referred to as a 'space station', meaning a satellite which is the source of radio transmissions. This usage seems to be restricted to legal documents about frequency allocations and orbital slots; communications satellite engineers do not normally refer to their satellites as space stations.

- **Space Weapon**
  - A space weapon is any space object (sense 1), or device on a space object, designed or used to deliberately cause physical or electronic damage to another space object or to targets on the ground.

Note that ground-based weapons, such as powerful radio jammers or lasers, may also damage space objects. They are not ‘space weapons’ by my definition. That does not make them less bad.

Also note that self-destruct mechanisms, as used on many Soviet satellites, cause damage to the host space object and may generate space debris that accidentally damages other space objects, but are not space weapons by this definition. Further note that the definition involves intent, which is notoriously hard to determine.

A hand gun carried by an astronaut which could be used to harm another astronaut is a space weapon by this definition. However, we are usually interested in weapons that are designed to destroy free flying space objects: these are also called antisatellite weapons (ASATs). ASAT systems that have been developed include:

Type of ASAT	Description	Examples
Co-orbital with warhead	Orbital rendezvous or flyby followed by explosion	IS (USSR)
Suborbital nuclear	Flyby with explosion	Nike-Zeus 505, Thor
Suborbital kinetic	Physical intercept at high speed	F-15/MHV, Aegis SI

The other kind of space weapon is that aimed at targets on the ground. By my definition of space object (sense 1) this includes any weapon that travels through space on its way to the target, including live-warhead ballistic missiles (MRBM, IRBM, ICBM). (One might argue that tests with dummy warheads are tests of a space weapons *system* but are not in themselves space weapons.)

Less controversially, it includes weapons that are based in space. Laser battle stations proposed by the US during the Reagan Administration would fall in this category. Weapons temporarily in orbit are also included. Tests of such a weapon were carried out by the USSR from 1966 to 1971: the OGCh (Orbital Payload) of the R-36O missile, known in the West as FOBS (Fractional Orbital Bombardment System), which completed one or slightly less than one orbit and delivered its reentry vehicle and dummy warhead to a test range target. No live warheads were carried.

Under the Outer Space Treaty, no weapons are allowed on the Moon or other planets. Weapons are however allowed in orbit, except for weapons of mass destruction, including nuclear weapons - they are (since 1967) not allowed in space at all.

- **Spacecraft**
  - **Sense 1** (broad) A spacecraft is any space object which is a rocket stage or payload, including satellites (sense 3, 4 or 5) and space probes.

The term 'space vehicle' is also used,.

  - **Sense 2** (narrow). The term spacecraft is sometimes used in a restricted sense only for space objects with human crews, or associated with the human spaceflight program. In this sense it is opposed to '(other) artificial satellites'. I use the term 'spaceship' instead.

- **Spaceship**
  - **Sense 1** (general) I use the term spaceship to mean a spacecraft carrying humans, or one designed to carry humans. In particular I use the word in senses 2 to 5 below but not in senses 6 or 7. We'll cross the bridge of sense 8 when we come to it.
  - **Sense 2** Launched with humans aboard (e.g. Friendship Seven, Soyuz MS-03)
  - **Sense 3** Launched empty, but humans came aboard later (e.g LM Eagle, Destiny module, EMU suit)
  - **Sense 4** Designed to support humans, but flew with other species aboard instead (e.g. Kosmos-110, Bion, Mercury-Atlas-5)
  - **Sense 5** Designed for humans, but test flight (e.g. Gemini 1, Soyuz-2, Kosmos-929) or never got used (e.g. Salyut-2)
  - **Sense 6** Used human spaceship design with pressurized cabin for inanimate equipment (e.g. Zenit spy sats)
  - **Sense 7** Pressurized cabin with life support but not for humans (OFO, Biosatellite)
  - **Sense8** Unpressurized spaceship with sentient AI aboard (one day!)

- **Spacewalk**
  - A spacewalk, or EVA (extravehicular activity), involves a human in a spacesuit moving outside their host spaceship.

    The various space agencies track the duration of spacewalks, but use different definitions to do so. To carry out a spacewalk, a typical sequence involves depressurizing the airlock (DP) (marked at some specified pressure value); removing spacesuits from spaceship power to internal battery power (BP), airlock hatch opening (HO), egress (EG, i.e. physically emerging from the airlock), and then at the end of the spacewalk ingress (IG), hatch close (HC), suits to spaceship power (SP), and airlock repressurization start (RP) and end (RPE). The steps are not necessarily in the same order for different space programs. Example definitions are:

Agency/Program	Duration of spacewalk
NASA/Apollo	RP - DP (3.5 psi)
NASA/STS,ISS	RP - BP
Roskosmos	HC - HO
My records: RP - DP (0.7 psi).	

If you want to compare spacewalk records across programs you should use a consistent definition to do so, as the different methods can easily give durations that differ by 5 minutes or more. That's why I've gone to the trouble of estimating durations for all spacewalks by my own criterion.

During the Gemini program, some spacewalks involved DP/RP and HO/HC but no complete EG/IG (that is depressurization and hatch opening but no egress) - these were called SEVAs (Stand-Up EVAs). During the Mir and ISS programs, Roskosmos carried out 'spacewalks' with DP/RP but no single HO/HC and no EG/IG; they depressurized the transfer compartment of the station and then relocated hatches from one docking port to another without leaving the compartment. Whether these have been considered as spaceawalks varies; there are other similar examples.

For that reason I refer to and keep track of 'depress activities' (i.e. periods when the crew were in a pressurized spacesuit but not in any other pressurized environment) as a more general concept. I don't like the name but haven't been able to come up with a better one yet: the intent is to emphasize that it's the vacuum that matters (because that's what will kill you). The issue of whether you are inside or outside seems a secondary one to me. The issue of whether your suit is independently powered seems even less important; you can imagine a solar powered suit which was always on battery power, or a brief spacewalk in a suit that was entirely unpowered, or spending long periods in a self-powered suit entirely within the host spaceship. My choice of 50 mbar (0.7 psi) as the 'almost vacuum' pressure value used to mark the spacewalk start and end time is admittedly arbitrary - I feel that consistency is the most important thing rather than the exact choice.

- **Span**
  - **(GCAT):** The span of a space object is the longest distance between any two points on the object, including appendages. The idea of providing this data is that if you stay outside a sphere of diameter equal to the span you are guaranteed not to hit anything. The cross-sectional area of such a sphere is an upper limit to the cross-section of the object.

    See also length, diameter.
- **Speed**
  - see Velocity
- **Sphere of Influence**

– see Hill Sphere.

- **Stage**
  - A stage is a section of a rocket launch vehicle. As pointed out by Tsiolkovskiy, if you divide your rocket into separate 'stages' and throw away each stage when its propellant tanks are empty, you don't have to waste fuel pushing the structural mass of those now-useless tanks further into space.

    Nevertheless, there is overhead associated with each stage, and stage separation is a tricky thing that has caused many failures. Modern launch vehicles tend to have only two stages. In the past, some rockets have had five or more.

- **Specific Impulse**
  - The specific impulse (Isp) of a rocket engine is a measure of its efficiency; it is the effective exhaust velocity Ve of the rocket. Traditionally specific impulse is expressed in time units (seconds) instead of velocity units, by scaling it by 1 standard Earth gravity (9.807 metres per second squared): Isp = Ve / g. (Note that this scaling is just a units change; Earth surface g is always used, even for discussing specific impulse for rockets in Saturn orbit).

    The Isp plays a key role in the rocket equation. If a rocket vehicle has total initial mass M and burns a mass m of propellant, giving it final mass M-m, the change in velocity is
    dV = Ve ln(M/ (M-m))

    Isp is typically in the range 200 to 480 seconds for chemical rockets and several thousand seconds for electric propulsion (ion engines).

- **State**
  - **Sense 1: State vector (q.v.)** The position and velocity of a space object.
  - **Sense 2: Country.** I use the concept of the 'owner state' of a satellite in a slightly loose sense to include actual countries, autonomous regions (such as Hong Kong used to be) and certain intergovermental organizations, as described in the Space Organizations Catalog.
  - **Sense 3: Launching State.** Each satellite is, in principle, associated with a 'launching state' (a term from the UN Registration Convention). In practice this term can mean any entity which is allowed to establish a space object register with the UN, and includes a select group of intergovernmental organizations as well as actual countries.

In modern times there can be organizations from many countries involved in a space launch; the launch site, launch vehicle manufacturer, launch vehicle operator, satellite manufacturer, and satellite owner may all be from different states. There is no consistent practice defining which of these should report registration of the satellite to the UN.

In GCAT, I record the state of registration separately from the state of the owner - they are often the same, but by no means always.

Note that there is some legal disagreement about whether the state of registration of a satellite can change after launch, for example because the satellite is sold to another owner.

- **State Vector**

  - **Sense 1 (positional):** The state vector (or just state) of an object is a set of seven numbers: a time, a three-dimensional position vector, and a three-dimensional velocity vector. This is enough information to determine the past and future motion of an object if the forces acting (e.g. only gravity) are also known. For a given central body mass, if you know the state vector you can calculate the osculating Keplerian elements.

    Usually the vectors are given in Cartesian coordinates with the central body at the origin.
  - **Sense 2 (general):** A state vector is simply the coordinates of an abstract particle in any multi-dimensional parameter space at a particular time. For example, the state vector of an elementary particle might be a set of quantum numbers. The pointing and rotational state of a spacecraft (direction of X axis, rotation rates of axes) can also be called a state vector, athough I recommend specifiying that it's the 'attitude state vector' or some such term.

- **Suborbital**

  - **Sense 1 (broad):** An object is 'suborbital' if it is in an orbit whose periapsis is below the surface of, or within the atmosphere of, the orbit's central body.
  - **Sense 2 (narrow):** I will always use a narrower sense of suborbital which also requires that the apoapsis be in space (sense 3), i.e. above the Karman line for the central body. Trajectories which are entirely within the atmosphere I call 'endoatmospheric', rather than suborbital.
  - **Sense 3 (narrowest): As a formal orbit classification (SO, Suborbital) I also re** the perigee height be negative; suborbital

trajectories with perigee between 0 and +80 km are classified as TA (Trans-atmospheric, q.v.)

- **Subsatellite**

  - A subsatellite is a satellite payload that is ejected from another satellite payload (satellite, sense 5.) This is distinct from a secondary payload, one that is ejected from the launch vehicle but is smaller and lower priority than the primary payload.

- **Sun-synchronous orbit**

  - Next to geostationary orbit, sun-synchronous orbit is the most valuable and heavily used ‘special orbit’. In SSO, your satellite’s orbit passes the equator at the same local times each day. It’s a bit more complicated to explain.

    If you orbit a spherical world, your orbital plane stays fixed in inertial space (the longitude of ascending node is constant, see Keplerian Elements). Let us take as an example a satellite orbiting the Earth as it in turn orbits the Sun, but we’ll pretend the Earth is spherical instead of oblate.

    Then suppose you launch in January into a ‘noon-midnight’ orbit with almost polar inclination which passes over the centre of the Earth’s day side and the center of the night side. The Earth-Sun line passes through your orbit plane, and your orbit normal (the vector perpendicular to the orbit plane) is perpendicular to the Earth-Sun line.

    Now wait 3 months to April: the Earth has moved 90 degrees around its orbit. The orbit plane is pointing in the same direction in space, but the Sun is in a totally different direction (if it was right in front of you before, now it is at your left hand). The orbit plane is now (depending on the orbit inclination) more or less perpendicular to the Earth-sun line and your satellite is now passing over the terminator: regions of the Earth which are in dawn or dusk.

    3 months further on, and 180 deg round the Sun from the start, you’re back to noon-midnight.

    However, now lets squish the Earth at the poles to its actual oblateness. This causes orbital precession: in particular the orbit longitude of ascending node changes with time. This potentially annoying effect can be turned to good use: the rate of node change depends on height and inclination. At a given height there is a particular inclination (beween 95 and 101 degrees for heights in the LEO range) at which the node change exactly cancels out the change in the direction of the Sun as seen from the Earth in inertial coordinates So if you're in this orbit the orbit plane tracks the direction of the Sun, and a noon-midnight orbit remains a noon-midnight orbit. This means that shadows stay the same length (good for spy sats), you can watch storms forming in the Atlantic at the same time each day (good for weather sats), and that you can pick an orbit where the Sun never gets in your way when you are looking out into space (good for astronomy satellites). Super useful!

- **Time**

  – In this work I do not deal with strong gravitational fields, and relative velocities are limited to less than a millilight. I therefore ignore relativistic effects. Although I consider my fundamental timescale to be TDB (Barycentric Dynamical Time), I actually report times in UTC (Coordinated Universal TIme), despite the fact that this is a non-continuous timescale. (I often consider changing to use TT or TDB, but so far the weight of everyone else's practice has discouraged me from doing so. Be warned, I may bite that bullet one day.)

    These UTC times are presented in one of two representations:

    * Julian Date (JD), a continuous count of days starting at noon UTC on BC 4713 Jan 1 Old Style/Julian calendar, which is noon UTC on BC 4714 Nov 24 New Style/Gregorian calendar. Times within a day are expressed as decimal days. Remember that the JD always starts at noon. For example, 0600 UTC on 2020 Aug 1 is JD 2459062.7500; 1800 UTC on 2020 Aug 1 is JD JD 2459063.2500. Note that 12:00 UTC on Jan 1, 2000 is JD 2451545.0. This special epoch is the fundamental epoch of modern astronomy, known as J2000.0 for short.
    * Gregorian calendar date, in the traditional astronomical form: for example 2020 Aug 22 0413:22 UTC. Usually these dates are actually represented in what I dub 'vague date format' to incorporate an uncertainty estimate: see the (See Vague Date Format) definition.

    Some deep space missions follow the egregious practice of reporting events in so-called 'Earth received time' (ERT). They will say, for example, 'Opportunity landed on Mars at 0505 UTC', when they actually mean 'The radio signal Opportunity sent when it landed on Mars reached Earth at 0505 UTC', but the actual landing occurred at 0454 UTC - these are two different events, not two time representations of the same event. This practice is particularly heinous when they fail to specify which convention is being used. You will not find ERT in this work.

- **Thruster**
  - Term used for a small rocket engine, although 'small' is subject to taste. A space vehicle might have a main engine for large velocity changes and thrusters for small adjustments. Rockets used for reaction control systems (q.v.) are always called thrusters. In recent years, it has become more common to refer to the main apogee engine of a geostationary satellite as a thruster. While these engines are small compared to the engines on launch vehicles, this seems like a change in usage to me. See also Engine, Motor and Vernier.
- **Trans-atmospheric**
  - I use the term 'trans-atmospheric' as a classification for orbits which have apogees in space, but perigees in the atmosphere (perigee height between 0 and 80 km). Trans-atmospheric orbits are a marginal case between suborbital and LEO.
- **Translunar space**
  - **Sense 1 (broad):** Space beyond lunar orbit. See also cislunar.
  - **Sense 2 (narrow):** Space beyond lunar orbit but inside the Sun-Earth Hill sphere.
- **True anomaly**
  - see Keplerian Elements
- **Two-Line Elements (TLE)**
  - TLEs (Two Line Elements) are the traditional format for distributing satellite orbital elements. They are expected to be superseded by new formats, especially JSON based ones.
- **Velocity**
  - **1 (loose)** The speed of something in a particular frame.
  - **2 (precise)** The velocity vector of something; speed and direction. This can be represented as three cartesian coordinates (vx, vy, vz), or a magnitude and two angles (e.g. v, azimuth, elevation or v, ascent angle, out-of-plane angle).

    Special uses:

    * Keplerian Velocity: At a given radius from the center of a given central body, the speed of an object in circular orbit.

* Escape Velocity: At a given radius from the center of a given central body, the speed of an object in a parabolic orbit with periapsis at that point, i.e. an orbit in which the object has just enough energy to reach infinity (ignoring other massive bodies) with zero remaining energy.
* (Earth-)Relative Velocity or Earth-fixed Velocity: Speed relative to a fixed point on the Earth's surface radially below the object. Sometimes people just talk about 'relative velocity' when they mean Earth-fixed; this is sloppy and may cause confusion - all velocities are relative (to something). This term is as opposed to 'inertial velocity'. The corresponding Earth-fixed reference frame is sometimes called ECEF (Earth-centered Earth-Fixed) or EFG (Earth-Fixed Greenwich) and its zero longitude is (close to) the Greenwich meridian.
* Inertial velocity: speed relative to a local nearly-inertial (non accelerating) frame. Often used to mean a frame which is (nearly) the same as the Geocentric Celestial Reference System (GCRS) or the International Celestial Reference System (ICRS), to within a translation and rotation. The ICRS is centered at the solar system barycenter and has axes close the the J2000 equator and pole, and its zero longitude is the zero of Right Ascension. (The BCRS, Barycentric Celestial Reference System, is even better and is very nearly the same as ICRS). The GCRS is the Earth-centered equivalent.

  For space launches, 'inertial velocity' usually means 'velocity relative to the GCRS'; the ECEF rotates relative to the GCRS once a sidereal day.

  The Earth orbits the Sun at 30 km/s (i.e. roughly speaking its ICRS velocity is 30 km/s and the Sun's is 0.015 km/s). An object at rest relative to the Sun will then have an Earth-relative velocity that varies from -30 km/s to +30 km/s just becuse of the Earth's motion during one year. Because of this, 'what is the fastest space probe?' is a very problematic question, as the questioner often is thinking they mean '.. in the GCRS frame', and the answer is just not very useful because of the huge component just due to where the Earth is in its orbit at a given moment.

- **Vernier**

  – A Vernier engine is a small rocket engine used for steering, roll control and fine velocity adjustments for a stage which has a large, higher thrust, fixed main engine. It is named after the Vernier caliper used to provide a secondary scale to make small corrections to measurements, invented by Pierre Vernier in the 1630s. Pierre did not, however, mess around with rocket engines.

Some rockets (the Atlas sustainer, and the Chang Zheng 2 second stage) have main engine cutoff (MECO) followed by a sustained period of vernier engine firings followed by the final vernier engine cutoff (VECO) prior to stage separation.

- **Wet mass**
  - The mass of the satellite at launch including all propellants and consumables. See Dry Mass.
- **World**
  - I use the word 'world' to mean an object massive enough that self-gravity makes it round, but not massive enough to shine by nuclear fusion (i.e. not a star). The concept includes objects orbiting the Sun (planets and dwarf planets) or orbiting other worlds (large moons). Among other things, this avoids the whole war about what counts as a 'planet', but also emphasizes the importance of objects like Titan and Ganymede. The traditional emphasis on where things orbit (distinguishing planets from moons) instead of what kind of physical object they are tends to unfairly relegate such objects to relative obscurity.

    Although a rigorous geophysical definition of a world would have a size boundary depending on its composition, in practice I treat all nonstellar objects with radius greater than 200 km as worlds.