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LTA Aircraft Definitions

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Abstract

This document provides definitions with explanation of words or terms used for lighter-than-air (LTA) aircraft (i.e. balloons, aerostats, airships and so forth) primarily written for non-rigid types. It's felt that this is necessary to help people understand matters and to redress false or inadequate definitions provided on websites such as Wikipedia. Corrections and additions (if needed) may be made in future revisions following reasoned advice to the author, as above.

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Useful Abbreviations

6DOF	Six Degrees of Freedom	LTA	Lighter-than-air
AOC	Air Operator's Certificate	MOA	Maintenance Organisation Approval
ARDD	Automatic Rapid Deflation Device	MRO	Maintenance Repair and Overhaul
CB	Centre of Buoyancy	PDR	Preliminary Design Review
CDR	Critical Design Review	POA	Production Organisation Approval
cg	Centre of gravity	POC	Proof of Concept
CofA	Certificate of Airworthiness	R/C	Radio or Remote Control
CS	Certification Specification	R&D	Research and Development
DOA	Design Organisation Approval	STC	Supplemental Type Certificate
EQ	Equilibrium (of lift against weight)	TAR	Transport Airship Requirements
HAV	Hybrid Air Vehicle	TC	Type Certificate
HAP	High Altitude Platform	VTOL	Vertical takeoff and landing
HTA	Heavier-than-air	VLC	Vertical Launch and Capture
ISA	International Standard Atmosphere		

Definitions

Note: specific with regard to use for LTA aircraft.

6DOF: This refers to the motion of any body in three dimensional (3D) space that can move and/or be controlled in any of the six directions or ways (x, y, z, p, q, r) possible – i.e. linearly longitudinally along the 'x' axis, laterally along the 'y' axis and vertically along the 'z' axis, and in rotational pitch 'p' about the 'y' axis, yaw 'q' about the 'z' axis and roll 'r' about the 'x' axis.

Absolute pressure: The pressure of a gas or fluid – e.g. atmospheric pressure (p_o) is absolute.

Aerial crane: An aircraft designed as a flying crane to enable pick-up, transfer (normally over short distances) and accurate placing, usually in hovering or pseudo-hovering geostationary position holding flight of heavy under-slung loads. LTA aircraft can be designed for this purpose with greater range, endurance and load carrying capability (size and weight) than helicopters.

Aerodynamic drag: Resistance felt by a body in an air stream or from its movement through the air.

Aerodynamic head: Positive aerodynamic pressure during flight on an aircraft's leading surfaces, such as its nose and due to airspeed.

Aerodynamic lift: The force on an aerodynamically shaped body acting upwards due to airspeed, perpendicular to the direction of flight or of the undisturbed air stream. The word 'upwards' is used in the same sense that a person's head is above their feet.

Aerodyne: Any aerodynamically shaped body (not necessarily a vehicle) that is able to develop significant reliable aerodynamic lift due to airspeed for flight while minimising aerodynamic drag. Aeroplanes are aerodynes. **Note:** most aerostats also are aerodynes that can develop aerodynamic lift, although not usually as efficiently as wings. Lifting bodies also are aerodynes; where the aerostats of some HAV types (configured as lifting bodies) augment aerostatic lift with appreciable aerodynamic lift to sustain flight when significantly aerostatically heavy.

Aerostat: The body or vessel of an aircraft that is LTA and causes significant displacement of the atmosphere under static conditions in order to develop sufficient buoyancy from it for useful support of overall aircraft weight normally based on:

1) an envelope (usually flexible membrane) shell, bag or jacket containing an LTA substance (gas or hot air), which also may have systems for pressure stabilisation to maintain form, or
2) the combination of a set of flexible LTA-gas cells contained in a lightweight rigid structure with outer covers enclosing them.

Note: it is possible to develop HAV aerostats with ratios of aerodynamic to aerostatic lift that vary between 0 and 100% - i.e. from a fairly pure HTA aerodyne (an aeroplane) to a simple LTA balloon (pure aerostat).

Aerostatic equilibrium (EQ): Aerostatic EQ occurs when an LTA aircraft's gross weight* is exactly balanced by buoyancy experienced.

Aerostatic heaviness: The amount by which an LTA aircraft's gross weight* exceeds buoyancy.

Aerostatic lightness: The amount by which buoyancy exceeds an LTA aircraft's gross weight*.

Aerostatic lift: Buoyancy experienced from the atmosphere (an externally applied upward force opposite in direction to weight) on a body tending to cause flotation or the body to rise. **Note:** all bodies in the atmosphere experience this force.

Aircraft: Any flying vehicle supported by atmospheric air, such as an: aeroplane, airship, balloon, helicopter, glider, autogyro, drone, etc.

Airship: A dirigible powered LTA aircraft with propulsion units and an aerostat for flotation in the atmosphere that flies in a near aerostatic EQ state, able to achieve aerostatic EQ during normal flight operations.

Airspeed: The velocity of an aircraft relative to the air it is in.

All up weight: An HTA aircraft term for the gross weight of the vehicle (including disposable loads and payload). For LTA aircraft it also should include the aerostat's inflation gas.

ARDD: Automatic Rapid Deflation Device. It is a means to rapidly release the LTA gas from an aerostat under emergency conditions that may be operated remotely and/or automatically, depending on particular conditions (such as taking off without control), either to keep the aerostat on the ground or to bring it down. It is needed to prevent unintended launch or runaway when other means of control are unavailable.

For most LTA aircraft, particularly whilst moored, a rip system is the most secure way to ensure that, if an uncontrolled breakaway occurs, the gas is released, or to be used by the pilot and/or ground personnel when necessary.

ARDDs suit unmanned LTA aircraft and may use a burn-wire system to make holes in the upper envelope that either operates automatically (due to a particular situation) and/or by a remote operator at the press of a button when safe to do so.

Ballast: Any material (usually sand or water) used to:

- add weight for balance (such as lead at the nose of an airship, moving the cg forward to below the CB when tail heavy)
- counter aerostatic lightness
- release (cast overboard) if there is excess aerostatic heaviness or to reduce it and perhaps deliberately cause aerostatic lightness
- use during load exchange to maintain EQ, or to
- set a particular weigh-off state (aerostatic heaviness or lightness) desired for subsequent flight.

Ballast thus may be of a fixed nature (to offset a permanent condition) or disposable to suit variable weight needs. Disposable ballast is used during load exchange (when airship gross weight may change substantially). It also is used for trim purposes if gross airship weight increases (e.g. due to rain) or buoyancy reduces (e.g. when super-heat reduces). **Note:** disposable ballast must be of a form and/or releasable in a way that does not harm.

Ballonet: A chamber within a non-rigid or semi-rigid airship's aerostat for air bounded by a flexible membrane preventing mixture with the LTA gas in the aerostat that freely inflates or collapses when respectively filled or vented as part of a pressure management system to compensate for changes in gas volume as atmospheric pressure and temperature change and to maintain aerostat super-pressure through controlled over inflation. **Note:** its function as part of the pressure management system ceases when empty of air (totally collapsed – usually at the pressure height) or fully inflated with air (usually when descending after significant LTA gas loss).

Balloon: A simple bulbous aerostat as just an inflated envelope.

Barrage balloon: A simple wartime defensive tethered aerostat method with a strong line (difficult to see) let up as an obstacle in the way of aircraft that may fly into them, protecting ground arrangements and people below from attack. They also could carry nets hanging between them.

Battens: Long shaped ribs used to support other parts (e.g. a nose cone), stiffen and spread load into a non-rigid aerostat's envelope.

Bed down: The action to restrain an aerostat at ground level with a net or cover and/or lines to anchor positions or screw-pickets around it. This may involve temporary mooring-out methods after removing protruding lower parts and then hauling it down – sometimes until squeezed against the ground (not necessarily).

Blimp: A colloquial term for a non-rigid airship often also used to describe a tethered aerostat.

Body of revolution: The 3 dimensional outer hull profile of a vessel (such as an aerostat) with varying circular section about a straight axis.

Buoyancy: In air, the aerostatic lift force of the atmosphere on the body causing its displacement. **Note:** all bodies in the atmosphere experience it.

Under ISA sea level conditions air has a density of 1.225 kg/m^3. Hence, with standard gravity, g_n = 9.80665 m/s^2, a displaced 1^3 m volume applies 12.013 N buoyancy on the body causing the displacement (regardless of what it contains).

Buoyant aircraft: LTA aircraft that have an aerostat for atmospheric displacement purposes to enable effective buoyancy to be experienced, which includes types that may not be able to achieve EQ without other lift augmentation methods (i.e. aerodynamic and/or vertical thrust) such as some HAVs.

Buoyancy control: Perhaps a misnomer, as buoyancy from the atmosphere is practically impossible to control directly due to remoteness and the way it freely changes. However, buoyancy and weight are forces opposite in direction that both result from the effects of gravity (so are interrelated), where weight change may be used to counter (so control) buoyancy. Also, because buoyancy results from displacement of the atmosphere, it may instead be controlled through the displacing body's volume change. Practically, it thus involves indirect methods that are manageable.

Gross weight may be reduced by releasing ballast. It may be increased by collecting rainwater or (if used) by combustion engine exhaust water recovery, and by in-flight transfer (e.g. a bucket and line to collect water over-flown). The displaced volume (so buoyancy) may be reduced by venting LTA gas or by cooling it, although the latter isn't practical yet. It may be increased by heating the LTA gas (provided it can freely expand) or by introducing more from pressurised or liquefied storage (also provided it can then freely expand), where the latter is only practical from ground facilities. Purported methods involving in-flight compression to reduce the displaced volume or increase weight when desired are fallacious[1] due to resulting excess parasitic system weight.

Camp out: To remain in attendance with an LTA aircraft or aerostat at a temporary site away from its main base for ground handling purposes.

Capture: Activity of transition from free flight to restrained from the ground.

Catenary curtain: An arched load curtain to evenly spread load from suspension system lines on a non-rigid aerostat's envelope.

Conventional airship: A unidirectional airship built in the style of most previous types, which were classic rigid, non-rigid or semi-rigid types. **Note:** this could change in the future if other types overtake the number of classic style airships produced.

Classic airship: An airship in the traditional style adopted before 1900 with an elongated ellipsoid or cigar shaped aerostat or hull form that is unidirectional.

Control reversal: This is when the intended effect of a tail surface elevator control movement causes the aircraft to do the opposite thing (e.g. descend when climb is desired). It may occur due to a combination of strong pendulum stability from low cg position and poor airspeed. When understood this can be of benefit to assist takeoff if aerostatically heavy, but otherwise could cause a crash.

Cycloidal propeller: A propeller (like paddle wheels) with straight blades parallel, but equally offset and positioned, around a drive-shaft (connected to it by radial arms) and with a swash plate plus rod and hinged link mechanisms similar to helicopters for blade pitch control as they rotate around the drive-shaft axis. The arrangement is similar to Voith Schneider propellers used by some ships (e.g. tug boats) but for aircraft. The benefit of such propellers is that they may enable almost instant vectored thrust at full power in any radial direction through 360°. However, they don't exist yet as a certified propeller for aircraft in regular production.

Dead weight: The weight of an item to be lifted – usually its effective weight.

Disposable load: Crew, payload, fuel, oil, disposable ballast and other such things onboard that need replenishment; sometimes referred to as tare or useful weight.

Differential pressure: The difference of absolute pressure on each side of a surface, e.g. ($p_i - p_o$) where p_i is pressure inside an aerostat and p_o is the atmospheric pressure.

Dirigible: Vehicle ability to be controlled (steered) on a particular course (heading). Airships often are referred to as dirigibles due to the way this ability was established, although it is a term that may be used to describe the controlled motion of any vehicle.

Displacement: For an LTA aircraft, the weight (or amount) of atmospheric air displaced by its immersed body (primarily its aerostat – the displacement vessel). This may be determined knowing the air's density and the volume of it displaced.

Displaced volume: This is tricky to define because aerostats usually have air within them; for non-rigid and semi-rigid types, used to fully inflate and pressure stabilise their envelope after a partial LTA gas-fill (necessary to allow for expansion), and for rigid types, filling the space between their outer covers and the gas cells that is difficult to quantify. However, during ascent the LTA gas expands while the air vents until at the pressure altitude the LTA gas either exactly fills the aerostat's envelope with ballonets empty or, in rigid types, the gas cells exactly fit their bounding compartments (both of known volume from their geometry).

Ignoring the volume of the aerostat's parts and other aircraft features' (considered negligible by comparison) these geometric volumes are equal to the displaced volume at that altitude. Using the gas laws and atmospheric data charting temperature, pressure and air density, the displaced volume then may be calculated for other altitudes – so the resulting buoyancy and gas-fill to use.

Even so, rigid airships in the past often were just filled full of gas (hydrogen) under warm hangar conditions (causing super-heat when undocking) and loaded up with sufficient disposable ballast to release under way as gas vented when expanding, buoyancy reduced due to loss of super-heat and fuel was consumed, not worrying too much about it.

Docking: Movement of an airship into a large shed or aircraft hangar.

Ducted propeller (or fan): A conventional screw propeller concentrically and closely located within a short annular shroud aerodynamically designed to enhance propeller disc airflow, significantly improving efficiency compared with a similar propeller on its own. A ducted fan is similar but uses a larger number of rotor blades.

Dynastat: Perhaps an unnecessary term due to others (such as *HAV*, *hybrid airship* or *buoyant aircraft* that have been taken up) said to be a body something between an aerodyne and an aerostat. Mowforth[2] was clear with his definition, supported by illustrations of example types, saying that, for hybrid airships, "When aerodynamic lift is used the vehicle combines the characteristics of an aerodyne and an aerostat and may then be termed a dynastat." Also saying, "This type of hybrid must generally take off and land with a ground run, as does a conventional aeroplane."

Wikipedia[3] (under the title 'Hybrid airship') states, "a *dynastat* is a dynamic lift airship typically intended for long-range cruising." Maybe! However, all aerodynes displace the atmosphere (causing some aerostatic lift) and aerostats develop aerodynamic lift/drag from airspeed. The issue then is what exactly is the term needed for, apart from a product name, and where otherwise all aerodynes and aerostats (the common terms used) would be *dynastats*?!

Since the intention probably was to provide a term for new unidirectional airship types arranged (i.e. formed or configured) in such a way as to enable greater aerodynamic lift than possible for conventional airships, the following is offered:

A buoyant aircraft body arranged to develop greater aerodynamic lift than possible for classic style airships that needs airspeed for takeoff, climb, level flight and safe landing with a short ground run when aerostatic heaviness is significant. This recognises that, as fuel is consumed, aerostatic heaviness reduces without means to regain weight lost, but that may still be significant when returning to the ground – particularly after an aborted take off. Such types have yet to be certified and enter commercial service, and may need special arrangements to manage unstable behaviour on the ground in difficult weather.

Effective buoyancy: The buoyancy experienced by an aerostat less the weight of LTA gas inflating it.

Effective weight: The dead weight of an item as measured in the atmosphere or other surrounding fluid/gaseous substance, which buoys the item.

Elevator: An aerodynamic control surface hinged about a mainly horizontal axis usually at the rear of an aircraft to develop a downward or upward force in flight from airspeed that lowers or raises the aircraft's tail, causing angular pitch to respectively ascend or descend from resulting wing and body aerodynamic lift (+ve or –ve). Whether it does or not is another matter, where tail surface elevators can cause the opposite effect – see *Control reversal*.

Empennage: A collective term for the tail surfaces of an aircraft.

Envelope: For non-rigid and semi-rigid aerostats, the outer container, bag or jacket (usually a flexible membrane) to hold internal LTA substances (gases and/or air).

Eta patch: A fabric assembly with a single D-ring line attachment point reinforced with splayed load spreading finger tapes or cords, entirely affixed to a non-rigid membrane to carry tensile line loads applied.

Exhaust water recovery: The process to condense and extract water using a suitable system from the exhaust products of an internal combustion engine. This is possible because of the burning process which reforms the mixture of the fuel's hydrocarbons and oxygen from the air (drawn from the atmosphere outside) to make water (H_2O) plus carbon dioxide (CO_2). Due to the chemical relationships of the process, it is possible to collect a greater weight of water (due to added oxygen from the atmosphere) than the weight of fuel used, enabling an airship's overall weight to be maintained (even increased, depending on efficiency) while fuel is consumed.

Fender: A protective unit with shock absorbing capability to prevent vulnerable structure being damaged at possible contact or impact positions.

Flight: For an LTA aircraft this is its free motion in and through the atmosphere (the air). This may be with airspeed (due to propulsion), when induced aerodynamic forces arise and heading is controlled, or without airspeed, when it drifts as a floating vessel with ground speed and direction as for the air (wind).

Gas balloon: A balloon filled with an LTA gas (often hydrogen) instead of hot air, for efficiency to minimise size/weight and maximise flight endurance, which supports a suspended basket for payloads and/or people. It is sustained in flight due to just the buoyancy it experiences – otherwise free to drift with the air.

Gas cell: A lightweight flexible bag or vessel (like a balloon or bladder) to contain a partial LTA gas-fill, which normally swells without stretching significantly or collapses to suit gas volume expansion or contraction, used in rigid airships and simply retained inside a bounding compartment.

Gas-fill: Quantity (mass) of LTA gas put into an aerostat's envelope or its gas cells. **Note:** except for leakage or deliberate venting and from topping up, this remains reasonably constant during flight – so, although volume may vary considerably, the amount does not.

Geostationary: For aircraft, ability to hold a particular station and height in 3 dimensional space relative to a point on the earth's surface.

Gondola: The nacelle or car of an LTA aircraft normally arranged with a cabin and flight deck for passengers and crew.

Gross weight (mass): The all up weight, including the weight of contained LTA gas. The gas mass is needed for LTA aircraft dynamic analysis, which also needs virtual inertia.

Ground handling: Primarily, the operations and activities to manage LTA aircraft at ground level, including: launch, capture, cross-field movement, mooring, unmooring, docking, undocking, haul down, bed down, ballasting and ballast management, load exchange, loading and unloading, weigh-off, and so forth. Also, operating site setup, ground systems and equipment management, plus operating site assistance concerning non-rigid aerostat test and inflation, LTA aircraft assembly and rigging, aerostat pressure watch, weather monitoring, site security, LTA gas plant management, LTA aircraft breakdown, packing for shipping and similar tasks typical at airports for HTA aircraft. Road train duties to follow an LTA aircraft on tour to support them at temporary sites also involves ground handling to load/unload vehicles and drive them.

Grounding: Descent of an airship to the ground with intent to remain there, usually followed by capture (so grounded). **Note:** airships remain primarily airborne at ground level, so do not actually land unless the buoyancy keeping them afloat (so airborne) somehow is lost. Thermal types normally are landed when their hot air is vented, but this doesn't usually occur with gas filled types.

Haul down: The action to pull an elevated aerostat restrained by ground lines against buoyancy down to the ground using manpower, tirfors, capstans or winches on the lines for the purpose. **Note:** if buoyancy first is countered by sufficient ballast attached to the aerostat, then haul down is eased and may be undertaken with just manpower – only sensible if the elevated aerostat is within reach.

Heavy operation: The method used to deliberately fly a dirigible LTA aircraft with significant aerostatic heaviness, which needs augmentation of buoyancy experienced with aerodynamic lift (needing enough airspeed) and/or vertical thrust upwards.

Helistat: This is an airship with an aerostat to develop buoyancy that supports gross weight, carrying a lower nacelle with arms or pylons extending symmetrically each side to support helicopter type rotor systems at their ends for vertical lift (essentially operating clear of the aerostat). The arrangements also may have separate propellers for thrust and control in other directions and, if designed as a unidirectional type, an empennage for stability and control of flight.

The arrangement enables aerodynamic lift of its helicopter type rotors to be used with full effect to carry a payload perhaps without need for load exchange (i.e. without needing compensating ballast). See also *Hybrid airship* and *Rotastat*.

Helium: An inert (so non-inflammable) gas used to partially inflate LTA aircraft aerostats at ground level (allowing space for expansion) as a bulk component to fill out, support and stabilise its flexible container (i.e. the aerostat's envelope), which in turn displaces the atmosphere. Under ISA sea level conditions pure helium has a density of 0.169 kg/m^3. Hence, with standard gravity, g_n = 9.80665 m/s^2, a 1^3 m volume of pure helium under the same conditions weighs 1.657 N, acting against buoyancy experienced.

Hot-air-balloon: A bulbous naturally shaped non-rigid aerostat with an open lower aperture, inflated with air that subsequently is heated by a burner supported on frame legs over a basket for payloads and/or people – suspended from the aerostat below its aperture. The hot-air-balloon is sustained in flight due to just buoyancy experienced when the weight of contained air reduces sufficiently from heating (causing expansion and thus cold air with greater density to be expelled) otherwise free to drift with the air.

Hull: The exposed outer shell or membrane of a vessel such as an aerostat. For example, one may refer to the outer profile of a rigid airship as its hull.

HTA aircraft: Aircraft unable to achieve aerostatic EQ, needing lift by other means (e.g. aerodynamic lift and/or vertical thrust) to take off and fly without descending.

Hybrid airship: An awkward term that perhaps confuses matters. Wikipedia[3] states, "This is an aircraft that combines characteristics of LTA technology with HTA technology, either fixed-wing or rotary-wing." Mowforth[2] says that it is, "An airship in which a substantial proportion of the gross weight is sustained in flight by aerodynamic or rotor lift, the remainder being carried by aerostatic buoyancy."

The main problem with both definitions is that they are too broad (incorporating rotor technology that needs separate treatment) and where today the emphasis is on unidirectional types (which classic airships are) based on HAV methods. An alternative definition is:

A buoyant aircraft using lifting body principles and/or winged to develop significant aerodynamic lift (say 40%) that supplements buoyancy to carry overall aircraft weight, maybe able to float (reach equilibrium) when fuel and/or payload is low.

It's mooted that they have the advantage of being able to operate without ballast.

However, the terms 'Buoyant aircraft' and Hybrid air vehicle' tend to make this term superfluous. Also, what is hybrid about the airship type, where uninformed people may think it is something to do with being diesel/electric powered?

For types adopting rotor technology and methods, see *Helistat* and *Rotastat*.

Hybrid air vehicle (HAV): An aircraft that uses a combination of aerodynamic and aerostatic lift plus vertical thrust to remain airborne. It is a newly coined term currently associated with dirigible unidirectional LTA aircraft types (classic airships) with a broadened aerostat and/or wings to develop significantly greater aerodynamic lift than conventional airships today and where they are considered to be a hybrid of HTA and LTA technology.

Hydrogen: An inflammable gas used to partially inflate some LTA aircraft aerostats at ground level in a similar way to helium, but needing ways to prevent ignition. Under ISA sea level conditions pure hydrogen has a density of 0.0853 kg/m^3. Hence, with standard gravity, g_n = 9.80665 m/s^2, a 1^3 m volume of pure hydrogen under the same conditions weighs 0.8365 N, acting against buoyancy experienced.

Landing: An HTA term that, for LTA aircraft (usually remaining airborne after capture), is the loss of buoyancy from collapse of their aerostat due to venting the LTA inflation substance (gas or hot-air) so that the aircraft's full weight transfers to support from the ground (landed). Because HTA aircraft land in a quite different way to LTA aircraft, this term should be avoided to obviate confusion; where the terms 'capture' and 'grounding' should be used instead for the similar action of an LTA aircraft's descent to the ground.

Launch: For free balloon systems and airships, activity for release and takeoff into free flight. For tethered aerostats, the action to pay out restraint lines for aerostat ascension.

Lenticular: Of a similar outer profile to a lens or lentil seed – the shape of a discus.

Lifting body: An aerodyne (normally without wings), which an aerostat also is, shaped to develop significant aerodynamic lift due to airspeed for flight while minimising aerodynamic drag.

Lifting gas: A misleading false term widely used by many people to describe the LTA gas put into aerostats, which has weight rather than lifting ability. Buoyancy experienced by a body in water is derived by the same principle (espoused by Archimedes over 2000 years ago), but without such incorrect referral to the air that usually fills their displacement vessel as a 'lifting substance'; where it's recognised that it's buoyed externally by the water it's in. Buoyancy on an aerostat in the atmosphere is derived in the same way as an external force from the air that pushes it up, rather than magically being lifted by the LTA gas inside. The term therefore should not be used any more.

Note: See the definition for 'LTA gas', offered as the correct term to use.

Lighter-than-air (LTA): Literally that; where the item concerned simply weighs less than air.

Load exchange: The process to exchange one load for another in order to maintain balance and/or EQ within manageable limits. It applies to any change in the combination of payload, ballast, fuel or other disposable load. It also applies to moored LTA aircraft that remain afloat during maintenance to, for example, replace a heavy part such as an engine with ballast – removed when the part is reinstalled.

Load panel: A panel that acts like a catenary curtain affixed normally at its upper edge to spread single point tensile line loads applied on a fabric or membrane structure.

Load patch: An Eta patch for use to spread tensile line loads applied on a fabric or membrane structure.

Loitering: Prolonged flight at low to zero airspeed, as may be needed for patrol, observation, survey, photographic and so forth duties; or simply to wait until the ground crew are ready for capture & mooring, the weather is manageable to continue, and/or the circumstances are right (say for an event, such as showing up at the right time and then remaining generally overhead for a while).

Note: LTA aircraft with facilities for the purpose also may deploy a sea anchor or grapnel to hold against the wind without power, waiting out on duty for longer periods (loitering in the patrol area with intent – ready for action).

LTA aircraft: Aircraft able to float in aerostatic EQ without lift augmentation by other means (e.g. aerodynamic lift and/or vertical thrust).

LTA gas: This is the correct term to use for the gaseous substance put into an aerostat's envelope or gas cells as a component with bulk to support their thin flexible membranes, so that they don't loose form against atmospheric pressure; enabling the air's displacement without mixing and thus buoyancy on the aerostat. The reason it's used is to minimise weight of the displacement vessel (the aerostat), of which it is an integral part that otherwise would be useless for the purpose.

Metalclad: A type of rigid aerostat construction based on a thin metal (aluminium) shell (monocoque) with minimal supporting structure, just enough to sustain its own weight, requiring moderate pressure stabilisation to function reliably under load during flight and against atmospheric pressure. Rarely used, such vessels also are classified with other pressure airships that need super-pressure to stabilise their form (preventing collapse).

Module: Any unit or nacelle to contain people, systems, freight and so forth individually or together, that is readily mountable & removable or can be simply picked up & set down to enable: maintenance in a workshop, quick replacement with fresh pre-prepared arrangements, rapid role change (say from passenger transport to aerial surveillance) and load exchange – helping to minimise turn-round time.

Monocoque: Literally 'single-shell': a monocoque hull comprises a continuous hard shell, which for an LTA aircraft's aerostat may be an assembly of moulded sandwich panels able to carry in-plane shear and compression, so differing from the thin single ply shell of former metalclad types. Aerostats based on monocoque construction with sandwich panels are 'rigid' and shouldn't need internal super-pressure to stabilise the shell due to greater bending stiffness of the panels. Airships with such monocoque aerostats have frequently been proposed, but none have so far been built. They are suitable for very large airships that naturally have higher airspeed, enabling form to be maintained.

Moor or Mooring: For LTA aircraft, the action for connection to a restraint system. Classic airships typically moor to a mast. Mooring also may be by a ground anchor system that fixes the LTA aircraft's aerostat.

Mooring Mast: A vertical stanchion or tower, which may be braced, with a coupling facility at its head for unidirectional LTA aircraft (typically conventional airships) to connect to; where connection normally is at the LTA aircraft's nose, but sometimes through an alternative point (e.g. a chin position). An important aspect of the mast and coupling arrangements (mast and LTA aircraft) is that it must freely permit the LTA aircraft's weather vane, pitch and roll movements under any weather conditions – allowing it to align with the wind.

Masts may be a fixed installation (permanent), temporary installation (i.e. stick or expeditionary types) or mobile (allowing relocation by road and/or airfield movement with an LTA aircraft attached). They also may be tall (a high mast) with the LTA aircraft held aloft, or short (a stub mast) with the LTA held next to the ground (facilitating access, load exchange and servicing).

Multi-hull airship: An airship with two or more aerostats of conventional form joined together as a single unit, usually a horizontal group analogous with a marine "catamaran" or "trimaran".

Multi-lobe hull: An aerostat of "lobed" (e.g. cloverleaf) cross-section. Usually found in non-rigid airships and formed by internal lacing of the aerostat's envelope, mooted to improve bending stiffness and be easier for attachment of suspended structures. New HAV types have adopted such multi-lobe aerostat methods.

Non-rigid airship: An airship that uses an aerostat with a flexible membrane envelope (usually pressure stabilised) without any framework as the main carriage system for the airship's principal parts, aircraft systems, equipment and the payload.

Parachute balloon: A barrage balloon with a basket for people that, when elevated, may be used as a lookout point for distant observation and from which occupants may alight with a parachute – also used for parachute training purposes.

Parasitic weight: Useless or excess parts and systems weight (without needed purpose) unnecessary for an aircraft to bear, reducing payload and/or other disposable load (e.g. fuel) that may otherwise be carried.

Payload: The items (people, cargo, systems and equipment) normally carried for revenue earning or particular customer purposes.

Pendulum stability: The effect from low mass (acting at the cg) where gravity causes a centring moment towards a resting position directly below the centre of buoyancy (CB). If disturbed from the rest position the LTA aircraft rocks (pitches and/or rolls) as a pendulum until the motion stops from air resistance or control, when it regains a steady upright attitude.

Platform: A term often used for an aircraft holding a geostationary position at altitude as a stable means to support installed user systems or a payload aloft.

Pressure airship: An airship with an aerostat structure of non-rigid, semi-rigid or monocoque form, which uses super-pressure to stabilise that form against atmospheric pressure and the effects of flight.

Pressure altitude or Pressure height: The altitude (1) when a non-rigid's LTA gas expands to completely fill its containment vessel (the aerostat's envelope) without increasing super-pressure and when the ballonets just become empty of air. In a rigid type it is when the gas cells swell (due to gas expansion) to just fill their bounding compartments.

If the LTA aircraft ascends further super-pressure then increases (begins to develop in rigid types) until gas vent valves open (2), when LTA gas is lost. Depending on rate of ascent (if it continues) and gas loss rate, super-pressure may continue to rise with danger that the envelope may burst or rigid structure may fail due to excess super-pressure with catastrophic effect. Aerostat weight thus reduces due to gas loss, exacerbating the situation. However, atmospheric displacement reduces at a faster rate due to ascent into thinner air (reducing buoyancy), which helps to slow, stop ascent and (3) cause descent.

Assuming that the envelope doesn't burst (unlikely due to factors of safety used in design) when the LTA aircraft descends to a level where the valves close (no more gas loss) and super-pressure returns to its previous value with the envelope or bounding compartments just full of gas again, the pressure height (4) will be at a higher altitude than before (from reduced gas-fill). When the LTA aircraft further descends towards the ground, gas volume will reduce – needing air to be blown into the ballonets (for non-rigids) to maintain super-pressure (required to stabilise the envelope). When it reaches the previous pressure height (1), assuming temperature/pressure conditions are the same, buoyancy experienced will be less – causing aerostatic heaviness and needing ballast release to regain the previous EQ state.

Then, depending on descent rate (if too fast) gas volume may reduce at a greater rate than the blowers can manage to fill the ballonets of non-rigids with compensating air, causing reduced super-pressure, reducing aerostat stiffness with potential loss of form (not good but not necessarily catastrophic).

Assuming this doesn't happen and depending on the gas loss at altitude, when nearing the ground the ballonet of non-rigids may become full (so ineffective) again resulting in loss of super-pressure, when another way to force air into the envelope is needed to maintain it (degrading LTA gas purity from mixing).

The loss of LTA gas due to ascent above the pressure height is wasteful and causes increased aerostatic heaviness; it is therefore customary to operate below this height wherever possible. The pressure height may be increased only by reducing the gas-fill and hence the available buoyancy. LTA aircraft thus should in general operate at low altitudes to maximise payload weight carried.

Pressure management: A system of ducts, fans (blowers), valves and ballonets for non-rigid aerostat super-pressure control.

Pressure stabilised: This refers to the way super-pressure contained by a non-rigid or semi-rigid aerostat's envelope of flexible membrane or thin monocoque shell form is used to stiffen it; where positive differential pressure induces bi-axial tension in the membrane or shell, enabling it to function as a rigid structure under compressive load effects without buckling.

Pressure watch: Ground activity to monitor & control a non-rigid or semi-rigid aerostat's super-pressure and other things affecting their condition, plus monitoring the weather when they are parked (moored).

Prismatic Coefficient: The ratio of an aerostat's volume and the volume of a cylinder with the same diameter and principal dimension (length or height).

Release:

1) The act of launch when an LTA aircraft is fully 'let go' from ground restraint to thus take up free flight. Cast off.
2) Let go from mooring restraints – a mast or ground pickets.
3) Drop ballast or cast it overboard.

Rigging: The various lines (cables, wires, cords, ropes) and their associated fittings (buckles, links, turnbuckles, shackles, etc) used in a suspension system and for: bracing, handling, mooring, climbing, safety and so forth.

Rigid airship: An airship that either has an aerostat structure of light wire-braced frames, girders and connecting members with separate internal compartments, each bounding a flexible gas cell, with light outer covering for smooth aerodynamic form (typical of former Zeppelins) or uses a stiff outer monocoque shell, which also may be compartmentalised, to contain LTA gas; both using the stiff structures to support their principal parts, aircraft systems, equipment and the payload. Such airships enable very large types to be constructed and flown.

Note: when the aerostats of very large airships are produced a way to undertake gas-fill practically and safely is needed; where the amount of LTA gas is vast (making supply difficult, needing to be undertaken in stages) and where the buoyancy experienced as a result is huge (needing a way to be restrained). Rigid airship construction helps to overcome these issues.

Rip system: This is a simple method using a strong line attached to rip panels on the upper surface of an aerostat's envelope that, when used, causes a large hole to be made by tearing or cutting action, releasing the LTA gas – necessary to rapidly destroy buoyancy. When the line is connected at its lower end to a fixed ground point it causes deflation if the aerostat were to break free and as it drifts down wind. Otherwise, the line's end is located and affixed in such a way that it either is available for ground personnel or the pilot to deliberately use under emergency conditions when the LTA aircraft must be prevented from leaving the ground (to enable escape). Tragically[4], this was not available for one pilot when the airship he was flying was consumed by fire that started from leaking fuel lines.

Rotadyne: An aircraft sustained in flight entirely by powered lifting rotors (e.g. a helicopter). Also, a powered rotating body with radiating blades that pitch collectively to develop positive or negative aerodynamic lift.

Rotastat: Wikipedia[3] (under the title 'Hybrid airship') states, "A *rotastat* is a rotorcraft/airship hybrid typically intended for heavy lift applications." Maybe! Mowforth[2] says, "With rotor lift the vehicle's characteristics become those of a rotadyne and an aerostat, and it becomes a rotastat." Also that, "This type of machine is capable of VTOL." In addition, it's mooted that such aircraft have the advantage of being able to operate without ballast. Perhaps!

Even so, as shown by Mowforth's illustrations of typical types, it's clear that there are at least two distinctly different LTA aircraft versions.

1) Those with a fixed unidirectional aerostat similar to that of conventional airships, but carrying a lower structural arrangement of arms or pylons extending each side to support helicopter type rotor systems for vertical lift at their ends. These arrangements also may have separate propellers for thrust and control in other directions.
2) Contraptions based on an aerostat that rotates either about a longitudinal or vertical axis, carrying a set of hinged blades (wide rotors) radiating equi-spaced about the rotation axis and each supporting hinged T-planes at their ends (functioning like cycloidal propellers), all supported in place by bracing cables. The arrangements also have propellers to cause rotation of the whole

vehicle, which work like giant floating and swirling propellers configured to direct aerodynamic forces generated by the blades and T-planes to enable vertical lift for under-slung payload carriage and thrust in any other direction for motivation plus control.

In addition, Mowforth illustrates an LTA aircraft with a rotating spherical aerostat on a horizontal axis that deliberately gets aerodynamic lift from airspeed (enabled by thrust units at each end of the rotation axis that are supported from a hanging yoke) derived from the Magnus effect (as for a swerving ball).

With regard to the first group, the arrangements clearly are for a type that has an aerostat to develop buoyancy to counter gross weight so that the aerodynamic lift of its helicopter type rotors can be used with full effect to carry a payload; otherwise functioning as conventional airships. In this respect they are helistats, as their individual type names suggest.

On the other hand, the second group clearly are rotating aerostatic propeller systems, where they appear to be correctly defined as rotastats. These rotastats also develop aerodynamic lift derived from the Magnus effect, which may not be desired but is a consequence from rotating the aerostat. The spherical type, which is omni-directional, thus also is a rotatstat. The explanation below thus is offered to better define the term.

A rotating aerostat that develops Magnus effect aerodynamic lift from airspeed that may also carry hinged blades and or planes to develop lift in other directions.

Semi-rigid airship: An airship that uses an aerostat with a flexible membrane envelope (usually pressure stabilised) together with a rigid framework (usually a keel with bow members) that provides additional stiffness to spread load, as the main carriage system for the airship's principal parts, aircraft systems, equipment and the payload. This enables bigger types with low envelope super-pressure; where the weight of aircraft parts plus payload to be supported by the aerostat and buoyancy experienced increases in proportion with L^3 (i.e. displaced volume).

Slenderness ratio: The ratio of the axis of revolution's distance between an aerostat's ends and its maximum diameter.

Slosh: For aerostats, a sort of wave movement of gas cells or the air in a ballonet and the ballonet membrane (similar to liquid slosh).

Super-pressure: The differential pressure of a non-rigid or semi-rigid aerostat or closed balloon at its lowest position.

Super-heat: For an aerostat, the result of a temperature difference between internal gas and external air; where positive super-heat is when the gas temperature is greater than the air's temperature.

Suspension system: For an LTA aircraft with a non-rigid aerostat, this is the arrangement of internal and/or external rigging by which external lower aircraft units (baskets, modules, nacelles, pods, gondolas, cars and so forth) are supported from it.

Takeoff: An HTA term, which for LTA aircraft (practically airborne beforehand due to buoyancy) is the act of launch into free flight. Because HTA aircraft takeoff in a quite different way to LTA aircraft, this term should be avoided to obviate confusion; where the terms 'release' and 'launch' should be used instead for the similar action of an LTA aircraft's movement from the ground into free flight.

Tethered aerostat: This normally refers to an LTA aircraft as a non-rigid unidirectional aerostat with stabilising fins (that may be pressure stabilised fabric structures), which is continuously held by a single tether line from a ground winch system – used to let the aerostat ascend or to haul it down against excess lift (where buoyancy experienced is greater than gross weight plus the weight of the tether line). Rightly or wrongly, such arrangements often also are called Blimps.

Thermal Airship: An airship that uses heating methods to reduce the density of the contained LTA substance (normally hot-air instead of gas) and usually non-rigid.

Undercarriage: A ground fender beneath an LTA aircraft's lower features to protect them from ground impact damage and to minimise the shock felt by occupants when the descent rate is arrested.
Note: an LTA aircraft's undercarriage may be a bumper bag, skid or wheeled leg arrangement (similar to HTA aircraft). However, wheels usually must be allowed to rotate freely about their leg

and shouldn't have brakes, since they are fenders that must accommodate the direction of impact rather than landing units along a runway that support aircraft weight.

Undocking: Movement of an airship out of its hangar.

Unmooring: Release from a mooring restraint system.

Upend: Rotation of a horizontally aligned body (e.g. an aerostat) of unidirectional form such that the end points of its longitudinal axis move respectively to the upper and lower positions with the longitudinal axis then vertically inclined. The rotation may be either way. This may occur at a mast when a classic style airship appears to undertake a nose stand with its tail in the air above the mast or in free flight with low gas-fill (such as for stratospheric types at low altitude) if the gas moves to one end or the other, when it pitches 90° due to pendulum action.

Valving off: The release of LTA gas (venting) from an aerostat either deliberately (e.g. in order to increase weight of air contained in the ballonets without increasing super-pressure) or automatically should super-pressure rise above set limits via pressure relief valves for safety; such as when ascending above the pressure height.

Vectored thrust: Directed force from an adjustable propeller system at various angles as required for manoeuvring or control, lift, propulsion and air braking.

Vertical Launch and Capture (VLC): For LTA aircraft, the respective actions of release into flight and grounding from flight with vertical ascent and descent.

Vertical takeoff and landing (VTOL): This is an HTA aircraft term that is a natural ability for most LTA aircraft with regard to vertical launch, ascent/descent and return to the ground, where the acronym often is used to convey the ability. However, because LTA aircraft normally remain airborne at ground level from buoyancy experienced without airspeed, a better term and acronym is: vertical launch and capture (VLC).

Virtual inertia: An apparent added mass effect due to surrounding air movement entrained by the aerostat's own movement.

Weather-vane: For classic airships, the rotating (yaw) motion about a nose attachment point to a mooring mast, where they move like a weather cock around the mast (depending on the wind direction) to align with the wind (nose into wind), minimising aerodynamic loads. The airship also may pitch in a similar way depending on wind strength, wind direction and EQ state.

Weigh-off: The action to determine an LTA aircraft's EQ state prior to launch or during flight (normally prior to capture) by:

- Prior to launch, raising it a little, holding it steady, then letting go and observing whether it ascends or descends. Then adding or removing ballast and repeating the process until it neither ascends nor descends, when EQ is established. Following this a particular amount of ballast may be added or removed to suit the flight plan.
- Prior to capture and in level flight, reducing airspeed to practically zero with attitude that minimises aerodynamic lift and zeroing vertical thrust, then observing the descent or ascent rate and using judgment to assess EQ state. Following this a particular amount of ballast or LTA gas may be released to suit capture.

Zeppelin: A rigid airship with an internal cable braced framed structure of the type produced by Luftschiffbau Zeppelin GmbH up to 1938 and now any airship produced by ZLT Zeppelin Luftschifftechnik GmbH & Co KG. The term is sometimes applied indiscriminately to any type of airship (normally rigid).

* Total weight, including payload, ballast, etc.

Notes

- The rev B edition was updated and broadened following review of the glossary published by Mowforth[2] in, *An introduction to the Airship*, which is an excellent and comprehensive treaties of the subject matter originally from a time when the re-emergent industry was setting up. Some definitions here were added (although revised) for completeness and some were revised for compatibility with his glossary. Terms not added were considered either to be not in common use today, although this may change in the future (when they may be added), or to suit his own purposes – so not generally applicable to all types. Some definitions here also are different, written to avoid common misconceptions of the LTA aircraft physics and practices involved.

- The rev C edition was mainly to revise the layout (no longer a table).
- Rev D amends the document's header and footer and is to correct some definitions mainly associated with the physics of buoyancy in the atmosphere.
- For further definitions of LTA aircraft words or terms see:
  - BS 185-7:1969[5]
  - The Rigid Airship[6]
  - Appendix E "Glossary of Airship Ground Handling Terms" of Giles Camplin's thesis[7]
- For more information or interaction to enable further revisions contact the author.

References

1 Chapter XI, Common Airship Fallacies, item (2) Compressing gas or air for ballast, page 286 of book, "Airship Design", by Charles P Burgess, 1927.

2 Book, "An introduction to the Airship", by E Mowforth, 1985 (third edition, 2007).

3 Website: https://en.wikipedia.org/wiki/Hybrid_airship

4 Summary report, website: http://aviation-safety.net/wikibase/wiki.php?id=123038

5 British Standard, available from website: http://webstore.ansi.org/RecordDetail.aspx?sku=BS%20185-7:1969&source=msn&adgroup=BS

6 Book by E. H. Lewitt, 1925.

7 Thesis, "Rediscovering the Arcane Science of Ground Handling Large Airships", by Giles Camplin, City University, London, February 2007.