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Unmanned Aerial Vehicles (UAVs) and Other Airborne Objects

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Introduction

An unmanned aerial vehicle (UAV) is an aircraft that is deliberately designed or modified *not* to carry a human pilot and which is operated through transmitted electronic means and/or by an autonomous onboard flight management control system not calling for active intervention by a flight controller. According to one source, "Today, no less than 45 countries fly hundreds of different UAV models. UAVs are indeed multiplying. A large wall chart published annually by the American Institute of Aeronautics and Astronautics lists (in 2009) many features for each of the UAV listed: viz., official name of the vehicle, contractor, production status, type of propulsion, gross weight, payload, wingspan, endurance, range, ceiling, and mission. Worldwide, these UAVs range in size from the palm-size Black Widow "micro" UAV spy plane (6 inches in diameter; 1.5 oz.) to Northrop Grumman's RQ-4/Global Hawk (weighing in at 25,600 lb).[1]" www.paktribune.com/pforums/posts.php?t=39926; http://www.uavforum.com/vendors/systems.htm It would be naïve to state that UAV have yet to come into their own as operational aero-vehicles.

As civil uses for UAV continue to expand rapidly some will operate in airspace that is already heavily populated by manned airplanes, e.g., so-called medium altitude long-endurance (MALE) UAVs (typically between 18,000 and 40,000 feet altitude). Concern has already been expressed by Reynish (2004) regarding UAV detection and collision avoidance by commercial airplanes within this part of the national aerospace system.[2] The UAV National Industry Team (UNITE) was established (see www.access5.aero) in fiscal year 2004 to work toward approval of both MALE and HALE (High Altitude Long-Endurance) UAV flight in the national aerospace system and in foreign airspace. Interested readers should also

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[1] Global Hawk is the only UAV that is currently approved to fly in civil airspace because it can climb and descend inside tightly controlled military airspace, cruises well above altitudes were civil aircraft fly, complies with all military airworthiness standards, and doesn't need to carry collision avoidance hardware. A hydrogen powered follow-on vehicle with even longer flight durations has been announced recently by Boeing (Aviation Week & Space Technology, March 8, 2010).

[2] www.aviationtoday.com/av/categories/bga/UAVs-Entering-the-NAS_1139.html; www.psi.nmsu.edu/uav/conops/

consult (www.auvsi.org) for information about the Association for Unmanned Vehicle Systems International whose aim is to cover UAV flight operations below 18,000 feet altitude. This paper will not consider the military uses of UAV which are already extensive. (http://forums.yaleglobal.yale.edu/thread.jspa?threadID=1614).

A purist on the subject of unmanned *spherical* UAV[3] would find very little to discuss. While UAVs vary widely in size, shape, and capabilities there are few, if any, absolute spheres of any size. The present discussion has been expanded, therefore, to include aero-vehicles that appear essentially spherical from a distance and also balloons in general. Considered from the side virtually all blimps are elliptical in shape, in order to have better control and maneuverability but considered from the front and rear some are round. Likewise most large diameter balloons tend to be more teardrop shaped than spherical. Nevertheless, some balloons are spherical until they are outfitted with a payload that distorts them. There may be baskets or other equipment, which effectively bespoil the perfect spherical form. Nevertheless, the development of UAVs and airships is accelerating, and it is appropriate to update this research every few years, to keep abreast of the development of new and more capable spherical craft.

I. Unmanned Aerial Vehicles

Balloon UAVs

Figure 1 shows a typical balloon used in the 1970s. Raven Industries developed this balloon for the U.S. Government. The man standing beneath it provides a size reference. Balloons such as this that function as UAVs could carry as much as a 1,000 pound payload into the stratosphere for very long flights. If such a balloon flew without its instrumentation package, or lost its package, it could appear spherical under certain illumination conditions and could fly at very high altitude for an indefinite period.

Figure 1. Typical Polyester Spherical Superpressure Balloon

[3] This class of aero-vehicle is also sometimes known by other names: Medium altitude long-endurance (MALE) and High altitude long-endurance (HALE) UAV; Micro Aerial Vehicles (MAV); Operational Unmanned Aerial System (OUAS); Remotely Piloted Vehicle (RPV); Unmanned Aircraft System(s) (UAS); Unmanned Air Vehicles (UAV); Unmanned Combat Air System (UCAS); Unmanned Combat Air Vehicle (UCAV); drones; and others (See for example, http://en.wikipedia.org/wiki/Unmanned-aerial-vehicle)

Airships

Figure 2 pictures the TSI SA-90 unmanned airship under development. Clearly, it is not spherical. However, in Figure 3, the same vehicle is shown in a frontal view. From this aspect, it appears essentially spherical, with only the small propellers protruding from the moldline. The SA-90 is a member of a family of unmanned airships that range in diameter from 94 to 150 feet, range in ceiling from 15,000 to 65,000 feet, and can stay aloft for as much as 10 days. They are diesel-electric powered and use thrust vectoring for steering.

There is a vast array of airships manufactured and flown worldwide. Some are piloted, some are operated remotely, and some are tethered. Few are truly spherical. However, as with the SA-90, most could be seen as spherical under certain viewing conditions. These ships could be any combination of colors and could be at nearly any altitude. There are many manufacturers of these craft.

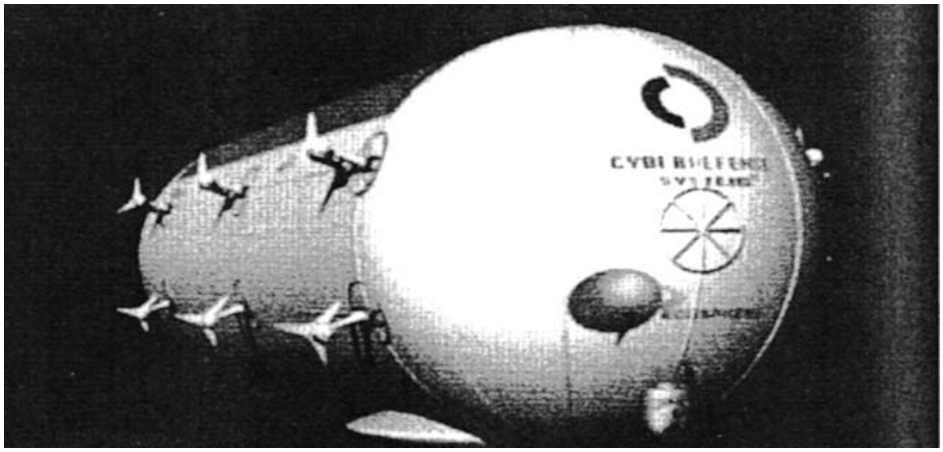

Figure 2. TSI SA-90 Airship, Oblique View

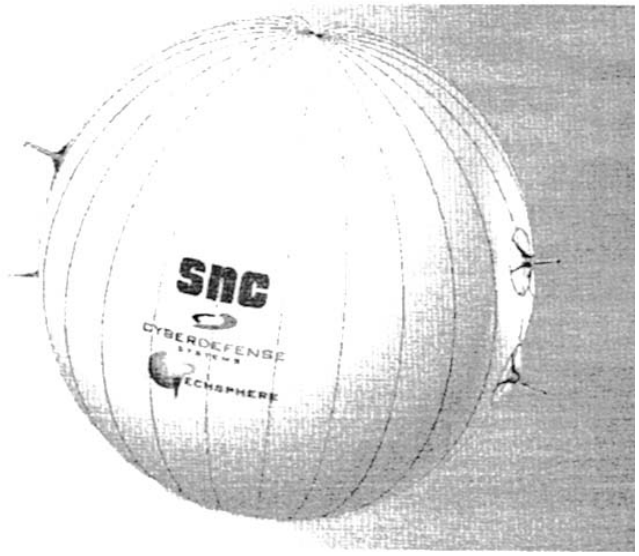

Figure 3. TSI SA-90 Airship, Frontal View

A spherical airship has been developed and flown by Cyber Defense Systems, Inc. and Techsphere Systems International. Called the SA-60, the low altitude surveillance vehicle was flown for more than three hours to 10,000 feet altitude and lofted a payload of over 500 pounds for the U. S. Navy in Maryland in March 2004. While a pilot was on-board the company claims that later-larger models will be unmanned. A color photo of it was published in the August 2004 issue of Popular Mechanics.

Heavier-Than-Air Vehicles

We were unable to find any information on large, high-flying, spherical, heavier-than-air vehicles. This, of course, does not mean that there are no such craft. Proprietary and classified projects could involve the use of such vehicles. Some information was found on small, remotely operated craft that, though not perfectly spherical, could appear essentially spherical when viewed from certain aspects.

Perhaps the best example of a remotely controlled vehicle that could appear spherical is the Kamov Ka-137 helicopter. This vehicle is seen in Figure 4. It has dual rotors with no tail structure, four permanent legs, and a piston engine. It has a takeoff weight of 620 pounds, a service ceiling of 16,000 feet, a hovering ceiling of 9,500 feet, a range of 290 nm, a cruising speed of 80 nm/h, and an endurance of 4 hours. It is small, but can carry a special payload of as much as 80 kg of reconnaissance equipment. The Ka-137 may be painted to minimize its detection.

Figure 4. Kamov Ka-137 Unmanned Helicopter

Figure 5 shows the Bertin SmartBall remotely controlled vehicle. Developmental units were flown, but there were stability problems.

Figure 5. Bertin SmartBall Developmental Vehicle

Bertin redesigned the SmartBall, adding a cylindrical section that improved the stability, and renaming it as the Bertin HoverEye. It is seen in Figure 6, being launched and controlled by a soldier on the ground.

The HoverEye appears less spherical than the SmartBall. However, it tilts for steering, and from certain aspects could appear nearly spherical. The HoverEye weighs 7 pounds, is 16 inches in diameter, is 24 inches tall, and is powered by an electric motor. Propulsion is by two rotors within the spherical section. It has a maximum line-of-sight mission radius of 1.2 miles.

Figure 6. Bertin HoverEye

Figure 7 is a photograph of the IT 180-5 Infotron remotely controlled or autonomously operated surveillance helicopter. It has dual counter-rotating rotors above and below the

fuselage. There are three non-retractable legs. The fuselage is not exactly spherical; however, it could appear spherical from certain aspects. The legs are small, and when the rotors are in motion, the vehicle could appear to be spherical.

Figure 7. IT 180-5 Infotron

The Infotron has an electric motor, but a small diesel-powered engine is optional. The vehicle weighs 22 pounds and has a maximum weight of 33 pounds. The rotors are 6 feet in diameter. The maximum speed is 60 mph, the ceiling is 10,000 feet, and the mission radius is 3 miles. Its nominal (flight time) endurance is 90 minutes. A photo gallery of additional UAV of various shapes is presented elsewhere. <http://www.popsci.com/announcements/article//2010-02/march-2010-issue-aerobot-invasion>

II. Other Spherically Shaped Airborne Objects

Efishoff (4.1) has reviewed the characteristics of generally spherical weather balloons but there are other lighter-than-air (LTA) craft in the skies of many nations today as well that might be misinterpreted as UAP and pose a threat to flight safety.[4] Lally (1968), in the specific context of UFO sightings, discussed flight profiles, kinds, and visibility of balloons making a distinction between neoprene (rubber), polyethylene, and super-pressure balloons. We will revisit some of his findings below. While these kinds of aeronautical "craft" come in many different sizes, shapes, and colors we will only consider those that are spherically shaped here.[5]

These particular spherical objects gain their aerodynamic lift by being lighter than air. The two main types are hot air- and gas-filled balloons.[6] These manmade LTA craft (objects) vary

[4] An example of the misidentification of a balloon as a UFO is found in a special 1951 USAF Project Grudge report no. 1 where the pilot of an airplane flying north along the New Jersey coast reported an unidentified object which was later identified as a weather balloon launched from Camp Evans. <www.infoage.org/html/cs-2003-08-28-p20n26.html>

[5] Several other shapes are included only because they will appear round when seen from a particular vantage.

[6] See <www.hotairballons.com/hotairballoon-air-pressure.asp> for further information.

widely in their size and capability to lift heavy payloads; they range from stratospheric research balloons to small diameter hobby and sport balloons. For the sake of convenience they are divided here into three groups: research, commercial, and private

Research Balloons[7]

A research balloon is always designed to carry instruments to high altitudes. They can drift at altitudes of over forty thousand meters for years or more.[8] Spherical balloons may contain a half-million cubic meters of gas (or more) and possess a diameter of 150 m or more. In clear air when they reflect sunlight their high contrast makes it possible for them to be seen thousands of miles away. The earliest example was NASA's Echo 1A and 2 balloons launched in the 1960s to very high altitudes. (Figure 8) Their metalized Mylar polyester (and PET) film reflected sunlight and made them visible by the unaided eye over most of the Earth. Echo 1A was 100 ft. diameter remained aloft for almost eight years. Echo 2 was 135 ft. diameter and remained in orbit over five years.

Figure 8. Echo Research Balloon (NASA)

A number of nations have launched large diameter high altitude balloons over many decades for research purposes. Some of them have been seen and reported by pilots due to

[7] The non-profit organization *Edge of Space Sciences, Inc*. (EOSS) promotes science and education by exploring frontiers in amateur radio and high altitude balloons. Creditable studies of the Earth's upper atmosphere are carried out using (mainly) off-the-shelf hardware by students and others affiliated with EOSS. (www.eoss.org/pubs/) The organization has lofted as many as thirteen balloon projects in a single year over eastern Colorado to a typical (maximum) altitude of 95,000 feet. Of course there is no threat to commercial aviation once the balloons attain these altitudes.

[8] The longest recorded balloon flight in 1970 was more than four years and circumnavigated the earth more than one hundred times! See http://stratocat.com.ar/globos/indexe.html for a list of stratospheric balloons launched worldwide since 1947 and associated information.

peculiarities in ambient illumination and solar reflection(s). They do not normally constitute a threat to flight safety even at low or intermediate altitudes because: (1) They are large enough to be seen at considerable distances during daylight hours in clear air and therefore can be avoided, (2) Their flight is announced in advance through NOTAMS, and (3) Some carry anti-collision beacon(s) after dark. They move through the air passively and cannot exceed the ambient velocity of the wind[9]. At altitudes of fifty thousand feet or more research balloons do not pose any significant threat to commercial flights. Of course if they are at lower altitudes conditions of reduced visibility and nighttime could make them a greater threat as could the periods of time when they are ascending through Low and High Level flight routes or when they are dropping their payloads (by parachute). Following are several photographs of research balloons to illustrate some of their odd shapes.

Among the more recent impressive launches that have been conducted by NASA's Balloon Program Office is the Ultra Long Duration Balloon (ULDB) mission that was launched from McMurdo Station, Antarctica. It was not likely seen by any commercial pilots. It ended on February 20, 2009 after 54 days, 1 hour, 29 minutes in flight. Fully inflated, this balloon's volume was seven million cubic feet and seen from the side, looked something like a pumpkin. Figure 9 is a NASA drawing showing its outline shape and size (at launch) relative to the Washington Monument (left) and fully expanded (right) <www.csbf.nasa.gov/album.html>

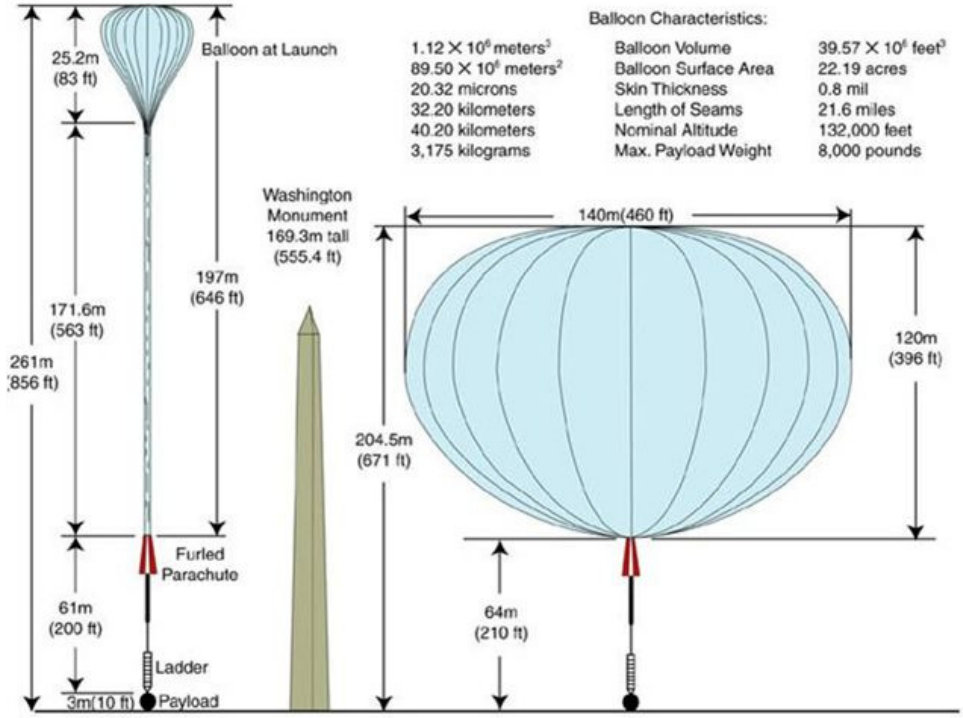

Figure 9. NASA's Super-Pressure Research Balloon Shape, Size and Dimensions

[9] Some LTA craft that are remotely controlled incorporate propulsion system(s) to support their specific missions. They may fly faster than the ambient wind speed.

NASA launches most of its research balloons either from the Columbia Scientific Balloon Facility at Palestine, Texas (typically 2 - 6 flights/year; each lasts about twelve hours per flight) or from Fort Sumner, New Mexico during a Spring and Fall launch campaign (typically 3 - 9 flights/campaign; each lasts about 36 hours per flight).

Depending upon such factors as atmospheric visibility (clarity), altitude and location of a high-altitude research balloon, solar illumination and balloon surface geometry and reflectivity it is possible that observers on the ground might have been able to see some research balloons. At great viewing distances, however, they would appear only as optical points of light (i.e., they would have no frontal area) and would not traverse the sky at very high angular rates.

Winds must be calm during their inflation (typically just after sunrise or just before sunset) and the gas bags can assume odd shapes before they are fully inflated as is shown in Figure 10, NASA's Super-Pressure Balloon.

Figure 10. Early Stage of Inflating NASA's

Super-Pressure Balloon

Figure 11 shows a Super-Pressure Balloon when it has filled more than in Figure 10 and has assumed a somewhat more symmetrical form. Notice its grayish-white color and translucent quality. Strips of glass fiber tape are sometimes used to reinforce the gore seams. A virtually 100 percent inflated super balloon is also shown in Figure 1.

Figure 11. Partially Inflated NASA
Super-Pressure Balloon

Tested on August 2, 2007 by NASA, an approximately 27 m "diameter" "Sweden replicate" balloon is shown in Figure 12 inside a blimp hanger (to protect it from wind). This photograph gives a good idea of the high degree of transparency of the special 2-part "fabric" (Zylon and Polyethylene) out of which the 200 separate "lobes" or gores are made.

Figure 12. NASA's Reduced Size "Sweden Replicate" Balloon

Another highly transparent balloon that was developed by NASA to carry weather instruments aloft in the vicinity of rocket launch pads on launch days. It is shown in Figure 13. These solar powered helium-filled balloons weigh only 130 grams and are the size of a beach ball. The payload includes GPS, temperature, pressure, and humidity sensors.

Figure 13. NASA's "Smart" Weather Balloon

Figure 14 is a photo taken by T. Dunham of the Lowell Observatory through an 8" reflecting telescope of a high-altitude research balloon launched from Fort Sumner, New Mexico on June 11, 2009. It shows the tear-drop-shaped balloon with an estimated diameter of about 600 feet at this point; it finally reached an altitude of between 110,000 and 120,000 feet and was seen by many people on the ground in Arizona the same evening of the launch. (Lowell, 2009).

Figure 14. Appearance of Research Balloon at High Altitude

Commercial Balloons

A commercial balloon is defined as any LTA airship designed for advertising, telecommunications, for-profit-sport, ground surveillance, or other purposes. The largest category of such LTA craft are hot-air balloons that take people aloft for pleasure flights. Most commercial hot-air balloons are brightly colored and cannot be misidentified as something else. Figure 15 shows large arrays of such typical hot-air balloons at special festivals and competitions. Very few are spherical in shape; most are extremely colorful. Local and regional balloon festivals take place in America and several other nations www.blastvalve.com/Balloon_Festivals/USA/

Figure 15a. Hot Air Balloons at Competition and Rally in Ireland

Figure 15b. Balloons Participating in the 39th Irish Championships

Balloons residing in the stratosphere have been proposed as cell phone transmission stations <http://mobilitytoday.com/news.php?n=0065738&p=balloon_cell_tower > One firm[10] has proposed to launch inexpensive balloons to altitudes of about twenty miles taking along a payload about ten cubic inches in size and weighing under twelve pounds. One such balloon is six feet diameter at launch and thirty feet diameter upon reaching maximum altitude. According to one source, the balloons rise so high that they exceed their transmission range and eventually burst; a parachute brings the electronics back to earth for reuse.

[10] Space Data Corp.

The familiar Goodyear blimps in the U.S.A. are also LTA craft and are used both for advertising purposes as well as providing a television camera platform to cover outdoor sporting events from above. Only when seen from the front or rear do these blimps appear circular. They do not appear spherical. With their externally hung engines and propellers they can fly against the wind at relatively slow speeds.

An interesting use of a balloon made out of rear-projection fabric and located within a second balloon is for product advertising <http://livedesignonline.com/map/up_away/> The surface of the balloon becomes an optically reflecting surface for still and video images. In one application two individual ten-foot diameter balloons were used for special indoor advertising presentations. It remains to be seen if such an approach will be used outdoors.

An article published in Defense Week[11] mentioned that as far back as 1991 the U. S. Army was considering a new PSYOPS Hologram System as a part of its non-lethal weapons system program. Allegedly, it would project 3-D images of various kinds above a battlefield. Whether or not an inflated balloon would be required as a projection surface remains to be seen as the program has not been mentioned since 1994. It isn't known whether "typical" holographic projection techniques are used.

Another odd shaped LTA craft is shown in the artist's rendering of a "Vertical Airship." (Figure 16) flying above a large city. It is presented only to indicate the possibility that a spherically shaped airship could also be used.

Figure 16. Artistic Rendering of Vertical Airship

[11] www.defencetalk.com/forums/space-defense-technology/psyops-holographic-technology-9604/

Private Balloons

A "privately" owned and operated balloon may be designed to serve a wide range of uses, most of which will determine the size, shape, and lifting capacity of the balloon. The first example is a private research balloon.

A particularly impressive private launch called the High Altitude Object (HALO) was completed on October 8, 2007 from Lucknow, Ontario, Canada. The payload weighed less than 1.5 kg and was lofted by a KCI 1200 Totex sounding balloon (its helium volume was approximately 4.06 m^3). The balloon and payload operated well and reached a maximum projected altitude of 31,666 m making temperature and absolute pressure measurements enroute; impressive still and video images were also obtained, some of which are found elsewhere <www.natrium42.com/halo/flight2/>. Figure 17 was taken by the still camera on the HALO flight at an altitude of 27,784 m. looking vertically upward at the balloon. The sky background is a dark blue; the balloon's circumference is not exactly round by a factor of one part in a hundred.[12]

Figure 17. High Altitude Object (HALO) Balloon
Photographed from Beneath

Personal balloons are also used for sporting purposes, sometimes just to prove that a certain feat can be accomplished. There is a very small community of people worldwide who practice the extreme sport of cluster ballooning. Figure 18 shows John Ninomiya on one of his colorful flights. In theory, a single balloon could become liberated from the cluster and fly away on its own. It could be any color and could rise to well above 20,000 feet. The authors are not aware that this has ever happened; however, it is entirely plausible.

[12] This asphericity may be the result of air-current distortion of the balloon.

Figure 18. Manned Flight Using Cluster Balloons

Figure 19 shows a person hanging below a single balloon made of circumferential panels. The air heating element must be out of sight within the base of the balloon.

Figure 19. Hot Air Balloon Supporting One Person

When LTA balloons ascend they may assume unusual shapes when viewed from different vantage locations. The balloon shown in Figure 20 has assumed a fattened teardrop shape as it rises.

Figure 20. Teardrop Shaped Research Balloon Photographed from the Ground

Another class of balloons that must be considered are latex rubber party balloons that are available in a wide range of colors, shapes, and sizes. Hundreds if not thousands of such balloons are sometimes launched at the same time during sporting and religious festivals.[13] Should one or more of these balloons be injested into a jet engine intake they probably would not cause significant damage, however pilots might change their flight path abruptly to avoid a dense cluster of such small balloons. Figure 21 was taken in Mexico in 2009 and shows a dozen reddish balloons in the desert sky.

Figure 21. Multiple Balloons in the Sky in Mexico

[13] <www.thingsasian.com/stories-photos/2207>

An evening photograph shown in Figure 22 was taken in Cambridgeshire, England and was reported in the Daily Mail on June 15, 2009. The identity of these luminous globes has not been determined so far. <http://dandare.wordpress.com/category/ufo-photographs/>
It is interesting to speculate about what a pilot might do if he saw these objects ahead of him at night.

Figure 22. Photograph of Eleven Luminous Globes

The final aerial object considered is the Dynalifter. Figure 23 shows a small developmental model of it seen from the front and at ground level. It is almost circular with four stubby wings. When seen from the side, however, the so-called Heavy Freighter is almost four times the length of a Boeing 747 jet airplane! <http://www.dynalifter.com>

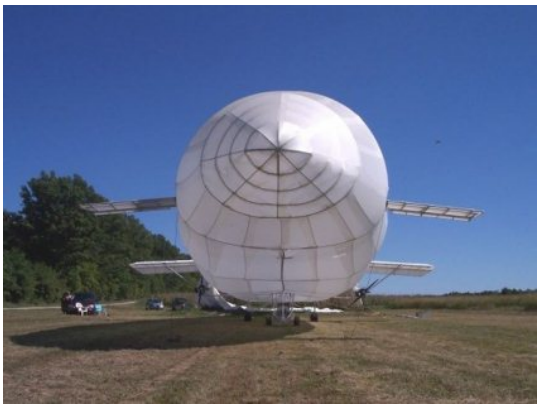

Figure 23. Front View of Developmental Dynalifter Airship

Balloon Conspicuity and the See and be Seen Rule of Aviation

Aviation in the United States of America and many other nations is still guided largely by the *See and be Seen Rule* which places final responsibility for in-flight collision avoidance in particular and flight safety in general upon the pilot. The pilot is ultimately responsible for seeing obstacles to flight and operating their airplanes in such a manner that they are also seen by other flight crews and air traffic control personnel on the ground.[14] Of course, if the atmospheric visibility conditions are poor and/or if the distant target object or vehicle is small or camouflaged the see and be seen rule is partially or totally compromised and radar is required.

The conspicuity of balloons is an important consideration in flight safety. If a flight crew cannot see a balloon in time when the airplane is flying on a direct approach path to one a collision is inevitable. Commercial jets and most military airplanes travel at such high speeds that relatively small balloons may not become visible until it is too late to avoid hitting them. A review of near-miss pilot reports in the UK describe a number of spherically shaped objects that narrowly missed the airplane (Ridyard, 2000). The Aviation Safety Reporting System managed by NASA for the FAA in America contains many more.

Whether or not the presence of a balloon can be perceived is a complex result of such factors as its angular size and shape, its contrast with its visual background, its angular velocity relative to nearby fixed visual referents, and to a lesser degree its color.[15] Intervening atmosphere will largely determine its contrast, brightness, and color. The surface characteristics of the balloon will largely determine its specular[16] and directional reflectivity. Compare the appearance of the balloons shown in Figure 10, 11, 12, 13, and 19. Each presents a different degree of transparency relative to their background sky brightness and color. In Figure 12 it is only the intense solar reflected highlights that make the surface visible at all, the rest of the balloon's surface becomes almost invisible!

As Lally (Ibid. pg. 759) points out, small diameter neoprene weather balloons are launched after dark for nighttime soundings in many other nations than the U.S.A. In order to make them visible from the ground at night small candles (or battery operated lamp) are suspended beneath them in a wind-shielded holder. In the U.S.A. the FAA requires that all large diameter research balloons below 60,000 feet altitude must carry a light. Collom's (2009) article in The Arizona Republic newspaper describes a recent evening sighting in clear air of a conspicuous object by a number of eye witnesses on the ground. They used such expressions as "dazzling light," "orb that shone like diamonds," "huge, shiny object," and "…a cable hanging from the orb could be seen by the naked eye." An official at Sky Harbor International Airport in Phoenix said the object was a weather balloon.

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[14] The second is accomplished by activating on-board transponding equipment upon ATC request.

[15] Some useful guidelines and discussion for making these calculations are given elsewhere (Haines, 1980).

[16] Specular reflections are mirror-like in that a very high percentage of incident radiation is reflected and the angle of incidence equals the angle of reflectance. This principle is used in some stealth aerovehicles.

Weather (radiosonde) balloons are made of neoprene rubber that is opaque regardless of its color.[17] However, as it slowly expands as it rises the rubber becomes thinner, more translucent and it scatters more ambient (solar) illumination. At an altitude of about 20,000 feet their relatively small diameter make them virtually invisible from the ground with the naked eye. However, neoprene reflects more ambient illumination than polyethylene at any altitude.

Super-pressure "Ghost" balloons are usually almost spherical and of small size (five feet diameter at 20,000 feet, seven feet at 40,000 feet, ten feet at 60,000 feet.

Polyethylene (research) balloons absorb about five percent of incident solar radiation, the other ninety-five percent is reradiated from its surface sometimes in visually unusual ways. Simple scattering can account for up to thirty percent of this radiation (Lally,1968).

FAA Rules Concerning Unmanned Balloons

The Federal Aviation Administration has issued requirements to be met by anyone wishing to launch unmanned balloons. They are found in Part 101, sub-chapter F, Air Traffic and General Operating Rules within the Title 14 of the Code of Federal Regulations. At the most general level no unmanned free balloon will (be permitted to) create a hazard to other persons or their property. Different regulations have been issued depending on payload weight: Four pounds or less (exempted); four to six pounds (exempt only if the weight is under three ounces per square inch along the smallest side); Six pounds or more (certain operating limitations apply such as maximum cloud cover, marking requirements, formal notification and location reporting to Air Traffic Control.).

Equipment and Marking: (a) Payload must be able to be cut down by two independent systems, (b) Two independent means of terminating the balloon's flight, (c) A radar reflector must be included, (d) Lights for all night flights, (e) Color pennants attached to all suspension cables longer than 50 feet, and (f) The parachute must be a highly conspicuous color.

Operating Limitations: (a) Must not ascend higher than 2,000 feet if within a control zone (unless permission is received from ATC), (b) Not permitted if cloud cover is greater than fifty percent, (c) Not permitted within congested areas for the first 1,000 feet of altitude, (d) Not permitted where impact may create a hazard to persons or property.

Notification Requirements: (a) At least no less than six to twenty-four hours before launch, (b) At launch, (c) Cancellation (if applies), (d) Location (geographic and altitude, as required), (e) Derelict status (if control is lost), and (f) At landing.

[17] There are seventy national launch sites for radiosonde balloons in the conterminous USA. Two balloons are sent up every day, twelve hours apart. (www.spectrasensors.com/wvss/>

Balloons as Threats to Aviation

Balloons (and their payloads)[18] can pose a threat to flight safety as the FAA has made clear (AIM, Section 7-5-4). The *Airman's Information Manual* points out that most unmanned free balloons have a suspension device to which the payload or instrument package is attached, or a trailing antenna wire (or both). While the balloon may be visible to pilots flying nearby these suspended cables and payloads may not be visible due to their small size. Therefore, "…aircraft should remain well clear of all unmanned free balloons and flight below them should be avoided at all times." (Ibid., pg. A-406) In addition, section h of paragraph 3-2-1 of Chapter 3 "Airspace" specifies that unmanned free (flying) balloons may not be flown below 2,000 feet altitude if they are inside the "lateral boundaries of Class B, Class C, Class D, or Class E airspace designated for an airport." (Ibid., pg. A-118)

Selected In-Flight Incidents

An interesting in-flight collision in the United Kingdom occurred on June 13, 1997 between a Cessna 421 in cruise flight and an "unidentified object." The Golden Eagle flight was at FL 180 near ROLAMPONT VOR when something unexpectedly struck the left windshield. The glass was shattered, the pilot reduced airspeed and altitude immediately and the flight continued to its destination. The incident was investigated by the CAA and the object was never identified. (Occ. number 199702943).

Another near-miss incident in England took place on June 9, 1998 near London LHR when an MD-81 commercial jet was climbing after takeoff. The crew reported seeing an "illuminated metallic grey object, in and out of cloud, passing slightly above and 30 - 50 metres away." The object was not detected on ground ATC radar. (Occ. number 199803283).

An Airbus A319 was on the downwind leg of an approach to London-Heathrow airport's runway 09L on March 3, 2001. At about 17 km ENE of the runway the crew saw "five or six blue balloons suspending a white device." They were at FL 80 at the time and the object(s) passed by them at an estimated lateral distance of 100 feet and from 100 to 200 feet below the jet. The meteorological office confirmed that their balloons are orange. (Occ. number 200101399)

Another near-miss with a weather balloon occurred on June 5, 2004 about eight miles from Trent, UK. The pilot of a B-737 in descent mode at FL 158 when he called ATC to report passing a weather balloon or drogue parachute. The meteorological office confirmed that the balloon was not one of theirs. (Occ. number 200403706).

Other possible near-misses with balloons in the U.K. are found in CAA Occurrences number: 8003311C; 8100542C; 8201671B; 8302525A; 200000766; and 200303567.

[18] The mass of a typical payload usually exceeds that of the balloon used to take it aloft. It is the mass of the object striking an airplane times the impact velocity that determines the resultant impact force that will determine the resultant amount of destruction (if any).

Conclusions

As this brief review has shown there are several small UAV as well as some large balloons that approach a sphere in form. Under certain viewing conditions it is possible for a large balloon to be seen at almost any altitude from the ground and at large horizontal distances. There are also a number of UAV and balloons that could appear round from some viewing perspectives but not others. However, no absolutely spherical heavier-than-air craft were discovered. We could find no information on large UAVs that fly at high altitudes and could be mistakenly identified as spherical. This could change with new developments, and this review should be updated within a few years.

While most balloons are passive and are borne by the ambient wind others are self-powered and can fly against the wind. Although there are about two hundred NOAA weather balloons launched every day in the USA alone and scores of others that may or may not ascend as high there does not appear to be particular concern expressed by aviation officials about mid-air collisions with them. The probability of a mid-air collision is so small that this lack of concern appears to be justified on statistical grounds alone.

References

Collom, L., Light spotted in sky IDed as weather balloon. The Arizona Republic, June 11, 2009.

Federal Aviation Regulations/Aeronautical Information Manual, Jeppesen Sanderson, Inc., Englewood, Colorado, 1999.

Jane's Unmanned Aerial Vehicles and Targets, 2009. Jane's Information Group, Coulsdon, Surrey, UK.

Lally, V.E., Balloons - Types, Flight Profiles and Visibility. Chpt. 8 In D. S. Gillmor (Ed.), Scientific Study of Unidentified Flying Objects. Bantam Books, New York,1968.

Lowell, 2009 <www.lowell.edu/blog/wp-content/uploads/balloon_090611>

Reynish, W., UAVs Entering the NAS. www.aviationtoday.com/av/categories/bga/UAVs-Entering-the-NAS_1139.html, October 1, 2004.

Ridyard, C., Appeal to the Ombudsman: Britain's UFO Secrets Revealed. UFO Magazine, September - October 2000.

http://commons.wikimedia.org/wiki/File:Kamov_Ka-137.jpg

http://defense-update.com/products/h/hovereye.htm

http://www.aviastar.org/helicopters_eng/ka-137.php

http://www.aiaa.org/aerospace/article.cfm?issuetocid=365

http://www.popsci.com/announcements/article/2010-02/march-2010-issue-aerobot-invasion

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

http://www.infotron.fr/

http://www.uavforum.com/

http://pbs.org/wgbh/nova/spiesfly/uavs.html