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Airships in U.N. Humanitarian and Peace Operations: Ready for Service?

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Introduction

The United Nations (U.N.) and its Humanitarian Air Service (UNHAS) have an urgent need to transport large quantities of aid and supplies to U.N. peace operations and humanitarian centres located in "the world's most remote and challenging locations, often under precarious security conditions" (World Food Programme, 2017). This study examines whether the United Nations should take steps in the near future to exploit lighter-than-air (LTA) aircraft, whose natural buoyancy provide, in principle, distinct operational advantages. This issue is timely, given the broad progress made by numerous manufacturers in the construction, propulsion, and operational management of LTA systems over the past several decades. These developments potentially offer U.N. airlift planners some credible options to exploit the inherent flexibility and energy efficiencies of these systems. At the same time, recent progress has accentuated persistent challenges to reliable and safe LTA operations, particularly in the face of bad weather and threats from groups hostile to the U.N. operations mission. Consequently, this report will provide some historical and technical background and will proceed through four discussions: (1) the potential advantages of LTA operations; (2) their disadvantages; (3) current developments in available systems; and (4) their general application to peace and humanitarian operations.

Background

Powered and steerable LTA aircraft, technically referred to as dirigibles (with large ones typically called airships), have been in service at varying levels since 1897. During WWI, Germany used large dirigibles in bombing operations against Britain and France. Between the World Wars, several countries continued to use them for military and naval reconnaissance, while Germany developed a pair of partly successful passenger liners, the Graf Zeppelin and the Hindenburg. The aviation industry and the public lost confidence in long-range LTAs as passenger liners after the flaming crash of the hydrogen-filled *Hindenburg* in 1937 (United States Department of Commerce, 1937). The U.S. and other countries continued to use smaller LTAs in maritime reconnaissance, and as radar early warning platforms, until the late 1960s. Thereafter, the industry sputtered with occasional projects to produce commercial airships, most of which failed, except as advertising platforms (Owram, 2016). By 2012, "less than two dozen airships were flying anywhere in the world" (Prentice & Hochstetler, 2012).

Perhaps not surprisingly, given the smallness and inconstancy of the industry so far, the United Nations has not explored the use of LTAs in practice, despite its continual involvement in humanitarian relief operations where LTA cargo carriers might be useful. By contrast, the United Nations has decades of experience with aircraft (over 300 leased at present, including jets, propeller-driven and rotary wing aircraft) and recent innovated with aerostats (tethered balloons in both Mali and Central African Republic) but has only recently begun to consider the potential use of airships (Dorn, 2014).

LTA aircraft derive their lift from two sources: the buoyancy of their lifting gases (hydrogen or helium) and dynamic lift from the flow of air over their outer hulls. To provide a quantitative and scientific explanation: the sea-level buoyancy of 1,000 cubic feet of hydrogen, for example, is 75 pounds (Robinson, 1973). Dynamic lift is produced by increasing the angle of attack of symmetrical or "cigar-shaped" LTAs or by forming the hulls of hybrid airships to generate lift at low angles of attack in cruise flight. Lockheed Martin's current hybrid airship design produces up to 20% of its lift dynamically (Hybrid Enterprises, 2017). Theoretically (since none have been built) several studies predict that putting wings on symmetrical LTAs can increase their lift as much as 300%, while increasing drag only about 40% (Andan, Asrar, & Omar, 2012).

Dirigible LTAs are also characterized by low drag when compared to aircraft of similar weight. The most important reasons for this are buoyant lift and low cruise speed. Since all or most of the weight of LTAs is sustained by their buoyancy, they do not need to fly fast to produce the dynamic lift that sustains heavier-than-air (HTA) aircraft. This is a useful and necessary feature, since LTAs are also characterized by high air impact and friction drags as a consequence of their voluminous shapes. For most military and commercial dirigibles in the past, the balance of these drag characteristics were manifested in cruise speeds in the 55–75 knot range. The LZ 129 Hindenburg, a passenger ship from the mid-1930s cruised at about 75 knots, while the modern Lockheed Skylifter cruises at about 60 knots.

The special operational characteristics of LTA aircraft mean that the advantages and disadvantages have to be considered, both generally and for specific applications. This paper is the first to examine the potential application in peace and humanitarian operations, using studies from various other applications and general considerations.

Advantages

Comparative studies suggest that airships can compete with other forms of commercial transportation on some but not on all criteria. A 2012 study (Table 1), for example, gave airships strong marks in areas such as point-to-point speed of delivery and flexibility and competitive marks in other areas of consideration, except their usability in poor weather conditions.

Table 1

Comparing Transport Airships to Other Forms of Transport Vehicles, Ranked from 1 (best) to 5 (worst)

Quality	Airship	Truck	Freight Railway	Airplane	Bulk Ship
Cost	3	2	4	5	1
Speed	2	3	4	1	5
Capacity	3	4	2	5	1
Flexibility	2	1	4	3	5
Reliability (Weather)	4	1	2	5	3
GHGs	3	4	2	5	1

Note. GHG means emission of Green House Gases. Adapted from "Transport Airships: Not Just Another Aircraft," by B. E. Prentice and R. Hochstetler, 2012, Canadian Transportation Research Forum. Reprinted with permission.

Endurance

The inherent endurance of airships would be a valuable advantage in future U.N. operations. By exploiting buoyant lift, their fuel consumptions in cruise flight are modest and, consequently, their operational costs per ton-mile of productivity are low in comparison to equivalent-payload, HTA aircraft. The greater range and the ability to supply multiple outposts in single missions, instead of individual missions, are airship advantages that allow fewer aircraft to maintain the same throughput (Johnson & Arthur, 2011). Endurance can enhance the resilience and security of airships in threat environments. Airships can use their ranges to circumvent threat areas and to loiter away from active threats until security forces bring them under control. Though large and easy targets, helium-filled airships have in the past, and could be designed in the future, to tolerate gas bag punctures from small arms fire (Ryan, 1992). Their evasive capabilities make them less vulnerable, in threat environments, than U.N. logistics planners might at first presume, though their slow speed and large size makes them easier targets.

Remote Access

The major appeal of airships is their ability to take-off and land in almost any area. When arriving in theatre, hybrid airships would have a modest requirement of 1,500 feet or so of landing space. Studies done for remote locations in Canada's Arctic, lacking infrastructure and in need of strategic lift, conclude that "hybrid, heavy-lift, airfield-independent airships show potential to deliver this capability" (Murphy, 2011). They can hold a stationary aerial position, affixed to a mooring mast or similar structure, without expending any energy. Unlike helicopters or planes, they can carry heavy payloads great distances without refuelling and then land without an actual runway. Depending on their design characteristics, airships may need short, open fields to make hybrid landings, exploiting both buoyant and aerodynamic lift while others can make fully vertical take-offs and landings.

Fuel Efficiency

The fuel consumptions of airships generally are much lower than those of HTA aircraft of comparative lift capacity, which equates to lower operational and freightage costs. When considering the cost of Arctic air freight to the Canadian north, *The Economist* pegged the price at C$1.90 per tonne per km for cargo airplanes in 2013 (Airships in the Arctic, 2016), compared to a potential cost of only C$1.07 per tonne-kilometer for airships.

For a cost comparison, for Operation Boxtop, the biannual resupply for the Canadian Forces station in Alert, Nunavut, the estimated cost per resupply cycle of the SkyCat-50 airship tallies to $4 million versus $6.7 million for the currently deployed CC-130. For Northern Canadian Forces missions, "potential cost avoidances of up to 60% would be realized on the sustainment lift by using airships instead of the current transportation approach" (Ghanmi & Sokri, 2010).

Payload Capacity

Even airships of relatively modest size could, in principle, meet most U.N. payload requirements. U.N. peacekeeping operations mostly use Lockheed's L-100-30 Hercules, and the military version, C-130, for logistical resupply and cargo transport (Novosseloff, 2017). It can carry the largest payload of the fleet with a 21,000 kg capacity. Lockheed Martin's LMH-1 airship has a co mparable projected payload capacity of 20,000 kg, but with more flexible landing options (Hybrid Enterprises, 2017). Lift requirements for refugee camps can involve "piece" items, such as passengers, food rations, tents, comfort items, and medical supplies. All of these items can be broken into load increments to fit the capacities of whatever airships are available. Peacekeeping could require movements of large items, such as civil engineering equipment and protected vehicles. But, the weights of even these equipment items could potentially be lifted by mid-sized airships. An up-armored High Mobility Multipurpose Wheeled Vehicle (HMMWV or Humvee), for example, weighs in at around 4,500 kilograms, requiring an airship of around 15,000-20,000 cubic meter gas capacity to lift it, along with its own structure and fuel. This load demand falls well within the capacity of many of the airships under development, such as the 38,000 m^3 Airlander 10.

Outsize Cargo

In comparison to airplanes, airships should be able to handle exceptionally large or awkwardly shaped cargo loads with minimal preparation or breakdown. A large water tank, 3 meters or more in diameter or 15 meters or more in length, would not fit into an aircraft as large and expensive as a C-130 but could be slung under an airship for transportation to a distant refugee camp. The slow speed of the airship would ease the problem of keeping the load stable through rigging of its slings, use of small drag parachutes, application of temporary fins, or other techniques. Similarly, the use of external slinging could allow U.N. logisticians to prefabricate buildings, platforms, towers, and other items in, say, the organized environment of a coastal city and then transport them intact to distant locations.

Low Carbon Emissions

Airships emit considerably less Green-House Gases (GHG) than heavier-than-air vehicles for a given distance of travel. Recognizing this, the International Air Transport Association (IATA) assesses airships as a promising means to meet international GHG targets. According to one IATA spokesman, "[a]n airship produces 80 to 90 percent fewer emissions than conventional aircraft. They also fly at the lower altitude of 4,000 feet instead of 35,000 feet, which means their water vapour trails contribute almost nothing to global warming" (as cited in Prentice, 2016, p. 17). Given the U.N.'s leadership in global climate issues, such reduced GHG impacts are not a small consideration. But there are several downsides to airships for transport.

Disadvantages

Low Speed

Compared to other aircraft, airships are extremely slow, though they are competitive with the speeds of trucks and rail. The large frontal area and wetted surfaces of airships keep their practical speed limits around 100–185 km/h. These slow speeds make airships proportionately more vulnerable to ground-speed reductions due to headwinds and increases due to tailwinds. They also suggest that future cargo airships will utilize pressure-pattern navigation techniques, whereby they will follow the winds around high- and low-pressure areas, rather than fly directly through them. In such cases, the longer routes around pressure areas often will be faster than straight-line flights to airship destinations.

Large Size

The immense size of airships, compared to other aircraft, causes several problems. Finding places to park and secure air vehicles hundreds of feet long often will be a challenge, especially since no ground handling system for cargo airships has been developed (Prentice & Ahmed, 2017). An airship needs at least the circular space to allow it to swing around its mooring mast with changes in wind direction. Mooring facilities will require approximately at least a balloon-length in radius for each airship (Sherwood & Prentice, 2010). Rapid deflation may be needed to deal with storms. If security were an issue, an additional area would be needed to put its perimeter beyond the typical, 500-meter effective ranges of small arms and rocket propelled grenade fire, through balloon punctures on the ground or in the air only cause slow deflation. An M16 rifle has a maximum effective range of 550-meters (U.S. Department of the Army, 2011), and even that space would offer inadequate protection from longer-range weapons, such as mortars and heavy machine guns, which can have ranges of several kilometers. Of course, the immense size and slow speed of airships make them an easier target for light weapons up to about 3,000 feet above ground, and to soldier-portable missiles and light antiaircraft weapons up to 15,000 feet (McDaniel, 1990).

Difficult Control and Weather Dependence

Compared to airplanes and helicopters, airships are difficult to control. Altitude control for airships is a complex and often sluggish process of managing the volume and pressures of large masses of lifting gas and the limited authorities of relatively small flight controls operating at slow airspeeds. The sudden addition, or release of, heavy cargo loads can just as suddenly overwhelm the ability of crews to control the buoyancies of their airships. Directional control presents similar challenges, particularly in “cigar” shaped airships, which are particularly susceptible to wind shear turbulence and the violent updrafts and downdrafts of storms (e.g., sand, thunder, or regular rain storms). Experts describe large airships as slow to respond to the helm and prone to swing away from side gusts, rather than into them for better directional control (Khoury, 2012, p. 291). In keeping with these control challenges, the U.S. National Transportation Safety Board reported that winds and other weather conditions were primary or secondary causes of at least 8 of 14 airship accidents reported over the last 40 years. In a relevant recent experience, a strong sandstorm at Kidal, Mali irreparably damaged a tethered surveillance aerostat (United Nations, 2016).

Storage and Ground Handling Needs

Protecting airships from weather hazards will also be a challenge. Except, perhaps, at their homeports, airships at rest will have to either be moored to strong masts or towers, or deflated (Khoury, 2012, p. 153). Moored ships will have to swing with changing winds. But, even then, restraining such large aircraft in high winds will be difficult and fraught with hazard (Prentice & Ahmed, 2017). Most of the hazard will lie in airships breaking free from their moorings, a common event in airship accidents (May, 2015). The option of deflating and inflating airships as needed is notionally attractive but difficult to do in practice and risky. Leaking connections, handling of airship structures and coverings, will consume a lot of trained manpower, and likely result in wasted gas and accelerated wear and tear of the aircraft and support equipment. A large, deflated airship lying on an open field is also at risk of blowing away in a strong wind, perhaps more than an inflated one swinging on a mast.

Helium Needs

Helium is about 25 times more expensive than hydrogen, but it is nearly as buoyant and does not explode. That sums up the economic challenges and operational necessity of using helium as the lifting gas of most, if not all, future airship cargo operations. If managed properly, hydrogen is actually a safe gas to use in airships; the Graff Zeppelin flew over one million accident-free miles in the late 1920s and early 1930s with hydrogen in its non-flammable bags (Brewer, 1991). But, the inescapable reality is that hydrogen could burn, so it would be difficult for any commercial operator to obtain governmental permission to operate and insurance for large hydrogen-filled airships.

Current Developments

According to one analyst of airship operations, "there is a worldwide race to develop cargo airships" (B. E. Prentice, personal communication, March 13, 2017). Consequently, the array of modern airship designs available for application to U.N. requirements is increasing. Indeed, some industrial users are considering or even preparing to utilize airships for transportation in remote areas and harsh climates. At the leading edge of this development, licensed airship operators Straightline Aviation and Hybrid Air Freighters will receive the first two dozen of Lockheed Martin's LMH-1 models forecast for 2019. Straightline Aviation has contracts to deploy the technology in various roles, such as transporting liquefied natural gas to Alaska, operating a medical airship for a radiology non-profit, and, at one time, transporting equipment for the now troubled Canadian mining company, Quest Rare Minerals (Boettger, 2017; Straightline Aviation and RAD-AID, 2016; Owram, 2016).

Hybrid Airships

Hybrid airships probably hold the most promise for future support of U.N. operations. Since they have negative buoyancy when at rest, they are less sensitive to weight increases and decreases during cargo operations (Prentice & Knotts, 2016). They are at least as fast as traditional designs (to produce aerodynamic lift) and are probably more controllable in adverse wind conditions. Consequently, they are the most common design option among the many airship development projects underway (Haque, Asrar, Omar, & Suleiman, 2016). Some developers also propose using lifting gas compression to provide vertical take-off and landing capabilities without the need for a ballast. Overall, there are more than two dozen viable airship projects underway worldwide. Table 2 tabulates some of the more advanced projects.

Table 2

Selected Hybrid Airships and their Status

Manufacturer/ (Country)	Model	Size (m)	Shape	Range	Payload	Status
Aeroscraft (U.S.)	ML866	170 / 54	Ellipsoid	5,741 km	59,874 kg	R&D
	ML868	235 / 90	Ellipsoid	9,445 km	226,796 kg	R&D
	ML86X	280 / 108	Ellipsoid	9,445 km	453,592 kg	R&D
Hybrid Air Vehicles (U.K.)	Airlander 10	92 / 44 26 m (height)	Catamaran	5 days (endurance)	10,000 kg	Prototype
Lockheed Martin (U.S.)	LMH-1	85 / 45 23 m (height)	Catamaran	2,600 km	20,000 kg	Prototype (close to production)
Skylifter (Australia/ UK/Germany)	Skylifter	150 m (diam.)	Lenticular	2,000 km	150,000 kg	R&D
Solarship (Canada)	Nanuq	100 m (wingspan)	Deltoid	2,000 km	30,000 kg	R&D
	Wolverine	50 m (wingspan)	Deltoid	500 km	5,000 kg	Prototype

Note. Size gives a measure of length/wingspan or width.

Application to U.N. Peace and Humanitarian Operations

Recent U.N. operations offer many insights into the attractiveness of airship transportation. For example, the capital of land-locked Central African Republic (CAR), Bangui, depends on Main Supply Road 1, a trucking route from Douala, the main port of Cameroon, for 90% of imports and exports. Not only does the United Nations Multidimensional Integrated Stabilization Mission in the Central African Republic (MINUSCA) depend on the route, so does the entire capital region. In the summer of 2015, 750 trucks became stranded between Douala and Bangui when drivers demanded additional security from MINUSCA (UNICEF, 2015), following the deaths of dozens of drivers at the hands of insurgents (Kindzeka & James, 2015). Similarly, the roads in the Vakaga region of CAR become unusable during the rainy seasons. During a period of inaccessibility in 2012, the World Food Program and UNHAS were obliged to conduct expensive airdrop operations to deliver hundreds of tons of food into dozens of locations in the region (Stephenson, 2012; World Food Programme, 2016).

At least notionally, airships could mitigate many of the operational challenges of these kinds of transportation challenges. For a large camp of over 100,000 people in a remote location with unfriendly militia units in the area, a fleet of moderate-sized, Vertical Take-off and Landing (VTOL) LTAs offer advantages over vehicle convoy and airplane transportation modes. Given an approximately 100-ton daily throughput required for food, medicines, shelter materials, etc., a set of seven to eight 10-ton-capacity aircraft operating at 140 kph over 500 kilometers could be the main transportation means, presuming weather or other factors permitted each to fly two sorties per day. Alternately, a smaller fleet of larger aircraft could offer advantages in personnel and operating costs. Reliable support from such a fleet also could allow the U.N. and other NGOs to move some of their key support infrastructure (hospitals, etc.) and even some of the camp's most vulnerable people — parents with small children, the sick and injured, and so on — rearward to more secure and more easily supported camps. From some sea-ports, this LTA fleet would also allow direct ship-to-camp transfers that would further increase the security and reduce the costs of the movements.

Conclusion

This study asks whether the United Nations should take steps in the near future to exploit the operational characteristics of LTA aircraft in support of its peace and humanitarian operations. In addressing that question, the study suggests that airships offer potential or demonstrated advantages over HTA aircraft, particularly in the realms of operational economies, endurance, load flexibility, and their ability to operate into undeveloped infrastructures. But they also come with some nagging operational drawbacks, most importantly related to weather and controllability. Technologically, the airship industry remains largely developmental, but may be on the cusp of fielding viable systems of relevance to U.N. needs. Given the U.N.'s continuing need to sustain robust airflows into remote regions, therefore, this study suggests that the world organization take steps to stay abreast of airship developments and possibly experiment with airship operations on a small scale, as proven designs become available.

From this point, the U.N.'s engagement with airships should take several steps. First, the U.N. and UNHAS should be cognizant of the airship industry on behalf of the U.N. operations and humanitarian organizations in general. Second, when a proven system becomes available, the U.N. should take the modest risk of integrating it into a specific humanitarian operation where an airship's operational characteristics would be valuable and could be tested. Most likely, such a pilot project should be based on an airship of modest size, perhaps of only a few tons capacity over ranges of a few hundred miles. The operations of such a ship would illuminate most of the operational advantages and disadvantages of airship logistics likely to characterize even much larger ships. Then, if the industry progresses to provide proofs of success by larger ships in sustained operations, the U.N. should seek contractual partnerships with appropriate operators, before eventually acquiring a small fleet of LTAs. The timeline for taking these steps will be dependent on the pace of airship technology and commercial development. But now is the time to start watching those developments and making contacts with industry. The opportunity to experiment with actual operations may come sooner than the current state of the industry might now suggest.

References

Airships in the Arctic. (2016, June 9). *The Economist*. Retrieved from https://www.economist.com/news/americas/21700417-dirigibles-are-being-floated-future-mules-great-white-north-airships-arctic

Andan, A., Asrar, W., & Omar, A. (2012, March-April). Investigation of aerodynamic parameters of a hybrid airship. *Journal of Aircraft, 49*(2), 658-662. doi:10:2514/1.C031491

Boettger, B. (2017, April 24). Kenai-based airship may arrive in 2019. Retrieved from http://peninsulaclarion.com/news/2017-04-24/kenai-based-airship-may-arrive-2019

Brewer, G. (1991). *Hydrogen aircraft technology*. Boca Raton, FL: CRC Press.

Dorn, A. W. (ed.). (2014). *Air Power in UN Operations: Wings for Peace.* Burlington, VT: Ashgate Publishing. Retreived from http://www.unairpower.net

Ghanmi, A., & Sokri, A. (2010, January). *Airships for military logistics heavy lift* (Canada, Defence R&D, Centre for Operational Research and Analysis). Ottawa, ON: National Defence.

Haque, A. U., Asrar, W. A., Omar, A. A., & Suleiman, E. (2016). Wind tunnel testing on a generic model of a hybrid lifting hull. *Journal of Aerospace Technology and Management, 8*(4), 467-474. https://doi.org/10.5028/jatm.v8i4.645

Hybrid Enterprises. (2017). Hybrid Airships. Retrieved from http://hybridhe.com/hybrid-airship

Johnson, A., & Arthur, D. (2011). *Recent development efforts for military airships.* Washington, DC: Congress of the United States, Congressional Budget Office.

Khoury, G. A. (2012). *Airship technology*. New York, NY: Cambridge University Press.

Kindzeka, M. E., & James, M. (2015, October 25). Supply Road to CAR Too Dangerous, Say Aid Drivers. *VOANews.com*. Retrieved from http://learningenglish.voanews.com/a/supply-road-to-car-too-dangerous-aid-drivers-say/3018741.html

Lockheed Martin Corporation. (2015). Hybrid Airship Product Card. Retrieved from https://www.lockheedmartin.com/us/products/HybridAirship.html

May, J. (2015, October 28). The Latest: Adrift military blimp had residents on edge. *U-Wire,* UWIR. Retrieved from https://www.apnews.com/b138a614c1eb4cf9a43ef8ed0debf801

McDaniel, M. L. (1990, February). Offensive uses of the naval airship. *U.S. Naval Institute Proceedings, 116*(2), 90.

Murphy, S. D. (2011). Up in the air: An airship solution for strategic lift? *Canadian Aerospace and Joint Studies*, 2, 97-134.

Novosseloff, A. (2017, October). Keeping Peace from Above: Air Assets in UN Peace Operations. International Peace Institute.

Owram, K. (2016, November 21). 'No roads, no problem': How blimps could help northern Quebec's miners overcome their infrastructure woes. *Financial Post.* Retrieved from http://business.financialpost.com/news/transportation/no-roads-no-problem-how-blimps-could-help-northern-quebecs-miners-overcome-their-infrastructure-woes

Prentice, B. E. (2016, Fall). The Role of the Airship in the New Low-Carbon Era. *The Shipper Advocate,* pp. 16-19.

Prentice, B. E., & Ahmed, S. (2017). Ground-Handling Systems for Cargo Airships. 52nd Annual Meeting Proceedings: *Canadian Transportation Research Forum*, Forthcoming.

Prentice, B. E., & Hochstetler, R. (2012, June 1). Transport Airships: Not Just Another Aircraft. 47th Annual Meeting Proceedings: *Canadian Transportation Research Forum.*

Prentice, B. E., & Knotts, R. (2016). Sustainable Transportation: Airships Versus Jet Airplanes. 51st Annual Meeting Proceedings: *Canadian Transportation Research Forum*, pp. 305-312.

Robinson, D. (1973). *Giants in the sky: A history of the rigid airship.* Seattle, WA: University of Washington Press.

Ryan, D. E., Jr. (1992). The Airship's Potential for Intertheater and Intratheater Airlift. Air University, United States Air Force. Retrieved from www.dtic.mil/get-tr-doc/pdf?AD=ADA425995

Sherwood, B., & Prentice, B. E. (2010). Airship logistics centres: The 6th mode of transportation. *45th Annual Meeting Proceedings: Canadian Transportation Research Forum, Toronto, ON*, 413-427.

Solarship. (2017). Mission: Peace and Freedom. Retrieved from https://www.solarship.com/mission

Stephenson, C. (2012, September 21). WFP airdrops food to isolated populations in CAR. *World Food Programme*. Retrieved from http://www.wfp.org/stories/wfp-airdrops-food-vulnerable-populations-car

Straightline Aviation and RAD-AID. (2016, September 12). Straightline Aviation and RAD-AID Sign Agreement to Launch Medical Hybrid Airship Program for Humanitarian Aid [Press release]. Retrieved from https://www.prnewswire.com/news-releases/straightline-aviation-and-rad-aid-sign-agreement-to-launch-medical-hybrid-airship-program-for-humanitarian-aid-593151491.html

UNICEF. (2015, September 8). Central African Republic Humanitarian Situation Report. Retrieved from https://www.unicef.org/appeals/files/UNICEF_CAR_Humanitarian_SitRep_August_2015.pdf

United Nations, Reports of the Secretary-General on the Situation in Mali, UN Docs. S/2016/281 of 28 March 2016 (para. 51) and S/2016/819 of 29 September 2016 (para. 63).

United States Department of the Army. (2011). *Rifle Marksmanship M16-/M4-Series Weapons* (FM 3-22.9). Washington, DC: Department of the Army.

United States Department of Commerce. (1937). Report of Airship "Hindenburg" Accident Investigation. Air Commerce Bulletin (2nd ed., Vol. 9). Washington, DC: United States Government Printing Office.

World Food Programme. (2016, September). Operational Snapshot January – June 2016. Retrieved from http://documents.wfp.org/stellent/groups/public/documents/communications/wfp287245.pdf?_ga=1.11853495.2036565037.1490924518

World Food Programme. (2017). UN Humanitarian Air Service. Retrieved from http://www1.wfp.org/unhas