Transportation and Logistics
Technology Reviews

- Unmanned aerial vehicles/drones
- Airships

Philippines, Mabalacat, Luzon
Microlite aircraft fly above a rift in the meters-thick layer of lahar ash that covers this area. The ash came from the Mt Pinatubo volcanic explosion two years earlier.

Credit: Chris Stowers – Panos

Unmanned aerial vehicles/Drones

What is the challenge or opportunity?

The proliferation of unmanned aerial vehicles (UAVs) – commonly known as drones – that are easy to use and low cost is leading to their widespread deployment in aerial inspection tasks, mapping physical and social phenomena, providing unmanned cargo deliveries, and taking aerial photography and video. There is a clear opportunity to transform the way development organisations collect and deliver data and physical objects, enabling these tasks to be undertaken faster, safer, cheaper, more efficiently and more accurately than ever before.

Over the coming decade, low-cost, commercially available drones could be used for a range of applications, disrupting industry landscapes as varied as agriculture, infrastructure management, policing, and transportation & logistics.

Drones as a frontier technology

The idea of computer-controlled or enabled flight is not new. The military has used unmanned aircraft since the 1970s to perform intelligence, surveillance and reconnaissance missions considered to be too dangerous, dull or dirty for human pilots. Since the mid-1980s, computers have been able to take over most aspects of flying commercial aircraft, including navigation, take-off and landing. Thanks to recent developments in a cluster of technologies including machine vision, sensors, actuators and batteries, UAVs have come into widespread commercial and personal use.

Over the coming decade, low-cost, commercially available drones could be used for a range of applications, disrupting industry landscapes as varied as agriculture – where drone-assisted monitoring could boost crop yields – infrastructure management, policing, and transportation and logistics. Sales of drones are booming in the consumer and commercial sectors; whose sales in the United states (US) they are expected to rise from 2.5m units in 2016 to 7m in 2020.[157]

The growing availability of these automated flying vehicles, which can operate over large spaces, with the capacity to gather and transmit high-quality data and carry lightweight cargo, is expected to have a huge impact on business. According to a projection by professional services firm PwC, by 2020 UAVs could replace business services and labour with a current value of $127bn, across a range of sectors from delivery and logistics to construction, agriculture, and assessing assets and insurance claims.[158]

Definition

A UAV is simply an aircraft without a human pilot on board. UAVs operate with various degrees of autonomy: either under remote control by a human operator using radio frequency or satellite remote network connections; or intermittently or fully controlled by on-board computers. UAVs emerged from military applications, but their use is now expanding in commercial, scientific, recreational and a whole host of other applications. In fact, civilian and commercial drones now vastly outnumber military drones, with estimates of over 4.3m sold globally in 2015. Civilian UAVs can be classified according to their size – ranging from mini-drones through to people-carrying drones – the altitude they can reach, and their range or autonomy.[159]

AfricanskyCAM uses multirotor UAVs to get high resolution video and imagery of news stories in real time as they unfold. Photo credit: AfricanskyCAM, www.africanskycam.com

UAVs can be divided into three main categories based on their flight mechanisms:[160]

• **Multirotor UAVs** – These may have four, six or eight rotors. They are capable of hovering in a fixed position and flying in any direction, carrying out manoeuvres quickly and efficiently. They can get airborne without a runway, but have slower maximum speeds, and shorter flight times, than fixed-wing drones.[161]

Zipline uses low-cost fixed-wing drones to deliver medicine, vaccines, blood and small medical supplies in Rwanda.
Photo credit: Zipline, http://flyzipline.com/product

- **Fixed-wing UAVs** – These have a simpler structure than other UAVs, similar to an aeroplane. They can fly for longer, and at higher speeds, and thus can be used to survey cover larger areas. They are able to carry heavier payloads over longer distances by using less fuel and energy. As a result, they can carry bigger and better sensors and cameras. Fixed-wing UAVs need a runway or launcher to take off and land, and must stay in constant forward motion.[162] Zipline is a delivery company working across a number of African countries, most prominently in Rwanda, that uses low-cost fixed-wing drones to deliver medicine, vaccines, blood and small medical supplies.[163]

- **Hybrid model (tilt-wing)** – These drones are able to hover but can also transition to faster and more efficient fixed-wing flight.[164] They offer some of the best features of the other two types. The number of tilt-wing drones on the market is low at the moment, but companies including Amazon are working on new models, particularly for delivery applications.[165]

Potential for acceleration

Civilian UAVs have come a long way since unmanned helicopters were used for the first time in Japan at the beginning of the 1980s, and proved to be an efficient way to spray pesticides on rice fields. Drone technology can now be considered a mature, if fast-evolving, technology. Developments in UAVs' underlying technologies are helping to drive improvements in their performance and capacities; these include image processing, chips, artificial intelligence, improved control and communications, battery capacity, and drone detection and avoidance technologies. The overall market is booming, and further price falls are likely to accelerate the trend towards ever-greater capabilities.

Shipments of consumer drones will more than quadruple over the next five years, fuelled by increasing price competition and new technologies.

While the military sector is expected to continue to lead the way in drone-related spending in the coming 5–10 years, this is due to military drones' high cost and the growing number of countries willing to acquire them for military purposes. According to PwC, shipments of consumer drones will more than quadruple over the next five years, fuelled by increasing price competition and new technologies.[166] Regarding commercial use of drones, the main challenge has been regulatory issues, which limit the use of commercial drones to a select few industries and applications, and to specific geographies. However, the accelerating pace of drone adoption is pushing governments to create new regulations and find new ways of balancing safety and innovation. As a result of these legal developments, growth in shipments and revenues in the enterprise sector are expected to outpace the consumer sector.[167]

Drone technologies are most likely to be used in and transform sectors that require mobility and high-quality data. Businesses that manage assets dispersed over wide regions (such as large-scale capital projects), infrastructure maintenance and agriculture, could benefit greatly from the integration of drones into day-to-day business. Insurance and mining will find potential process improvements as they gain new levels of data quality and accessibility; and the entire transportation industry could evolve its approach to last-mile delivery through the use of networks of drones.

Potential value generation and impacts

UAVs are expected to generate immense value among many industries and public services. A non-exhaustive list of sectors where drones generate considerable value and impacts includes:

• **Infrastructure** – For example, in inspection of power lines and pipelines;

• **Transport** – AfroTech plans to use drones to deliver blood transplants/samples and medical supplies;[168]

• **Insurance** – Over US 100 firms have received regulatory approval for using drones in inspections and surveys, enabling improvements in risk assessment, risk management, loss control and surety;[169]

• **Media and entertainment** – African SkyCAM uses drones to get aerial footage for journalists in hard-to-reach areas, replacing the need to use expensive helicopters;[170]

• **Agriculture** – For crop and land surveying; SenseFly supplies drones for precision agriculture;[171]

• **Security** – For reconnaissance missions, border patrols, surveillance, crowd monitoring; the TIRAMISU project uses drones to spot landmines;[172]

• **Wildlife and environmental monitoring** – Including poacher tracking, pollution monitoring (e.g. illegal landfill detection);

• **Mining** – For example, RocketMine provides mining companies in South Africa with low-cost survey and mapping services;[173] and

• **Disaster management** – Including forest fire detection, landslide measurement, post-disaster surveys and targeted disaster response.

Compelling UAVs innovations have focused on humanitarian efforts. After the 2015 earthquake, Kathmandu Flying Labs brought together Nepali UAV experts and a global network of crisis-mapping specialists to generate and analyse images of earthquake affected areas.

UAVs could clearly become an important tool for international development, as many of the above applications have considerable potential. In developing countries, for example, drones can provide value for actors who are constrained by a lack of proper transportation infrastructure and under-developed basic services. The improved data collection capacity that drones provide and their agile payload delivery functions are useful, and could lead to rapid and dramatic gains in efficiency and productivity in key areas of public service delivery.

In Africa, Ghana, Rwanda and South Africa and Ghana have taken a lead and shown a clear commitment towards establishing ICT infrastructure and commercial drone use, for example by implementing new regulatory frameworks.

In Africa, Ghana, Rwanda and South Africa and Ghana have taken a lead and shown a clear commitment towards establishing ICT infrastructure and commercial drone use.[174] They have implemented, for example, modern regulatory frameworks for commercial UAV's, something especially noteworthy when compared with the relative regulatory hesitancy in the US and most European countries.[175] Thanks to this movement, these countries are increasingly becoming testbeds for commercial drone services and new UAV delivery businesses. For example, RocketMine provides miners, farmers, civil engineers, and water and forestry companies in South Africa with low-cost survey and mapping services.[176] Flying Donkey and RedLine seek to create a cargo delivery network in Africa to overcome logistical constraints in humanitarian aid and health.[177]

UAVs also have considerable potential in disaster relief, in everything from mapping disaster-affected areas to delivering of emergency supplies. Some compelling innovations in the field of international cooperation on UAVs have focused on humanitarian efforts, such as the Kathmandu Flying Labs, which following the 2015 earthquake brought together Nepali UAV experts and a global network of crisis-mapping specialists to generate and analyse images of earthquake-affected areas.

Drone delivery of urgently needed medical supplies, such as medicine or blood, to inaccessible places makes it possible to avoid logistical problems related to road transport conditions altogether.

Potential benefits for development

UAVs offer opportunities to improve tasks that development organisations have historically performed, by doing them faster, cheaper, more safely, more efficiently or more accurately than before. But drones also increasingly offer the possibility to rethink how things are done, and provide new types of dynamic and adaptive processes for the delivery of public services.

Medical payload delivery services in emergencies provide a clear example. Drone delivery of urgently needed medical supplies, such as medicine or blood, to inaccessible places makes it possible to avoid logistical problems related to road transport conditions altogether. But to achieve real change, the whole system should be rethought; for example, by training community health workers who visit small villages and determine local demand for basic needs such as vaccines, nutritional supplements and antibiotics. They could communicate the demand to regional distribution centres via SMS (text message) and arrange for their delivery to remote points of care.[178] This is a model that Zipline provides in Rwanda, in cooperation with the government.[179]

A great deal of drone-based experimentation has been taking place in various sectors that have a focus on developing countries. While most of these projects have operated at small scale, and have had varying levels of success, they provide a useful indication of the potential of the technology. UAVs have been used in:

- Transporting medical supplies (medicines, samples, blood);[180]
- Spotting landmines;[181]
- Search and rescue operations for migrants in the Mediterranean;[182]
- Drone journalism;[183]
- Crisis mapping and disaster preparedness;[184]
- Conservation and poaching prevention;[185]
- Supporting UN peace-keeping missions;[186] and
- Agricultural analysis.[187]

Enablers and barriers

Despite the growth in the commercial and personal use of drones, several enablers and barriers that might serve to either facilitate or slow down the wider adoption of the technology. Some of these issues and drivers are technical in nature; others relate more to regulatory frameworks.[188]

Regulatory frameworks

Regulatory frameworks are the key factor affecting the pace of adoption of UAVs by businesses and government units. National and international aviation authorities have started developing frameworks to guarantee safe drone operation, while allowing innovation to continue. Once regulatory frameworks have been established, many more companies may decide to adopt drone-based solutions.

Companies have been using satellites, planes and helicopters to gather photogrammetry and geospatial data for many years. However, drones are much more cost effective and guarantee higher data quality.

Growing demand for high-quality data

Companies have been using satellites, planes and helicopters to gather photogrammetry and geospatial data for many years. These kind of images are very expensive and do not provide the best level of detail and quality. Drones are much more cost effective and guarantee higher data quality. Growing demand for data will increase the use of drones for commercial purposes, displacing manned aviation and satellites.

Enhancing data processing and accessibility

Data acquired during drone operations has to be processed to deliver substantial benefits for businesses. Data accessibility is going to be one of the key drivers that fuels adoption of drone technologies in business processes. This is also connected with the trend of simplifying and automating the use of drones. Another example may be the development of autonomous

flight control systems, enabling businesses to automatically operate whole fleets of drones on various kinds of missions.

New technological opportunities

Drones are composed of many technologically advanced parts that determine their efficiency, safety and reliability. Constant improvements in hardware solutions and decreasing prices will contribute to the rising number of possible drone applications. Technological breakthroughs – especially in the areas of hardware, software and data processing – will drive the growth of drone applications. The development of new types of power sources, engines and structural materials will affect the drone market's potential.

Constant improvements in hardware solutions and decreasing prices will contribute to the rising number of possible drone applications.

Drone manufacturers are working to implement autonomous avoidance, to stop them crashing into other flying objects, and automatic take-off and landing systems.

Safety of drone operations

The most urgent challenge that national aviation authorities and the private sector have to face is ensuring secure supervision of recreational and commercial drone operations. One part of a secure supervision system will be mandatory drone registration, allowing authorities to identify drone pilots who break the law. Additionally, there is a need for air traffic management systems for UAVs to prevent collisions with other flying objects. Technologies such as collision avoidance will make flying drones safer and give regulators the confidence to allow larger numbers of drones taking to the skies.[189]

Privacy and trust issues

When UAVs fly over certain types of sites, they can collect large amounts of data, potentially including confidential or sensitive information about private property or behaviour. Given the very broad definition of personal data, it is not clear how companies should store this data, what types of data should not be collected, or how individuals and companies can defend their privacy rights. Market growth increases the pressure to regulate this area, although it will take time to prepare and pass legislation. In some developing countries drones have been used for military operations, including surveillance and to attack military targets including people and

infrastructure; it has been widely reported that many civilians have also been injured or killed in such attacks. In these contexts, much more resistance and mistrust to programmes using drones should be expected.

Insurance coverage availability

In most countries, regulators oblige aircraft users to have insurance to meet their liabilities in case of accidents. The laws governing UAV operators are still evolving, and insurance will need to become part of the regulatory framework, to provide coverage in case of physical losses or liabilities during and after drone operations. Drone manufacturers and insurers are starting to offer these services, enabling customers to overcome one of the barriers to commercial use.

What next for development sector actors?

Civilian attitudes and perspectives on drones vary widely and it is vital for development and humanitarian applications to be grounded in – and to build on – national and local interests and needs.

- **Regulatory and procedural frameworks** – Such frameworks are necessary for the use of drones in situations that are neither commercial nor personal, but instead relate to delivery of public services or other forms of socio-economic support. At present, such regulatory aspects are ambiguous or non-existent in relation to issues such as accidents, security and privacy. Where guidelines or codes exist – such as the UAViators Code of Conduct – they are not always applied 'with teeth', but are instead voluntary in nature.

- **Better assessment and evaluation of drone pilot programmes** – Evidence of UAV efficacy and effectiveness is limited at present. Most initiatives have focused on what drones can offer, without assessing whether this has a positive impact or not.

- **More systematic learning** – It is important to have a better sense of the costs and benefits in different settings and in relation to different challenges.

- **Strengthening national and local capacity to test, learn, use and maintain drone technology** – Building on existing networks and initiatives, such capacities could be further strengthened through training, knowledge exchange, and mentoring of national and local actors. As well as capacity development, a concerted effort is needed to educate the general public about the pros and cons of drone technology use.

Airships

Airships require little or no infrastructure to land making them ideal for delivering goods and supplies to remote areas developing countries or areas inaccessible via conventional transport after natural disasters. Photo credit: VariaLift Airships, www.varialift.com

Modern airships have the potential to transport fully assembled goods, supplies, and even large structures from the point of manufacture directly to their point of use without the need to build any of the usual transportation infrastructure such as roads, railways, runways or airports.

What is the challenge or opportunity?

Some of the most remote areas in the world have long been unreachable using conventional transport. According to the World Bank Rural Access Index, over one billion people in rural areas lacked access to adequate transport systems and infrastructure in 2010.[190] Moreover, due to increasing numbers of disasters and crises, it is not possible to reach growing numbers of people on a temporary basis. A lack of, or heavy damage to, infrastructure makes it difficult to deliver essential goods, and supplies.

Airships as a frontier technology

A new generation of airships and hybrid aircraft are emerging that require little to no infrastructure, and which thereby hold the potential to meet the needs of people living in such settings and conditions. Conventional means of transport are limited in their ability to carry large quantities of cargo to these areas. Aeroplanes require too much infrastructure (e.g. roads and runways) that is often unavailable or inaccessible in these areas; and helicopters are limited in terms of range – not much more than 500 nautical miles even in extreme cases when they are not carrying much cargo – and their load carrying is also limited – the maximum amount is around 10 tons.

Definition

Airships, also often referred to as 'lighter than air' vehicles, are aircraft that are wholly or partially held aloft by a body of gas that is lighter than air (typically non-flammable helium). Hybrid aircraft are heavier than air, but get an advantage from combining buoyant lift from the gas with aerodynamic lift – the aerodynamic (or wing-shape) lift countering the weight of the aircraft. Airships have been around since the late nineteenth century, but newer versions of the technology have been developed that overcome many of the constraints that previously restricted their widespread adoption. Modern airships have the potential to transport fully assembled goods, supplies, and even large structures from the point of manufacture directly to their point of use without the need to build any of the usual transportation infrastructure such as roads, railways, runways or airports. Airships could be a game changer for communities living in areas that are permanently or temporarily inaccessible by more conventional means due to geographic remoteness or temporary factors, such as disasters or weather conditions.

Figure 9 Landing sites for conventional airships (Aeroscraft) and hybrid airships

LANDING SITE FOR THE AEROSCRAFT

LANDING SITE FOR HYBRID AIRSHIP
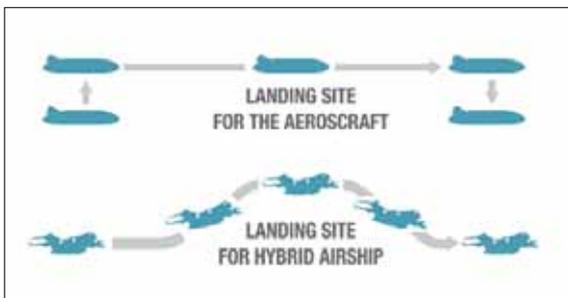
Source: Aeros (2016)[192]

There are two main types of airships: conventional and hybrid (see Figure 9). 'Conventional airships control heaviness by changing aerostatic (buoyant) lift and ballast' meaning they take off vertically. Hybrid airships combine characteristics of airships, helicopters and aeroplanes: 'Hybrid airships combine aerostatic (buoyant) lift with aerodynamic lift (wing-borne) and direct (propulsive) lift.'[191] Hybrid airships often have a vertical take-off capability, but normally use a more efficient standard horizontal rolling take-off. They can do this from a variety of flat(ish) surfaces, typically taking off within a body length or two.

Potential for acceleration

Airships have been around since the late 1800s,[193] and were the first air vehicles capable of controlled flight. They saw their heyday in the early twentieth century as the quickest form of long-haul travel. In the 1920s, airships were regarded as the first reliable form of intercontinental travel and the Graf Zeppelin model had circumnavigated the world by 1929. However, by the 1930s and 1940s, other modes of transport had overtaken airships: they were not capable of transporting as many passengers as quickly as airplanes; and could not carry as much cargo or freight as trains or ships. They were also susceptible to weather, difficult to manoeuvre, and required large operational teams on hand to assist during take-off and landing.[194] The decline of airships was accelerated by the high-profile crash of the Hindenburg in 1937, attributable to the flammable hydrogen gas that the first generation of airships used. The advent of jet aircraft confirmed airships literal and figurative decline from grace.[195]

Researchers at the Smith School of Enterprise and Environment project that airships will be able to carry up to nine times as much cargo as a Boeing 747.

Several companies seem to have overcome these structural hurdles and have found potential paths for future acceleration of the technology. Among them are Worldwide Aeros Corporation, Lockheed Martin and Hybrid Air Vehicles. Moreover, issues of safety have now been overcome with the use of non-flammable helium rather than hydrogen. Ballasts are no longer needed – at least in most scenarios – and take-off and landing is controlled by in effect gently sinking the aircraft to the ground because they are heavier than air so very few or no personnel are needed on the ground. Modern airships are getting to the stage now of being capable of loading and unloading cargo with far fewer personnel than other means of cargo transport. Although it has not yet demonstrated this capability, Aeros claims its Aeroscraft only requires one person – the pilot – to load and unload a payload.[196]

Airships provide the capability to move fully functional machinery and structures directly from where the machinery is made to where it will be used, decreasing the need to assemble it on site and thereby saving time and money for businesses and operations in in remote areas.

Moreover, modern airships are able to offer cargo bays that are far larger than the cargo space in other aircraft and are therefore capable of shipping bigger and heavier cargoes.[197] Additionally, given their lower speeds, airships and hybrids should be better able to carry outsize and underslung loads than other aircraft. Researchers at the Smith School of Enterprise and Environment project that airships will be able to carry up to nine times as much cargo as a Boeing 747. [198] The Aeroscraft ML868 is projected to be able to carry up to 250 tons of cargo, while the ML86x could carry up to 500 tons of cargo.[199] Hybrid Air Vehicles' Airlander 10 is now the largest flying aircraft in the world and can carry up to 10 tons of cargo; and the company already has plans to build the Airlander 50, which will be much larger and carry up to 50 tons of cargo, with designs also underway for a hybrid airship that will be able to carry up to 200 tons.[200]

Potential value generation and impacts

If successfully commercialised, airships could 'open trade and supply routes to regions lacking surface transportation infrastructure' and for industries and sectors including mining, oil exploration, energy installations and logging.[201]

In extractive industries such as mining and oil, airships provide the capacity to transport fully assembled heavy machinery such as tractors directly from the factory to mining sites and oil fields and other remote areas. A lot of large industrial infrastructure is required in remote areas, such as bridges, pipelines, power-line masts and mobile phone base stations, and airships could be invaluable in transporting these to their destinations and bringing in replacements when needed.

Airships could transport entire wind turbines directly to wind farms, a transportation process that typically requires up to eight stages using multiple transportation modes under current practices.[202] This is also good in environmental terms, because large swathes of forest or other areas can need levelling to create roads to get the wind turbines to their remote locations. More generally, airships provide the capability to move fully functional machinery and structures directly from where the machinery is made to where it will be used, decreasing the need to assemble it on site and thereby saving time and money for businesses and operations in in remote areas. They can also move raw materials out of remote areas after they have been extracted.

Airships require little infrastructure of even the most basic kind – paved ground or concrete are not always necessary – which allows them to take off from unconventional places. This is in marked contrast to planes, automobiles and trains that are largely reliant on airports, roads, and railways. As well as enabling physical delivery of materials, goods, supplies and infrastructure it also means airships are less likely to disrupt or affect the environment around take-off and landing sites. More widespread haulage of cargo via airships could help to decrease airport, road, and railway congestion, and because they fly at lower altitudes than airplanes, their widespread use is also anticipated to reduce air traffic congestion and related conflicts.[203]

Airships require little infrastructure of even the most basic kind – paved ground or concrete are not always necessary – which allows them to take off from unconventional places.

The Airlander 10 takes off for its maiden flight in Cardington Airfield in Bedfordshire, UK in 2016.
Photo credit: Hybrid Air Vehicles, www.hybridairvehicles.com

After delivering necessary supplies, airships can be used to evacuate injured or vulnerable people on outbound/return legs. Airships could also 'open trade and supply routes to regions lacking surface transportation infrastructure' including remote areas in Africa, Asia and polar regions.

Having been one of the biggest supporters and promoters of innovation in the sector, militaries are expected to be among the most prominent airship clients. For example, the US military funded the DARPA Walrus HULA (Hybrid Ultra Large Aircraft) project between 2008 and 2010 in hopes of building an aircraft with the capacity to carry up to 1,000 tons of cargo over distances up to 22,000km.[204] Aeros anticipates that its Aeroscraft models will be extensively used by militaries for resupply, humanitarian, medical and fire containment missions. Airships can reduce dependence on foreign airbases and ports, and provide the capability to transport entire tanks and other heavy weaponry directly to combat arenas.[205]

Aeros also claims that the Aeroscraft can be used as an air-deployed mobile hospital, fully equipped with operating rooms and emergency equipment, which could quickly enter and exit hostile environments. Hybrid Air Vehicles won a contract with the US Army to develop an unmanned (drone) airship for military surveillance that could stay in the air for 21 days at a time. This ultimately led to the creation of the Airlander 10, which is being developed under civil regulation and for manned operations.[206] Because airships can carry many tons of water and have the ability to fly at low speeds and hover, they are also seen as ideal for fighting forest fires.

Airships also hold promising applications for leisure and tourism. Hybrid Air Vehicle's hopes that the windowed lounge viewing deck of its Airlander 10 could be used for safaris, and other luxury tourism and sky-based cruises.[207] Aeros has proposed that its airships could soon be converted into sky cruisers and luxurious sky-yachts to directly compete with sea-based cruises. Potentially airships could also be used as an alternative mode of transport for customers travelling short distances.[208]

Airships could also relay WiFi and broadband signals to focused areas. Although similar in some ways to the technologies covered in the technology review on alternative internet delivery in this report, airship manufacturers have suggested that airships would be best suited to the localised provision of temporary internet and wireless services in specific geographic areas; for example, for large gatherings of people at big sports events or festivals, where existing network

Because airships can take off and land without the need for a runway, there is great potential for their use in responding to emergencies.

capacities may be overstretched. There would seem to be less scope for airships to be organised into wide-scale, permanent installations with the aim of reaching the digitally disconnected.

Leapfrogging infrastructure

Because airships can take off and land without the need for a runway, there is great potential for their use in responding to emergencies; for example, after tsunamis, earthquakes and other natural disasters when infrastructure has been destroyed and it is difficult to transport supplies by other means (see figure 10 for how airships might be positioned relative to other transportation types). Although not all airships take off vertically, the ones that do not are still generally able to take off from almost anywhere, given enough open space: while they take off at an angle, they do not require a road to get airborne. Emergency response missions are plagued by logistical challenges involved in transporting large quantities of goods using roads, ports, airports and railway systems that have typically been damaged and are under heavy strain due to excessive use. Increased demand places severe strain on local skills and capacities, escalating freight costs, and in the worst cases leading to logistical shutdowns; for example, as happened at Port-au-Prince Airport after the January 2010 earthquake in Haiti.[209]

Because they can transport goods, equipment and people directly from point of origin to point of delivery, airships can overcome these bottlenecks in emergency response. Some airships will be able to carry hundreds of tons of cargo, which might include basic relief supplies such as fuel, medicine, water, or anything else affected communities and disaster responders need.[210] Moreover, after delivering necessary supplies, airships can be used to evacuate injured or vulnerable people on outbound/return legs.[211]

Airships could also 'open trade and supply routes to regions lacking surface transportation infrastructure' including remote areas in Africa, Asia and polar regions. This could be especially useful for transportation to the poorest rural areas of developing countries, where there is a lack of adequate infrastructure and where there is low likelihood of this being addressed with short-to-medium term investments.[212] Airships also overcome the challenges of maintenance that often limit the sustainability and development impact of infrastructure investments in remote areas. Carey, Inderwildi, and King believe that:

> in less developed parts of the world, the need for expensive and carbon heavy infrastructure projects could be removed by fleets of

NASA has noted that airships could feasibly be entirely powered by renewable energy.

> "lorries in the sky" providing multi-drop capability, and connecting distant communities with international markets. This lack of infrastructure also appeals to aid agencies, which see airships as a possible method of delivering significant levels of supplies… quickly, and at much lower cost, than current multimodal methods.[213]

The potential is not limited to developing countries. NASA analysis suggests that Alaska and northern Canada may be among the best initial markets for airships.[214] Around 82 per cent of Alaskan communities are not currently served by a road network, while the whole of

Figure 10 Positioning of airships
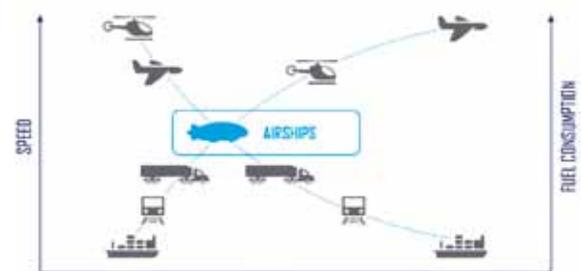
Source: Lockheed Martin (2016) [222]

northern Canada has very sparse transportation networks. The ability for airships to take off and land just about anywhere makes them an attractive alternative to building infrastructure in these areas to meet the needs of remote communities.[215] Montreal-based company LTA (Lighter Than Air) Aerostructures plans to build airships capable of transporting pre-fabricated houses to solve the indigenous population's housing crisis in the north.[216] This is part of a broader interest across Canada, with the national House of Commons calling in 2016 for airships to be trialled in service delivery to remote indigenous communities.[217] Because of the similar bottlenecks and opportunities that exist for communities in developing countries, companies that perform successfully in tests could have a large number of potentially lucrative markets to tap into globally.

Airships are less physically damaging to the environment than conventional aircraft because they do not require the construction of runways and their engines make much less noise.

Greener transportation

Although most airships in operation today are partially powered by diesel engines, they are much less polluting that conventional means of transportation. Researchers at the Smith School of Enterprise and Environment estimate that that the transport of a load of cargo of 220 tons would emit only 4.2 tons of carbon dioxide (CO_2) emissions compared to 42 tons over the same distance by a typical jet plane.[218] They are also more fuel efficient, requiring one-third of the fuel of cargo planes and one-tenth of the fuel of helicopters to haul the same amount of cargo over the same distance.[219] This enhances their environmental credentials and also offers potential operational cost savings.[220] Beyond fuel costs, Aeros claims its aircrafts require one-third of the acquisition and maintenance costs of other air-based cargo transport methods.[221]

Because of the lack of constraints in terms of the size and shape of the payload module, airships and hybrids are likely to be early adopters of electric engines – they will be able to carry the weight and size of batteries to make them workable. Hybrid Air Vehicles is part of a UK government programme looking into 'More Electric Aircraft', which proposes an airship design with two electric engines at the front and two diesel ones at the back. This will make it easier to negotiate regulatory hurdles and ensures there is sufficient power on take-off, when the four engines are needed.

Governments have played an active 'entrepreneurial state' role in the development and advancement of airship technologies to their current position.

This is seen as a first step to an all-electric aircraft, which could ultimately be powered by a thin film of solar panels that would cover the entire upper side of the hull. A technical memorandum by NASA has noted that airships could feasibly be entirely powered by renewable energy. Solar- and wireless microwave-powered airships have already shown promising results in prototyping efforts, and more pilots are under way to test other sources of renewable energy.[223] Moreover, as mentioned above airships are less physically damaging to the environment because they do not require the construction of runways and their engines make much less noise.

Such factors have led NASA to declare airships to be 'the most environmentally responsible transport technology',[224] with the wider dissemination of airships having the potential to make the global logistics and freight sector far more environmentally friendly.

Enablers and barriers

Thanks to determined efforts made to overcome the technological and safety issues of previous generations of airships, a number of obvious markets have emerged for airships in hard-to-reach areas with little – or damaged – infrastructure. Where airships can be more economical than conventional shipping and transport methods it is expected that early adopters such as the military will start to use them in growing numbers.[225] As already noted, airships can potentially leapfrog the need to build airport and other infrastructure to transport goods.[226]

Airships are becoming increasingly flexible in terms of when, where and how they are deployed. Some airships, such as the Airlander 10, can land on or hover over land, water and ice. Others do not need to land to make deliveries, and can operate at low speed, hovering in the air while picking up and dropping off goods, equipment and personnel.

The airship market has been estimated by industry experts to grow to $50bn over the next 20 years, with more than 500 airships expected to be in operation by 2036.[227] Lockheed Martin signed a non-legally binding letter of intent with Sraightline Aviation in early 2016 to deliver 12 airships at an order value of $480m. Straightline Aviation plans to use them to deliver cargo to remote and hard-to-reach areas that lack adequate infrastructure.[228]

Governments have played an active 'entrepreneurial state' role in the development and advancement of airship technologies to their current position. The US military committed $300m to Hybrid Air Vehicles in 2001, with a further $90m for intellectual property rights, but the investments have been plagued by slow development and spending cuts. After a successful test flight in 2012, Hybrid Air Vehicles was able to buy back its patents.[229]

Although the US military has not continued to fund the venture, past backing for over a decade as well as grants from the UK government have played a role in Hybrid Air Vehicles' being able to claim that its technology is years ahead of its competitors.[230] Further use of airships by militaries after the new generation of airships is commercialised is likely to spur more research and development investments, with strong potential for the development of airships that cross over into the consumer and international development spheres.

However, although airships have been proposed for passenger flights, they are too slow to compete with fixed-wing aircraft across continents or large distances. For example, the fastest model currently in development is the Airlander 10, which travels at about at a speed of 148 km per hour.[231] They would most likely be best suited for flights over relatively short distances

where infrastructure constraints do not allow faster transportation methods. More generally, they should not be viewed as alternatives/replacements for existing modes of transport, but as a means of extending existing infrastructure into remote and inaccessible areas. One industry expert notes that the most probable market for short-haul flights may be sightseeing trips and experience flights.[232]

The emerging reliance of airships on helium comes in the context of growing demand for helium for a wide range of medical,[233] high-tech, military, and space applications, resulting in increased prices for the gas. Although there have been concerns over a potential shortage of helium,[234, 235] these fears may prove to be misplaced. As with fossil fuels, helium is a finite resource. However, the current supply is expected to continue as long as natural gas is being drilled. There have been a number of reports of helium shortages in the near term, but most helium – captured in natural gas wells – is simply released into the atmosphere. As the supply–demand curve balances, more helium will be captured. In 2014 the US government estimated that there were sufficient helium reserves for 177 years. Moreover, in June 2016, using methods similar to oil exploration, scientists discovered a rich helium reserve in Tanzania, which they estimated contains approximately seven times the annual global helium demand.[236]

Hybrid Air Vehicles Head of Partnerships Chris Daniels estimates that there are currently 20 true airships flying and only about 12 are in service at any time. Moreover, the airships currently in commission are mostly older-generation airships (blimps) used for advertising, research and surveillance.[237] Most of the new-generation airships mentioned above are merely prototypes and not yet fully operational or commercial, and there have been some issues with testing of new models. If demand increases, it is unclear how prepared manufacturers will be to scale up production.

No airships exist that are devoted to emergency response, nor have any been deployed for such missions. It is unclear if current models of airships would meet the needs of humanitarian organisations or emergency response missions. Such an airship could require a tailored design that could be costly and take a long time to design and build. Little dialogue has taken place between airship manufacturers and humanitarian aid organisations, although there is no reason this could not change.[238]

Airships should not be viewed as alternatives or replacements for existing modes of transport, but as a means of extending existing infrastructure into remote and inaccessible areas.

The Canadian government's support for airships to address very similar challenges to those found in developing countries is good news for development organisations. Rather than starting from scratch, development organisations could collaborate with the Canadian government to learn from its experience and share findings.

The airship has been seen as 'the technology of the future' since the nineteenth century, but has never quite managed to achieve its potential. Many ventures have tried to revive the industry since its high-profile decline but have resulted in failure. The most recent example was Cargolifter AG, based in Germany, which went bankrupt in 2002 after attracting hundreds of millions of dollars from investors.[239] Time will tell if today's technologies and ventures will be able to turn the current interest – and hype – into commercially viable businesses. A good number of investors seem to think so; an example of the public interest was the Airlander 10 crowdfunding campaign in 2016, which raised more than £3.5m over two rounds.[240]

What next for development sector actors?

• **Demonstration projects and pilots** – Airship manufacturers could undertake tests in areas and under conditions similar to those encountered during emergency response missions, which could be very useful to help test their merit in such contexts. These could be incentivised and brokered through challenge funds and other mechanisms. The Canadian government's support for airships to address very similar challenges to those found in developing countries is good news for development organisations. Rather than starting from scratch, development organisations could collaborate with the Canadian government to learn from its experience and share findings.

• **Cross-organisational engagement** – Along with engagement with the private sector, this could help determine whether current airship models are appropriate to address challenges in development and humanitarian settings. Test runs may be worth exploring, as well as identification of specific development and humanitarian opportunities where existing infrastructure does not meet organisational or community needs.

• **Funding for airship initiatives** – Projects that seek to use airships to reach remote communities are likely to require public or donor support. Even more than the other technologies covered in this report, the use of airship technology has not yet been proved and governments may be hesitant to put scarce taxpayer money into it just yet. Development organisations and innovation funds could invest in small-scale exploratory research projects, and a compelling case could be made for funding research to better understand the challenges and opportunities for airships in development.

157 FAA (2016) *Aerospace Forecast Report. Fiscal Years 2016 to 2036*, Federal Aviation Administration

158 Mazur, M, *et al.* (2016) *Clarity from above. PwC global report on the commercial applications of drone technology,* May, PwC

159 See Technology Reviews Part 2: Connectivity – Alternative internet delivery for more details.

160 Australian UAV (2016) *Types of Drones: Multi-Rotor vs Fixed-Wing vs Single Rotor vs Hybrid VTOL – AUAV,* www.auav.com.au/articles/drone-types/

161 http://uavamerica.com/

162 http://arc.aiaa.org/doi/abs/10.2514/1.8371

163 http://flyzipline.com/product/

164 http://people.sabanciuniv.edu/munel/Publications/JournalPapers/Mechatronics-2012.pdf

165 www.amazon.com/b?node=8037720011

166 http://www.pwc.pl/pl/pdf/clarity-from-above-pwc.pdf

167 Camhi, J (2016) T*he Drones Report. Market Forecasts, Key Players and Use Cases, and Regulatory Barriers to the Proliferation of Drones*, BI Intelligence

168 http://afrotech.epfl.ch/page-115280-en.html/

169 www.riskandinsurance.com/insurers-flying-high/

170 www.africanskycam.com/?pagerd_76q9ca/

171 www.sensefly.com/applications/agriculture.html/

172 www.microdrones.com/en/news/detail/after-the-flooding-drones-search-for-land-mines-indisaster-areas/

173 Mazur *et al.* (2016) *Clarity from above*

174 Bright, J (2016) 'Africa's Commercial Drones Take Off', *TechCrunch*, March

175 Bright, J (2016) 'Africa Is Becoming a Testbed for Commercial Drone Services', *TechCrunch*, May

176 www.rocketmine.com

177 www.flyingdonkey.org; www.aeroshuttergh.com

178 Schroeder, A and Meier, P (2016) 'Automation for the People: Opportunities and Challenges of Humanitarian Robotics', *Humanitarian Exchange Magazine* 66

179 Stewart, J (2016) 'This Startup Wants to Use Drones to Drop Blood, Not Bombs', WIRED, 9 May

180 http://afrotech.epfl.ch/page-115280-en.html; https://mttr.net; http://flyzipline.com

181 Irwin, A (2016) 'View on Disability: Inventive Ways to Clear Landmines' *SciDev.Net*, 10 March

182 Mathers, I (2014) 'View on Migration: Drone Searches Aid Refugee Rescues', *SciDev.Net*, 11 December

183 Holton, A, *et al.* (2015) 'Unmanned Aerial Vehicles. Opportunities, barriers, and the future of drone journalism', *Journalism Practice* 9, no. 5

184 https://irevolutions.org/category/crisis-mapping

185 Raxter, P, and Young, R (2015) 'Drones Can Curb Poaching, But They're Much Costlier Than Alternatives', *National Geographic*, 23 May

186 Sandvik, K and Lohne, K (2014) 'The Rise of the Humanitarian Drone: Giving Content to an Emerging Concept', *Millennium – Journal of International Studies*, 43, no. 1

187 van Vark, C (2015) 'Drones set to give global farming a makeover', *Guardian*, 26 December

188 Mazur *et al.* (2016) *Clarity from above*

189 Camhi, J (2016) 'The Drones Report. Market Forecasts, Key Players and Use Cases, and Regulatory Barriers to the Proliferation of Drones', *BI Intelligence*

190 World Bank (2010) *Rural Access Index (RAI)* – Data, http://data.worldbank.org/datacatalog/rural-access-index

191 NASA (2014) *Airships 101: Rediscovering the Potential of Lighter-Than-Air (LTA)*, p.21, http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120010650.pdf

192 Aeros (2016), *Capabilities copy*, http://aeroscraft.com/capabilities-copy/4580476906

193 Encyclopedia.com (2016) *Airships Facts, information, pictures – Encyclopedia.com articles about Airships*, www.encyclopedia.com/topic/Airships.aspx

194 Fernholz, T (2013), '76 years after the Hindenburg, can airships make an industrial comeback?', Quartz, http://qz.com/158611/76-years-after-hindenburg-can-airships-make-anindustrial-comeback/

195 Carey, C, Inderwildi, O and King, D (2009) 'Just Hot Air? The Development of Lighter-than-Aircraft and their possible impact', *Aviation and the Environment*, 10, pp.33–7

196 Aeroscraft.com (2016) *Capabilities copy*

197 *Ibid*.

198 Carey, Inderwildi and King (2009) 'Just Hot Air?'

199 Aeroscraft.com (2016) *Commercial applications*, http://aeroscraft.com/applications/4580412718

200 Neild, B, and Delgrossi, S (2016) 'World's largest aircraft readies for takeoff', CNN.com, http://edition.cnn.com/2016/03/23/aviation/airlander-10-worlds-biggest-aircraft/

201 NASA (2014) *Airships 101)*

202 Aeroscraft.com (2016), *Commercial applications*

203 NASA (2014) *Airships 101)*

204 Congress of the United States Congressional Budget Office (2011) *Recent Development Efforts for Military Airships*, www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/11-01-Airships.pdf

205 Aeroscraft.com (2016) *Military applications*, http://aeroscraft.com/applications/4580412718

206 *Ibid*.

207 Neild and Delgrossi (2016) 'World's largest aircraft readies for takeoff'

208 NASA (2014) *Airships 101)*

209 Guy, D (2014) T*he logistics of international emergency relief: are airships the solution?*, ODI HPN, http://odihpn.org/blog/the-logistics-of-international-emergency-relief-are-airships-the-solution/

210 Aeroscraft.com (2016) *Military applications*

211 Hybrid Air Vehicles (2016) *Rapid Recovery Unit (RRU) Countering Natural Disaster through the Innovation Inspired by Industry Partnerships*

212 NASA (2014) *Airships 101)*

213 Carey, Inderwildi and King (2009) 'Just Hot Air?', p.37

214 https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120010650.pdf

215 NASA (2014) *Airships 101*

216 Rukavina, S (2016) 'Could giant blimps help solve the Indigenous housing crisis? A Montreal company thinks so', CBC.ca, www.cbc.ca/news/canada/montreal/montreal-blimps-housing-crisis-1.3576706

217 *Canadian Press* (2016) 'Test airships for remote communities, MPs say', CBC.ca www.cbc.ca/news/canada/north/test-airships-for-remote-communities-mps-say-1.1376853

218 Carey, Inderwildi and King (2009) 'Just Hot Air?', p.37

219 Fernholz (2013) '76 years after the Hindenburg'

220 Guy, D (2014) *The logistics of international emergency relief: Are airships the solution?*

221 Aeroscraft.com (2016) *Military applications*

222 Lockheed Martin (2016) *Hybrid Airship: Revolutionizing Remote Transportation*, www.lockheedmartin.co.uk/us/products/HybridAirship.html

223 Skuza, J, Park, Y, Kim, H and Seaman, S (2014) 'Feasibility Study of Cargo Airship Transportation Systems Powered by New Green Energy Technologies', *NASA Technical Report*, 218241.

224 *Ibid*.

225 Fernholz (2013) '76 years after the Hindenburg'

226 Hybrid Air Vehicles (2016), *Airlander: The Future of Aviation has Arrived*, www.youtube.com/watch?v=1ZMz8ga1_vs

227 *Ibid*.

228 Dillow, C (2016), 'Lockheed Finally Inks $480 Million Deal for its Cargo-Hauling Hybrid Airship', *Fortune*, http://fortune.com/2016/03/30/lockheed-inks-480-million-deal-for-airships/

229 Barrie, J (2016) 'Iron Maiden's Bruce Dickinson has an insanely ambitious plan to bring huge Zeppelins back to the skies', *Business Insider*, http://uk.businessinsider.com/iron-maidenzeppelins-airlander-10-2015-4

230 www.hybridairvehicles.com/news-and-media/news/project-spotlight-hybrid-air-vehicles

231 Hybrid Air Vehicles (2016), Hybrid Air Vehicles – *Project spotlight: Hybrid Air Vehicles*, www.hybridairvehicles.com/news-and-media/news/project-spotlight-hybrid-air-vehicles

232 Daniels, C (pers. comm. 2016)

233 Mainly for use in magnetic resonance imaging (MRI) scanners.

234 Fernholz (2013) '76 years after the Hindenburg'

235 Mirani, L (2013) 'As if the debt ceiling weren't enough, US Congress has to deal with the looming helium ceiling', *Quartz*, http://qz.com/126076/as-if-the-debt-ceiling-wasnt-enoughcongress-has-to-deal-with-the-looming-helium-ceiling/

236 Cole, B (2016) 'That Dire Helium Shortage? Vastly Inflated', *WIRED*, www.wired.com/2016/06/dire-helium-shortage-vastly-inflated/

237 Csomor, M (2016) 'Man seeks to stage around-the-world blimp race', CNN.com, http://edition.cnn.com/2012/08/17/tech/innovation/world-blimp-race/

238 Guy, D (2014) *The logistics of international emergency relief: Are airships the solution*

239 Dillow (2016) 'Lockheed Finally Inks $480 Million Deal'

240 Crowdcube (2016) *Hybrid Air Vehicles Raising £2,000,000 Investment On Crowdcube. Capital At Risk*, www.crowdcube.com/investment/hybrid-air-vehicles-18450