Solar Energy and Battery Development for Unmanned Aerial Vehicles: Leading to Increased Proliferation?

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ABSTRACT

In recent decades, research into energy production and battery technologies in the space, military and civil industries have taken huge strides. These advances have sparked new ideas and innovations in defence industries and militaries around the world. This article focuses on how technological advances in solar and battery power create opportunities for the research and development of unmanned aerial vehicles (UAVs). It draws on how some technologies help militaries overcome strategic and political obstacles. It focuses on the development of the Zephyr solar UAV, as representative of the technologies that magnify the positive and negative implications of UAV use for military and commercial purposes. The article concludes that as solar and battery technologies get cheaper, this may lead to increased proliferation of UAVs, since the operational cost of solar UAVs is less than their fuel-driven counterparts and offer unique and superior capabilities. While battery energy density has a long way to go match fossil fuel power, if energy density can double, then it would be possible to see electric jet-sized planes in the 2020s. However, solar UAV development may magnify the security, political and judicial dilemmas that already exist with UAV use.

Keywords: solar, battery, hybrid, UAV, zephyr, military

SOLAR ENERGY AND BATTERY PRICE FALLS: AN OVERVIEW

The spacecraft and satellite industry was one of the first major industries seeing the potential to produce electricity from sunshine by solar photovoltaic (PV) means. The industry needed energy to power spacecraft and stations in orbit, with solar being the most practical source.

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Since there are no clouds or similar obscurations in space, the energy supply was predictable and reliable. Solar energy made it possible to avoid transporting heavy fuel from earth, and solar energy catching modules were, even at this time, thin, relatively lightweight, foldable and could be placed on many areas of the spacecraft. Solar energy could be stored in batteries limited in size for short-term use.

Over the years, solar energy products proliferated, eventually leading to a fall in prices. In the early years of space exploration, solar battery power was extremely expensive. The space industries of the major powers and their politicians were consistently criticised for absorbing money away from more pressing matters, such as healthcare. It later became clear that, in spite of the immense space programs expenditures, many positive bi-products came out of the initial explorations. Solar PV was one. During the last half-century, the products have been improved - simultaneously minimising material use, reducing costs and increasing surface area efficiency. Mass production has resulted in falling costs, and with it, the cost of batteries has fallen significantly. Research and development in the private sector of electric vehicle batteries has similarly resulted in improvements, mass production and cost reductions.

Companies like Tesla, Nissan and General Motors now indicate that the approximate cost of their mainly Lithium-Ion battery cells will, in future, fall from below 300 USD per kWh to approximately below $100 in as soon as 2020 (Osmundsen, 2016, para 7). Simultaneously, battery energy density in Wh per litre is forecasted to grow from today's 200 to slightly below 400 in 2020 ("Electrifying Everything," 2017). Solar PV market growth has been 30-40 per cent annually, which has led to increased solar proliferation. Solar PV has experienced a 20 per cent price fall each time the global capacity doubled. Additionally, the cost of solar PV systems today is only one percent (1/100th) of the price three decades ago. There are several trends that indicate a steady move away from fossil fuels: Despite the success of Norway's 'Pension Fund' (previously named 'Oil Fund'), Norway have decided to pull out of oil and coal investments. On a global scale, during 2015, ninety per cent of the new global power production came from solar PV, wind and hydro ("World Energy Outlook," pp.1-8). Solar and battery technology could, as a result, make fossil fuels obsolete in 25–30 years (Goodall, 2016, p. 6).

SOLAR AND BATTERY USE FOR LAND AND SEA WEAPONS AND EQUIPMENT

Solar power and long-life battery storage offer several benefits for militaries operating on land and at sea. Using solar power at military bases, for example, allows militaries to limit operational costs by reducing the need to transport fuels, thereby reducing the chances of convoys being attacked in conflict zones (Gardner, 2017, para 3). In the field, solar power allows the military to turn off diesel-powered generators to recharge battery-powered equipment, thus reducing noise that can be detected. The U.S. armed forces have supposedly doubled renewable energy power generation between 2011–2015 and have initiated many projects to use renewable energy for domestic U.S. bases (ibid, para 6).

From major conventional weapons to small arms and light weapons and equipment, batteries are versatile for a variety of uses. Batteries can now be made as small as the tip of your finger, allowing a range of uses, including powering tiny spy devices, to as large as Tesla's 100MW battery project in South Australia, which is intended to be used in large-scale power outage emergencies.

There are some large conventional weapons that rely on high-density batteries to give a military edge. Japan, for example, may be the first country in the world to launch a fleet of Lithium-Ion battery and diesel submarines. It has been argued that using Lithium-Ion allows their submarines to dive much faster than traditional air-independent propulsion (AIP) technologies. Japanese contractors also argue that using Lithium-Ion makes their submarines stealthier (GlobalSecurity.org, n.d.). Hybrid technologies like gas or diesel-electric battleships also save fuel and, crucially, limit the amount of time ships need to stop to refuel at ports or at sea, making them less vulnerable to attacks (Gardner, 2017, para 4). Thus, there are numerous examples of how batteries and hybrid technologies have significantly changed the landscape for military, security and police forces using military installations, light weapons, equipment, and major conventional weapons. What is less understood is the significance of solar power and advances in battery technologies used for aerial vehicles.

POTENTIAL OF SOLAR POWER AND STORAGE: EXAMPLES FROM COMMERCIAL PLANES TO MILITARY UNMANNED AERIAL VEHICLES

Commercial Developments

There are numerous examples of how the solar PV and battery combination has presented new ideas to produce public transport and aircraft. Likewise, the opportunities for aerial vehicles has demonstrated to be enterprising and innovative. The recent Solar Impulse single piloted RTW flight clearly demonstrated the possibilities offered to the aircraft and military industries (see Solar Impulse Foundation, n.d.). The aircraft industry, represented by Airbus and Siemens, have indicated that short distance routes with hybrid-electric aircraft carrying up to 100 passengers could be possible before 2030. In April 2016 Airbus and Siemens began working on developing hybrid electric flights, with the aim to develop "carbon free" aircraft. The collaboration will cover many types of aircraft and several propulsion systems from 100 kW in small UAVs and unmanned vessels to 20 MW in classical short and medium distance planes. The first step is to develop and fly a hybrid electric plane with less than 20 seats (Godske, 2017, para 17).

Boeing has chosen another path. Instead of participating directly in the development of electric planes, the company has invested in a new start up Zunum Aero together with the low-cost airline JetBlue. Their goal is to develop a hybrid plane that by 2030 will be able to fly 1120 km with 10-50 passengers (Zunum Aero, n.d.). The idea behind the project is to enhance the capacity of smaller airports in the United States by offering short distance flights. Today only 140 of the 13500 U.S. airports provide 97 percent of the passenger traffic. There is hence an enormous potential to travel shorter distances with electric while avoiding the big hubs.

The limitation so far has been the batteries, since solar PV modules are already well developed as stiff modules or thin film that can cover the body and the wings of a plane. Such applications already exist on sailing boats or as bicycle lane surfaces in the Netherlands and in France.

Military Developments: The Opportunities for UAVs

Similar to developments in the commercial sector, Peter Singer, previously senior fellow at the Brookings Institution, stated that military UAVs were a "game-changing technology, akin to gunpowder, the steam engine, the atomic bomb—opening up possibilities that were fiction a generation earlier but also opening up perils that were unknown a generation ago" (Singer and Wright, 2013, p.41). Diesel and electric military, civilian and commercial UAVs can carry various payloads and are adaptable for many military and commercial purposes, such as reconnaissance, convoy protection, law enforcement, bombings, counter-piracy, and delivery. Some are modified to fly at high altitudes, others for low-noise stealth, or for flying at high speeds. UAVs can be as minute as a mosquito to as large as a jumbo jet. They are seen by militaries as strategically convenient and safer than committing humans to tasks such as reconnaissance or offensive operations. Specially modified UAVs can operate undetected in any environment and terrain.

Defence companies are gravitating towards research and development in the UAV market, and by 2020 global militaries are estimated to spend approximately $70 billion on UAVs (Goldman Sachs, n.d.). This is partly because specially modified UAVs currently require only one member of crew to identify and strike multiple targets in one flight. This is a vast leap from WWII bombing squadrons that required hundreds of planes and thousands of aircrews to strike one target with varying degrees of success and with high casualties. Even in modern conflicts such as the First Gulf War, one pilot in a Lockheed F-117 Nighthawk would usually be capable of identifying and striking two targets in one flight (Hansen, 2009, slide 4). States with technical constraints that are unable to manufacture advanced military UAVs, or are unable to acquire the latest systems, are therefore significantly behind in capability and operational know-how.

Due to the availability of relatively small, lightweight and high-density batteries, small electric unmanned vehicles have been widely used by militaries and non-state actors for surveillance and reconnaissance. While armed UAVs are mostly larger fuel-driven machines (due to heavier payloads), the potential of battery power and hybrid technologies, as demonstrated in commercial initiatives such as the Solar Impulse, combined with designs in lightweight materials, may make hybrid, solar and/or electric-powered armed conflict viable in the future, if expertise is shared. Most countries can acquire high-density batteries, and therefore, if hybrid technologies grow to become the norm, this may lead to a more levelled playing field in terms of capability.

Additionally, cheap and highly persistent fuel and electric UAVs allow continuous communications relay for both commercial and military UAVs, and this constant availability will make it easier for operators to use other UAVs and aircraft anywhere and at any time. It allows more efficient use of other UAVs for other purposes, since one aircraft can survey a wide area. High-endurance UAVs can also significantly reduce costs for other purposes, such as border control and humanitarian aid. Therefore, cheap and highly persistent UAVs could change the military landscape.

While current developments in the commercial sector makes long-haul flights with large payloads possible in the future, how will military solar and electric military UAVs develop? If batteries manage to reach an energy density of 400 Wh per litre, there is of course still a long way towards airline fossil fuels that contain 12,000 Wh per litre. Comparatively, 100 tons of fuel for a Boeing Dreamliner would be equivalent to facilitating a 2.000-ton battery bank (in today's batteries), per aircraft, at an airport. But if battery energy density doubles as expected, 1,000 tons per aircraft would, for example, enable airports and military bases to facilitate more aircraft, and that is not considering other technological milestones after 2020.

Considering that one conventional UAV uses approximately 2,000 tons of fuel per year (Airbus, n.d., para 1), accommodating mega-battery banks may be more practical and cost-effective. As demonstrated in Tesla’s mega-battery project, major installations can be installed in less than 100 days. If the plane’s body is also covered with solar thin film or some solar PV sprayed on the body, the energy storage need would be reduced, since energy is produced while the plane is flying or parked. There is thus huge potential for defence industries to develop lethal solar planes. But at what price?

The use of military UAVs can favour governments by reducing political costs to launching military intervention. Having service personnel dying in foreign lands and investing large sums of money in conflicts can, as demonstrated by strategic shifts by the U.S and U.K in the Middle East, draw a high degree of public criticism. In the simplest terms, military UAVs can be used for surveillance, for ‘neutralising’ subjects or for destroying infrastructure, without the need to deploy armies or specialist units in foreign territories. This allows governments to operate secretly and remain less accountable considering international laws attributable to (but not limited to) the United Nations Charter, Chapter VII, Action with Respect to Threats to the Peace, Breaches of the Peace, and Acts of Aggression (United Nations, n.d.).

While not being an adequate replacement to ‘boots on the ground’ and other capabilities, military UAVs not only reduce risks and prevent loss of life (for the operators) by replacing pilots, they offer the persistence that any normal human being would not be able to manage (Cole, 2015, para 2). Crews can ‘simply change shifts on the ground while the drone remains in the air’ (ibid). Companies and law enforcement bodies have also explored the development and potential of a range of UAVs to deliver riot control agents, such as tear gas (Crowley, 2015, p, 22, para 2). While there are serious concerns about the use of riot control agents from UAVs with poor accuracy; for military and security actors dealing with riots, for example, it may offer a host of security solutions.

Unsurprisingly, states currently involved in conflicts and with large defence and research budgets are exploring strategic and technical opportunities in military UAVs (Farley, 2015, para 2). The major players in the industry are Israel, the United States, and China, but in terms of acquisition, joint ventures and technical development, other states such as the United Kingdom, France, Iran, and Russia are steadily narrowing the contrasts in capability. It is thought that up to 23 countries can produce UAVs (New America, 2016). How many have acquired advanced UAVs is not known.

The current record of military UAVs is not without controversy. It is often argued by civil society groups that the use of lethal UAVs inclines operators to kill rather than capture particular individuals in combat (see Alston, Morgan-Foster, and Abresch, 2008). It is also widely argued that military UAVs facilitate and legitimise the practice of extrajudicial and arbitrary killings. Furthermore, UAV operators, sometimes stationed thousands of miles away, are detached from the horrors of war due to the video game-like environment from which they operate, potentially making them 'trigger happy' (Cole and Wright, 2010, para 8). Current technological developments in endurance, payload and surveillance capabilities, in military and commercial spheres, could also 'make possible the dramatic expansion of the surveillance state' (ibid, para 9).

Following consistent and mounting pressure from NGOs and other organisations, the Obama administration released figures (ODNI report) suggesting that between 64 and 116 civilians had been killed through UAVs and other airstrikes targeting terrorists (who were not in "war zones") between January 2009 and fall 2015 (Dyer, 2016, para 6). This was much less than estimates suggested by independent news organisations and researchers (ibid, para 2). It also did not include deaths resulting from air strikes in Afghanistan, Iraq and Syria, which are, without doubt, much higher.

Non-military UAVs have received a comparatively favourable press, particularly for example those used for humanitarian purposes or detecting bushfires. DJI, a China-based distributor of UAVs and related equipment, argue that UAVs (military and non-military) have been used to save at least 59 people in 18 potentially life-threatening incidents around the world between 2013 and 2017 (DJI, 2017, para 1). While this is not an entirely objective source, not-for-profit humanitarian bodies such as UNICEF are considering using UAVs to assist their humanitarian efforts (UNICEF, 2017). This stems from a UNICEF initiative to deliver HIV blood samples from a remote area of Malawi for laboratory testing (ibid).

Huge strides have been being made in the commercial/security sectors in the design of high endurance UAVs that could help to bring internet bandwidth and delivery to remote areas of the world. For high-altitude UAVs, examples such as the Boeing Phantom Eye (liquid-nitrogen fueled), AeroVironment's Global Observer (hydrogen powered), NASA

Pathfinder (solar power) and Facebook Aquila (solar power) demonstrate that there are major commercial interests in the UAV sector. Such technologies have so far demonstrated that low/zero-carbon emitting machines can carry relatively large payloads at very low cost, although some of these projects have been terminated or are on hold.

Thus, there are many opportunities and concerns with regard to how new technologies could be utilised to make war cheaper, less accountable, and more effective through the use of UAVs. The Zephyr UAV is one of example of a major step in breaking the barriers to endurance and payload capacities.

ZEPHYR SOLAR UAV

In 2017 the UK's Ministry of Defence (MOD) tested its third solar-powered Zephyr UAV (S) for concept demonstration purposes (Chuter, 2016, para 2). Described as high-altitude "eternal planes," or "daddy long legs," the Zephyr (S) has broken world records as the longest duration and highest altitude UAV, flying for nearly 630 hours at the edge of space, reaching over 70,000 ft. While its specific function for the UK armed forces has not been clarified, its primary purpose is persistent surveillance and communications relay (ibid, para 7).

The latest model of Airbus Defence and Space's (ADS) Zephyr 8 (single-tail), while currently under tests, is likely to be used by the UK's armed forces in the near future. Research and development is also being carried out by the US Army and US Navy as part of of a UK-US joint capability technology demonstrations (JCTD) program (Air Force Technology, n.d., para 3). Born out of information-technology warfare, the Zephyr, while radically different from other UAVs, is part of a broader transformation of warfare that heavily relies on sophisticated, secure, and precise surveillance and communications technologies.

The combination of solar power and unmanned aircraft can be traced back to 1970s (Michel, 2015, para 5), but major milestones have been made with the Zephyr in recent years. Zephyr was initiated by British company QinetiQ in 2003 and has since gone through various prototypes and modifications. Having joined the Airbus High Altitude Pseudo-Satellite (HAPS) programme, it is sometimes known as Airbus Zephyr. Originally launched from a helium balloon (Van der Zwaard and Aalberse, 2017, para 5), the structure of the Zephyr design was later strengthened, and after successful flight tests, launched manually from ground. After improvements in flight times, payload capacities, and after gaining greater understanding of stratospheric flying extremities, the Zephyr project attracted funding from the US Department of Defense, securing its future development (ibid, para 7).

Paul Davey, Zephyr's Business Development Director, explained that the aircraft flies on solar power, charges its batteries during the day, and discharges its batteries during the night, allowing it to remain aloft the following dawn, and then the cycle is repeated (Fildes, 2007, para 14). The Zephyr has been designed for use in both military and commercial purposes, from improving surveillance and communication in remote areas, to detecting bushfires in Australia (McHale, 2010, para 2). It is argued that since it operates in the stratosphere, it is less affected by weather and air traffic (Martin, 2016, para 6).

It therefore overcomes many limitations experienced with lower-flying machines, and at potentially lower cost; around 10% of the cost of current UAVs, and 1% of the cost of a satellite (McHale, 2010, para 10). Additionally, it is said that replacing one conventional UAV with a Zephyr would save 2,000 tons of fuel each year (Airbus, n.d., para 1). Compared with other manned and unmanned aircraft, it is said to produce virtually no noise and is more difficult to detect on radar (Van der Zwaard and Aalberse, 2017, para 4), and requires less servicing and logistical attention since its operational length is exceptionally higher than many other UAVs (Flatley, 2010, para 10). The Zephyr's ability to fly at high altitudes for long durations means that it can survey a large area over an extensive period, and therefore identify multiple targets.

Jon Saltmarsh, Zephyr Programme Director said: "By being able to remain over a location for weeks or months at a time, it can usefully deliver a host of practical and more affordable solutions to both civil and military customers" (Flatley, 2010, para 7). Unlike satellite "snapshot per orbit," armed forces can confine their chosen operations within a particular area up to a diameter of 600 miles, and obtain higher resolution images (McHale, 2010, para 8). On Airbus's and QinetiQ's websites, they argue that it could also be used for missile detection, battlespace awareness, signals intercept, and continuous imagery.

Currently, the development of the single-tailed Zephyr S, which carries a payload of 5kg, is being outmatched by the Airbus's twin-tailed Zephyr T, which could potentially manage up to 20kg (Martin, 2016, para 7). Further developments in ultra-lightweight payloads, such as optical sensors and GPS (Air Force Technology, n.d.), and lightweight body designs and technologies, will make room for other systems.

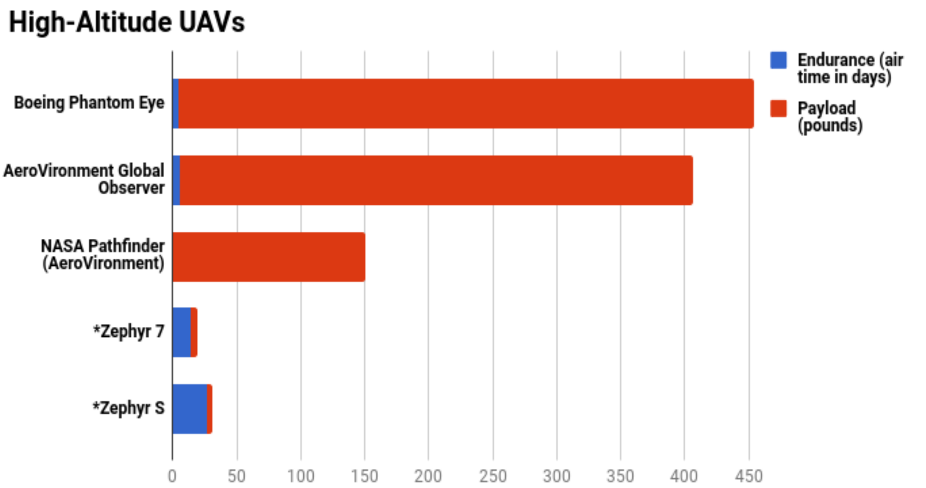
Table 1. Evolution of Zephyr UAV Capabilities*

Type	**Year(s) Tested**	**Wingspan**	**Endurance**	**Max Altitude**
Zephyr UAV	2003-2005	12m	6 hours	27,000 ft
Zephyr 5	2005-2006	15m-16m	18 hours	36,000 ft
Zephyr 6	2007-2009	18m`	54-82 hours	61,000 ft
Zephyr 7	2010	23m	336 hours	70,740 ft
Zephyr (S) 8	2018	25m	630 hours	74,000 ft
Zephyr T	2017 - present	33m	TBD	TBD

*Information obtained from publicly accessible sources

While there are many factors based on specific needs that go into the development of high-altitude UAVs, there are clear correlations between low flight time and large payloads. While there is currently little to compare with high flight time and payload capacity, the Zephyr 8 is far from potentially being used for offensive military action, such as bombings, as a heavy payload would defeat its primary purpose. While its payload is a major limitation in military contexts, it is said that the current development and testing of the Zephyr T, however, will be able to accommodate heavier software, such as RADAR (Airbus, n.d., para 1). This model is set to be operational in 2019.

Figure 1: Endurance and payload*



* It is not clear if the 5kg payloads have been achieved. The Zephyr T is expected to exceed the duration and payloads of previous prototypes, with a 20kg payload. Information obtained from publicly accessible sources.

The development of Zephyr demonstrates how unmanned vehicles that rely particularly on solar energy may be a common sight in the foreseeable future. These developments in larger wingspans and lightweight designs begs many serious questions. The most prominent issue is whether the Zephyr would contribute to the proliferation of UAVs by enabling and facilitating their use, particularly in terms of acquiring consistent data feeds for other armed UAVs to utilise.

Another issue is whether current developments in military and commercial solar aerial vehicles means that we may have high endurance, highly stealthy, jet-sized and cheap lethal solar UAVs in the near future? Is this technology going to be essential for all States in the coming future, thereby increasing their proliferation? Additionally, by remaining aloft and out of sight, will the Zephyr contribute the expansion of surveillance by states on their citizens? These questions remain unanswered, but there are many indicators that make this more practical than theoretical.

Considering that the U.K is not believed to be a major innovator of solar PV systems and high-density batteries (at least compared to Germany, China, and the U.S. in solar innovations, and Japan, China, South Korea and the U.S. in battery density), its collaborative work with other European, U.S. companies and national institutions means that many other states are, theoretically, capable of producing highly capable and advanced solar UAV systems. The U.S., on the other hand, have demonstrated that they require little financial or technical assistance in developing advanced UAVs domestically. Corporations in the U.S. have set the bar high in investing in solar and hybrid UAVs which have demonstrated that very large payloads can be carried for long periods of time. These capabilities will not be easily matched by emerging UAV manufacturers in the short term.

However, if solar UAVs prove to be game-changing, it may be necessary for countries to share knowledge to enable capability and interoperability within traditional alliances, particularly within the NATO alliance, Israel, Japan, South Korea, and Australia. This is already seen between the U.S and the U.K (e.g. Zephyr UAV) and Japan (e.g. missile technologies). China - a country that is growing technologically and militarily, with a highly innovative and cheap solar and battery market, and a comparatively liberal national arms export control system - have proven capable of developing systems akin to, and possibly even cheaper than, current hybrid and solar UAVs.

Likewise, such capabilities can be exported to China's traditional allies, thereby potentially triggering a quantitative and qualitative "race" in high-endurance UAV capability. China's Caihong-T4 (CH-T4), with and wingspan of 40 metres, solar-powered UAV 'designed to stay in the air for months,' is a notable example of its emerging solar UAV capability. Built by the Chinese Academy of Aerospace Aerodynamics, the CH-T4 has much of the same qualities of the Zephyr in concept and in appearances (see Lin and Singer, 2017). Russia's (solar) LA-252, as well as other prototypes, are also comparable models in terms of endurance and intended function.

These developments demonstrate how investment into solar UAVs aligns with a broader trend in solar and battery technological advances, UAV investment, and the need for persistent, sophisticated, secure, and precise surveillance and communications technologies in modern warfare. Additionally, considering that only a handful of countries have satellites, building a high endurance solar UAV is potentially more cost-effective than funding and developing a satellite and launch capabilities. This means that persistent UAVs are extremely marketable.

CONCLUSION

Alongside technological advances made in solar energy and batteries, the nature of war is changing dramatically to adapt to new security needs and technologies. For militaries, solar energy and battery storage makes it possible to avoid transporting heavy and flammable fuel in warzones. It can make operations cheaper and more practical. Solar and battery technologies are getting progressively cheaper and more area efficient as competition and research expands, and as mass production increases. While there are limitations to using solar power in cold and dark climates and territories in the troposphere, improvements in battery energy density could overcome these limitations, provided that future forecasts are accurate. Other hybrid-electric technologies also provide many opportunities for defence companies.

UAVs have proven to be “game-changing” in certain military contexts. Research and development into UAVs are increasing, since they can, in theory, lower the real political costs to military intervention and reduce casualties for the end-users. The use of military UAVs, however, is highly controversial. Advances in solar and energy storage, in tandem with research and development into lightweight materials, makes the practicalities of solar-fuelled warfare very possible.

‘Disruptive technologies’ or disruptive innovations can also accelerate research and funding into solar energy and batteries. For example, ‘tandem [solar] cells,’ though costly, can double the efficiency of today’s cells by using two-layer cells to double the amount of energy produced. This is currently being tested for small-scale projects. Chinese and Russian developments in solar UAV technology may intensify research and development in many countries. Thus, if energy density can double, it would be possible to see jet-sized planes powered by electric motors in the skies in the next decade. What does this mean for the potential for solar-powered warfare? For military UAVs, what makes solar different from fuel?

The Zephyr is the best example to address these questions. Uniquely, solar UAVs like the Zephyr increases the time UAVs can spend in the air, therefore potentially increasing military effectiveness by extending operational length and expanding surveillance area. UAVs can recharge in the air and on land. They could potentially venture further and higher in the battlefield, with the persistence that neither humans nor fuel-driven machines can ever manage.

Flying in the stratosphere, they are less detectable and less affected by weather and air traffic, making them more effective for surveillance and therefore deadlier. Considering the earth's orbit and axis, as well as technological milestones in solar and batteries, solar UAVs may therefore be able to operate anywhere in the world. Solar UAVs like the Zephyr are significantly lower in cost compared to current UAVs and satellites, and, considering current production and procurement trends, and increasing research and development by states like China, proliferation will likely increase. UAVs like the Zephyr and other prototypes developed by US, Russian and Chinese actors may be very appealing to states with limited satellite capability.

On the other hand, using "eternal" UAVs for humanitarian purposes or to monitor natural disasters may radically improve the effectiveness agencies and bodies helping in disaster relief efforts, or controlling forest fires, for example. By being able to accommodate heavier equipment as testing progresses, solar UAVs may have a range of uses.

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