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PERLAN-II: THE CUTTING EDGE OF AEROSPACE TECHNOLOGY

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Introduction

Starting from the earliest experiments in Russia, Europe and America, aerospace technology has been led by innovation and visionary individuals who pushed the knowledge of their times to an extreme. These attempts gave the world, in 1884, the Russian Mozhaisky's[1] steam powered aircraft that crashed after about 100 feet of flight, and the flight, in 1893, of the Briton Hiram Maxim's[2] steam engine powered biplane with two propellers, which led on to the Wright brothers' flight in 1903 and the Brazilian Alberto Santos-Dumas' flight, in 1906, in Paris of his14 s Bis aircraft[3]. In later years innovations led to ever more capable piston engines aircraft for myriad roles. In the second half of the twentieth century jet engines made even more capability available to aviation practitioners. One trend line points to innovative new power plants such as scramjet engines that could enable aircraft to fly at hypersonic speeds. Alongside these power and fuel hungry technologies, an old and in fact possibly one of the earliest technologies that enabled man to take to the air, that of the unpowered glider, has continued to evolve. Gliders have the inherent disadvantage of carrying no engine and hence being limited in endurance and range as compared to powered aircraft. Recent demonstrations and programs have given this old technology a new sheen that demands attention.

Gliders Reinvented

India's Air Force cadets at the National Defence Academy (NDA), Kharakvasla, Pune get their first air experience in gliders in their last term at NDA. The winch launched gliders at NDA are able to fly a basic circuit. Some instructors have been able to stay aloft above NDA for several hours through use of thermal updrafts on hot summer days. A glider, as it lacks an engine, has to rely upon a winch system to propel it along ground fast enough for its wings to lift it into the air. Once airborne the glider is essentially in free fall towards the ground. Through careful design for low aerodynamic drag and a wing that generates high lift with minimum drag gliders are designed to maximise forward travel for height lost in descent. The high glide ratio enables gliders to travel respectable distances or to stay aloft for some time. A glide ratio of 10:1 implies that for every unit of height lost the glider travels ten units forward. As gliders rely upon using air currents for staying aloft, the glider pilot attempts to enter pockets of air that are rising in comparison to the surrounding air mass to gain more height. These thermal updrafts are useful to the glider pilot in gaining height that can be then traded for more time in the air or for distance covered. Any air mass that is rising in comparison to its surroundings is useful to the glider in its attempt to gain altitude. When a mass of air moving horizontally across the earth's surface due to pressure gradients comes across obstructions such as mountain ranges, the air mass is forced to rise and flow above the obstruction. Hence the air in proximity of mountain ranges provides several excellent regions of strong updrafts. Most wind patterns over earth follow a roughly east-west direction. Hence mountain linked updrafts are most prominent in proximity of mountain ranges with a north-south orientation such as the Rocky mountains in north America and the Andes ranges in South America. These mountain ranges lie across the normal direction of the airflow thus forcing the air to rise on the windward side of the mountain range and descend on the leeward side of the mountain range. The Rocky mountains and the Andes mountain ranges provide some excellent sites for usable updrafts. Due to earth's rotation about its north-south axis, there is a vortex of air that lies in proximity of the two poles. The southern polar air vortex lies close enough to the southern end of the Andes mountain range for an object in one wind pattern to possibly jump into the other. Say an object in the mountain waves over the Andes mountains could transit into the southern polar air vortex. The Antarctica polar air vortex can extend up to an altitude of 70,000 feet above mean sea level (AMSL)[4] and speeds of the air in it can go up to 100 miles per hour (mph)[5]. The polar jet stream that lies in a ring on the northward side of the southern polar vortex completely circumnavigates Antarctica[6].

Gliders have been in use for pleasure flying all over the world since the infancy of aviation. Usually these are launched through use of ground mounted winches or by being pulled along the ground by suitable vehicles such as jeeps. An alternative launch method has been to tow the glider into the air by use of a cable tied to a powered aircraft. At a pre-determined altitude the cable is released to leave the glider in free flight, in both the winch and towed method of launch. Gliders have been used for more serious purposes also in several cases. During World War-II gliders were used by the German forces and by the Allies to carry troops across borders into enemy territory. Such gliders were usually towed by bombers or transport aircraft and released at pre-determined points so that they could glide across the borders silently and after landing disgorge the armed troops carried within. The first aircraft designed in India at then Hindustan Aircraft Limited (HAL) at Bangalore by HAL's Chief Designer, Dr. Ghatage, was the G-1 ten seat troop carrying glider[7]. The Germans also utilised scaled down and even full scale wooden glider models of new aircraft to test the aerodynamics of the design as part of the new aircraft design and development process. In India also Prof. Kurt Tank, the designer of the KF-24 fighter, used a full scale wooden glider model of the HF-24 Marut fighter [8] to test the aerodynamics of the design before going on to build the first complete prototype. Thus gliders have always had more utilitarian applications than mere pleasure flying.

Some aviation purists swear by glider flying as it most closely approaches natural flight as enjoyed by birds. Gliders are almost one with nature as they use natural air currents for remaining aloft bereft of mechanical assistance such as that of lighter than air bladders or fossil fuel burning power plants. Glider flying most closely involves application of knowledge of the environment to achieve fight, indicating a close interaction of man and nature without polluting the environment.

The advent of rockets in the mid-twentieth century led in stages to development of the first vehicles able to access outer space in the form of space launch rockets. Even today, much improved versions of the first space launch rockets used earlier, continue to be the most common vehicle for access to space.

Lowering Space Access Costs

Rockets as used today are expensive due to the fact that these are single use items and all the component parts are discarded after the single use. Hence per kilogram costs or placing objects into outer space remain very high. There are attempts in progress to reduce launch costs through two similar but different technologies. One technology attempts to recover used stages of rockets for refurbishment and reuse, thus potentially reducing launch costs. Towards this the American private space launch company SpaceX has twice demonstrated the successful recovery of the first stage of its Falcon rocket through soft landing it on a barge at sea[9]. Amazon.com owner Jeff Bezos company 'Blue Origin has thrice demonstrated a vertical launch of its New Shepard rocket into near space and recovered it through a vertical landing[10]. Both companies hold out hope of reducing launch costs by over one third over disposable rockets. The technologies used by Space X and Blue Origin rely upon retro rockets to control and soft land the stage or rocket as applicable. By its very nature this technology requires very high accuracy inertial systems to sense and correct the precisely vertical alignment of the vehicle and also considerable amount of the initial fuel load to achieve the soft landing. Thus soft landing of rockets or their stages reduces the lifting power available to the initial rocket launch and could be a constraint in full exploitation of launch capability.

A second technique being explored is the two stage to orbit (TSTO) system wherein a rocket assisted launch propels a vehicle to very high speeds from where the vehicles utilises atmospheric oxygen to operate a supersonic combustion ramjet (scramjet) engine to achieve escape velocity adequate to place payloads in orbit. Thereafter the vehicle is recovered through a conventional landing for reuse. Several countries including the US, China, Russia, and India are working on developing this technology. It is expected that finally TSTO may lead on to a single stage to orbit (SSTO) craft able to take off like an aircraft, reach space and return to land like an aircraft. This line of development has potential to offer very low launch costs as there is no wasted fuel fraction unlike the vertical landing of rocket (stages) technique. TSTO and SSTO technology requires very high end design and engineering skills along with development of new technologies such as scramjets and hypersonic glide craft.

A point that deserves mention is that most fuels used for launch of rockets is very toxic. Even if there is no mishap and the rocket functions as planned, the exhaust plume contains toxic materials that contaminate the air as well as footprint areas of the exhaust plume on the surface of the earth. In case of accidents the toxic nature of the fuel adds to the humanitarian and environmental disaster in the area. Environment protection issues are becoming increasingly important all over the world.

Perlan Missions

An attempt to obtain clean access to space or near-space was planned by the Perlan project in America. The plan is to achieve access to near space without use of an engine. The Perlan-I craft was a modified German DG Flugzeugbau DG505M glider. This craft initially carried a two stroke engine to enable the glider to launch itself. The cockpit was unpressurised forcing the two man crew to wear pressure suits. The two stroke engine was removed and replaced by battery powered research equipment. The glider was towed aloft for launch. Perlan-I weighed 390 kilograms (kg) empty with a gross weight of 631 kg[11]. The wing span was 59 feet[12] giving it an aspect ratio of 19.52[13]. **Between years 1992 and 1998 Perlan founder Einar Enevoldson collected evidence that atmospheric mountain waves propelled by the polar vortex could reach over 130,000 feet AMSL[14]. Perlan-I, in August 2006, established a glider could transition from lower altitude wave structures generated by surface winds to higher level wave structures that interact with the polar vortex. It was postulated that this transition would take place at about**

59,000 feet AMSL[15]. Perlan-I flew up to 70,000 feet AMSL. Perlan-I's second objective was to identify the regions of the world where this high level wave interaction effect was most feasible[16]. Lastly it also explored whether a glider could achieve near space altitudes through exploitation of these weather phenomena and established the equipment needed to keep a glider crew alive at such altitudes[17]. Perlan-I was unpressurised and the crew flew in space suits borrowed from NASA.

Airbus has bought into the Perlan project to gain responsible cutting edge technology developer credentials. In fact Airbus is trying to derive maximum benefit from its name being attached to the Perlan Project[18]. Several technologies that are part of the Perlan project such as very strong and light airframe structures have spin off applications in other segments of the aviation industry as well[19].

Based on the learning from Perlan-I the craft for Mission Perlan-II has been modified extensively. The Perlan-II craft features composite material construction that gives it an empty weight of 575 kg and a gross weight of 818 kg[20]. The wingspan is 84 feet with an aspect ratio of 27. A pressurised cockpit has been incorporated to allow greater freedom of control and comfort for the two man crew[21]. Perlan-II was test flown on May 07, 2016 in Nevada, to test the basic structure of the innovative ultralight but strong enough for the stratosphere craft[22]. After proving the safety and reliability of the craft the group aims to take it to Argentina where they will exploit the mountain waves over the Andes mountains and the Antarctica polar vortex to climb to a planned 90,000 feet AMSL[23] in the glider to set a new world record and to pave the way for mission Perlan-III which will aim to reach up to 130,000 feet AMSL or 39.634 km[24]. The Karman Line, the globally accepted boundary between the atmosphere and space is placed at 100 km AMSL or 3,28,081 feet AMSL. The Perlan project will, if it succeeds reach close to space but fall short of the Karman Line by a wide margin, as it is planned as of now at least.

Analysis

The Perlan missions are an innovative and very high technology initiative. The ability to reach the Karman Line, the accepted division between the earth's atmosphere and space, without use of any fuel or engine is noteworthy. Apart from the cost of building the reusable glider there are no costs if one discounts the cost of towing the glider into the air. This technology could be excellent for space tourism and for scientific study of the higher atmosphere as a direct beneficial side effect of the Perlan system is that there is no contamination of the atmosphere as happens when using rockets, TSTO or SSTO craft etc. however the ability to utilise such ultra-high altitude gliders is restricted to regions of the world where mountain waves interact beneficially with the polar vortices. These regions are limited to South America, and possibly some regions of North America where the Rocky Mountains may allow utilisation of the arctic polar vortex and finally north Russia where the Ural mountains may allow entry into the arctic vortex. It is evident from this cursory look at world geography that regions where such technology is usable are very limited. This places limits on exploitation of this technology. It would be possible to utilise this technology for space access only in close collaboration with countries situated astride the practically usable mountain wave generators. Such a fact, apart from the dynamics within formal alliances indicates that such technology in likely to be usable only for international collaborative peaceful science and near-space tourism.

Military and / or national strategic utilisation of this unpowered space access technology would be limited to countries located where mountain waves of suitable amplitude exist. Other countries would perforce remain with rockets and later possibly TSTO and SSTO capability.

The Perlan project clearly brings out the potential of thinking outside the box and of innovative application of common scientific knowledge. Wind patterns all over the globe have been studied and mapped for several decades at least. The concept of high aspect ratio gliders is almost as old as if not older than modern aviation. Bringing the two together is where innovation and application come in. There are, however, myriad spinoffs possible from the Perlan project for aerospace industries all over the world.

Conclusion

From its very beginning aviation has relied upon innovation for its advent and success. The aviation age soon gave way to the space age through development of space launch rockets. While this reach into space progressed the simplest flying machines, gliders, continued to be used for serious purposes as well as for recreational flying. The glamour of ever faster and higher flights by powered aircraft and rockets took the spotlight away from gliders for the most part.

Space access has been expensive due to the single use nature of space rockets. Attempts to reduce launch costs have involved trying to recover the rocket or its parts for reuse as demonstrated by Blue Origin and Space X and attempts to develop TSTO and SSTO craft by a handful of countries.

Alongside this the Perlan project originated in the US to try and reach space without an engine at all. Airbus has invested in this project in a big way. Perlan –I achieved its objectives of proving the feasibility of the concept and Perlan-II is poised to attempt a record breaking flight to reach 90,000 feet AMSL, while Perlan-III will aim to go a further 40,000 feet higher than Perlan-II.

Utility of this innovative and extraordinary technology is likely to be limited for the most part to international scientific and space exploration missions. National security needs of very few countries can be met by this technology due to the constraints of geography.

(Disclaimer: The views and opinions expressed in this article are those of the author and do not necessarily reflect the position of the Centre for Air Power Studies [CAPS])

Notes

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[2] Ibid.

[3] Ibid.

[4] .ccpo.odu.edu, "3 -- THE ANTARCTIC POLAR VORTEX", http://www.ccpo.odu.edu/SEES/ozone/class/Chap_11/11_3.htm, accessed on May 09, 2016.

[5] Ibid.

[6] Ibid.

[7] SC Keshu, *Third HAL Information Folder, (*Bangalore, HAL: 1984), pp1.

[8] Globalsecurity.org, "HF-24 Marut", http://www.globalsecurity.org/military/world/india/marut.htm, accessed on May 09, 2016.

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[10] Sarah Fecht, "To the edge of space and back again", http://www.popsci.com/blue-origin-third-rocket-landing-watch-it-here, accessed on May 10, 2016.

[11] Perlanproject.org, "Perlan-I", http://www.perlanproject.org/aircraft, accessed on May 10, 2016.

[12] Ibid.

[13] Aspect ratio is a ratio of the span , the length from wingtip to wingtip to the average cord of the wing. A higher aspect ratio indicates a wing optimised for high lift with minimum drag and meant for the subsonic flight regime.

[14] Perlanproject.org, "Perlan-I", http://www.perlanproject.org/mission, accessed on May 10, 2016.

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[16] Perlanproject.org, "Missions", http://www.perlanproject.org/missions, accessed on May 10, 2016.

[17] Ibid.

[18] Agence France-Presse, "With Perlan 2 Glider, Airbus Claim Mantle Of Space Pioneer", http://www.ndtv.com/world-news/with-perlan-2-glider-airbus-claim-mantle-of-space-pioneer-1404247, accessed on May 10, 2016.

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[21] Ibid.

[22] AFP, "Airbus sets sights on the stratosphere with glider flight", http://www.dailymail.co.uk/wires/afp/article-3579006/Airbus-backs-glider-setting-sights-stratosphere.html, accessed on May 10, 2016.

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