



AVIATION TECHNOLOGY: BRIDGING THE GAP BETWEEN SATELLITES AND AIRCRAFT

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Surveillance was the first military use that aerial craft were put to. This trend started with tethered hot air balloons that carried men aloft. The soldier in the balloon could observe out to large distances behind enemy lines and report his observations either through dropping messages weighted with stones to his side below. Later once the telephone had been invented, a telephone line running along the balloon's tether enabled two way communications between the balloonist and his commanders on the ground. The advantages of such observation from an elevated platform were immense. Commanders could verify deployment of enemy forces and the position and movement of enemy reserves. Once heavier than air machines became available, one of the first roles assigned to such aircraft was that of observation of enemy forces.

Background

The lightly armed and fast "scout" aircraft was developed specifically for this role by all countries that had an aircraft industry and modern military forces. In fact later development of the weapons and tactics for aerial combat grew from the need to deny the enemy use of his scout aircraft while retaining own use of these assets. As aviation and military aviation grew in strength with new technological innovations in the following decades, the reconnaissance aircraft continued to remain important. In the years after World War-II (WW-II), in the jet era specialist aircraft were developed for this role. One outstanding such machine was the US U-2. The U-2 was a subsonic aircraft that based its survival on being able to fly very high, thus staying outside the engagement envelope of most anti-aircraft weapons. The loss of a U-2 to a Soviet anti-aircraft missile on 01 May 1960 led to a rethink on the safe and effective surveillance options still available.ⁱ

Satellites and Aircraft the Gaps in Capability

The advent of the space age with launch of man's first artificial satellite in 1957 spurred interest in use of satellites for surveillance and reconnaissance in preference to manned aircraft. Satellites, however, suffered from several drawbacks. The more important of these are, in simple terms, firstly the relatively low resolution available from satellites. Satellites required operating in space and even the lowest feasible orbits for reconnaissance satellites involved operation at several hundred kilometres above the earth's surface. In order to derive useful information from these satellites very advanced optics were developed in order to obtain high resolution. Technological issues still remained. High resolution required a very narrow field of view, which in turn led to a very limited scan area being covered in each pass. Multiple passes were required to cover even moderate areas on the earth's surface. This required a "revisit" by the satellite. Orbital mechanics restricted the revisit capability of satellites as their orbits comprised progressive paths over the earth's surface. Revisit could usually be achieved only after a gap of several hours if not days. A solution was to manoeuvre the satellite in order to change its orbit adequately to ensure an earlier revisit. Such manoeuvres consume significant quantities of the limited and fixed fuel onboard the satellite thus adversely affecting its useful life. More fuel planned into the satellite from the design stage onwards inevitably led to a heavier satellite requiring more complex launch systems. The launch of multiple satellites so that at least one would be viewing the area of interest at any given time required a fairly large number of satellites being launched thus increasing the overall cost and complexity. A further complicating factor was the inevitable development of anti-satellite weapons able to destroy or degrade the enemy's satellites. Use of such a weapon by an enemy could blind the space based surveillance system at crucial times. One logical solution could be to launch extra satellites as in-orbit reserves able to fill in slots of destroyed space-craft and plug gaps rapidly; alternatively satellites could be kept ready on the ground for quick launch from earth when required. Both of these are expensive options that also involve a reaction time during which surveillance is compromised. These complications in use of satellites alone to fill surveillance requirements ensured that the manned surveillance aircraft avoided being consigned to the dustbin of history. Prominent surveillance aircraft include the US A-12/ SR-71 "Blackbird" and the Soviet MiG-25R both of which combined very high altitude operation, above 80,000 feet above mean sea level (AMSL) and very high speeds, Mach 2.8 to 3.2 to carve out a small pocket of invulnerability for themselves on reconnaissance missions over unfriendly countries while staying safe from hostile anti-aircraft weapons. The inevitable advancement of anti-aircraft weapons systems led to this narrow window on safety being progressively closed. Modern anti-aircraft weapon systems such as the Soviet era S-300 and US Patriot forced a switch from these manned surveillance aircraft towards firstly a change in tactics wherein development of very advanced surveillance electronics enables effective surveillance from large

standoff ranges. This can be best seen in the recent US surveillance missions off China's east coast with EP-3 and P-8A aircraft. These aircraft fly in "open airspace" over "international waters" and still, without violating the target nation's airspace collect usable intelligence. Some types of information still require over flight or very close proximity approach to the area of interest which itself may lie within a sovereign country's territory and airspace.

Advent of Unmanned Aircraft

Where satellites could not achieve the desired result unmanned aircraft came to be developed. Use of these enabled missions in very dangerous airspace could be undertaken with near impunity. The lack of a man on board helped firstly to reduce the size and complexity of the unmanned aircraft with a corresponding reduction in its radar, infra red (IR) and visual signature. The reduced signature reduced vulnerability to enemy anti-aircraft weapons. In eventuality of an unmanned system being shot down the lack of a man on board increased deniability and the embarrassment of having one's serviceman in enemy hands. Hence unmanned surveillance systems found ready acceptance and proliferated rapidly on a global scale.

Unmanned Aircraft Bridging the Gap with Satellites

Unmanned surveillance systems suffered from a few old drawbacks in addition to a few new ones unique to unmanned aircraft. The old drawbacks include limited fuel on board and the old fuel weight vs. useful payload / endurance / range trade-off. Light weight of the vehicle allowed larger useful payload but limited the fuel to be carried aloft and hence the range and endurance. Operating height was also an issue as lower operating heights AMSL led to increased vulnerability to surface based as well as to airborne threats. Unmanned aircraft require control from ground station to which they also download data through use of wireless data links. The control and download data links are both limited by physics due to the line of sight nature of such links. One very complicated solution tried out earlier has been to use a relay unmanned craft to extend the useful operational range of another such vehicle. Another potential solution being attempted is to utilise satellites to convey control instructions to the unmanned craft and use a similar channel for data recovery. This latter solution has suffered from limitations of satellite communication antenna and associated hardware's size and weight. Attempts have been on for several years to reduce these shortcomings of unmanned aircraft. On relatively large and powerful fossil fuel engine powered unmanned aircraft such as the US Predator and Reaper incorporation of satellite communication systems was achieved. It is good to bear in mind that the Predator and Reaper are very powerful unmanned aircraft in that their power plant is able to carry aloft the aircraft fitted with satellite

communication and control systems in addition to integrated surveillance and targeting equipment and still can carry four Hellfire missiles on external high drag (conventional) weapons stations; each Hellfire missile weighs approximately 100 pounds. The Reaper is even more powerful, and in addition to its satellite communication and control system plus the surveillance and targeting equipment it can carry up to 1,500 pounds of external ordnance on six external weapons hard points. Satellite communication and control systems that can be fitted on these very powerful unmanned aircraft are unlikely to be suitable for lighter unmanned aircraft, hence the challenge. Smaller and lighter unmanned aircraft posed a bigger challenge due to size and weight limitations for incorporation of satellite communication systems, especially for countries other than the US. The US having achieved some level of miniaturisation of satellite communication and control equipment for the Predator and Reaper naturally moved to deny proliferation of their new technology to other countries for strategic reasons. Recent news reports indicate that some headway has been made by the United Kingdom and Europe in achieving greater utility from unmanned systems through overcoming earlier drawbacks while enabling potential new uses of these systems.

The solar powered Zephyr 7 High Altitude Pseudo Satellite (HAPS) has demonstrated a single flight of over eleven days duration. The zephyr 7 was initially developed by the British company QinetiQ. It has now become a part of Airbus Industry's HAPS program.ⁱⁱ The Zephyr 7 is reported to have achieved an altitude of 70,000 feet AMSL while carrying a surveillance / reconnaissance payload of 5 pounds on an aircraft weighing a total of 118 pounds; this weight of 118 pounds includes the weight of the satellite communications and control system installed on it.ⁱⁱⁱ The test flight was reportedly carried out in a region and season of relatively short daytime

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periods and longer nights.^{iv} The Zephyr 7 was reportedly controlled through a satellite link.^v These seasonal conditions make the achievement of over 11 days aloft even more remarkable as the vehicle's solar cells would have had lesser time to charge on board batteries than in a situation of longer sunlight duration as against night time. Zephyr 7 showcases European advancements in development of small and light satellite communication and control equipment as well as development of quick charging high density light weight batteries in addition to higher efficiency solar cells.

The flight of the Zephyr 7 shows that a possible technological solution to fuel weight on board for endurance may have been found through use of solar cells and lightweight energy dense batteries. The payload reported at 5 pounds is quite low, but as testing and development continues this could be reasonably be expected to increase. The successful use of a satellite link to control the Zephyr 7 indicates that miniaturisation of satellite communications equipment has reached a level wherein a relatively compact and light device is available for use on unmanned aircraft thus overcoming the limitation of line of sight for unmanned aircraft control.

Apart from helping fill the capability gap for surveillance the Zephyr 7 test throws up other opportunities for military use. Satellites as seen earlier have technological problems apart from their cost and complexity. Rapid launch capability for satellites is expensive and limited to a small number of countries. Looking a little further shows that satellites achieve their effectiveness from the fact that they are located very high above the earth's surface. Such elevation gives them freedom from most interceptions save by specially designed anti-satellite systems. The large line of sight achieved by very high location is what satellites leverage to deliver their advantages. In view of the great advantages conferred by satellite based surveillance, communication, and navigation systems it is likely that one's own satellites would be targeted and destroyed by the enemy in the early stages of a conflict itself. The option of replacing such lost satellites at short notice is technologically and financially very challenging. The name given to the program, HAPS, in which Zephyr 7 is the technology demonstrator points towards another potential use of these vehicles. Very high altitude operation capable unmanned vehicles that can maintain station for several days

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could in adverse situations stand in, as it were, for lost satellites if they are configured to carry similar equipment as earmarked for the satellite at much lesser cost and technological difficulty. The advantage of the high elevation above the surface could now be achieved at lower cost for several days at a time thus giving a larger time window to prepare and launch replacement satellites. In other circumstances such unmanned craft could supplement satellites in times of need more efficiently than launching additional satellites would. This last aspect will be clear to the reader if he considers the advantage in resolution obtained from an optical payload located at say 80,000 feet AMSL as compared to the same optical payload located on a satellite at several hundred kilometres above the surface. The revisit and dwell time issue would also be more favourable than obtained from satellites. The trade off could be the inability to maintain station deep inside the enemy's territory safely for a long time. Due to this last limitation such high endurance high altitude unmanned systems would be unable to replace satellites completely but would be a useful complement to satellites especially in regions close to the borders where the land or marine war could be expected to be taking place.

Conclusion

Surveillance was the very first role assigned to craft able to venture above the earth. This role continued to remain important through the years and even in current times a combination of satellites and manned / unmanned aircraft have been in use for this important mission. However, both satellites and aircraft suffered from lacunae that limited their full and effective exploitation. Recent advances in unmanned aircraft technology point towards the gap in capability being addressed effectively while delivering additional advantages through used of high altitude operation capable unmanned aircraft.

(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))

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ⁱ "American U-2 spy plane shot down", <http://www.history.com/this-day-in-history/american-u-2-spy-plane-shot-down>, accessed on 01 Sep 2014.

ⁱⁱ Richard Tomkins, "Satellite used to control unmanned aerial vehicle", http://www.spacedaily.com/reports/Satellite_used_to_control_unmanned_aerial_vehicle_999.html, accessed on 01 Sep 2014.

ⁱⁱⁱ Ibid

^{iv} Ibid

^v Ibid