Exploiting Indigenous Technologies for Unmanned Air Vehicle Surveillance System

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ABSTRACT

This paper describes the need for an unmanned air vehicle surveillance system performing the job of a low cost satellite system. It discusses the requirements of such a system and outlines a strategy to achieve it.

Keywords: Unmanned air vehicle, surveillance, reconnaissance, low-altitude sensor

1. INTRODUCTION

The purpose of reconnaissance is to gain intelligence about the enemies, or potential enemies preparedness, movements, possible intentions, vulnerable points and vital targets. Victory is assured for the better prepared and better informed side. The advantages of aerial reconnaissance for intelligence gathering are three folds: (i) timeliness of the information secured, (ii) the depth of penetration possible, and (iii) the relative difficulty the enemy has in preventing it.

There are two fundamental points to be considered, viz., the principle of precedence, and the principle of continuity. Aerial reconnaissance precedes, both in time and space, the operations of other components of naval, ground and air units. One of the basic principles of aerial reconnaissance is to provide security for friendly forces. This can be guaranteed only when the reconnaissance is continuous, i.e. with surveillance. Surveillance refers to watching a particular area or target for an extended period of time.

Geopolitical circumstances around India dictates the need for heightened surveillance of military and political hot spots. These situations can be at sites that are far apart, they can spring without warning and often occur simultaneously. Rapid access to a region of interest is provided by a sustained presence in the region. It can be achieved, in principle, by a high altitude satellite sensor with a near hemispheric view. It is difficult, however, to achieve the desired image quality from a sensor at near geosynchronous altitude[1]. The other alternative is to have a fleet of low-altitude sensors that collectively maintain its presence in the region. Low-altitude sensors include: Low-earth orbit (LEO) satellites, manned aircraft and unmanned air vehicles (UAVs).

A drawback in providing surveillance with LEO satellites is that they are constrained by the laws of orbital mechanics and cannot quickly revisit a region of interest. This problem can be overcome by providing a larger constellation of surveillance satellites, but at a significantly increased cost. Manned airborne sensors can linger in a region of interest but have practical time constraints, such as fuel

Revised 27 April 2001

capacity and crew fatigue. To maintain constant surveillance over a reasonable area, several manned aircraft-borne sensors are required. The cost of maintaining constant surveillance is a function of the operational cost of individual aircraft and the number of aircraft needed and their survivability. These factors have generated high interest in UAVs. The UAVs can stay aloft longer than manned aircraft, because crew fatigue is not a factor. Additionally, the weight saved by eliminating the crew and the environmental control system can be utilised for fuel. The UAVs are less expensive because the safety, security and comfort of the crew need not be considered in their design. The ideal UAV should be inexpensive to build and operate, carry multiple high quality sensors, and be invulnerable to enemy defences. These are mutually conflicting objectives.

This paper considers the requirements of such UAV surveillance system and discusses how the indigenous technology could be harnessed and exploited. It also suggests ways to achieve it. Underlying philosophy is: 'accept limitations', 'improve where feasible and essential', and 'build to strength'. Also the aim is to get on par with leaders in the UAV area at least ten years from now.

2. OBJECTIVES OF UAV SURVEILLANCE SYSTEM

The objectives of UAV surveillance system are:

(a) Airborne moving target surveillance

(b) Ground moving target surveillance

(c) Ground surveillance.

Apart from its use during graytime and wartime, the main purpose of such a system would be to patrol a neutral zone during peacetime for any violations.

2.1 Concept of Operations of High Altitude Endurance UAV Surveillance System

This system can provide broad area coverage, point target reconnaissance, sustained point surveillance, and deep target surveillance. Requirement is to patrol all borders during peacetime for violations. In wartime, keep surveillance over regions of interest deep inside enemy territory also. Area coverage required per day could be 1,50,000 km^2 over one border itself. It could also be used to provide point targets for pre-and-post strike missions.

3. REQUIREMENTS OF UAV SURVEILLANCE SYSTEM

The requirements of UAV surveillance system can be listed as

- Survivability
- All-weather performance
- Wide area surveillance
- Air surveillance
- Ground surveillance
- Low speed
- Miniaturisations versus normal
- Degree of autonomy
- Solar power
- Data exploitation and communication
- Automatic take-off and landing.

3.1 Survivability

Surveillance platforms are valuable. If they are to survive these vulnerable assets must be stealthy, high flying or operate from long stand-off ranges. Its threat are antiaircraft guns, air defence missiles, surface-to-air missiles (SAMs) and attack by manned fighter aircraft. To make the UAVs survivable[2], one could operate these only after the enemy's air defences have been suppressed. It would impose a severe limitation on the use of UAV system. Low observability would give the UAV necessary survivability. This feature would be compromised when its radar sensor and data link are operating. Low probability of intercept (LPI) techniques allow the radar to be discreet. Similarly, satellite communication (satcom) gives the data link discreetness especially for high altitude UAV. There is an associated problem of cost and maintaining the low observability feature in service without degradation. The threat of engagement of UAVs by manned fighter aircraft with guns and rockets still looms large for both low observable UAVs and UAVs operating from long stand-off ranges. Long stand-off ranges require sensors with required resolution at associated ranges. An extremely high altitude of flight of the UAV, such as 25 km, can give it the necessary survivability as this altitude is higher than the capability of most SAMs and antiaircraft guns. Even there are not many fighter aircraft which can reach this altitude. High altitude with limited stand-off capability can give it the necessary survivability. Also by carrying a suite of countermeasures, it can confuse enemy SAMs.

3.2 All-Weather Performance

Of the types of surveillance available, imagery is probably the most useful and easily interpreted. Visible, IR and synthetic aperture radar (SAR) sensors all offer advantages for surveillance[3]. Visible sensors yield, under optimal conditions, the highest quality imagery in terms of resolution and ease of interpretation, but their effective operation is limited to daytime clear weather conditions. IR sensors function similar to visible light sensors but can operate day and night and penetrate camouflage. Longer IR wavelengths can penetrate atmospheric haze better than the visible waves.

The SAR has many advantages. The most important one being all-weather operation, making delivery of results far more dependable, especially in areas with chronic cloud coverage. A pair of SAR apertures on a single platform can implement an interferometric SAR mode (IFSAR) that allows accurate measurement of terrain elevation or target height. The SAR image resolution of a meter or less compares favourably with most satellite systems. Typical SAR sensors can switch favourably among modes e.g. using a strip mode for wide area coverage and a cued high resolution spot mode for particular targets. It is necessary to provide imagery from all the three sensors and allow user to select appropriate sensor for a given circumstance or derive information through fusion of two or more sensors. At 25 km, the average wind speed is significantly less than at altitudes below tropopause. Take-off and landing can be planned at favourable wind speed conditions as the UAV has very long endurance. This altitude of flight provides relatively clear weather free from turbulence and rain. The stability of the span-loaded flexible structure and vibration-free environment can permit mounting of sensors rigidly to the structure without requiring a stabilised gimbal system.

3.3 Wide Area Surveillance

Indian borders are very long. Even to keep surveillance over 100 km into enemy territory along one border area works out to be 1,50,000 km^2. High altitude surveillance with SAR offers such wide area surveillance over air and ground. Todays SAR for wide area surveillance covers more than 1 km^2/s with a resolution of 2×1 m^2.

3.4 Air Surveillance

High altitude UAV flying at 25 km with SAR at a stand-off range of 150 km, would give it the necessary survivability from even missiles of SA-10 class. It can be used as a stand-alone low-cost air surveillance system. A multi-beam antenna with the necessary area, sensitivity and power would give it a range of 300 km. Use of bistatic mode of operation offers potential survivability, antijam and antistealth advantages over alternative surveillance approaches. The UAV with the illumination could be over a really safe region, whereas the UAV with the receiver could be over more hazardous territory.

3.5 Ground Surveillance

Similar to air surveillance, ground surveillance with UAV-SAR is feasible. The aperture requirements are reduced when compared to that for air surveillance. One could also use SAR with foliage or ground penetration. As in the case of air surveillance, bistatic mode of operation gives definite advantages.

3.6 Low Speed

Relatively slow moving (150 ms^{-1}) flight speed permits the use of electric brushless motor driven with variable pitch propellers[4]. Low speed when compared to high speed appears to give the UAV increase in the synthetic aperture length in the use of SAR.

3.7 Miniaturisation versus Normal

High altitude endurance UAVs would permit normal size line replaceable units (LRUs) and sensors to be used when compared to miniaturised ones required for short range medium endurance UAVs as the size and the weight restrictions are not severe there.

3.8 Degree of Autonomy

Degree of autonomy covers (i) autonomous flight control, way point navigation, take-off and landing, and (ii) autonomous payload control over long distances, time critical operations and hostile actions make conventional 'human-in-the-loop payload control' impractical. Also multiple UAVs can be employed in a cooperative cluster e.g. one set of UAVs for wide area surveillance could cue a second set operating at low altitudes on areas of interest for higher resolution sensing or to increase the probability of detecting and classifying obscured or ambiguous targets. The critical requirement for payload autonomy is onboard sensing leading to automatic target recognition.

3.9 Solar Power

Long endurance requires lightweight propulsion system. Solar rechargeable UAV will give a virtually eternal and low-cost relocatable platform for surveillance. Propulsion system requires electric motors, solar cells and a power management system. It also requires suitable means of storing energy for night-time flight.

The largest area available for harnessing sunlight on an aircraft exists on the flying surfaces. The intensity of sunlight that shines on the wing varies with the earth's orbit, atmospheric attenuation and the angle of incidence of the wing. Flight at 25 km avoids atmospheric attenuation, and tropical location of India yields necessary solar flux.

3.10 Data Exploitation & Communication

The image collection efficiency of a high altitude UAV is such that the system can generate imagery at the rate of 1000 km^2/hr. This volume of data at 1 m resolution is too extensive for an image analyst to review and process on time. Hence, an aided target recognition or automatic target recognition algorithm is required to find and identify targets of interest. It may not be feasible to identify conclusively a target as a threat or not. In the event of ambiguity in classifying a target, the image is to be exploited and enhanced. Aerial views offer an advantage if two sets of images of a given area are obtained with slightly different angles of view, three-dimensional pictures can be visualised. Communications must deal with data links for sensor outputs and provide service to the users. It should overcome horizon limitations. Use of satcom offers attractive and affordable communications capability for high altitude endurance UAVs. It also gives these enhanced survivability.

3.11 Automatic Take-Off & Landing

Key technology area to support the concept of high altitude UAV is low Reynolds number airfoils with extremely high lift-to-drag ratios[5] of over 50:1. Significant challenges are there in automatic landing and take-off of such high lift airframes.

4. STRATEGY FOR HARNESSING & EXPLOITING INDIGENOUS TECHNOLOGY

India has been working in the field of UAV development for more than two decades. It has also been working on satellites. UAV system design engineering needs to be improved upon to realise optimal solutions. Research in aerodynamics to realise high lift-to-drag ratios of 50 is to be carried out. Competent researchers and infrastructure in this area are available. To realise efficient low weight airframe designs, advances in process technology of composites is required. Automatic way point navigation has been realised successfully. However, electronic packages used should have the high reliability demanded by long endurance UAV system. Automatic take-off and landing is a new area which is required to be addressed. Technology demonstration projects on small UAVs need to be launched before it can be attempted on larger UAVs described in this paper. Solar power for ground and satellite applications is already in use. It has to be adopted for airborne application. Highly reliable brushless motors need to be developed.

Derated satellite sensors for UAV surveillance are needed. Efforts put in on SAR need to be augmented considerably to realise SAR for air and ground surveillance. Software capability available is to be harnessed efficiently for onboard processing, and developing 'aided/automatic target recognition' techniques. Communication for data dissemination on ground could be effectively planned. Available satellite communication technology could be harnessed.

The strategy would be to fund and direct research in well-defined problems right from now and demonstrate the same in manned aircraft platforms or small UAVs before the system design of the high altitude endurance UAV platform as a low cost alternative to satellite system is attempted.

5. CONCLUSION

The requirements of a UAV system for surveillance is described. Some thoughts on harnessing and exploiting indigenous technologies to achieve this UAV platform, with the aim of coming on par with world leaders in UAVs, are discussed. If the need for this system and then the requirements are understood, identification of areas in which large-scale funding of research and development will become clear. Software strengths should be harnessed to address areas of image exploitation, image enhancement, aided/automatic target recognition, etc.

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Shri J Jayaraman obtained his AMIE from Indian Institute of Science, Bangalore. He joined DRDO at the Aeronautical Development Establishment in 1961. During a span of four decades, he held positions as Associate Director, Group Director of Unmanned Air Vehicles Programme, Project Director of *Lakshya*, Head of Structures and Materials, and Mechanical Engineering Design Divisions. His areas of interest are: Composite materials, mechanical systems design, airframe design, and unmanned air vehicle systems. He was given *Dr VM Ghatge Award* (1991) of the Aeronautical Society of India for outstanding contribution in the field of aeronautics. He also received two *DRDO Cash Awards* for the development of fluffy and reusable rocket pod. Later on, he was given *DRDO Scientist of the Year Award* (1994) in flight sciences. He also received *Performance Excellence Award* (2000) as Team Leader on behalf of the team. He is a fellow of the Institution of Engineers India, Aeronautical Society of India and Indian National Academy of Engineering. He has presented and published several papers in national conferences.