Initial Efforts toward Mission-specific Imaging Surveys from Aerial Exploring Platforms: UAV

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ABSTRACT

A number of researchers throughout globe have proposed the use of unmanned/remotely piloted aerial explorers to perform scientific investigation of remote areas and aerial surveys for specific missions - land mapping, tropospheric sampling etc. One of the essential tasks for any aerial explorer is to be able to perform scientifically valuable imaging surveys. The focus of this paper is to discuss the challenges implicit in, and recent developments in India related to, acquiring mission-representative imaging data from a small fixed-wing UAV. The high-level of mobility, and unique observational perspective, afforded by aerial vehicles makes them potentially extremely valuable tools.

In the last years UAV (Unmanned Aerial Vehicle)-systems became relevant for applications in precision farming and in infrastructure maintenance, like road maintenance and dam surveillance. This paper gives an overview about UAV (Unmanned Aerial Vehicle) systems and their application for photogrammetric recording. UAVs are mostly low cost systems and flexible and therefore a suitable alternative solution compared to other mobile mapping systems. In the last years, more and more applications of UAV-systems in photogrammetry became common. This development can be explained by the spreading of low cost combined GPS/INS-systems, which are necessary to navigate the UAV with high precision to the predicted acquisition points. Some systems are used without GPS/INS-systems, especially for the capture of aerial images for terrestrial measurements. For the applications using UAVs only and for the reduction of the number of control points, the GPS positioning should reach decimeter accuracy.

In this paper, we present the development of Unmanned Aerial Vehicles for specific scientific missions at Aurora Integrated Systems in conjunction with Indian Institute of Technology, Kanpur.

Keywords: Aerial Imaging, UAV, GPS/INS Navigation

1. INTRODUCTION

AIAA Committee of Standards, Lexicon of UAV/ROA, defines UAV to be an aircraft which is designed or modified, not to carry a human pilot and is operated through an electronic input initiated through the Flight Controller or by an onboard autonomous flight management control system that does not require flight controller intervention. The modern UAV era originated in the early 1970s. Designers in the United States and Israel started experimenting with smaller, slower, cheaper UAVs. Their most important feature was that they used new, small video cameras that could send pictures to the operator in real time.

We started the UAV development program in 2002, and recently we have established Aurora Integrated Systems, devoted to the cause of UAV technology development and commercialization of the technology. Aurora Integrated Systems, along with IIT Kanpur strives to facilitate the following:

- Design and manufacturing of operating aerial vehicles to meet the requirements of a variety of individual research and test programs
- Developing new instrumentation to meet increasing challenges for improvements in meteorological and oceanographic measurements., as well as facilitating defense reconnaissance missions
- Calibrating, maintaining, and operating the facility's airborne instruments in accordance with individual mission specifications
- Integrating auxiliary payloads as required and handling flight safety and logistics tasks, allowing the user to concentrate on his specific mission goals

The foremost technology that goes onboard as payload is vision, providing visual data useful for a large number of Civil and Defense applications. Custom imaging payloads are required for a variety of missions. We outline here configuration of a Medium Altitude Long Endurance UAV, and a Low Altitude Surveillance System – which are respectively better suited for Civil and Defense Missions. Subsequently we will focus on some of the applications we are developing, and customizations to the UAV system as a whole.

2. Navigation and Control

2.1 Autopilot

Autopilot based on various sensors it acquires the attitude, velocity, position and acceleration of the air-vehicle. These data are then passed on to the flight control system which based on a PID control law actuate the servos to deflect the control surfaces. It is important that if onboard processing of payload is required that there is redundant processor along with flight control processor.

2.2 Ground Control Station

Ground Control Station provides you the in-flight data and allows you to monitor the flight. The user can also manually override the path of flight by feeding new way-point using Ground Control Station. If required the payload data i.e. images, video etc. can be transmitted to the GCS or stored onboard for post-processing after flight. The telemetry data transmitted by the UAV is required often as the metadata for correction in the payload data e.g. camera look angle, azimuth etc. are used for orthorectification of the image acquired by the UAV.

2.3 Way Point Navigation

The way point navigation is the de-facto standard of UAV navigation today. The user using an annotated map of the area, can mark the waypoints, so as to create a flight plan for the mission. It is important that during the mission planning the way point are chosen such that the entire area which needs to be monitored, surveyed etc. is covered with minimum redundancy. Optimization techniques are used to create flight plans so as to ensure minimum redundancy.

3. Imaging Applications of UAV

3.1 Civil Applications

- *Precision Agriculture*

Western countries have been deploying technology for periodic assessment of high value crops. However with the advent of agriculture based trading companies in India and growing awareness, there is a significant investment for technology development for precision farming. Unmanned Aerial Vehicles are capable of carrying imaging payloads (Electro-optical / IR / Hyper spectral). Such mission would help scientists improve the characterization of terrestrial biomass, leaf level chemistry and canopy water content. The science data will provide vegetation 3-dimensional structure and information on composition and chemistry. In addition, the observations will elucidate functional groups and physiological impacts on the carbon cycle.

The commercially viable data that can be generated using such aerial images includes NDVI (Normalized Difference Vegetation Index) etc.

- *Disaster Management*

Unmanned Aerial Vehicles can provide live footage of a disaster struck area to facilitate the relief operations and planning for disaster prevention. UAVs were used extensively during Katrina relief operations in USA, and tsunami relief operations in India.

  - Flood relief operations. Such a system would have been of great help in situation like Tsunami.
  - Landslide rescue missions
  - Monitoring riot situations/patrolling

- *Oil & Gas Pipeline monitoring*

There are various environmental and human activities that need to be monitored on a routine basis to ensure the safety of huge investment gas pipelines. Some of the monitoring activities are:

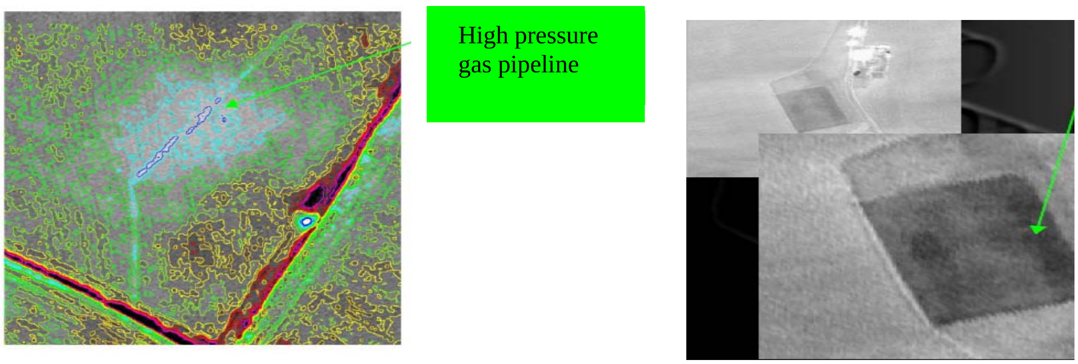
  - Construction Work
  - Earth Movement and Excavation
  - Laying of pipes, cables etc.
  - Erection of buildings
  - Soil upheaval and erosion
  - Water logged surfaces
  - Plantation of shrubs and trees

- Discoloring of vegetation

The purpose of an aerial imaging platform in such a scenario is to perform object detection and location, and moving vehicles. The spatial requirement for aerial images translates to

- Monitoring strip of 200m
- Metallic machinery 2m X 1m
- Objects e.g. pipes 0.2 m X 5 m
- Excavations 0.5m X 5m 0.5m
- Tree tops diameter : more than 2 m
- Location accuracy : 5m

The platform should also ensure weather independency and surveillance frequency of more than once in a week. Pipeline monitoring is an important safety related task for which global satellite solutions are not available. Currently, the choices are manned helicopters and airborne systems, however the solutions is not cost effective, translating into lower surveillance frequency.



(a) **(b)**

Figure 1. (a) *Artificially generated thermal image* ***(b)*** *Change in ground compaction*

Figure 1(a) shows the monitoring of pressure within pipelines, using thermal imagery, whereas **Figure 1(b)** depicts the changes in ground compaction due to human or natural activity which could be of potential danger to gas pipelines. There are a number of other parameters that could be observed using high resolution electro-optical (visible spectrum) or thermal/hyperspectral imagery.

- *Forest Fire Detection / Forest management*

Aerial images obtained from the UAV can be automatically analyzed using software to detect the presence of forest fire and its location. Similarly, aerial images obtained from the UAV are used to monitor the activities in the territory of a forest, keep a track of plantation growth, and to obtain an estimate of recession/growth of forest boundaries.

- *Atmospheric Sampling Missions*

The greatest utility of UAVs of MALE class is its capability to fly autonomously at such heights so as to carry out scientific research missions in troposphere and stratosphere.

Aerosonde UAV [3] developed by Aerosonde Pty. Ltd, Australia was the first UAV to be used by NASA for such missions.

- *Landscape Mapping*

Aurora Integrated Systems has developed a suite of GIS software which is being integrated with the UAV round Control Station (GCS), so as to create on the fly geo-referenced maps from Aerial Images being downlinked from the UAV. Such maps can be generated almost in real time, and would greatly facilitate urban planning activities.

3.2 Defense Applications

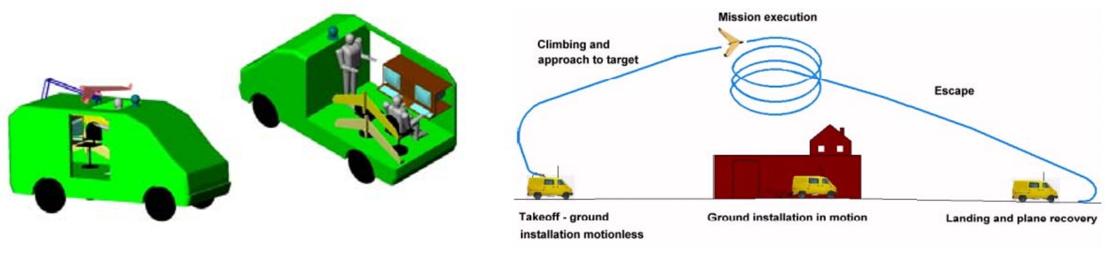
Low Altitude Surveillance System class UAVs are used for in-field aerial reconnaissance. They are small, low weight, modular UAVs, and can be operated by a single person. They are hand launched and belly landed with deep stall; they can be carried in a back-pack and Ground Control station consists of a ruggedized laptop and visual display unit. Laptop runs the navigation software to set waypoints for autonomous navigation of UAV. Onboard UAV are EO sensors and wireless transmitter to transmit the live video feed to ground display unit.

Medium Altitude Long Endurance UAVs are also used for surveillance purposes, for a longer range and require a Mobile Vehicle housed Ground Control Station as depicted in **Figure 2.**

Both these aircrafts are used to carry out Over-the-Hill reconnaissance missions.

4. UAVs (MALE & LASS)

Aurora Integrated Systems has developed prototype of two classes of Unmanned Aerial Vehicles – MALE and LASS which are respectively better suited for Civil Applications and Defense Applications.



(a) **(b)**

Figure 2. (a)*The concept of a Ground Station for MALE UAV*
(b)*Mission Profile of a MALE UAV*

- *Medium Altitude Long Endurance UAV (Under Development)*

The Medium Altitude Long Endurance (MALE) system is meant to be modular, easy to operate, intelligent and versatile UAV. The weight less than 15 kg makes it possible to launch from car top or a small runway. It can carry 2 kg of payload with full fuel load, with wingspan less than 6 ft. The key feature is its versatility in terms of altitude from 300 ft to 18000 ft which makes it possible to capture near earth images as well as capture atmospheric conditions and dynamics at meso scale, and non line of sight control. The range of over 2500 kms with cruise velocity of 75 km/hr and flight duration including taxing more than 24 hrs makes it extremely useful in spy, surveillance and reconnaissance missions, in mountainous as well as marine regions. The stability characteristics combined with the aforementioned range and altitude makes it an ideal plane for the mineral resource exploration and exploitation as well as environment monitoring in natural disaster stricken areas.

- Specifications:
  - Weight < 15 kg, Payload up to 5 kg
  - Modular assembly, ease of operation
  - Non line of sight control (NLOS)
  - Range > 2500 KM
  - Endurance > 24 hours
  - Operational Altitude: from 300 – 20000ft
  - Maximum altitude: 30000 ft
  - Fully autonomous flight capability including launch and landing
  - Mission plan created with graphical user interface
  - Imaging Payload : Gimbaled EO and IR sensors

Figure 4 depicts the typical mission profile for a MALE UAV. It is launched from a car rooftop, navigates using waypoints to target location and transmits over wireless link live high resolution imagery. The waypoints can we modified during flight and uploaded to onboard autopilot using wireless modem link. So as to enable longer ranges, a high gain tracking antenna is used on ground to obtain noise free video footage.

We are carrying on the work to upgrade the MALE UAV and Ground Control Station to support multiple wireless data links, and to upgrade the communication system to incorporate satellite communication. With the satellite link in place range can be enhanced by upto ten times.

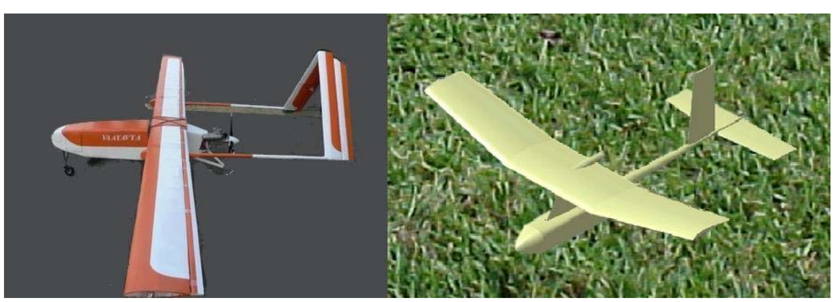


Figure 3. *MALE and LASS prototype under development at Aurora Integrated Systems*

- *Low Altitude Surveillance System*

The Low Altitude Surveillance System (LASS) is modular, small, lightweight and easy to operate. The wingspan is less than 5 feet and weight under 3 Kg. It could be hand launched or bungee launched and providing real time color or infrared aerial observation, day or night. The desired range is to be over 10 Kms. The recovery method is aimed to be conventional under belly horizontal landing. It carries Dual Forward and Side-Look camera along with a side-look IR camera. The endurance is more than 50 minutes with rechargeable Lithium Polymer battery and operational height of 100 to 500 feet.

It will be able to be deployed and ready to perform in challenging environment within a very short time. With the operational speed from 25 Km/hr to 60 Km/hr, this UAV will be a product compliant with international standards of the UAV of this class.

- Specifications:
  - Weight < 3 kg, EO/IR payload included
  - Modular assembly, ease of operation
  - Non line of sight control (NLOS)
  - Range > 50 KM
  - Endurance >1 hours
  - Operational Altitude: from 300 – 1000ft
  - Maximum altitude/ceiling: 5000 ft
  - Fully autonomous flight capability including launch and landing
  - Mission plan created with graphical user interface

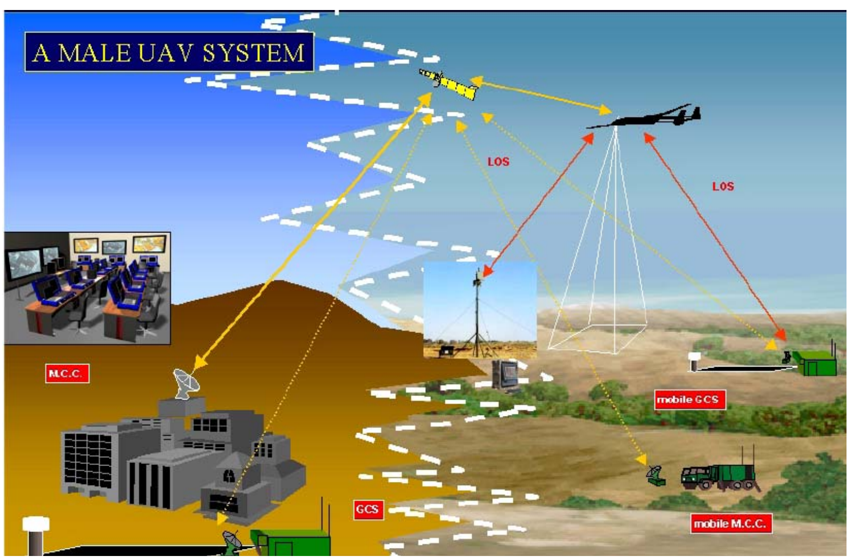


Figure 5. *A full fledged operation of a MALE UAV and its GCS*

5. Conclusions

India has yet not evolved to the usage of UAV for aerial imaging applications which can reduce the effort and expenses involved in mapping and other GIS applications. However with the availability of technology and adequate mission planning, we can accomplish all the missions described in this paper. We have already demonstrated the feasibility of such imaging missions.

Acknowledgements: Authors acknowledge the support provided by Dr. A.K Ghosh, Head, IIT Kanpur Flight Lab Facility

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