PEGASUS, A UAV PROJECT FOR DISASTER MANAGEMENT

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ABSTRACT

The Flemish Institute for Technological Research (Vito) in Belgium has initiated in 2000 the PEGASUS (Policy support for European Governments by Acquisition of information from Satellite and UAV-borne Sensors) project which envisages the development of a solar powered UAV (Unmanned Aerial Vehicle) containing several types of instruments for remote sensing and flying at an altitude of about 20 km. The aircraft can be deployed rapidly in crisis situations and provide disaster managers with ~1 m resolution images (or better if required) of the affected area. High quality data shall be received in less than half an hour from a mobile ground station that is in direct contact with the UAV, which can operate as long as requested by the user. The PEGASUS HALE-UAV is a flexible and cost-effective tool that will allow officials and local authorities to dispose quickly over relevant geographical information in an emergency situation. The first demonstration flight of the PEGASUS HALE-UAV shall take place in the summer of 2005 over Flanders.

Keywords

HALE UAV, High Resolution Data, Remote Sensing, Geographical Information

INTRODUCTION

Remote sensing data has an important role in investigating and monitoring environmental and climate changes both on a global and on a local scale. Mostly, geographic information is collected through traditional airborne and spaceborne systems which are basically trading off temporal for spatial resolution (Everaerts 2004). Both systems have their advantages, but also their disadvantages. There is a need for an extremely flexible and cost-effective platform providing high spatial resolution (< 1 m) and high temporal resolution measurements: a High Altitude Long Endurance Unmanned Aerial Vehicle (HALE-UAV). Therefore, the Flemish Institute for Technological Research (Vito) has initiated the PEGASUS project in 2000. This project envisages the development of a solar powered HALE-UAV platform carrying several high resolution instruments for Earth Observation purposes, among which security and disaster management. The PEGASUS HALE-UAV will operate in the stratosphere (14 - 20 km altitude above sea level) using a combination of solar cells and batteries in order to fly continuously for several months. To cover a maximum of the user community requirements, the UAV shall be equipped with four different sensors: a multi-spectral camera, a thermal camera, a Lidar and a Synthetic Aperture Radar (SAR) - offering a 24 hour per day and all-weather observing capability. The first flight of the HALE-UAV containing a multi-spectral camera is scheduled for the summer of 2005 over Flanders. Further demonstration flights are foreseen in the course of 2006. The other instruments will be operational by the end of 2008. The HALE-UAV will be controlled from a mobile ground station through which the data will be down linked. The user will be able to access high quality data products from the Internet in a near-real time fashion. This means that data in a ready-to-use format will be available to the users within half an hour or even less at lower resolution. The data workflow shall be operated by Vito in a central Processing and Archiving Facility (PAF). UAVs are ideal for performing dirty, dull and dangerous tasks (Aldridge & Stenbit 2002) and they can assist in emergency response by near-real time remote sensing of the area of interest for long periods of time. Sending a UAV with the right capabilities to a disaster site affords an opportunity to mitigate disaster outcomes because it can provide the right information to the right people at the right time regarding the situation on the ground.

DISASTER MANAGEMENT

Various disasters like earthquakes, landslides, volcanic eruptions, fires, flooding and cyclones are natural hazards that kill thousands of people and destroy billions of dollars of habitat and property each year. The rapid growth of the world's population and its increased concentration often in hazardous environment has escalated the impact of natural disasters. Developing countries suffer more or less chronically from natural disasters because of the tropical climate and unstable land forms. The respective governments and non-governmental organizations rely on data from the disaster site to respond in an optimal way with warnings, evacuations, rescue to even damage control.

Disaster Management is a set of actions and processes designed to lessen disastrous effects either before, during or after a disaster. There are several phases in the response to a disaster and all of these activities could benefit from near real-time information from a HALE-UAV with a major focus on providing emergency response (Cuny 1993).

The Preparatory Phase. The preparatory phase of a disaster response includes all of the activities that help a society and the disaster agencies to prepare for a disaster event. Activities carried out in the preparatory phase include organization, legislation, development of procedures, inventories of resources and establishment of response plans. These activities are broadly classified as disaster prevention, mitigation and preparedness. In general, disaster prevention is event-focused. The objective of prevention is to prevent the disaster from occurring. Disaster mitigation accepts the fact that some natural events may occur, but it tries to lessen the impact by improving the community's ability to absorb the impact with minimum damage or disruptive effect. Disaster preparedness assumes that a disaster will occur; it focuses on structuring the emergency response and on establishing a framework for recovery. From remotely sensed data of the PEGASUS HALE-UAV, topographic maps could be made of risk areas such as villages at the foot of a volcano, near a fault line or a river. The maps are a good tool for setting up an emergency plan.

Warning Phase. Most disasters are preceded by a period of time during which it becomes obvious that something hazardous is going to happen. Certain specialists focus on trying to detect signs of an impeding threat. By monitoring events, they look for indicators that tell when, where and what magnitude the event may be. This is known as prediction or forecasting. The objective is to provide disaster managers with enough information so they can give the people at risk adequate notice or warning to prepare for the disaster and if necessary to evacuate. At the present time, warning is possible for droughts and famines, cyclones and most severe weather phenomena, volcanoes, large scale fires, and in some cases earthquakes (Rao 1993). If there are indications from ground measurements (gauges, buoys, seismographs, etc…) and satellite data that an event is going to take place, then a UAV can take-off within a few hours for an early monitoring of the area. The rapid deployment of the aircraft is one of its assets in a crisis situation.

Emergency Phase. This phase of disaster response involves actions that are necessary to save lives and reduce suffering. They include search-and-rescue, first aid, emergency medical assistance and restoration of emergency communication and transportation networks. Some disasters also necessitate evacuation from areas still vulnerable to further disaster events and provision of temporary shelter, food and water. Other actions taken during the emergency phase include initial disaster assessment and emergency repairs to critical facilities. In this part of the disaster management plan it is most profitable bringing a HALE-UAV into action. The aircraft can make an immediate assessment of the damaged area and from the retrieved images a profound logistic organization and coordination of the rescue teams can be established. As such, the first aid can be brought to the most affected areas from accessible gateways. Data shall be collected and archived in a data base in order to make comparison to the situation afterwards.

Rehabilitation Phase. This transitional phase is a time period when people begin to return to work, to repair infrastructure, damaged buildings and critical facilities and to take other actions necessary to help the community to return to normal. Here, the HALE-UAV can be employed to permanently monitor the affected area in order to examine the evolution in the recovery and in some cases as a warning system in case the event recurs.

Reconstruction Phase. The reconstruction phase of a disaster involves the physical reordering of the community and of the physical environment. During this period people reconstruct housing and other community facilities and agriculture returns to normal. In this part the insurance companies will try to estimate the cost of suffered damage. The archived high resolution images of the disaster could be used to make this assessment.

APPLICATIONS AND INSTRUMENT PERFORMANCE

There are many potential situations that can be considered disastrous for the human population, among them are forest fires, flooding, earthquakes, tsunami and volcanic eruptions, etc…. The disastrous effect of these events can be studied among others by data derived from four different sensors: a multi-spectral digital camera, a SAR, a Lidar and a thermal digital camera. The performance of these instruments has been derived from an application - mapping - requiring high resolutions. For example the multi-spectral camera shall have a resolution of less than 20 cm and the thermal camera shall have a ground resolution less than 2 m! These are performances that are not achieved by the instruments on today's satellites. The ASTER instrument designed for the EOS mission has a spatial resolution in the thermal of merely 90 m! It must be noted that for monitoring catastrophic events no such high resolution images will be required. In order to make a first assessment of the situation, disaster managers shall receive raw images of resolutions of 1 m in the visual within minutes. Finally, for disaster management purposes, the instruments shall be designed with less performing requirements but this is not an issue as it is technologically much more difficult to design the high resolution systems than to build sensors offering a lower resolution. So a HALE-UAV system specifically designed for disaster monitoring could have for example a 1 m ground resolution over a 12 km swath in the visual.

Forest fires

Areas affected by recurrent forest fires may be monitored by UAVs. The UAV will provide information on the condition of the vegetation and its susceptibility to fires. It can monitor and detect commencing fires, providing crucial information to fire fighters and damage prevention experts to organize their activities. Forest fires are best monitored from the combination of instruments operating in the visual and thermal. The multi-spectral camera will operate in the 400 – 1000 nm of the spectrum and will provide images in 10 spectral bands of 10 nm. The ground pixel size is expected to be less than 20 cm. Identically to the multi-spectral digital camera, the thermal digital camera will be composed of line sensors operating in two channels: 3-5 µm and 8-12 µm. The ground resolution will be between 1.13-2.25 m (Lewyckyj & Everaerts 2004). From an altitude of 20 km the swath width will be about 2400 m.

Flooding

The capacity of laser scanners aboard UAVs to accurately determine elevation, may also be used in hydrology (flooding estimation by means of accurate digital terrain models, river discharge estimation by measuring the water level). This information coupled with a hydrological model can forecast water levels hours in advance and rapid adjustments can be made thanks to fast updates, warning people and taking preventive actions against the upcoming water. The most suitable sensors for monitoring flooding before a catastrophic event are the multi-spectral digital camera and two active remote sensing systems, the LIDAR and the SAR. The LIDAR instrument will provide elevation information of the visible surface with a point density between 1 point per 2-4 m². After post-processing a Digital Surface Model (DSM) an a Digital Terrain Model (DTM) will be generated. The SAR adds an all-weather, day-and-night capability to the sensors suite. It will operate in the X-band and the ground resolution is expected to be 2.5 m over a swath width of 4500 m.

Earthquakes

Earthquakes are caused by the abrupt release of strain that has built up in the earth's crust. Most zones of maximum earthquake intensity and frequency occur at the boundaries between the moving tectonic plates that form the crust of the earth. Major earthquakes also occur within the interior of crusted plates such as those in China, Russia and the south-east of the United States. Considerable research has been carried out to predict earthquakes using conventional technologies, but the results to date are inconclusive. Seismic risk analysis based on historic earthquakes and the presence of active faults is an established method for locating and designing dams, power plants and other projects in seismically active areas. Successful prediction of minor earthquake have, however, been reported. Among the major earthquakes, Chinese scientists predicted an earthquake 1-2 days ahead in 1975 (Vogel 1980). Information on earthquakes is in general obtained from a network of seismographic stations. However, very recently the space geodetic techniques and high resolution aerial and satellite data have been used for earthquake prediction (Rao 1998). Earthquakes can best be studied from data from SAR (interferometry) and LIDAR.

Volcanic eruptions

Many times precursors of volcanic eruptions have been observed in various areas of volcanic activity. Ground deformations, changes in the compositions of gases emitting from volcanic vents, changes in the temperatures of fumaroles, hot springs and crater lakes as well as earth tremors are preceding volcanic eruptions. Thermal infrared and SAR remote sensing has been applied for volcanic hazard assessment (Henderson & Lewis 1998, Mc Garry 2004).

The use of HALE-UAV for disaster management is certainly not restricted to the few applications described above. Crisis management in case of industrial catastrophes, oil spills, massive refugee movement, etc… are other typical situations were geographical data with a very high spatial and temporal resolution is required by the decision makers (government, humanitarian organizations, local authorities, etc…). Using the best available technology, the HALE-UAV system will offer a very flexible platform, sensor complementarity, possible continuous survey, near-real time availability of the data via internet, very high spatial resolution and, last but not least, a lower price of the data as compared to satellite and airborne systems.

CONCLUSIONS

The PEGASUS project aims to support decision making in the case of a potential or actual disaster, using geographical information with a spectral, spatial and temporal resolution better than any satellite can offer because of the orbital constraints. Moreover, the high quality data will be inexpensive and available to the user in near-real time. The combined use of the different sensors allows all-weather and a 24 hr/day survey of the affected area. The acquisition of low resolution data is possible, allowing a larger swath, thus covering larger areas of interest. The aircraft can be deployed rapidly and is very flexible in the choice of trajectory that is determined by the user. The HALE-UAV shall make its first flight with a multi-spectral camera in the summer of 2005.

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