A STRATOSPHERIC PLATFORM FOR REMOTE SENSING AND PHOTOGRAMMETRY

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ABSTRACT:

Today, remote sensing and photogrammetry can be conducted using spaceborne or airborne systems. While the former already offer sub-meter resolution, their positioning ability is limited. Furthermore, it does not seem reasonable to expect full global coverage at this level of detail in the near future. On the other hand, traditional airborne systems are increasingly hindered by other air traffic and the presence of clouds. As user requirements for spatial resolution and positioning become more important, the need for a third alternative becomes apparent.

VITO proposes the use of a stratospheric platform with very long endurance to complement the earth observation capability of traditional systems. This platform has some unique advantages, among which the ability to remain above an area for near real time observations in support of crisis management (natural disasters as well as industrial accidents). The system features an extremely lightweight aircraft and earth observation instruments, direct data downlink and fully automated data processing. To be able to remain at up to 20 km altitude for up to 8 months, the platform is unmanned.

The project has received official support from the Flemish Government, and the first flights are currently planned for early 2006.

RÉSUMÉ:

A ce jour, la télédétection et la photogrammétrie peuvent être réalisées en utilisant soit des satellites soit des plateformes aéroportées. Tandis que les premiers offrent une résolution spatiale de l'ordre du mètre, leur précision concernant la position exacte est limitée. De plus il semble irraisonnable d'espérer une couverture globale à ce niveau de détail dans un future proche. D'autres part, les systèmes aéroportés traditionnels sont de plus en plus sujet aux limitations imposées par le trafic aérien et par la couverture nuageuse. Vu que les requêtes des utilisateurs s'orientent vers une plus grande résolution spatiale et un meilleur positionnement, le besoin d'une troisième alternative apparaît.

Le VITO propose d'utiliser une plateforme stratosphérique à très longue endurance afin de compléter les possibilités d'observation de la terre fournies par les systèmes traditionnels. Cette plateforme offre certains avantages uniques, entre autre la possibilité de survoler constamment une même zone afin de délivrer des données en temps réel pour l'aide à la décision en cas de gestion de crises (catastrophes naturelles et/ou accidents industriels). Le système est caractérisé par un avion et par des instruments d'observation de la terre extrêmement légers, une transmission directe des données ainsi qu'un traitement des données entièrement automatisé. Afin de pouvoir rester pendant près de 8 mois à une altitude de 20 km, la plateforme est inhabitée.

Ce projet à reçu l'avale et le support financier du gouvernement Flamand et les premiers vols sont prévus pour le début de l'année 2006.

KURZFASSUNG:

Fernerkundung und Photogrammetrie können heutzutage aus dem Weltraum oder mittels luftgetragener Systeme durchgeführt werden. Obwohl erstere bereits Auflösungen im Sub-Meter-Bereich bieten, ist ihre Fähigkeit zur korrekten Positionierung begrenzt. Außerdem kann wohl in naher Zukunft eine weltweite Flächenabdeckung auf diesem Niveau an Detail realistischerweise nicht erwartet werden. Andererseits werden die traditionellen, luftgetragenen Systeme in zunehmendem Maße durch anderen Luftverkehr und die Anwesenheit von Wolken gestört. Da die Anforderungen der Anwender an die räumliche Auflösung und Positionierung immer höher werden, wird die Frage nach einer dritten Alternative immer lauter.

VITO schlägt nun die Verwendung einer stratosphärischen Plattform mit sehr langer Lebensdauer zur Komplettierung der Erdbeobachtung mit Hilfe traditioneller Systeme vor. Diese Plattform bietet einzigartige Vorteile, zum Beispiel die Fähigkeit, über einem bestimmten Gebiet in der Luft zu verbleiben um Beobachtungen nahezu in Echtzeit zur Unterstützung bei Krisen auszuführen, sowohl bei Naturkatastrophen als auch bei industriellen Unglücken. Dieses System besteht im Wesentlichen aus einem extrem leichten Flugzeug und Erdbeobachtungsinstrumenten, direktem Datenverbindung und vollautomatischer Datenverarbeitung. Um in einer Höhe von bis zu 20 km bis zu 8 Monate lang verbleiben zu können, ist die Plattform unbemannt.

Dieses Projekt wird offiziell durch die Flämische Regierung unterstützt. Die ersten Flüge sind für Anfang 2006 geplant.

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1. INTRODUCTION

In the past, remote sensing applications have concentrated on extracting information of terrestrial processes based on the spectral properties of the reflected solar radiation, or from thermal observations. Photogrammetry has concentrated more on the geometric aspects, where spatial resolution and accuracy is paramount.

The PEGASUS system aims to provide data and derived information to both communities. It also responds to the user community's call for more spatial, spectral and temporal resolution (Mondello *et al.*, 2004)

2. DATA ACQUSITION

2.1 Spaceborne systems

The spatial resolution of satellite imaging systems has improved significantly in the past 10 years, allowing the general user to access images with panchromatic ground pixel sizes of 1 meter or even slightly better (Dupéret *et al.*, 2004). With proper care, these images can be used for general topographic mapping applications, provided sufficient ground control is used (Kurczynski and Wolniewicz., 2005).

Typically, Earth Observation satellites follow low polar orbits, revisiting almost all places on the Earth with regular intervals. This global reach of a single observation platform is one of its most prominent advantages. It should however not be taken for granted that all places on Earth are actually imaged every so often, as image acquisitions are programmed according to user requests. Table 1 shows the area covered yearly by IKONOS and Quickbird satellites, first based on cloud free conditions, secondly using a global average cloud cover of 54% (ISCCP, 2005).

Yearly Coverage	IKONOS	Quickbird
	km^2	km^2
Ideal	26.10^6	70.10^6
Using global cloud cover	12.10^6	32.10^6

Table 1. Yearly coverage or IKONOS and Quickbird satellites

Using the statistics taking into account the cloud coverage, one can predict how long it would take to realise a global coverage, if image acquisitions are programmed for this purpose. To obtain 95% coverage, IKONOS would require more than 23 years, compared to 6 years for Quickbird.

Improving on the currently available spatial resolution from satellite platforms involves either using larger optical systems (in terms of focal length and in aperture) or lowering the orbit. Although both are technically possible, it is expected that the associated costs would be high.

	IKONOS	Quickbird
Volume (m^3)	1.52 x 0.78 x 0.78	1.15 x 1.41 x 1.95
Mass (kg)	171	380
Focal length (m)	10	8.8
Aperture (m)	0.7	0.6
GSD at nadir (m)	0.61	0.83
Orbit (km)	450	681-709
Orbital speed (km/s)	7.64	7.51

Table 2. Physical properties of HR instruments on IKONOS and Quickbird satellites

As for positional accuracy, these high resolution sensors are inferior to airborne systems. Standard imagery products have georeferencing accuracies of 10 or more pixels. Unless special attention is paid to this, it is impossible to use these images for any application that requires change detection, or for the generation of maps.

2.2 Airborne systems

When strict time constraints are set for an aerial or satellite survey project (e.g. for crop inventory, where an extended area needs to be completely covered during the growing season), the orbital movement of the satellite is a disadvantage – it takes the satellite away from the survey area for most of the time. So, usually, these projects are executed by standard airborne aerial survey systems (film-based or digital), even at 1 or 2 m ground pixel size (Molander, 2003).

Aircraft are more flexible, taking more advantage of the possibilities offered by passing weather fronts. However, in times of unstable weather, the aircraft stay grounded, as it is not economical to conduct aerial survey in these circumstances – reflights would be almost inevitable. Also, from weather balloon observations, there is evidence that the average cloud base height is decreasing by 4 m annually (to roughly 600 m in 1999), while average cloud top height is increasing by 16 m annually (to about 9 000 m in 1999) (Chernykh et al., 2001), so the zone where traditional aerial survey is performed is filled with more cloud every year.

Over Europe, more than 10 million aircraft overflights are recorded annually, of which 1 million over Belgium alone (Eurocontrol, 2004). The airspace is congested with passenger and freight transport, leaving almost no freedom for aerial survey (in some places, permanent contact with air traffic control is required, so that two pilots need to be present in the aircraft).

2.3 New types of platforms

To overcome cloud cover and air traffic congestion as described above, two options are available, either to fly at low altitude or at high altitude.

Low altitude systems are ideal for surveying limited areas at very high resolution. A representative example is the helicopter-based Fli-map system (Flimap, 2003), carrying both a laser altimeter and a digital camera. These systems are typically used for corridor mapping.

Until a few years ago, only military aircraft were able to fly for more than a few hours at altitudes above 14 km, but recently, a number of projects have been proposed to place platforms in the lower stratosphere. Similar to satellites, they will serve different purposes, with telecommunications and earth observation as dominant ones.

Sanswire Networks LLC proposes to use a so called "Stratellite". This is a blimp, measuring 74.7 m in length, 44.2 m in width and 26.5 m in height; its total volume is 36800 m^3. It is stated that it has a payload capacity of 1360 kg, to provide wireless internet services over an area with more than 300 km radius (Sanswire, 2005). It is planned to have an 18 months endurance at 20 km altitude, using solar cells for power generation.

The Helios prototype aircraft developed by AeroVironment for NASA was a solar powered airplane that reached almost 30 km altitude in 2001, but crashed at low altitude in 2003 (AeroVironment, 2005). It had a wingspan of 75 m, exceeding that of a Boeing 747. Before the crash, it successfully demonstrated the use of this type of platform for telecom relay (Skytower, 2005). It was planned to stay at altitudes above 18 km for up to 6 months, powered by solar cells during day time, and regenerative fuel cells over night.

Other initiatives on these types of platforms include Sun-H2 (Sun, 2005), Heliplat (Tozer and Grace., 2001), and a stratospheric airship under development by JAXA in Japan (Sasa, 2004).

All of the systems that intend to have long endurance are designed to be unmanned. This eliminates the provision of life support systems, food, etc., …

2.4 The Pegasus platform

The Flemish Institute for Technological Research has advocated the use of a stratospheric platform since 2000, and it received funding for its project, called Pegasus, from the Flemish Government in 2004.

VITO has chosen to use an aerodynamic platform (airplane) rather than an aerostatic one (blimp), because the cost of realising the latter is estimated to be at least 3 times higher, and the technical challenges are considerably larger (to name just a few: to build a large airship, a large hangar needs to be build; launching the airship requires exceptionally stable meteorological circumstances; mounting the solar arrays on the airship when it is fully inflated will be very difficult). Also, the choice was made to use a relatively small aircraft, which requires a rather small solar array and battery mass to guarantee flight endurance of weeks or months. As a drawback, the maximum payload mass is only 2 kg. A scale model of this craft is shown in Figure 1.

Figure 1. Scale model of the Pegasus platform

3. PEGASUS PAYLOAD AND DATA PROCESSING

The PEGASUS platform will be equipped with a set of remote sensing instruments:

- A high-resolution multispectral digital camera;
- a high-density laser scanner altimeter;
- a digital thermal camera;
- a synthetic aperture radar system.

The characteristics of these instruments have been described earlier (Everaerts *et al*., 2004).
The first instrument to be flown is the HR multispectral camera, which will produce images with ground resolution better than 20 cm, and comparable positional accuracy. This instrument can be built using existing technology integrated in an innovative way.

To correct the data that are acquired (radiometrically, geometrically, atmospherically, georeferencing), a processing chain computer system is being built. This is a modular system based n the Linux operating system. For specific tasks (e.g. GPS processing), off-the-shelf software can be incorporated, even if that requires the use of Windows operating system. Both the storage and processing capacity can easily be increased.

Whenever possible, existing (open source) software is used. For instance, the data is archived in HDF-5 format (HDF, 2005), also used by NASA for earth observation missions. Atmospheric corrections are calculated from MODTRAN4 (Berk *et al.*, 1999) and ATCOR-4 (Richter, 2004).

By using concepts from satellite data processing, the PEGASUS system will provide data of constant and documented quality, that can be consulted from library via an Internet portal. In this way, it will bring high resolution data to many users that were not able to use it previously.

4. APPLICATIONS

4.1 Regional coverage of high resolution imagery and elevation data

This platform is as flexible as a traditional aircraft or even more: it is permanently available, unaffected by flight authorisations or Air Traffic Control regulations (flying above 14 km). Although it needs to take cloud cover into account, it will be able to acquire imagery through holes in the cloud cover. Even in these conditions, a high resolution camera (20 cm ground pixel size) carried on the Pegasus platform will cover areas as large as 125 000 km^2 during a single 8 month flying season (Everaerts, 2004). If equipped with a dedicated instrument with 1 m ground resolution (and positioning accuracy!), the system is able to cover more than 500 000 km^2 annually.

A fleet of 50 of these craft can renew a complete image coverage (at 20 cm ground resolution) of the whole of the European Union every year.

The laser-scanner altimeter will produce a digital surface model with an average point density of 1 point per 4 m^2. In this case, it makes no sense to update the model every year, except for areas where changes are important (urban, areas prone to flooding), which make up a small percentage of the total ground surface only. In this case, a 10-year mapping period is foreseen, with more regular surveys cities and flood plains.

For photogrammetric applications, the imagery will not be suitable for elevation mapping via stereoplotting. Unlike the ADS 40 camera from Leica Geosystems, no forward or backward looking line sensors are planned. The reason for this is the long focal length, which implies that the view angle is limited to 6°. This angle is insufficient for reliable height extraction. The laser altimeter will provide the elevation data, so that ortho or orthoTrue images can be generated.

4.2 Near real-time survey of crisis areas

A property that sets the Pegasus platform apart from traditional platforms is its ability to hover over a specific area for continuous observations, e.g. during crisis situations arising from natural disasters or industrial accidents.

In that case, high temporal update rates are more important than precise georeferencing or accurate atmospheric correction. By eliminating these time-consuming tasks, an turn-around time between data acquisition and delivery as short as 30 minutes can be guaranteed. This will allow authorities to analyse the situation and anticipate the required actions.

Deploying the PEGASUS system to a crisis area can be done by either autonomously flying to the area or by transporting it in standard containers. It can be assembled and launched in 6 hours.

5. CONCLUSIONS

The Pegasus project's aim it to demonstrate a stratospheric platform for remote sensing and photogrammetry, by using proven technology and methods in an innovative way. One of the most important aspects of this is the use of the chain processing concept from satellite data processing: raw data will be geometrically, radiometrically and atmospherically corrected in an automated way. This is a strict requirement: up to 1 terabyte of raw data will be acquired during operational surveys every day.

There is no specific focus on either geometry (the photogrammetrist's point of view) or on radiometry (the interest of the remote sensing specialist). The software that is developed is suited for the instruments on the Pegasus platform as well as for digital photogrammetric cameras and for imaging spectroscopy instruments. As the instrument suite for the Pegasus platform is built up, the processing software will also incorporate LIDAR, thermal imaging and SAR.

The first demonstration flights will be conducted over Flanders in early 2006; the system will enter operational service in the summer of 2006.

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