RAPIDEYE – A NOVEL APPROACH TO SPACE BORNE GEO-INFORMATION SOLUTIONS

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ABSTRACT:
RapidEye AG was incorporated 1998 as a private enterprise in Germany. RapidEye's approach to building the space and ground infrastructure is to task an experienced general contractor to deliver the entire system in orbit, fully functioning and calibrated. The system includes the satellites, the satellite control center, a customer ordering and delivery system and the ground processing solution to produce as standard image product ortho-rectified image data. The RapidEye business objective is to deliver geo-information solutions to customers which are fully integrated into the work flow of the customers. To meet this objective we have to build a reliable system which enables us to "guarantee" the delivery of services, this in turn necessitates a system which allows regular monitoring of large areas, daily access to any location on the globe and processing of the image data into information products within 24hrs. These operational requirements are met by our system which consists of 5 satellites, each carrying one optical payload with 5 spectral bands (b, g, r, red-edge, NIR), a GSD of 6.5m, and the appropriate ground processing power. RapidEye will deliver geo-information products for customers with a focus on biomass, such as agriculture, forestry etc, will produce cartographic information and will deliver satellite images and pre-processed data to the wider public. Launch is scheduled in late 2007 and the system will become fully operational early 2008, ready for the vegetation season of the northern hemisphere.

KURZFASSUNG:
RapidEye AG ist ein 1998 gegründetes privatwirtschaftliches Unternehmen in Brandenburg/Havel (Deutschland). Das Satellitensystem von RapidEye wird von einem erfahrenen Generalauftragnehmer entwickelt und hergestellt und vollständig in-orbit kalibriert übergeben. Es besteht aus 5 Satelliten, die auf einer gemeinsamen sonnensynchronen Umlaufbahn die Erde in 630 km Höhe umkreisen, dem Satelliten-Kontrollzentrum, einem elektronischen Bestell- und Ausliefersystem und einem Bildverarbeitungssegment, mit dem die Ortho-Satellitenbilder als RapidEye - Standardbildprodukte hergestellt werden. Das Geschäftsziel von RapidEye ist die Generierung und Lieferung von Geoinformationen, die voll in den Arbeitsprozess des Kunden integriert sind und mit hoher Sicherheit termingerecht bereitgestellt werden können. Um dieses Ziel zu erreichen, wurde das RapidEye-System so konzipiert, dass eine Erfassung großer Flächen innerhalb kurzer Zeit, eine tägliche Erreichbarkeit jedes Punktes auf der Erdoberfläche sowie die Verarbeitung dieser Bilddaten innerhalb von 24 Stunden gesichert ist. Das optische System liefert multispektrale Bilder in 5 Bändern (b, g, r, red-edge, NIR), einer geometrischen Auflösung von 6.5 m. Der Sensor hat eine Aufnahmebreite von 77 km. Die multitemporalen Bilddaten geben unter anderem Aufschluss über Biomasse und Wachstumsentwicklungen auf Ackerbauflächen oder für die Forstwirtschaft, ermöglichen feldgenaue Kartierungen von Unwetterschäden und weitere kartographische Anwendungen. Der Start ist für Ende 2007 vorgesehen, und die volle Operationalität wird Anfang 2008 mit Beginn der Vegetationsperiode auf der nördlichen Halbkugel erreicht.

1. INTRODUCTION

RapidEye is a satellite commercial mission being developed in cooperation with MDA. RapidEye will provide quick delivery of land information products and services. The benefit of RapidEye is the frequent coverage. Hence it is the only imaging system capable of collection of multispectral image data at high resolution over large areas with the capability to reach any point on Earth every day. The system can collect more than 4 million square kilometres per day with multispectral data spanning the visible to red edge and to near infrared portions of the spectrum. Moreover the satellite constellation offers an unrivalled ability to differentiate land cover, assess vegetative conditions and ground features in a single data set. These unique capabilities make RapidEye also a one-stop source of imagery data and products for any mapping application, especially those requiring guaranteed coverage of large regions in a short period of time or on a periodic basis.

2. BUSINESS CONCEPT

The RapidEye core business concept was developed first by scientists of the Kayser-Threde GmbH under contract with the European Space Agency (ESA). RapidEye received seed
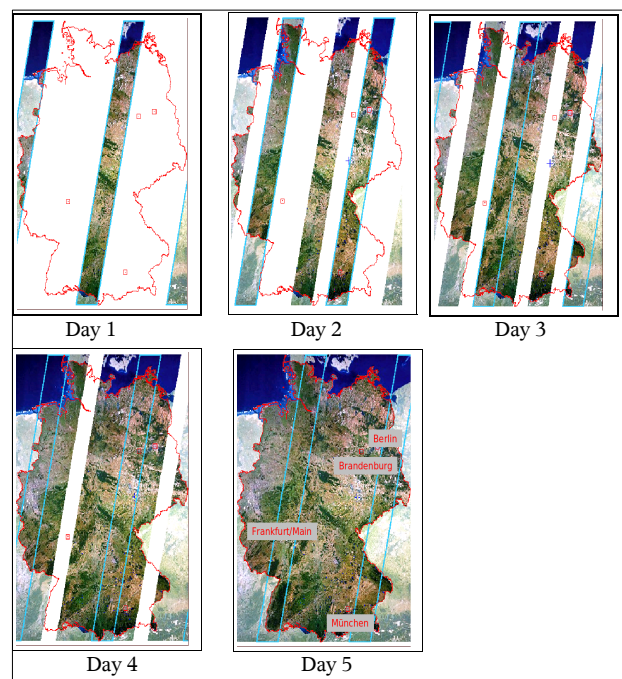

Figure 1: Coverage example for entire Germany, simulated image of Landsat TM (Source: RE, 2006)

financing from the Germany's Space Agency (DLR), the Vereinigte Hagelversicherung Germany's largest agro-insurance company, as well as the private sector before becoming an independent company. RapidEye has assembled a team of strategic partners and investors to turn the original concept into reality. The business plan and the company's original objectives remain focused on providing end-to-end solutions to clients, whose geospatial information needs include large-area coverage, repetitive monitoring and frequent revisits of an area. Figure 1 shows an example of our quick coverage capabilities.

3. SERVICES AND SOLUTIONS

One of the focuses of RapidEye is to monitor agriculture areas. Especially the Red Edge Band – unique to RapidEye – will identify and measure changes in the health of green vegetation. One of the main abilities of the Red Edge Band is to detect crop changes. The picture below shows main agricultural areas of the world.
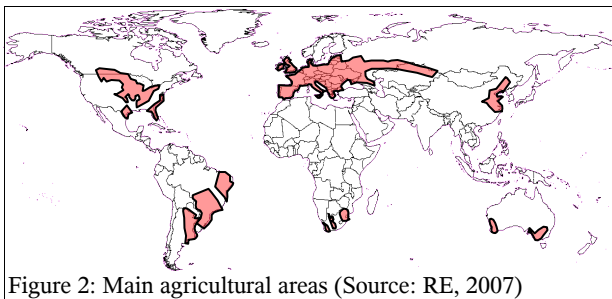

Figure 2: Main agricultural areas (Source: RE, 2007)

RapidEye´s technical teams cover all aspects of digital image processing and information extraction. RapidEye integrates fundamental geospatial processing capabilities as the foundation upon which each customized solution is built:

- Multi-sensor, multi-temporal land cover classification
- Object-orientated approach to feature identification
- Large area monitoring and/or change detection
- Vector and feature extraction
- Custom modules to automate service processing
- Near-real time data service analysis and delivery

3.1 Multi-Temporal Monitoring and Change Detection

The high-resolution imagery over large geographic areas provides the baseline for most monitoring and change detection services. For example:

- Monitor pipelines in a remote region
- Monitor national forests to identify deforestation
- Monitor large strife-ridden or disputed territories to map unexpected change
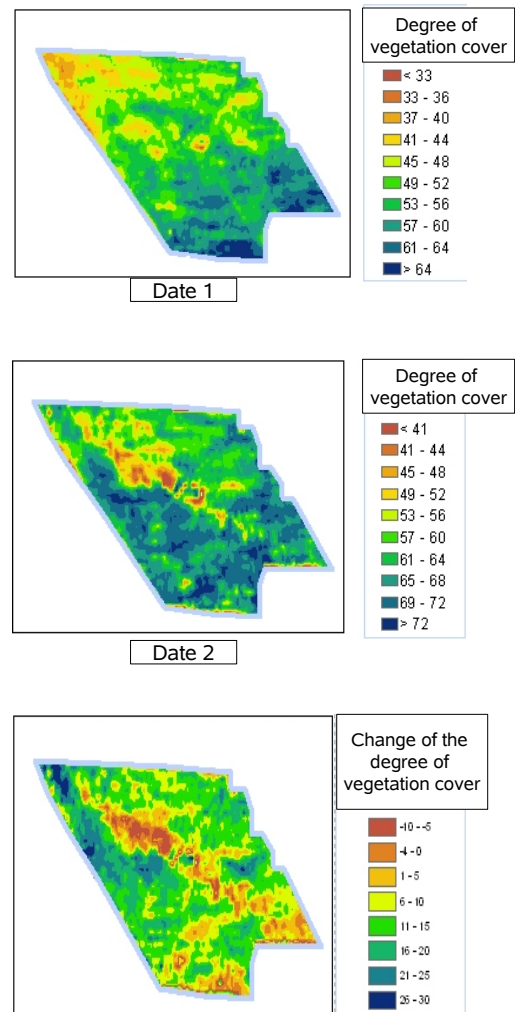- Identify damage classes within individual agricultural fields after hail storms events.

Figure 3: This maps illustrates the principle of using change detection to detect anomalies at an early stage

3.2 Land-Cover Analysis and Vegetation Identification

The Multi-temporal data sets allow to develop custom services that accurately and routinely identify and classify vegetation and other landforms based on how they change throughout the year. The multi-temporal approach significantly increases accuracy over single date methods, and the reliable, repetitive nature of the RapidEye collection program allows for deployment of a quick response. Capabilities include:

- Regional and national land cover analysis
- Crop identification and acreage estimation
- Repetitive analysis of vegetative change throughout the year
- Low-cost, standardized land cover updates on a periodic basis

The results may be applied in practical ways to monitor changing land-use patterns around the world's largest cities or to identify the number of acres of a specific crop early in the season to affect a country's food security policy.
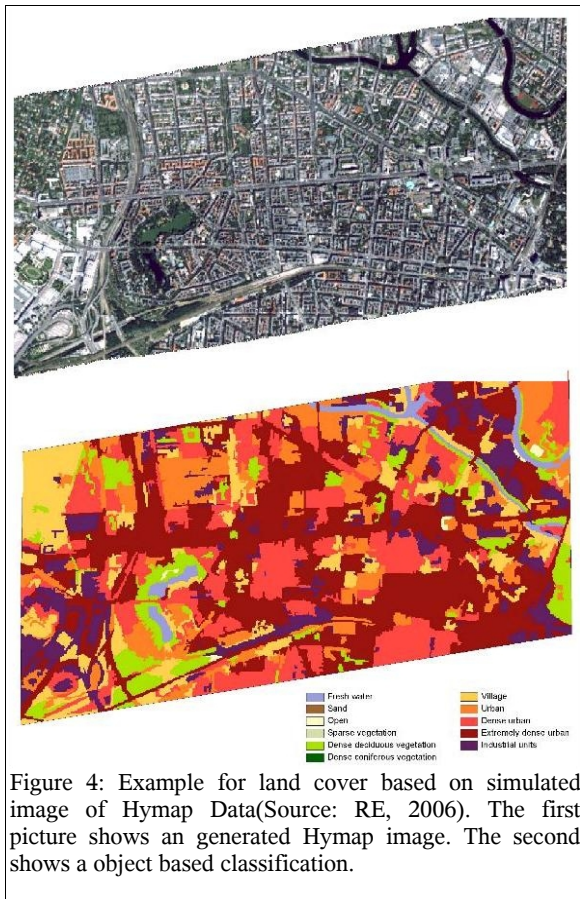
Figure 4: Example for land cover based on simulated image of Hymap Data(Source: RE, 2006). The first picture shows an generated Hymap image. The second shows a object based classification.

3.3 Acreage and Production Estimates

The imaging and information processing capabilities for agricultural and forestry markets provide new opportunities for governments and organizations concerned with food or resource supply issues using staff domain knowledge and analytical skills. The system offers a complete suite of services focused on assessing agricultural crop supply, quality and quantity. These assessments include:

- Early season acreage estimation
- Emergence date estimation
- In-season condition assessments
- Production assessment

Figure 5: RE simulation imagery, generated on the basis of IKONOS True Colour (Source: RE, 2006)

Figure 6: RE simulated image, generated on the basis of IKONOS CIR (Source: RE, 2006)

4. SYSTEM

The RapidEye system is comprised of a space and a ground segment. The space segment includes a constellation of five Earth observation satellites unmatched in their ability to provide large-area coverage, frequent revisit, high resolution and multispectral imaging. The ground segment includes preprocessing and processing systems to handle customer orders, perform image data correction, generate standard and customized products and services, and manage the data archive.

4.1 Preprocessing System

The RapidEye Ground Segment is comprised of preprocessing and processing systems. The preprocessing system, called Data Management System (DMS), handles incoming orders from clients, generates imaging schedules and prepares the acquired data for generation into products by the processing system. The DMS is being developed and built by MDA, Canada.

4.2 Product Processing System

RapidEye has designed and built a Product Processing System (PPS) that receives preprocessed data from the Data Management System (DMS) and generates standard and customized products. Highly automated and fully redundant, the PPS is comprised of multiple customized modules that enhance and process satellite imagery and other geospatial data, either raster or vector, to create integrated information products.

RapidEye has built the PPS as a centralized framework composed of a high performance cluster of compute nodes, database servers and file servers. The PPS is expandable to accommodate the addition of new processing modules that will be developed to meet future client information needs.

4.3 Our Satellites

Built by Surrey Satellite Technology Ltd. (SSTL) in England, each satellite is based on an evolution of the flight-proven MicroSat-100 bus, which is considered a reliable, low-risk imaging platform. Each satellite measures less than one cubic meter and weighs 150 kg (bus + payload). On board digital recorders will store image data until the satellite passes within range of a ground receiving station. SSTL designed each satellite with a seven-year design life. Figure 7 presents an schematic view of the satellite with the optical instrumentation.
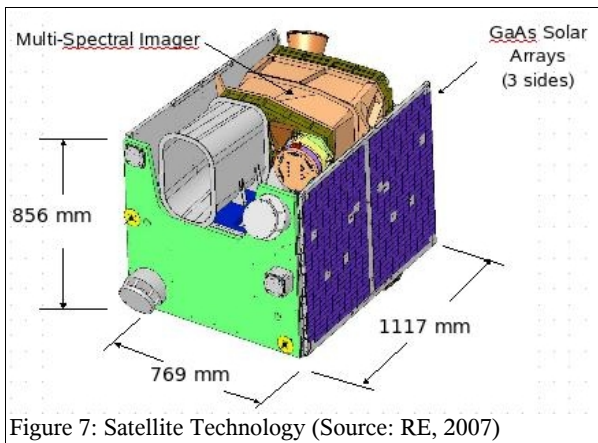
Figure 7: Satellite Technology (Source: RE, 2007)

In table 1 the main parameters of the satellite, the orbit, and the data transmission are given.

Spacecraft Roll Angle	+/- 25 degrees
Global Revisit Time (All)	1 Day
Image Data Downlink Speed	80 Mb/s
Telemetry Downlink Speed	9.6 kb/s
control Uplink Speed	38.4 kb/s
Pointing Control	0.1 degrees in each axis
Orbital Position Knowledge	< 10 meters with 95% confidence
Orbit Sun Synchronous	
Inclination	97.8 degrees
Period	96.7 minutes
Descending Node	11 a.m

Table 1: RapidEye Satellites - Specifications

5. IMAGE DATA PRODUCT SPECIFICATION

The constellation of remote sensing satellites will provide unparalleled global coverage for clients who need frequent wide-area imagery at high resolution. Collecting more than 4 million square kilometers of multispectral data per day, the five-satellite constellation can acquire data for the same area on Earth every 24 hours. Image data will be acquired in five multispectral bands spanning the Blue, Green, Red, Red-Edge and Near-Infrared portions of the spectrum pictured in Figure 8, orthorectified to five-meter pixel size, and available in the archive for ordering and delivery.

The RapidEye data management system is fully automated to process and archive the entire daily download. Data will be commercially available with atmospheric correction as an option (table 3).

RapidEye is establishing automated ordering and distribution mechanisms to provide customers with quick, self-service ordering and delivery. Delivery medium will depend on file size and client preference, including FTP and DVD.
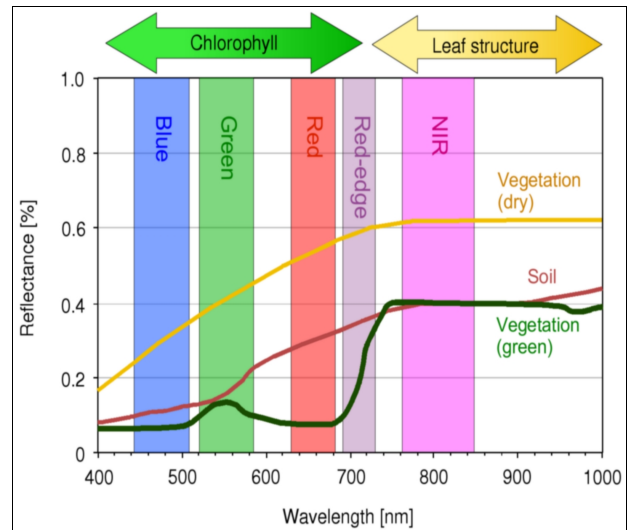

Figure 8: Spectral performance of the RapidEye sensor (Source: RE, 2006)

Table 2 and 3 give a brief summery of the data product specification.

Digital Data Product Specifications	Information
Spectral Bands	Capable of capturing any subset of the following spectral bands: Blue 440 – 510 nm Green 520 – 590 nm Red 630 – 685 nm Red Edge 690 – 730 nm NIR 760 – 850 nm
Ground sampling distance (nadir)	6.5 m
Pixel size (orthorectified)	5 m
Swath Width	77 km
On board data storage	1500 km of image data per orbit
Equator crossing time	11:00 am (approximately)

Table 2: RapidEye digital data product specifications

Level	Description
0	Raw image data, metadata and calibration data. These data are for internal use only.
1	**Sensor-Level Product** - Radiometric sensor corrections applied to the data. On-board spacecraft attitude and ephemeris applied to the data.
2A	**Systematic Geo-corrected Product** - Radiometric sensor corrections applied to the data, but no ground control points are used for positional accuracy. Images are map- projected (North facing).
3A	**Orthorectified Product** - Radiometric sensor corrections applied to the data. These products have been orthorectified using 30m DEMs and appropriate ground control to meet 1:25,000 scale accuracy standards.

Table 3: RapidEye Data Processing Levels