

The RapidEye optical satellite family for high resolution imagery

STEFAN SCHERER and MANFRED KRISCHKE, Munich

ABSTRACT

RapidEye AG intends to establish a global monitoring service for agriculture and cartography to be operational in 2004. As primary data source RapidEye will operate an innovative space based geo-information system. Data will be generated through a constellation of small satellites with significant competitive advantages due to high resolution, quality, availability and capacity. The satellite constellation will have the unique characteristics:

- Frequent monitoring of large areas (large image swath)
- Daily global revisit (4 Satellites)
- High spatial resolution (6.5m) in all spectral bands

RapidEye will provide a range of earth observation products and services to a global market in the fields of:

- Agriculture: e.g. crop monitoring and mapping, damage assessment, yield prediction
- Cartography: e.g. satellite based maps, change detection services, DEMs
- Other Markets: e.g. spectral data, 3D-visualization, disaster assessment

The RapidEye system will have the capability to provide regular and frequent multispectral high resolution image coverage of all agricultural areas in Europe and the US. The current work concentrates on the generation of agricultural information services based on the multi-temporal data from the satellite system in combination with various other data sources on ground or in space. RapidEye AG is a German venture founded in 1998.

1. INTRODUCTION

In spite of rather optimistic prognoses regarding growth, the commercial success of Earth observation is primarily hindered by the fact that required data cannot be generated at the desired time and thus cannot be made available. This, however, is vital for the establishment of professional applications in the field of agriculture, insurance and cartographic services. A potential customer will change his procedures only if the availability of the alternative is guaranteed.

Consequently, a commercially operated system must primarily aim at offering guaranteed availability of data. A satisfactory availability for optical sensors can only be achieved by minimizing the time between the individual revisits and providing a sufficient capacity to generate frequent image coverage of even large areas of interest. This understanding led to the definition of the RapidEye commercial concept and the RapidEye imaging system.

RapidEye Inc., incorporated in 1998, is a new satellite based GEO-information service company which concentrates on customers in the agricultural and cartographic field. Data will be generated through a system of small satellites with significant competitive advantages due to high resolution, quality, availability and capacity. To fulfill the customer needs RapidEye will not stop at delivering raw image data. RapidEye's key clients will receive jointly developed geographic information products which are integrated in the client's work processes and therefore offer significant cost advantages and / or new revenue potential.

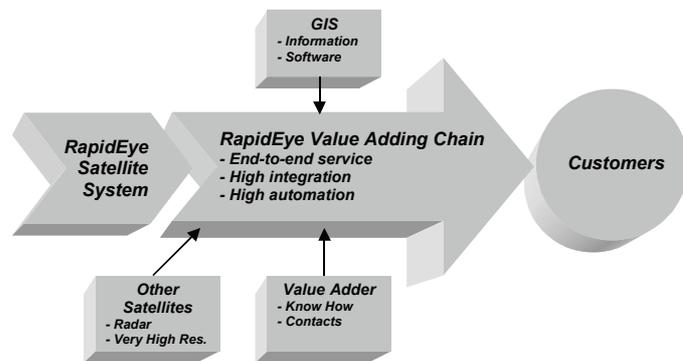
RapidEye has been selected as key-project for commercialization of space technology by the DLR and part of the German space program.

2. MEETING USERS' NEEDS

The demand for high-quality, current GEO-information is set to grow rapidly during the current decade. Market analyses have identified significant potential in the agricultural and cartography market segments in the European and US market.

RapidEye is targeting a range of information users, which permits the exploitation of its products across a wide customer basis. RapidEye's research demonstrates that the targeted information users have common top-level requirements which are driven by mutual demands.

| Information User | User-Specific Information Needs |
|---|---|
| Farmers, Producers, Food companies, Insurance companies | Generation of statistics of agricultural usage, development and damage assessment |
| Commodity brokers, Food companies | Determination of agricultural yield predictions |
| Insurance companies, Disaster relief organizations | Development of crisis management strategies |
| Commercial, Civil and Military organizations | Creation of cartographic information |



For all users a very high degree of vertical integration is essential. Therefore the RapidEye concept is based on two key elements:

- a high resolution earth monitoring system
- image analysis and information systems

Since the market focus is on a limited number of key customers the product development can be tailored to the specific users needs.

3. RAPIDEYE HIGH RESOLUTION EARTH MONITORING SYSTEM

The key features of the RapidEye earth monitoring system are:

- Daily revisit of each point on Earth
- Large imaging capacity
- Multispectral high resolution imager

The RapidEye owned data source comprises a 4-small-satellite constellation, an operations center, ground stations and a data pre-processing and archiving center.

All four satellites are on a sun-synchronous orbit evenly spaced in one orbital plane. Each satellite carries a digital optical imager. The altitude is 600 km and the local equator crossing time is at 12:00 hours (noon). A regular full repeat coverage can be generated within 3-4 days depending on latitude. A revisit time of one day can be obtained with body-pointing techniques.

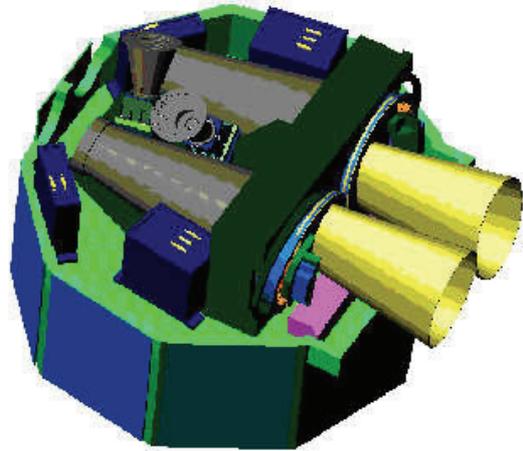
The fundamental idea of RapidEye is based on technologies that do -to a large extent- already exist combined with additional innovative detail solutions. RapidEye has signed an agreement with Surrey Satellite Technology (SSTL) in which SSTL will become the prime contractor for the turn-

key system and will become an equity investor in RapidEye. The camera is going to be built by SIRA Electro – Optics.

3.1. RapidEye Imaging Instrument

The RapidEye imaging instrument is a multispectral pushbroom instrument, providing a swath width of 158 km with continuous observation coverage of up to 1500 km in length. The spatial resolution (GSD) of the imagery is 6.5 m. The camera is based on a dual optical-system design resulting in a dual-swath (both swaths of 79 km are slightly overlapping) observation.

The Earth imaging system captures 6 spectral bands (blue, green, red, red-edge, near infra-red and panchromatic) with 12 bit sampling. The source data are compressed in real-time prior to on-board storage and/or downlink transmission.

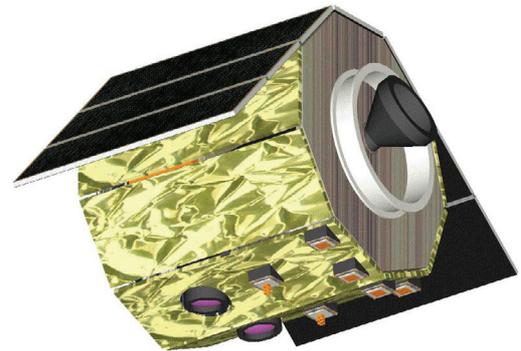


Lossless (1:2) and/or lossy compression techniques can be selected on command. The design of the imager focuses on high geometric stability and good radiometric sensitivity.

3.2. RapidEye Satellite Platform

The satellite bus is based on Surrey's UoSat12. The wet mass of each RapidEye satellite is approx. 315 kg, the design life is seven years.

Each satellite is three-axis stabilized. The spacecraft uses a redundant GPS receiver for orbit determination and on-board time provision. Attitude sensing is provided by star sensors. The pointing knowledge is expected to be less than +/-50m on ground.



A body-pointing capability in the roll axis of the spacecraft exists which permits a $\pm 30^\circ$ FOR (Field of Regard) for camera observations into any direction however, the feature is planned to be used only in the cross-track direction.

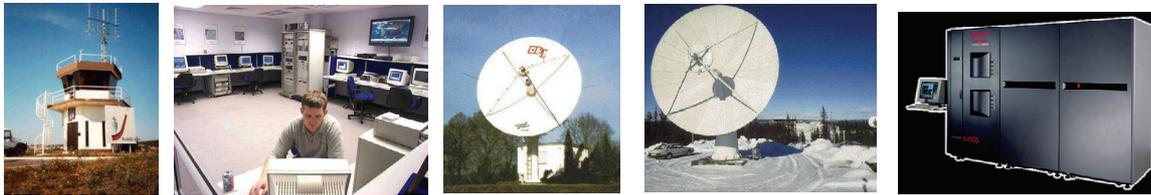
The X-band downlink will operate at a data rate of 150 Mbit/s and allow to download more than 7 Gbytes per average ground contact.

The RapidEye constellation is planned to be installed in two separate launches (two S/C each) on a Russian launch vehicle in 2003 and in 2004.

3.3. RapidEye Ground Segment

The ground segment of the data source comprises the space craft operations center, X-band ground stations, and a data pre-processing and archiving facility.

RapidEye’s dedicated Spacecraft Operations center will be installed at RapidEye’s headquarters and shall form a hub of the RapidEye system. The S-band communication system will allow user requests to be uploaded to the RapidEye satellite constellation on short notice and will permit RapidEye’s experts to carry out spacecraft health monitoring and station-keeping. RapidEye’s image tasking will make use of short term weather predictions and statistics to optimize the performance of the system. RapidEye will use existing X-band ground stations for data reception.

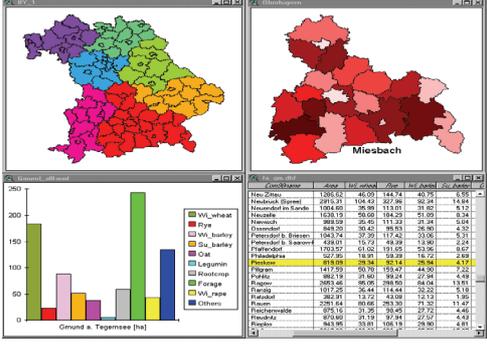


All data received will be processed immediately to ortho-images. The output will be calibrated, terrain corrected data sets with a localization accuracy for most monitoring areas of 1 pixel or better. A extensive image archive and catalogue will be the backbone of the RapidEye data infrastructure. It will hold several hundreds of tera bytes of image data, products and auxiliary data.

4. RAPIDEYE IMAGE ANALYSIS AND INFORMATION SYSTEMS

A key element of RapidEye is the seamless integration of data source, image analysis and the customer information systems. Together with it’s key customers RapidEye is currently developing a number of information services. The focus is on agriculture and cartography.

| Customer group | Product | Product sample |
|---------------------------|---|----------------|
| Agricultural Insurance | Crop map Crop monitoring Damage assessment Risk analysis | |
| Producers (Farmers) | Soil maps Crop vigor maps Crop stress Field management information | |

| | | |
|--|---|--|
| <p>National and International Institutions / Governments</p> | <p>Yield predictions Subsidies Control Damage assessment</p> |  |
| <p>Cartography and Military</p> | <p>Global image mapping 1:25'000 Continuous map update Change Detection DEM</p> |  |

5. CARTOGRAPHIC POTENTIAL OF RAPIDEYE

Although planned as agricultural monitoring system RapidEye has the potential to revolutionize also global cartographic mapping. The system has the capability to generate and maintain a global coverage of

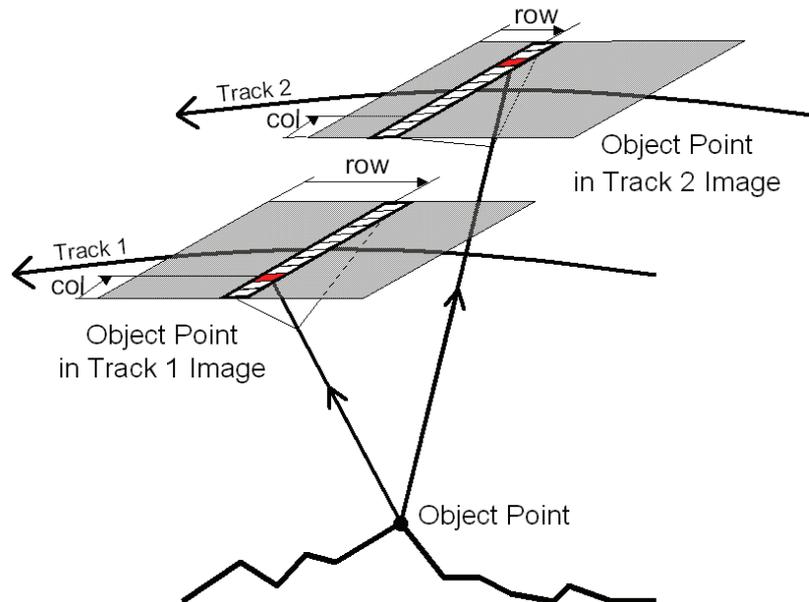
- DEM with 20 grid size and 5m vertical accuracy
- Up-to-date ortho-image maps at a scale of 1:25'000

RapidEye is currently investigating concepts for generating and marketing both potential data sets.

5.1. Global DEM coverage

The capabilities of the RapidEye system to generate global digital elevation models have been investigated together with the Institute For Photogrammetry, Stuttgart.

RapidEye has the ability to acquire off track stereo images with only a time delay of ~24 min. This can be achieved by imaging the same area of interest from two subsequent satellites. The viewing angle varies with the latitude and phasing of the satellites in the orbital plane. The level of coherence of the stereo pairs will be close to the one of in-track stereo pairs. Also the cloud situation will be nearly identical.



Cross track stereo acquisition (Source: IFP)

The DEM generated from RapidEye data will have the following characteristics:

- Grid size: 20m x 20m
- Absolute vertical accuracy: ~5m
- Relative vertical accuracy: ~2-3 m
- Coverage: +/- 82° N/S

The quality of the RapidEye DEM will exceed the DEM generated by the SRTM mission (DTEDT Level 2). The generation of a global coverage of stereo pairs is estimated to last 1-2 years. The acquisition could be finished by 2004/5.

5.2. Global ortho image map

Topographic maps at a scale 1:50'000 and 1:25'000 are not available in many areas of the world and if so they are often totally outdated. Even in the well mapped areas like the USA and Europe the maps are too old to comply with the requirements of commercial users as mobile network planners or car navigation system providers. RapidEye has the capability to generate and maintain an up-to-date global ortho image set at a scale comparable to 1:25'000 maps (6.5m ground resolution) with a potential geo-location accuracy of +/- 5m globally.

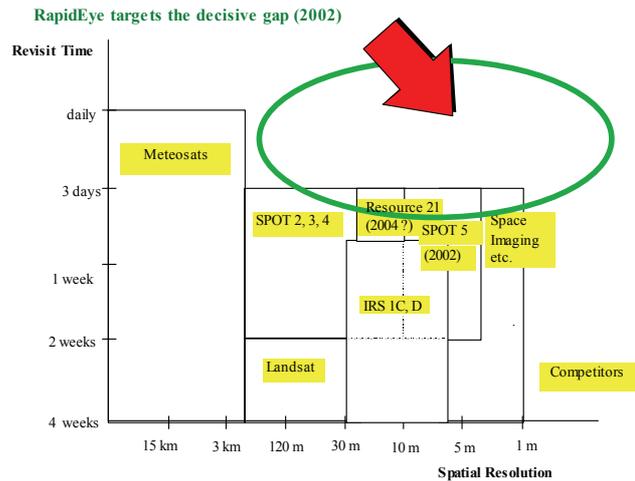
To achieve this the imager and the satellite platform are designed for a very high degree of geometric stability. The a-priori pointing knowledge will be better than +/-50m. This will enable RapidEye to produce large ortho-corrected image coverages with a very limited number of ground control points. However the provision of the required high accuracy ground control points is critical and has to be investigated. The global image coverage shall be updated every 1-3 years depending on the region.

6. THE COMPETITION

RapidEye’s market analysis has identified many shortcomings in current and future systems and can therefore demonstrate the competitive advantages of the RapidEye system. RapidEye’s strength lies in its combination of innovative approaches: the supply of high-resolution images of large areas with a daily revisit capability which for the first time allows guaranteed full coverage of large regions within short time.

The value of the information generated by the current competitors (SPOT, LANDSAT, IRS) is limited due to their slow revisit rates resulting in a lack of availability and real-time data delivery.

Four new entrants (EarthWatch, OrbView, SpaceImage and West Indian Space) are focused on the high-resolution data market and will not offer complete coverage or rapid data availability. A fifth potential new entrant, Boeing’s Resource21 system, plans to target a similar market as RapidEye but with a resolution of 10 meters and a revisit rate of 4 days. RapidEye’s system demonstrates significant advantages.



7. SCHEDULE

The schedule for RapidEye is tight and leads to a start of the service at beginning of 2004. The satellites will be ordered after financial closing in 2001. During the years 2001-2003, emphasis is primarily placed on the development of customer specific products and their introduction onto the market.