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PFG – Jahrgang 2002, Heft 1

Inhaltsverzeichnis

Originalbeiträge

Berichte und Mitteilungen

Sensoren und Plattformen – Ergebnisse des IAA-Symposiums für Kleinsatelliten-Missionen zur Erdbeobachtung

RAINER SANDAU, Berlin

Im April 2001 konnte bereits das *3. „Symposium on Small Satellites for Earth Observation“* der *International Academy of Astronautics (IAA)* in Berlin durchgeführt werden. Wie bei seinen Vorgängern lag die Organisation wiederum in den Händen des Instituts für Weltraumsensorik und Planetenerkundung des DLR (Deutsches Zentrum für Luft- und Raumfahrt).

Was nun ist die IAA? Und warum führt sie solche Symposien durch? Die IAA wurde 1960 in Stockholm gegründet und hat jetzt konstant etwa 1000 gewählte Mitglieder (Personen) aus 64 Ländern. Die Mitglieder haben sich zum großen Teil in verschiedenen Komitees und Subkomitees zusammengefunden, um die weitgestreuten Erfahrungen und Interessen im Sinne der Akademie wirksam zu machen. Zu den im Statut festgelegten Zielen der IAA gehört die Förderung der Entwicklung der Astronautik für friedliche Zwecke. Im IAA „Committee on Small Satellites“ wird dieses Ziel noch untersetzt und konkretisiert durch die Aufgabe dazu beizutragen, dass jedes Land in die Lage versetzt wird, Kleinsatelliten zu bauen. Zur Umsetzung dieser Aufgabe auf dem Gebiet der Erderkundung wurde vom IAA „Subcommittee on Low-Cost Earth Observation Missions“ im Jahre 1996 das „Symposium on Small Satellites for Earth Observation“ ins Leben gerufen.

Mit der Teilnahme von etwa 200 Ingenieuren, Wissenschaftlern und Managern aus etwa 25 Ländern wurde auch im 3. Symposium das weiterhin bestehende Interesse an der Nutzung von Kleinsatelliten für dedizierte Erderkundungsmissionen von wissenschaftlichen Missionen bis hin zu Missionen zur Technologiedemonstration gezeigt. Im Ergebnis des Call for Papers konnte das internationale Programmkomitee 57 Beiträge für die Präsentation in den verschiedenen Fachsektionen und 26 Posterpräsentationen für die Themengebiete

– Small Satellite Mission Programs
– Objectives for Small Satellite Missions
– Mature (Off-the-shelf) Systems
– Advanced Technology Approaches
– Low-Cost Management Aspects
– Results of Small Satellite Missions
– User Requirements and Expectations

auswählen.

Wie auch in den vorhergegangenen Symposien zeigten die Beiträge den großen Bereich an verschiedenen Aufgaben und Aspekten, die mit den dedizierten Kleinsatellitenmissionen verbunden sind. Diese Missionen können relativ schnell und kostengünstig durchgeführt werden. Der Satellitenbus, die Instrumente und das Bodensegment können entweder existierende, für den speziellen Einsatz optimierte Systeme sein, die wenig oder keine neuen technologischen Entwicklungen erfordern, oder sie können auch auf neuen Entwicklungen basieren, die schon Nutzen aus den Möglichkeiten der Hochtechnologien ziehen.

In schon bewährter Weise war das Symposium aufgeteilt in 15 Fachsektionen, eine Postersektion und 2 Podiumsdiskussionen. Zu den 15 Fachsektionen gehörten auch 2 Spezialsektionen, die diesmal den Themen „Small Satellite Constellations“ und „NASA Technologies for the New Millennium“ gewidmet waren. Die Podiumsdikussionen beschäftigten sich mit den Themen „User Requirements and Expectations“ und „New Technologies for Small Satellite Missions“.

Die Auswahl der in diesem Heft vorgestellten Beiträge orientiert sich an den Themen, denen sich der Arbeitskreis Sensoren

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und Plattformen der DGPF widmet. Aber auch aus dieser Sicht musste eine Beschränkung auf 12 Beiträge erfolgen, die jedoch viele Teile der im Symposium vorgestellten Aspekte repräsentieren. Insgesamt überdecken die vorgestellten Beiträge die Spektren:

- von experimentellen bis zu kommerziellen Missionen
- von bewährten Komponenten bis zu Hochtechnologieentwicklungen
- von Spezialplattformen bis zum standardisierten Satellitenbus
- von Einzelsatelliten bis zu Konstellationen
- von Erfahrungen und Ergebnissen aus aktiven bis zu geplanten Missionen
- von überwiegend nationalen Vorhaben bis zur internationalen Kooperation.

Um den Rahmen einer kurzen Einführung nicht zu sprengen, möchte ich mich auf weitergehende Kommentare zu 3 Beiträgen beschränken:

Der Beitrag *„The New Candidates for ESA Earth Explorer Core Missions“* zeigt, dass auch bei großen wissenschaftlichen Missionen der ESA durch Beschränkung der Aufgabenstellung auf die Untersuchung spezifischer physikalischer Phänomene und durch Einsatz neuester Technologien zwanglos Kleinsatellitenmissionen resultieren können.

Die Themen Satellitenkonstellationen und Kommerzialisierung wurden im Beitrag *„Micro-Mini-Satellites for Affordable EO Constellations: RAPID-EYE & DMC“* angesprochen. Rapid Eye ist als kommerzielle Kleinsatellitenmission geplant. Die Mikrosatelliten-Konstellation DMC (Disaster Monitoring Constellation) ist ein besonders interessantes Konzept, weil es internationale Partnerschaft aus zwei Beweggründen kreiert:

– „contribution sharing“, d. h. jedes Land bringt einen eigenen Mikrosatelliten in die Konstellations-Mission ein.

– „cost sharing“, d. h. Aufwendung nur im Rahmen des eigenen Mikrosatelliten-Beitrages, aber Nutzung der Daten der komplexen Konstellation.

Auf den Beitrag „The BIRD mission is completed for launch with the PSLV-C3 in 2001“ möchte ich aus aktuellem Anlass besonders hinweisen. Der experimentelle Kleinsatellit ist für die Erkennung und Analyse von Hochtemperaturereignissen, wie z. B. Waldbrände, Kohleflözbrände, vulkanische Aktivitäten optimiert. Die Instrumentierung besteht aus einer Kombination eines vorhandenen Instruments (Stereokamera WAOSS, ursprünglich entwickelt für die russische Planetenmission Mars 94/96) und Hochtechnologielösungen für den Zweikanal-Infrarot-Pushbroomsensor. Der Satellit ist ein 94 kg schwerer Würfel mit ca. 60 cm Kantenlänge. In der Zeit zwischen dem Symposium und dem Erscheinen des vorliegenden Heftes der PFG ist BIRD am 22. 10. 2001 auf der indischen Rakete PSLV-C3 gemeinsam mit dem indischen Hauptsatelliten TES (Technology Experiment Satellite) und dem ESA-Satelliten PROBA (Project for On-Board Autonomy) in einen 568 km hohen Erdorbit gestartet worden. Alle Systeme des in Deutschland entwickelten und gebauten Satelliten arbeiteten sofort einwandfrei.

Die für das Symposium in englischer Sprache eingereichten Kurzfassungen wurden nur teilweise weiter gekürzt und durch einen deutschsprachigen Abstrakt ergänzt. Die Originale der Kurzfassungen können im Sammelband des Symposiums (Small Satellites for Earth Observation, Digest of the 3rd International Symposium of the International Academy of Astronautics, Berlin, April 2–6, 2001, Wissenschaft & Technik Verlag Berlin) nachgelesen werden. Der Beitrag „Advanced Detectors and Instruments for Small Satellites“ ist in vollständiger Form in der ACTA ASTRONAUTICA, Vol. 39, No 9–12, S. 731–740, veröffentlicht.

Aus den Äußerungen vieler internationaler Teilnehmer am Symposium konnten die Organisatoren schließen, dass die Veranstaltung informativ und anregend war und viele fruchtbare Diskussionen stimulierte. Ich hoffe daher, dass die hier veröffentlichten Beiträge ähnlich wirksam sind, bei den Mitgliedern der DGPF und darüber hinaus.

Anschrift des Autors: siehe Seite 46

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The new Candidates for ESA EARTH EXPLORER CORE MISSIONS

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Abstract: The second cycle of ESA Earth Explorer Core missions has started with the selection of five candidates for initial studies. The mission requirements lead to satellites of all classes, from a constellation of mini-satellites (100 kg class), to satellites of above 1500 kg dictated by the needs for synergetic observations with several instruments from the same platform.

Zusammenfassung: *Die neuen ESA - Satelliten für die Erderkundung*. Die zweite Runde der ESA-Erderkundungsmissionen begann mit der Auswahl von fünf Kandidaten für vorbereitende Studien. Die Missionsanforderungen führen zu Satelliten aller Klassen, begonnen bei Mini-Satelliten (100-kg-Klasse) bis zu Satelliten von etwa 1500 kg, bestimmt durch die Anforderung, von einer Plattform aus gleichzeitig Beobachtungen mit verschiedenen Instrumenten durchzuführen.

Introduction

The Earth Explorers are the research missions of ESA's dual mission strategy that also includes the service oriented Earth Watch Missions. The Earth Explorers are proposed, selected, defined and exploited by the research community. There are two classes of Earth Explorers: core and opportunity. The core missions are larger missions addressing broad issues. The opportunity missions are smaller missions with more limited objectives. Both classes are implemented in separate cycles. Two missions are selected per cycle. A mission of each class is launched every two years. The first cycles of core and opportunity missions are ongoing. Four missions, two core and two opportunity, are under development. All four are implemented with relatively small satellites (700–900 kg) compatible with small launchers.

CRYOSAT (launch 2003) will measure variations in ice topography and thickness. GOCE (2005) will measure the gravity field and the geoid. SMOS (2005) will measure soil moisture and ocean salinity. ADM-Aeolus (2006) will provide profiles of wind speed.

The second cycle of core missions has started. The second cycle of opportunity missions will be initiated in 2001.

The second Cycle of EARTH EXPLORER CORE MISSIONS

Ten proposals were received in response to the call for mission ideas for the second cycle of Earth Explorer Core missions. After evaluation by scientific peer groups and the Earth Science Advisory Committee (ESAC), five mission ideas have been preselected for further development prior to start of phase A. The five candidates are introduced below.

Atmospheric CHEMISTRY EXPLORER

The objectives of the Atmospheric Chemistry Earth Explorer Mission (ACHEM) are to measure and understand the human impact on the chemistry and composition of the lower and middle atmosphere, and to investigate the interactions between atmospheric chemistry, atmospheric composition and climate. This demands to observe simultaneously and accurately numerous species in the upper troposphere and lower strato-

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sphere, globally and with high vertical resolution. A multi-instrument payload is required, including:

– A mm-wave limb sounder called MASTER with four bands in the 296–505 GHz range
– A limb sounder operating in the infrared between 4.15 and 14.6 micron which would be an advanced version of ENVISAT's MIPAS (called hereafter A-MIPAS)

In addition to this minimum core payload, three instruments have to be also considered:

– A nadir looking spectrometer working in the 0.75–3.5 micron range
– A cooled limb sounding spectrometer working in the sub-mm / far infrared range
– A nadir and limb sounding spectrometer operating in the ultraviolet and visible range

MASTER would be a large instrument dominated by its 2 m × 1 m antenna. It is estimated that it would have a mass of 320 kg, require 325 W of electric power and generate 250 kbps of data. For A-MIPAS it is estimated that the mass would be 310 kg, require 240 W of electric power and generate data at 5.5 Mbps. The resulting satellite would have a mass of 1400 kg, consume 1 kW of electric power. The data would be stored on board and downlinked to a single ground station at Northern latitude at 100 Mbps in X-band.

ACHEM is a medium size satellite. Adding instruments to the core payload would increase the size of the satellite and the cost of the mission. This problem was addressed in the first cycle for a similar candidate. The candidate in the first cycle included only MASTER on an 800 kg satellite. The MIPAS observations were obtained by exploiting the occasional coincidence of observations with MIPAS on ENVISAT. Concerning the additional payload, a solution at the time, albeit of less performance, was to fly the satellite in formation with Met***Op***, on the same orbit and ahead so that MASTER and the nadir looking instruments of Met***Op***, GOME, IASI and AVHRR, would have observed the same volume of atmosphere simultaneously. The coincidence of ENVISAT and the Explorer was not considered sufficient by the scientific users and A-MIPAS is now part of the core payload. The synergy with Met***Op*** can still be considered now reducing the needs for the additional payload.

EarthCARE

EarthCARE, for Clouds, Aerosol and Radiation Explorer, is the result of the evolution and merger of the previous candidate Earth Radiation Mission (ERM) and the Japanese ATMOS-B1.

The mission would be implemented by a single satellite in sun-synchronous low Earth orbit, around 350–400 km altitude. The satellite would carry a backscatter atmospheric lidar (ATLID), a cloud profiling radar (CPR), a multi-spectral imager (MSI), a broadband radiometer (BBR) and Fourier Transform Spectrometer operating in the infrared (FTS-IR).

The ERM satellite was compatible with a small launcher. EarthCARE however has more ambitious scientific objectives that imply a larger satellite.

Concerning the backscatter lidar, the "simple" single wavelength (1040 nm) instrument would be replaced, either via a dual wavelength instrument (1040 nm and 532 nm or 355 nm) or by a single wavelength instrument (at 532 nm or 355 nm) with higher spectral resolution. In addition the instrument will have a cross polarisation channel, provide multiple field of view and higher radiometric accuracy. As result, the laser transmitter may need to provide higher energy pulses at higher frequency, the telescope diameter would need to be increased. The instrument budgets would increase, to around 300 kg for mass, 270 W for power and 2.5 Mbps for data.

Several features have to be studied to enhance the 94.5 GHz single channel CPR of ERM for EarthCARE. These include the addition of a second channel at 237.95 GHz, the extraction of the Doppler shift which could require to increase the pulse repetition frequency by 50 % and the antenna size to

4 m, and the provision of five beams. Each of these options will have considerable impact on the instrument size, mass, power and data rate.

Compared to the cloud imager of the ERM, the MSI of the EarthCARE includes a new channel at 2.2 micron and three times better spatial resolution, though the swath can be reduced by a factor 2 with respect to ERM. Mass and power budgets will increase. The data rate will also increase by a factor 6. The changes in the BBR should not affect the instrument resources. The FTS-IR was not included in the ERM. Based on studies in Japan and in Europe, e. g. REFIR, the FTS-IR would have a mass of 70 kg, require 100 W of power and generate 180 kbps of data.

Another important consideration is the launch date. At 350 km the effect of air drag, which depends on solar activity, is considerable. The 100 kg propellant foreseen for ERM if launched in the first round would become 300 kg if launched near the solar maximum in the second round.

If ERM could have been implemented with a 1100 kg satellite compatible with a Rockot launcher, EarthCARE would likely be above 1500 kg (not considering changes to the CPR!). The split of the instruments in small satellites flying in formation was studied in the previous cycle and the performance of the split-scenario implementation was found insufficient and not recommended by the scientific mission advisory group and ESAC.

SPECTRA

The objective of the SPECTRA (Surface Processes and Ecosystems Changes Through Response Analysis), mission is to study the effects of climate variability on vegetation by observing the structural, functional and biochemical response of ecosystems. The goal is to improve the understanding and modelling of the energy, water and carbon cycles.

This is to be achieved by observing selected and instrumented sites around the Earth in the 450 nm to 2350 nm range of the spectrum with high spectral resolution (10 nm typical, 5 nm in certan bands) and in two thermal bands in the 10.3–12.2 micron region. The sites will be accessed every three days under different across track angles and during a pass will be observed under at least 7 angles along track for determination of the BRDF. The required spatial resolution at nadir is 25 m and the size of the scene at nadir is 50 km. As additional objective, the SPECTRA mission could provide co-located wide swath observations at coarser spatial resolution and in a reduced number of bands. This would allow to scale the main objective from the "local scale" of the observed sites to regional and global scales.

The SPECTRA mission is largely based on a candidate to the first cycle, the Land-Surface Processes and Interactions mission (LSPIM). The main changes with impact on the satellite are the finer spatial resolution (25 m for SPECTRA and 50 m for LSPIM), spectral resolution (10 nm or better for SPECTRA, 15 nm in the SWIR for LSPIM), the shift of the thermal bands towards longer wavelengths and the possible presence of a wide swath low resolution sensor called VISIR.

As result of preliminary analysis, the SPECTRA satellite would be a manoeuvering satellite capable of fast slew for access to sites and orientation to the sun or ground stations, and fine control around roll, pitch and yaw, for image taking. The mass is estimated to be 900 kg and the required electric power ranges from less than 600 W during stand-by (no image taking or data transmission) to above 800 W during imaging. The data storage and could range from 250 Gb to 450 Gb depending on the acquisition strategy and the data downlink rquirements could range from 60 Mbps to more than 200 Mbps.

WALES

The objective of the WALES (water vapour lidar experiment in space) mission is to provide better insight into the distribution of water vapour and aerosol in the upper troposphere and lower stratosphere for research and applications in climatology and numerical weather prediction. This is to be achieved by providing globally accurate profiles of water vapour concentration (0.05–0.5 g/kg) at high vertical (0.5–2 km) and horizontal resolution (10–50 km) and with high reliability (95%).

In the preliminary concept, the WALES mission would be implemented by a single satellite in sun-synchronous dawn-dusk orbit at 450 km altitude carrying a differential absorption lidar DIAL. The DIAL works by transmitting laser pulses at two different but close wavelengths. At one of the wavelengths pulses are attenuated by water vapour. At the other wavelength the attenuation is negligible. The exploitation of the return at the two wavelengths allows to derive water vapour concentration. In the preliminary concept the DIAL would work around 940 nm. Based on a preliminary sizing, including scaling of the Doppler wind lidar of ADM-Aeolus, the estimates for the WALES DIAL are 1.5 m telescope diameter, 435 kg of mass, 1 kW of electric power and 60 kbps of data rate. The satellite will have a dry mass of 1100 kg and need 1.5 kW of electric power including 20% margin. 150 kg of propellant could be loaded for the 450 km altitude orbit.

WATS

The objective of the WATS (Water vapour in Atmospheric Troposphere and Stratosphere) is to monitor variations in the global atmospheric water vapour distribution. This should be achieved by deploying a constellation of 12 small satellites in two arrays of six each at two different altitudes 650 km and 850 km. Each satellite of an array is in a different plane with the same inclination. Each satellite has two instruments: a GNSS receiver for atmospheric sounding (GRAS) and a Cross-link Atmospheric LEO-LEO sounder (CALL). GRAS exploits the signals from rising and setting GPS and GLONASS satellites (possibly also GALILEO at the end of the decade) modified after travelling through the atmosphere. CALL exploits the occultation technique between the WATS satellites. Each instrument transmits signals at 10 GHz, 17 GHz and 23 GHz that are received by CALL instruments of other WATS satellites after travelling through the atmosphere. The occultation can be used to generate accurate, high resolution humidity profiles. The 12 satellite constellation would produce 6500 profiles a day with GNSS occultations and 1600 profiles a day with LEO – LEO occultations.

The GRAS instrument is an evolution of the present generation of GNSS sounders. The CALL instrument has large commonality with GRAS. It is estimated that the WATS satellites would have a mass of 100 kg, require 70 W of electric power provided by fixed solar arrays, generate data at 20 kbps that could be stored in a 200 Mb memory and downlinked in S-band every orbit to allow near-real time utilisation of the data.

A key issue of the WATS mission is the launch strategy as each satellite is in a different orbit plane.

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The Amazon Rainforest Monitoring Satellite – SSR-1

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Abstract: The Brazilian Amazon region is the greatest rainforest in the world and it is undergoing complex and fast changes influenced by human activities and natural events. It is of extreme importance to Brazil to have an efficient monitoring system in order to manage the natural resources and to protect the environment of this region. The SSR system presents an innovative solution to monitor the Amazon region, through a small remote sensing satellite placed in a low equatorial orbit, providing synoptic images of the entire region several times a day. The SSR images will be distributed directly to users, in a near real time basis, via small and low cost terrestrial stations. This paper presents the result of a feasibility study for the SSR payload, showing a payload concept and analyzing the accomplishment of the requirements.

Zusammenfassung: *Ein Beobachtungssatellit für den Amazonas-Regenwald – SSR-1.* Die Amazonasregion Brasiliens ist das größte Regenwaldgebiet der Welt und unterliegt derzeit komplexen und schnell voranschreitenden Veränderungen durch Aktivitäten des Menschen und natürliche Faktoren. Für Brasilien ist es äußerst wichtig, auf ein gutes Kontrollsystem bei der Bewirtschaftung der natürlichen Ressourcen und für den Umweltschutz der Region zurückgreifen zu können. Mit einem Fernerkundungs-Kleinsatelliten in einem äquatorialen Orbit, präsentiert das SSR-System eine innovative Lösung für die Beobachtung der Amazonasregion mit einer Wiederholrate der Überfliegung mehrmals am Tag. Abgesehen vom Missionszentrum wird das System auch in der Lage sein, die SSR-Daten über kleine Niedrigkosten-Bodenstationen den Nutzern direkt zugänglich zu machen mit einer Datenübertragung nahezu in Echtzeit. Dieser Aufsatz zeigt sowohl die Ergebnisse einer „feasibility“ Untersuchung der SSR Nutzlast als auch ein Konzept für die Anwendung der Nutzlast und evaluiert, ob die Vorbedingungen durchgeführt werden können.

Introduction

The Brazilian Remote Sensing Satellite (*Satélite de Sensoriamento Remoto* – SSR) is a small satellite which is part of the Brazilian National Space Activities Program. The Program has as main objectives: 1) to develop application satellites that fulfill Brazilian needs; and 2) to develop Brazilian technological knowledge and industry. The Brazilian Amazon region is the greatest rainforest in the world, with an area close to 5 million km^2 which is comparable to the entire west Europe. The Amazon region is undergoing complex and fast changes influenced mainly by human activities (forest fires, deforestation, wood and mineral extraction) and natural events (rain, flooding and droughts). It is of extreme importance to Brazil in ecological, economical and strategical terms to have an efficient monitoring system to manage the natural resources and to protect the environment of this region. Such a monitoring system must have the capability to provide a fast response to either natural or man made events, which leads to the demand of quick access to ready available data, acquired on a high rate basis, which are not available nowadays. One important factor that precludes the efficient monitoring of tropical regions is the severe cloud cover conditions associated with the low revisit rate of the current available optical remote sensing satellite systems. In-

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deed, most satellites have sun-synchronous orbit, with a revisit period of 1 to 30 days, which is not adequate to monitor fast changing events such as ongoing fires and deforestations. For instance, with the revisit period of 16 days of the Landsat images it is common to have less than one cloud free scene a year in certain parts of the Amazon region. With the SSR it should be possible to acquire cloud free images, either directly or via multitemporal composed images.

SSR Mission Requirements

The SSR intends to solve the lack of available data for monitoring purposes in the Amazon region, through an innovative solution. Taking advantage of the geographic localization of the Amazon region, the SSR should be placed in a low equatorial orbit providing synoptic images of the entire region several times a day. The sensor should have an Earth surface swath of 2200 km able to image the entire planet region comprised between the latitudes of 5° North and 15° South. The images should be provided in 4 spectral bands in the visible-VIS (blue, green, red) and near infrared-NIR plus a mid infrared band-MIR. The spatial resolution at nadir should be 40 m for the VIS/NIR bands and 500 m for the MIR band.

Several applications to monitor and study the Amazon region are being proposed with the SSR images, such as: a) quantitative evaluation of deforested areas; b) detection of burning and burned areas; c) characterization and classification of vegetation cover; d) natural vegetation regrowth; e) phenology of vegetation; f) agricultural activities; g) flooding and inundation; and h) mining activities. Since not only the Amazon region will be covered by the SSR images but also the whole equatorial belt around the world, other useful information should be provided by the SSR to: a) desertification studies; b) oceanography; c) geology; d) solar radiation, among others. The SSR mission aims to provide relevant data to both scientific community and governmental agencies.

To reduce the latent time in data distribution, besides the standard centralized mission center, the system should also have the capability to distribute the SSR data directly to users in a near real time basis, via small and low cost stations. The SSR system will consist of the satellite and its ground segment.

Mission Constraints

The SSR payload shall be modular and compatible with the Brazilian multimission platform and existing Ground Segment. The following constraints apply for the SSR payload module: a) payload module mass limit is 100 kg; b) average power shall be less than 140 W; c) down link bit rate shall be less than 150 Mb/s; and d) mission lifetime in orbit shall be 4 years.

SSR mission peculiarities

Due to its unusual orbit and large swath width, this system brings some difficulties and challenges compared to usual systems with satellite in sun-synchronous orbits. One peculiar characteristics is the wide variation range of solar incidence angles over the target. In an equatorial orbit, during a 12 minutes pass the satellite will span 3 time zones. This means that in a single image, the local time in one extreme will be 3 hours less than the local time in the other extreme, with great changes not only in illumination conditions but also in the size and direction of shadows. Besides that fact, the satellite should pass over a region several times a day (approximately every 100 min) and, therefore, solar azimuth will vary greatly for the different passes. Another important factor is the extreme view conditions to image regions between latitudes of 10° S and 15° S. For instance, at 15° S the viewing geometry has an off-nadir angle of 56° and target view angle of 20° above the horizontal. This will cause a significant increase of the length of the path through the atmosphere, introducing fading and distortions that will require special atmospheric correction techniques and procedures. In addition, the spatial resolution will be degraded from 40 m at nadir to 200 m at 15° S.

In order to assess the technical feasibility of the payload a study for the SSR payload was performed by DLR – *Deutsches Zentrum für Luft- und Raumfahrt*, in the frame of scientific and technological cooperation with INPE. The objective of this study was to demonstrate the capability to meet the requirements, to assess the quality of image in the extremes of the coverage and to show the compatibility with the Brazilian multimission satellite platform. As part of this study an airborne flight campaign was performed in the Amazon region using the HyVista hyperspectral camera-HyMap.

SSR-1 Payload Concept

The study presents a payload concept that can fulfill the majority of the requirements and constraints. The payload design has taken into account the following principles: a) well-proven technology; b) small size; c) low power; and d) low cost. The baseline SSR imaging system consists of a VIS/NIR sensor unit, a MIR sensor unit, a Digital Data Processing and Control unit, and a RF unit.

The VIS/NIR sensor is a pushbroom CCD camera with three optical heads, combined to achieve the FOV and geometrical resolution requirements. Each focal plane assembly has 5 parallel CCD lines, one for each spectral band. This design is based on the DLR High Resolution Stereo Camera (HRSC) heritage. The five spectral bands are blue (B1; 0.447–0.502 μm), green (B2; 0.518–0.566 μm), red (B3; 0.636–0.682 μm), NIR (B4; 0.786–0.890 μm) and an additional channel (B5; 0.814–0.844 μm) for the estimation of the water vapor content, that will be used in an atmospheric correction procedure. The main optic characteristics of the three lenses are: 1) focal length of 137 mm for north and middle lenses and 190 mm for South lens; 2) f number of 4.85 for all three lenses; 3) FOV of 31.8° for north and middle lenses and 23.1° for south lens; 4) aperture of 115 mm for north and middle lenses and 100 mm for south lens; and orientation from nadir of +15°, −17° and −44.5° for north; middle and south lens, respectively. The detectors are Thomson THX 7834C linear CCD image sensor with 12000 pixels. The ground sample distance achieved with this configuration is approximately 50 m, 100 m and 200 m at 5°, 10° and 15° of latitude, respectively. The output of the CCD detectors is converted to digital by a 14 bits A/D converter. This high resolution A/D converter will allow to accommodate the whole signal dynamic range and to operate in all illumination conditions without gain switching. The estimated raw bit rate for this camera is 252 Mbps. Due to the limited downlink rate of 150 Mb/s, data compression will be employed. The selected method is online compression, using Constant Rate Wavelet based Image Compression (CWIC).

The MIR sensor is a pushbroom camera with two optical heads with 32° FOV, combined to increase the total FOV. Each optical head has one focal plane assembly with two staggered 512 pixels HgCdTe line detectors. A stirling type split cooler will be used to refrigerate the detectors, which shall operate at the temperature of 80 K. This design is based on the DLR BIRD heritage. Due to the high power consumption and the degradation of the geometrical resolution at high latitudes, it was decided not to cover the whole swath width of 2200 km with this sensor. The MIR sensor will cover the swath between 5° N and 5° S, with a GSD varying from 500 m to 700 m. The MIR sensor shall cover the mid infrared spectral band from 3.4 to 4.2 m and the output of the detectors is converted to digital by a 14-bit A/D converter. Since this dynamic range is not enough to avoid saturation, the sensor performs real-time processing to detect high illuminated pixels and reacquire those portions of the image with smaller integration time. The MIR sensor shall have a Noise Equivalent Temperature Difference better than 0.5 K. In order to improve the performance of fire detection in the presence of smoke, the inclusion of a TIR sensor was recommended by DLR.

All payload items are mounted on a dedicated panel, which provides the interface with the platform. This solution simplifies the interface definition, assembly, integration and test activities. The camera heads are mounted in a common optical bench to meet the co-alignment requirements. The payload module key parameters are: a) mass of 95 kg; b) volume of 1084 mm × 1130 mm × 322 mm; and c) power of 375W / 97W (without heater).

The accomplishment of the mission requirement was demonstrated using data from a flight campaign in order to simulate SSR-1 data and performing computer simulations to assess the performance of the sensor in different conditions. The flight campaign was carried out using the HyMap sensor (Cocks et al. 1998) in April 2000 over Amazon rain forest in the State of Acre, Brazil. To simulate the SSR-1 data the following scenarios were addressed: a) varying solar illumination condition over daytime; b) varying viewing geometry over wide angle; and c) target and atmospheric characteristics.

To simulate the varying solar illumination condition it was planned to acquire HyMap images every two hours from 8:00 AM to 4:00 PM. However, due to intense cloud cover conditions during the period allowed for the flight campaign (two weeks) data were acquired only for one favorable day around 8:00 and 10:00 AM. For the 8:00 AM path data were acquired at both nadir and off-nadir (up to 65°) by banking the airplane in order to simulate the viewing geometry over a wide angle. The targets were typical Amazon rain forest and deforested areas with pasture for cattle raising.

The main conclusions for the accomplishment of the mission requirements can be summarized as follows: 1) the noise equivalent reflectance for the blue, green, red and near infrared channels can be fulfilled under a standard atmosphere (10 km meteorological range) for up to 8° S; further south this can be fulfilled only under good atmospheric conditions (23 km meteorological range); 2) at the southern extremity of the swath (15° S) the slant view shading effects may pose problems; for instance, at the latitude of 15° S, a tree with an height of 40 m will project a shade of 115 m; 3) strong view angle effects can be corrected taking into account turbidity, water vapor content and wavelength dependence of the aerosol scattering; 4) the influence of view angle on water vapor column content proofed to be systematic and should be correctable; 5) due to radiometric effects, in combination with the slant view shading and cloud shadows, the number of useful images are strongly restricted, despite of the high data acquisition rate; 6) although much less HyMap data were acquired than initially planned they proved to be very useful not only to simulate illumination and viewing conditions but also to define the band characteristics; 7) interpretation of the HyMap data showed that even under extreme view angles important data products like the NDVI and water vapor path content can be extracted; and 8) future studies are necessary to develop standard methods adapted to the special characteristics of the SSR-1 images influenced by both sensor and target.

Conclusion

The preliminary results of the study show that the majority of the SSR requirements can be fulfilled with a payload composed by two instruments: a VIS/NIR and a MIR camera. It was concluded that due to power and mass limitations of the small satellite, it will not be possible to meet the geometric resolution and the swath width for the MIR camera. It was also found that a significant loss in the image quality will occur for latitudes between 13° S and 15° S. Nevertheless, due to its high revisit rate, images from these region can be useful for certain applications. The introduction of a TIR camera was recommended due to its suitability to perform accurate fire detection during daylight in the presence of smoke.

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Flight Experiences with DLR-TUBSAT

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Abstract: DLR-TUBSAT is a microsatellite joint project of the Institute of Aerospace at the Technical University of Berlin (TUB) and the German Aerospace Centre (DLR). It was launched on 26 March 1999 with the Indian Polar Spacecraft Launch Vehicle (PSLV) as secondary payload. DLR-TUBSAT was designed for interactive earth observation where the target is not identified in advance, a search action is involved or a target has to be visually followed. Whereas classical earth observation uses nadir pointing satellites the design of DLR-TUBSAT was made for using interactive control strategies. Since the start of the operation many different strategies for different acquisition and operation modes are developed and tested. New software programs on satellite and ground segment and new ground control procedures are a result of this development. Possible applications of the produced earth observation data could be defined and were integrated in the new control strategies. DLR-TUBSAT showed that it can serve new market areas of earth observation and new customers, which cannot use or do not want to use classic earth observation satellites. The main advantages are the interactive search abilities, very high repeat cycles (1 day) and the low mass and low costs of the satellite system.

Zusammenfassung: *Flugerfahrungen mit dem DLR-TUBSAT.* Der DLR-TUBSAT ist ein gemeinsames Mikrosatelliten-Projekt des Instituts für Luft- und Raumfahrt der Technischen Universität Berlin (TUB) und des Deutschen Zentrums für Luft- und Raumfahrt (DLR). Er wurde am 26. März 1999 mit dem indischen Polar Spacecraft Launch Vehicle (PSLV) als Sekundärnutzlast gestartet. Der DLR-TUBSAT wurde zur interaktiven Erdbeobachtung entwickelt, bei der das Ziel vorher noch nicht klar identifiziert ist, eine Suchaktion durchgeführt werden muss oder ein Ziel visuell verfolgt werden soll. Während die klassische Erdbeobachtung Nadir-blickende Satelliten nutzt, wurde der DLR-TUBSAT für interaktive Kontrollstrategien entwickelt. Seit Beginn des Betriebes wurden viele verschiedene Strategien für verschiedene Lageregelungs- und Betriebsmodi entwickelt und getestet, woraus neue Softwareprogramme für das Satelliten- und Bodensegment sowie neue Bodenkontrollprozeduren abgeleitet wurden. Mögliche Anwendungen der erhaltenen Erderkundungsdaten konnten definiert und in die neuen Kontrollstrategien integriert werden. DLR-TUBSAT zeigte, dass seine Daten neue Segmente des Erdbeobachtungsmarktes abdecken können sowie für neue Kunden interessant sind, die nicht die klassischen Erdbeobachtungssatelliten nutzen können oder wollen. Seine grundlegenden Vorteile sind, neben geringer Masse und niedrigen Kosten des Satellitensystems, die Fähigkeit zu interaktiven Such- und Beobachtungsoperationen und seine sehr hohen Wiederholrate der Beobachtung eines Zielgebietes (1 Tag).

1 Introduction

Satellite remote sensing is going to be a commercial market in the last years, but most of the systems are still governmental projects. With IKONOS a high resolution earth observation system is available for commercial users. With the panchromatic resolution of 1 m and a multispectral resolution of 4 m IKONOS can serve new commercial users of earth observation. But nearly all these systems have some identical characteristics:

1. They use nadir pointing.
2. They have repeat cycle rates from 3 to 26 days.
3. They are not interactively controlled. Targets must be exactly defined.

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4. They only deliver photos, not moved pictures. Most of the pictures must be processed before they can be used.
5. They are heavy systems with huge development and start costs.

The main design idea of DLR-TUBSAT was to go new ways in earth observation. As a microsatellite the system is smaller, cheaper and lighter than classic earth observation systems. This has two important effects: On the one hand the system can be offered to customers who are not able to pay several millions for a satellite. Normal commercial systems have many users and sometimes there are conflicts between the different needs of the users. Microsatellites offer the possibility to create a payload for the special needs of the user and to fly the wanted orbit without rising costs. The optimisation of the orbit is possible because there are many new small launchers (e.g. SHTIL) on the commercial market in the last years, most of them converted military ICBMs. For nearly the same price a user can have his own satellite and can use it the whole time by himself. The disadvantages of using a microsatellite are the small payload volume and mass and the small power supply. Because of that it is not possible to make radar observation with microsatellites but it is possible to use the visible and near infrared spectrum with resolutions of 3 to 6 m by flying in LEO.

On the other hand the low mass of microsatellites makes it possible to control the satellite interactively and to use smaller and cheaper launchers. In this case interactive earth observation means that the user in the ground station receives video images from the satellite and is able to steer the pointing direction of the camera platform (by moving the satellite) interactively via keyboard, mouse or joystick control to the interesting event (see Fig. 1). Interactive earth observation makes earth observation possible where the target is not identified in advance, a search action is involved or a target has to be visually followed. This and the real time video pictures of such a microsatellite open the earth observation market for many new users.

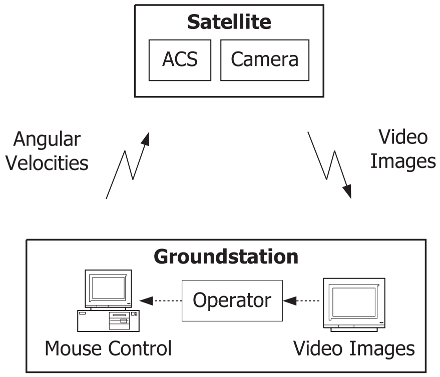

Fig. 1: Interactive earth observation.

The last two years of operations with the DLR-TUBSAT show that possible applications are for instance:
1. Monitoring of areas with repeat cycle rates of 1 day.
2. Observation of boarders, ship and air traffic, pollution, vegetation etc. by searching around without knowing where the target is located.

This second point is the most important for operating DLR-TUBSAT. We can supervise a great area by using small resolution and can switch to high resolution if we see an interesting object. There is no difference if this object is stationary or moves with high velocity.

2 The DLR-TUBSAT System

DLR-TUBSAT is a microsatellite joint project of the Institute of Aerospace at the Technical University of Berlin (TUB) and the German Aerospace Center (DLR). TUB was responsible for the satellite bus and DLR for the payload. It was launched on 26 March 1999 with the Indian Polar Spacecraft Launch Vehicle (PSLV) as secondary payload. In the frame of operation the TUB has a co-operation with the German Remote Sensing Data Center (DFD) in Neustrelitz. The TUB Satellite Control Center is responsible for health monitoring and telecommanding and the DFD for receiving the S-band video signal.

2.1 *Space Segment*

The cube shaped satellite measures 32 cm × 32 cm × 32 cm and weights 44.81 kg. DLR-TUBSAT is subdivided into a Payload, a Housekeeping and an Attitude control module. Telemetrie and telecommand are transmitted via VHF (2 m) band or UHF (70 cm) band with FFSK modulation and a data rate of 1200 baud. Both antennas are omnidirectional dipol antennas. The analogue video signal is transmitted via S-band with a bandwidth of 8 MHz. The beam width of the helix antenna is 70°. The payload module contains two fore field cameras (16 mm and 50 mm focal length) and a high resolution telescope (1m focal length) with a ground pixel resolution of 6 m. The power supply is done by 4 duplex NiH2 battery cells which are charged by 4 solar panels, each containing a single string of 34 silicon cells. A single string of solar cells is attached at the surface in the z-axis and is used for sun acquisition manoeuvre. The attitude control system contains 3 reaction wheels, 3 optical gyros and two different magnet torquers. For interactive attitude control of the satellite we use the reaction wheels, the gyros, the analogue video signal and the solar cell telemetry (solar cell current). The magnet torquers are only used to reduce or to increase the angular momentum.

2.2 *Ground Segment*

The primary ground segment contains the TUB Satellite Control Center and the DFD S-band receiving station. The satellite is controlled by the TUB VHF/UHF ground station. TUB is not able to receive the wideband video signal in Berlin because the S-band antenna is not great enough to get a good signal to noise ratio. That is why the S-band video signal is received by the DFD Neustrelitz. A reduced video signal is send to the TUB via internet. With this reduction of the video signal it is possible to send the picture information to Berlin in real time, what is important for the interactive satellite control. The original video signal is recorded on SVHS video tapes in Neustrelitz.

In course of the satellite operation phase a complete satellite control station in Tromsö (Norway) was build up and a cooperation with a satellite control station in Rabat (Morocco) was started. This two stations can control the satellite and receive the wide band video signal.

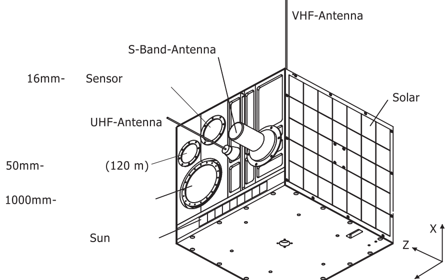

Fig. 2: DLR-TUBSAT.

3 Acquisition and operating strategies

The main advantage of the DLR-TUBSAT system is the interactive attitude control. One design requirement was to keep the system as simple as possible and to build a cheap system. Because of that no star sensor or GPS system was used. That is the reason why other acquisition strategies than in the classical earth observation systems must be used. Since the start of the operation many different strategies for different acquisition and operation modes are developed and tested.

3.1 *Acquisition strategies*

In normal case the satellite power system is shut off and the satellite is in free rotation. The first step is to stabilise the satellite and to orientate the camera axis to the earth. Without that we would have no S-band connection and no video signal could be received (S-band antenna is located in the camera axis – see Fig. 2). Different possibilities were tested. Which strategy is to be used depends on the season and the geographical position of the ground station.

In the early beginning of operation we use sun pointing modes. For this acquisition mode we do not need any video signal, only the electrical telemetry of the solar cells is used. At first we start the Attitude Control System (ACS) and send the ACS damping command to the satellite. ACS damping means that the rotation in each axis is stopped by the reaction wheels. Sensor signals are delivered by the laser gyros. After stopping the rotation we use the electrical telemetry of solar cells to rotate the satellite till all sunlight is shining on the $-z$ solar panel. The satellite is orientated when $-z$ solar cell has more than 910 mA current in summer and more than 980 mA in winter. Then the camera axis ($+z$) is pointing to earth, S-band signal can be received (after switching on the Camera System) and interactive attitude control can start. With this procedure we reach an orientation accuracy of 5°.

The main problem of this procedure was, that in winter the sun is standing too far in the south. By using this sun pointing mode the satellite looks too far to the north or, if Tromsö station is used, the cameras look into the space. For stations in the nearness of the equator it is not a problem. To solve this problem we tested a new sun pointing mode. Instead of orientate the $-z$ axis into sun, we use the $+x$ axis for that. After putting the $+x$ axis to the sun we start a rotation around the x-axis and wait for the S-band signal from DFD. Disadvantage of this procedure is that we do not know in which direction we are looking. The orientation by the earth surface must be done by looking for the geographical characteristics of the earth surface.

The big advantage of both sun pointing modes is, that no signal from the cameras is needed. So it was possible to write boot software for the satellite to make this acquisition automatically. This boot program can be started by a timer clock and the satellite could be orientated to the earth before we get the first contact. The whole acquisition procedure needs 100 sec.

But we are not satisfied with the accuracy of the orientation. An accuracy of $\pm 5°$ is not good enough for a good predestination what we will see in the video pictures. It could be compensated by the interactive control (searching around and orientation by geographical characteristics) but it could not be the development's end.

That is why we decided to use the video pictures for acquisition. At first we start with stopping the satellite rotation. Then we switch on the camera system and make a 6°/sec rotation around the x-axis. If the earth horizon is reached, we stop the rotation and rotate around the z axis till the earth horizon is vertically shown in the video picture. Then we make a 64° rotation around x-axis to the earth centre. Now we are nadir pointing with an accuracy of $\pm 1°$. It could be that we do not see the earth horizon by rotation around the x-axis, because we are scanning pass by the earth. With 6°/sec rotation we make one round in one minute and if we do not see the horizon in 60 sec then we will stop the rotation and start a rotation around the y-axis and then we will get the horizon. The advantage is that we reach a very good accuracy of orientation and for day overflights the procedure is working in every season for the ground stations in Germany and Morocco. At night it is a little bit more difficult to find the horizon because only a little part of the horizon is visible as an enlightened crescent. The Tromsö station has the same problem in polar night. In this case it takes more time to find the horizon but the rest of the procedure is the same. The disadvantage is the long time of up to 4 min we need for this operation if we do not find the horizon by rotating around x-axis. Another disadvantage is that we require the video signal in real time. The internet is too slow for transfer of the whole video information and so we can only use a reduced video picture in Berlin. The stations in Rabat and Tromsö do not have this problem.

A solution of this problem is an addition of sun pointing to earth horizon orientation. At first we use the automatic sun pointing mode and then we start the acquisition with the video pictures. With this procedure we can be sure that we will get the horizon by the first rotation around the x-axis. Because of the good orientation accuracy and the acceptable acquisition time this is at the moment our preferred procedure.

3.2 *Interactive earth observation*

After the acquisition phase the earth observation can start. The first step is the north-south orientation of the video picture to get a picture as known from the atlas. If we use the sun pointing mode with all sunlight on the x-axis the picture is orientated to the south, that means south is on the upper boarder of the monitor. In every other case we must make the orientation by hand. To make the north-south orientation we use the temporal changing of the video picture. We know that the footprint of the satellite is moving from the north to the south (at day) or from the south to the north (at night). By rotating the satellite around the z-axis we can make the picture move from the lower to the upper side of the monitor (at day; at night reverse). Now north is at the upper boarder of the monitor.

The real interactive earth observation starts with searching around with the 50 mm telescope to find the target area. The camera axis is controlled via keyboard, joystick or mouse control commands. We have learned that the control via keyboard is too difficult and it is too susceptible to mistakes (finger trouble). Because of that we developed the joystick and mouse control. In this case the user can control the camera as known from other computer applications without looking to the keyboard. The user can look the whole time to the monitor picture and can change between the 50 mm and 1 m cameras. At this point we must say that we have a light problem with the 16 mm and 50 mm cameras. If it is cloudy the cameras are overexposed because it was planned to do earth and star observation with this cameras. Only the 1 m camera does not have this problem.

The target pointing could be made by joystick or mouse control or by using keyboard commands for rotation around the y-axis. The reason for the north-south orientation of the video picture was not only the better orientation on a map. The precise orientation makes it possible to compensate the moving of the satellite footprint by rotating the satellite only around the y-axis. The rotation speed for starting target pointing at nadir pointing position is 0.55°/sec. It goes down to 0.1°/sec depending from the deviation to nadir pointing. If the orientation is not precise the picture breaks out to the left or right. It must be compensated by rotating a specific angle around the z-axis. If the rotation speed around the y-axis is not correct the picture breaks out to the upper or lower boarder. If the target moves to the lower border the rotation speed must be reduced, if it moves to the upper border it must be increased.

Our experiences show that a target search and target pointing with keyboard commands is possible but too jerky and too susceptible to mistakes. Joystick and mouse control work better but the rotation speed about the axis can be better controlled by mouse. Only the north-south orientation corrections should be done by keyboard, because these are angle and not angle velocity commands.

In the near future we want to update the software. The goal is to made the acquisition and the north-south orientation automatically. This should be done by detecting the earth horizon (black to white transition) and the temporal changing of the horizon.

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CHAMP – the first FLEXBUS in Orbit

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Abstract: The launch of the German research satellite CHAMP was the successful premiere for a new ASTRIUM GmbH satellite concept.

The Flexbus satellite design and management concept was developed in view of shrinking budgets and great demand on reliable satellites enabling affordable missions in the area of science and earth observation. Compared to a conventional design and management approach the Flexbus concept applied on the CHAMP satellite development resulted in a cost reduction by factor 3.

The use of a mature basic architecture for the spacecraft bus and the combination of proven components with mission-specific payload elements make CHAMP a satellite which optimally adapts to individual mission and payload requirements.

Also the cooperation with the customer and principal investigator GeoForschungs-Zentrum Postdam (GFZ) and the satellite operator DLR was based on a new approach. Both partners were involved very early in the design and development phase.

Besides the proven technologies CHAMP features a first in orbit use of the in-house developed Coarse Earth and Sun Sensor CESS, foam isolated body fixed solar arrays and a low cost boom deployment mechanism. All three new developments performed very well.

Zusammenfassung: *CHAMP – Der erste Flexbus im All*. Der Start des deutschen Forschungssatelliten CHAMP war die erfolgreiche Premiere für ein neues Satellitenkonzept der ASTRIUM GmbH.

Das Satellitendesign- und -management-Konzept für den Flexbus wurde mit Blick auf die sinkenden Budgets und auf die große Nachfrage nach zuverlässigen Satelliten entwickelt, die Missionen für Wissenschaft und Erderkundung zu erschwinglichen Preisen ermöglichen. Verglichen mit einem konventionellen Design und Management wurde durch das beim CHAMP-Satelliten genutzte Flexbus-Konzept eine Kostensenkung um den Faktor 3 erreicht.

Dank der Nutzung einer ausgereiften Basisarchitektur für den Satellitenbus in Kombination mit bereits weltraumerprobten Komponenten und mit missionsspezifischen Nutzlastelementen konnte CHAMP optimal an individuelle Missions- und Nutzlastanforderungen angepasst werden.

Auch die Zusammenarbeit mit dem Nutzer und wissenschaftlichen Leiter, dem GeoForschungs-Zentrum Potsdam (GFZ), und mit dem Satellitenbetreiber DLR basierte auf einer neuen Herangehensweise. Beide Partner wurden frühzeitig in Entwicklung und Konstruktion einbezogen.

Neben den erprobten Technologien wurden bei CHAMP erstmals der im eigenen Unternehmen entwickelte Erde-Sonne-Sensor (Coarse Earth Sun Sensor CESS), fest montierte schaumisolierte Solararrays und ein kostengünstiger Ausklappmechanismus für einen Ausleger im Weltraum eingesetzt. Alle drei Neuentwicklungen haben sehr gut funktioniert.

1 Introduction

On 15th July 2000, the German geo-research satellite CHAMP was injected into its orbit by a COSMOS launch vehicle from Plesetsk, Russia. All satellite payload- and bus systems show excellent in-orbit performance and the nominal science mission activities are successfully under way. CHAMP is the first satellite which was built following the Flexbus approach, a concept specifically developed by ASTRIUM GmbH in the mid-90's to satisfy the world-wide demand for "faster, better, cheaper" access to space.

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The paper gives a general overview of the Flexbus concept and its influence on the individual steps of the satellite design and verification process. Using CHAMP as example, a summary is given of the engineering, product assurance and management guidelines followed during satellite development, production and testing to achieve the desired high quality product at minimum cost.

2 Technical Capabilities and Electrical Architecture

The Flexbus concept is tailored to serve a class of satellites with the following technical capabilities:

- Typical S/C mass between 150 kg and 1000 kg
- Typical S/C power up to 4 kW peak (battery supported) and 150 W to 1000 W orbit average (no real upper limit)
- 32 kbps / 1 Mbps S-Band downlink for HK and small payloads up to 300 Mbps X-Band downlink
- Up to 30 arcsec pointing performance via GPS / Star Tracker
- Lifetime typically 5 years
- Typically compatible with small satellite launchers like Athena, Taurus, Cosmo, ROCKOT etc.

The Flexbus electrical reference architecture is based on the idea to build a mission tailored solution out of a set of existing and well proven modules and units.

Cold redundant chains and cross strapping capabilities are applied on unit and system level. This approach allows to match recurring costs with mission specific requirements without additional implementation of riscs.

The quality approach for EEE-parts requires as a minimum compliance with MIL 883 class B for integrated circuits, JAN TX for discrete parts and MIL ER with failure rate R for passive elements. Radiation tolerance is typically 10–20 krad and design measures to withstand single event upsets or latch ups are mandatory.

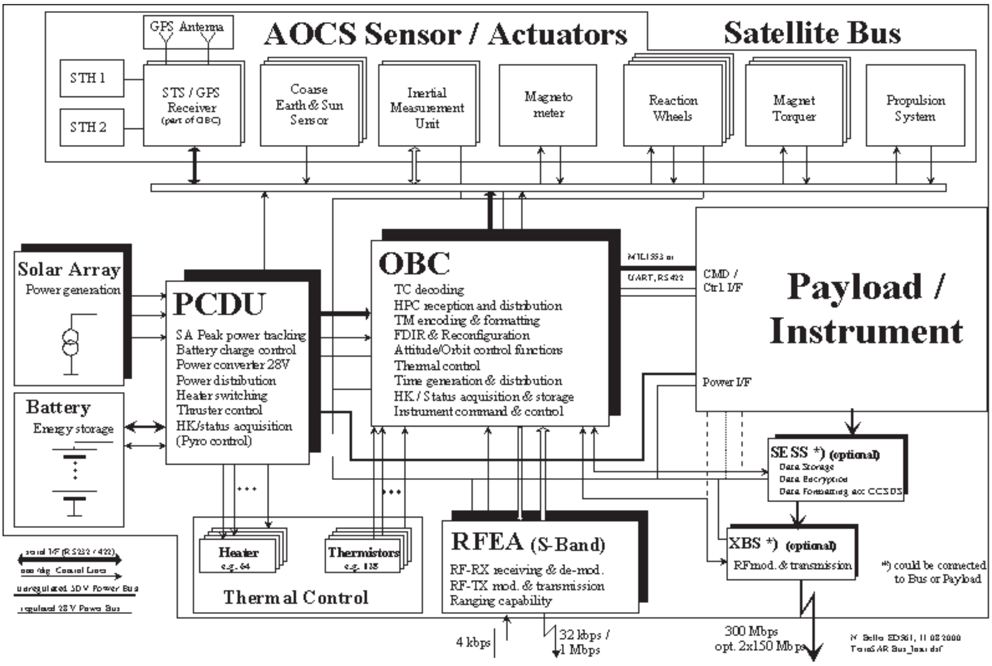

Fig. 1: Flexbus Electrical Reference Architecture.

3 Project Management, System Engineering and Verification

The Flexbus concept asks for a close cooperation with the customer starting with begin of the mission and requirements definition phase and ending with the in orbit commissioning. The engineering team should be staffed by both partners and co-location of the team is recommended. The selected satellite operating organization should be involved in the project team with definition of the check-out environment including the staffing of check-out operators.

The Flexbus concept does not foresee to subcontract system engineering tasks. Subcontracts are limited to component level tasks. Payload elements are utilized for bus functions where ever reasonable. The system design process is based on a thoroughly performed FMECA resulting in an adequate FDIR concept fulfilling the required single point failure tolerance.

The definition and verification process of requirements is usually described in one document which is commonly developed and serves as contractual basis. The design is verified by analytical models for structure, thermal, AOCS, CESS, boom deployment and mass properties. Results of analysis are compared with system test results where ever feasible. The bench mark to proof flight worthiness is a tough and complete functional and environmental test program. For CHAMP this program resulted in an accumulated satellite on ground operating time of more than 2000 hours. Test cases are defined on system level in order to identify interface problems and system design weaknesses. I.e. during the thermal vacuum test a complete loss of power situation was established in order to proof the satellites capability to recover autonomously once the solar array is sufficiently illuminated by the sun.

4 New developed Hardware Elements

4.1 *CESS – Course Earth Sun Sensor*

The patented CESS hardware consists of six single sensor heads arranged on the satellite in such way that an omnidirectional and unobstructed view to space is given. Each head is equipped with two equally sized optical surfaces of different properties. The IR absorptance is the same but the visible light absorptance is different. Behind each reflector three PT 1000 thermistors are placed.

This hardware configuration allows to take temperature measurements driven by earth and sun illumination. The readings are weighted by majority voting and averaging and then extrapolated to steady state equilibrium temperatures.

Based on this input temperatures an algorithm derives overall heat flux input and corrects for earth albedo. The output is a computed earth vector and a computed sun vector transferred into the satellite body fixed coordinate system.

The expected in orbit performance is 6° for the sun vector knowledge and 15° for the earth vector knowledge. The full performance as designed could not be completely verified on CHAMP because two of the six sensor heads were degraded by ex-

● Integrated System Test (2 times) ● Mission Simulation Test (2 times) ● Abbreviated Functional Tests (20 times) ● RF – Compatibility Test at Ground Station ● End to End tests with Mission Operations System (3 times) ● Full functional system test in TV ● End to End tests of AOCS sensors & actuators ● Boom deployment tests ● Cold Gas System proof pressure and leak tests	● Thermal Balance / Thermal Vacuum Test ● Random and Sine Vibration Test ● EMC Test ● DC Magnetic Test ● Acoustic Test ● Physical Properties ● Static & Dynamic Balancing Pyro shock test

Fig. 2: Summary of CHAMP satellite functional and environmental test program.

cessive heat load during ascent. The early mission experience shows that the CESS even with its degraded hardware configuration allows a safe attitude control of the satellite in case of fine attitude loss. The design will be used on GRACE satellites without change.

The basic advantages of the design are low mass, negligible power demand and minimum on board processor resources and low recurring costs for future applications.

4.2 *Foam isolated solar panels*

The CHAMP mission specifics asked for body mounted solar panels. The generic advantages of body mounted solar panels are high μg – quality; high agility of spacecraft, quick re-establishment of fine pointing requirements and high aerodynamic design capability. The generic drawback is that high thermal isolation between spacecraft body and surface of the solar panels is needed. Traditional designs cover this need by the implementation of spacers and Multi-Layer-Insulation between the basic satellite structure and the solar generator. This is costly.

For the CHAMP mission ASTRIUM introduced a new isolation concept. The MLI was replaced by 40 mm thick foam made of Kapton open pore material. This is a commercially available product fulfilling all basic material requirements for the use in space. The foam is directly glued to the face sheet of the honey-comb structure and covered by a CFRP face sheet. The solar cells are glued to the face sheet according existing standards.

The thermal insulating capability proved to be very efficient. This is verified by extensive vacuum tests on ground as well as by the excellent in orbit performance on CHAMP. Temperatures on the cells surface range from $+120°$ to $-120°C$ pending on orbit conditions while the temperature of the inner panels surface is damped to $20°C$ typically. Initial problems with the gluing process are completely solved. The design will be used on GRACE satellites without change.

4.3 *Boom deployment mechanism*

The magnetic sensors of the CHAMP payload need to be placed as far as possible off the satellite's body. This configuration is established in orbit by the deployment of 4 m long boom. In order to match the launch configuration requirements under the fairing an 180 deployment angle is required. ASTRIUM adapted a design already flown on 64 Globalstar missions. The mechanism consists of four springs bent by 180 degrees and such carrying the energy necessary for successful boom deployment once the launch hold down is released. The springs also serve to pull the boom in a stiff and predefined configuration to the satellite body once the deployment motion is damped out by friction. CHAMP in orbit data show both, as designed deployment behaviour and as designed stiff fixation to the satellite body.

5 Summary

With the successful start of the mission CHAMP it is demonstrated that the Flexbus concept is a good solution to realize robust and reliable satellites on a commercial basis which is affordable in terms of costs and schedule for scientific institutions.

The CHAMP satellite was designed, built, tested and launched within 42 months. The costs are roughly one third compared with traditional programs. The in orbit results of the initial mission phase are very promising and confirm the accomplishment of all system requirements.

ASTRIUM appreciates very much the open attitude of GFZ and DLR approaching the Flexbus management and design concept and thus paving the way for more affordable and successful missions.

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FUEGO: A dedicated Constellation of small Satellites to detect and monitor Forest Fires

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Abstract: The objective of FUEGO programme is the design and development of a space-based system for the early detection and monitoring of forest fires. The studies carried out lead to a LEO constellation of small satellites as the best solution to fulfil the user requirements. This solution allows the utilisation of small service buses as the ones like INTA MINISAT series, reducing the mission complexity and costs. The system consists on a Walker constellation 12/3/2 at 700 km altitude and 47.5 deg inclination orbit, which optimise parameters such as the revisit time and image resolution. The payload is based in a MIR camera to detect forest fires assisted by a VIS/NIR and TIR cameras to improve the resolution of the fire monitoring and to reject false alarms. The acquisition is made by means of a pushbroom technique, using a steerable mirror to point the sensor beam and pitch manoeuvres to increase the coverage.

Zusammenfassung: *FUEGO: Eine ausgewählte Zusammenstellung kleiner Satelliten zur Erkennung und Beobachtung von Waldbränden*. Ziel des FUEGO-Programms sind das Design und die Entwicklung eines weltraumgestützten Systems für die Früherkennung und Beobachtung von Waldbränden. Die bisher durchgeführten Studien ergaben, dass eine LEO-Konstellation von Kleinsatelliten am besten den Nutzeranforderungen entspricht. Diese Lösung erlaubt es, kleine Servicebusse wie die der INTA-MINISAT-Serie zu verwenden und dabei die Missionskomplexität und die Kosten zu reduzieren. Das System basiert auf einer Walker-Konstellation 12/3/2 bei 700 km Höhe und 47,5° Orbitinklination, wodurch Parameter wie die Wiederholungszeit der Überflüge oder die Bildauflösung optimiert werden. Die Nutzlast besteht aus einer MIR-Kamera zur Detektierung von Waldbränden, ergänzt von einer VIS/NIR- und einer TIR-Kamera, um die Auflösung der Brandbeobachtung zu verbessern and Fehlalarme auszuschließen. Die Sensoren arbeiten im Pushbroom-Modus. Mit Hilfe eines Ablenkspiegels und Neigungsmanövern wird die Überdeckungsrate vergrößert.

1 Introduction

The forest fire phenomena in temperate latitudes represent a serious economical and ecological problem, especially in some areas as the Mediterranean ones in Europe. The current fire fighting systems are not efficient enough to manage this problem, as can be seen from the statistics of forest fires and area burnt every year.

Nowadays the forest fire fighting strategy is based on fixed towers with observers on the top, supported by mobile ground patrols or aerial means. There are also some new technologies as IR towers, but their operational results do not completely satisfy the users.

FUEGO is a space-based system designed to provide fire fighters with a powerful tool for early fire detection and monitoring of forest fires, as well as an efficient risk and damage assessment tool.

FUEGO has been conceived from the outset as a user driven system, it has been designed and developed in cooperation with final users (forest fire fighters, forest fire fighting organisations, civil protection organisations . . .) by means of users confer-

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ences, meetings, and questionnaires. Users have been involved in every stage of the design process and have been periodically informed about the evolution of the system, ensuring that the system is tailored to the forest fire-fighting services needs.

2 System Requirements

The most important user requirement is the early detection of small fire outbreaks, to allow a fast control of the fire when it has not reached an unmanageable size. The geolocation accuracy is another key requirement as well as the monitoring resolution and the reception of the data in real time. The main user requirements, fulfilled by the system, are:

– Data reception, processing, and dissemination in near real time at regional level

– Continuous service in time, coverage of 100% of risk areas, easy to use by the ground staff, robust, reliable, and low cost

- Detection phase
  - – Outbreaks time detection of less than 15 minutes in average, that is a revisit time in the order of 25 minutes
  - – A minimum detection size of fire of $50\,m^2$, with automatic alarm generation and intensity classification
  - – Geolocation of fire alarms within 300–500 m
  - – The probability of false alarm should not exceed 5% of the cases.
- Monitoring phase
  - – Automatic monitoring information for on-going fires larger than 25 ha, without previous request.
  - – The geo-location of monitoring products should have accuracy of the order of magnitude of the pixel (35–50 m), as well as the resolution of the images.

The areas of surveillance are located in the temperate forest latitudes (37 deg – 46 deg) in both hemispheres. The main areas are located in the Mediterranean area of Europe (30 Mha), the rest of the areas are located in the west coast of USA, Florida, Canada, Chile, and Australia.

3 Mission description

The main constraint of the system is the detection time, and several solutions have been studied to minimize it. The revisit time requirement leads to a LEO constellation of twelve satellites as can be seen hereafter.

- **GEO**: It would be able to cover all the risk areas in Europe with only one satellite (three for a world wide coverage) in a continuous way. But the dimensions of the payload and specially of the optics to meet the image resolution requirements would be very high, for a monitoring resolution of 144 m, the corresponding focal length is 5.35 m. This makes unfeasible the utilization of a small platform, with small costs.

- **MEO**: It can be reached a good revisit time, lower than 10 minutes in some cases, with only eight satellites between 5000 km and 15000 km. However, in this case the main drawback is again the size of the telescope to provide a useful resolution for the detection phase, the monitoring is unaffordable for altitudes over 5000 km due to the mass and size requirements of the payload needed and imposed to the platform.

- **LEO**: A revisit time of less than 25 minutes can be reached with twelve small satellites at 600 to 900 km of altitude. The payload required is small enough to allow the utilization of small platforms, easy and cheap enough to make the system economically feasible.

Several studies have been carried out in order to select the optimal constellation to fulfil the user requirements. The constellation altitude, inclination and number of satellites have been optimised to reach an economical system, which is able to provide the forest fire fighters with a useful tool.

Taking into account the geometrical and radiometric resolution required by the users, the distribution of the areas of surveillance, the technological constraints of the sensors (detectors size, optic aberrations) and system cost, the trade offs carried out lead to a configuration with a swath of 2500 km, a field of view of 177 km at nadir, and a circular orbit of 47.5 deg inclination at 700 km altitude. This configuration provides a resolution up to 20 m at nadir.

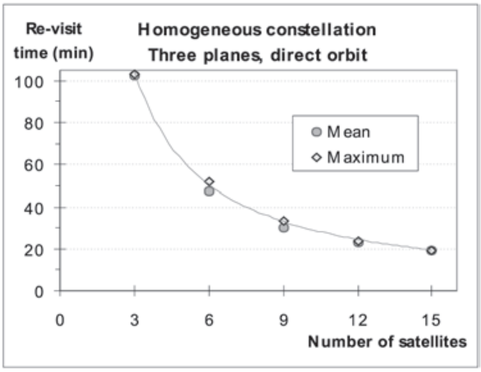

Fig. 1: Simulation result for latitude 40 deg.

In general, since a unique satellite placed in this orbit is able to observe the same region during around 5 consecutive passes (the orbital period is around 100 min so this takes 5×100 min $\cong 8$ hours), at least three different planes are needed to provide continuous service during 24 hours per day. But 100 min revisit time is not enough frequency, therefore there is needed to insert more satellites into those planes. Constellations of N times three have been considered, yielding the results shown in Fig. 1.

The twelve-satellite solution is a good compromise to provide 25 minutes re-visit time. In order to homogenize the observation pattern a direct Walker 12/3/2 constellation has been selected. The constellation parameters can be seen in Tab. 1.

Tab. 1: Baseline mission parameters

Orbit Profile	
Altitude	700 km
Orbital inclination	47.5 deg
Orbital period	98.8 min
Orbital geometry	Circular
Satellite constellation design	
Number of satellites	12
Configuration	Direct Walker (12/3/2)
Symmetry	Homogeneous
Revisit time	23.8 min medium & 25.8 min maximum
Service	Continuous (24 h a day)

The main products offered by the system will be fire outbreak detection and fire monitoring:

– Fire detection. Small fires (20–220 m^2) will be detected in less than 15 and 25 minutes of average and maximum time, respectively. Additional information could be included as meteorological information, GIS, ...

– Fire monitoring. Fires larger than 25 ha in the areas of risk will be monitored in an automatic way, with a temporal resolution of 25 to 90 minutes and a image resolution of 20–80 m. Users can ask for the monitoring of the areas of interest when necessary.

Other products can be offered as post-fire phase products (identification fire hotspots with potential danger to restart a fire, burnt area assessment ...) or other Earth studies (applications like vulcanology, hot events, meteorology, forestry, etc.). For those products other areas of interest are defined apart from the ones mentioned above.

The system will be available 24 hours per day, 365 days per year. Both products will be offered by means of an easy to use graphical interface like the one shown in Fig. 2.

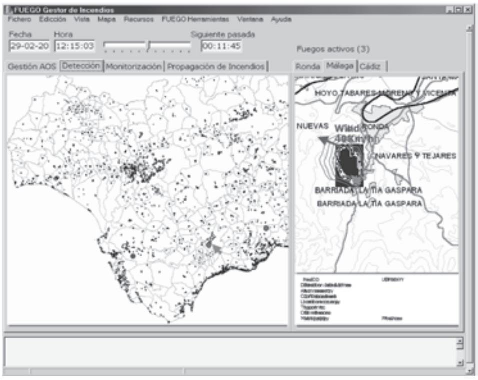

Fig. 2: FUEGO System Demonstrator.

4 Operational concept

In detection mode the data acquisition is made by means of a pushbroom technique using a steerable mirror to point to the areas of interest (Fig. 3). One of the advantages of the FUEGO system is that the satellites

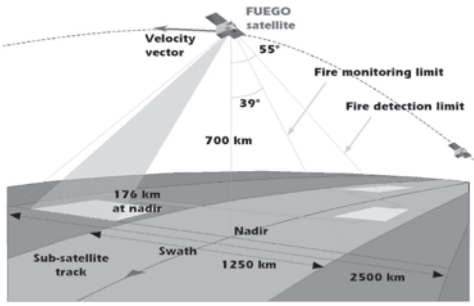

Fig. 3: Geometric Observation Sketch.

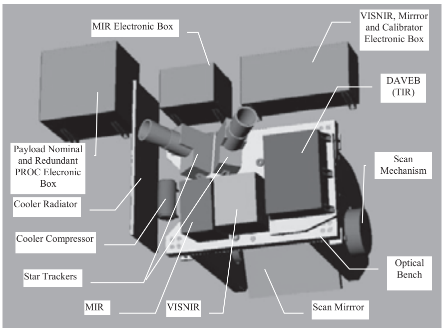

Fig. 4: FUEGO instrument.

are capable of concentrating the observation mostly on the interesting areas, being not necessary to cover the whole satellite swath. The satellite will be able to perform pitch manoeuvres in order to have more than one observation opportunity on certain track points in which the satellite is not able to observe the whole areas of interest with just one pass.

The areas of surveillance can be updated every day by the users. This information is sent to the Mission Control Centre from the Primary User Stations. With all of this information the MCC generates the 'Plan of Observation' by means of coverage simulations. This plan contains the tasks to be performed by the payload, as well as satellite pointing required, both referenced in time. After that, the MCC schedules all satellite operations and generates the proper telecommands to be transmitted to the satellite by the Primary Ground Station.

The payload data are directly transmitted to user ground stations in real time by means of a L-band communication subsystem. The data will be processed on ground at the local user stations, which will generate the final FUEGO product.

5 Payload description

The payload required by the system has been designed to fulfil the user requirements with the minimum mass and power consumption as possible. This constraints make possible to fit the payload into a small satellite.

The payload mass has been reduced to 62 kg. The power consumption depends on the duty cycle of the satellite (time for observation, sun-pointing, stand by, calibration, . . .). The daily average of acquisition is 14% of the time. The peak power consumption during these periods is 180 W, and the average 140 W. During the stand-by periods the payload power consumption remains below 75 W.

The FUEGO system is provided with four cameras:

- **MIR:** This medium infrared camera is the most appropriate to detect potential fires since it has the optimal spectral range in terms of maximum fire / background contrast for detection of hot spots. Staggered sensors are used to increase the image resolution.
- **VISNIR:** This visible and near infrared camera data is required to discriminate false alarms due to small sun glints. It is also used to provide high-resolution data for the fire geolocation and for monitoring images and for the NDVI calculation.
- **TIR:** This thermal infrared camera provides information on cloud presence and it also helps to reject false alarms due to warm surfaces.

A payload processor will be used to perform the payload data management (the data flow estimated is 3.2 Mbps) in order to free the OBDH of this task and reduce the data processing time. A scan mirror is used to point the sensor beam across track. Other payload elements are the calibration

Tab. 2: Summary of payload parameters.

	MIR	TIR	VIS	NIR
Geometry				
Num elements per row	1100x2	240@45°	8800	8800
Num elements total	2200	480	8800	8800
Element foot-print (m)	128	519	18	18
Spatial sampling (m)	80	367	20	20
Effective resolution (m)	101	436	80	80
Field of view (deg)	14.41	14.41	14.41	14.41
Radiometry				
Channel centre (m)	3.80	10.0	0.63	0.83
Channel width (m)	0.70	4.0	0.10	0.14
Sampling time (s)	12.49	57.23	3.122	3.122

objects and the optical bench, a rigid structure to which all the instruments are attached.

6 Service bus description

The reduced dimensions (volume, mass and power) of the FUEGO payload make it suitable to be fitted in a small service bus. At present, an adaptation of the INTA-CESAR service bus and the FUEGO payload has been carried out in order to converge both elements into a feasible satellite.

The communications subsystem is based on a S-band system for service module and payload telemetry and telecommand, and a L-band for the payload data downlink.

The service module is able to provide the payload the power required as well as the pointing control [0.15 deg across track and 0.1 deg along track] and stability [6 arcsec (1σ) from 0.5 Hz to 2 Hz and 3 arcsec (1σ) from 2 Hz to 150 Hz] required for the data acquisition. The capability of the service module to perform pitch manoeuvres of 45 deg in 30 seconds is required to improve the observation strategy of the areas of surveillance. This agility is favoured by the service bus design, outstretched along the axis of rotation. The dimensions of the service bus are 750 mm × 750 mm × 1800 mm, without solar panels.

The baseline launcher is Rockot. The geometry and mass (less than 240 kg) of the satellite allow the launch of four satellites at the same time. Since there are four satellites per plane, this launching strategy is optimum requiring only three launches for the whole constellation, with the resulting cost saving for the system.

7 Conclusions

FUEGO is being developed under the EU 4th Framework Programme and the European Space Agency Observation Programmes, and plans to start full operational service in 2005. It is a good example of cooperation between private and public actors to set up a space operational system.

FUEGO will provide fire-fighting organisations with an innovative and powerful tool to manage the forest fire problem. FUEGO concept has been defined through interaction with the users and based on a design-to-cost approach.

FUEGO has demonstrated that user requirements can be fulfilled using small satellites in a LEO constellation. This solution is based mostly on COTS components, resulting a low-cost full operational system.

Coverage will be provided to 30 Mha in Europe and 30 Mha in the rest of the world, resulting in an estimated service cost of 0.7 EUR/ha per year. The predicted cost of the system is estimated to 203 MEUR, while the income will be 265 MEUR for a lifetime of 7 years.

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MICRO- MINI- Satellites for Affordable EO Constellations: RAPID-EYE & DMC

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Abstract: Operational Earth Observation from space requires daily imaging of areas of interest. Single satellites cannot achieve this but constellations are ideally suited to providing multiple looks at land-based fast changing phenomena. The first low Earth orbiting satellite constellations attempted to provide mobile and multimedia communications on a global basis, but the extremely high investment and technical risk has led to business failures. However, microsatellites can for the first time provide an affordable constellation which will give operational EO coverage. In order to be economically viable such systems need to be based on new approaches that are associated with more affordable implementation and operating costs.

SSTL's low cost micro- and mini-satellites provide an affordable solution for profitable commercial space constellations. SSTL has pioneered the field of low cost small satellite technology for the past 21 years and based on its skills, experience and resources, is now set to execute a new breed of satellite constellations. SSTL's approach calls for low initial investment but can ensure realistic revenue returns.

SSTL has recently started work on RapidEye and the Disaster Monitoring Constellation (DMC) targeted for a variety of EO applications. These are pioneering the use of Low Earth Orbit constellations for Earth Observation. The DMC has forged the concept of a Novel International Partnership that provides the synergy of a multi-satellite constellation for nations each contributing a satellite, whilst retaining individual ownership. This heralds a new way of making access to space even more affordable.

Zusammenfassung: *Kostengünstige Micro- und Mini-Satelliten-Konstellationen: RAPID-EYE und DMC*. Die operationelle Erderkundung aus dem Weltraum erfordert die tägliche Beobachtung der interessierenden Gebiete. Einzelne Satelliten sind hierzu nicht in der Lage, Satelliten-Konstellationen jedoch sind geeignet, vielfache Blicke auf sich schnell ändernde Phänomene auf dem Festland zu werfen. Die ersten Satellitenkonstellationen in einem niederen Erdorbit sollten erdumfassende Mobilfunk- und Multimediakommunikation ermöglichen. Die extrem hohen Investitionen und technischen Risiken führten jedoch zu Geschäftseinbrüchen. Es ist aber erstmals möglich, mit Hilfe von Mikrosatelliten eine kostengünstige Konstellation zu realisieren, die eine Abdeckung zur operationellen Erdbeobachtung bietet. Damit ein solches System ökonomisch durchführbar ist, müssen ihm neue Herangehensweisen zugrunde liegen, die mit bezahlbaren Implementierungs- und Betriebskosten einhergehen.

Mit seinen kostengünstigen Mikro- und Minisatelliten präsentiert SSTL eine preiswerte Lösung für profitträchtige kommerzielle Weltraumkonstellationen. In den vergangenen 21 Jahren war SSTL Wegbereiter auf dem Gebiet der Niedrigkosten-Kleinsatellitentechnologie und geht nun – dank seiner Erfahrungen, Fähigkeiten und Ressourcen – daran, eine neue Generation von Satellitenkonstellationen herzustellen. Das Vorgehen von SSTL erfordert niedrige Einstiegsinvestitionen, garantiert jedoch realistische Gewinneinnahmen.

SSTL hat vor kurzem die Arbeiten an RapidEye und der Disaster Monitoring Constellation (DMC) begonnen, die auf vielfältige Erderkundungszwecke ausgerichtet sind. Sie markieren den Beginn der Nutzung von Satellitenkonstellationen im niederen Erdorbit für die Erderkundung. Mit dem DMC wurde das Konzept einer neuen internationalen Partnerschaft kreiert, das auf dem Synergieeffekt einer Mehrfachsatelliten-Konstellation beruht, zu der verschiedene Länder ihren Satelliten beisteuern, ohne dass ihr Eigentümerstatus geändert würde. Hier deutet sich ein neuer Weg an, den Zugang zum Weltraum noch kostengünstiger zu gestalten.

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Introduction

Space traditionally is funded by governments. The commercialisation of space has been attempted for many years, however the majority of funding for space activities still originates from governments. The only exception is the GEO communications satellites market which has been effectively and profitably exploited by the private sector.

In the mid 1990's, it was very popular for private investors to put money into new LEO communications constellations – such as Iridium. However the subsequent bankruptcy of Iridium and ORBCOMM has seriously undermined the confidence of the space investment market, especially in LEO constellations.

Taking advantage of many years of investment by the US government in Earth observation from space, EarthWatch with Ikonos has managed to initiate a commercial business in the hitherto difficult Earth Observation data market. As this business has just commenced, the market waits with interest to see whether it will prove truly commercially viable.

Surrey Satellite Technology Ltd (SSTL) in the UK has pioneered advanced micro-minisatellites over the last 20 years. Its range of low cost, rapid-response, small satellites has catalysed new business opportunities, especially based on commercial constellations, which have only matured during the last two years. SSTL has commenced work on the Disaster Monitoring and the RapidEye EO constellations. This paper describes how SSTL and its products meet the demands of private investors, the current projects available for investment, and future business opportunities for small satellites.

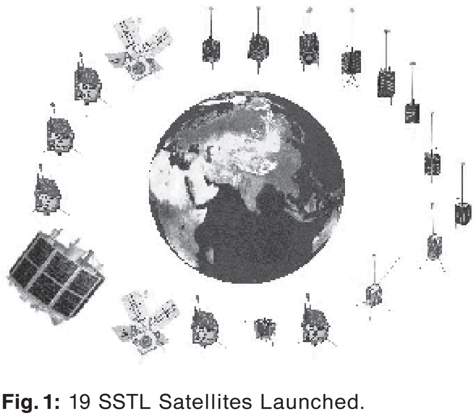

Fig. 1: 19 SSTL Satellites Launched.

Symbiosis of Industry & Academia Yields Innovative Small Satellites which Create the Market

SSTL's strength is founded on the key concept of symbiotic academic and commercial partnership, allowing the Company to innovate rapidly and also appeal to a hitherto almost virgin market associated with in-depth satellite know-how transfer and training working with the Surrey Space Centre. SSTL's core business now has two complimentary elements – know-how transfer & training missions and manufacturing turn-key satellite missions. Importantly, each of these businesses stimulates the other.

The opportunities offered by micro-mini-satellites in realising affordable constellations for Earth observation and LEO communications were first described at the IAF'96 and have since matured to reality by IAF'2000. Surrey's increasing reputation, built upon almost annual launches and rapidly developing capabilities demonstrated in orbit, has also catalysed a substantial number of 'turn-key' satellite manufacturing missions and, more recently, subsystems and studies.

COTS and End-to-End Capability at SSTL

In parallel, SSTL pursued a policy of 'complete in-house capability' in order to decouple itself as far as possible from the onerous management and risk of relying unduly on subcontractors; to be able to react rapidly; and to be able to offer credible and detailed satellite know-how transfer & training. This policy also had the important effect of maintaining SSTL's independence from the 'aerospace establishment', a position that has proved highly advantageous. SSTL has developed a practical COTS satellite engineering philosophy, backed by extensive real in-orbit experience, that has since become the benchmark for the small satellite community.

In addition to concentrating on complete satellites, SSTL has also ensured that it can offer a 'one-stop-shop' for complete mission requirements, including the supply of groundstations, launch services and insurance to those customers who need these.

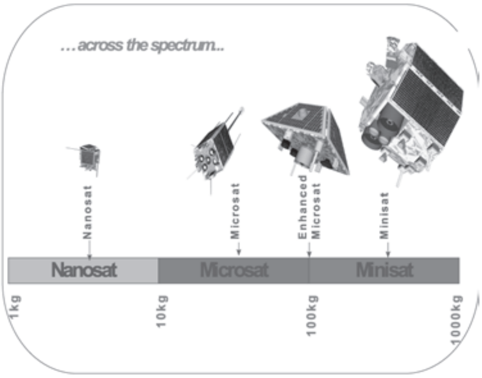

Fig. 2: Across the spectrum.

Low Cost, Regular Launches Critical to Market Development

SSTL has expended considerable marketing effort, since its formation, on promoting low cost launch facilities for micro-minisatellites as this has been a serious bottleneck in the commercial development of the low cost small satellite business – acutely illustrated within the USA. SSTL played a key catalytic role in the development of the first commercial secondary payload facility for microsatellites on Ariane and in the commercialisation of secondary and affordable primary launches in the FSU. This has been fundamental to enabling SSTL to achieve a high mission launch rate and, consequently, a high innovation rate to meet customers' requirements.

Low-Cost Micro-Minisatellites enable Affordable Constellations

The small satellite market sector has grown gradually during the last decade, but has recently gathered pace as the capabilities of micro-minisatellites to meet real applications has been demonstrated – particularly illustrated by SSTL through the landmark Thai-Paht & UoSAT-12 missions.

SSTL currently occupies over 80 % of the accessible micro-mini satellite market sector – and the value of this sector is growing to become in excess of £ 100M p.a. in 2001.

SSTL's marketing activities have contributed substantially to the international impetus for the development of small satellites by repeatedly illustrating to both established and emerging space organisations the practicality and benefits of 'affordable access to space'. Small satellites are now widely perceived as the most commercially practical means of implementing satellite constellations – and constellations are seen as the key to commercialisation of space.

By 2000, SSTL has diversified its product range to extend from 6 kg nanosatellites through 100 kg enhanced microsatellites to 400 kg minisatellites. These products have demonstrated in orbit a dramatic increase in technical capability – particularly associated with attitude and orbit control – which has successfully separated the Company from its nearest potential competitors in the market sector.

SSTL's ability to be selected for satellite contracts by space 'superpowers' NASA, USAF, French government/MoD, and by China to form the first satellite Collaborative Joint Venture manufacturing company in PRC, and the establishment of the Surrey Space Club with 11 international members, have contributed very substantially to the Company's strong market standing.

The recent decision by the UK government, through BNSC, to support small satellites and the subsequent award of £ 11M to SSTL to support three advanced product missions has further reinforced SSTL's reputation and position as a foremost commercial space company.

Small Satellite Business

In order to win satellite contracts from established space countries, SSTL has, over 20 years:

- developed low cost small micro – mini-satellites
- developed "Low Cost Small Satellite System Engineering" techniques & practices
- accumulated extensive experience and expertise for low cost small satellite manufacture and orbital operations
- lived on the low cost small satellite market

Traditional satellite companies have been set up primarily to execute expensive government funded space missions therefore they are not tailored to take on low cost satellites contracts, which are rather unattractive compared to the business maintained by national government funding.

Stimulated by SSTL's success, many small companies and universities are becoming active in the low cost small satellite market during the last few years, however most of them are not run on a fully commercial basis and also mainly rely on national government funding for missions or projects.

SSTL is probably the only truly commercial satellite manufacturing company which operates solely on the low cost small satellite market.

Strengths of SSTL and SSTL's Products

In order to create a commercially-sustainable market, SSTL has developed micro-minisatellite products and services that are:

- low cost
- rapid response
- utilise advanced technologies

and has demonstrated these through extensive heritage based on:

- 19 micro-mini-nanosatellites built and launched and
- 9 microsatellite know-how transfer & training programs completed with international customers.

Turn-key Satellites: To date, SSTL has sold 16 turn-key satellites (i. e. satellites without know-how transfer) to public and private organisations in the USA, France, and Germany.

Satellite Know-how Transfer Programmes: SSTL has sold know-how transfer and training programmes (including satellite and ground station unless noted) to:

- SUPARCO, Space and Upper Atmosphere Research Organisation, Pakistan
- KAIST, Advanced Institute of Science and Technology, South Korea
- ConsortioSat, Portugal
- Mahanakorn University, Thailand
- ATSB: a public-private partnership in Malaysia,
- Nanyang University, Singapore
- Tsinghua University, China
- TUBITAK-BILTEN research institute, Turkey
- CNTS: the national remote sensing centre, Algeria
- National Space Research and Development Agency, Nigeria

In the 15 years since the formation of SSTL, the Company has achieved a total sales worth £ 70M from the small satellite marketplace.

Over 20 years, Surrey has developed 'Low Cost Small Satellite System Engineering' concepts to manage this type of satellite manufacture which is very different from the traditional satellite manufacturing process – being nearer to a combination of concepts and techniques resulting in best practice from modern 'Computer System Engineering & IT' and 'Traditional Satellite System Engineering industries.

EO Constellations for Small Satellites

The rapid development of micro-minisatellite capabilities demonstrated in orbit during the last 2 years by SSTL has catalysed commercial constellations of small satellites such as the RapidEye, GANDER and DMC constellations targeted for a variety of applications.

RapidEye Constellation: SSTL has been selected for the German RapidEye constellation of four 380 kg Earth Observation mini-

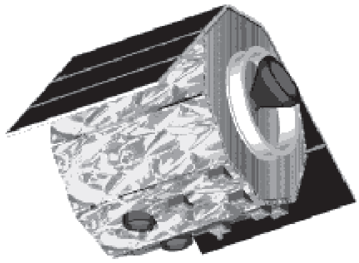

Fig. 3: RapidEye Minisatellite.

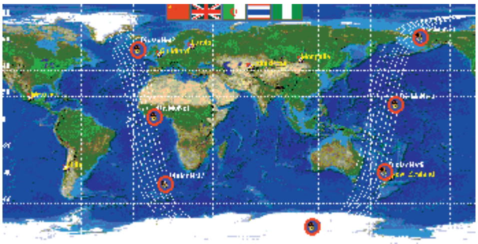

Fig. 5: Disaster Monitoring Constellation of 5–7 MicroSatellites.

satellites designed for mapping and agricultural applications.

RapidEye will provide 6.4 m GSD, wide swath 6-band multispectral imaging with daily revisits in the European region for precision farming and improved crop harvest prediction.

RapidEye will generate a significant impact upon the agriculture and food trading sectors. The total budget of the constellation is approximately $100M including satellites, launches and groundstations.

Disaster Monitoring Constellation (DMC): Lastly, the Disaster Monitoring Constellation (DMC) of at least 5–7 satellites led by Surrey, is being built with the humanitarian objective of disaster assessment, monitoring and mitigation and the commercial objective of dynamic remote sensing services. The DMC consists of an international consortium of partners. Each partner owns one satellite and the whole constellation will be managed by a DMC consortium to share satellite resources in the constellation. The British government supports one satellite, through the British National Space Centre Small Satellite Initiative, and the other partners include Algeria, Nigeria, China, and Thailand.

The constellation will comprise five 70 kg enhanced microsatellites – each satellite being contributed by a consortium of international partners. The DMC will provide 36m GSD multispectral (Green, Red and Near-Infrared) with and extreme swath width of 600 km. Two cameras consisting of 10,000 pixels linear CCD arrays will be mounted side by side, at fixed offset, to provide the 600 km swath (with a 120 km overlap).

The DMC is the first example of a Novel International Partnership whereby 5 different organisations each contribute a microsatellite into the constellation – to be operated in concert whilst maintaining individual ownership. Each partner thus derives significant synergy benefits. The constellation is scheduled to be launched in 2002 into a 686 km sun synchronous orbit.

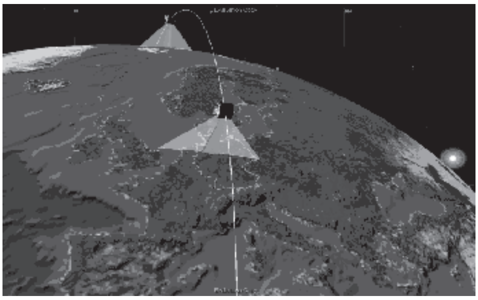

Fig. 4: RapidEye constellation of 4 minisatellites.

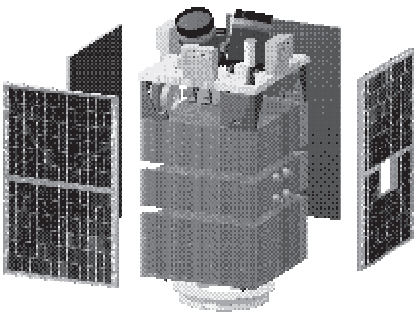

Fig. 6: DMC Microsatellite.

International Collaboration through-Surrey Space Club

In order to promote and provide a means of developing international co-operation, as exemplified by the DMC, the Surrey Space Club was formed in 1998.

The Surrey Space Club provides ongoing after-sales-services for KHTT customers, help on maintaining sustainable national space programmes and promotion of international long-term co-operation.

The members of Surrey Space Club are able to participate the following activities co-ordinated through an annual conference of members:

- share satellite resources in orbit
- share global groundstation network
- exchange new ideas on research and development
- build small satellite constellations together
- co-ordinate low cost launch opportunities
- assist in long-term national space program planning

Future business opportunities for small satellites

On completion of the DMC, SSTL is planning to call for participation every two or three years for the following low cost small satellite constellations:

- Ionospheric measurement for Earthquake prediction
- Microwave measurement of temperature for Earthquake prediction
- Higher Resolution Optical Enhanced Micro-satellites ($\sim$ 2 metre GSD)
- Higher Resolution Optical Mini-Satellites ($\sim$ 1 metre GSD)
- IR Imaging Minisatellites
- SAR Minisatellites
- LEqO or NEqO remote sensing micro-mini-satellites
- LEqO or NEqO microsatellites and mini-satellites for communications
- Swarms of Nano-satellites
- Navigation minisatellite constellations

Conclusions

The demonstrated capability of the latest SSTL microsatellites and minisatellites has catalysed new business opportunities, particularly associated with affordable constellations for optical Earth observation and radar remote sensing.

Compared with conventional satellites, these modern small satellites now enable any country, company or university to have direct access to and benefit from space at low cost, low risk and on a short timescale.

Acknowledgements

The authors would like to thank all SSTL's customers listed in the paper for their support and contributions to this emerging market.

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Photogrammetrie • Fernerkundung • Geoinformation 1/2002, S. 37–41, 1 fig., 1 tab.

The Role of Emerging Technologies in Imagery for Disaster Monitoring and Disaster Relief Assistance

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Abstract: Emerging technologies enable new concepts in low-cost Earth observing constellations. In this paper we posit an architecture that addresses a largely unmet need for real-time disaster monitoring and disaster relief assistance. A satellite based system capable of being controlled from, and downlinking data to, a relatively primitive ground site would be invaluable for focusing disaster relief efforts. In this concept, real-time continuous high resolution imagery from a system capable of selecting wavelength bands for specific needs would be implemented. The system is comprised of elements at geosynchronous and L1 altitudes. From geosynchronous altitude, focused high-value imagery is provided by steerable cameras with a 250 m resolution. At L1, full disk imagery provides context for mesoscale high resolution imagery.

Zusammenfassung: *Fernerkundungstechnologien für den Katastrophenschutz*. Neue vielversprechende Technologien ermöglichen neue Konzepte für Erderkundungs-Konstellationen im Niedrigkostenbereich. In diesem Beitrag stellen wir eine Architektur vor, die auf das bislang nicht erreichte Ziel einer Realzeitüberwachung von Katastrophen und auf die Unterstützung bei deren Eindämmung abzielt. Ein satellitengestütztes System, das in der Lage ist, von einer relativ einfachen Bodenstation aus kontrolliert zu werden und über diese den Datentransfer zu realisieren, wäre für den gezielten Einsatz von Gegenmaßnahmen im Katastrophenfall von unschätzbarem Wert. Mit diesem Konzept würden kontinuierlich hochauflösende Echtzeit-Bildaufnahmen mit einem System realisiert, mit dem die Wellenlängen entsprechend den spezifischen Anforderungen ausgewählt werden können. Das System besteht aus Elementen in erdsynchroner und L1-Höhe. Aus erdsynchroner Höhe werden punktuell hochwertige Bilder durch eine steuerbare Kamera mit einer Auflösung von 250 m geliefert. Aus der vollflächigen Erdabbildung aus L1-Höhe wird der Kontext für mittlere Auflösungen gewonnen.

1 Introduction

The **G**lobal **O**bservations and **A**lerts from **L**1 and **G**eosynchronous **O**rbit (GOAL&GO) concept is proposed as an example of what will soon be practical through the use of new technologies under development for spaceflight implementation. The architecture we discuss here will provide real-time weather and disaster monitoring information directly to users.

The GOAL&GO measurement concept provides for continuous mapping (5 km × 5 km) of ozone, aerosols, and clouds from L1 (VISHNU) while the entire Earth is accessible for surveillance for disaster monitoring and land-use assessment by an IR/Visible sensor (SHIVA) with 250 m × 250 m resolution from geosynchronous orbit. The complete constellation would consist of the VISHNU instrument at L1 and three (or more) SHIVA instruments in geosynchronous orbit. The instrument packages would be designed to produce as little impact as possible upon the spacecraft that provides systems support, thus enabling accommodation of GOAL&GO on existing platforms.

The **S**upporting **H**igh-resolution **IR V**isible **A**pplications (SHIVA) instrument is a narrow field of view (1.5°) system with a

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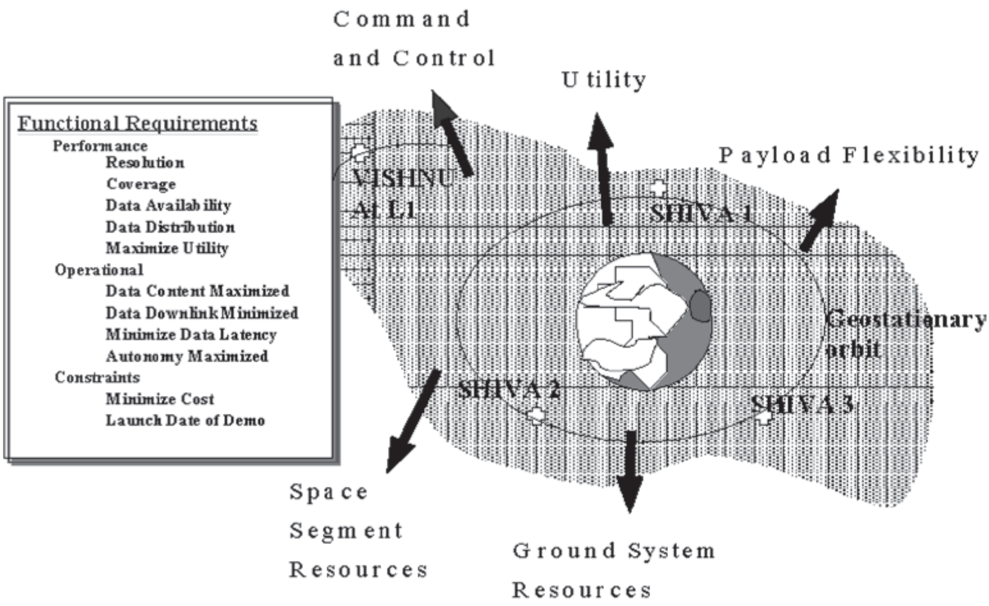

Fig. 1: Mission Concept. GOAL&GO applies new technologies to the functional requirements of a basic research mission with demonstrable utility to the public. GOAL&GO incorporates appropriate new technology in a system design that maximizes the return from a high data volume imaging mission while minimizing costs. The design areas are indicated in the figure as those drivers lying outside the GOAL&GO constellation. The SHIVA and VISHNU sensors share many of the same system and design elements.

large field of regard (20°) within which SHIVA obtains Earth imagery at 250 m resolution, day and night, for hazard and disaster monitoring and warning, and basic science measurements. New technologies for precisely pointing an optical system over large angular excursions make this system possible. Three SHIVA sensors could image most of the Earth from geostationary orbit: continuously observing a particular region anywhere in the world, patrolling a region, or exploring the connection between the small scale behavior of the atmosphere and biosphere (250 m pixels) to that of the global system as imaged by VISHNU. Because SHIVA is pointable and has relatively high spatial resolution for a science mission, it can be operated as a virtual companion to other Earth observing missions when they are within its field of regard. This can greatly enhance the science or commercial data return.

At L1, the **V**isible/IR/UV **I**maging **Sy**stem **H**ardware for **N**ew **U**ses (VISHNU) is a compact multispectral imager which will deliver, through the use of imbedded image compression software, full disk sun-illuminated imagery of the Earth in real-time at selected wavelengths designed to map ozone, clouds, and aerosols. VISHNU has significantly enhanced capabilities beyond the planned TRIANA mission, will be ready to be online at the end of the TRIANA mission life and provide enhanced, lower cost services with greater science content.

2 Overview of the Mission Concept

The GOAL&GO mission consists of two kinds of imagers. The L1 component (VISHNU) is directed toward addressing current open scientific questions and providing large-scale contextual measurements whereas the geostationary components

(SHIVA) perform two functions: (1) focused investigations of regional problems and (2) hazard assessment and information dissemination.

Our design study shows that a Cassegrain telescope meets the requirements of small field-of-view (FOV), wide spectral range, and long focal length. The 0.5° FOV is imaged on a 4096 × 4096 CCD (14 micron pixel size). For an f/10 system this gives an aperture of 64 cm. With the small FOV, image quality will be acceptable without the use of additional image flattening optics. The optical path allows for the introduction of a beam splitter which feeds two cameras. One uses an LCTF for band selection (a separate path and mechanism may be required if the wavelength coverage of the filter system needs to be handled by two LCTF) while the second uses a conventional filter assembly with narrow band-pass filters (temperature controlled) optimized for specific tasks. The optical paths are arranged so as to place the detector assemblies for optimal coupling to the cold plate. This all-reflection design can be used by SHIVA, too.

The SHIVA instrument flies on a platform in geostationary orbit and images an area of about 1000 km × 1000 km at 250 m pixel size. For SHIVA we add a cooled InSb array behind a filter wheel. This second camera is used to detect and map high altitude cirrus clouds, fires, and burn scars. The SHIVA instrument will implement high-displacement piezoelectric actuators to point the imager's FOV, as commanded, anywhere on the Earth's disk (or slightly off for characterization). We anticipate the need to move the entire telescope rather than just the mirror in order to improve off-axis rejection performance; this requires us to keep the telescope's acceptance angle at 1.5°. SHIVA uses a dedicated telemetry dowlink antenna that can be pointed. This system, nominally operating at S band (1 Mbps at 2.2 GHz with a transmitter power of 20 W), would have a 1000 km coverage diameter for a 0.5 meter ground station antenna diameter. The receiver could, then, be either inside or outside of the SHIVA FOV and would be designed to be transportable. During disaster support operations the transmitter could be directed to cover the imaged area for disaster recovery or assessment efforts or a site outside the affected area which was still able to receive the SHIVA telemetry. SHIVA enable a hazard "pager" utility for use by people in remote locations.

3 Measurement Requirements

GOAL&GO uses a LCTF for band selection to obtain space and time resolved spectral images of atmospheric pollution and tracers (e. g. ozone, aerosols, sulfate pollution, volcanic ash, and SO2), water vapor, vegetation, surface albedo, and ocean color. These measurements do not require either high spectral resolution (the 5 nm achievable with current LCTF technology is adequate) or contiguous wavelength coverage (i. e. spectra). Some measurements do require higher spectral resolution (or detectors sensitive to longer wavelengths) and those, consistent with the GOAL&GO vision, are accommodated in a second camera on VISHNU (or SHIVA), respectively. The science is mature as are the algorithms for the production of data products and/or onboard feature extraction.

VISHNU and SHIVA are complementary aspects of an investigation of the global biogeochemical cycle. In the list that follows, VISHNU provides the global context for the smaller scale observations of SHIVA and can be used to determine where to point SHIVA. Existing algorithms, developed for the TOMS and AVHRR flight programs as well as the MODIS development program, provide the means to confidently make the step from a measurement to a useable product. The majority of these algorithms are quite simple. SHIVA's 1000 km × 1000 km sample size provides super-regional data at extraordinary spatial and temporal resolution. The ability to point accurately means that SHIVA's FOV can "fly along" with other platforms as they make an underflight. (Note that the slew rates are very modest – about 0.2°/minute peak rate!). For the complete GOAL&GO system, SHIVA could be cued using VISHNU data.

SHIVA's second camera is optimized for fire detection. Wildfires are an important hazard: SHIVA will provide direct broadcast of the location and extent of these fires in real-time. SHIVA will enable the "tactical" use of real-time satellite remote sensing data by local emergency personnel. SHIVA will improve our understanding of the intensity and location of wildfires and our ability to model their development and assess the risk of occurrence by coupling observations of the fires to local cloud cover, land use, land cover (NDVI), soil moisture and rainfall history.

SHIVA will document trends in land-cover, biodiversity, and global primary production by monitoring biomass burning. Agricultural burn-off alters land cover and the rate of evaporation and run-off. CO, CH_4, NMHCs, and NO are produced by biomass burning and lead to the photochemical production of ozone in the troposphere. CH_3Cl, and CH_3Br are produced during biomass burning and thus lead to the addition of free radicals in the stratosphere that lead to the catalytic destruction of ozone. Burning alters the biogeochemical cycling of NO, N_2O, CO_2, CO, and CH_4 from the soil to the atmosphere. We do not have a full description of the extent of biomass burning and both MODIS and AVHRR have too low a spatial resolution ($1000\,m \times 1000\,m$) and too low a saturation temperature (500 K and 320 K) to be able to accurately map the extent of small cool fires or large hot ones. Wildfires and agricultural burn-off leave fire scars that alter the land albedo and affect the local radiation budget. Most agricultural burn-off scars in developing countries are too small to be detected by MODIS and AVHRR and the burn-off rates are under-reported if reported at all. SHIVA will be able to image these scars and map their location and time evolution.

SHIVA will be able to examine the regional consequences of short-term climate variability by providing unique data on droughts, severe storms, and flooding. SHIVA, by providing land cover information along with water and snow cover information, will enable users to combine these data with topography, soil moisture and rainfall history information from other sensors to improve the accuracy of local and regional flood forecasts.

SHIVA will be able to study global urbanization by imaging the location of artificial illumination at night. The data can be used to define the extent of human interaction with biomass burning as well as a measure of the evolving hazard from uncontrolled fires. This is especially important for developing nations that lack much of the infrastructure we take for granted in the United States. The extent and location of urban development is required to fully assess effects on climate and the source of pollutants as well as worldwide or local food security. Food security issues can also be addressed by combining vegetation stress signature data from the dayside with nightside urbanization images. The diurnal cycle of lighting is also an indicator of economic growth and activity.

4 Enabling Technologies and their Application to GOAL&GO

A mission such as GOAL&GO, while possible, is not practical given current technologies. New technologies are under development for implementation on space missions. These applicable new technologies have been identified and are summarized in Tab. 1 along with their impacts.

5 Summary

GOAL&GO is a breakthrough application of technologies to solve a real and evolving problem: as the human race expands and its material infrastructure increases the impact of changes in the global biogeochemical cycle have increased dramatically. The technologies required to get warning and assessment information to the people who need it, in a timely and useable fashion, are revolutionary. No current sensor provides real-time warning of fires and ash plumes or severe storms or the spatial and temporal resolution required to study the evolution of

Tab. 1: Application of Key New Technologies to GOAL&GO.

System Driver	Enabling Technology to be Used	Impact
Realtime hazard monitoring and detection	Science Feature Extraction	Enables scene selection for cueing of SHIVA by VISHNU (or other means) and adjustment of SHIVA FOV
Scene selection and real-time hazard warning	Onboard Engineering Data Summarization and Beacon (hazard ''pager'')	Reduces requirement for data review by indicating when hazard has been detected – designed for s/c could be applied to data stream
Capture and use of custom data sets by remote user	Science from a Laptop	Enables remote users to configure SHIVA and collect data over their site
Coordination with EOS/ESSP missions	Virtual Platform	Enhanced science synergy by adding to effective instrument complement of existing platforms by simultaneous sampling of the common volume
Pointing of the SHIVA system	High-Displacement Piezoelectric Actuators	Allows improved performance by enabling pointing of FOV over large angular range
Stability of fast high angular resolution optics	Silicon Carbide Mirrors and Structures	Improves performance of backend of system and enables ground resolution requirements to be met
Data rate reduction	High Performance Data Compression (HPDC)	Reduces downlink requirements enabling lower transmitter power and/or receiver dish diameter
Spacecraft stability – Jitter requirement reduction	High Precision Pointing and Stabilization of Mirrors	Allows use on off-the-shelf spacecraft
Large aperture precision mirror	Deployable Mirror	Reduces package size while meeting science driver for resolution and collecting area
Communications from HEO while minimizing package size	Deployable Reflectarray Antenna	Enables implementation on a wider range of buses and potentially decreases requirements on ground segment
On-board image processing	Spaceborne Fiber Optic Data Bus (SFODB)	Transports large amounts of data for image processing in space
Low temperature IR focal planes	Low T Long-life Cryocoolers	Provides cooling for SHIVA fire detection array
Selectable bandpass for imager	Liquid Crystal Tunable Filter	Provides science flexibility and meets SNR requirements for images while reducing jitter spec by allowing longer effective integration period than spectrographs or other scanning or rastering systems
Imaging of thermal radiation	Large Format SWIR/MWIR InSb arrays	Enables fire detection mission for SHIVA with accurate cloud removal

these phenomena on a global basis. These key capabilities could be demonstrated by the flight of SHIVA on a mission of opportunity. Commercial or international cooperative ventures could provide the funding for the implementation of the full-up system.

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Photogrammetrie • Fernerkundung • Geoinformation 1/2002, S. 43–46, 2 figs., 1 tab.

Advanced Detectors and Instruments for Small Satellites

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Abstract: This paper presents some approaches to the development of advanced detectors and to miniaturized instrument design which are pursued in the Institute of Space Sensor Technology and Planetary Exploration of DLR (the German Aerospace Center). The instrument design approach is demonstrated for a low-weight (3 kg) dual camera system with narrow-angle in-track stereo and wide-angle multispectral features. Each camera has its own signal processor and 0,5 GBit mass memory. The activities for advanced detector development are concentrated on two different kinds of detectors and instrumentations: infrared detector arrays and instruments at wavelengths out to about 240 µm, and superheterodyne receivers in the submillimeter and far-infrared spectral ranges.

Zusammenfassung: *Neue Detektoren und Instrumente für kleine Satelliten*. Dieser Beitrag zeigt einige Möglichkeiten für das Design hochentwickelter Detektoren und miniaturisierter Instrumente auf, die im Institut für Weltraumsensorik und Planetenerkundung des DLR verfolgt werden. Die Herangehensweise beim Instrumentendesign wird an einem leichten (3 kg) Dual-Kamera-System demonstriert, das sowohl relativ hoch auflösende Stereoaufnahmen als auch multispektrale Übersichtsaufnahmen ermöglicht. Die Aktivitäten auf dem Gebiet der hochentwickelten Detektoren werden auf zwei verschiedene Detektor- und Instrumentierungsarten konzentriert: Infrarot-Flächendetektoren und -Instrumente im Wellenlängenereich bis etwa 240 µm und Superheterodyn-Empfänger im Submillimeter- und fernen Infrarot-Bereich.

1 Introduction

Due to the progress in different fields of technologies used for detector development and for instrument design, the application of small satellites for Earth observation becomes increasingly attractive. This paper shows a design approach for a miniaturized, low-weight (3 kg) dual camera system with narrow-angle in-track stereo and wide-angle multispectral features. This approach was enabled due to the progress in the high integration microelectronics technology and the application of Multichip Module (MCM) technology as well as due to the application of special materials and design principles for the construction elements and the housing.

The activities for advanced detector development are targeted to future projects with largely increased performance parameters. There are two directions: infrared detector arrays and instruments at wavelength out to about 250 µm and superheterodyne receivers in the submillimeter and far-infrared spectral region.

In this paper, the sequence of description of detectors and instruments starts with the VIS/ NIR region of the electromagnetic spectrum heading to the IR and then to the submillimeter region. At the same time, the emphasis changes from the instrumentation aspects to the advanced detector aspects.

2 Miniaturized Camera Design

In the large class of imaging systems, pushbroom imagers using CCD line arrays are currently of high interest because they are targeted for small satellite applications with severe mass and power consumption constraints. CCD line arrays can be produced with a high number of CCD elements having small dimensions to obtain a high potential ground resolution. For multispectral imaging, such CCDs can be covered individually

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with filters to meet the actual application requirements. Even along-track topographic imaging is possible using the three-line geometry. This stereo principle has already been implemented in two stereo cameras of DLR: High Resolution Stereo Camera (HRSC), and Wide-Angle Optoelectronic Stereo Scanner (WAOSS).

It is obvious, using CCD lines with different spectral filters also multispectral imaging can be obtained by means of push broom imagers.

In order to show the potential of a miniaturized push broom camera design, a hypothetical dual camera system (DCS) may serve as an example. The tasks of that camera system are considered to be:

– synoptic observation of atmospheric and surface features and their dynamics in three spectral bands
– topographic mapping of the Earth with medium resolution
– support to data interpretation of other remote sensing instruments of the small satellite which may observe across-track in all angles from nadir to limb.

The DCS shall be implemented as a monoblock structure with two independent cameras:

– WACI – Wide-Angle Colour Imager
– NASI – Narrow-Angle Stereo Imager

Each Camera consists of:

– Optics
– Focal Plane Module (FPM) with three CCD lines, 7 µm pixel distance
– Front End Electronics (FEE) including 14 bit-ADC
– 32 bit DSP for camera control, data correction, data preprocessing and data compression
– 0,5 GBit Mass Memory (MM)
– Spacecraft-Interface (IF)
– Power Supply Unit

The low weight design of DCS can be achieved by using:

– special materials and design, principles for the construction elements and the housing
– high integration microelectronics technology

Tab. 1: Technical Data and Performance Characteristics.

DCS		
mass	3 kg	
power consumption	18 W	
dimensions	160 mm × 150 mm × 130 mm	
S/C-Interface	MIL-1553 / RS 422	
	WACI	NASI
focal length	16 mm	90 mm
FOV	≤ 180° (fish eye)	18.5°
IFOV	0,44 mrad	78 µrad
CCD: lines	3	3
active pixels	6180	4200
pitch	7 µm	7 µm
convergence angle	± 1,1°	± 10°
spectral bands	3 (R, G, B)	1 (panchrom., TBD)
radiometric resolution	8 bit	8 bit
radiometric dynamic	14 bit	14 bit
DPU	TMS 320 C 40	TMS 320 C 40
Mass memory	0.5 GBit	0.5 GBit
compression	S/W (e. g. JPEG)	S/W (e. g. JPEG)
ground pixel size: Δx, Δy *)	285 m (nadir)	50 m
Δz	–	> 50 m
swath width *)	limb-to-limb	210 km

*) circular Earth orbit, H = 650 km.

– application of Multichip Module (MCM) technology to the digital electronics

The 3 kg, 18 W dual camera system can be realized as a cube with roughly 150 mm side lengths.

3 Infrared Detector Arrays

Infrared wavelengths longwards of 1 µm bear great potential for the exploration and surveillance of our immediate environment, the earth's surface, its oceans and atmosphere, as well as for observations of our planetary system, the milky way and out to the most remote galaxies. The Infrared Array Technology group of the DLR Institute concentrates on the design and development of detectors and instruments for infrared astronomy, currently at wavelengths out to about 240 µm (see Fig. 1).

Of course, the results from this group can be and are used in earth observation applications. The experience s of the Infrared Array Technology group are based on different projects, e. g. for the Infrared Space Observatory ISO (since 1995) and for the Kuiper Airborne Observatory (KAO, NAA). To meet the requirements coming from new porjects, the group is expanding its test and assembling capabilities for IR ans FIR detector arrays. For wavelengths up to 40 µm commercially available devices will be used but their instrumental set-up and operation will be customized to the needs of specific projects.

Longer wavelength Ge-arrays and stressed detectors are not commercially available and will be developed in house. Together with several European and US partners large detector arrays are being developed for the instrumentation of SOFIA and FIRST. In collaboration with industrial partners new readout electronics need to be developed to meet the stringent requirements of airborne and space astronomy. It is planned to built a far-infrared photometric array camera as part of the German SOFIA instrumentation and operate it as a PI-type instrument.

4 Far-Infrared Technology for Super-Hetero-Dyne Spectrometers

The Heterodyne and Laser Techniques group of the Institute of Space Sensor Technology investigates the earth atmosphere and astronomical objects in the submillimeter and far-infrared spectral regions ($\lambda = 50\,\mu m - 1\,mm$, $\nu = 300\,GHz - 6\,THz$) using superheterodyne receivers (see Fig. 2). In these sensors, the weak incoming signal

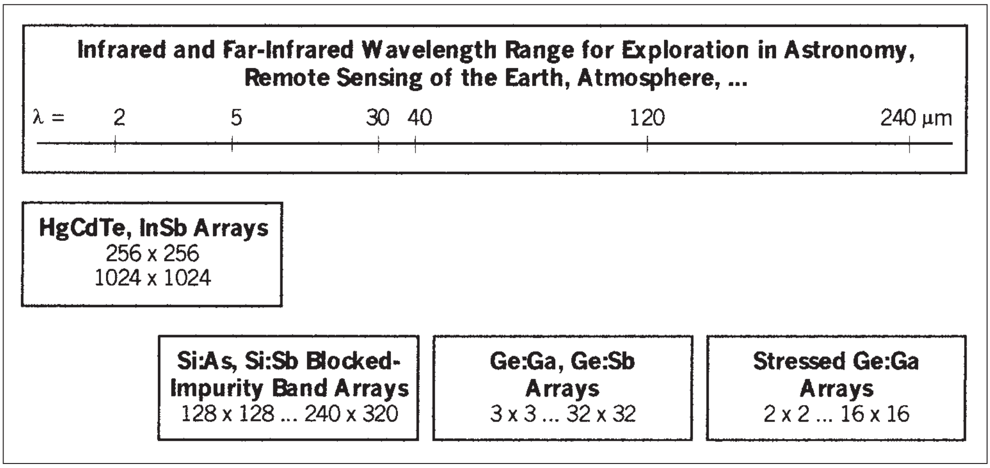

Fig. 1: Infrared and far-infrared wavelength range and commonly used detector arrays.

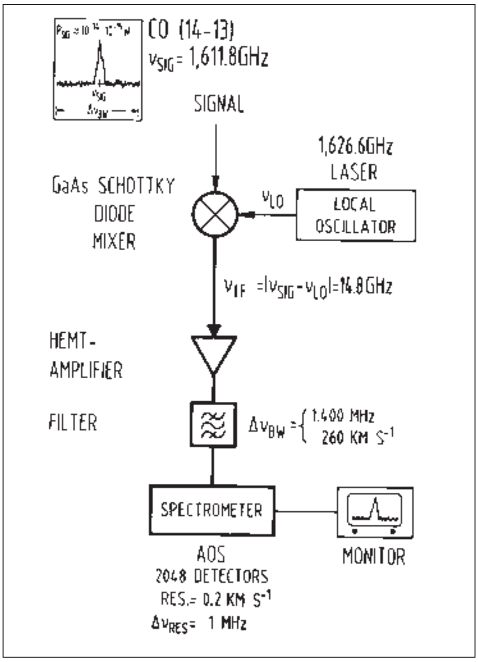

Fig. 2: Block scheme of a superheterodyne receiver.

is superposed to a strong fixed frequency radiation in a nonlinear detector. At the output of the detector, the difference or intermediate frequency (IF), which is typically in the 1–18 GHz range, is further amplified and filtered by off the shelf commercially available micro-wave components. The IF is further split by a spectrometer back-end into its high spectral resolution components which yield the scientific information. In atmospheric chemistry, the scientific goals are the better understanding of the chemical and physical processes in the middle atmosphere (10–80 km altitude) which are important for ozone depletion and global warming.

The group's main work is in the 1–6 THz spectral region. A typical state of the art heterodyne receiver for this frequency range consists of a GaAs Schottky barrier diode mixer in a corner cube mount and a FIR gas laser LO which is optically pumped by a carbon dioxide laser. The signal and LO beams are combined using a power splitting (Mach-Zehnder) or polarization switching (Martin-Puplett) interferometer (diplexer). As spectroscopic back-end an acousto-optical spectrometer is used. The group pursues several ways to develop more sensitive heterodyne spectrometers. In collaboration with the University of Virginia the newest Schottky diodes produced there are characterized and investigated. One result of this characterization is that for a specific diode at optimum LO power the optimum current is proportional to the frequency.

Together with different cooperation partners, further activities are directed to the development of FIR solid state laser local oscillators and superconducting hot-electron bolometers.

Considering future spaceborne applications, the choice of detector is defined by the application. For long term monitoring missions of the earth atmosphere room temperature Schottky diodes will be preferred. However, for the THz region, this depends on the development of space qualified optically pumped gas lasers or THz solid state local oscillators. For shorter term applications, where liquid He operation is possible, the higher sensitivity and lower LO power requirements of low temperature superconducting Hot Electron Bolometers will be of advantage. Such a system could be operated with a tunable solid state LO source, for example a multiplied Gunn oscillator.

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Low Cost Hyperspectral Imaging from Space

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Abstract: This paper describes a concept for a low cost hyperspectral mission that will provide data for environmental and geological users. The instrument based on heritage from the Compact High Resolution Imaging Spectrometer (CHRIS) provides data across a spectral range of 450 to 2500 nm. The instrument is accommodated on a small satellite under 200 kg, which provides cost effective sub-systems that meet mission and instrument requirements.

Zusammenfassung: *Kostengünstige Hyperspektralmission*. Der Beitrag beschreibt ein Konzept für eine kostengünstige Hyperspektral-Mission, in deren Rahmen Daten für Nutzer auf dem Gebiet des Umweltschutzes und der Geologie gewonnen werden. Das Instrument, das auf der Grundlage des Compact High Resolution Imaging Spectrometer (CHRIS) entwickelt wurde, liefert Daten im Spektralbereich von 450 bis 2500 nm. Das Instrument wird auf einem Kleinsatelliten (unter 200 kg) platziert, der mit preisgünstigen Subsystemen ausgestattet ist, die den Missions- und Instrumentenanforderungen Rechnung tragen.

1 Introduction

Hyperspectral imaging (HSI) aims to maximise the spectral (as opposed to spatial) information recovered from an Earth observation system. Current multispectral systems can sense less than 10 different spectral colours or wavebands. This is enough, for example, to distinguish between broad classes of vegetation. Hyperspectral systems may have up to 300 contiguous spectral bands. This allows the much more complete reconstruction of the spectral reflectance curves of individual materials, giving insights into subtle details such as vegetation species mix, healthy or unhealthy growth, and different varieties of mineral types.

Historically, both scientific and commercial hyperspectral programs have been unable to secure the funding for a dedicated hyperspectral space program. However the availability of small and micro satellites provides an opportunity to develop a low cost system. Certain fundamental limitations need to be accepted before a practical small satellite system is considered. The available size power and volume are constrained, resulting in limited aperture, data storage, downlink capability, and orbit control.

In 2001, ESA's PROBA (Project for On-Board Autonomy) micro-satellite will be launched. PROBA will fly an advanced compact high resolution imaging spectrometer (CHRIS) on a 100 kg spacecraft. PROBA is primarily intended to demonstrate in-orbit autonomy through on-board navigation and calculation of manoeuvres to view desired imaging targets, but the CHRIS instrument gives an indication of the capability that can be obtained from the micro-satellite format.

PROBA is constrained by several of the limitations described previously – it will be launched as a passenger, so does not control final orbit. It has no propulsion, so must accept orbit evolution. It has limited power, and on-board storage. It uses an S-band downlink with a nominal 1 Mbps rate.

Based on the experience gained from PROBA, Astrium and Sira Electro-Optics have undertaken the development of the SPECTRE programme, using a derivative of the Advanced Microsatellite Mission (AMM) platform being developed for ESA

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by Astrium Ltd. and System Engineering and Assessment Ltd. The AMM platform represents a significant advance from PROBA, with a payload mass fraction >45%, up to 200 W of payload power available, orbit maintenance, and a high rate data downlink.

2 Objectives

The main objective of the work was to determine the feasibility of a low cost hyperspectral system that could deliver data to meet the requirements of a range of user groups. For a low-cost mission, the launch cost becomes a major driver of the overall spacecraft characteristics. The spacecraft must be small and light in order to ensure compatibility with small low cost launchers, in addition to this the system must maintain feasible methods of meeting the instrument requirements for size, mass, power and thermal control.

3 Design

SPECTRE is designed to fly a high performance hyperspectral sensor derived from CHRIS, which will image the Earth in multiple spectral bands from the visible into the short wave infrared (450 nm to 2500 nm). This wide spectral range will allow broad range of requirements to be met, including: geological and land use surveys and vegetation and environment monitoring. Dual spatial resolution (15 m visible/near-IR, and 30 m short wave IR) is proposed to optimise the total product. The preliminary specifications defined for the mission are shown in the table below.

3.1 *Instrument Design*

The instrument requirements have been developed from the mission specification. The main emphasis is on commercial value, looking forward to the next generation of hyperspectral imagers that will provide large

Tab. 1: SPECTRE Mission Specification.

Requirement	**Mission Specification**
Spectral coverage and band spacing	Contiguous coverage from 450–2500 nm typically 15nm SWIR, less than 10nm VNIR
Band-to-band registration	10% of a pixel between bands in SWIR and VNIR
Signal-to-noise ratio All for a 30% albedo target at 450 latitude in spring with a solar zenith angle of 60°	typically over 400:1 across SWIR typically over 300:1 across VNIR ≥100:1 in the panchromatic band
Spatial resolution: for SWIR hyperspectral bands for VNIR hyperspectral bands for panchromatic bands	 ≤30 m at nadir ≤15 m at nadir ≤10 m at nadir
Swath Width	30 km
Positional accuracy: without GCPs with GCPs	goal 1 pixel at nadir ½ pixel at nadir
Revisit Time	6 days with 30° off-nadir viewing
Orbit	Sun-synchronous
Equatorial crossing time	10:30am
Design life	3 years
Key products	Mineralogical and vegetation maps and others to be defined
Spacecraft mass	<200 kg

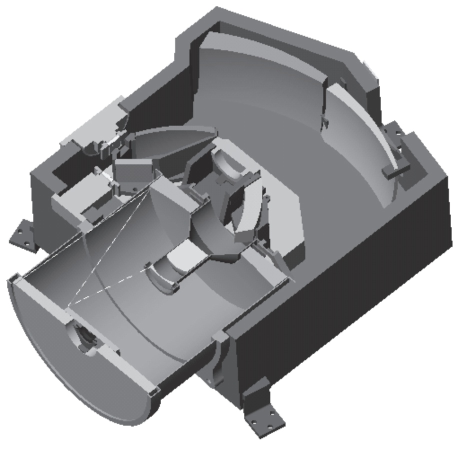

Fig. 1: Baseline Instrument Optical Design.

volumes of high quality data. The instrument design benefits from the CHRIS heritage, a key design philosophy of this being for a lightweight solution. The instrument is a conventional imaging spectrometer, with a telescope forming an image of the Earth onto the entrance slit to a spectrometer, and an area-array detector at the spectrometer focal plane. The instrument will operate in a push-broom mode during Earth imaging. The spacecraft will be required to provide pointing in the across track direction to improve the revisit time. The platform will also be required to provide slow pitch during imaging at higher spatial resolution, in order to increase integration time of the instrument. The optical design is shown in Fig. 1. The system comprises a catadioptric telescope and a dispersive imaging spectrometer.

The preferred basic design form for the spectrometer is similar to that of the CHRIS instrument. It will be based on the Offner relay, which can be extremely well corrected over moderate field areas and very wide spectral ranges. The Offner relay is turned into a spectrometer by adding curved prism (or wedged lens) elements.

For the telescope, two-mirror catadioptric systems are the preferred option, for CHRIS and also for SPECTRE. They provide a compact solution with a length typically less than the focal length. The mirrors for the telescope will be aspheric; however being used on a common axis they will have a relatively low cost (compared for example with three-mirror anastigmat mirrors) and will be relatively easy to align.

Two area-array detectors will be included. A special silicon CCD detector for the visible/near-IR band will provide 2000 spatially-resolved elements in the across-track direction (swath width), while a mercury cadmium telluride detector will provide 1000 spatially resolved elements at lower resolution in the short-wave IR. A separate telescope and a linear array detector will provide panchromatic imaging at higher resolution.

"Motion compensation" – use of slow platform pitch during imaging – will be used to increase the sensor integration time by a factor up to 2, and reduce data rates during imaging at higher spatial resolutions. However little or no motion compensation will be required during imaging at lower spatial resolution, which will typically be used to survey large land areas in long continuous strips.

3.2 *Spacecraft Design*

The instrument and the spacecraft solutions have been developed in parallel to achieve the required mission performance at minimal cost. Work carried out has shown that a low-mass spacecraft solution with image motion compensation and across track pointing is feasible. A 10:30 am sun-synchronous orbit at approximately 512 km height gives the necessary ground-track repeat cycle and signal to noise ratio. The revisit requirement is met by a $\pm 30°$ off-track pointing capability.

Platform agility required for off-track pointing and motion compensation can be provided by a set of four reaction wheels. The attitude determination can be achieved using 2 autonomous star trackers; preliminary analysis shows that gyros are not needed for the required system performance.

To achieve the specified radiometric resolution the SWIR detector needs to be cooled to between 160 K and 180 K. Thermal analysis shows that a detector temperature of 180 K can be achieved passively by using the cold face of the spacecraft as a radiator and a baffle to block environmental fluxes from hitting the radiator. The implementation of a thermo-electric cooler between the radiator and the detector will further reduce the temperature and provide the required temperature stability.

The large amount of data generated by the hyperspectral instrument translates into a need for a high volume of on-board data storage and a high rate data downlink. To minimise the mass and power requirements the latest generation of low-mass, low-volume mass memory modules such as the 1.28 Gbit module from 3D-Plus Electronics can be used. A high rate X-band data downlink can be achieved without the use of expensive steerable antennas by utilising the agile platform capability in pitch and roll to steer the antenna towards the ground station.

The preferred mission platform is a derivative of the Advanced Microsatellite Mission (AMM) platform. The AMM development is aimed to be an agile platform, and will benefit from avionics allowing a high degree of autonomy. This closely matches the mission requirements.

4 Conclusions and recommendations for further work

From the work carried out to date it appears feasible to produce a low cost hyperspectral

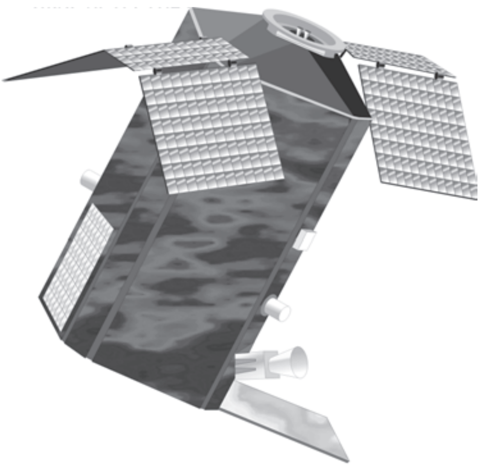

Fig. 2: Feasible SPECTRE Concept.

system that can provide commercial data to both the geological and environmental user groups. However there are critical technologies requiring further development.
The requirements on the SWIR detector for high performance and fast readout are challenging. Current development activities will demonstrate the technology required.

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Photogrammetrie • Fernerkundung • Geoinformation 1/2002, S. 51–54, 2 figs., 3 tab.

A Conceptual Study on RICESAT

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Abstract: The conceptual study results on a small satellite named "Ricesat" is performed. This satellite carries dual frequency (L band and C band) SAR dedicated for rice paddy area classification and grow monitoring. A non-sun synchronous orbit is chosen with the inclination angle of 28 degrees and altitude of 618 km so that it covers most of rice growing area and achieves high observation repeatability.

Zusammenfassung: *Eine Konzept-Studie zum Ricesat*. Die Ergebnisse der konzeptionellen Studie über den Kleinsatelliten „RICESAT" liegen vor. Dieser Satellit trägt ein Dual-Frequenz-SAR (L-Band und C-Band), das für die Klassifizierung von Reisfeldern und Wachstumsmonitoring vorgesehen ist. Ein nicht-sonnensynchroner Orbit mit einem Inklinationswinkel von 28° und einer Höhe von 618 km wird ausgewählt, so dass der größte Teil der Reisanbauflächen überdeckt und eine hohe Wiederholbarkeitsrate der Überwachung erreicht wird.

1 Introduction

In 6th Asia Pasific Regional Space Agencies Forum held at Tsukuba Space Center of NASDA, Japan (1999), a group of experts from Asian countries created an idea to initiate a satellite system to benefit regional people in Asian countries and proposed an Earth observation satellite which carries synthetic aperture radar. Mission of the satellite is to provide means to evaluate rice harvest and grow monitoring from space, and to establish real time direct data path to local end users. This paper introduces a design of a satellite and sensors to fulfill their requirements.

2 Basic Requirements

To realize the mission of the satellite system, basic parameters were set as design goal. They are:

(1) Sensors are dual frequency and dual polarization
(2) Spatial resolution of SAR must be less than 30 m
(3) To observe all area of interest once a week,
(4) Capability of repeat path interferometry,
(5) Satellite path covers only tropical areas.

3 Total System Concept

Total system concept is drawn by reflecting slow response of data distribution. Basic concept is to deliver satellite row image data to local end users on real time basis. The computer environment is matured enough to handle row SAR data on PC as well as SAR data analysis on PC. Only the problem is data link margin for small ground antenna of end users. To solve the problem satellite data link antenna coverage is designed to illuminate the SAR antenna coverage. End users located SAR observation area can receive real time data by the concentrated data link antenna illumination. Traditional wide coverage data link also remains to accumulate regional archive of data or analysis. Total system configuration is illustrated in Fig. 1.

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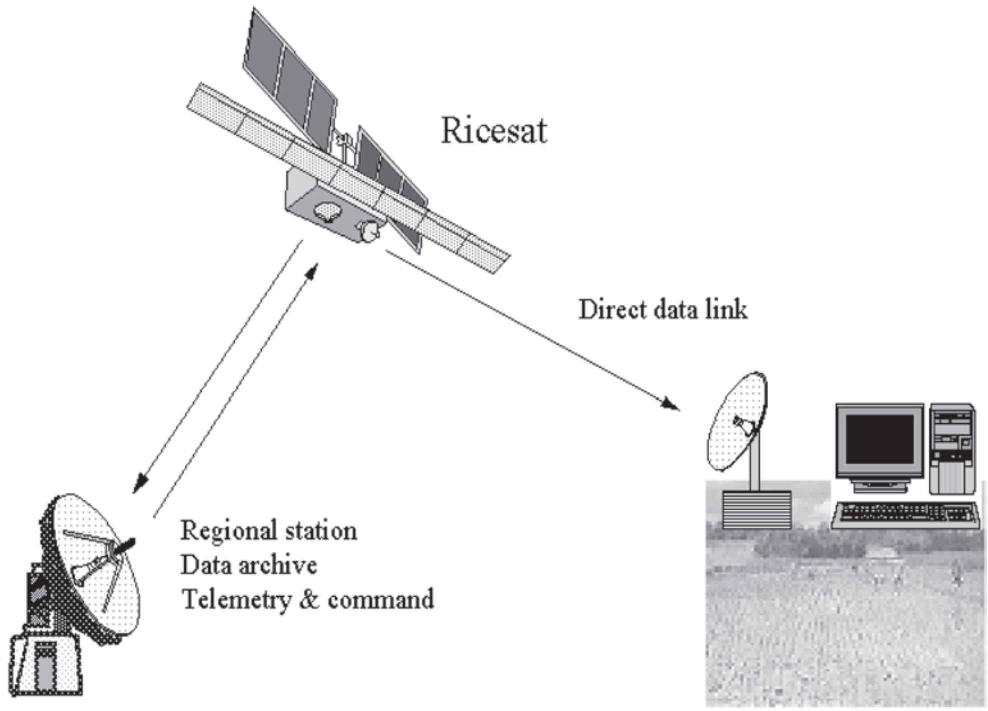

Fig. 1: System concept of ''Ricesat''.

4 Satellite Orbit Design

Orbit design of SAR satellite is mainly restricted by achievable swath width of SAR. To fulfill the requirement of high repeatability, swath width must be as wide as possible. As a result, along track SAR antenna size become large. Alternative for SAR design to reduce SAR antenna dimension is to use short burst scan SAR but it increases complexity of SAR antenna design and increase mass of antenna sub system. In our design, simple strip mode SAR is adopted and achieves swath width of 210 km.

In order to satisfy the request of high repeatability to all observation region and to achieve repeat path interferometry, an sun-asynchronous quasi recursive orbit is adopted. By choosing sub recursion as 7 days, any location is observed every 7 days. To fill gaps between adjacent sub tracks by the 200 km swath, orbit inclination is reduced significantly compared with polar orbited sun synchronous satellite. To satisfy the capability of repeat path interferometry, orbit of the satellite must return to the same orbit with very small displacement. In our approach a small orbit control error is allocated to achieve the small displacement. As the result of several candidates an orbit parameter is

Tab. 1: Orbit parameters.

Parameter	Value
Altitude	617.74 km
Inclination	28.075 degree
Period	97.057 minutes
Major recursion	49 days
Sub recursion	7 days
Nodal cycle	727

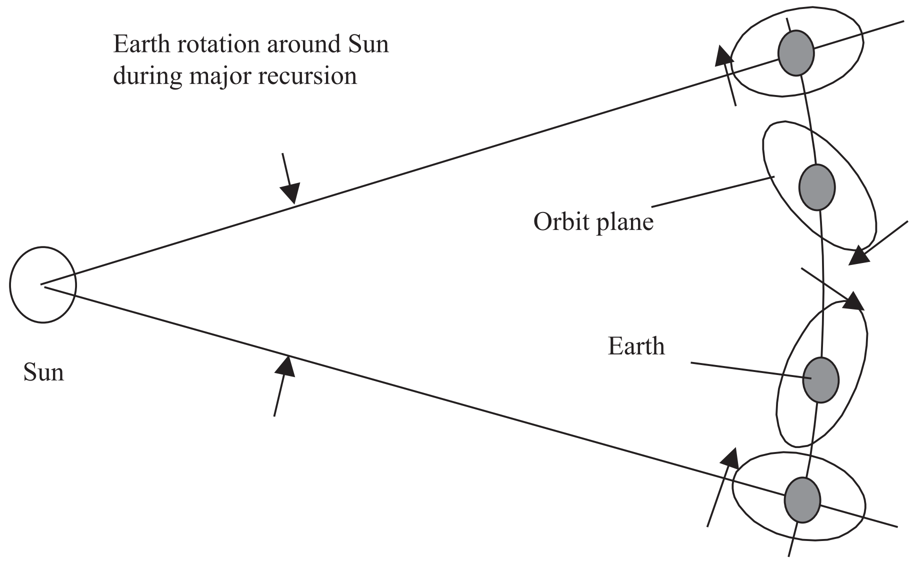

Fig. 2: Nodal point rotation of synchronous recusive orbit.

selected to satisfy most of the orbit requirements as shown in Tab. 1.

Orbit inclination is 28 degrees, by which most of rice growing area is covered by SAR observation. Sub recursion of the orbit is 7 days and major recursion is 49 days. By strip mode SAR operation, a place on the Earth is observed every 7 days with 7 different incident angles. A pair of single look complex data with 49 observation day separation make an interferometry pair. By the low inclination angle, there is no gap between adjacent 7 days sub recursion locus of sub satellite trace even with 210 km swath width SAR. Nodal point of orbit in inertial space rotate opposite direction of earth rotation, which is illustrated in Fig. 2.

5 SAR System Design

SAR system is simple strip mode operation. Designed parameter is shown in Tab. 2 (L and C band). Rice paddy area estimation is mainly performed by L band SAR and grow monitoring is performed by C band SAR. Since the target area is agriculture field, noise equivalent sigma naught is set relatively high compared with all purpose SAR system. This setting allows us to realize the system with feasible electric power range onboard satellite.

Tab. 2: SAR parameters.

Item	L band	C band
Frequency (GHz)	1.3	5.3
Incident angle (degree)	26.5	26.5
NE sigma naught (dB)	−25	−22
Resolution (meter)	25	25
PRF (pps)	1184	1184
Number of Looks	4	4
Antenna size (meter)	12.75 × 0.85	12.75 × 0.21
Signal Band width (MHz)	16.11	16.11
Bit/sample	3	3
Data rate (Mbps)	76.09	76.09
Transmission Power (Kw)	2.43	4.51
Power Consumption (Kw)	0.58	1.18

Data rate is still high for local PC data reception system. Relaxation of ground resolution or reduction of sample bit may be required in more detailed design phase.

6 Satellite Design

To realize the satellite system, satellite bus system must be carefully designed. In consideration of the request for interferometry,

Tab. 3: Mass Allocation.

Subsystem	Mass	Note
SAR Antenna	100 kg	L(HH,HV) + C(HH,HV)
SAR Electronics	60 kg	L + C
Sat. Structure	120 kg	
Thermal	25 kg	
Power	100 kg	16 sqm, Power = 2.3 Kw (EOL), battery is minimum (no operation at eclipse)
TT&C	26 kg	
ADCS	40 kg	Attitude determination and control
Propulsion	40 kg	
Total	511 kg	

satellite attitude control system is 3 axis stabilization. From existing component and our experience, rough sketch of satellite mass allocation is estimateds as shown in Tab. 3. Total mass exceeds 500 kg at this level which may a bit heavy from general small satellite concept. To reduce total mass, mission must be separated into several satellites like L band mission and C band mission, or narrow swath convoy of satellites. This mission separation will also relax data link restrictions.

7 Conclusion

In conclusion, "Ricesat" design is performed with a feasible design example. From the designed parameter, data link is a bit heavy load and mass of the satellite is exceeding small satellite concept. We may have to divide satellite into 2 or more separate missions to reduce the size of satellite in the more precise design phase. Yet, SAR satellite with sun-asynchronous orbit is a promising solution for the monitoring of Earth's surface.

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The BIRD MISSION is completed for Launch with the PSLV-C3 in 2001

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Abstract: DLR has a longstanding experience in the Earth observation. BIRD is the first complete satellite with payload which has been developed and built by DLR. The main BIRD payload is a bispectral IR pushbroom sensor dedicated to recognise and analyse high temperature events (HTE) such as forest fires, coal seam fires and volcanic activities on Earth surface.

The design-to-cost mission BIRD is to demonstrate new and compact infrared imaging sensor technologies as well as small satellite technologies for a micro-satellite with a total mass less than 100 kg. The BIRD satellite and payload have been completed. BIRD is scheduled for a piggy back launch together with an Indian remote sensing satellite in the middle of 2001.

Zusammenfassung: *Die Bird-Mission ist vorbereitet für den Start mit PSLV-C3 2001.* BIRD ist der erste komplett im DLR entwickelte und gebaute Satellit mit Nutzlast. Die Hauptnutzlast von BIRD ist ein Zweikanal-Infrarot-Pushbroom-Sensor, der für die Erkennung und Analysierung von Hochtemperaturereignissen, wie zum Beispiel Waldbrände, Kohleflözbrände und vulkanische Aktivitäten auf dem Festland, bestimmt ist.

BIRD soll sowohl neue und kompakte Infrarot-Bildsensor-Technologien demonstrieren als auch Kleinsatellitentechnologien für Mikrosatelliten mit einem Totalgewicht unter 100 kg. Der Satellit BIRD und die Nutzlast sind fertiggestellt. Im Oktober 2001 ist BIRD für einen „Huckepack"-Mitstart mit einem indischen Fernerkundungssatelliten vorgesehen.

Introduction

Fire has a deep and increasing impact on the life on our planet. Current spaceborne sensor systems can be used to generate products of fire susceptibility evaluating time-series of vegetation state data, occurrence and coarse location of active fires, as well as smoke and burnt areas (fire scars). However, existing and planned operational space-borne sensors show serious limitations (e. g. partly channel saturation leading to reduced high temperature event discrimination, spatial resolution worse than 1 km) if accurate geophysical parameters have to be obtained. The Bi-spectral Infra-Red Detection (BIRD) small satellite mission is a technology demonstrator of new infrared pushbroom sensors dedicated to the recognition and quantitative characterisation of HTE on the surface of the Earth and for small satellite technologies. The starting point of the BIRD development was the successful completion of the feasibility study "Fire Recognition System for Small Satellites" by OHB-System and DLR in 1995.

Mission Objectives

The BIRD mission has to answer scientific and technological questions. The primary mission objectives are:

- test of a new generation of infrared array sensors adapted to Earth remote sensing with an adaptive radiometric dynamic range,
- detection and scientific investigation of High Temperature Events (HTE) such as forest fires, volcanic activities, and coal seam fires,

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Tab. 1: Spacecraft bus components.

Subsystem	**Components**
Attitude Control and Navigation System	2 star sensors (accur.: 10 arcsec) 3 axis gyroscope system (resol.: 2.7 arcsec) 1 3-axis magnetometer 1 GPS receiver 4 pair Sun sensors 4 reaction wheels (max. >0.3 Nms) 3 magnetic torquers (max. 3 Am2) ACS computer like board computer on-board navigation system
Board Computer (OBDH)	Power PC core, 8MB SDRAM, 2 MB Flash, Real Time Operation System
Telemetry & Telecommand System	low gain and high gain (2dBic max.) S-band antennas, S-band receiver S-band transmitter (BPSK, max. 5 W RF power), PCM encoder
Structure & Mechanisms	ground plate, electronics plate, payload platform, frames, connection elements, deploy mechanism, eject mechanism
Power System & Harness	power generation: 3 solar arrays with Si high-□-cells; power storage: 8 NiH2 cells, 12 Ahrs; charge regulation: direct energy transfer; power distribution: unregulated 20 V bus
Thermal Control System	MLI, spacecraft radiator, IR sensor system radiator, heat pipes, heaters, temperature sensors

- test of small satellite technologies, such as an attitude control system using new star sensors and new actuators, an on-board navigation system basing on a new orbit predictor and others.

Furthermore, BIRD has a number of secondary mission objectives:
- scientific issues related to the diagnostics of vegetation conditions and change and the discrimination of smoke and water vapor clouds by combination of stereo and IR data,
- testing of an on-board neural network classificator experiment.

Spacecraft BUS

The BIRD space segment is a 3-axis stabilized micro satellite without a propulsion system. The satellite consists of a box-shaped main body. The complete main body is covered by MLI with cuttings for the instruments and radiators. Deployable solar arrays and the eject mechanism are mounted on the body. Fig. 1 gives a general view to the BIRD spacecraft and the main components. The payload is mounted on a special platform and takes 1/3 of the body volume and the total mass of the spacecraft. The special designed platform is close connected with the satellite bus to keep the line of sights of the instruments under all circumstances very stable. Due to this design conception the spacecraft bus and the payload platform are easy separable. This allows to modify the BIRD spacecraft easily for other missions with quite different payloads. Tab. 1 gives an overview of the subsystems of the BIRD spacecraft bus. Special characteristics of the BIRD spacecraft bus are:
- 3-axis stabilized micro satellite bus of the 100 kg-class
- spacecraft bus designed for operations in a circular or elliptical low Earth orbit (LEO) and at any inclination
- bus is prepared and qualified for a PSLV-launch into a low Earth orbit, but is easy adaptable for a lot of launchers into LEO
- supplies up to 200 W peak power for the payload up to about 20 min in one orbit
- high pointing accuracy (7 arcmin)

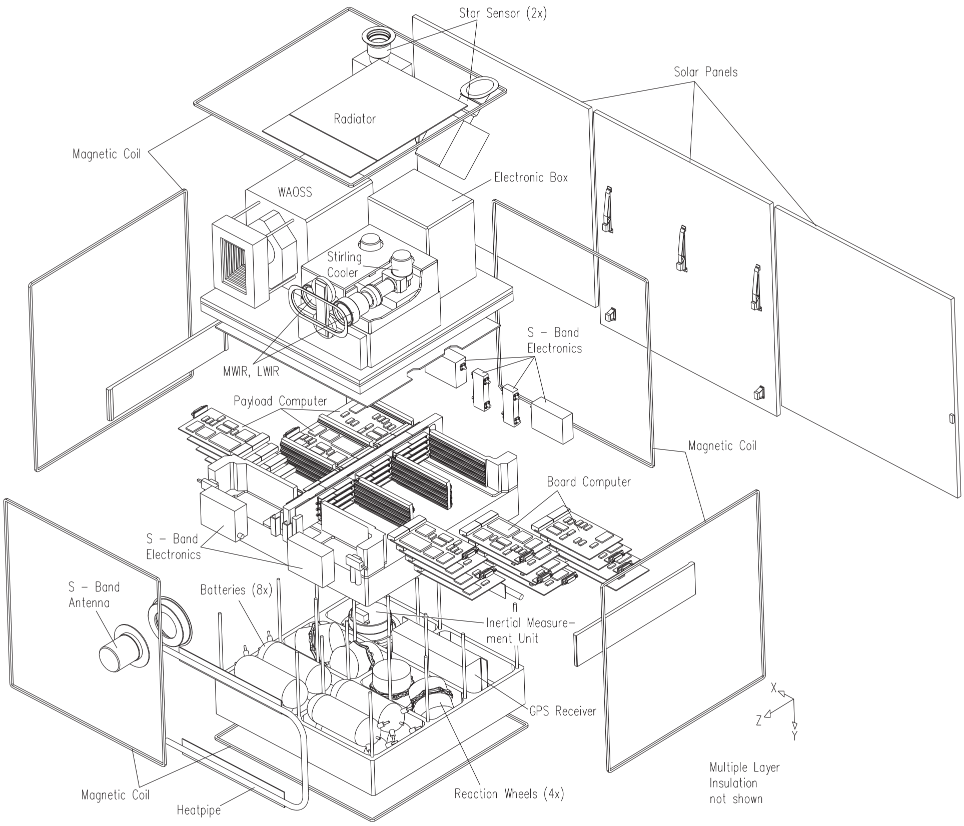

Fig. 1: Explosive view of the BIRD spacecraft.

- on-board navigation system with a high position accuracy (< 100 m)
- down link data rate: 2 Mbps (S-Band)
- design life time: 1 year

Payload

The payload of BIRD consists of:
- the Infrared Sensor system dedicated for hot spot recognition and investigation,
- the Wide-Angle Opto-electronic Stereo Scanner WAOSS-B for vegetation analysis and fire ‘‘false alarm’’ rejection,
- a payload data handling system to control the instruments and the data storage of a 10-minute’s data take,
- an on-board classificator experiment, basing on a neural network chip.

Tab. 2 gives an overview on the characteristics of the BIRD instruments. Because of the high peak power consumption of the BIRD payload it is not possible to assure a continuous observation of Earth, but a data take with a duration of 10 min only in one orbit. The data volume can be dumped down simultaneously or stored in a mass memory (2 × 1 Gbit). BIRD is an experimental satellite to test new technologies and scientific evaluation methods so there is no need in continuous payload operations.

Cooperation

The BIRD small satellite Earth observation mission is a research and development project of the German Aerospace Center (DLR) executed by the DLR Institute of Space Sensor Technology and Planetary Exploration, the German Space Operation Center and the German Remote Sensing Data Center.

Tab. 2: Characteristics of the BIRD instrumentation at an average orbit altitude of 572 km.

	WAOSS-B	**MWIR**	**TIR**
Wavelength	600–670 nm 840–900 nm	3.4–4.2 µm	8.5–9.3 µm
Focal length	21.65 mm	46.39 mm	46.39 mm
Field of view	50°	19°	19°
f-number	2.8	2.0	2.0
Detector	CCD lines	CdHgTe Arrays	CdHgTe Arrays
Detector cooling	passiv, 20°C	Stirling, 80 K	Stirling, 80 K
Pixel size	7 µm × 7 µm	30 µm × 30 µm	30 µm × 30 µm
Pixel number	2880	2 × 512 staggered	2 × 512 staggered
Quantization	11 bit	14 bit	14 bit
Ground pixel size[1]	185 m	372 m	372 m
Swath width[1]	533 km	190 km	190 km

WAOSS-B Wide Angle Opto-electronic Stereo Scanner
MWIR Medium Wave Infrared Sensor
TIR Thermal Infrared Sensor

Other non-DLR project participants are the German Gesellschaft für Mathematik und Datenverarbeitung (GMD), Astrium Jena-Optronik GmbH, Astro- und Feinwerktechnik GmbH, Global Fire Monitoring Center at University Freiburg, and Technical University Berlin. BIRD is furthermore supported by scientific Co-Investigators from France, Spain, Turkey, Finland, Greece, Portugal, Italy, Russia, Brasil, USA, Canada and Germany.

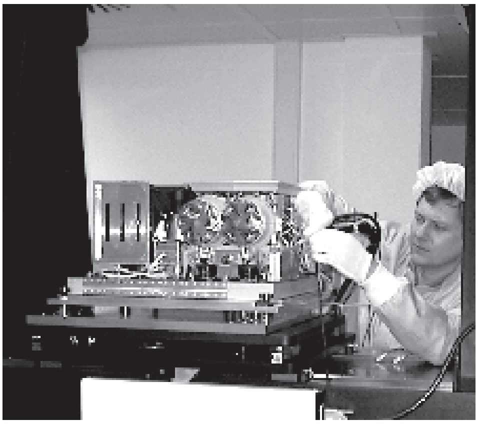

Fig. 2: BIRD payload platform with instruments at the calibration facility.

Fig. 3: Structure Thermal Model of the BIRD satellite without MLI.

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SAC-C Mission and the International AM Constellation for Earth Observation

RAÚL COLOMB, CARLOS ALONSO & IDA NOLLMANN, Argentina

Abstract: Mission Outline: SAC-C is an international Earth observing satellite mission conceived as a partnership of CONAE and NASA but with considerable additional support in instrumentation and satellite development from the Danish DSRI, the Italian ASI, the Brazilian INPE, and the French CNES. It was successfully launched by a Delta II rocket on November 21, 2000, from Vandenberg AFB, California.

The primary mission of SAC-C is to provide multispectral imaging of terrestrial and coastal environments, measurement of the Earth's geomagnetic field, and studies of the structure and dynamics of the Earth's atmosphere and ionosphere. The primary scientific objectives are to monitor the condition and dynamics of the terrestrial and marine biosphere and environment, better understand the Earth's geomagnetic field and related Sun-Earth interactions, and to develop and utilize new GPS based techniques to globally measure atmospheric phenomena for the study of weather, seasonal, interannual and long term climate change.

The payload of SAC-C consists of: the Multispectral Medium Resolution Scanner (MMRS), the GPS Occultation and Passive Reflection Experiment (GOLPE), the Magnetic Mapping Payload (MMP*),* the Argentine experiment to track the migratory routes of the Eubalanea Australis whale (Whale Tracker), the French experiment to study the Influence of Space Radiation on Advanced Components (ICARE), two Italian experiments to develop fully autonomous onboard navigation for orbiting satellites (IST and INES). In addition, Argentina added a High Resolution Technological Camera (HRTC) to the MMRS system to improve imaging resolution and a High Sensitivity Camera (HSC) to study light intensity in urban areas, as well as a Data Collection System (DCS), that will collect environmental data coming from ground stations.

In June 1999, NASA and CONAE created the first International Constellation for Earth Observation (the AM Constellation), in which the NASA satellites Landsat-7, EO-1 and Terra and

Zusammenfassung: Die Mission: SAC-C ist eine internationale Erderkundungs-Satellitenmission, die als Partnerschaftsprojekt von CONAE und NASA angelegt ist, jedoch auch beträchtliche Unterstützung seitens DSRI (Dänemark), ASI (Italien), INPE (Brasilien) und CNES (Frankreich) bei Instrumentierung und Satellitenentwicklung erfährt. Die Mission wude am 21. November 2000 erfolgreich mit einer Delta-II-Rakete von Vandenberg AFB, Kalifornien, gestartet.

Das Hauptziel der SAC-C-Mission ist es, multispektrale Abbilder von Festland- und Küstenzonen zur Verfügung zu stellen, Messungen des geomagnetischen Felds der Erde vorzunehmen und Studien zu Struktur und Dynamik der Erdatmosphäre und Ionosphäre zu ermöglichen. Die wichtigsten wissenschaftlichen Ziele sind: Beobachtung des Zustands und der Dynamik von Biosphäre und Umwelt des Festlandes und des Ozeans, besseres Verständnis des geomagnetischen Feldes und der damit verbundenen Sonne-Erde-Interaktionen, Entwicklung und Nutzung neuer GPS-basierter Techniken, um im globalen Maßstab die atmosphärischen Phänomene im Zusammenhang mit Wetterstudien, saisonalen, kurz- und langfristigen Klimaänderungen zu messen.

Die Nutzlast von SAC-C besteht aus dem Multispectral Medium Resolution Scanner (MMRS), dem GPS Occultation and Passive Reflection Experiment (GOLPE), der Magnetic Mapping Payload (MMP), dem argentinischen Experiment zur Verfolgung der Migrationsrouten der Eubalanea-Australis-Wale (Whale Tracker), dem französischen Experiment zur Untersuchung des Einflusses von Weltraumstrahlung auf hochentwickelte Komponenten (ICARE), zwei italienische Experimente zur Entwicklung einer vollständig autonomen An-Bord-Navigation für Satelliten in einer Erdumlaufbahn (IST und INES). Darüber hinaus wurden von Argentinien eine Hochauflösende Technologische Kamera (HRTC) zur Verbesserung der Bildauflösung (Ergänzung des MMRS), eine hochsensible Kamera (HSC) zur Untersuchung der Lichtintensität in urbanen Gebieten und ein Datensammelsystem (Data Collec-

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the Argentine satellite SAC-C will share data in order to enhance the scientific objectives of their individual missions. The four satellites will pass over the same point with a difference of half an hour.

ting System DCS), das Umweltdaten von Bodenstationen erhält, hinzugefügt.

Im Juni 1999 kreierten NASA und CONAE die erste internationale Konstellation zur Erderkundung (AM-Konstellation), in der sich die NASA-Satelliten Landsat-7, EO-1 und Terra sowie der argentinische Satellit SAC-C in der Datenerfassung ergänzen, um die wissenschaftlichen Zielstellungen ihrer individuellen Missionen wirksam zu erweitern. Die vier Satelliten überfliegen denselben Punkt in einem zeitlichen Abstand von 30 Minuten.

Mission Profile

The SAC-C satellite is an Earth observation mission designed for a 4 year's lifetime. It was successfully launched by a DELTA 7320-10 rocket on November 21, 2000.

SAC-C is a three axis stabilized, Earth pointing spacecraft. The pointing accuracy required is 1.5 deg, the pointing stability is 0.1deg/sec and the required pointing knowledge is 0.2 deg 3 on the three axes.

Orbit characteristics:
- Nominal altitude 705 km
- Inclination 98.2 deg
- Type circular Sun-Synchronous – 10:21 AM
- Track error +/−10 km EOL.

Spacecraft characteristics:
- Spacecraft dimensions: 1.85 m × 1.68 m × 2.4 mts.
- Spacecraft weight: The maximum SAC-C injected mass was 485kg, including 12.5kg of hydrazine.
- Payload weight: 104 kg.

Instrument Description and Objectives

1. MMRS (**M**ultispectral **M**edium **R**esolution **S**canner): This instrument was provided by CONAE to study the terrestrial and coastal marine environment. The MMRS images will be used to study and evaluate desertification processes and their evolution in time. They will also be used to monitor and predict agriculture production, to monitor flooded areas and to study pollution and productivity in coastal and fluvial areas.

The MMRS is a multispectral camera with 5 spectral bands:

B 1: 480–500 nm Blue-green
B 2: 540–560 nm Green
B 3: 630–690 nm Red
B 4: 795–835 nm NIR
B 5: 1550–1700 nm SWIR

The MMRS has two operational modes, a normal mode of 175 meters and a low-resolution mode of 350 meters ground pixel size.

Normal mode: allows to transmit data in real time at a bit rate of 3.774 Mbit/sec and/or store for a later transmission of an image of up to 360 km × 12000 km depending upon the chosen data compression ratio. Given this swath, every point on the planet can be observed every 7 and 9 days with different viewing angles.

Low-resolution mode: allows for transmission in real time at a bit rate of 0.943 Mbit/sec. This lower-bit rate transmission rate will be useful to field programs, research institutes, universities and schools because the requirements of ground reception equipment will be minimized.

2. HRTC (**H**igh **R**esolution **T**echnological **C**amera): It is provided by CONAE to acquire high resolution panchromatic images over portions of MMRS scenes to aid in data analysis. It has a ground resolution of 35 meters and a spectral response within the range of 400 to 900 nm. The HRTC will record images of size 90 km × 1150 km in its own mass memory of 96 Mbytes. A couple of mirrors allow the camera to be commanded to select a defined fringe of 90 km along the MMRS swath.

3. HSC (**H**igh **S**ensitivity **C**amera): This camera has been designed with the objective of performing studies of light intensity in urban areas, the presence of electric storms, fires over forest areas, as well as the dynamics and evolution of polar auroras.

The camera swath is 700 km and it will make observations during the night pass of the satellite (approximately 22 h 30 min). Spatial resolution for this camera is 300 m and the sensitivity is 0.1 saturation with a point source of 2 kW, equivalent to 78 W/DN. The HSC can work in real time and has capacity for storing data. It operates between 450–850 nm.

4. DCS (**D**ata **C**ollection **S**ystem): It will utilize ground based Data Collection Platforms provided by CONAE. These platforms will be operated by the users and will permit insertion of ground data upon the collected images. The type of data definition depends on the users needs and the specific applications.

5. MMP (**M**agnetic **M**apping **P**ayload): Developed by the Danish Space Research Institute and NASA/JPL, to perform observatory quality measurements of the magnetic field. It consists of a vector (CSC) and scalar (SHM) magnetometers. The vector magnetometer is mounted on an optical bench with a non-magnetic star imager camera head to determine vector field directions.

Primary objectives:

1-To perform highly accurate and sensitive measurements of the Earth's magnetic field in order to:

- Determine models of the main magnetic fields and its secular variation
- Study physical properties of the fluid core
- Study electrical conductivity of the mantle
- Investigate correlation between the geomagnetic fields and variations in the length of the day
- Study lithospheric structure and evolution

2-To study the interaction between the Earth's magnetic field and the solar wind in order to:

- Study the structure and variability of high-altitude fields and currents
- Investigate relationships between field-aligned and ionospheric currents in the cleft and cusp
- Determine the external magnetic fields as functions of local time, season, and solar wind conditions
- Determine ionospheric signatures of localized processes in the outer magnetosphere
- Study substorm processes

6. Gps OccuLtation and Passive reflection Experiment (GOLPE): It consists of one TurboRogue III GPS receiver, provided by NASA JPL, attached to four independent high gain antennae respectively pointed in the zenith, nadir, fore and aft velocity directions. The objective of the instrumentation is to record all of the direct, refracted and Earth reflected GPS signals as received by the low earth orbiting SAC-C satellite. The TurboRogue GPS is capable of providing satellite positioning to better than a decimeter and timing to better than 1 nanosecond when post processed using the IGS global reference network. The precise positioning capability can be used to measure the long wavelength component of the Earth's gravity field augmenting other sources of these data.

The high gain fore and aft antennae will receive setting and rising satellites occulted by the Earth's limb permitting the use of GPS occultation techniques to determine atmospheric temperature and water vapor at a rate of nearly 500 per day uniformly distributed over the globe. The nadir pointing antenna will be used to determine the utility of GPS signals reflected from the Earth's surface to characterize the elevation and roughness of the Earth's surface for applications such as the determination of oceanic circulation and surface winds.

7. Whale Tracker: It is a joint project between CONAE and the Secretary for the Environment of Argentina to study the migration pattern and behavior of the Eubalanea Australis. The goal of the project is to learn enough of the migration routes to protect this specie from depredation.

8. ICARE (**I**nfluence of Space **R**adiation on **A**dvanced **C**omponents): Was developed by the French Space Agency,CNES. The objectives of the instrument are to contribute in:

- The improvement of risk estimation models for radiation effects on latest generations of integrated circuit technologies.
- The improvement of environment models for radiation responsible for degradations and breakdowns in electronic components.
- Real time monitoring of environmental conditions in order to be prepared for possible incidents and to dispose of analysis elements if a breakdown occurs.

9. IST (**I**talian **S**tar **T**racker): Was developed by Alenia Aerospazio under funding of the Italian Space Agency, as a technological payload to test a fully autonomous system for attitude and orbit determination.

10. INES: The INES experiment is composed of two separate systems: the GPS Tensor receiver and the Lagrange GNSS receiver. These two receivers have completely different objectives. The INES instruments are developed by LABEN under funding by the Italian Space Agency (ASI).

10.1. GPS TENSOR: The GPS Tensor is used by the SAC-C satellite as a primary AOCS sensor providing navigation and attitude solutions. Although this receiver is part of the satellite bus, ASI and LABEN are interested primarily in validating the attitude determination capabilities and accuracy of the receiver.

10.2. LAGRANGE: a dual frequency (L1, L2) GPS/GLONASS receiver. The main scope of Lagrange is for applications in the fields of Atmospheric Sounding, Geodesy, Ionospheric profiling and Precise Orbit Determination and Real-Time Navigation using combined GPS/GLONASS constellations. The Lagrange receiver that will be provided for the SAC-C mission will have a reduced configuration with only one antenna mounted with a pointing direction between horizon and zenith. Therefore, the main scope of Lagrange on SAC-C will be on one side a technological validation of the instrument and on the other side the execution of a Precise Orbit Determination experiment.

The AM Constellation

The Constellation will increase the synergy between observing instruments of the satellites that compose it, provide new Earth Observation capabilities, explore the utility of coordinated synoptic observational capabilities proposed for future satellite systems and compare new observational technologies, such as formation flying.

The four satellites (Landsat 7, EO-1, Terra and SAC-C) will follow the same path over the Earth surface, and they will orbit at an altitude of 705 km, with an inclination of 98.21 degrees, the Equator crossing time being 10:00, 10:01, 10:15 and 10:30 hs. respectively (UTM, Universal Time).

The satellites will follow the World Wide Reference System, with a repeat cycle of 16 days, which total 233 revolutions.

More than 200 projects using data from SAC-C and the Constellation have been presented for the Announcement of Opportunity.

The cooperative effort in the Constellation included as well:

- A Flight Campaign of the NASA AVIRIS instrument over the Argentine territory during January and February of 2001, for validation and calibration of the different instruments of the satellites that integrate it.
- The installation of three Aeronet stations in the Argentine territory for the measurement of aerosols components in the atmosphere.
- The installation of jointly operated ground GPS reference site at Cordoba to support GPS atmospheric sounding.
- Jointly sponsored technical workshops.

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Berichte

OEEPE-Workshop „Integrated Sensor Orientation“

Hannover, 17.–18. September 2001

Die Europäische Organisation für experimentelle photogrammetrische Forschung (OEEPE) initiierte einen groß angelegten Test, dessen Ziel es war, das Potenzial und die Einschränkungen der direkten Georeferenzierung mittels GPS/INS für großmaßstäbige Luftbilder zu untersuchen. Das Institut für Photogrammetrie und GeoInformation (IPI) der Universität Hannover unter der Leitung von Prof. HEIPKE übernahm die Leitung dieses Testes. Die Präsentation der Ergebnisse dieses OEEPE-Testes gab den Anlass für diesen Workshop, zu dem sich etwa 40 Teilnehmer in Hannover einfanden. In 6 Sitzungen mit insgesamt 17 Vorträgen beschäftigte man sich allgemein mit dem Thema der direkten Sensororientierung und speziell mit dem OEEPE-Test.

Für den OEEPE-Test (Weitwinkelaufnahmen 1:5 000) lieferte die direkte Georeferenzierung Bodenpunkte mit einer Genauigkeit von 5–10 cm in Lage und 10–15 cm in Höhe. Obwohl dieses Genauigkeitsniveau um den Faktor 2–3 schlechter ist als jenes der konventionellen Aerotriangulation (AT), ist die direkte Georeferenzierung auf Grund ihrer speziellen Vorteile (der prinzipiellen Unabhängigkeit von Passpunkten, der freien Blockgeometrie, der geringeren Bildanzahl und des rascheren Arbeitsflusses) eine ernsthafte Alternative für Aufgaben, bei denen das Augenmerk weniger auf die Genauigkeit als auf die rasche Verfügbarkeit der Ergebnisse gelegt wird (z. B. Orthophotos für Disastermanagement). Wie A. GRIMM in seinem Vortrag erwähnte, ist die direkte Georeferenzierung in Gebieten, wo keine Bodenpasspunkte zur Verfügung stehen (z. B. in Myanmar wegen der politischen Situation oder im Falle vieler kleiner vorgelagerter Inseln vor Saudi Arabien), überhaupt die einzige Möglichkeit Photogrammetrie zu betreiben.

Um das genannte Genauigkeitspotenzial der direkten Georeferenzierung erreichen zu können, ist eine Kalibrierung des gesamten Systems (GPS/INS und Kamera) vor dem eigentlichen Projektflug unerlässlich. Auf Grund der z.T. mangelnden Stabilität der Kalibrierungsgrößen ist u.U. auch eine Post-Kalibrierung in Erwägung zu ziehen. R. ALAMÍS et al. präsentierten eine interessante Methode, die Systemkalibrierung direkt mit Hilfe eines Teils der Bilder des Projektfluges durchzuführen. Im Zuge der Kalibrierung ist eine korrekte Modellierung des Systems wichtig, denn wie K. JACOBSEN in seinem Vortrag angemerkt hat, ist konventionelle AT methodisch eine Interpolation, direkte Georeferenzierung hingegen eine Extrapolation, bei der sich Modellfehler naturgemäß stärker auswirken. So sind die unterschiedlichen Bezugssysteme für die Rotationen zu beachten (M. BÄUMKER & F.J. HEIMES), die Kompensation der GPS-Fehler über den „shift-and-drift“-Ansatz oder eher über eine rigorose GPS-Modellierung durchzuführen (M. SCHMITZ et al.) und auch der Einfluss des gewählten Referenzsystems (Tangentialsystem bzw. Landessystem) ist zu beachten.

Problematisch ist die Verwendung der Daten der direkten Sensororientierung als Modellorientierung für die Stereoauswertung. Auf Grund der zufälligen GPS/INS-Fehler, der Instabilität der Kalibrierungsgrößen und der nicht berücksichtigten Bildverzeichnung (Ø. ANDERSON, B. NILSEN) verbleiben in den Stereomodellen nämlich sehr große y-Parallaxen (z.T. $\geq 20\,\mu m$). Mit Hilfe einer kombinierten AT (GPS/INS + Verknüpfungspunkte) kann dieses Problem beseitigt werden. Um aber durch die (manuelle) Verknüpfungspunktemessung nicht die vielen Vorteile der direkten Sensororientierung zu verlieren, wird in diesem Zusammenhang die Automatische AT mit GPS/INS-Unterstützung in Zukunft an Bedeutung gewinnen.

In zukünftigen Forschungsaktivitäten wird man sich mehr der Untersuchung der Stabilität der Kalibrierung von GPS/INS und der Kamera widmen. Mehr Aufmerksamkeit wird man auch der Vorprozessierung der GPS/INS-Daten schenken, die zurzeit eher den Charakter einer Black-Box hat. Die Weiterentwicklungen in der Satellitengeodäsie (GPS III, Galileo) sowie der Übergang von Einzel-Referenzstationen zu ganzen Netzen von Referenzstationen versprechen – so I. COLOMINA im Hauptvortrag des Workshops – einen Gewinn an Genauigkeit und Zuverlässigkeit, der auch für die direkte Georeferenzierung von Vorteil sein wird.

Alles in allem boten die Vorträge in diesen zwei Tagen einen tiefen theoretischen und praktischen Einblick in diese relativ neue – in Zukunft aber immer wichtiger werdende – Methode der Sensororientierung. Abschließend sei Prof. HEIPKE und seinem Team für die großartige Organisation des Workshops gedankt, die unter den tragischen Ereignissen vom 11. September, der auch auf diese Veranstaltung seinen Schatten geworfen hat, keine Leichtigkeit gewesen ist.

Die Tagungsbeiträge sind auf CD-Rom erschienen und am Institut für Photogrammetrie und GeoInformation (IPI), Universität Hannover, Nienburger Str. 1, D-30167 Hannover, Tel.: ++49-511-762 2482 Fax: ++49-511-762-2483 erhältlich.

CAMILLO RESSL, TU Wien

Joint Workshop of ISPRS Working Groups I/2, I/5 and IV/7: „High Resolution Mapping from Space 2001"

Hannover, 19.–21. September 2001

Der im 2-jährigen Turnus an der Universität Hannover vom Institut für Photogrammetrie und GeoInformation (IPI) durchgeführte Workshop stand in diesem Jahr im Schatten der Ereignisse des 11. September. Er wurde trotz der tragischen Hintergründe mit ausdrücklicher Unterstützung durch die amerikanischen Fachkollegen durchgeführt und von 57 Teilnehmern aus 16 Nationen besucht.

Nach einem einleitenden Beitrag von I. DOWMAN zum Thema des Workshops bestand der fachliche Teil des Programms aus 9 Vortragsblöcken, in denen die einzelnen Themenbereiche *IKONOS, Line Detector Cameras, Current and Future Missions, Calibration, INSAR, Image Processing and Visualisation, Topographic Mapping* sowie *Interpretation and Semantic Applications* in insgesamt mehr als 30 Präsentationen behandelt wurden.

Zum Thema IKONOS wurden Anwendungsbeispiele (LOHMANN; MOTT et al.; TOUTIN) sowie kritische Analysen der geometrischen und radiometrischen Eigenschaften (BALTSAVIAS et al.; FRASER et al.) dargestellt, in denen die geometrische Verarbeitung von IKONOS-CARTERRA Geo-Produkten unter Anwendung einfacher geometrischer Transformationen durchaus mit den (kostenintensiven) high-end Produkten vergleichbare Ergebnisse liefern.

Im Bereich der Line Detector Cameras wurden neben theoretischen Beiträgen zur indirekten Orientierung mit Hilfe von Freiformkurven (ZALMANSON & SCHENK), zur direkten Sensororientierung des japanischen TLS-Systems (POLI) und zum Design des ADS-Systems (ECKHARDT & REULKE) die erfolgreichen Anwendungen zur passpunktlosen direkten Georeferenzierung von HRSC-Daten (SCHOLTEN et al.) anhand von Test- und Anwendungsbeispielen numerisch und anhand von hochauflösenden Datenprodukten belegt.

Nach einem Überblick durch G. KONECNY wurden im Bereich der aktuellen und kommenden Satelliten-Missionen die Instrumente der BIRD-Plattform (BRIESS et al.), das RAPIDEYE-Konzept (SCHERER), das aktuelle französische PLEIADE-Programm (BAUDOIN) sowie Konzepte verschiedener Konfigurationen von SAR-Clustern (RUNGE) vorgestellt. Im Themenbereich INSAR standen Arbeiten zur SRTM-Mission (ADAM et al.; BREIT et al.) sowie zur Erstellung und Nutzung von DTMs aus ERS-1/2 Daten (KOSMAN et al.; SPRECKELS et al.; TRINDER & CHENG) im Vordergrund. Weiterhin wurden im Themenkomplex Kalibration über Erfahrungen mit der In-orbit-Kalibration des MOS-Systems (SÜMNICH et al.), die Möglichkeiten sehr hoch auflösender TDI-Kameras (SCHRÖDER et al.) sowie über Aktivitäten der CEOS-Working Group CV (DESNOS) berichtet.

Am letzten Tag wurden spezielle Anwendungen auf der Basis verschiedener Datengrundlagen dargestellt. Die Möglichkeiten der topographischen Verarbeitung von flugzeugbasierten HRSC-Daten und IKONOS-Daten (JACOBSEN) wurde ebenso erläutert wie der Blockausgleich von LANDSAT-7 Daten (TOUTIN), die Verifizierung von MOMS-2P basierten Höhenmodellen (MÜLLER et al.), generelle Verfahren zur radiometrischen Bildverbesserung (NÓBREGA), die Nutzung von ehemaligen CORONA US-Spionage Daten von Marokko (GOOSENS et al.) und China (SCHNEIDER et al.) sowie die Nutzung von Fernerkundungsdaten für die Überwachung der Desertifikation in Libanon (KHAWLIE et al.). Darüber hinaus wurden Arbeiten zur objektorientierten Klassifizierung (BUCK et al.) sowie zur interaktiven 3D-Visualisierung (KANDAWASVIKA & HAHN) präsentiert.

Abgerundet wurde das vielseitige Programm durch vom IPI ausgerichtete, traditionell gesellige Treffen mit der Gelegenheit zu weiteren Fachgesprächen.

FRANK SCHOLTEN, Berlin.

OEEPE/ ISPRS Workshop: „From 2D to 3D – Establishment and Maintenance of National Core Geospatial Databases“

Hannover, 8.–10. Oktober 2001

Staatliche und private Geodatenproduzenten stellen eine steigende Nachfrage nach 3D-Geodaten fest. Nun stellt sich die große Herausforderung, möglichst kostengünstig und rasch regionale und nationale 3D-Geobasisdatenbanken aufzubauen und neue Geschäftsmodelle zur Finanzierung dieser Aufgabe zu entwickeln. Der Workshop zu dieser Thematik wurde gemeinsam organisiert durch die OEEPE Kommissionen 2 ‚Image analysis and information content‘ und 4 ‚Core geospatial databases‘, durch die ISPRS Inter-Commission Working Group II/IV ‚Systems for automated geospatial data production and update from imagery‘ und die ISPRS Commission Working Group IV/3 ‚Data generalization and data mining‘.

Der dreitägige Workshop fand in den Räumlichkeiten der LGN Landesvermessung + Geobasisinformation Niedersachsen statt und wurde vom Institut für Photogrammetrie und GeoInformation (IPI) und dem Institut für Kartographie und Geoinformatik (ikg) gemeinsam mit dem LGN durchgeführt.

Am Workshop nahmen mehr als 60 Personen aus 12 verschiedenen Ländern teil, mit einer ausgewogenen Zusammensetzung von Teilnehmenden aus Amtsstellen, Hochschulen und Privatindustrie. In insgesamt 6 Sessionen referierten Fachleute aus Wissenschaft, Verwaltung, Softwareentwicklung und von der Seite der Datennutzer über die Aspekte Benutzeranforderungen, Datenerfassung, Datenverwaltung und -visualisierung, Datennachführung, Datenintegration und über die Aktivitäten der Geodaten-Amtsstellen. Diese technischen Sessionen wurden ergänzt durch Diskussions-Sessionen mit unterschiedlichen Themenschwerpunkten und durch eine informative Führung durch die LGN.

Nach der Workshop-Eröffnung durch den LGN-Gastgeber Herrn ERNST JÄGER und mehreren Grußworten, referierte Prof. ANDRÉ FRANK in seiner Keynote-Adresse zum Thema ‚3D-Daten: Märkte und Geschäftsfelder‘ und stellte dabei interessante Überlegungen an zum Potenzial von Geodaten, zum Geodatenmarkt und zu den Faktoren, welche über Erfolg oder Misserfolg einer Technologie entscheiden. Er zeigte, dass der Geodatenmarkt sehr limitiert und spezialisiert ist und dass Geodaten selbst keine markttreibende Kraft darstellen. Er illustrierte anhand eines interessanten Beispiels, dass das Hauptwachstum vielmehr von (3D-) Geoinformations-Anwendungen und -Produkten zu erwarten ist, welche gut definierte spezifische Probleme zu lösen vermögen.

In der ersten Session zum Thema ‚Anforderungen und Anwendungen von 3D-Geodaten' zeigte sich, dass sich zurzeit viele Vermessungsämter in Europa schwergewichtig mit der Etablierung bzw. Fertigstellung ihrer topographischen 2D-Geodatenbanken beschäftigen. Die dritte Dimension gewinnt in der Form hochgenauer digitaler Höhenmodelle an Bedeutung, vor allem im Flachland und in Küstenregionen. In einem interessanten Vortrag zum Thema 3D und Fahrzeugnavigation wurde gezeigt, dass Japan im Bereich der 3D-Fahrzeugnavigation eine führende Rolle spielt und dass dort bereits kommerzielle Systeme im Einsatz stehen.

Im Zentrum der zweiten Session stand das Thema ‚Erfassung von 3D-Geodaten'. Dazu wurden verschiedene Ansätze der automatisierten Extraktion von 3D-Gebäudegeometrien mittels Photogrammetrie, Laserscanning und SAR präsentiert. Dabei waren sich die meisten Referenten einig, dass ein Schlüssel zur Steigerung des Automatisierungsgrads und der Zuverlässigkeit in der Integration verschiedener Datenquellen liegt. In einer weiteren Präsentation wurden die Vorteile einer direkten Anbindung eines photogrammetrischen Systems an ein 3D-GIS dargestellt.

Der zweite Tag wurde mit einer Session zum Thema ‚3D-Geodatenbanken und -visualisierung' eröffnet. Dabei wurden neue 3D-Datenmodelle präsentiert und Projekte vorgestellt, welche die Verwaltung und Visualisierung nationaler Landschafts- und Stadtmodelle zum Ziel haben. Dabei wurde in mehreren Vorträgen auf die zentrale Bedeutung von Mehrfach-Repräsentation und Detaillierungsgrad (LOD) im 3D-Umfeld hingewiesen. In einer Life-Demonstration des Projekts dilas (Digital Landscape Server) der Fachhochschule beider Basel wurde die Machbarkeit einer web-basierten Verwaltung und Visualisierung landesweiter 3D-Landschaftsmodelle vorgeführt. Schließlich wurden in einem Vortrag zum Atlas der Schweiz der Entwicklungsstand und die aktuellen Trends in der Hypermedia-Kartographie in Richtung Online-Inhalte und dynamische 3D-Visualisierungen aufgezeigt.

In der anschließenden Session stellten verschiedene europäische Vermessungsämter ihre Strategien und Lösungen zur Nachführung und Verfeinerung ihrer topographischen Datenbanken vor. In einem Vortrag vom Institut Cartogràphic de Catalunya wurde die laufende Umstellung von einem karten-orientierten Datenmodell zu einem objekt-orientierten digitalen Landschaftsmodell vorgestellt. Wegen der dabei aufgetauchten praktischen Probleme wurde hier sogar der Entscheid für eine photogrammetrische Neuerfassung gefällt. In einem weiteren Vortrag wurde die Vision für ein nationales 3D TLM (topographisches Landschaftsmodell) des Schweizerischen Bundesamts für Landestopographie vorgestellt mit den zu erwartenden tiefgreifenden Auswirkungen auf die Produktionsprozesse und mit einem interessanten Kooperationsmodell mit so genannten Referenzpartnern.

Die erste Session am dritten Tag war dem Thema ‚Konzepte, Algorithmen und Systeme zur Nachführung von Geodatenbanken' gewidmet. Dabei wurden Architekturen für eine dezentrale Datenerfassung und -nachführung von Geodatenbanken, eine automatisierte Kontrolle und Nachführung von ATKIS-Daten aus Bilddaten und ein Projekt aus Israel zur 3D-Nachführung von 2.5D-Karten vorgestellt. In der abschließenden Session wurden ‚Aspekte der Datenintegration: Zeit, Maßstab und geometrische Dimension' behandelt. Die ersten Referate dieser Session konzentrierten sich auf Mehrfachrepräsentation (MR) und auf die Aufgaben der automatischen Ableitung verschiedener Repräsentationen von 3D-Objekten und der automatischen Nachführung von Änderungen in einem solchen MR-Rahmen.

Die wichtigsten Erkenntnisse und Schlussfolgerungen aus diesem interessanten Workshop können wie folgt zusammengefasst werden:

- Der Aufbau, die Nachführung und die web-basierte Visualisierung regionaler oder nationaler 3D-Geobasisdatenbanken ist heute technisch möglich.
- Zu den wichtigsten technischen Herausforderungen gehören die Aspekte der

Mehrfach-Repräsentation, der automatischen Generalisierung von 3D-Objekten und der Datenmodelle, welche eine Integration von 2D- und 3D-Geodaten unterstützen.

- Mindestens so wichtige Schlüsselfaktoren, um 3D-Geoinformationen zu einem wirtschaftlichen Erfolg zu verhelfen, sind die Identifikation neuer 3D-Anwendungen für den Massenmarkt und deren Umsetzung in neuen Geschäftsmodellen.
- Erfolgreiche zukünftige 3D-Anwendungen erfordern eine Navigation im Freien und in Innenräumen und eine Integration der entsprechenden Daten.
- Es besteht großer Handlungsbedarf bei der Standardisierung von 3D-Geodaten.

Stephan Nebiker, Basel/Schweiz

10 Jahre TERRA Bildmessflug

Am 1. 1. 1992 gründeten M. Schnelzer und U. Sach die Firma TERRA Bildmessflug GmbH in Marbach a.N. mit der Idee, nur den Bildmessflug als Spezialgebiet zu betreiben, damit Ingenieurbüros im photogrammetrischen Bereich einen unabhängigen und zuverlässigen Partner mit der neuesten Technik für den Bildmessflug zur Verfügung haben. Da die Aufnahmen letzten Endes für die Folgearbeiten unabdingbar sind, wollten wir an diesem wichtigen Punkt der Projektabwicklung unsere langjährige Erfahrung mit einbringen. Diesem Konzept sind wir bis heute treu geblieben. Wir fliegen inzwischen zusammen mit unserem langjährigen Partner, der Weser-Bildmessflug in Bremerhaven, für mehr als 20 Ingenieurbüros in ganz Europa.

Durch die enge Zusammenarbeit mit der Weser-Bildmessflug und die günstige Stationierung unserer Flugzeuge im Norden und Süden kann sehr effizient und kostengünstig gearbeitet und angeboten werden.

Und hier noch ein paar Zahlen der ersten 10 Jahre: Die Flugstrecke, die in ca. 4000 Flugstunden zurückgelegt wurde, beläuft sich auf ca. 1000000 km, das sind etwa 24 Erdumrundungen. Dabei wurden rund 300000 Aufnahmen ausgelöst, das sind ca. 80000 m Film.

Auch für die nächsten 10 Jahre haben wir uns einiges vorgenommen. Wir freuen uns, zusammen mit unseren Kunden die nächsten Herausforderungen des digitalen Bildzeitalters anzunehmen.

Der Vorstand der DGPF schließt sich den Gratulationen zum 10-jährigen Bestehen von TERRA Bildmessflug an und wünscht viel Erfolg in der Zukunft.

Jochen Berger, Marbach

Nutzungsrichtlinien für kommunale Geodaten

Jetzt, zu Beginn des neuen Jahrhunderts, explodiert der Markt für Geodaten förmlich. Zunehmender Tourismus, die wachsende Nachfrage nach Geodaten für Internet-Anwendungen (auch auf mobilen Endgeräten) und der forcierte Aufbau geographischer Informationssysteme auch in Kommunen sind dafür einige der wichtigsten Ursachen. Das nationale und das EU-Urheberrecht schützen kommunale Geodaten (als Landkarten und/oder in Datenbanken) dabei vor missbräuchlicher Verwendung. Bei den Kommunen setzt sich im Zuge dessen zunehmend die Erkenntnis durch, dass das Nutzungsrecht an ihren Geodaten ein marktfähiges (und vermarktbares) Produkt ist. Um ihr Urheberrecht an ihren Geodaten zu realisieren, müssen Kommunen Richtlinien formulieren, die festlegen, unter welchen konkreten Bedingungen und zu welchen Kosten amtliche kommunale Geodaten genutzt werden dürfen.

Vielfach werden solche Richtlinien als „selbst gestrickte“ Insellösungen der dort tätigen Geodatenproduzenten formuliert oder es werden Einzelfallentscheidungen getroffen, was die potenziellen Kunden – insbesondere in Ballungsräumen – mit einer Vielzahl von verschiedenen Kosten, Rabatten, Datenformaten, Ge- und Verboten für das aus ihrer Sicht jedoch inhaltlich identische wahrgenommene Produkt „Nutzungsrecht“ konfrontiert. Hinzu kommt eine weit verbreitete Unsicherheit darüber, wie und in welchem Umfang kostenfreie Angebote für Internet-Nutzungen formuliert werden können, ohne mit dem Urheberrecht in Konflikt zu geraten. Dies alles muss die Verwendung kommunaler Geodaten erheblich hemmen.

Bereits seit 1991 gibt es aus diesen Gründen in der Region an Rhein, Ruhr und Wupper eine Arbeitsgruppe, die einheitliche, freiwillig anwendbare Richtlinien für die Erteilung von Nutzungsrechten an amtlichen kommunalen Geodaten erarbeitet und jährlich an die Veränderungen des Marktes anpasst. Sie setzt sich aus Fachleuten von zehn kreisfreien Städten, einer kreisangehörigen Stadt und zweier Landkreise zusammen. 2001 ist nun eine inhaltlich von Grund auf neu erarbeitete Fassung der *„Richtlinien zur Erteilung von Nutzungsrechten an amtlichen kommunalen Geodaten“* entstanden. Erklärte Ziele sind:

- so wenig Regeln wie möglich, keine Bürokratie
- konsequente Orientierung am Kunden
- Einbindung in ein stringentes kommunales Geodatenmarketing
- Standardisierung des Verfahrens und Kostentransparenz
- Berücksichtigung der Anforderungen von Internet und Geoinformationssystemen
- Anwendung freiwillig „aus gesundem Menschenverstand“ (kein Vertrag zwischen den Gebietskörperschaften)

Die Richtlinien, Version 1.00 vom 24.10. 2001 liegen in gedruckter Form mit 24 Seiten Umfang vor:

– Arbeitskreis Regionale Kartographie –

Stadt Bochum · Stadt Düsseldorf · Stadt Hamm · Stadt Köln · Kreis Mettmann · Stadt Mönchengladbach · Stadt Neuss · Stadt Remscheid · Stadt Solingen · Stadt Wuppertal

Einheitliche Richtlinien für die Erteilung von Nutzungsrechten an kommunalen Geodaten
(ER-Kom)

Die Richtlinien sowie ein Muster-Nutzungsrechtvertrag stehen allen Interessierten zur Übernahme in die eigene Verwaltung oder als Anregung zur Entwicklung eigener Lösungen zur Verfügung und können bei dem Vermessungs- und Katasteramt des federführenden Kreises Mettmann angefordert werden.

Auskünfte:
Landrat Amt 62, Postfach, D-40806 Mettmann, e-mail: richard.goergen@kreis-mettmann.de

Persönliches

Professor Werner Rüger zum 90. Geburtstag

Am 14. Januar 2002 vollendete Prof. Dr.-Ing. (em.) Werner Rüger sein 90. Lebensjahr. Die Technische Universität Dresden würdigte diesen Anlass mit einer akademischen Ehrung des Jubilars durch ein Ehrenkolloquium an seiner alten Wirkungsstätte am 18. 01. 2002. Groß war die Zahl der Gratulanten aus dem Kreis seiner Kollegen, früheren Mitarbeiter und Schüler sowie seiner Freunde. Auch die Deutsche Gesellschaft für Photogrammetrie und Fernerkundung überbrachte einem ihrer ältesten verdienstvollen Mitglieder herzliche Glückwünsche.

Nach seiner Promotion an der TH Dresden wurde der Jubilar 1955 als Professor und Direktor des Institutes für Geodäsie und Photogrammetrie an die Bergakademie Freiberg berufen, wo er bis 1968 in Lehre und Forschung eine umfangreiche praxisrelevante wissenschaftliche Arbeit, besonders zum Einsatz der Photogrammetrie im Braunkohlenbergbau der DDR, leistete. Danach kehrte er als Ordinarius auf den vakanten Lehrstuhl für Photogrammetrie an seine alte akademische Ausbildungs- und Lehrstätte, an die Technische Universität, nach Dresden zurück. Bis zu seiner Emeritierung 1978 setzte er sich als Hochschullehrer mit ganzer Kraft für den Fortschritt der Photogrammetrie in der DDR ein. In diesem Sinne war er viele Jahre auch aktives Mitglied in einer Vielzahl von Arbeitsgremien sowie Vorsitzender der Gesellschaft für Photogrammetrie in der DDR. Über die Grenzen der DDR hinaus bekannt wurde er als verantwortlicher Autor des Lehrbuches „Photogrammetrie – Verfahren und Geräte der Kartenherstellung“, das in 3 Auflagen von ihm und einem Autorenteam seiner Mitarbeiter an der TU Dresden erarbeitet wurde.

Mit großer Freude konnten die Gratulanten den Jubilar zu seinem Ehrenkolloquium persönlich begrüßen. Mehreren Operationen und dem Geschick der Ärzte ist zu danken, dass ihm seine Mobilität und sein Augenlicht weitgehend wieder zurückgegeben werden konnten. Bewundernswert sind nach wie vor sein hervorragendes Gedächtnis, seine vielseitigen Interessen, seine geistige Regsamkeit und die menschliche Wärme des Jubilars. Gern sucht er auch heute noch den Kontakt und den Gedankenaustausch mit seinen Kollegen, die nun schon in der zweiten Generation die Geschicke des Institutes für Photogrammetrie und Fernerkundung an der TU Dresden leiten und die das Ehrenkolloquium durch ihre Vorträge zu einer Würdigung für den Jubilar werden ließen.

Im Namen seiner Schüler, seiner ehemaligen Mitarbeiter und seiner Kollegen – zu jeder dieser Spezies habe ich viele Jahre gehört – wünsche ich dem Jubilar von Herzen alles Gute, gelassene Zufriedenheit über das in seinem langen Leben als Wissenschaftler und Hochschullehrer Erreichte sowie Gesundheit für viele weitere Lebensjahre.

Karl Regensburger, Dresden

Professor Günter Weimann zum 80. Geburtstag

Am 6. Juni 2001 hat der Emeritius der Photogrammetrie Univ.-Prof. Dr.-Ing. Günter Weimann sein 80. Lebensjahr vollendet, Anlass für einen Rückblick und eine Würdigung seines beruflichen Werdegangs und Lebenswerkes.

Günter Weimann wurde 1921 in Berlin geboren. Er ging dort bis zur Mittleren Reife zur Schule, absolvierte eine Lehre als Vermessungstechniker beim Bezirksvermessungsamt Berlin-Treptow, ein dreisemestriges Studium an der Staatsbauschule Neukölln und legte 1940 die Staatsprüfung als Ingenieur für Vermessungstechnik ab.

Die erste berufliche Tätigkeit in der Vermessungsabteilung der „Ruges“ m.b.H., Berlin und die Jugendzeit endeten mit der Einberufung zur Deutschen Kriegsmarine im Februar 1941.

Mit dem Kriegsende geriet der Leutnant zur See d.R. Günter Weimann in englische Kriegsgefangenschaft, aus der er im November 1945 nach Kiel entlassen wurde.

Die Einstellung in einem Vermessungsbüro seiner Heimatstadt bis zum Beginn seines

Studiums des Vermessungswesens an der Technischen Universität Berlin im Mai 1946 brachte ihm zwar keinen Lohn, aber eine kalorienreichere Lebensmittelkarte.

Ab dem WS 1948 waren GÜNTER WEIMANN und ich dann Kommilitonen. In dem mir gewidmeten Beitrag „Studium im Berlin der ersten Nachkriegsjahre, Erinnerungen an eine außergewöhnliche Zeit" in der Geodätischen Schriftenreihe der Technischen Universität Braunschweig Nr. 7, 1987 hat er die damalige Situation und Stimmung hervorragend geschildert. Am 27. März 1951 legte GÜNTER WEIMANN die Diplomhauptprüfung ab.

„In der Zeit tiefster Arbeitslosigkeit" (Zitat WEIMANN) hatte Prof. OTTO LACMANN inzwischen seinen sehr guten Diplomanden an Prof. SCHWIDEFSKY bei der Fa. Carl Zeiss in Oberkochen vermittelt. Dort war Dipl.-Ing. WEIMANN ab August 1951 wissenschaftlicher Mitarbeiter in der Abteilung für Bildmessung, bis er am 1. März 1955 als wissenschaftlicher Assistent an den Lehrstuhl für Photogrammetrie und Kartenkunde der TU Berlin zurückkehrte, den inzwischen Prof. RUDOLF BURKHARDT übernommen hatte. Bereits am 15. Februar 1956 wurde er zum Oberingenieur ernannt.

Eine besondere Hürde in seiner wissenschaftlichen Laufbahn stellte die Promotionsordnung der TU Berlin mit der Forderung nach der bestandenen Reifeprüfung als Voraussetzung für ein Promotionsverfahren auf. Nach eineinhalbjähriger Vorbereitung an einer Privatschule legte GÜNTER WEIMANN – inzwischen gestandener Photogrammeter, Ehemann und Familienvater, 20 Jahre älter als die Mitabiturienten – am 8. Mai 1959 die Reifeprüfung ab.

10 Jahre später – nach der Promotion im Mai 1965 – wurde Dr.-Ing. GÜNTER WEIMANN im Mai 1969, nach Abschluss seines Habilitationsverfahrens, die „Venia Legendi" von der Fakultät für Bauwesen der TU Berlin für das Lehrgebiet „Photogrammetrie" verliehen. Im August 1969 wurde er zum Wissenschaftlichen Rat und Professor und am 1. April 1970 zum Professor ernannt. Professor WEIMANN war 1971/1972 Mitglied des Akademischen Senats der TU, stellvertretender Vorsitzender und danach Vorsitzender des Fachbereichs Bauingenieur- und Vermessungswesen von 1970 bis 1972, Mitglied der Ausbildungskommission und der Forschungskommission und seit Juni 1971 Geschäftsführender Direktor des Instituts für Geodäsie und Photogrammetrie. Im Februar 1974 wurde ihm das Fachgebiet „Photogrammetrie und Kartenkunde" übertragen, das seit Oktober 1974 in „Photogrammetrie und Kartographie" umbenannt war.

Seine Forschungsarbeiten lagen vor allem auf den Gebieten der Sonderanwendungen der Photogrammetrie. So haben Probleme des Bauingenieurwesens, der Elektronenmikroskopie, der Architektur und Archäologie, der Tierzucht, des Schiffbaus und der Meteorologie in Zusammenarbeit mit den Experten der entsprechenden Disziplinen zu einer Reihe hochinteressanter Projekte geführt.

Nach zwanzigjährigem, sehr erfolgreichen Wirken für die Photogrammetrie an der TU Berlin nahm Professor WEIMANN dann einen Ruf an die TU Braunschweig an. Er verwaltete zunächst ab WS 1975/76 den Lehrstuhl für Photogrammetrie und Kartographie, dessen Leitung ihm mit der Ernennung zum ordentlichen Professor am 11. Februar 1976 endgültig übertragen wurde.

Die Hauptarbeits- und Forschungseinrichtungen seines Lehrstuhls – ab dem 1. Oktober 1982 Institut für Photogrammetrie und Kartographie – lagen auf den Gebieten Architekturphotogrammetrie, Archäologie und Denkmalpflege sowie Ingenieurphotogrammetrie, z.T. unter Entwicklung bzw. Einsatz unkonventioneller Methoden und Instrumente. Aus der Vielzahl der Projekte seien hier nur einige Beispiele genannt: Herstellung eines Replikats des Tympanons im Nordwestportal der Godehardikirche in Hildesheim, Aufnahme und Auswertung des Braunschweiger Burglöwen, Rekonstruktion der Fassade des „Wedekindhauses" in Hildesheim mit Hilfe alter Architekturfotografien, begleitende Aufnahmen bei der Öffnung der Sarkophage der Kaisergrablege in der Stiftskirche Königslutter, Auswertung von Geschossspuraufnahmen, Stahlblechdeformationen, Ermittlung der Bewegungsabläufe im Kniegelenk und stereo-mikroskopische Aufnahmen des Wachstums von Eiskristallen. Aber auch klassische photogrammetrische Arbeiten dürfen nicht unerwähnt bleiben, so z. B. die Auswertung von Luftaufnahmen einer Islandbefliegung von 1960 aus Papierkontaktabzügen für zwei Arbeitsgebiete meines Instituts im Maßstab 1:20000 und die DFG-Projekte Deformationsbestimmung aus Luftbildpaaren sowie die Neubefliegung der Riftzone Krafla/Gjastykki in Nordost-Island 1982.

Diese Erfahrungen liegen auch seinen beiden Lehrbüchern „Geometrische Grundlagen der Luftbildinterpretation, Einfachverfahren der Luftbildauswertung“ und „Architektur-Photogrammetrie“ zu Grunde.

In seiner liebenswürdigen und ausgeglichenen Art war er stets offen, aber auch kritisch, forderte und förderte die Kreativität seiner Doktoranden und Mitarbeiter, legte großen Wert auf die gegenseitige Information und Kommunikation der Institutsangehörigen und schuf damit die Grundlage für das gute Institutsklima.

Die umfangreiche Liste seiner Veröffentlichungen, Forschungsarbeiten und Projekte weisen Prof. Weimann als ideenreichen und vielseitigen Wissenschaftler aus, anerkannt und hochgeschätzt nicht nur von den Fachkollegen, sondern auch von seinen Partnern und Experten anderer Disziplinen. Seit 1976 ist Prof. Weimann ordentliches Mitglied der Deutschen Geodätischen Kommission bei der Bayerischen Akademie der Wissenschaften und seit 1985 ordentliches Mitglied der Klasse für Bauwissenschaften der Braunschweigischen Wissenschaftlichen Gesellschaft.

Bedingt durch einen schweren Herzinfarkt ließ sich Prof. Weimann nach Vollendung seines 65. Lebensjahres emeritieren und übergab seinem Nachfolger, Prof. Wester-Ebbinghaus am 1. Tag des WS 1986/87 ein wohlgeordnetes Institut, das sich unter seiner Leitung strukturell, personell, instrumentell und in der räumlichen Ausstattung sehr positiv entwickelt hatte.

Obwohl der Emeritus Günter Weimann nun in das Heim der Familie im schwäbischen Heidenheim einzog, war die Verbindung zu Braunschweig zunächst noch recht eng, denn das Buch „Architektur-Photogrammetrie“ musste noch vollendet werden und immer wieder war er noch bereit, Geographiestudenten, die vor Jahren bei ihm gehört hatten, zu prüfen.

Aus Anlass seines siebzigsten Geburtstages fand 1991 in der TU ein geodätisches Kolloquium statt. Prof. Jörg Albertz, TU Berlin, hielt eine sehr eindrucksvolle Laudatio und Prof. Armin Grün, ETH Zürich, den Festvortrag mit dem Titel „Von Meydenbauer zur Megaplus. Die Architekturphotogrammetrie im Spiegel der technischen Entwicklung“. Prof. Wolfgang Niemeier brauchte 1996 als Leiter des inzwischen aus den beiden geodätischen Institutionen entstandenen Instituts für Geodäsie und Photogrammetrie einige Überredungskunst, um Prof. Weimanns Zustimmung zu einem weiteren Festkolloquium anlässlich seines fünfundsiebzigsten Geburtstages zu erhalten. Aber dann war dieser doch sehr erfreut über den Vortrag seines ehemaligen Doktoranden Hans Joachim Hellmeier, Vertriebsleiter des Geschäftsbereiches Photogrammetrie, Fa. Carl Zeiss, Oberkochen, über „Die Entwicklung der Photogrammetrie aus Sicht der geräte-/systemherstellenden Industrie“, in der Günter Weimann 45 Jahre zuvor seine berufliche Karriere begann.

Bis heute ist Günter Weimann trotz zeitraubender nichtfachlicher „Nebentätigkeiten“ in seinem Herzen Photogrammeter geblieben, der im April 2001 beim Festkolloquium zu Ehren von Prof. Jörg Albertz in der TU Berlin von zahlreichen Kollegen freudig begrüßt wurde, beginnend mit seinem Doktorvater Prof. Burkhardt bis zu seinem Doktoranden Prof. Ayhan Alkis, dem heutigen Rektor der Yildiz-Universität in Istanbul.

Sie alle und auch der Vorstand der Deutschen Gesellschaft für Photogrammetrie und Fernerkundung wünschen mit mir Günter Weimann nur Gutes für das neue Lebensjahrzehnt.

Dietrich Möller, Braunschweig

Vorankündigungen

2002

18.–23. Februar: International Congress on **GEOMATICA 2002** „Spatial Information to Economic, Social and Environmental Decision Making" in **Havana**, Cuba. Auskünfte durch: GEOMATICA 2002 Organizing Committee. Tel.: +53-7-22 17 94, 23 74 44, 23 41 01, Fax: +53-7-24 28 69, e-mail: geomatica2002@mic.cu, geocuba@teleda.get.tur.cu

11.–13. März: **GIS 2002** in **Le Royal Meredien, Bahrain**. Auskünfte durch: BSE, Tel.: 973 () 727 100, Fax: 973 () 729 819, e-mail: mohandis@batelco.com.bh, www.mohandis.org

17.–20. März: **GITA 2002** Conference XXV in **Tampa, FL**, USA. Auskünfte durch: GITA 2002, Tel.: 1-303-337 05 13, Fax: 1-303-337 10 01, e-mail: education@gita.org, www.gita.org

18.–22. März: **Master-Course LASER RANGING** (LIDAR) in Airborne Photogrammetry and Remote Sensing in **Barcelona**, Spanien. Auskünfte durch Institute of Geomatics, Parc de Montjuïc, E-08038 Barcelona, Tel.: +34-93 567 15 00, Fax: +34-93 567 15 69, e-mail: info@IdeG.es, www.IdeG.es

8.–11. April: **GEOTec Event** in **Toronto**, Kanada. Auskünfte durch: Matt Ball, GEOTec Media, Tel.: 1-303-544-0594, e-mail: mball@aip.com

18.–19. April: The First **International Conference on the State of Remote Sensing Law** in **Oxford**, Mississippi, USA. Auskünfte durch: Ms. Edie King, Tel.: +1-662-915-68 51, e-mail: eking@olemiss.edu, www.olemis.edu/depts/nrsslc

19.–26. April: XII. **FIG Congress** & XV. **General Assembly** in Conjunction with **ACSM-ASPRS** in **Washington, DC.** Auskünfte durch: Markku Villikka, Tel.: +45-3886-1081, Fax: +45-3886-0252, e-mail: fig@fig.net und Mary Clawson, e-mail: Mgclaw@aol.com oder:
Nadine George, 6220 Montrose Road, Rockville, MD 20852 USA. Tel.: 1-301-984-9450, ext.11, Fax: 1-301-984-9441, e-mail: nadineg@conferencemanagers.com

25.–27. April: The First **International Workshop on Future Intelligent Earth Observing Satellites** in **Washington, DC.** Auskünfte durch: Dr. Guoqing Zhou, Tel.: +1-757-683-36 19, Fax: +1-757-683-56 55, e-mail: gzhou@odu.edu, www.fieos.gmu.edu/

25.–27. April: 5th AGILE Conference on Geographic Information Science **AGILE 2002: Towards the European Research Area** in **Palma de Mallorca**, Spanien. Auskünfte durch: Michael Gould, Tel.: +34-964-72 83 17, Fax: +34-964-72 84 35, e-mail: gould@lsi.uji.es, www.agile-online.org/ und http://agile2002.uib.es

8.–9. Mai: **World of Geomatics** in **Donington**, UK. Auskünfte durch: Stephen Booth, PV Publications, Suite L, 17 Park Place, Stevenage, Hertfordshire SG1 1DU, UK. Tel.: 44-1438-352 617, Fax: 44-1438-351 989, e-mail: steve@pvpubs.demon.co.uk

21.–23. Mai: **4. SA*POS*®-Syposium** ‚Satellitenpositionierungsdienst der deutschen Landesvermessung, mit dem Motto: „**SA*POS*® verbindet…**" in **Hannover** . Auskünfte durch den Veranstalter: Die Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV), www.adv-online.de und die Ausrichter: LGN-Landesvermessung + Geobasisinformation Niedersachsen, Dr. Robert Winter, Podbielskistr. 331, 30659 Hannover, Tel.: 0511-64609-131, Fax: 0511-64609-168, e-mail: robert.winter@

lgn.niedersachsen.de, www.lgn.de und IfE-Institut für Erdmessung der Universität Hannover, www.ife.de.

4.–6. Juni: 22nd **EARSeL Symposium and General Assembly: Geoinformation for European-Wide Integration** in **Prag**, Tschechische Republik. Auskünfte durch: Dr. Tomas Benes, UHUL Forest Management Institute, Tschechische Republik. Tel.: +42-0202800121, Fax: +42-0202803371, e-mail: benes@uhul.cz, www.uhul.cz und: Mme. M.Godefroy, Tel.: +33-1-45-56 73 60, Fax: +33-1-45-56 73 61, e-mail: EARSeL@meteo.fr, www.earsel.org/

11.–13. Juni: 3rd International Symposium **Remote Sensing of Urban Areas** in **Istanbul**, Türkei. Auskünfte durch: Prof. Dr. Derya Maktav (Chair), Istanbul Technical University, e-mail: dmaktav@ins.itu.edu.tr, www.ins.itu.edu.tr/deryamaktav oder Prof. Dr. Carsten Jürgens (Co-Chair), Universität Regensburg, e-mail: carsten.juergens@geographie.uni-regensburg.de, oder Prof. Filiz Sunar Erbek (Sekretariat), Istanbul Technical University, Tel.: 0090-0212-2853801, Fax: 0090-0212-5737027, e-mail: fsunar@ins.itu.edu.tr, www.ins.itu.edu.tr/rsurban3

24.–28. Juni: **IEEE/ IGARSS 2002** in **Toronto**, Kanada. Auskünfte durch: Tammy Stein, IEEE Geoscience and Remote Sensing Society. Tel.: +1-281-251 60 67, Fax: +1-281-251 60 68, e-mail: tstein@phoenix.net. Web: www.igrss.org

7.–8. Juli: **Joint ISPRS-ICA Workshop „Multi-Scale Representation of Spatial Data“** in **Ottawa**, Kanada. Auskünfte durch: Prof. Dr. Monika Sester, ikg, Universität Hannover, e-mail: monika.sester@ikg.uni-hannover-de und www.ikg.uni-hannover.de/isprs

9.–12. Juli: **ISPRS Symposium Com. IV: „GeoSpatial Theory, Processing and Applications** und 10. Konferenz **Spatial Data Handling 2002** des Canadian Institute for Geomatics in **Ottawa**. Auskünfte durch: Pres. Dr. Costas Armenakis, Tel.: +1-613-992 44 87, Fax: +1-613-995 41 27, e-mail: armenaki@nrcan.gc.ca, www.geomatics2002.org, http://www.commission4.isprs.org/wg3, oder: Tom Herbert, Tel.: +1-613-224 98 51, Fax: +1-613-224 95 77, e-mail: exdircig@netrover.com, Admin CIG e-mail: admincig@netrover.com, www.geomatics2002.org/

20.–23. August: **ISPRS Symposium Com. II: „Integrated System for Spatial Data Production, Custodian and Decision Support** in **Xian**, China. Auskünfte durch: Dr. Jie JIANG, Tel.: +86-10-68 48 32 18, Fax: +86-10-68 42 41 01, e-mail: isprs2@nsdi.gov.cn oder: Mr. Xinhu CHEN, Tel.: +86-10-68 42 40 76, Fax: +86-10-68 42 41 01, e-mail: isprs2@nsdi.gov.cn, http://isprs2.nsdi.gov.cn/, www.commission2.isprs.org/

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16.–18. September: **ISPRS Symposium Com. VI** in **São José dos Campos**, Brazil. Auskünfte durch: Pres. Dr. Tania Maria

Sausen, Tel.: +55-12-345 68 62, Fax: +55-12-345 68 70, e-mail: tania@ltid.inpe.br, www.inpe.br/isprs/events.htm und www.commission6.isprs.org/

18.–20. September: **EARSeL Special Interest Group on RS for Developing Countries** an der Universität **Bonn** . Auskünfte durch: Tel.: 49-228-729 701, Fax: 49-228-739 702, www.rsrg.uni-bonn.de

24.–26. September: **22. Wissenschaftlich-Technische Jahrestagung der DGPF**
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11.–20. Oktober: **IAF/ COSPAR World Space Congress** in **Houston**, USA. Auskünfte durch: Tel.: +703-264-75 00, Fax: +703-264-75 51, www.aiaa.org/wsc2002/sub/news.html

16.–18. Oktober: **INTERGEO 2002** in **Frankfurt a.M.** Auskünfte durch: DVW-Geschäftsstelle, Leiterin Frau Christiane Salbach, e-mail: christiane.salbach@dvw.de oder DVW-Office@t-online.de, http://www.Intergeo.de

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Buchbesprechungen

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KLAUS SZANGOLIES, Jena

ALBERTZ, JÖRG: Einführung in die Fernerkundung. Grundlagen der Interpretation von Luft- und Satellitenbildern. 2., überarb. u. erw. Aufl. X, 250 S. mit 60 Farb- u. 141 s/w Abb., gebunden. Wissenschaftliche Buchgesellschaft. Hindenburgstr.40, 64295 Darmstadt. DM 68,– bzw. € 34,90. ISBN 3-534-14624-7

Nach der Erstausgabe 1991 unter dem Titel ‚Grundlagen der Interpretation von Luft- und Satellitenbildern' ist nun die zweite – stark überarbeitete und erweiterte – Auflage dieses Standardwerks von Prof. ALBERTZ erschienen. Mit einem Umfang von 250 Seiten will das Buch bewusst nicht mit der Vielzahl vor allem englischsprachiger Fernerkundungsbücher (und der zunehmenden Zahl von Fernerkundungstutorien auf dem www) konkurrieren; es soll vielmehr Neulingen aus verschiedenen Bereichen ohne große Vorkenntnisse den Zugang zur Fernerkundung und Luftbildinterpretation ermöglichen.

Wie schon der Untertitel deutlich macht, bezieht ALBERTZ in stärkerem Maße als andere Autoren neben der Satellitenfernerkundung ausdrücklich auch die Luftbildinterpretation und Orthophotogenerierung ein. Beide stehen im Inhalt etwa gleichwertig nebeneinander.

Das Buch beginnt mit Kapiteln zu physikalischen Grundlagen der Bildentstehung und zur Aufnahmesensorik, wobei auch auf aktuelle Entwicklungen im Bereich der hochauflösenden Satellitenbilddaten sowie auf Radarsysteme und die vom Autor selbst mitgetragene Entwicklung des Dreizeilenkamerakonzepts eingegangen wird. Nach einem Exkurs über die Eigenschaften von

Luft- und Satellitenbildern und einem kurzen Abriss über Möglichkeiten der Bildverarbeitung folgt ein Kapitel ‚Auswertung', welches vor allem auf die visuelle Bildinterpretation, die (Differenzialentzerrung, Stereokartierung und Verfahren der multispektralen Klassifikation eingeht. Ein weites Spektrum von Anwendungsbeispielen, von der Kartographie über Land- und Forstwirtschaft bis hin zur Ozeanographie, runden das Werk ab.

Das Buch gefällt auf Anhieb durch seinen festen Einband und die sehr gute Druckqualität. Dieser Eindruck bleibt beim Lesen dank der guten Verständlichkeit und der sehr anschaulichen Dokumentation mit über 200 teils farbigen Abbildungen immer erhalten. Es kann vor allem Studierenden, aber auch Lehrenden und Praktikern im Gebiet der Geowissenschaften und Geoinformatik mitsamt ihrer vielen Randbereiche uneingeschränkt empfohlen werden.

HANS-GERD MAAS, TU Dresden

AHERN, F.J., GOLDAMMER, J.G. & JUSTICE, C.O., Hrsg. (2001): Global and Regional Vegetation Fire Monitoring from Space: Planning a Coordinated International Effort. 302 S., SPB Academic publishing bv, The Hague, The Netherlands. ISBN 90-5103-140-8

Das Buch mit seinen 13 Beiträgen von international anerkannten Autorenkollektiven gibt auf etwa 300 Seiten einen hervorragenden umfassenden internationalen Überblick über den aktuellen Stand und die zukünftigen fernerkundlichen Aktivitäten im Bereich der Erfassung und Dokumentation von Waldbränden.

In einem längeren Vorwort der Herausgeber wird auf die Bedeutung des 1997 vom Committee on Earth Observation Satellites (CEOS) initiierten Pilotprojekts „Global Observation of Forest Cover" (GOFC) und dessen Einbindung in internationale Programme hingewiesen. In den einleitenden drei Kapiteln formulieren C. JUSTICE & S. KORONTZI, C.W. DULL & B. S. LEE sowie B.J. STOCKS et al. die Wünsche, Anforderungen und Möglichkeiten der integrierten Nutzung verschiedenster fernerkundlicher Daten und Produkte für ein globales Feuermonitoring aus unterschiedlichen Perspektiven.

Der internationale Vergleich von J.M.C. PEREIRA et al. zeigt den operationellen Stand des Feuermanagements mit Fernerkundung anhand von sieben regionalen Beispielen. Abgesehen von der detaillierten Erfassung durch Feuer zerstörter Vegetation in Portugal mit Hilfe von Landsat TM, beruhen in allen anderen Beispielen die Auswertungen auf NOAA-AVHRR Daten, die preiswert, zeitlich und räumlich hoch aufgelöst sind.

In den Beiträgen von J.G. GOLDAMMER und J.-M. GRÉGOIRE et al. wird die regionale Perspektive um eine globale Sichtweise ergänzt und das World Fire Web network vorgestellt. Um die Vorteile der verschiedenen bisher eingesetzten Sensoren zu kombinieren und alle relevanten Fragestellungen von der zeitnahen Erfassung der Feuer bis hin zur Modellierung der verbrannten Biomasse wird ein Multi-Sensor-Konzept vorgeschlagen.

Die Beiträge von E.M. PRINS et al. und C.D. ELVIDGE et al. beleuchten die Möglichkeiten und Limitierungen der operationellen Feuererkennung mit globalen Wettersatelliten (GEOS) und dem Defence Meteorological Satellite Program (DMSP-OLS), das nächtliche Feueraktivitäten beobachten kann. Bei den Abbildungen zum saisonalen Ausmaß der mit dem DMSP-Sensor erfassten Feuer, z. B. in der Sahelzone oder in Australien bekommt der Leser den Eindruck, dass ganze Landstriche innerhalb einer Saison dem Feuer anheim fallen. Hier fehlt m.E. ein Hinweis, dass ein Bildelement mit einer Kantenlänge von z. B. 2.7 km × 2.7 km schon bei einem geringen Anteil als „Feuerpixel" klassifiziert und dargestellt wird, was sicherlich zu einer flächenmäßigen Überschätzung der von Waldfeuern bzw. Buschbränden betroffenen Fläche führt.

Die Beiträge von Z. LI et al. und G. GUTMAN et al. erläutern die Arbeitsschritte und verschiedene Algorithmen zur Detektion von Feuern sowie die in digitalen Archiven verfügbaren Daten der NOAA-AVHRR-Familie, die seit über 20 Jahren mit verschiedenen Sensoren im Orbit ist.

Zum Monitoring verbrannter Oberflächen und dessen Bedeutung geben O. ARINO et al. einerseits eine kurze Übersicht was die verschiedenen Vegetationsindices und die notwendige räumliche und zeitliche Auflösung angeht und andererseits einen Überblick verschiedener operationeller Projekte z. B. aus Italien, Australien, bei denen vor allem SPOT VEGETATION und ERS SAR bzw. ATRS-Daten zum Einsatz kommen.

Die Limitierungen der bisherigen satellitengestützten Systeme liegen vor allem darin, dass diese nur das Auftreten eines Feuers ab einer bestimmten Größe dokumentieren können. Für zukünftige operationelle Systeme, die eine Feuerbekämpfung aktiv unterstützen können, sind weitere aktuelle Informationen notwendig, wie z. B. die Feuerintensität und die genaue Lage (< 500 m) des Feuers. Auf der Grundlage dieser Anforderungen beschreiben und vergleichen D. OERTEL et al. die verschiedenen geplanten Missionen, z. B. die vom DLR entwickelten Sensoren BIRD und FOCUS sowie die europäische Initiative FFEW-FUEGO.

Das abschließende Kapitel des Buches von AHERN et al. fasst die Ergebnisse des GOFC-Workshops 2000 als einen Maßnahmenplan zukünftiger Aktivitäten zusammen, der an alle beteiligten Nutzer, Entwickler und Entscheidungsträger gerichtet ist.

Die Adressaten dieses Buches sind neben Wissenschaftlern und Studenten auch Praktiker und Entscheidungsträger in den Forstverwaltungen weltweit, die sich für die aktuellen und zukünftigen Möglichkeiten der Fernerkundung in diesem speziellen Gebiet interessieren.

Der Herausgeberband zeichnet sich durch renommierte Autorenkollektive und geringe Überschneidungen zwischen den Kapiteln aus. Insgesamt ein sehr informatives, empfehlenswertes und rund um gelungenes Buch

GÖRRES GRENZDÖRFFER, Rostock

PFG-Autorenhinweise

1. Originalbeiträge

Die Zeitschrift der Deutschen Gesellschaft für Photogrammetrie und Fernerkundung PFG „Photogrammetrie · Fernerkundung · Geoinformation“ veröffentlicht Originalbeiträge aus dem Gesamtbereich der Photogrammetrie, der Fernerkundung und Geoinformation.

Die Manuskripte und die Korrespondenz dazu sind zu richten an die Schriftleiter:

– Prof. Dr.-Ing. habil. KLAUS SZANGOLIES, Closewitzer Str.44, D-07743 Jena, Tel./ Fax: 03641-82 22 59, e-mail: Klaus.Szangolies@t-online.de oder:

– Dr.-Ing. ECKHARDT SEYFERT, c/o Landesvermessung und Geoinformation Brandenburg, Heinrich-Mann-Allee 103, D-14473 Potsdam, Tel.: 0331-88 44-113, Fax: 0331-88 44-126, e-mail: eckhardt.seyfert@lvermap.brandenburg.de

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DIETER FRITSCH & RUDOLF SPILLER (Eds.), 2001: Photogrammetric Week '01. 342 S. mit CD ROM. Herbert Wichmann Verlag, Hüthig GmbH & Co. KG, Heidelberg. ISBN 3-87907-359-7

ECKHARDT SEYFERT (Hrsg.), 2001: Vorträge 21. Wiss.-Techn. Jahrestagung der DGPF vom 4. bis 7. 9. 2001 in Konstanz. Publikationen der DGPF, Bd. 10 mit CD ROM, 588 S. ISSN 0942-2870. Zu beziehen durch: Geschäftsstelle der DGPF, c/o EFTAS GmbH, Ostmarkstr.92, 48145 Münster, e-mail: praesident@dgpf.de

JÖRG ALBERTZ, 2001: Einführung in die Fernerkundung. Grundlagen der Interpretation von Luft- und Satellitenbildern. 2., überarb. u. erw. Aufl. X, 250 S. mit 60 Farb- u. 141 s/w Abb., gebunden. Wissenschaftliche Buchgesellschaft. Hindenburgstr. 40, 64295 Darmstadt. DM 68,– bzw. € 34,90. ISBN 3-534-14624-7

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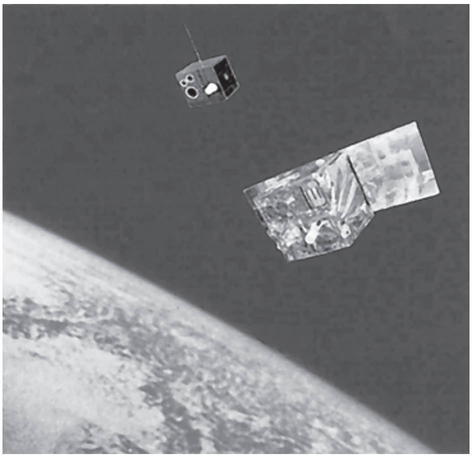
Zum Titelbild

3. IAA Symposium „Kleinsatelliten für die Erdbeobachtung"

des Deutschen Zentrums für Luft- und Raumfahrt (DLR), Institut für Weltraumsensorik und Planetenerkundung, in Verbindung mit der International Academy of Astronautics (IAA) vom 2. bis 6. April 2001 in Berlin.

Sponsoren der Veranstaltung waren außerdem die European Space Agency (ESA) und die Deutsche Gesellschaft für Photogrammetrie und Fernerkundung (DGPF).
In diesem Heft 1/2002 der Zeitschrift PFG werden auf den Seiten 5–62 einige der wesentlichsten Ergebnisse und neuen Erkenntnisse des Symposiums dargelegt.



Im Titelbild sind die zwei Satelliten DLR-TUBSAT (unten) und BIRD (Mitte) schematisch dargestellt.