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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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