A MICRO SATELLITE OCEAN COLOUR IMAGING MISSION

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ABSTRACT

Only few space missions are in orbit or planned which are dedicated to scientific objectives which are related to ocean colour imaging. For systematic Earth monitoring of ocean regions and for the scientific investigation of ocean parameters a global coverage and an high time coverage of ocean colour data are required. The paper describes one of the possibilities to supplement the consisting or planned ocean remote sensing experiments or missions with a micro satellite mission for ocean colour imaging. In difference to other missions with similar objectives the described mission follows strictly a design-to-cost philosophy. One of the main cost driver of each space mission, the launch, will be defined as piggyback launch. So the total mission cost can be kept low. This paper should give a feeling about the feasibility of an ocean colour imaging mission by means of a micro satellite. The proposed mission is the result of a study work and not yet in preparation. Basing on the scientific objectives a 8 channel wide-angle imaging instrument suitable for micro satellites is proposed in this paper. The designed micro satellite for a low Earth orbit is characterized by a three-axis stabilization, a size 450mmx450mmx600mm and a mass of about 50kg.

KURZFASSUNG

Im Orbit oder in der Planung sind nur wenige Weltraummissionen, die auf wissenschaftliche Ziele der Ozeanfernerkundung spezialisiert sind. Für die systematische Erdbeobachtung von Ozeanregionen und für die wissenschaftliche Untersuchung von Ozeanparametern sind eine globale Deckung und eine hohe zeitliche Auflösung gefordert. Der Beitrag beschreibt eine der Möglichkeiten um die bestehenden oder geplanten Ozeanfernerkundungsexperimente oder -missionen mit einer Mikrosatellitenmission für die multispektrale Ozeananalyse zu ergänzen. Im Unterschied zu anderen Missionen mit ähnlichen Zielen folgt die beschriebene Mission einer strengen kostenorientierten Entwurfsphilosophie. Einer der Hauptkostentreiber jeder Weltraummission, der Start, wird als piggyback-Start definiert. So können die Gesamtkosten niedrig gehalten werden. Der Beitrag soll das Gefühl der Machbarkeit einer multispektralen Ozeanmfernerkundungsmission mit Hilfe eines Mikrosatelliten geben. Die vorgeschlagene Mission ist das Ergebnis einer Studienarbeit und befindet sich gegenwärtig nicht Vorbereitung. Ausgehend von den wissenschaftlichen Zielsetzungen wird eine 8-Kanal-Weitwinkelkamera vorgeschlagen, die für Mikrosatelliten geeignet ist. Der entworfene Mikrosatellit für einen niederen Erdorbit ist durch eine 3-Achsen-Stabilisierung, einer Größe von 450mmx450mmx600mm und einer Gesamtmasse von 50kg charakterisiert.

1. INTRODUCTION

Ocean colour imaging measurements are used to study

- the marine productivity,
- the distribution of suspended matter within the ocean,
- the distribution of chlorophyll,
- the marine pollution especially at coastal-zones,
- the coastal-zone water dynamics like eddies, current etc.
- or other ocean biological parameters.

For systematic Earth monitoring of ocean regions a global coverage to monitor the parameters above is required. This should be both in real-time for operational applications (e.g. detection of coastal pollution) and on time scales characterize the ocean variability. For ocean colour measurements sensors with a high spectral resolution within the VIS/NIR wavelength range and a poor spatial resolution are required. Further required characteristics of a dedicated sensor system are

- a lot of different narrow spectral bands,
- a high signal-to-noise ratio within all spectral bands,
- no blooming effect,
- low polarization sensitivity,
- high dynamic range or high saturation level,
- no saturation at land surfaces
- strong support of the atmospheric correction of the signals.

Basing on the scientific objectives and the defined orbit parameters a technical instrument solution is proposed with the following characteristics:

- ocean colour imager in pushbroom mode
- 7 spectral channels, one of them redundancy, and 1 polarization channel
- sensor temperature feedback control
- on board analog processor with additive and multiplicative correcting capability
- high dynamic range by on board correction of dark signal, channel offsets and PRNU
- high Signal-Noise-Ratio due to macropixel generation
- integration time control
- electronic zoom by macropixel control
- capability of electronic windowing of Field-of-View to reduce data rates at zoom

and other features.

2. MISSION OBJECTIVES

The mission objectives are determined by the investigation of ocean color related phenomena of the oceans. It should support the study of the relationship between the ocean dynamics, the whether and the climate. A further characteristic of this mission are the secondary mission objectives (tab. 1.)

Tab. 1: Mission Objectives

Mission Objectives	
Primary objectives	• to map the pigment distribution in ocean regions • to study the marine productivity and the dynamics of meso-scale eddies • to study the influence of atmospheric aerosol on remote sensing
Secondary objectives	• to study the polarization properties of ocean and atmosphere • to study local ocean related weather phenomena without delay

The secondary objectives require two special features:

- the special feature of the instrument to measure the polarization of the reflected light from the ocean
- and the fast data distribution to the scientific user.

3. LAUNCH SYSTEM

The mission should be characterized by a piggyback low-cost launch. For this reason the micro-satellite must be compatible to the auxiliary payload adapter of several launcher: Ariane(A.S.A.P.), Zenith, Zyklon, Cosmos, PSLV; Delta II and other.

4. ORBIT DEFINITION

Baseline for the mission design is the piggyback opportunity. The orbit can not be selected from the scientific point of view only. For the launcher selection it is better to define a range of possible orbit altitudes and inclinations. For instance for the access of the satellite by a German ground station the inclination should be more than 53°. A optimum orbit altitude would be 600km. The coverage with the ocean color imager (FOV=60°) within a 600km Sun-synchronous orbit of one day is shown in fig. 1. But the satellite design should also take into account the compatibility to other orbits depending on a convenient launch opportunity.

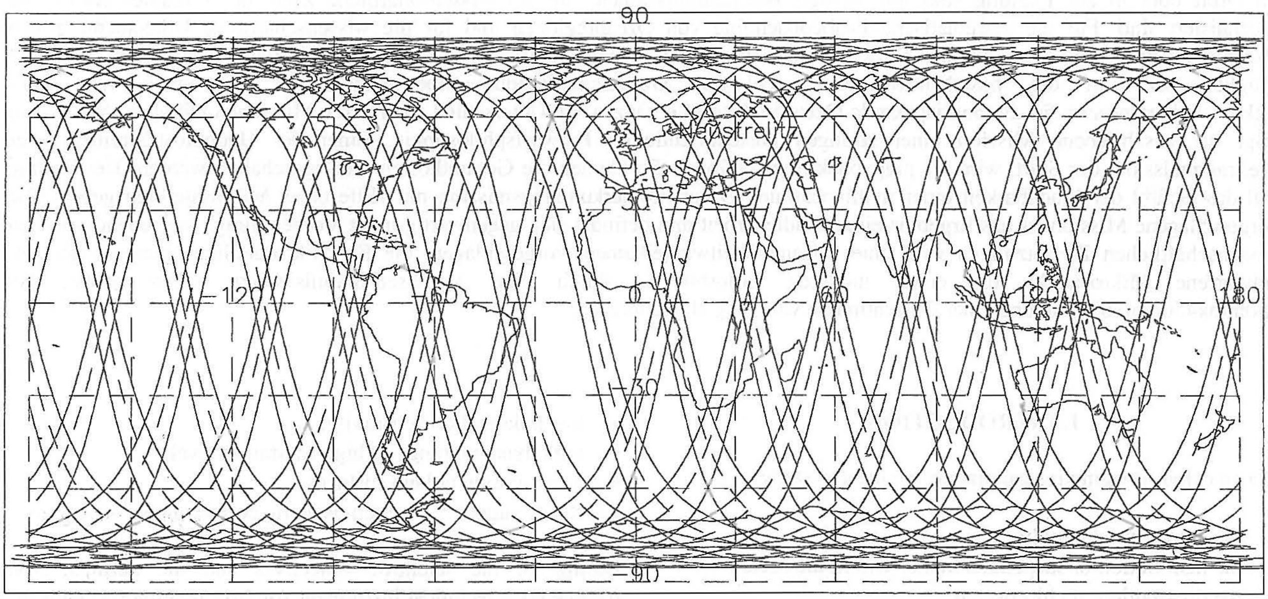

Fig. 1: Coverage of one day by the ocean color imager (FOV = 60°) within the 600km x 600km circular Sun-synchronous orbit

5. SPACE SEGMENT

5.1 Payload

The payload follows the mission objectives in tab.1. There will be two payload devices:

- an ocean colour imager
  to collect multispectral data according to the scientific objectives and
- a GPS receiver
  to support (in combination with the attitude information of the spacecraft from the AOCS) the fast and distributed data processing for the study of local ocean related weather phenomena.

The basic payload parameters are according to the Announcement of Opportunity for the Ocean Colour Imager of the ROCSAT-1 Mission (NSPO, 1992). The baseline for the proposed payload was developed by the German Institute for Space Sensor Technology of DLR (Sandau, 1993). It was called Wide-Angle Ocean Colour Camera (WAOCC). Some characteristics are summarized in tab. 2.

The GPS receiver is an additional payload of the micro satellite. It should give the position and time of the collected data as auxiliary data without delay. The GPS data and the attitude data of the satellite will be transmitted to ground together with the payload data for a fast and distributed ground data processing.

Tab. 2: Major technical and performance data of the WAOCC instrument

Parameter	Data
Field of View	60°
Dynamic Range	11bit
max. Power Consumption	≤ 20W
max. Mass	≤ 12kg
mounting accuracy	< 0.3 deg per axis
mission life - on the shelf - in orbit	1 year 2 years
camera reliability	0.95
polarization sensitivity - without corr. -with correction	≤ 5% < 2%
Absolute radiance accuracy	≤ 5%
relative precision	≤ 1% non-linearity
band-to-band precision (relative)	≤ 5%
Spectral bands: blue: chlorophyll absorption bluegreen: pigment absorption green: chlorophyll absorption yellow: hinge point/sediment red: aerosol correction NIR: aerosol correction	 433-453nm 480-500nm 500-520nm 2x 545-565nm 2x 660-680nm 845-885nm

5.2 Spacecraft bus

The micro satellite mission is characterized by a three axis stabilized satellite with a size of 450mm x 450mm x 550mm and a mass of 50kg for a 600km circular orbit. The satellite has a duty time of 9:00 to 15:00 local time and is able to store 0,5Gbit on board. A data compression is foreseen to collect data from 2 orbits and send it down to a ground station. The special micro satellite design should be compatible to other orbits with slight modifications of the bus. The availability of a piggyback launch is an important design driver for the spacecraft. The proposed spacecraft design should be a first approach to these requirements. Tab. 3 gives a summary to the spacecraft configuration. The main body is a cubic box compatible to most of the launch adapters for secondary payloads. 3 sides of the spacecraft are completely covered with solar arrays and 1 side bears the instrument and antenna platform. The remaining 2 sides are occupied by solar arrays and radiators.

5.3. Spacecraft configuration

The spacecraft represents a micro satellite design with a mass of 50 kg within a volume of 130 dm³. Due to the operation constrains one of two opposite sides of the rectangular solid carries the main payload oriented to the Earth and the other the solar panel system oriented to the Sun (see fig. 3). To reach the required solar radiant area two side walls will be deployable from the launch configuration (fig.2) to the flight position as shown in the figure 3. So an solar cell area of about 0.65 m² is available after deployment.

The spacecraft structure mainly consists of the front and the back instrument plates (reinforced carbon fibre construction) connected by 6 cylindrical supports. The instrument units mounted between are attached to each of the instrument plates. So a rigid core compartment of the satellite can be built.

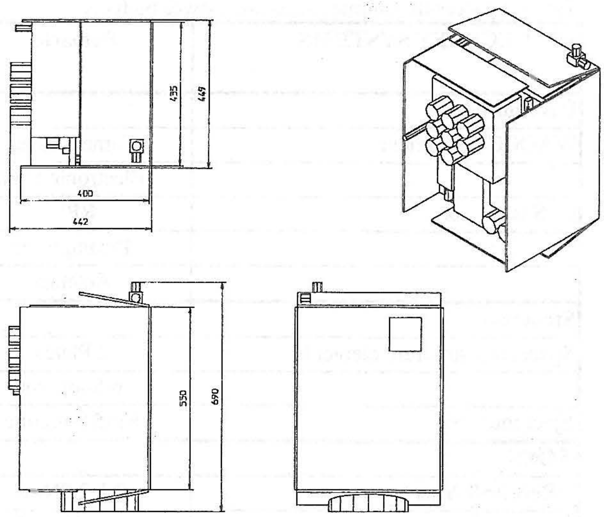

Fig.2: Launch configuration of the micro satellite

The eject adapter is fixed on the below front of this part to spread the launch loads to the structure elements. Also on this side and on the top the heat radiators are foreseen shadowed from sun light by the small solar panels for the initialization of S/C-positioning and emergency modes.

The arrangement of the payload and bus units can be taken from the figures 4 and 5.

The solar panels are based on self-sustaining structures. The completed bonnet-shaped system will be integrated on the spacecraft after surrounding with multi-layer-insulation (not shown in the figures).

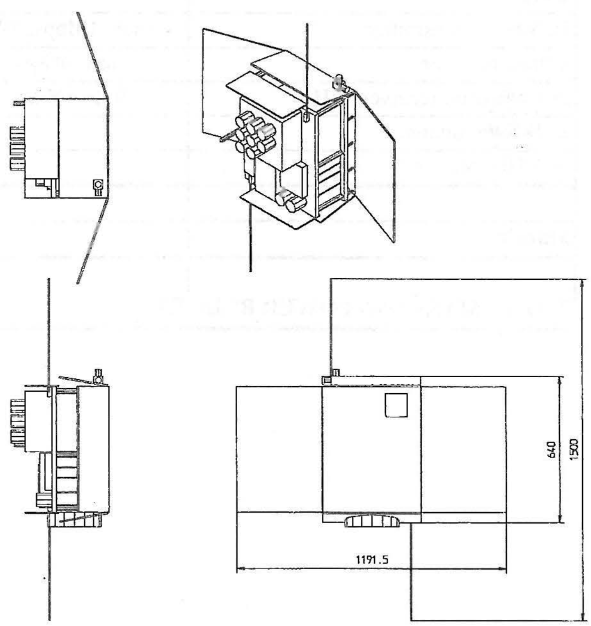

Fig.3: Flight configuration of the micro satellite

Tab.3: Spacecraft volume, mass and power budgets

SPACECRAFT SYSTEMS	Remarks	Dimensions mmxmmxmm	Mass kg	Power W (peak)	Power W (avg.)	Duty
Payload						
WAOCC instrument	Camera Head	265x268x167	5,0	18,0	4,5	0,25
	Electronic Unit	265x268x160	4,0			
GPS Receiver	RPU	127x241x56	1,6	3,5	0,9	0,25
	Preamplifier	97x83x12	0,2			
	Antenna	96x102x13	0,2			
Structure						
Spacecraft structure elements	2 Plates	435x550x20	4,0			
	6 Supports	dia.22x160	2,0			
Eject interface	Ring Structure	dia.240x60	2,0			
AOCS						
3 Reaction Wheels	0,1-2,0Nms	70x80dia.	3,0	3,0	3,0	1,00
3 Magnetic Torquer	max.15Am2	400x18dia.	1,2	4,8	0,5	0,10
Star Sensors	Sensor Head	80x80x45	0,5	1,0	1,0	1,00
	Electronic Unit	120x80x40	0,5			
Magnetometer		60x60x120	0,4	2,0	2,0	1,00
Gyro-Assembly		120x120x120	2,0	2,0		
Power System and Harness						
Solar Arrays (GaAs: 0,53m2)	3 plates	400(435)x550	3,0			
2xNi-Cd battery pack, 28V	2 x 2,4A-hrs	226x160x60	4,8			
Power regulation			1,9	8,0	2,0	
Power control unit		300x300x40	1,5	14,0	5,0	
Wiring mass			1,0		0,0	
Thermal Control System						
MLI, Coating			0,5			
Radiators	2 Plates	160x380	0,5			
OBDH						
2x DPU + Mass memory	0,5Gbit	200x160x40	1,5	6,0	6,0	1,00
TT&C						
2x S-band transmitter	max. 1Mbps, 5W	150x86x35	1,0	22,0	5,5	0,25
S-band receiver	max. 4kbps	170x150x40	1,0	2,8	0,3	0,10
2x Command receiver (UHF)	150 to 400Mhz	135x165x32	1,8	0,7	0,2	0,25
2x S-band antenna		dia.63x70	0,3			
2x UHF antenna		dia.7x500	0,8			
Margin			1,9	3,0	2,5	1,00
TOTAL MASS AND POWER BUDGET			**48,0**	**90,8**	**33,3**	

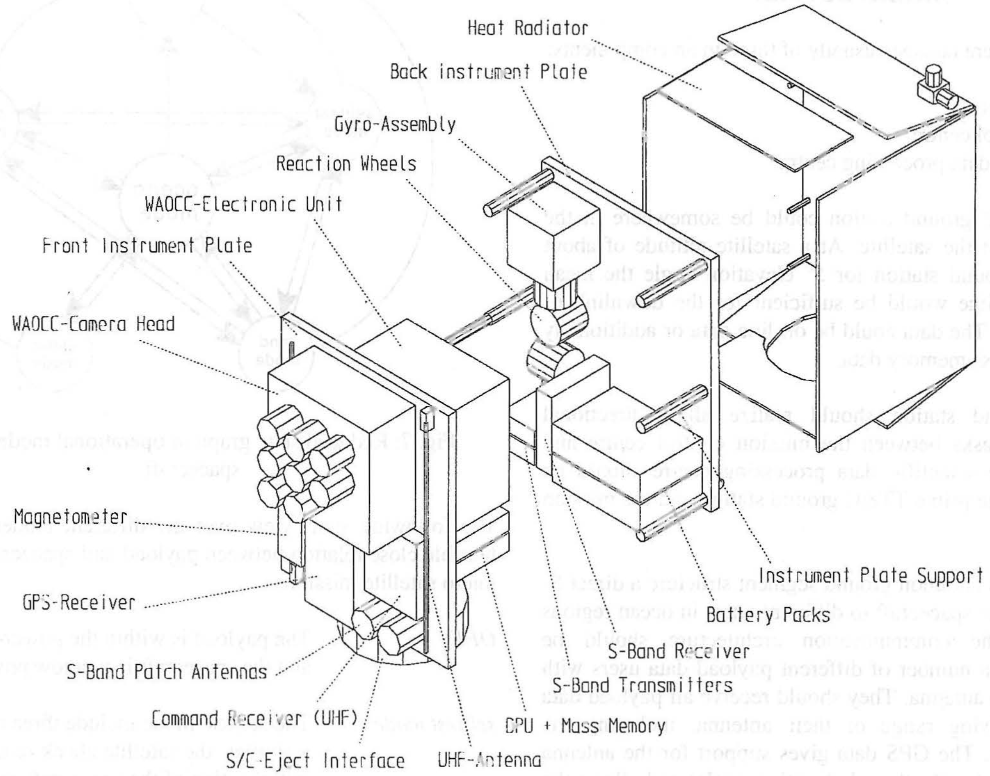

Fig.4: Integration scheme I of the micro satellite

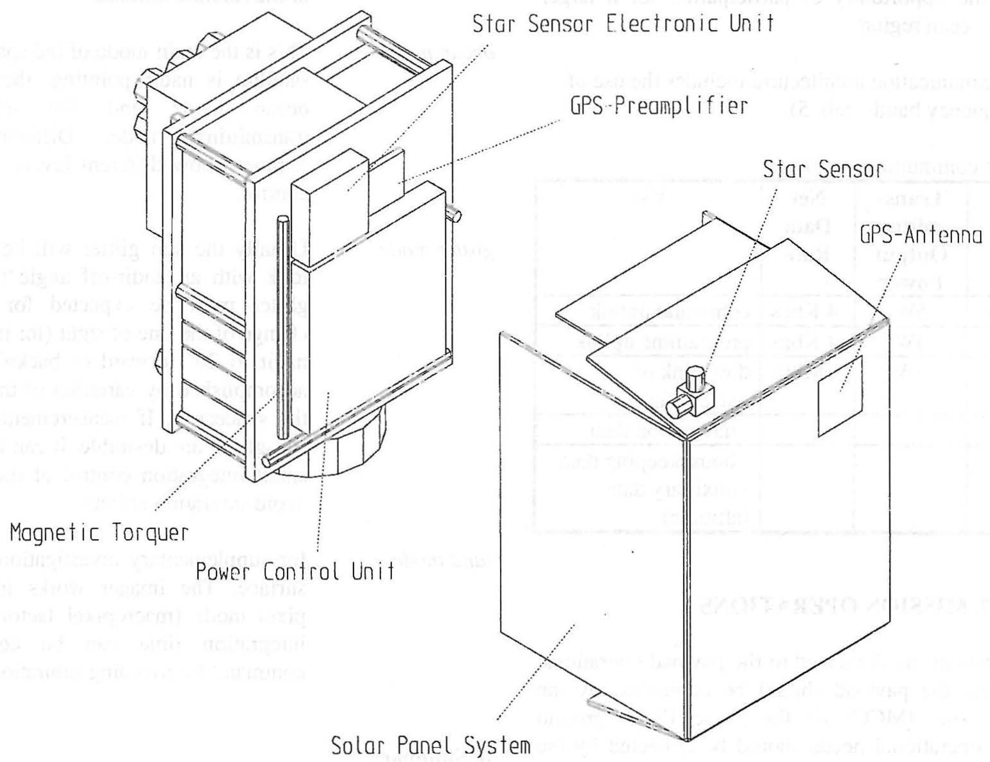

Fig.5: Integration scheme II of the micro satellite

6. GROUND SEGMENT AND COMMUNICATION ARCHITECTURE

The ground segment consists usually of three main components:

the ground station(s),
the mission control centre,
and the scientific data processing centre.

The prime TT&C ground station could be somewhere in the coverage range of the satellite. At a satellite altitude of about 600km and a ground station for 5° elevation angle the mean ground contact time would be sufficient for the downlink of compressed data. The data could be on-line data or additionally the half of the mass memory data.

The main ground station should realize all bi-directional communication tasks between the mission control centre and the satellite. The scientific data processing centre should be connected with the prime TT&C ground station and the mission control centre.

Additional to this common ground segment structure a direct S-band link from the spacecraft to different users in ocean regions is proposed. The communication architecture should be characterized by a number of different payload data users with their own S-band antenna. They should receive all payload data within the receiving range of their antenna, including the current GPS data. The GPS data gives support for the antenna steering (update of azimuth and elevation angle) and allows the immediately processing of the data by a distributed user community. One advantage consists in the possibility to study the local ocean related weather phenomena without delay. A further advantage consists in the simplification of the data distribution and the opportunity of participation for a larger community in the ocean region.

The proposed communication architecture includes the use of the following frequency bands (tab. 5).

Tab. 5: Use of the communication bands

Band	Frequency	Transmitter Output Power	Net Data Rate	Use
UHF	401Mhz	5W	4 Kbps	command uplink
S	2,1Ghz	5W	4 Kbps	programme uplink
	2,2Ghz	5W	1Mbps	downlink of - scientific data
				- navigation data
				- housekeeping data - auxiliary data (attitude)

7. MISSION OPERATIONS

The mission operations are dedicated to the payload operations. The spacecraft and the payload should be controlled by the mission control centre (MCC) via the prime TT&C ground station only. All operational needs should be collected by the MCC which will establish the mission operations plan.
The mission operations are characterized by 5 operation modes of the payload and spacecraft (fig. 7).

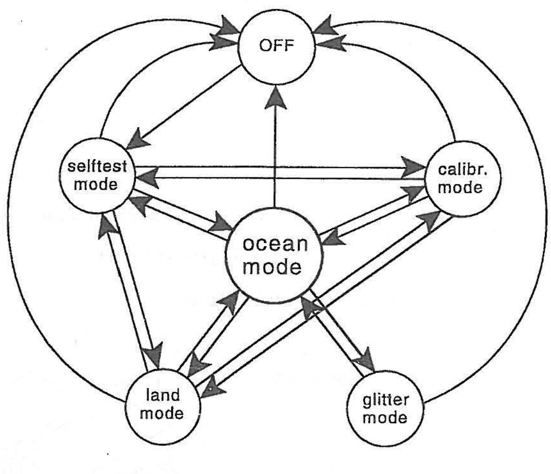

Fig. 7: Reduced state graph of operational modes of the spacecraft

The following short view over the different modes shows the feasible close relation between payload and spacecraft mode for micro satellite missions.

OFF — The payload is within the power-off mode and the spacecraft is in a low power mode.

selftest mode — The selftest mode include three main activities: the satellite check-out, the initialization of the spacecraft and the check-out and initialization of the payload.

calibration mode — The imager payload looks to the dark sky and to certain calibration areas by changing of the satellite attitude.

ocean mode — This is the main mode of the spacecraft. The satellite is nadir pointing, the payload in ocean mode and the telemetry in transmitting mode. Different payload regimes allow different levels of parameter control.

glitter mode — Usually the sun glitter will be avoided by look with an nadir-off angle (20°), if sun glitter must be expected for nadir. The change of the line of sight (for instance from nadir to 20° forward or backward) will be accomplished by variation of the attitude of the spacecraft. If measurements within the sun-glitter are desirable, it can be done by a smart integration control of the payload to avoid saturation effects.

land mode — for supplementary investigation of the land surface. The imager works in the single pixel mode (macropixel factor=1) and the integration time can be controlled by command for avoiding saturation effects.

8. Summary

- Other proposed ocean color imaging experiments or missions could be supplemented by a dedicated ocean color imager micro satellite mission. In combination with these missions it should give a special support for the investigation of time related ocean phenomena. The time coverage and the area coverage can be improved essentially by addition of the proposed mission.

- A dedicated spacecraft design, driven by the scientific objectives, the orbit, the instrument and the launcher requirements leads to the result, that a micro-satellite mission with the proposed ocean color imager WAOCC [2] seems to be feasible (spacecraft mass <50kg, dimensions less then 500mmx500mmx650mm). A main advantage of the micro satellite solution consists in the low launch costs as a secondary launcher payload.

- One of the peculiarities of the presented mission is the planned opportunity of the direct reception of the ocean data by users without delay. The single data user needs a steerable S-band antenna, a S-band receiver and data processing and archiving hard- and software. The hardware can be a PC in the most simple case and the software for antenna steering and data processing should be standardized in the user community.

- The received GPS-data by the satellite will be used for transmission of the ephimeris data to the user. Additional the attitude data can be transmitted. Then the user can they use for geo-referencing or geo-coding of the received ocean data. In this case the user data processing is completely independent from the payload control centre and other payload ground stations.

- The presented paper should give a feeling about the feasibility of an ocean color imaging mission by means of an micro-satellite and should show, that a possible implementation can fill up some gaps in the area and /or time coverage of the other existing and planned space remote sensing systems for ocean research.

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