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POMS, POLAR METEOROLOGICAL SATELLITE, A CONTRIBUTION FOR GLOBAL RADIATION BUDGET MEASUREMENT

Jurgen Puls

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16. Abstract

This paper gives a proposal for a climate research mission specialized to Earth radiation budget measurements. This requires daily global coverage established by a system of three orbiting satellites. One of them is represented by the ESA-satellite SEOCS, that is on a drifting orbit with respect to the sun with 57° inclination. The two others are polar orbiting satellites, POMS. An orbit selection is elaborated for them attended by the description of the technical concept.

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POMS, POLAR METEOROLOGICAL SATELLITE, A CONTRIBUTION TO THE MEASUREMENT OF THE GLOBAL RADIATION BUDGET /94*

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Summary: The present paper gives a proposal for a climate research mission specialized to Earth radiation budget measurements. This requires daily global coverage established by a system of three orbiting satellites. One of them is represented by the ESA-satellite SEOCS, that is on a drifting orbit with respect to the sun with 57° inclination. The two others are polar orbiting satellites, POMS. An orbit selection is elaborated for them attended by the description of the technical concept.

1. INTRODUCTION

At the urging of German meteorologists the DFVLR has worked out a concept for a small meteorological satellite, POMS (polar meteorological satellite) and has investigated a mission for measuring the global radiation budget in polar orbit over a time span of 3 to 5 years [1].

The present work treats the mission concept with reference to

- the payload side requirements
- the choice of orbit and orbit analysis as well as
- the satellite systems.

Here the following starting conditions shall be taken into account:

* Numbers in margin denote pagination of original foreign text

1. The mission is considered as a polar addition mission to a design, investigated for the ESA, SEOCS (Sun-Earth observatory and climatology satellite) [2,3].

2. Taking into account the mission requirements, the satellite shall be built up from cost-effective system components so that the total cost shall remain below those estimated for the satellite SEOCS.

The proposed radiation budget mission includes the simultaneous operation of 2 satellites which travel in polar orbits with nodes displaced from one another by 90^{o}.

Together with the SEOCS located on a drifting orbit of 57^{o} global coverage is achieved twice daily.

2. GOAL OF THE MISSION

Within the framework of the "Global-Atmospheric Research Program" (GARP) problems of climatic research are treated to an increasing degree [4]. In this way it shall be achieved that those mechanisms which generate and determine the climate of the earth and its changes, shall be understood better than before. Here the components surface of the land, oceans, atmosphere, cryosphere as well as biomass are considered in their mutual coupling by physical processes (transport processes, thermodynamics, etc.) as a total system. The state of this "climatic system" depends not only on the external, but also on the internal influence quantities whereby the external ones as compared to the internal ones change only slowly. The question whether changes of external parameters or the statistical influence of rapidly changing internal parameters accidently leads to changes in climate, has not been decided to date. Figure 1 presents today's concepts with respect to the climate system. It shows the most important external and internal processes as well as the direction of couplings.

The solar radiation M_1 incident on the earth is the most important energy source for the climatic events. In an energy equilibrium the energy provided by the sun, averaged with respect to time, must again be given up to space in the form of radiation; thus the global radiation budget must be equalized.

The radiation flux earth-space is composed of the reflected and the scattered radiation portion M_R of solar origin and the thermal self-radiation from earth and atmosphere M_E. Thus the global radiation budget can be represented by the relation

$$Q = M_1 - (M_R + M_E).$$

The longterm course of the radiation budget, averaged over a year, makes possible first suggestions with respect to the state of the climate system, whereby observations over a time span of about 30 years are considered to be necessary in order to be able to recognize trends in potential climate changes [4].

/95

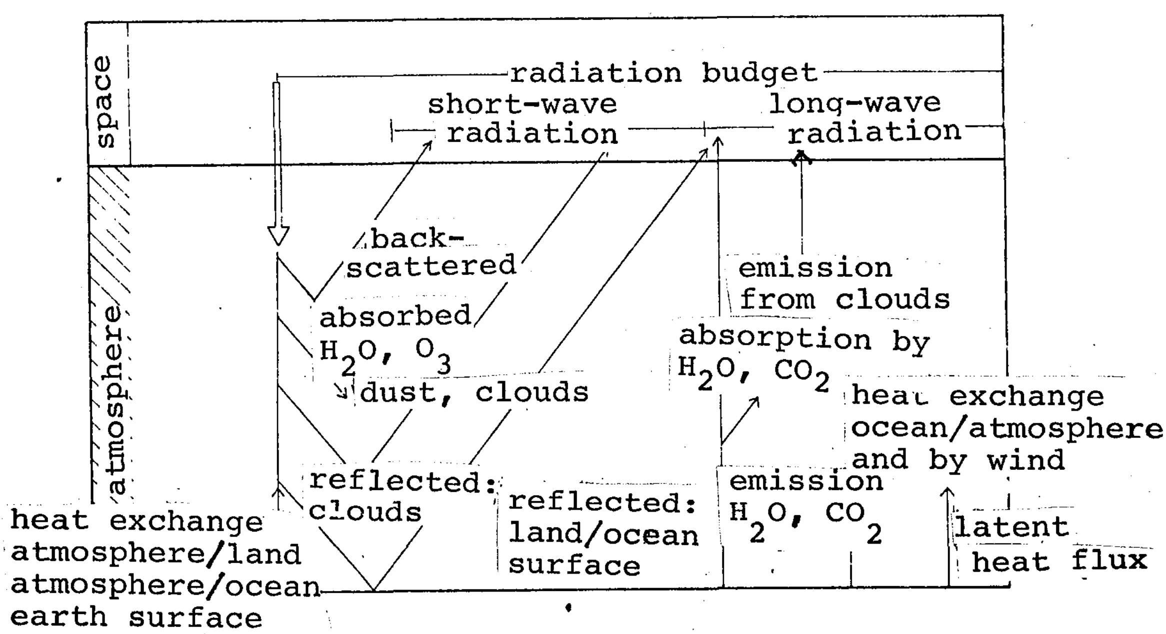

Figure 1: Components of the global radiation budget. Systematic representation of the coupling in the climate system (by means of arrows)

The radiation budget which is absorbed by the system earth-atmosphere and which serves to drive the atmospheric circulation and to maintain life processes in the biomass, is described by the portion

$$M_I - M_R.$$

The short-wave solar radiation M_R, reflected and back scattered into space, is affected by clouds, aerosols, and the molecules of the components of the air as well as by the condition of the surface of the earth. In a similar way the troposphere contributes to the long-wave emitted radiation portion M_E.

This state of affairs makes clear that the components of the global radiation budget can always be exposed to short-term as well as to long-term time- and space fluctuations, which additionally can be affected anthropogenically. Here we have two examples from cloud physics:

- the origin of clouds depends essentially on the presence of suitable condensation nuclei. Here anthropogenic aerosols can serve as condensation nuclei.

- The reflection properties of clouds are influenced, besides the type of clouds and their geometry, by the concentration of the anthropogenic aerosols contained in them.

With the present state of knowledge it is difficult to determine how changes of one component of the radiation budget affect the others and how this affects the global budget as a whole. Basically it is conceivable that, despite equalized total budgets, changes can occur in individual components which lead to local climate changes.

The discussion conducted to date concerning a long-term climate research program allows us to recognize two possible partial goals which can be achieved in steps with the aid of space travel technology:

1. Continuous measurement of the global and regional energy budget over a time span of about 30 years. An absolute measuring accuracy of 0.1% is required.

For this it is necessary to develop climate models with which the effect of changes of individual radiation budget components on the total climate system can be described. The verification of these models with the aid of space experiments requires a measuring accuracy which, in the light of present experiences, can only be achieved by the simultaneous use of several satellites. A more exact understanding with respect to the time fluctuations of the radiation budget components as well as their dependence on the angle can help to keep the measuring expenditures small through the use of suitable strategies. These are being developed at the present time in preliminary investigations concerning the usefulness of individual measurements.

2. Observations of the components of global and regional radiation budget with suitable space and time resolutions over a time-span of at least five years. Recognizing the effect of the sun spot activities. Required accuracy of measurement: 0.5% absolute.

These measurements will make a contribution to local and regional climate research. Here also the required accuracy of measurement will be achieved through simultaneous operation of several satellites.

The results of this program should also find application within the framework of the international regional planning, such as aid to developing countries.

3. PAYLOAD

To achieve the defined mission goals the following scientific individual tasks must be solved by the POMS mission:

A. Measurement of the solar radiation, resolved spectrally and with respect to time. /96

B. Measurement of the radiation reflected and scattered from the surface of the earth and the atmosphere, absolute as well as local, resolved with respect to time and spectrally. Investigation of the dependence on angle.

C. Measurement of the thermal radiation emitted from the surface of the earth and the atmosphere, absolute as well as local, resolved with respect to time and spectrally. Determination of the dependence on angle.

Here sun- and earth observations must be made simultaneously.

For global daily coverage of the surface of the earth both require two satellites, traveling simultaneously in polar orbits.

For the conduct of these individual measurements the climate researchers thus shows for the POM mission the following payload package which is also a part of the SEOCS payload [2]:

- pyrheliometer,
- pyranometer,
- pyrradiometer,
- conical scanradiometer.

The specifications of the individual instruments are listed in table 1. Their schematic representation is taken from the SEOCS study [2] resp., for the conical scan radiometer, the phase A-study [4] of the Dornier System Co. (figure 2a to d).

Radiation budgets are measured conventionally in the visible and the infrared region with radiometers. These generally consist of a hollow cavity with radiation absorbing walls. This is being heated by the incident radiation and the increase in temperature is measured. It is therefore important to state in advance a maximum allowable temperature gradient on the wall of the hollow cavity as well as a temperature level known accurately through calibration before the measurements are made. The opening of the hollow cavity is laid out in such a way that scattered light can not enter readily.

The measured radiation intensity can then be determined by the following relation:

Table 1: Specifications of the POM Instruments

	conical scan radiometer	pyrheliometer	pyranometer	pyrradiometer
measuring principle	conical scan: rotating mirror and "rocking" mirror, semiconductor detectors	measurement of the heating of the hollow cavity by means of solar radiation	heating of a hollow cavity, absolute measurement	heating of a hollow cavity, absolute measurement
field of view	2.5° sensor, 160° scan angle	10° full cone	136° full cone	136° full cone
range of wave length	3.5 µm to 72 µm +4 partial regions 0.3 µm to 3.5 µm +4 partial regions	unlimited	0.2 µm to 4.0 µm	unlimited
dimensions	sensor: 60 cm Ø x 45 cm electronics: 20 x 20 x 20 cm	sensor: 15 x 19 x 20 cm electronics: 15 x 15 x 25 cm	sensor: 20 x 20 x 15 cm electronics: 15 x 15 x 25 cm	sensor: 20 x 20 x 15 cm electronics: 15 x 15 x 25 cm
weight	sensor: 30 kg electronics: 10 kg	sensor: 4 kg electronics: 3 kg	sensor: 4 kg electronics: 3 kg	sensor: 4 kg electronics: 3 kg
power pickup	51 W	2 W	3 W	3 W
data transfer rate	6.9 kbit/s	14 bit/s	14 bit/s	14 bit/s
mechanisms	BAPTA "rocking" mirror	2 shutter, swivel carriage	2 shutter, drive for collimator	2 shutter, drive for collimator
mission profile	continuous	operation during sun acquisition	continuous	continuous
scientific task	meas. of the reflected solar radiation in 5 wave length ranges; meas. of the thermal radiation emitted from the earth in 5 wave length ranges	measurement of the solar constant with an accuracy of ± 0.1 %	measurement of the solar radiation reflected and scattered from the earth	measurement of the total radiation emitted from the earth

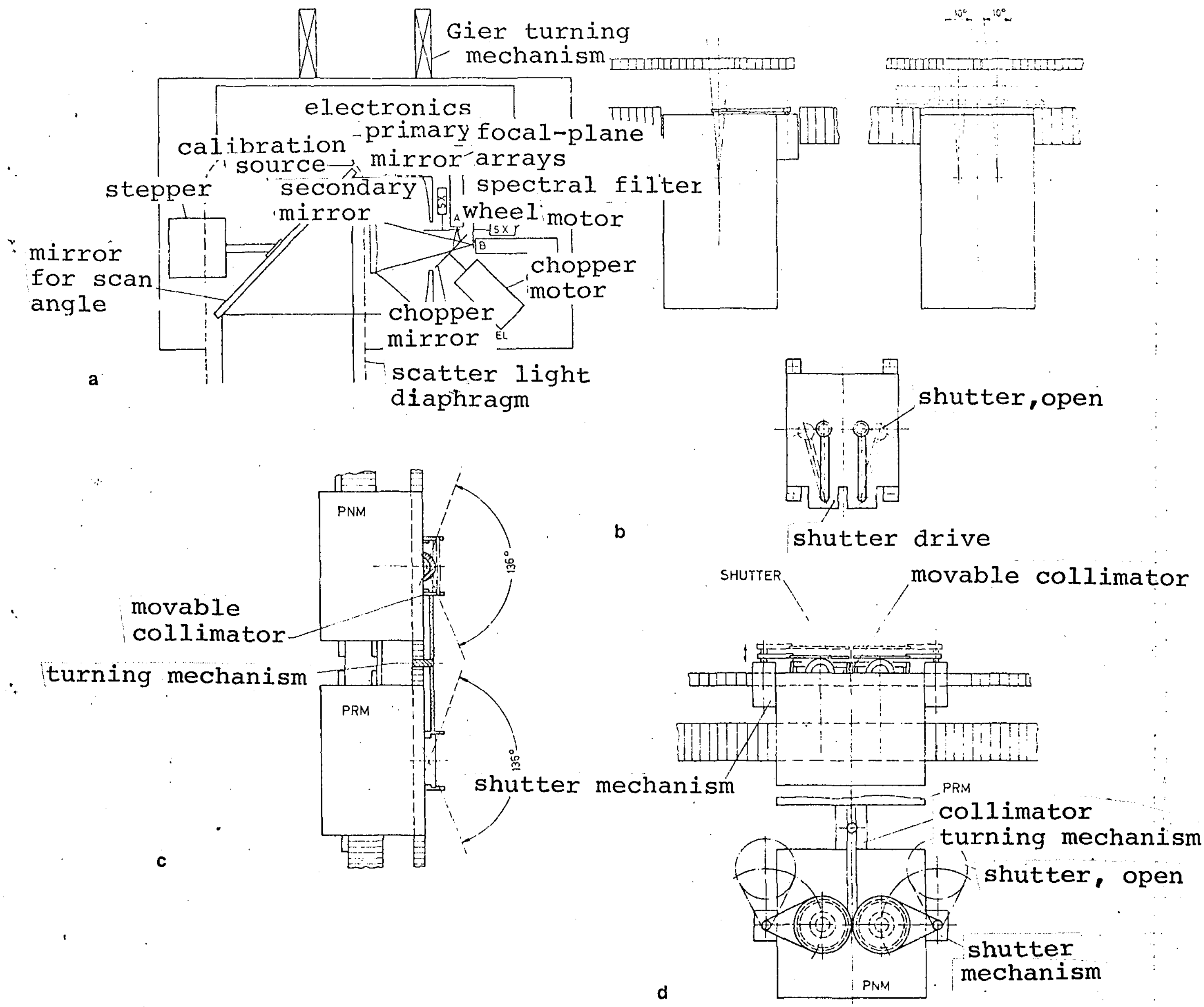

Figure 2: Schematic representation of the POM instruments
a) conical scan radiometer, b) pyrheliometer,
c) pyranometer and pyrradiometer, d) pyranometer

$$I_m = I_{eff}\{1 + \alpha[(d_1/d_0)^2 - 1]\}$$

with I_{eff} = effective radiation intensity
α = scatter light factor
d_1 = limiting aperture
d_0 = inlet pupil.

The above named individual measurement "A" is made with the pyrheliometer. It measures the total radiation incident upon the earth. Its spectrum is subdivided into the four partial ranges

0 - 0.33 µm
0.33 - 1.10 µm
1.10 - 2.50 µm
2.50 - ∞ µm.

In such radiometers the received radiation intensity is determined by the heating of the hollow cavity. Before installation in a satellite the instrument must be calibrated on the ground with an absolute radiometer.

Scatter light effects provide the greatest contribution to measurement error. Therefore an attempt must be made to measure the scatter light factor α directly. This can be done in a simple way in a laboratory by directing a laser beam of known intensity in such a way upon the edge of the receiver aperture that no direct light hits the hollow cavity detector. Then the hollow cavity is replaced by a silicone detector and the intensity I_{St} of the laser radiation scattered at the aperture is measured:

$$\alpha = \frac{1 - I_{St}}{I_{St}[(d_1/d_0)^2 - 1]}.$$

The measurement task listed under "B" is fulfilled jointly by the pyranometer and pyrradiometer:

The pyranometer measures either the radiation portion M_R reflected from the earth or the scattered portion M_E. By suitable choice of the color for the hollow cavity wall resp., the filter properties of the optic installed in front of it, it can be determined which of the two radiation portions is being measured. As an example, M_R is selected by concentrating on the portion of the spectral range from 0.2 μm to 0.4 μm. Thus the radiation intensity is found in the range 0 - 500 Wm^{-2}. The total radiation portion is measured by heating up of a hollow cavity in an absolute method. /98

The achievable measuring accuracy is limited, among others, by the series-connected radiation filter as well as by the calibration method employed. The total measuring error is estimated to be about 5% absolute.

The other radiation part, such as M_E is determined by the measurement of the total radiation $M_R + M_E$. Accordingly, their range of wave length must be practically unlimited in the visible and the IR-band. Otherwise it is very similar to the pyranometer with respect to function and construction.

Measuring errors are affected primarily by the spatial distribution of the incident radiation. For large angles of incident, deviations from the cosine curve must, therefore, play an important role.

The measuring task "C" is finally satisfied by the conical scan radiometer. It measures the components of the reflected solar radiation which is back-radiated from the earth and the (thermal) self-radiation of the earth. The measurement is made under various observation angles and in different spectral ranges, namely:

A_1-channel: 0.25 - 4.0 µm,
A_2-channel: 0.2 - 0.3 µm,
A_3-channel: 0.35 - 0.7 µm,
A_4-channel: 0.7 - 1.0 µm,
A_5-channel: 1.0 - 2.0 µm

for the observation of aerosols, clouds, and vegetation as well as:

B_1-channel: 4.0 - 70.0 µm,
B_2-channel: 5.4 - 7.2 µm,
B_3-channel: 10.0 - 12.0 µm
B_4-channel: 9.3 - 9.8 µm,
B_5-channel: 14.0 - 16.0 µm

for the determination of water vapor- and ozone concentration as well as of surface temperatures. The B_1 channel is intended to capture the planetary emission.

The direction of observation is adjusted by means of a scan mirror whose angular position varies with respect to time in accordance with a preset program; thus the so-called scan angle β can be determined. The azimuth scanning is made by continuous rotation about the optical axis of the radiometer with a frequency of 0.69 Hz. The radiation turned around at the scanning mirror is recorded by means of Herschel optics on a detector series.

Measuring errors arise primarily because of scatter radiation and self radiation of the sensors. Both components must be minimized by means of baffles and thermal devices.

4. SELECTION OF ORBIT

The climate researchers are interested to measure the radiation budget locally, resolved with respect to daily events. From this we obtain three requirements for the selection of the orbit:

1. twice daily global coverage,
2. each daily measurement must be made from different space angles,
3. reproducibility of the orbit.

The intensity of the back-scattered radiation depends on the direction of the incident radiation and varies with the makeup of the surface of the earth (land, water, ice, etc.). Therefore, to capture these functional relations quantitatively, each daily and regional measurement must be made from sufficiently numerous space-angle positions. The expenditures for the number of thus required satellites are too high compared to the mission goals. Therefore one must limit himself to make model function measurements for daily and spatial angle distribution.

A. Pietrass employs in his investigations in [1] the work of Harrison, Brooks, and Gibson* whereby the zonal monthly averages of emitted and reflected radiation can be determined with a 2-satellite system ($H_{1,2}$ = 600 km, $i_1 = 50^o$, $i_2 = 80^o$), resp. equally well with a 3-satellite system ($H_{1,2}$ = 800 km, $i_{1,2} = 98^o$, H_3 = 600 km, $i_3 = 50^o$).

From the above work we can also see that the shares of the emitted and reflected radiation can best be determined from a regional area by means of satellites with path inclination of $i = 50^o$ and $i = 80^o$. Daily events can best be determined by satellites in a drift orbit.

From this we conclude [1] that a 3-satellite system is optimally suited for obtaining monthly average values of the radiation budget and the following concept is proposed:

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* COSPAR - Report to ICSU and to IOC for GARP, Boulder, CO (1976).

1. Satellite: H = 1150 km,
i = 57.5°, trajectory plane by -4°/day, relative to the average sun 1/3.
possible satellite: SEOCS.

2. Satellite: H = 1100 km
i = 100°, synchronized with the sun
equatorial passage 6 o'clock/18 o'clock.
satellite: POMS-1.

3. Satellite: H - 1100 km, /99
i = 100°, synchronized with the sun
node position opposite POMS-1 displaced by 90°, i.e. equatorial passage
12 o'clock/24 o'clock
satellite: POMS-2.

Orbit height and scan angle β - for the conical scan radiometer up to 50° - must be adjusted such that daily global coverage is assured. For a prescribed sensor trace width b at the ground and scan angle β the orbit height can be calculated as follows:

$$H = R_E\left[\frac{\sin(180/\pi\, b/R_E)}{\tan\beta} + \cos(180/\pi\, b/R_E) - 1\right].$$

In this way we obtain, as an example, for a scan angle of β = 50° and a sensor trace width b = 1550 km the above named orbit height H = 1100 km.

An important selection criterion for the orbit height is the requirement for daily global coverage of the surface of the earth for a limited zenith angle of θ ≤ 65° for the climate instruments. As can be seen from figure 3 this limiting angle corresponds to an altitude of 950 km.

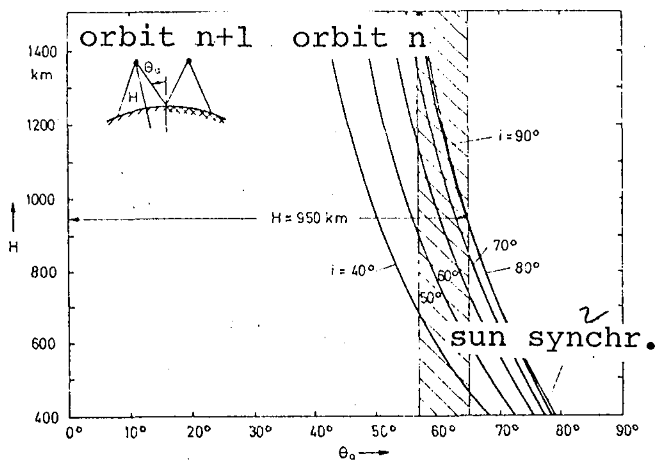

Figure 3: Maximum zenith angle θ for equatorial coverage in successive revolutions

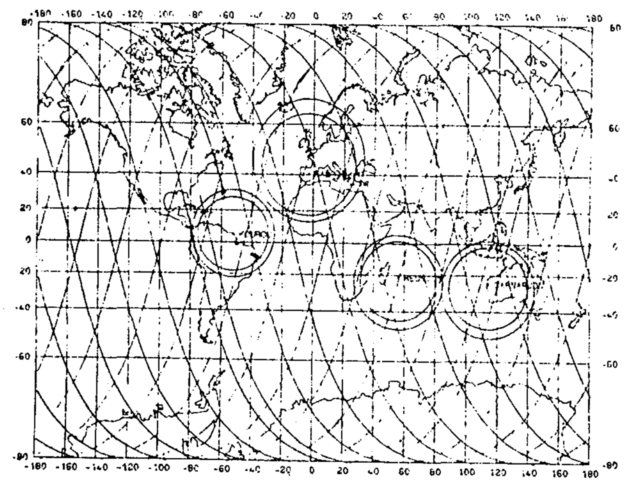

Figure 4: Coverage of the POMS-orbit during one day and visibility with respect to ground stations

The reproducibility of the orbit is assured if a subsatellite position of the rising orbit node is again flown over after N integral revolutions. For sun-syhchronized orbits this fly-over always occurs at the same average sun time. In between we find an integral number of N days. To lay out the orbit M and N are prescribed. The reproducibility of the ground coverage depends on the orbit height. Taking into account the above limitation this must be selected in a downward direction by the maximum zenith angle in such a way that a) the same regions of the earth cannot always be captured (integer-orbit) and b) the trace widths at the ground (shown in figure 3 with double cross hatching) do not form whole number multiples for various zenith angles. From these requirements we obtain for POMS an orbit height of H = 1098 km. For the zenith angle at the equator we obtain the value $\theta_a = 61.3^0$.

In figure 4 the local coverage for one day is represented by the foot-point curve.

Important parameters, determining the satellite orbit, are the inclination i, the eccentricity e as well as the node drift $\dot{\Omega}$. For circular orbits $e = 0$. Inclination and node drift are obtained from the prescribed values for orbit height and sun synchronism. For both POMS satellites $\dot{\Omega} = 0.2^0$/day. In general the node drift will affect the coverage geometry. In the single case one must check to what degree deviations are tolerable. If necessary the orbit height must be trimmed.

The inclination of the POMS orbits is selected for satellite-technical reasons in such a way that their path normals (for POMS-1) resp. their trajectory plane (for POMS-2) are always directed toward the sun. In this way the expenditures for the thermal budget and the solar generator for energy supply can be kept within limits.

The solar aspect angle b_0 is an important design parameter for the satellites. Its seasonal curve is obtained from the inclination of the ecliptic ($\varepsilon = 23.5^0$) and the path inclination ($i = 99.93^0$ for sun-synchronized orbit) and determines the heat balance of the satellite as well as the layout of the solar generator necessary for energy supply. It is defined as the angle between the orbit normal and the vector to the sun. Table II lists the curve values for one year for the satellite POMS-1 and POMS-2.

At the same time we thus obtain the shadow time per orbit revolution which, for circular orbits, correlates with the solar aspect angle. The POMS-1 orbit (6-18 o'clock dusk orbit) enters after 330 days into the shadow of the earth for 46 days. The shadow duration then amounts to 11 minutes per revolution. For the POMS-2 satellite the shadow duration lasts 35 minutes per revolution.

For the satellite POMS-2 directed toward the nadir the wide-angle instruments pyranometer and pyrradiometer see the sun twice per revolution since this extends in the 1098 km orbit by 9.5° beyond the horizon. For POM-1 we do not encounter this problem because the node position is displaced by 90°.

Table II: Seasonal course of the solar aspect angle b_0 for POMS-1 and POMS-2 /100

Time starting from the beginning of the year (days)	b_0 [$^{\circ}$] for POMS-1	b_0 [$^{\circ}$] for POMS-2
0	147	87
30	152	89
60	162	90
90	174	90
120	175	90
150	168	92
180	167	94
210	172	95
240	178	93
270	167	89
300	156	86
330	148	85
360	147	87

The pyrheliometer on POMS-1 is oriented in the direction of the path normals. The sun vector travels through its field of view of 10°. To make measurements possible throughout the whole year the pyrheliometer must be capable of being turned in the direction of the yaw axis with a turning range of 0^{o} to 34^{o}. The angle position is not changed during the measurement.

5. CONDUCT OF THE MISSION

The satellite mission POMS is based in principle on a thirty year measuring duration. Each individual satellite should have a life span of five years so that altogether twelve POMS satellites are required. To this should be added six basis-satellites SEOCS.

The satellites are started separately and are propelled into the prescribed orbit with the aid of a carrier rocket (Ariane). A special orbit control system as part of the satellite has the function to maintain the nominal orbit, i.e., to correct potential deviations. Here one can think of the following error sources:

- orbit insertion errors,
- secular orbit disturbances,
- periodic orbit disturbances.

The orbit insertion error depends on the carrier rocket and is generally specified for different heights. The orbit disturbances must be attributed to natural influences which, for orbits near the earth, are limited to the contributions of

- flattening of the earth,
- air resistance,
- solar pressure,
- sun-moon gravitation.

For the POMS mission the requirements with respect to accuracy of orbit are limited. The following should apply

- the orbit height $\Delta H = 5$ km
- the position of the node: $\Delta\Omega = 3^{o}$
- the node drift: $\dot{\Omega} = 0.23^{o}$/per day
- the inclination: $\Delta i = 0.04^{o}$.

Orbit corrections can be made by means of hot gas-propulsion systems (e.g. a hydrazene motor) which according to [1] must be able to produce a velocity increment of a total of

$$\Delta v = 51 \text{ ms}^{-1}$$

during the five year mission duration.

According to specification the transport capacity of Ariane for a sun-synchronous 1100 km orbit is about 1800 kg. This value includes the weights for the satellite, the rocket adapter including the separation mechanism and the payload enclosures.

The low weight of POMS (about 200 kg) would make possible a multiple start with respect to the carrier.

The node position, displaced by 90°, of both POMS orbits requires, even when the node drift is taken into account as a result of the flattening of the earth, a starting capability for the orbit control system of additionally

$$\Delta v = 10 \text{ kms}^{-1}.$$

However, such a large increment can only be produced by a rocket upper stage. We must, therefore, assume that for the 3-satellite system POMS-1, POMS-2, and SEOCS three rocket starts are necessary. The necessary starting costs can possibly be reduced by making use of other satellites whose orbit is compatible with the particular POMS orbit or the SEOCS orbit.

The contact with the ground is obtained with a ground station network. For this the ESA-network suggests itself. In figure 4 the individual stations

Madrid,
Kourou,
Reunion,
Carnavon

are listed; their contact ranges for the elevation 5° and 10°

are designated by circles.

6. SATELLITE CONCEPT

The selected concept for the POMS satellites is based on a system design for Spacelab-subsatellites [5,6] proposed by the DFVLR. This is characterized by the fact that, with the subsatellite, operation

- in the immediate surrounding of the space shuttle/Spacelab or /101
- at a greater distance to the shuttle from its orbit, or in higher altitude orbits, is possible.

For a utilization as economical as possible the satellite is made up of structure- and subsystem modules which should make possible a simple adaptation of the requirements to the particular mission. Accordingly the structure consists of a payload- and a service module which contain the subsystems of the satellite. The modules are made up of mounting platforms structural shapes which can be combined to different configurations. All have in common an octagonal cross-section of the satellite bodies. Figure 5 shows the shape selected for POMS. With the mounting platforms it provides the potential to arrange several experiments with great field of view. The geometric dimensions of the structure are as listed:

corner dimension:	150 cm,
key width:	138 cm,
height of service module:	28.7 cm,
height of payload nodule:	57.4 cm.

Figure 6 shows the total view with the solar generator unfolded (for POMS-2).

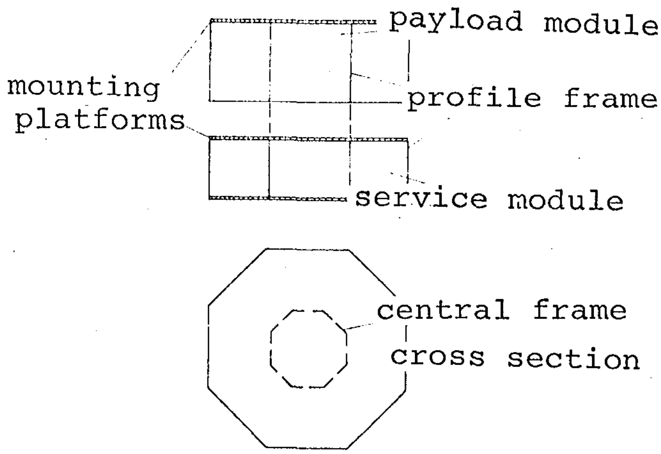

Figure 5: Structural elements of the POMS satellite

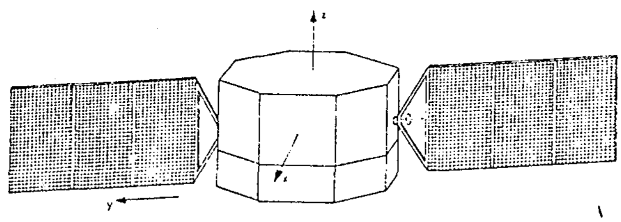

Figure 6: POMS configuration

6.1 Payload accomodation

In the payload module all radiation budget instruments are mounted on the mounting platform pointing to the earth. In accordance with the mission goals formulated in chapter 3 POMS-1 with the 6 o'clock/18 o'clock equatorial passage contains the experiments

pyrheliometer, PHM,
pyranometer, PNM,
pyrradiometer, PRM,
conical scan radiometer, CSR.

Except for the pyrheliometer the satellite POMS-2 (12 o'clock/ 24 o'clock orbit) contains the same payload. This instrument which measures the incident solar radiation for calibration purposes, can be used more effectively, because of the long exposition duration, for the dusk orbit of the POMS-1 and is placed on the y - panel in a swiveling position. In this way seasonal fluctuations in the position of the sun are compensated. For POMS-2 the measuring time per revolution is only a few minutes.

The conical scan radiometer must be capable of being turned about the z-axis continuously with a rotational speed of 0.69 Hz and must be attached to the nadir-oriented panel 1 and must protrude from the structure by about 20 cm [7]. Pyranometer and pyrradiometer are also mounted on panel 1 just as the electronic boxes for the instruments. Figure 7 shows the accomodation of all experiments for the case POMS-1.

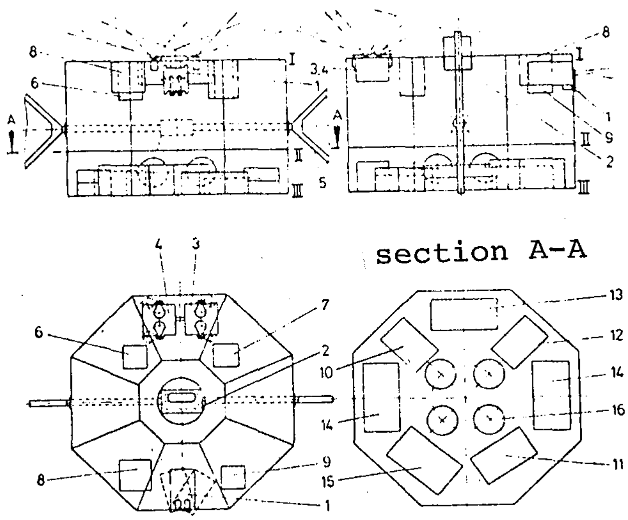

Figure 7: Accommodation of the POMS-1 payload and of the satellite service module

The solar generator including the starting drive mechanism necessary for POMS-2 is placed on the service-side mounting platform II. On platform III we find the subsystems for

energy supply,
thermal budget,
position stabilization,
telemetry-telecommanding system and
data preparation.

6.2 Subsystems

6.2.1 Thermal budget

The temperature control is designed for a passive system [5]. By means of suitable deposits on the external surface of the hull the average temperature level (about 15° C) specified for the subsystems and for the experiments is adjusted. A thermal insulation between hull and internal structure serves to provide sufficient heat decoupling. For this purpose coatings with low emission capability are used for the internal side of the hull. The effect of asymmetric solar radiation is reduced by good heat conduction in the hull. Similarly platforms and central pipes are connected with each other by good heat conductors. The solar generator backside is painted black and is connected to the rotating drive with heat insulation. /102

6.2.2 Energy supply

The power budget for the POMS-1 is 75 W, for POMS-2 80 W. This minor difference is caused essentially by the node position of both POMS orbits, differing by 90°, and by the thus required different layout of the energy supply system. The primary energy is supplied by a solar generator. For POMS-1 this consists of two wings with two doors each and thus provides a power of 111.5 W. Since this satellite orbits in a sun-synchronous fashion along the dusk line, a turning mechanism is not required.

The solar generator for POMS-2 must produce a power of 183.5 W. Therefore it is made up of two wings each with three doors and is rotatable with respect to the satellite body. The energy on board is supplied by two NiCd batteries which are being charged by the solar generator. The required battery capacity for POMS-1 is 11.4 Ah, for POMS-2 35.7 Ah.

6.2.3 Position stabilization

The position stabilization system is laid out in such a way that for all three satellite axes a positioning accuracy of $\pm 0.5^{\circ}$ is attained. This is possible without any technical expenditures with the aid of conventional control methods. For POMS a cold gas-control system is proposed which operates on the principle of impulse staggering [8]. The advantages of this method compared to the others are:

1. a pre-dimensioned pulse length,
2. quasi-optimal fuel comsumption and
3. an automatic adaptation to variable disturbance moments.

The principally achievable orientation accuracy for a 1100 km orbit with a disturbance moment peak of about 10^{-6} Nm is in general better than $\pm 0.1^{\circ}$ to $\pm 0.2^{\circ}$ (for 3 σ values).

The position measuring system consists of a static infrared sensor, a sun fine-sensor for POMS-1 resp. three sun fine-sensors for POMS-2. During the shadow phases an integrating rate gyro is used.

6.2.4 Telemetry/telecommanding system

This system is equipped with one receiver which amplifies the inlet signal, demodulates it, and passes it on to the data processing system. On the sender side the system is built up of two redundant grounds composed of two UHF parts and consists of each of three channels with a transmission speed of 7 kbit/s. Such a system is specified by the ESA and can be constructed from standardized elements.

In order to be able to make the radiation budget measurements on a global basis, we must additionally provide a board storage system such as a tape storage or - if available a bubble storage system. Since the maximum storage time for sun-synchronous polar orbiting satellites when limited to 4 ESA stations (figure 4) is 3 hours 20 minutes, a storage capacity for the above named data rate of about 84 Mbit is necessary.

6.2.5 Carrier

The structure of the satellite is laid out in such a way that the start can be made with the space shuttle. For the proposed orbit - even when a polar starting orbit is assumed - an additional propulsion system is necessary for boosting it into orbit. If we assume here, as an alternate, a start with the European Ariane carrier rocket, the problem of raising the orbit by about 800 km altitude difference would be eliminated and the requirements made of the drive system would be reduced to the orbit control (chapter 5).

7. CONCLUDING REMARKS

The subject work is based on a system study for climate investigation with polar orbiting satellites, set up by the DFVLR with the participation of several authors. Hearty thanks are extended here to the following colleagues for the close cooperation: Dr. P. Meischner, R. Nähle, M. Piening, A. Pietrass, B. Schmidt, H.P. Schmidt, and R. Stapf.

A follow-up investigation took up the question whether and, if applicable, with what costs a climate investigation such as POMS could be combined with a "classical" earth exploration investigation. The results of this work are currently being discussed with the interested user personnel and are being evaluated with respect to a European program which would have to be supported by the ESA.

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