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TUBSAT-1, SATELLITE TECHNOLOGY FOR EDUCATIONAL PURPOSES

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Abstract

TUBSAT-1 (Technical University Berlin Satellite) is an experimental low-cost satellite within the NASA GAS (Get Away Special) program.

This project is being financed by the German BMFT (Federal Ministry for Research and Technology, mainly for student education. The dimension and weight are determind by GAS requirement and it will be ejected from the space shuttle into an approx. 300 km circular orbit. It is a sun/star oriented satellite with an additional spin stabilisation mode. The first planned payload is to be used for observing flight paths of migratory birds from northern Europe to southern Africa and back.

Introduction

It was a big challenge for the students to design and develope a low-cost experimental platform which enable a rather precise orientation in orbit. GAS program provides a low-cost with high launch frequencies, so that the students can complete their own experiments in the short study period.

It was leading to the development of the GAS compatible satellite of the Technical University Berlin (Fig. 1). More than 50% of its volume is planned for useful experiments like navigation (white storks) equipment and components for space application (star sensor, GaAS solar cells), store forwards communication (mail-box), observation (CCD-chip camera).

The cooperation with MBB (Messerschmidt Bölkow Blohm) in this project is important in order to provide exchange between space industry and the university. Some of TUBSAT-1 subsystem and ground segment have been tested already using the flight opportunity of MIKROBA (OHB-SYSTEM project, supported by BMFT) in Esrange, Sweden in April 88.

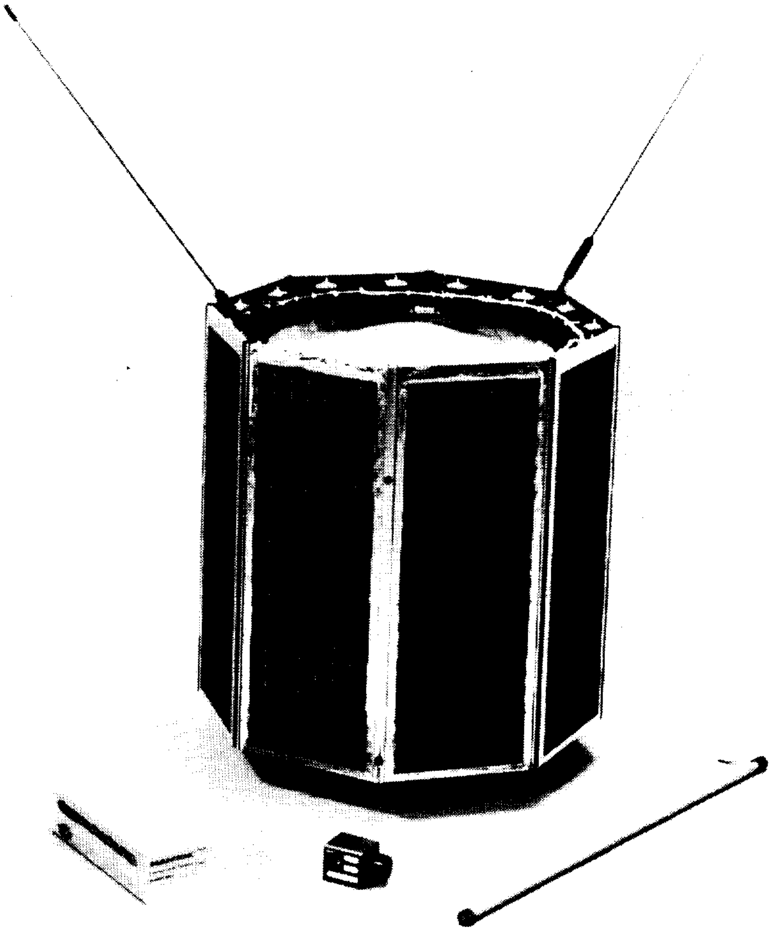

Fig. 1 TUBSAT-1
main component:

- FMW
- OBDH + TM/TC
- star-sensor
- magnetic rod

Mechanical Structure

The mechanical structure of TUBSAT-1 (fig. 7) consists of two major components, a central structure and outer shell.
The central structure is composed of two crosswise mounted sandwich plates, an octagonal shaped sandwich plate mounted at the top, and an adapter ring is placed at the bottom. The central structure provides rigid support to mount all TUBSAT equipment. The adapter ring has been designed for compatibility with the marman plate of the GAS ejection mechanism.

The outer shell is composed of eight panels and eight supporting struts. The panels provide support for the solar array. The struts interconnect the solar panel to the central structure, so that the outer shell can be easily dismounted from the central structure to ensure accessibility to all components.

The main parts of the structure are considered in strength verification analysis, using a detailed finite element model to calculate accurate forces and stresses with respect to the GAS payload safety requirements. It is to state that all parts are covered with positive margin of safety.

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Mass distribution:

- structure and interface ring	5.33 kg
- solar panel	4.02 kg
- fixed momentum wheel	7.60 kg
- batteries	3.84 kg
- electronics	3.21 kg
- TM/TC + OBDH	2.00 kg
- torque rods	6.00 kg
- payload	36.00 kg
total	68.00 kg

On bord data handling subsystem (OBDH)

The on bord data handling subsystem (Fig. 2) manages and coordinates all subsystem and experiments. It is based on Hitachi (HD 63701 X0) 8 bit CMOS single chip microcomputer unit (IC1) which contains 4k bytes of EPROM and 192 bytes of RAM. If excess information is to be stored, the included external 32 k bytes RAM (IC3) can be used. It also contains an analogue/digital converter (IC2) with 16 analogue inputs. The buffer (IC4) is used for the interface to the TM/TC subsystem. Additional serial interface are provided for the attitude control subsystem and for three different experiments. They all should have their own microcomputer to enable efficient communication. The "watch-dog-timer" (IC5,6) listens carefully every 65 ms to the heart pulse of the computer, in case of a heart attack (no pulse after 100 ms) shock therapy follows immediatly through resetting.

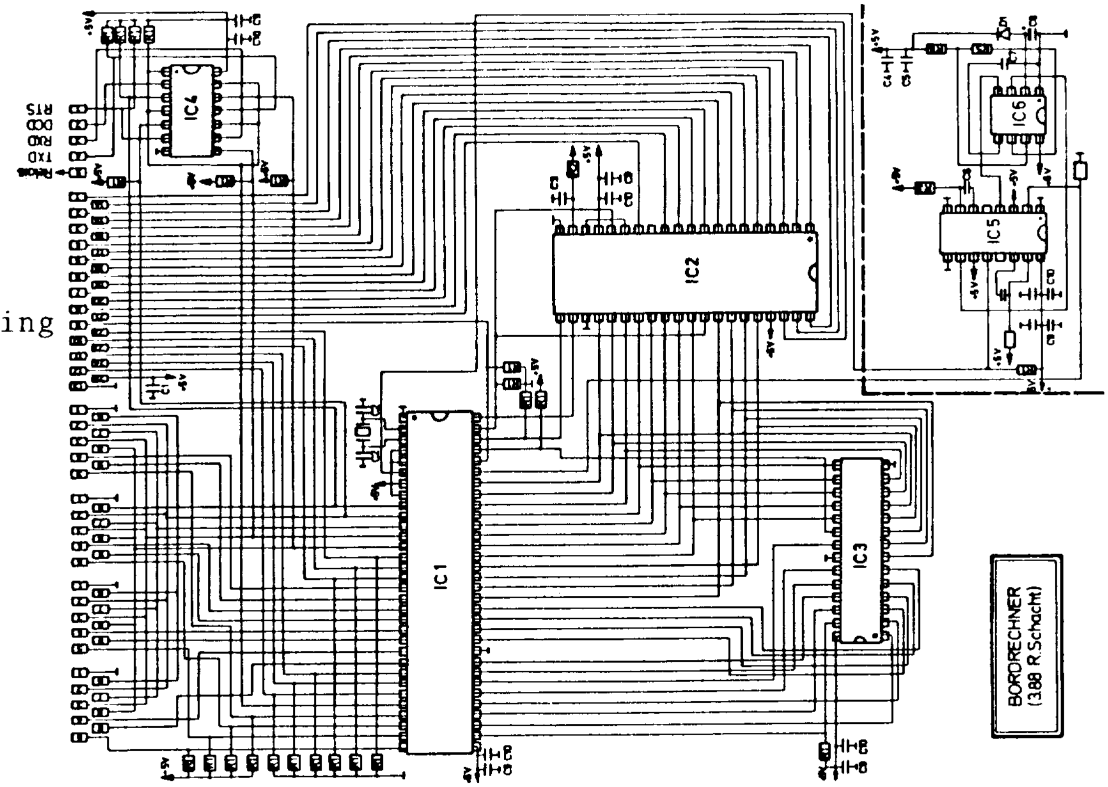

Fig. 2
On bord data handing subsystem

Thermal analysis

The successful operation of the battery, electronic equipment and payloads, requires a fairly close control of the temperature to which it is subjected. Even though it is a disadvantage from a thermal point of view to spread out the batteries around the momentum wheel, it has been done mainly for space optimisation reasons.
For the transient orbital temperature analysis, the TUBSAT orbit data have been assumed, taking into consideration the albedo, solar and earth source of radiation, and the dissipation power of the satellite equipment. One node model has been developed, it consists of 59 nodes with different heat rate input according to the three attitude modes.

A: 3-axes stabilised (solar panel edge pointed to the sun)
B: " " " " surface " " " "
C: spin stabilised

By using multilayer insulation (MLI) on the top and bottom of the structure, black painted equipment on the inside area, and white painted outside surfaces (Fig. 3).
100 orbit cycles were repeated in order to obtain an exactly permanent periodic state. In all three calculated attitude modes, the analysis has shown a possible operating temperature range as follows.

temp. °C/ mode	battery min	battery max	electronics min	electronics max	solararray min	solararray max
A	11	32	3	36	-33	64
B	9	31	0	28,5	-35	67
C	16,7	13,6	5	25	-24	32

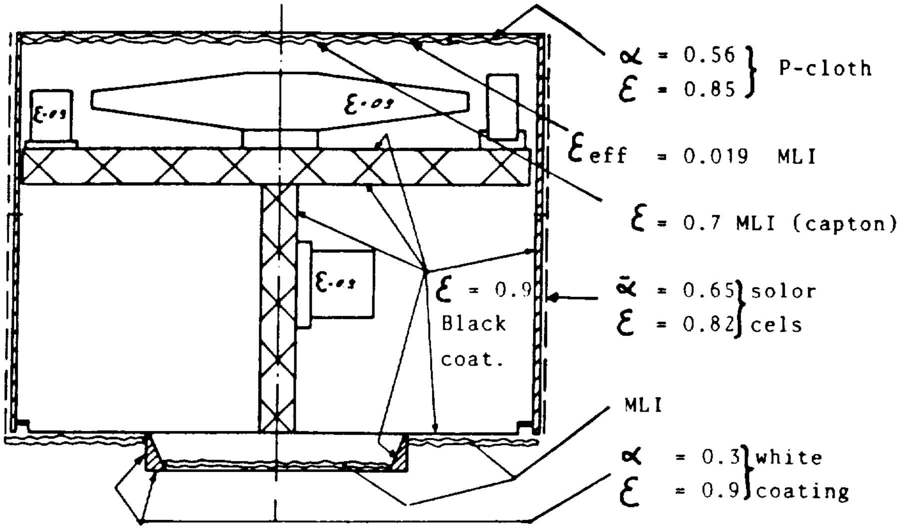

Fig. 3
Radiative properties in the node model

Power Subsystem

From examination of the mission profils, it is apperent that the solar generated power has a wide voltage variation, therefore it is necessary to provide good battery management to control and optimize the charge function of the battery. A maximum number of 49 solar cells of the type k7000 Spectrolabe (62.1x20.9 mm) can be attached to each of the eight panel. Matching process of all 392 cells have been done, considering the working point voltage of 23.5 V for each solar panel. This value is based on the maximum charge voltage available of the chosen batteries. So that each panel supplies an average current of 535 mA, almost the same power (12.65 W at 28° C) and 32 W (28° C) when light striks perpendicular to the pitch axis.
In the spin mode according to the thermal analysis the average temperatur of the arrays is less than 28° C so that a power increase is expected. In the 3-axes mode, a power drop of 40% from the panel facing the sun (60° C array temperature) is expected.
The battery system consists of a string of 16 Nickel-Cadmium cells each 7Ah, 1.47 V (VR7 SAFT). Assuming a 90 minute orbit with a 38 minute exlips time, a power supply of 32 W, with 75% of battery efficiency it would yield 17 W (23.5 V/0.72 A) available power consumption. This means, that the 15 W battery required charge power (charge rate of 0.1 C = 0.7 A), is in the safety margin. The 3-axes mode electronic includes step-up converter for each panel to increase the supply voltage to the proper charge value.
In the spin mode the shunt regulator uses a cell temperature signal to avoid battery overcharge, or "allowing" colder cells a full charge (Fig. 4).

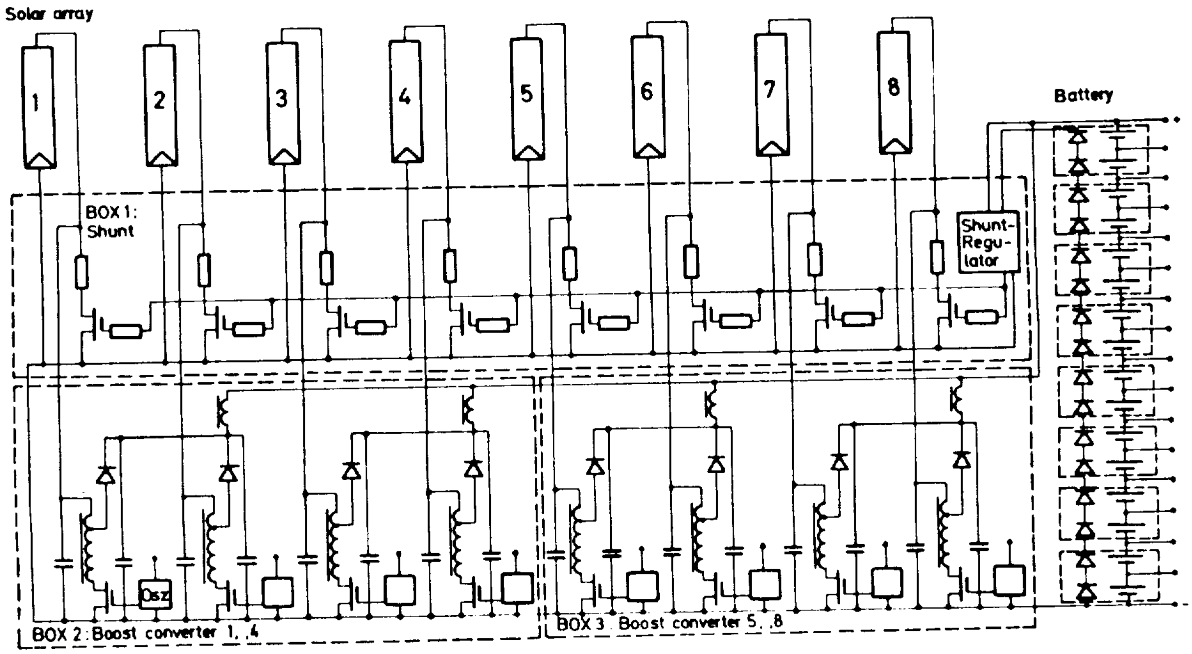

Fig. 4 Power subsystem

Attitude control and stabilisation subsystem

The attitude control and stabilisation subsystem (ACS) consists of a fixed momentum wheel (FMW,50nms,Teldix), magnetic rods, sun-, star- and geomagnetic field sensors (Fig. 6).
Two attitude modes are designed, spin and 3-axes stabilisation at momentum vector perpendicular to the sun. The additional possibilities of pointing this vector in any other direction will be tested later on. The ACS concept based on microcomputer unit (MCU) with additional A/D and D/A converters in order to collect and distribute signals for maintaining the required position with respect to any error signal. The star sensor has two working modes, differenciation mode, where every picture is compared to the previous one, and integration mode, where each new picture is being compared to the first one only.
The magnetic rods are used for dump nutation, wheel desatoration and presessing the momentum vector.
Here it is important to mention that the FMW used for the attitude stabilisation should be run up shortly before the satellite will be ejected. This matter has already been discussed in October 1986 with the GAS payload officer.

Telemetry and telecommand subsystem (TM/TC)

Using commercial components with minimum power consumption were the main requirements for design and development of the modem (modulator/demodulator, Fig. 5) and transverter. FM modulation has been chosen, with a bit rate of 400 baud. This value can be changed easily on demand through replacing only 2 resistors (increasing the bandwidth of the appropriate filters). To achieve a compact system, the request to send signals (RTS) is used to change the switch position (receive/transmit), so that the essential part of the system works for transmitting and receiving too. The receiving signal (29 MHz) is being mixed twice to 455 KHz (IC1,2). Variable control oszillator (VCD) compensates the Doppler effect and possible shifting of the other oszillators. The subcarrier frequencies are at 1300/2100 Hz.

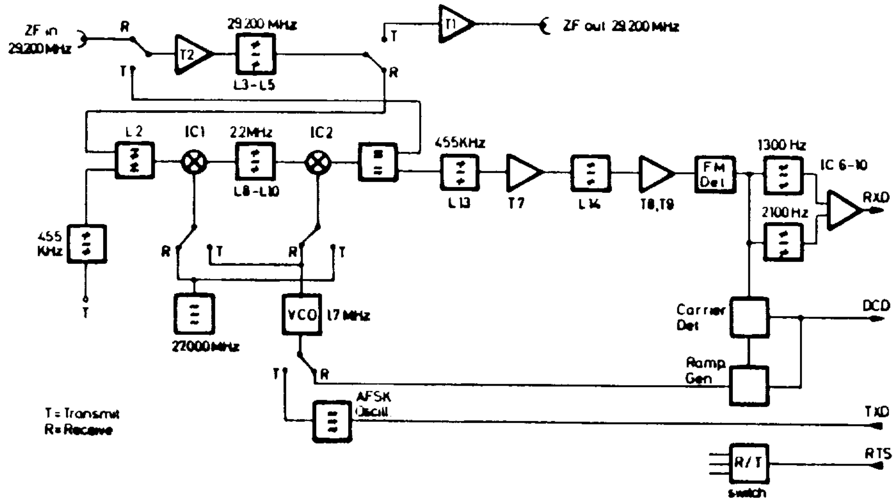

Fig. 5
Modem

2m - 10m transverter mixes and amplifies the modem output signal to the current TM frequencies of 137.8 MHz, 0.1 W power, and vice versa when receiving the 148.1 MHz uplink signal.

Ground station

With orbit inclination of 57° TUBSAT-1 will be controlled by the main ground station, which is placed at the Technical University of Berlin, in case of lower orbit inclination, the already existing portable ground station can be placed anywhere in the mediterranien countries to enable contact.

All ground stations are similar and use the same communication terminals as on board, with only different extensions.

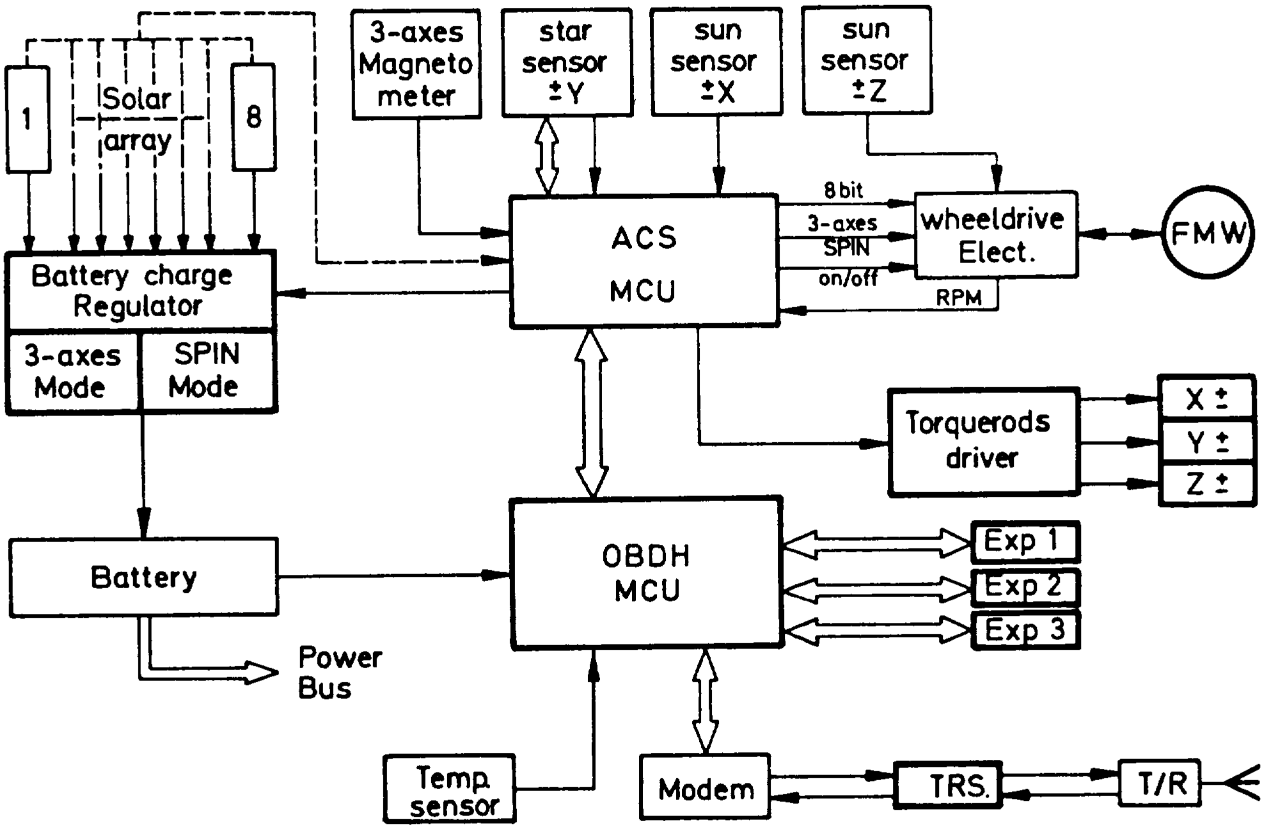

Fig. 6 TUBSAT-system diagram

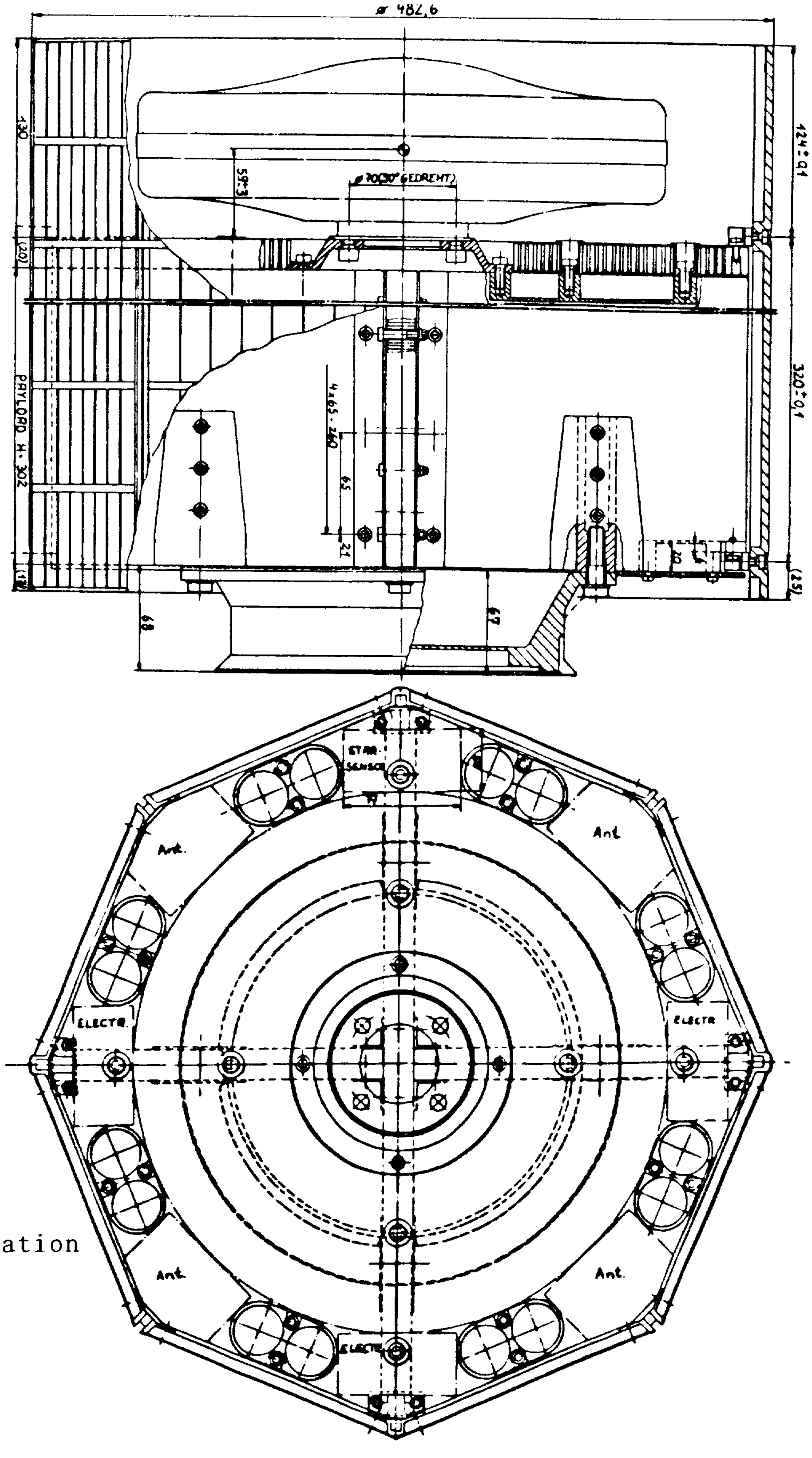

Fig. 7
TUBSAT-1
configuration