

DEVELOPMENT OF THE ØRSTED SATELLITE PROJECT

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Abstract

The Danish Ørsted satellite will carry four science experiments into an elliptical, polar, low earth orbit. Objectives are to map the Earth's magnetic field, measure the charged particle environment and collect occultation data. The science data from the 14 month mission will improve geomagnetic models, study the auroral phenomena and obtain atmospheric profiles. 75 scientific groups in 17 countries have responded to an announcement of opportunity to analyze the Ørsted data. A triaxial fluxgate magnetometer aligned with a star imager and an Overhauser magnetometer are mounted on an 8 meter long deployable boom. The science payload also includes six charged particle detectors mounted in the satellite body. The extended boom provides gravity-gradient passive attitude control. Active attitude control is maintained using magnetorquer coils. Position is determined by redundant GPS receivers. The satellite body weighs 60 kg and is 680mm X 450mm X 340mm. Modular electronic boxes accommodate all electronics except for the two GPS receivers and the star-imager electronics, which are located in special boxes. The Ørsted satellite will be launched as an auxiliary payload on a Delta II launch vehicle from Vandenberg Airforce Base, California, together with the P91-1/Argos satellite in early 1996. The Ørsted control center, science data center and three ground stations form the ground segment.

Introduction

This paper describes the key science objectives and system design aspects of the Ørsted satellite. The project is performed as a cooperative effort between a group of Danish universities, institutions and industries active in space activities, the project is managed by CRI A/S.

Science Overview

As stated in [4] the purpose of the Ørsted satellite mission is to conduct a research program in the field of solar-terrestrial physics in combination with research of the magnetic field of the Earth. In this respect the research of the Earth's magnetic field may be divided into two major areas. The first deals with the generation of the magnetic fields in the fluid core plus the magnetic and electrical

properties of a solid Earth. The second area deals with the magnetic field of the Earth as the controlling parameter of the magnetosphere and the consequent physical processes such as aurora and magnetic storms that take place in the Earth's plasma environment.

To improve the value of the science data obtained from the Ørsted mission, the satellite orbit has been changed from a circular, sun-synchronous orbit at an altitude of 840 km to an elliptical orbit with apogee 850 km, perigee 400 km, inclination 96.1 degrees with a resultant nodal drift of 0.77 degrees/day. This elliptical orbit enhances the value of the science data by enabling crustal field studies at the lower altitudes and will improve studies of the low altitude ionospheric currents. The increased local time coverage around the noon and midnight sectors implies a significant increase in the science potential of studies of the external field and its dependence upon the solar wind.

Space-ground correlative studies are planned between the Ørsted satellite project and the extensive Danish terrestrial magnetic research facilities in Greenland. In addition it is expected that the establishment of further ground-based research facilities in Canada and other northern areas will greatly enhance the value of the Ørsted science data.

Due to the global nature of this research there is considerable international interest in the mission. Following an "Announcement of Opportunity" to the international scientific community, responses were received from 71 scientific groups in 17 countries to participate in the data analysis. To coordinate this important effort a Science Data Center has been established at the Danish Meteorological Institute in Copenhagen.

Danish traditions are prominent in the field of solar-terrestrial and space physics, and Danish science groups have demonstrated an internationally recognized capability in measuring magnetic fields. It is therefore appropriate that the project is named after the Danish physicist Hans Christian Ørsted (1777-1851) who discovered electromagnetism in 1820. His name is also used as a measure of magnetic field strength (1 Oersted = $1000/4\pi$ A/m)

The satellite will carry four science experiments with the primary objective of performing highly accurate

measurements of the Earth's magnetic field. Secondary objectives are to globally monitor the high-energy charged-particle environment and a recently added feature is a dual band GPS receiver which will allow Ørsted to collect occultation data in a pilot project to obtain atmospheric profiles.

System Overview

The Ørsted satellite system consists of one partially autonomous satellite, three ground stations, a control center and a science data center. An overview of the system is presented in Figure 1.

Accurate positions along the orbit plane is determined using the Global Position System (GPS) through redundant GPS receivers on-board the satellite.

Up- and down-link between the satellite and the ground stations operate in S-band (2.1 GHz and 2.2 GHz).

There are three ground stations, all located in Denmark. Two of these ground stations are within higher educational institutions at Aalborg University and at the Engineering College of Copenhagen.

The primary ground station is located at the Danish Meteorological Institute (DMI) also in Copenhagen. All ground stations have steerable antennas and provide the interface necessary to control and monitor the satellite.

The Ørsted Control Center (ØCC) is located at CRI in Denmark and has executive control over the ground segment and the satellite during all post-launch operations. The ØCC utilizes an operations data base together with a Satellite simulator to assist in evaluation of orbital behavior. Science data is routed to the Science Data Center located at DMI. The data is stored, analyzed and then distributed to the users via Internet in accordance with detailed plans for international participation.

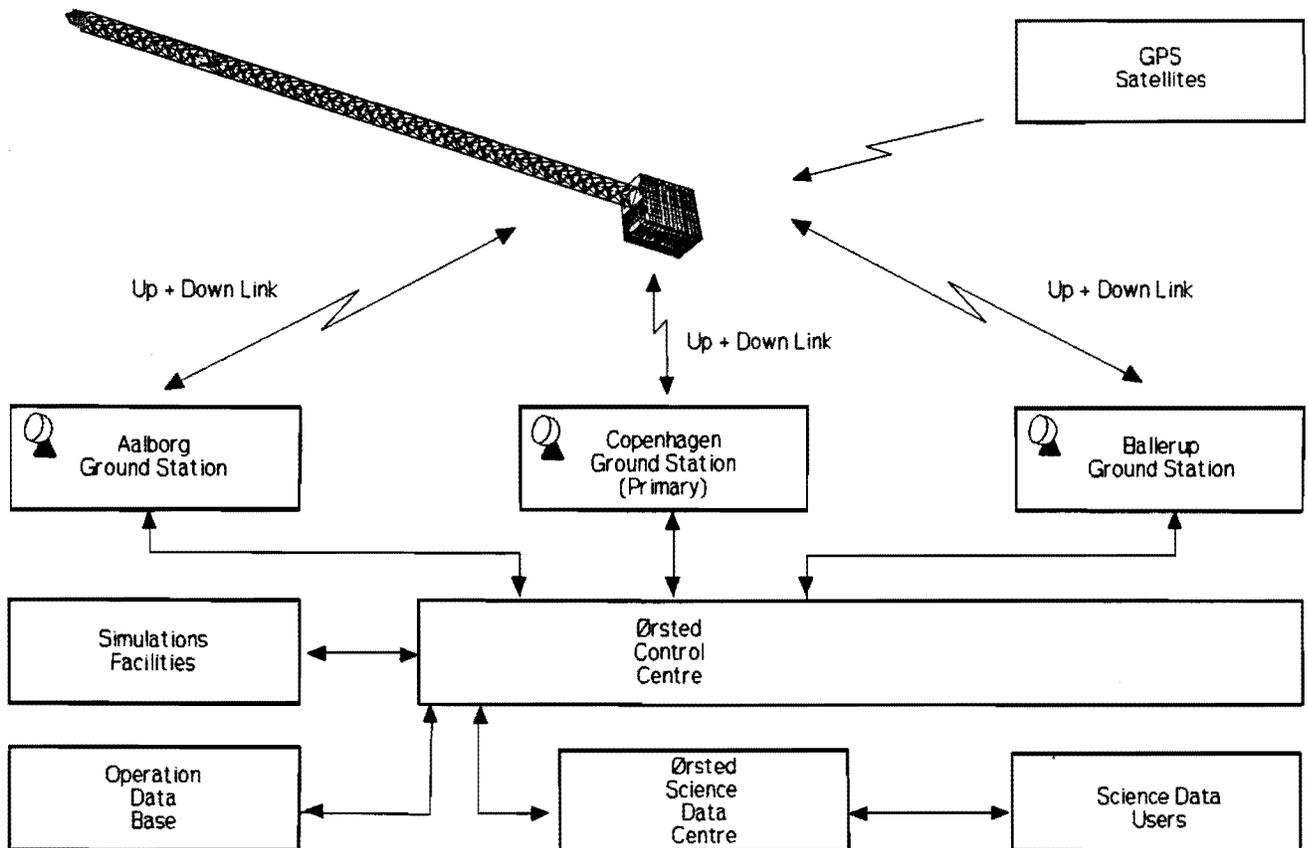


Figure 1: System Overview

Satellite

Overview

The satellite will be launched into a polar, 400/850 Km elliptical orbit with a nodal drift rate of 0,77 deg/day as an auxiliary payload on a MD-Delta II launch vehicle. Fig. 2 illustrates the satellite in the launch configuration. Following separation from the launch vehicle and autonomous attitude acquisition, an 8 m long boom is deployed by ground control to bring the satellite into the operational configuration shown in Fig. 3. In this configuration the satellite will be gravity-gradient stabilized with the boom pointing away from the center of the Earth. Active attitude control is achieved using 3 axis magnetorquer coils. The six charged particle detectors are housed within the satellite body and look out through apertures in the solar panels. Redundant S-band omnidirectional antennas are mounted on the underside of the satellite for communication between the satellite and the ground stations.

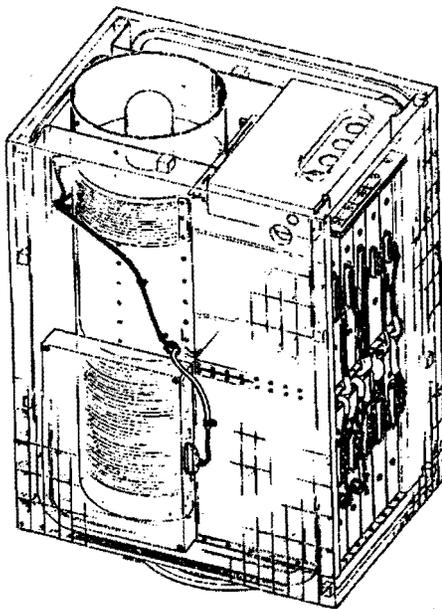


Figure 2: Ørsted Satellite in the Launch Configuration

Two magnetometers and a star-imager comprise the tip mass which together with the deployed boom provide the satellite with passive gravity gradient stabilisation. The vector (CSC) magnetometer and the star-imager are mounted and aligned together on an optical bench within the boom structure. The long boom serves to reduce the effect of any satellite magnetic field on the CSC magnetometer to an acceptable level and the requirement for attitude determination of the CSC magnetometer to within 20 arc

seconds can be met. Boom flexing effects on the CSC attitude determination are therefore also eliminated.

Ørsted is shaped as a box, 680 mm high x 450 mm wide x 340 mm deep. The four sides and the top of the satellite body accommodate solar cells.

Within the satellite body are the electronic boxes for the satellite and scientific payload functions, two battery packs, magnetorquer coils, sun sensors, the charged particle detectors, and the canister for the deployable boom.

Interface with the launch vehicle adapter is through the satellite separation mechanism mounted on the underside of the satellite body. Mounted above the separation mechanism are the lower platform, the vertical 'H' beam primary structure, a cable tray and an upper platform. Within the main structure envelope are two rows of electronic boxes separated by a cable tray, with space for nearly 10,000 cm² of printed circuit boards. During launch, the boom is packaged in a canister together with the two magnetometers and the star-imager. (See Figure 2).

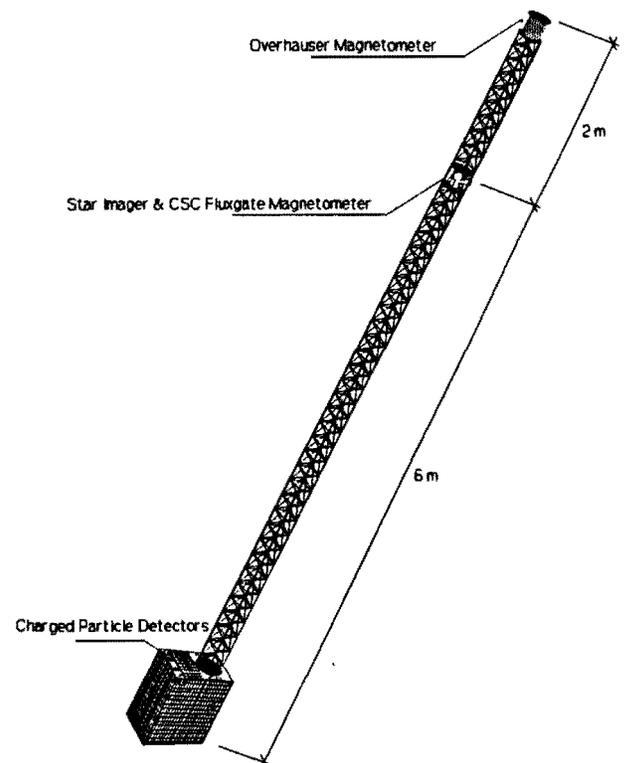


Figure 3: Ørsted Satellite in the Orbital Configuration

Telemetry data from the scientific experiments plus satellite housekeeping is stored in the on-board memory and downlinked when a ground station is in view. Attitude determination is based on data from the Star Imager, the CSC magnetometer, sun sensors and the GPS receiver. The attitude control system uses this data for active satellite attitude control via the magnetorquer coils. Commands, telemetry and data are handled by two central on-board computers, capable of controlling all satellite functions.

Features of the satellite are summarized in Table 1.

Item	Description
Body Size	H680 x W450 x D340mm
Power	GaAs body mounted solar panels 54 W EOM. Two Power Control Units. (PCU1 & PCU2) Two 6 cell NiCd 6Ah battery packs.
Primary Structure	'H' Beam with platforms.
Attitude Control	Gravity Gradient and Magnetorquers. (ACS)
Communication	S-Band with ESA Standard Packet TM/TC. Cold Redundant TX/RX (COM A & COM B)
Computers	Two computers, 16 Mbyte storage, 80C186 16 MHz CPU. (CDH1 & CDH2)
Position Det.	Redundant GPS (TANS & TR)
Payload	Overhauser Magnetometer (OVH), CSC Magnetometer (CSC), Star Imager (SIM), Charged Particle Detector (CPD) TurboRogue GPS (TR)
Boom	8 m Deployable 3 longeron
Thermal Control	Passive
Mass	60 Kg

Table 1: Features of the Satellite Design

The satellite electrical interfaces are set up as shown in Figure 4. This interface design implies a limited degree of redundancy, where the Communications subsystem is considered the most critical subsystem. It can be seen that in the event of a major anomaly in one of the on-board computers (CDH1 or CDH2) or in case of an anomaly in the power distribution (PCU1 or PCU2) it will only have an impact on half of the satellite, the mission can continue in a degraded manner with only one CDH or one PCU running. This complies with the overall design strategy. Throughout the design of the satellite, the strategy for contingencies is to survive one major anomaly and to be able to detect the subsystem in which it occurred.

Science Payload

The scientific payload fulfills two major objectives. The Primary objective is to map the Earth's external and internal magnetic fields. The secondary objectives are to provide measurements of the high energy particle radiation in the upper polar atmosphere and to collect occultation data.

Ørsted will carry four science experiments in order to meet these objectives:

- o Compact Spherical Coil (CSC) triaxial fluxgate magnetometer, for measuring magnetic field vectors with an angular resolution of 20 arcsec and an amplitude resolution of 1.4 nT.
- o Overhauser proton-precession magnetometer for measuring magnetic field amplitudes, with a resolution of 1 nT.
- o Solid-state charged particle detectors (six) for measuring electrons from 30 keV to 1 MeV, and protons and alpha-particles from 200 keV to 100 MeV.
- o TurboRogue Dualband P-code (and C/A-code) GPS receiver for collecting atmospheric occultation data

The two magnetometers are mounted on the 8 meter long deployable boom, whilst the particle detectors and the GPS receivers are mounted in the main body of the satellite (See Figure 3).

A Star Imager, mounted together with the CSC magnetometer, is also classified as part of the payload. This provides the absolute pointing accuracy of 20 arcsec for the CSC fluxgate magnetometer.

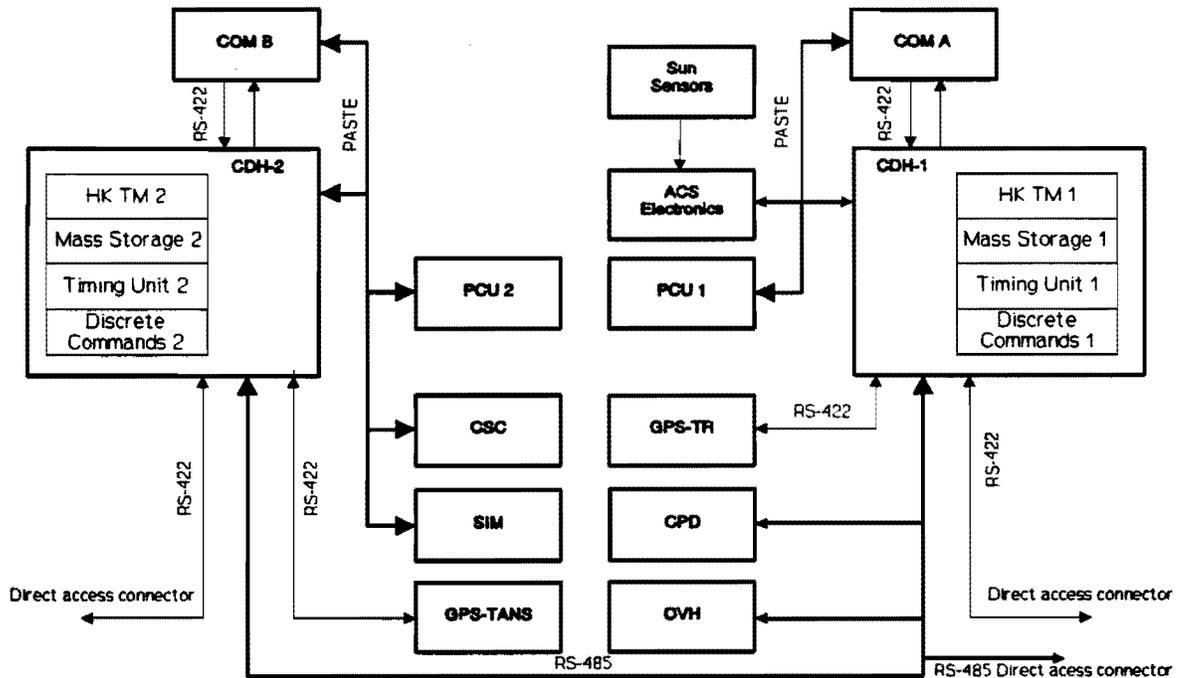


Figure 4: Satellite Electrical Interface Design

CSC Magnetometer. . .The CSC triaxial fluxgate magnetometer consists of three fluxgate sensors mounted with their axes at right angles to each other inside a set of small lightweight coils arranged on a spherical surface. The package is 90 mm in diameter, 102 mm high with a triangular footprint and weighs approximately 400 g.

To meet less than 3 nT magnetic field disturbance requirement, the satellite must be magnetically clean and the CSC magnetometer will be mounted on the boom 6 m away from the satellite body.

Overhauser Magnetometer. . .The Overhauser magnetometer (OVH) contains a Nitroxide solution surrounded by an RF resonator cavity and NMR detection coils. It weighs approximately 1.0 kg and is contained within a volume of 175 mm diameter by 100 mm high. The OVH is mounted 8 m away from the satellite body.

Particle Detectors. . .The solid-state charged particle detector (CPD) experiment detects electrons in the energy range from 30 keV to > 1 MeV and protons and alpha particles from 200 keV to > 100 MeV. Six individual detectors are mounted in the satellite body each approximately 30 mm diameter x 40 mm long with differing fields-of-view between 15 degrees and 45 degrees.

TurboRogue GPS Receiver. . .The TurboRogue (TR)

GPS receiver will apart from acting as the secondary GPS

for position determination also provide atmospheric occultation data. The GPS box weighs approx. 1915 g is 211 mm x 211 mm x 55 mm high.

Star Imager. . .The star imager (SIM) measures the satellite attitude by matching star constellations in the camera field-of-view with an on-board star catalog. Mapping is done by a 752 x 582 pixel charged coupled device (CCD) camera. Due to the proximity of the SIM to the CSC, the magnetic cleanliness of the SIM detector head must be strictly enforced.

Electric Power Subsystem (EPS)

The electric power subsystem comprises a solar array, a battery and two power control units to control battery charging, output voltages and the loads on the bus. Average solar array output over the sunlit part of an orbit is 58 W. Average power consumption by the satellite is about 26 W (excluding battery charge) leaving a margin on the solar array output of about 17%.

Solar Array. . .The solar array is composed of five solar panels mounted on the X, Y and top faces of the satellite body. These panels are assembled from 2 x 4 cm Gallium Arsenide solar cells which provide an average of 54 Watts of electric power at end-of-mission (EOM).

Battery. . .During eclipse operation power is provided by the battery. The battery consists of two identical packages each comprising six Nickel Cadmium battery cells of 6 ampere hours capacity. One pack is mounted on each side of the satellite structure. During nominal operation the battery depth-of-discharge will not exceed 15%.

Power Control Units. . .There are two identical power control units (PCU1 & PCU 2). Each includes a Battery Charge Regulator (BCR), a central DC/DC converter, power distribution units and necessary load control and protection devices.

Outputs of ± 5 V, ± 8 V and +15 V are available from the central DC/DC converters which provide the interface between the satellite subsystems including the payload and the power bus. All DC/DC converters have an efficiency of greater than 85%. The unregulated power bus nominally operates between 13.2-17.4 V.

Protection is provided by a combination of redundant fuses, and current limiters. Protection of the electric power system is also provided by turning off the power to all non-essential loads should the battery voltage fall below 12 V.

Analogue telemetry of selected voltages, currents, temperatures for the power sub-system is generated within the PCU. This data is forwarded to the Command and Data Handling Sub-system (CDH) for monitoring and processing.

Command and Data Handling Subsystem (CDH)

There are two identical on board computers (CDH1 and CDH2) which together form the satellite command and data handling subsystem. It provides the following processing capabilities.

- o Satellite housekeeping data acquisition and processing and storage.
- o Scientific experiment data acquisition and storage.
- o Time management
- o Data memory management
- o Data compression
- o Telemetry and telecommand format management
- o Command validation, distribution and execution
- o Attitude control data processing, monitoring and commanding.

The design is based on two Central Processing Units (CPU) Intel 80C186 16 MHz.

Data acquired by the science instruments and housekeeping sensors are routed to the on-board data handling subsystem.

Here they are monitored and pre-processed prior to storage. If the monitoring reveals any out-of-limits events, it is reported to the on-board supervisory facility which decides on how to respond to the event. When the spacecraft comes into view of a ground station and contact is established, data is retrieved, and down-linked. During periods of ground contact telecommands are also up-linked to the spacecraft, decoded and executed or stored as timetagged telecommands for later execution.

Science instrument data rates, to be handled and stored by the satellite are summarized in Table 2 below.

Autonomous control includes programming to handle the initial satellite operations after release from the launcher.

Telecommands are routed to the CDH via the satellite communication receivers. Telecommand coding and formatting complies with ESA Packet Telecommand Standard Document ESA-PSS-04-107.

Deployment of the boom is initiated and controlled by ground telecommand. Boom deployment takes place when the satellite is in view of a ground station and the deployment is monitored on ground by telemetry data. Telemetry data and format comply with ESA Packet Telemetry Standard Document ESA-PSS-04-106. The telemetry data bit-stream is generated by sampling science and housekeeping channels in accordance with sampling rates and sequences defined by the individual subsystems. All telemetry data are handled on a "store and forward" packet basis. The CDH includes sufficient interface channels for satellite housekeeping voltage, current and temperature monitoring and command status.

The CDH will also monitor electric power levels and battery state-of-charge and if a deficiency is found, it will deactivate selected on-board loads until the power deficiency is corrected.

Passes over the Danish ground stations will occur in groups of two or three consecutive orbits followed by an interval of up to 13 hours where no ground contacts are possible

16 Mbytes of RAM memory is provided for storage of scientific and housekeeping data. This suffices for more than 13 hours continuous satellite operation. Due to the radiation conditions in the Ørsted orbit, the memory is protected against bit errors by the use of a hardware Error Detection And Correction circuit (EDAC).

The CDH is capable of supervising and operating the satellite and science payload without ground control for

periods of at least 26 hours. If ground contact is not established within that period, the satellite automatically enters a hibernation mode to preserve science data until ground contact is established.

All satellite application software is capable of being reconfigured and reprogrammed from the ground.

The necessary software and command facilities are included to accomplish validated software modifications including the autonomous control functions and attitude. A description of the on-board SW development is presented in [1].

Attitude Control Subsystem (ACS)

The attitude of the satellite is monitored using the star imager, sun sensors and the CSC magnetometer and is controlled during all phases of satellite operation following release from the launch vehicle.

Stabilization of the satellite attitude is accomplished by passive and active techniques. The passive technique employs gravity-gradient stabilization using the deployed boom with a tipmass consisting of the two magnetometers and the star imager (3.1 Kg). The active technique uses magnetorquer coils located in three axes within the satellite body. The ACS maintains a yaw angle variation of ± 10 degrees to optimize the power output of the solar panels. The active attitude control system is capable of recovering the correct attitude from an "upside-down" attitude where the boom points towards the center of the Earth.

GPS receivers

The position of the satellite is continuously determined within 50 meters in any direction by a receiver using the Global Positioning System (GPS).

The GPS equipment comprises a primary single band 6-channel TANS GPS from Trimble Navigation and a secondary dual band 8-channel TurboRogue GPS from JPL.

Ceramic patch antennas from Ball Corporation are used by both receivers. The TANS receiver uses the C/A code on the L1 frequency carrier for position determination only.

The TANS GPS is regarded as the primary unit because it uses less power than the TurboRogue.

The TurboRogue receiver uses the P-code on L1 and L2 frequency carrier for collecting atmospheric occultation data, but it can also operate in a low power mode using only the C/A code on the L1 frequency carrier in order to act as backup for the TANS receiver. A full description of the TurboRogue GPS receiver is given in [2].

The GPS receivers provide three dimensional position and velocity of the satellite together with UTC time all in a digital format to the CDH nominally once per second.

UTC time accuracy is within ± 1.0 microseconds and velocity accuracy ± 0.5 meters/second.

The TANS GPS Antenna is mounted on the top face of the satellite body to view as many of the GPS satellites as possible and the TurboRogue dual band GPS antenna is mounted on the side of the satellite looking in forward or backward the velocity vector in order to view the satellites settling below or rising above the horizon.

Communication Subsystem (COM)

Telemetry and science data is transmitted to the ground via redundant transmitters. One transmitter is powered "on" at a time and with a low duty-cycle to conserve power. Redundant receivers are also provided for commanding.

The telemetry down-link is subjected to Reed-Solomon concatenated with convolutional encoding, yielding a negligible data package loss rate. When the spacecraft comes into view of a ground station, telemetry is down-linked to the ground. When the spacecraft is outside the view of a ground station, a spacecraft heart beat is transmitted comprising spacecraft identification, position, and various status telemetry.

Source	Normal Mode	Burst Mode
CSC Magnetometer	540 bits/second	5.40 kbits/second
Overhauser Magnetometer	20 bits/second	
Star Imager	232 bits/second	1.67 kbits/second
Particle Detectors (Average)	177 bits/second	177 bits/second

Table 2: Ørsted Science Data Rates.

The telecommand up-link is subjected to Bose-Chaudhuri-Hocquenghem (BCH) encoding. If command transmission fails the telecommands are re-transmitted. The up-link provides security facilities to avoid unauthorized access and to secure system integrity. Key communication parameters are summarized in Table 3.

Two turnstile communication antennas are mounted to the underside of the satellite (Earth facing) to provide the necessary link-margin and directivity. [3].

Structure

The primary load bearing structure consists of the lower platform, the vertical 'H' beam primary structure, a cabletray and an upper honeycomb platform. See Figure 5.

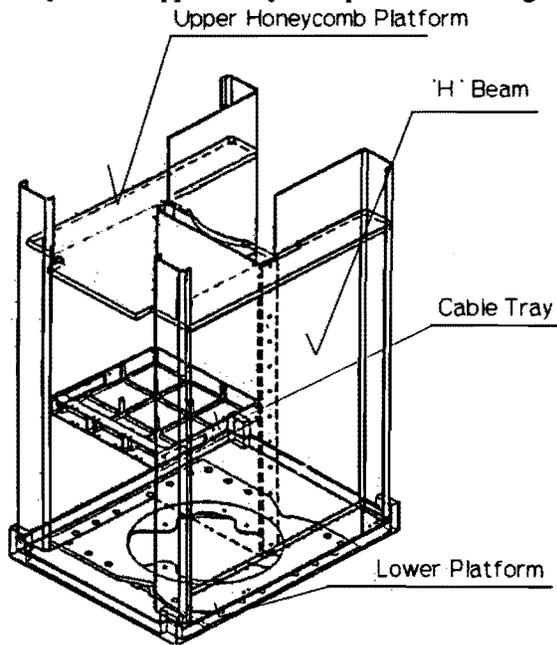


Figure 5: Main Structure

The main structural "H" beam configuration forms two vertical compartments, one on each side of the web of the "H" beam. The deployable boom assembly is mounted in one of these compartments. Two rows of modular electronic boxes, separated by a center cable tray, are mounted in the other compartment.

Each modular electronic box can accommodate two printed circuit boards and access to the interior of the box is via removable side plates. The box is attached to the web of the "H" beam structure by two long bolts which pass through the box from the front. A thermal interface is provided between the rear surface of each box and the primary structure for removal of heat.

Special electronic boxes for the GPS receivers and the star imager electronics are mounted on the sides of the satellite.

The deployable boom consist of three coilable longerons as shown in Fig. 6. The longerons are separated by radial spacers and tensioned by cross-wires when deployed. This boom configuration provides high inherent deployment torque without the need for external springs or other mechanical devices except for a restraining wire in the center of the boom to control the deployment. During Launch the boom is stowed in the canister also depicted in Figure 7.

Kevlar face-skin, aluminum honeycomb solar panel substrates attached to each side and the top complete the structure.

Parameter	Uplink	Downlink
Carrier frequency	2039.6 MHz.	2215 MHz.
Channel bit rate	1 and 4 kbit/s	4 and 256 kbit/s
Information bit rate	0.9 and 3.6 kbit/s	1.7 and 111.9 kbit/s
Probability of frame loss	Less than 10 ⁻⁷	Less than 10 ⁻⁸
Transmitter power (HPA)	13 dBW	-13 and 0 dBW
Antenna diameter on ground	1.8 m	-

Table 3: Key Communication Parameters

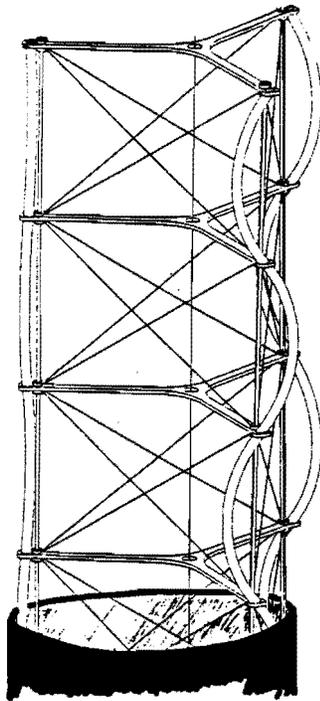


Figure 6: Section of Deployed Boom

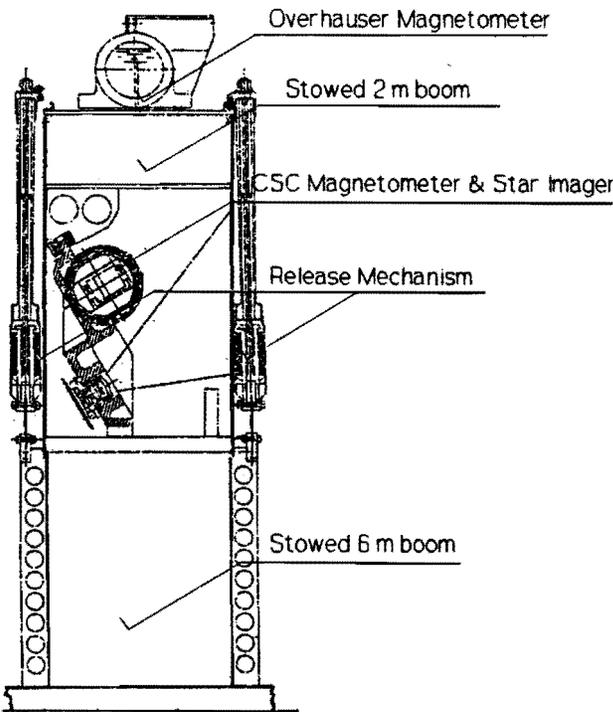


Figure 7: Boom Canister

Thermal Control Subsystem (TCS)

Thermal control of the satellite is accomplished by passive thermal design using multi layer insulation (MLI) and radiative surfaces. All equipment dissipating heat is thermally coupled to the satellite primary structure. The solar panel temperatures ranges between + 70° C and -40° C, depending upon the location of the panel and the orbital position of the satellite. Satellite internal body temperatures are expected to be within the range of + 4° C to + 12° C under the same conditions. Verification of the thermal design and equipment temperatures are done by modelling the satellite using the software tools ESARAD and ESATAN.

Magnetic Cleanliness

Magnetic cleanliness of the satellite is required to ensure quality and validity of the scientific data gathered during the mission. Control of magnetic moment is made by using good design practices at the subsystem and satellite levels, careful part selection with magnetic screening of each item, material controls and the minimum use of magnetic materials.

An Astatic magnetometer is used to screen all parts and materials for magnetic moment.

A detailed discussion of the steps taken to ensure a magnetically clean satellite is presented in [4].

Ground Segment

The Ørsted Ground Segment (ØGS) provides all the facilities required to manage and operate the satellite and process the telemetry data. It consists of three ground stations, a control center and a science data center. Figure 8 shows the ØGS infrastructure.

Ground Stations

There are three ground stations for the project. Each ground station has a satellite tracking antenna for the up and down-link communication channels with a minimum of 1.8 meter diameter to provide the required link margin. Automatic tracking drives the antenna to the correct azimuth and elevation for maintaining the best signal. The initial antenna contact coordinates are provided by the Ørsted Control Center (ØCC) prior to the satellite pass. A satellite heartbeat also facilitates antenna tracking. An overview of each ground station is presented in Figure 9.

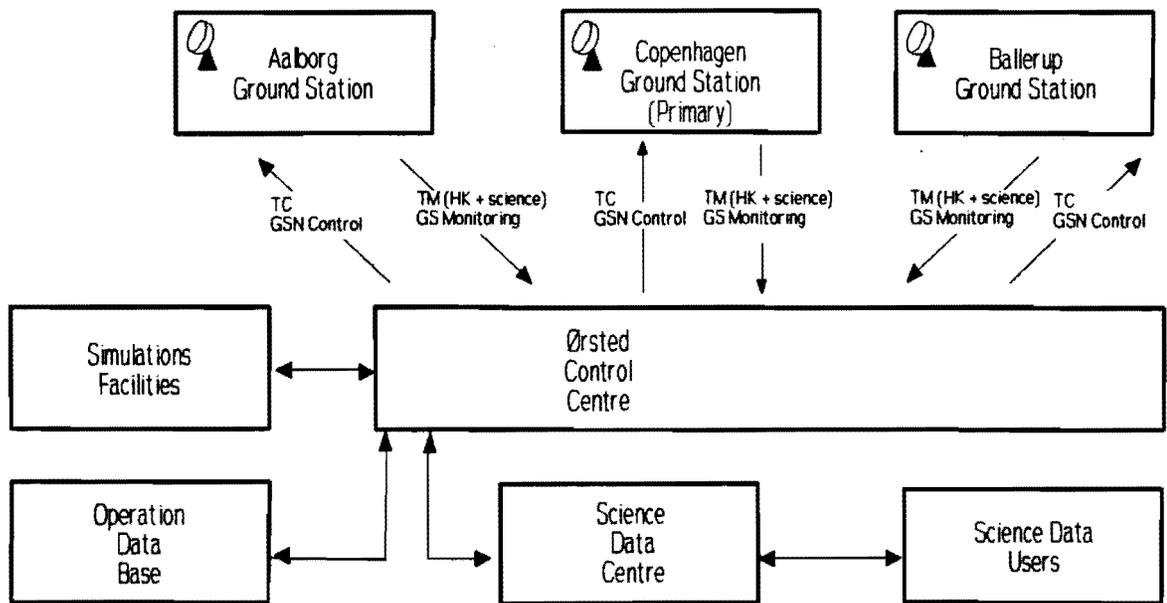


Figure 8: Ground Segment

Ørsted Control Center (ØCC)

The ØCC support the operation of the Ørsted satellite by controlling and monitoring the satellite and ground stations, and disseminating the science data to the science data center.

The control center is located in Birkerød, Denmark and has executive control over the ground segment and the satellite.

During post-launch mission phases satellite operations and communications are initiated and controlled from the ØCC.

Operations performed by ØCC includes monitoring telemetry and telecommands, providing satellite telecommands and back-up controls, data distribution, an operations database and a simulation facility. Emergency back-up facilities are provided for ØCC.

A functional overview of the ØCC is shown in Figure 10.

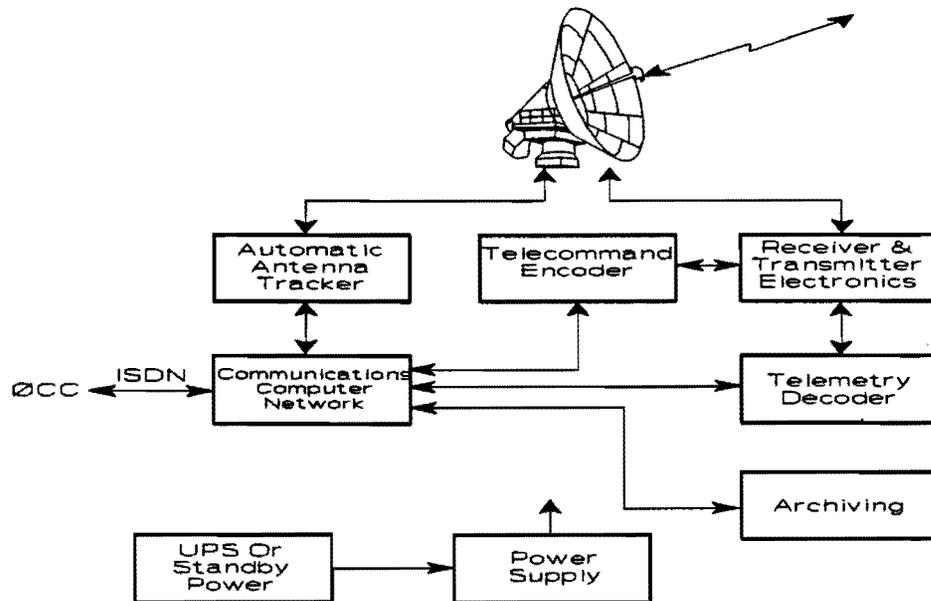


Figure 9: Ground Station Overview

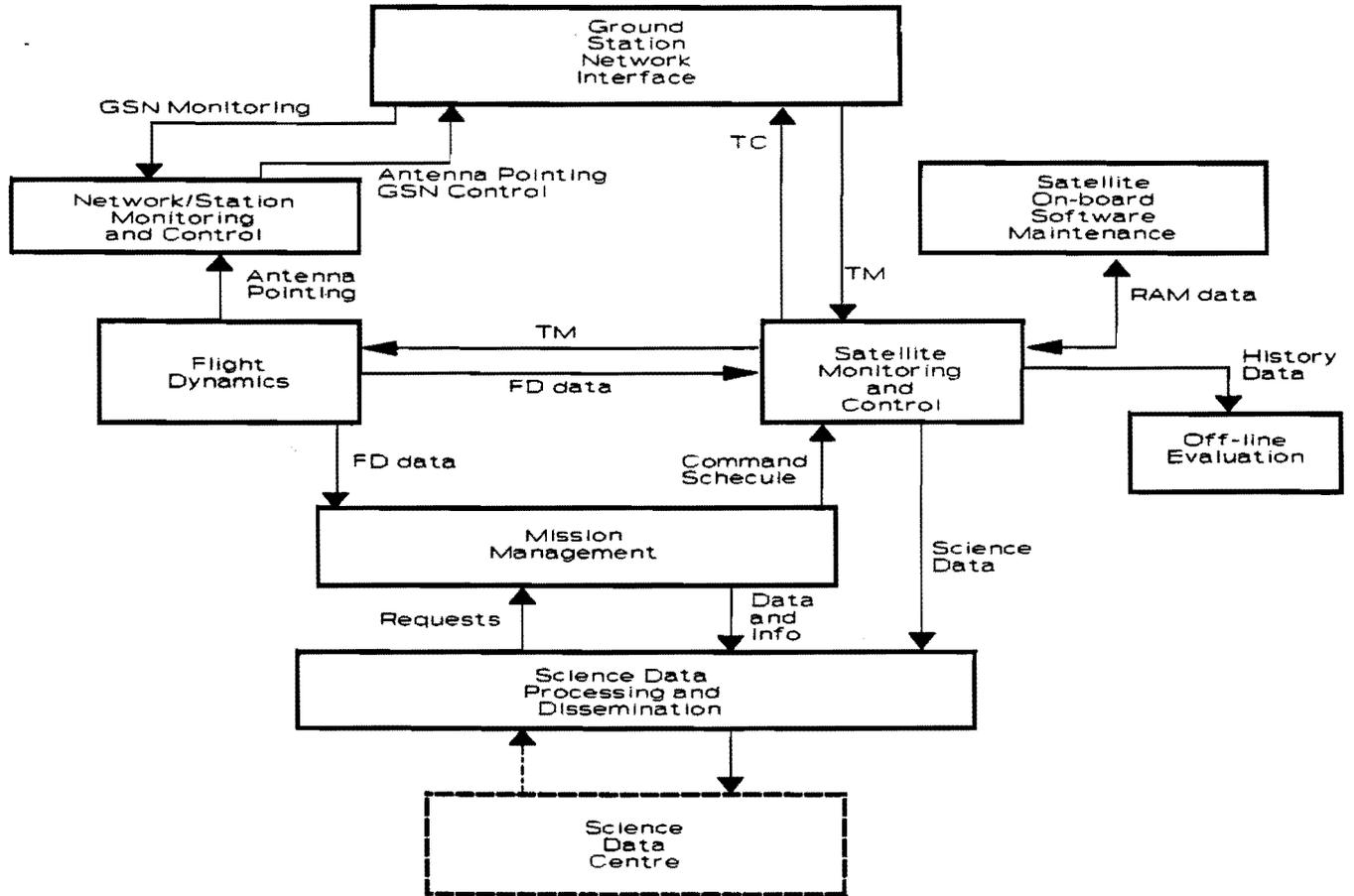


Figure 10: ØCC Functional Overview

ØCC Functions. . .The ØCC performs the following major functions with varying degrees of autonomy.

- o Mission Management
- o Satellite Monitoring and Control
- o Science Data Pre-processing and the Interface to the Science Data Center
- o Ground Station Monitor and Control
- o Simulation
- o Archiving

Satellite telemetry data is monitored and checked for out-of-limit conditions against pre-defined parameters stored in an operations database. In the event of an out-of-limit condition, an operator alert is activated.

Telecommands are generated by the Ørsted Control Center and validated prior to transmission.

A real-time display of essential monitored and processed telemetry and telecommand status is provided. Measured telemetry values are displayed and a "quick-look" display of the mission status and scientific data is also provided. A complete image of the on-board memory contents is maintained at the ØCC.

The operations database includes satellite housekeeping and science payload telemetry data, a telecommand file, engineering data for each subsystem, science payload data and satellite system simulations performed including non-nominal situations.

Science payload data is distributed to remote located experimenters and investigators through the Science Data Center located at DMI.

Suitable data storage, data access, print-out and archiving facilities are provided for all satellite telemetry and telecommand data, Ørsted Control Center traffic and all

mission operations.

Simulation consists of not less than all nominal satellite operating functions from the time of separation from the launcher plus performance analysis and effects using selected nominal and non-nominal conditions.

The ØCC extracts correlation between the on-board spacecraft reference time and UTC (Universal Time coordinated) ground time. The information required for this correlation is provided by a time correlation packet.

Science Date Center (SDC)

The SDC supports the scientific analysis of the data performed by the principal investigators.

SDC Functions. . .The SDC performs the following major functions (in co-operation with the appropriate principal investigators):

- o Determination of calibration parameters.
- o Correction and calibration of the raw (science payload) data set received from the ØCC.
- o Validation and data quality check.
- o Conversion of data into scientific units and Earth oriented coordinates.

- o Develop general data display software to be used by the participating institutions, Danish and foreign.
- o Generate summary listings of processing characteristics and data characteristics.
- o Generate summary plots (all data) as well as polar and orbit plots (selected data).
- o Acquisition and reduction of ancillary ground-based data.
- o Optional post-processing of Star Imager data in case of non-nominal on-board attitude data.
- o Archiving of final data sets, calibration, general data reduction, and preparation of specialized data sets for the scientific investigations.

The SDC is also responsible for the archiving of final data sets and for the distribution of preprocessed data to foreign co-investigators. Primary data flow during the Ørsted satellite mission as presented in Figure 11. The core of the SDC is located at the Danish Meteorological Institute, (DMI), which is the host institution for the Science Coordination Office. The SDC is equipped with network connections to the Principal Investigators's in Denmark as well as to the international scientific network, internet. Selected sub-tasks are defined at the SDC and transferred to appropriate institutions that have agreed to take the responsibility for these tasks. The SDC is capable of supporting visitors working with the scientific data for an extended period and supports data analysis workshops at regular intervals with the participation of Danish as well as foreign scientists.

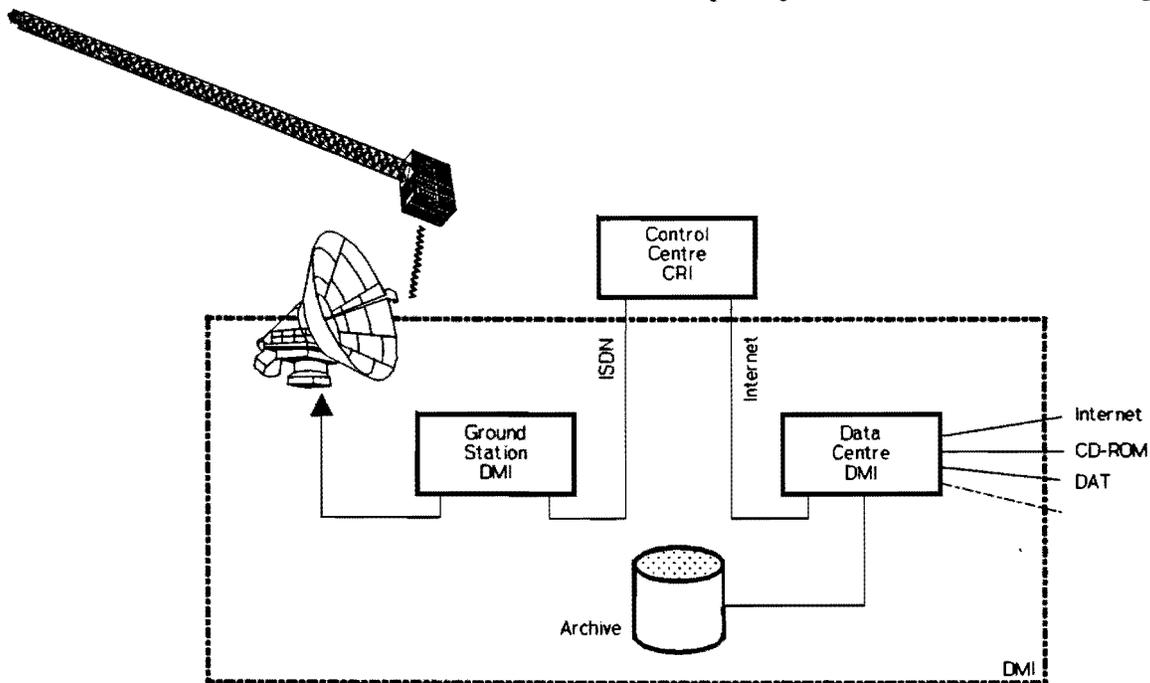


Figure 11: Primary data flow in the Ørsted mission

Integration and Test

Prior to satellite integration all subsystems except the primary structure and thermal items receive environmental and electrical testing. Following satellite integration, a complete functional test of all subsystems will be carried out and performance characteristics confirmed. After completion of the post-integration functional test and mass properties verification, a series of environmental tests are applied to the proto-flight satellite.

The satellite will be launched by the McDonnell Douglas Delta II launch vehicle. The test program is compatible with the environments described in [5], in terms of shock, vibration, interfaces, temperature, barometric pressure, acceleration, acoustic noise, etc.

Magnetic cleanliness of the satellite will be checked by mapping the satellite's static and dynamic magnetic fields in a magnetic test facility. Finally an integrated system test is conducted on the satellite to verify end-to-end operation.

International Participation

The Ørsted satellite is a scientific satellite which will provide accurate and comprehensive science data for further study of the Earth's magnetic field and charged particle environment by the international scientific community. The satellite has generated considerable international interest in both the hardware and in the science data return.

An announcement of Opportunity to analyze the science data returned by the Ørsted satellite has been issued. It resulted in expressions of interest from 75 scientific groups in 17 countries around the world.

Leti in France, supported by CNES has designed and is now constructing the Overhauser magnetometer. A GPS TurboRogue receiver designed by JPL will be provided by NASA. In addition NASA-OLS has arranged the launch as a piggyback on the Delta II launch Vehicle. Other hardware suppliers and support countries are Italy, England, USA, Germany and Sweden.

Conclusions

With funding in place and with increasing interest and support from the international scientific community, NASA, CNES and ESA, the Ørsted satellite project is progressing on schedule towards a launch expected to take place in January 1996. All design reviews are complete and all elements within the space segment and ground segment of the project have been defined. Detailed specifications and

documents have been written for both segments and the subsystems within these segments. This in turn allows the construction of engineering model hardware and the performance of a system integrated electrical test which is the essential forerunner of the protoflight satellite integration and test scheduled to take place next year.

The progress made in the development of the Ørsted satellite project has demonstrated the cooperation and enthusiasm of Danish educational and scientific institutions and Danish industry as well as all the international participants. This project is also demonstrating that it is possible for countries with limited resources to consider generating world-class science from a lightweight, low-budget, small satellite project with a short time schedule.

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