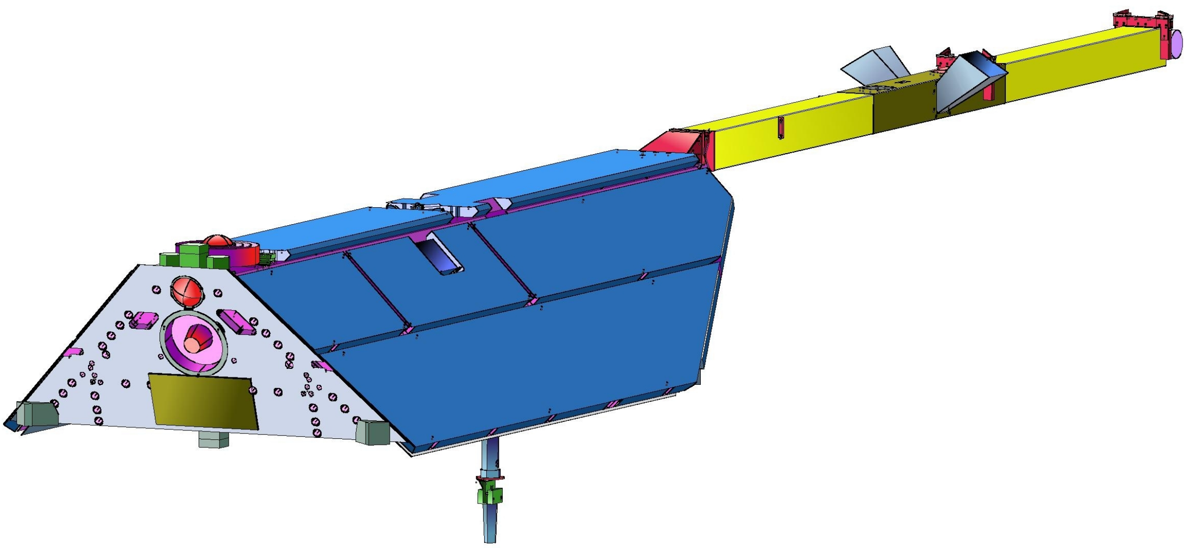
Announcement of Opportunity
for
CHAMP



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GeoForschungsZentrum Potsdam

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GFZ POTSDAM

http://op.gfz-potsdam.de/champ/

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1 DESCRIPTION OF OPPORTUNITY

The GeoForschungsZentrum Potsdam (GFZ) announces the opportunity to conduct basic scientific research and application-oriented projects using data and data products from its georesearch mission CHAMP (**CHA**llenging **M**inisatellite **P**ayload). CHAMP was launched on July 15, 2000 from the Russian cosmodrome Plesetsk into a near polar, circular and 454 km altitude orbit. The CHAMP overall system has been commissioned and validated over the last 9 months jointly with the cooperation partner DLR responsible for the mission operation and has proven to function as planned and specified. The system is now ready to deliver high quality data and data products to the users in an efficient and user-friendly manner. The design lifetime of CHAMP is five years so that the user community can expect a multi-year continuous high precision data flow for geosciences and atmospheric research. It is the purpose of this Announcement of Opportunity (AO) to stimulate calibration/validation activities as well as scientific studies and application investigations on the basis of CHAMP mission data and CHAMP data products to come up with new or value-added products besides those products routinely generated in the CHAMP processing system.

2 CHAMP MISSION OBJECTIVES, PARTNER AGENCIES, PROJECT ORGANISATION

2.1 Mission Objectives

The central task of geosciences in the next decades will be studying and trying to understand the Earth as a system: a system composed of solid, fluid and gaseous parts which show large variations in space and time and mutual complex interactions taking place on quite different time scales. Characterizing such an extensive, complex and heterogeneous system requires global long term and synoptic data series of the phenomena taking place within and between the various spheres of the system.

For this scientific goal and because of the fact that a special support programme for the East-German space industry was initiated by the German Space Agency DARA (now merged into DLR) in 1994, GFZ scientists (PI Prof. Christoph Reigber) proposed in the same year a small satellite mission with science instrumentation and orbit characterisation that would allow to simultaneously measure and drastically improve the gravity and magnetic field modelling. The instruments proposed to fly on a spacecraft in a medium to low altitude orbit were the following:

Gravity: a new generation GPS flight receiver for continuous tracking of the low orbiter by the satellites of the GPS constellation for accurately and continuously monitoring of the orbit perturbations, a high-precision three-axes accelerometer for measuring the surface force accelerations and a star camera pair for precise attitude determination of the spacecraft body.

Magnetics: a high performance Fluxgate magnetometer set measuring the three components of the ambient magnetic field in the instrument frame combined with a star camera pair determining the attitude of the assembly with respect to the stellar frame and a Overhauser scalar magnetometer serving as magnetic reference.

Atmosphere/Ionosphere: the instrumentation used for the recovery of the magnetic and gravity fields constitutes at the same time a powerful assembly of sensors for observing many parameters relevant for the characterisation of the state and dynamics of the neutral atmosphere and the ionosphere: GPS/CHAMP radio occultation measurements for the derivation of temperature and water vapour distribution in the atmosphere, digital ion driftmeter measurements for sensing the electric field, GPS/CHAMP soundings to determine the electron density distribution in the ionosphere and the high resolution accelerometer to sense the air density variations in CHAMP’s orbital environment.

Against this background the three primary science objectives of the CHAMP mission are to provide

- highly precise global long-wavelength features of the static Earth gravity field and the temporal variation of this field,
- with unprecedented accuracy global estimates of the main and crustal magnetic field of the Earth and the space/time variability of these field components,
- with good global distribution a large number of GPS signal refraction data caused by the atmosphere and ionosphere, which can be converted into temperature, water vapour and electron content.

CHAMP's multifunctional and complementary instrumentation is now in full operation. This instrumentation provides for the first time in space geodesy's history an almost continuous tracking of the spacecraft motion at a low altitude, a high precision in-situ measurement of the forces acting on the satellite surface and simultaneously a global mapping of the magnetic field with a precision and spatial resolution never achieved before. CHAMP has the potential to initiate quite a number of new multidisciplinary research activities, primarily for the Earth system components:

- Geosphere: investigation of the structure and dynamics of the solid Earth from the core along the mantle to the crust, and investigation of interactions with the ocean and atmosphere,
- Hydrosphere: more accurate monitoring of ocean circulation, global sea level changes and short-term changes in the global water balance as well as interactions with weather and climate,
- Atmosphere: global sounding of the vertical layers of the neutral and ionized gas shell of the Earth and relationship with weather on Earth and space weather,

and provides the first joint gravity, magnetic-field modelling input for the ‘International Decade of Geopotentials’.

2.2 Partner Agencies

During mission preparation the following three agencies proposed to provide on a non-exchange of fund basis science instruments, under development or in an upgrade stage in their own laboratories

- the *National Aeronautics and Space Administration (NASA)*, USA, providing a GPS Blackjack Flight receiver built by the Jet Propulsion Laboratory (JPL),
- the *Centre National des Études Spatiales (CNES)*, France, providing a precision STAR-accelerometer, fabricated by the Office National d'Études et de Recherches Aérospatiales (ONERA) and
- the *Air Force Research Laboratories (AFRL)*, USA, providing a laboratory-developed digital ion driftmeter (DIDM).

Memorandi of Understanding (MOU) and Instrument Implementation Plans (IPP) were signed between these agencies, the DLR and the GFZ, respectively, for the provision, implementation and flight control of their own instruments.

2.3 Project Organisation

The CHAMP project was established as a PI institution funded programme with the PI (Prof. Christoph Reigber) and his institution (GFZ Potsdam) being fully responsible for the successful implementation and execution of the mission. During the various mission phases the project was and is funded by the Federal Ministry of Education and Research (BMBF), the German Aerospace Center (DLR) and the GeoResearchCenter Potsdam (GFZ). Strong technical, organisational and scientific links were established with the aforementioned science instruments providing agencies NASA (Blackjack GPS), CNES (STAR accelerometer) and AFRL (DIDM). The cooperation arrangements between GFZ and DLR are established in a GFZ/DLR cooperation agreement, the cooperative activities with the partner agencies in the aforementioned MOUs and IPPs.

The CHAMP project's organisational structure for the post-launch mission phases is shown in the chart below:

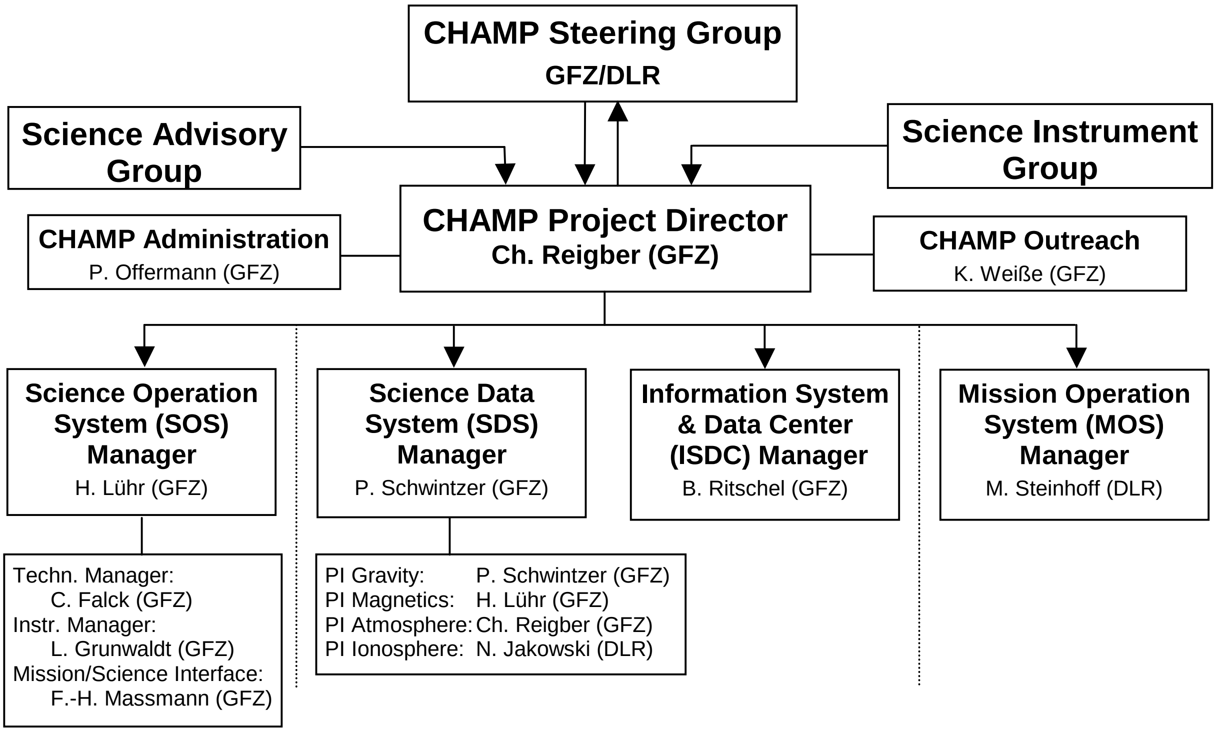

Figure 2-1: CHAMP project organisation and responsibilities

The CHAMP Steering Group is composed of the following members:

- Dipl.-Ing. K. Berge, Project Director Space Flight, DLR Bonn-Oberkassel
- Prof. R. Emmermann, Scientific Director GFZ Potsdam
- Prof. Ch. Reigber, Director of Division 1, GFZ Potsdam
- Prof. K. Wittmann, Director of German Space Operations Center, DLR Oberpfaffenhofen

The CHAMP Science Advisory Group consists of the members:

- Prof. G. Balmino, GRGS Toulouse, France
- Dr. D. Cooke, AFRL, Hanscom, USA
- Prof. E. Friis-Christensen, DSRI Kopenhagen, Denmark
- Prof. V. Haak, GFZ Potsdam, Germany
- Prof. Ph. Hartl, Munich, Germany
- Prof. K.H. Ilk, ITG Bonn, Germany
- Prof. K. Labitzke, FU Berlin, Germany
- Dr. W.G. Melbourne, JPL Pasadena, USA
- Dr. M. Pilkington, Geological Survey Canada, Ottawa, Canada
- Prof. R. Rummel, IAPG Munich, Germany
- Prof. K. Schlegel, MPI Katlenburg, Germany
- Prof. B.D. Tapley, CSR Austin, USA
- Prof. G. Tetzlaff, LIM Leipzig, Germany
- Dr. T. Yunck, JPL Pasadena, USA

In the CHAMP Instrument Group the experts for all the CHAMP science instruments are assembled:

- Dr. R. Biancale, GRGS Toulouse, France
- R. Bock, GFZ Potsdam, Germany
- Dr. P. Brauer; DTU, Lyngby, Denmark
- Dr. L. Grunwaldt, GFZ Potsdam, Germany
- Prof. J. L. Jørgensen, DTU Lyngby, Denmark
- Dr. J.-M. Leger, LETI, Grenoble, France
- Prof. H. Lühr, GFZ Potsdam, Germany
- T. Meehan, JPL Pasadena, USA
- Dr. A. Perret, CNES Toulouse, France

3 THE CHAMP SATELLITE

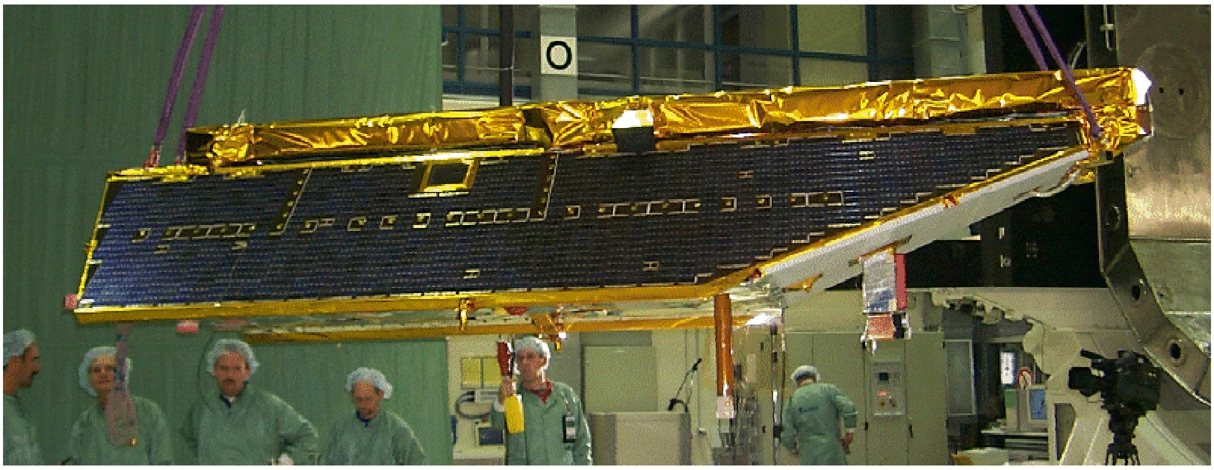

Figure 3-1: CHAMP satellite (boom stowed)

The CHAMP spacecraft was designed and manufactured under contract of GFZ by Daimler Chrysler Aerospace Jena Optronik GmbH (DJO) in an integrated industry effort with Dornier Satellitensysteme GmbH (former DSS, now Astrium) and the Raumfahrt und Umwelttechnik GmbH (RST).

The CHAMP satellite (see Figures 3-2, 4-1 and 4-2) has a robust structure design with fixed solar panels. The primary structure is mainly based on aluminium sandwich panels with an additional kapton foam layer on the outer panels. The shape of the satellite is an arrangement to optimise its aerodynamic behaviour, accommodation of instruments and subsystems and fitting into the fairing of the COSMOS launcher.

The two solar arrays are symmetrically inclined to the equipment panel with two additional solar panels on the roof top of the spacecraft. The satellite is closed at its aft and front side by sandwich panels of which the aft panel carries the GPS occultation antenna. The front panel carries the digital ion driftmeter and is covered by a conductive aluminium plate in order to avoid electrical charging in the space plasma. The nadir S-band antenna is mounted on a short boom beneath the forward compartment, while the zenith S-band antenna is placed on the rear antenna support structure.

The power requirements of the on-board equipment as well as the chosen orbit necessitate about 7 m^2 of body-mounted solar generator surface. A battery of NiH_2-cells ensures the appropriate power supply during eclipses.

Total Mass	522.5 kg (at launch)
Height	750 mm
Length	8333 mm (with 4044 mm boom)
Width	1621 mm
Area to Mass Ratio	0.00138 m^2/kg

Table 3-1: Physical parameters of the CHAMP satellite

For magnetic cleanliness reasons, the magnetometry assembly is kept at some distance from the satellite body. This is achieved by using a deployable boom mounted at the front end of the satellite. The length of the boom is approximately 4 m, thus guaranteeing that the magnetic strayfield at the location of the Overhauser magnetometer is less than 0.5 nT.

The boom consists of three segments: the outer part, carrying the Overhauser magnetometer, the middle segment with the optical bench on which two star sensor heads and two Fluxgate magnetometers are mounted, and the inner segment with the deployable part of the hinge. The boom eigenfrequency in deployed configuration is 2.3 Hz.

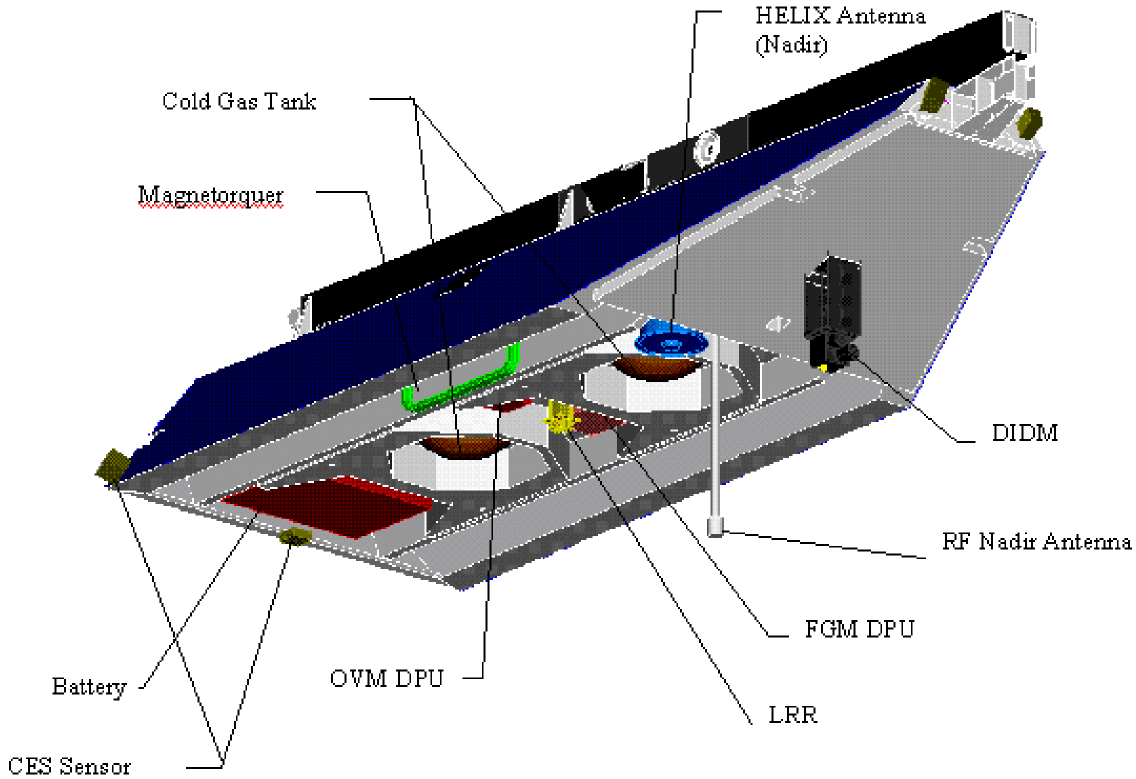

Figure 3-2: Bottom view of CHAMP

The primary structure houses the accelerometer at the satellite's Centre of Gravity (CoG). The surrounding subsystems and especially the two tanks carrying gaseous nitrogen are accommodated in such a way that the proof-mass of the accelerometer will coincide with the satellite CoG within 2 mm accuracy throughout the whole mission.

Subsystems

The CHAMP satellite is kept in a three-axis stabilised earth-oriented attitude with the boom pointing in flight direction. For the attitude and orbit control subsystem (AOCS), a cold gas propulsion system comprising 12 thrusters for attitude and another 2 for orbit change manoeuvres has been employed. A set of three magnetic torquers for pre-compensation of environmental disturbances supports the cold gas propulsion system. The task is to control the orientation and angular rates within a dead band of ±2° and ±0.1°/s. The payload instruments star sensors, GPS receiver and Fluxgate magnetometer are used as attitude sensors along with the Coarse Earth and Sun Sensors (CESS) for the safe mode.

The thermal control subsystem (TCS) guarantees a secure temperature for all instruments and subsystems during all possible space environment conditions. This is primarily achieved by employing surface coatings (e.g. paints and silverised tapes), thermal insulation (i.e., multilayer insulation) and a space radiator. For critical regions inside the spacecraft with high demands on temperature stability, active thermal control by means of heaters has been implemented.

Power generation, conditioning, distribution and storage is the tasks of the power subsystem. Therefore approximately 7 m² of solar cell surface, a combined Power Control and Distribution Unit (PCDU) as well as a NiH_2-battery consisting of 10 cells are implemented.

The on-board data handling (OBDH) subsystem manages all data from scientific instruments as well as housekeeping (H/K) data from satellite subsystems. Since some of the scientific data are also used as attitude and orbit information, the AOCS software forms part of the OBDH. The OBDH is synchronised to the GPS clock by a pulse every second. This reference pulse is also distributed to all instruments. Every 10 seconds the GPS receiver updates the onboard time. In addition the OBDH has limited autonomous capability of failure detection, isolation and recovery (FDIR) occurring during data handling. Data are stored in a mass memory unit (MMU) of 1 Gigabit capacity and are transmitted when CHAMP is in visibility of the receiving ground station.

Telecommunication is accomplished by means of the telemetry, tracking and command (TT&C) subsystem in S-band. This subsystem consists of a receiver, a transmitter, an encoding/decoding device and two antenna systems with complementary semi-spherical radiation patterns.

Attitude & Orbit Control System (AOCS)	- Three-axis stabilised; Earth-pointing - Pointing accuracy <5° (2° nominal) - Stability 0.1 °/s
Electrical Power	- Total power consumption 150 W - Payload power consumption 46 W - Generation (solar array) 6.9 m^2 - Storage capacity (NiH_2 battery) 16 Ah
Thermal Control	- Average temperature (equipment platform) +20 °C - Radiator emissivity 0.5 - 22 flat foil heaters, 7 W each - 60 temperature sensors PT1000 - System power sensitivity 1.6 °C/10W
Data Handling	- Operating frequency 12 MHz - Mass memory capacity 1Gbit - FDIR capabilities
RF Communication	- Uplink (S-band) carrier frequency 2093.5 MHz - Uplink data rate 4 kbit/s - Downlink (S-band) carrier frequency 2280 MHz - Downlink data rate 32kbit/s or 1 Mbit/s - RF output power 0.5 or 1.0 W

Table 3-2: CHAMP satellite subsystem characteristics

4 SCIENCE INSTRUMENTS

CHAMP carries 7 different instruments to fulfil the mission scientific objectives. The instruments are in a very good state and function as expected. A number of parameter and software updates have been involved in the calibration and validation phase. Early results prove that the state-of-the-art instruments make CHAMP a pioneer mission for recovering the Earth’s gravity and magnetic fields as well as for sounding its atmosphere.

This chapter will give a general description, the measurement principle, characteristics and the implementation of each payload instrument.

The following figures show the physical layout of the CHAMP spacecraft with the location of the instruments:

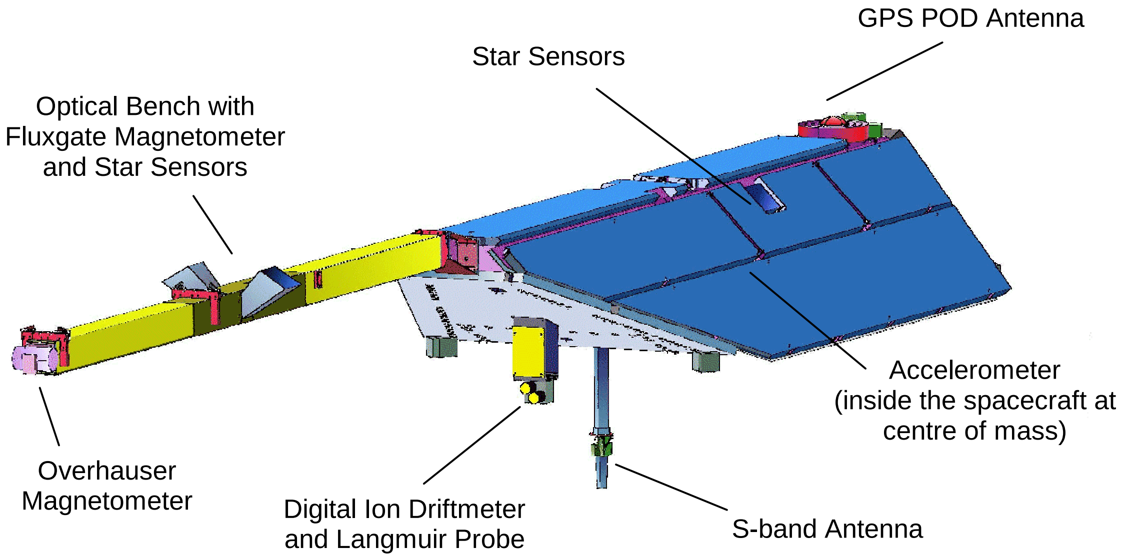

Figure 4-1: Front side view of CHAMP with location of instruments

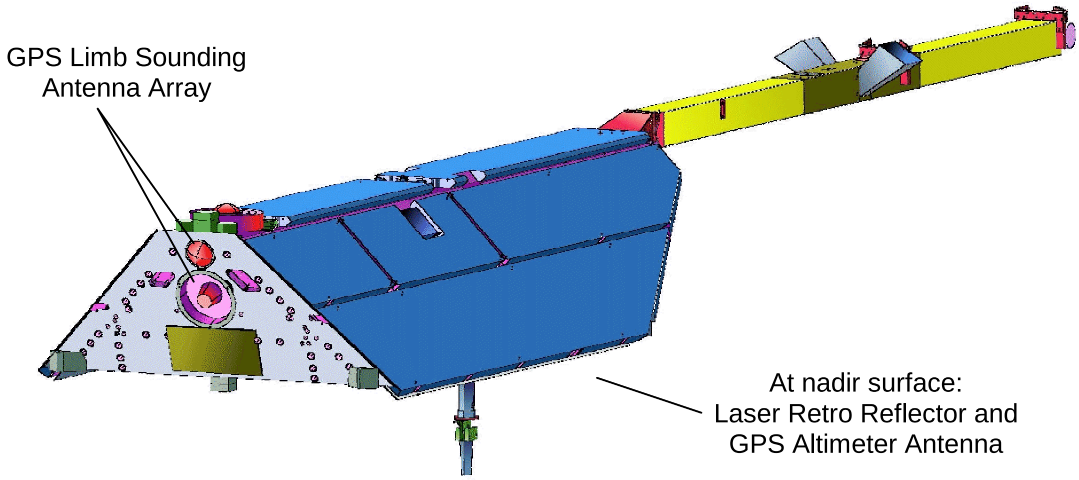

Figure 4-2: Rear side view of CHAMP with location of instruments

4.1 Electrostatic STAR Accelerometer

General Description

The STAR accelerometer sensor is provided by the Centre National d'Etudes Spatiales (CNES) and was manufactured by the Office National d'Etudes et de Recherches Aerospatials (ONERA) in Chatillion, France. It serves for measuring the non-gravitational accelerations such as air drag, Earth albedo and solar radiation acting on the CHAMP satellite. The STAR accelerometer uses the basic principle of an electrostatic micro-accelerometer: a proof-mass is floating freely inside a cage supported by an electrostatic suspension. The cavity walls are equipped with electrodes thus controlling the motion (both translation and rotation) of the test body by electrostatic forces. By applying a closed loop-control inside the sensor unit it is intended to keep the proof-mass motionless in the centre of the cage. The detected acceleration is proportional to the forces needed to fulfil this task.

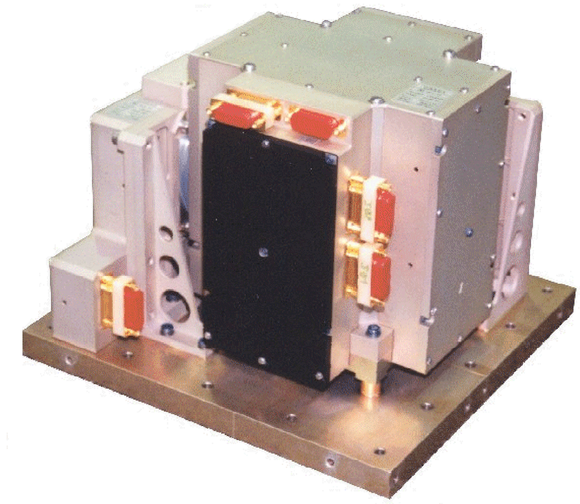

Figure 4-3: The CHAMP STAR accelerometer sensor

Measurement Principle

The sensor unit consists of the accelerometer cage containing the proof-mass and the control electronics as power supplies and servo-loops for the electrostatic forces acting on the test body. The walls of the cage (which carry the control electrodes) consist of Ultra-Low-Expansion ceramics (ULE) to keep the influence of thermal variations on the cage dimensions as low as possible. Six servo-channels (3 for linear and 3 for angular accelerations) act separately along the axes of the accelerometer. The pair of electrodes corresponding to each servo-loop is used both for capacitive position sensing and electrostatic force generation. From the measurement of the capacitive sensor, a Proportional-Integrative-Derivative (PID) controller determines the drive voltage to be applied to the opposite electrodes for the generation of the electrostatic field that stabilises the (naturally unstable) loop.

The output network provides the measurement of the actually applied voltage V which constitutes the analogue output of the accelerometer. This analogue output is digitised by 24-bit Analogue-Digital-Converters (ADCs) and reported together with the readout of the capacitive position detectors, the biasing voltage V_P which is applied to the proof mass and housekeeping parameters in telemetry. The digitising of the analogue signals, provision of secondary voltages and control of the accelerometer is performed by an Interface and Control Unit (ICU) which interfaces the STAR with the CHAMP spacecraft.

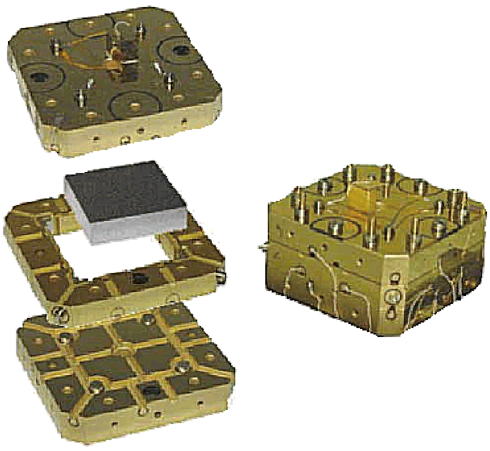

Figure 4-4: Components of the CHAMP STAR accelerometer sensor unit

STAR Accelerometer Characteristics

The origin of the measurement frame is the centre of the proof-mass. The orthogonality of the axes of this frame is better than 2.5 10^{-5} rad.

X: less sensitive axis, parallel to S/C z-axis (yaw)	phi: rotation about x-axis of accelerometer
Y: high sensitive axis, parallel to S/C x-axis (roll)	theta: rotation about y-axis of accelerometer
Z: high sensitive axis, parallel to S/C y-axis (pitch)	psi: rotation about z-axis of accelerometer

Table 4-1: Definition of the STAR accelerometer sensor axes via the surface normals of the parallel-epipedic proof-mass

Measurement bandwidth		10^{-4} ... 10^{-1} Hz
Linear accelerations:		
	Measurement range	$\pm 10^{-4}$ ms^{-2}
	Resolution[1)]	$< 3 \times 10^{-9}$ ms^{-2} (y- and z-axis) $< 3 \times 10^{-8}$ ms^{-2} (x-axis)
Angular accelerations:		
	Resolution[1)]	1×10^{-7} rad $\times$ s^{-2} (rotation about x-axis) 5×10^{-7} rad $\times$ s^{-2} (rotation about y- and z-axis)
Temperature stability of bias and scale factor:		
	Max. temperature coefficient of bias[2)]	5×10^{-6} ms^{-2} °C^{-1} (x-axis) 1×10^{-8} ms^{-2} °C^{-1} (y- and z-axis)
	Max. temp. coefficient of scale factor[3)]	2×10^{-3} °C^{-1} (x-axis) 5×10^{-3} °C^{-1} (y- and z-axis)

1) within the specified measurement bandwidth of 10^{-1} to 10^{-4} Hz
2) preliminary values
3) assuming a maximum temperature variation of <1°K per orbit

Table 4-2: CHAMP STAR accelerometer characteristics

Implementation of the STAR Accelerometer on CHAMP

In order to minimise the influence of measurement disturbances due to rotational accelerations and gravity gradients, the accelerometer sensor is positioned precisely in the centre of gravity of the CHAMP satellite (maximum deviation 2 mm). The exact orientation of the accelerometer axes in space is measured by means of two star sensors which are attached to the thermal housing of the sensor unit. The thermal housing guarantees a temperature stability of better than 1°K per orbit for the accelerometer sensor in order to minimise thermal effects on bias and scaling factor.

4.2 GPS Receiver TRSR-2

General Description

The GPS Receiver TRSR-2 onboard CHAMP is provided by NASA and manufactured at NASA's Jet Propulsion Laboratories (JPL) in Pasadena, USA. In combination with the STAR accelerometer it serves as the main tool for high-precision orbit determination of the CHAMP satellite and by this for the Earth’s gravity field recovery. Additional features are implemented for atmospheric limb sounding and the experimental use of specular reflections of GPS signals from ocean and ice surfaces for GPS-altimetry. A synchronisation pulse delivered every second is used for precise onboard timing purposes, and the autonomously generated navigation information is employed for both the CHAMP AOCS and the star sensors to update their orbit models.

The receiver has the following measurement modes:

- Tracking mode (default): this mode is enabled as soon as the TRSR-2 becomes switched on.

- Occultation mode: in this mode the receiver software schedules and performs 50 Hz tracking of setting occultations of GPS satellites.
- Altimetry mode: in this mode the nadir antenna collects specular reflections of GPS signals from the surface of the oceans and ice sheets.

Measurement Principle

The low orbiting CHAMP satellite and each spacecraft of the high orbiting GPS satellite configuration establish a so-called high-low satellite-to-satellite (SST) link. Each of the GPS satellites transmits a PRN modulated L1 and L2 signal which the TRSR-2 receiver acquires for a maximum of 12 satellites at the same time. From these signals the orbiting receiver generates at a frequency of 0.1 Hz pseudo-ranges and carrier phases for all GPS satellites which are in lock. By simultaneously using pseudo-ranges from at least 4 different GPS satellites with known ephemeris, both the three-dimensional coordinates of the CHAMP receiver and their respective change with time can be solved for, thus a navigation solution is obtained. The accuracy of this solution ranges down to better than 10 m for the position. Corrections for reference frame and dynamic and measurement model parameters for CHAMP will be achievable with high accuracy by making use of the much more precise carrier phase tracking data and a simultaneous full dynamic solution for the orbits of the GPS satellites and the CHAMP spacecraft. The remaining orbit perturbations are the input for the improvement of gravity field modelling.

A new field of use for GPS measurements is the observation of radio occultations of GPS satellites by the Earth from a low-orbiting satellite. For this purpose the signal of the occulting GPS satellite is sampled at a considerably higher frequency (50 Hz) while crossing the lower layers of the Earth atmosphere in comparison with a non-occulting GPS satellite (0.1 … 1.0 Hz).

A nadir pointing GPS antenna will be used in an experimental mode to collect specular reflections of GPS signals from the ocean surface. Knowing the precise position of the transmitting GPS satellite and the receiving CHAMP satellite, quasi-altimetry measurements can be carried out.

Performance Characteristics

The TRSR is a 48-channel Global Positioning System receiver. Up to 36 channels can be used for Precise Orbit Determination (POD); each tracked GPS satellite requires 3 channels for CA, P1 and P2. The TRSR is completely self-initialising from a cold boot. Once switched on, it operates fully autonomously. The receiver decides which GPS satellite to track in the various tracking modes, solves for the state vector (navigation solution) for the CHAMP satellite, schedules occultation and altimetry measurements and solves for the offset between the GPS receiver time and the GPS system time in order to provide an extremely accurate synchronisation pulse for the CHAMP onboard subsystem.

Computed position in telemetry	< 10 m (real-time navigation)
Time calibration accuracy	< 1µs from GPS time (resolution 0.1 ns)
Dual-frequency range and integrated carrier for POD at a 1s interval:	
Phase (ionosphere-free)	< 0.2 cm
Range (ionosphere-free)	< 30 cm
Dual-frequency integrated carrier phase and amplitude for atmospheric occultation:	
Phase (ionosphere-free)	< 0.05 cm
Range (ionosphere-free)	< 50 cm
Limb-sounding observables (prior to atmospheric de-focusing):	
L1 carrier phase	< 0.05 cm (1 s)
L2 carrier phase	< 0.15 cm (1 s)

Table 4-3: TRSR-2 GPS receiver characteristics

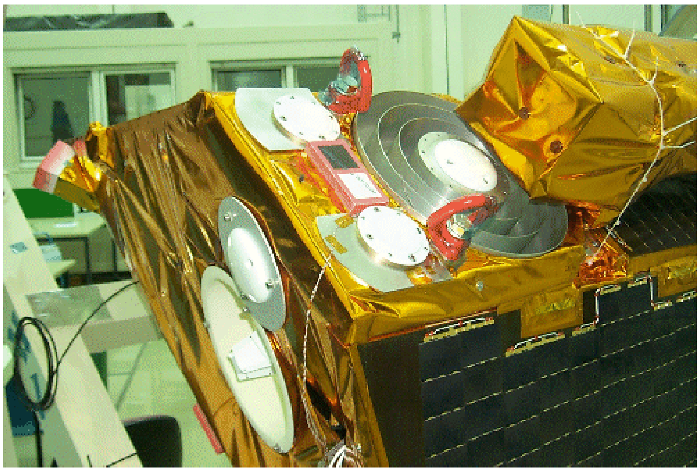

Figure 4-5: CHAMP GPS antenna assembly

Implementation of the TRSR on CHAMP

The GPS receiver system on CHAMP consists of a Receiver/Processor Assembly (RPA) containing the RF down-converter sections, an internal bus and the cold-redundant base-band processor cards, the RF coaxial cables to the 4 antennas and the antennas themselves. The following antenna types are used for the TRSR GPS receiver on CHAMP: zenith mounted POD antenna on a choke ring, spare POD antenna on the aft panel, high-gain helix antenna for occultation measurements, mounted on the aft panel (20° inclined towards nadir) and a high-gain nadir-viewing helix antenna for GPS altimetry experiments.

4.3 Laser Retro Reflector

General Description

The Laser Retro Reflector is a passive payload instrument consisting of 4 cube corner prisms intended to reflect short laser pulses back to the transmitting ground station. This enables to measure the direct two-way range between a ground station and the satellite with a single-shot accuracy of <1 cm without any ambiguities. These data are used for precise orbit determination in connection with GPS for gravity field recovery, calibration of the on-board microwave orbit determination system (GPS) and allows for two-colour ranging experiments to verify existing atmospheric correction models. The Laser Retro Reflector was developed and manufactured in-house at GFZ.

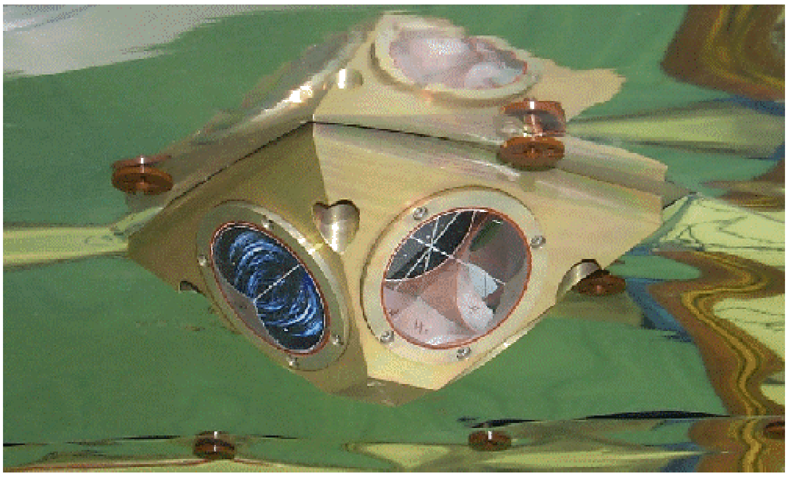

Figure 4-6: CHAMP Laser Retro Reflector

Design Description of the Retro Reflector

The Laser Retro Reflector (LRR) consists of only 4 cube corner prisms arranged in a densely packed array in order to have predominantly only one prism contributing to the reflected signal. Even during those short observation periods when more than one prism contributes to the signal (e.g. near culmination of the CHAMP satellite) the structure of the reflected pulses caused by the LRR (signature) will not be resolved by the presently existing Satellite Laser Ranging (SLR) systems. The resolution of the range measurements to the LRR will depend exclusively on the SLR ground station hardware thus making the CHAMP LRR an ideal target for high-resolution two-colour ranging experiments.

The individual cube corner prism of the reflector are made from fused quartz with metal coated reflecting surfaces. Two of the dihedral angles are rectangular to high precision whereas one angle has a tiny offset in order to produce a two-spot far-field pattern which allows for the aberration correction. The front faces of the prisms are uncoated and slightly spherical.

Vertex length	28.0 ± 0.2 mm
Free aperture of the front face	38.0 mm
Dihedral angle offset	-3.8 arc sec (less than 90°)
Radius of the convex front face	+ 500 m
Index of refraction @ 532 nm	1.461
Angular separation of the two peaks in the far field	24 arc sec
Width of the far field peaks (FWHM)	6 arc sec
Width of the far field peaks at 20% of maximum	10 arc sec

Table 4-4: Optical design parameters of the CHAMP LRR

The 4 cube corner prisms of the reflector array are mounted on a regular 45° pyramid.

Implementation of the LRR on CHAMP

The reference point of the CHAMP LRR is defined as the intersection of the optical axes of all 4 cube corner prisms. The LRR is mounted on a bracket exactly below the satellite's CoG (± 1 mm). At nominal satellite orientation the vector from the CoG to the reference point of the reflector is directed to nadir (the CHAMP +Z-axis) with a length of 250 mm.

A range correction has to be added to all measured laser ranges due to the fact that the point of light reflection does not coincide with the reference point of the reflector. This range correction depends on the orientation of the front surface of the cube corner prisms with respect to the ranging SLR station and varies in the range of a few millimetres for all possible joint orientations of CHAMP and the station. For many purposes this variable range correction may be replaced by the constant value $\Delta R = (4 \pm 2) mm$. A description of the computation of the exact range correction is available on request.

For the computation of the exact slant range to the CHAMP CoG, one also has to add the scalar product between the vector from the CoG to the LRR reference point (250 mm long and pointing nominally in nadir direction) and a unit vector aligned with the laser beam. The attitude of the satellite has to be taken into account for highly precise orbit determination in the mm-range. Because of the active attitude control keeping CHAMP Earth-oriented within a dead band of a few degrees in all 3 axes, the uncertainty in laser ranging is still less than 1 cm in case the actual attitude is not considered.

4.4 Fluxgate Magnetometer

General Description

The Fluxgate Magnetometer (FGM) was developed and manufactured under contract by the Technical University of Denmark (DTU) in Lyngby, Denmark. The design is based on a compact spherical coil (CSC) sensor which was newly developed for the Ørsted mission and presently demonstrates its outstanding performance in orbit. The FGM is probing the vector components of the Earth magnetic field. It is therefore regarded as the prime instrument for magnetic field investigations in the CHAMP mission. The interpretation of vector readings requires the knowledge of the sensor attitude at the time of measurement. For that reason the CSC is mounted rigidly together with star camera heads (cf. Advanced Stellar Compass) on an optical bench. For redundancy reasons and to resolve disturbances by the electronic units inside the spacecraft, a second CSC is accommodated on the optical bench, 60 cm inward from the primary sensor.

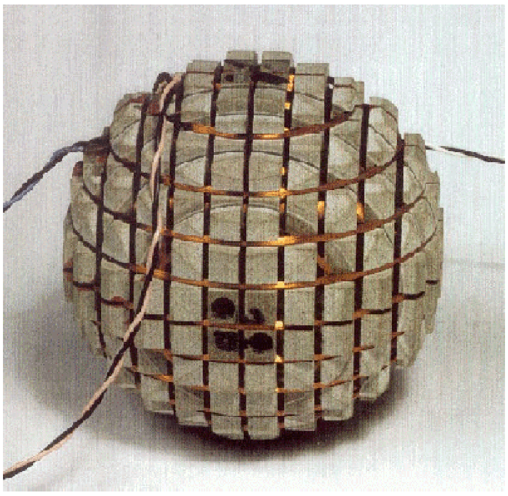

Figure 4-7: CHAMP Fluxgate magnetometer CSC sensor

Measurement Principle

The operational principle of Fluxgate magnetometers is well know and has proven in many missions to be very reliable and to provide high performance. The special features of the magnetometer are based on the design of the sensor. Three orthogonal sets of coils are wound on the surface of a 82 mm diameter sphere in a configuration which generates a homogeneous field within the spherical volume. The current through these coils are controlled by a feedback loop thus cancelling the ambient magnetic field in the interior. Three ring core sensors in the centre act as null-indicators. The particular design of the CSC has proven to exhibit superb linearity figures, no sensitivity to transverse fields and an excellent angular stability.

Fluxgate Magnetometer Characteristics

The FGMs cover the full ±65000 nT range of the Earth's field in all three components. The analogue outputs are digitised by 24 bit ADCs achieving a quantisation step size of 10 pT uncompressed and 125 pT compressed. Deviations from linearity are found to be in the range of ±100 pT and the overall noise level is of the order of 50 pT (rms). In nominal operation mode the field vector is sampled at a rate of 50 Hz providing a spatial resolution along the orbit of approximately 150 m. In order to reduce data rates and thus the demands on data storage and transmission, a compression mode and/or lower sampling rates can be selected.

Range	±65 000 nT
Resolution	10 pT (uncompressed) 125 pT (compressed)
Deviation from linearity	±100 pT
Noise level	< 50 pT (rms)
Sample rate	50 Hz (nominal), 10 Hz, 1 Hz
-3 dB bandwidth	13 Hz
Offset drift	< 0.5 nT
Sensor weight dimensions	 350 g (each) Ø 82 mm
Electronics box (for both sensors) weight dimensions power consumption	 3.5 kg 204 x 194 x 101 mm^3 2 W (each)

Table 4-5: Fluxgate magnetometer characteristics

Implementation of the FGMs on CHAMP

Both CSC sensors are mounted together with 2 star camera head units (CHU) on a common optical bench providing a mechanical stability between these systems of better than 10 arcsec. The optical bench as a part of the boom is placed about halfway between the satellite body and the Overhauser magnetometer (OVM) at the tip. This location is a compromise between avoidance of magnetic interference from the spacecraft and cross-talk between FGM and OVM.

Flying two FGMs on CHAMP is mainly for redundancy reasons, but such an arrangement with the sensors separated by 60 cm can also be used as a gradiometer when both instruments are operated. Differences in the reading of the two instruments can effectively be employed to detect and localise magnetic disturbances from the spacecraft.

4.5 Overhauser Magnetometer

General Description

The Overhauser Magnetometer (OVM) was developed and manufactured under contract by Laboratoire d'Electronique de Technologie et d'Instrumentation (LETI) in Grenoble, France. It serves as the magnetic field standard for the CHAMP mission. The purpose of this scalar magnetometer is to provide an absolute in-flight calibration capability for the FGM vector magnetic field measurements. A dedicated magnetic cleanliness program performed during manufacture of the spacecraft allows for an absolute accuracy of the readings of <0.5 nT.

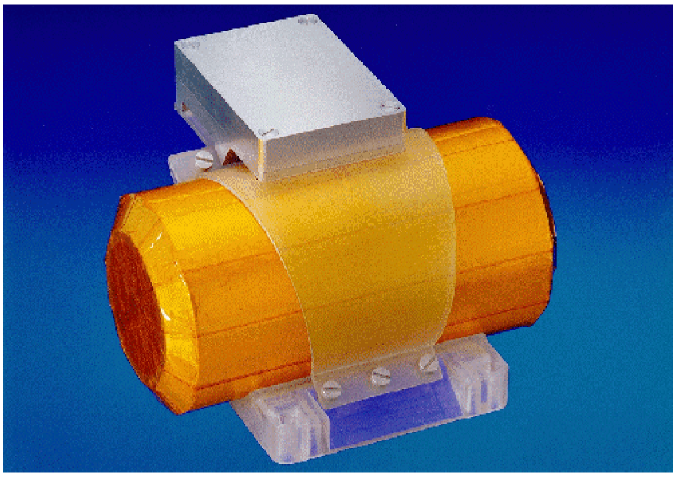

Figure 4-8: CHAMP Overhauser magnetometer sensor

Measurement Principle

The underlying idea of this scalar magnetometer is based on the principle of proton magnetic resonance. If a proton-rich liquid is exposed to a DC magnetic field, the protons will start to precess around the field direction with a frequency strictly proportional to the applied field magnitude. In principle there is no drift and no dependency on field direction or temperature. By exactly measuring the precession frequency (0.8 – 3 kHz) an absolute figure of the ambient magnetic field strength can be derived. The employed proportionality factor between frequency and field strength, called gyro-magnetic ratio, is one of the important CHAMP standards.

Overhauser Magnetometer Characteristics

The OVM continuously samples the ambient field strength at a rate of 1 Hz. It can cope with fields from any direction, i.e. there are no dead zones as often encountered with instruments of this type. The deviation from omni-directionality is less than 0.2 nT. The internal crystal oscillator is regularly checked against GPS clock to ensure a precise determination of the proton precession frequency.

Range	18 – 65 µT
Resolution	10 pT
Noise	< 50 pT @ B > 30 µT 100 pT @ B = 18 µT
-3 dB bandwidth	0.28 Hz
Sample rate	1 Hz
Absolute accuracy	< 0.5 nT
Gyro-magnetic ratio	23.4872037 nT/Hz
Sensor weight	1 kg
Electronics weight	2 kg
Power consumption	4.5 W
Sensor dimensions	Ø 90 x 180 mm
Electronics box dimensions	200 x 135 x 76 mm^3

Table 4-6: CHAMP Overhauser magnetometer characteristics

Implementation of OVM on CHAMP

In order to keep the influence of the DC magnetic stray field of the spacecraft as low as possible the OVM sensor is mounted at the tip of a 4 m long deployable boom. The electronics box is mounted on the instrument platform inside the satellite body.

4.6 Advanced Stellar Compass

General Description

The Advanced Stellar Compass (ASC) has been developed and manufactured under contract by the Technical University of Denmark (DTU) in Lyngby, Denmark. The design of this star imager is based on a new development presently flown on the Ørsted satellite. On CHAMP there are two ASC systems each consisting of two Camera Head Units (CHU) and a Data Processing Unit (DPU) that provides processing power for image analysis, pattern recognition, data reduction, system protection and communication with the OBDH. One ASC is part of the boom-mounted magnetometry optical bench unit while the other provides high precision attitude information for the accelerometer sensor unit at the spacecraft CoM. Additionally the ASCs serve as sensors for the satellite attitude control system.

A special feature of the ASC, very important for magnetometry missions, is the magnetic cleanliness of the camera heads. It allows to mount the camera and the magnetometer close together on a rigid structure which significantly improves the validity of attitude solutions transferred from one system to the other. The ASC is a fully autonomous system that directly outputs the attitude quaternions.

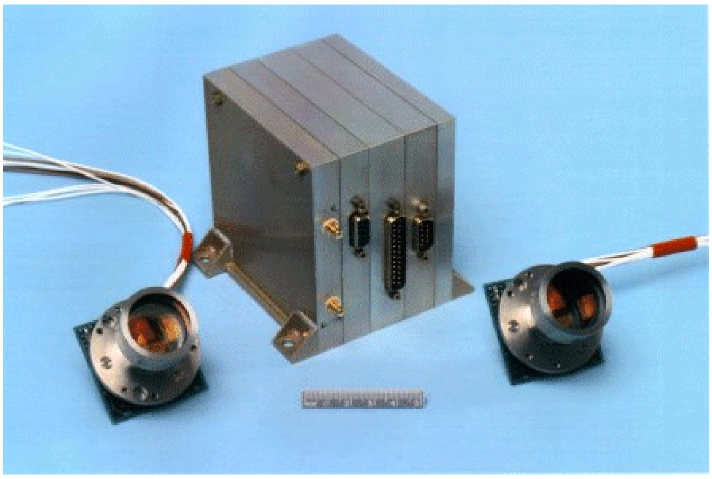

Figure 4-9: Star sensor DPU with two camera head units

Measurement Principle

An image of the stars within the field-of-view is acquired by integrating the light focused onto a photo-sensitive charge coupled device (CCD) array. The pattern is serially read, transmitted in analogue form to the Data Processing Unit (DPU) where a frame-grabber digitises the image. This image is then sifted for stars brighter than $m_V = 6$ and corrected for lens distortions resulting in a list of calculated star centroids with sub-pixel precision. The determined star centroids are subsequently matched against the expected star positions derived from the onboard star catalogue and the previous attitude. For further improvement of the attitude solution a GPS updated orbit model is maintained to perform astronomical aberration correction on-board and also to account for the epoch of the star constellation.

ASC Performance Characteristics

The boom-mounted ASC camera heads provide the high precision attitude needed for the magnetic field vector measurements. The two transverse directions, Right-Ascension and Declination, can be determined with an accuracy in the arc second range. Whereas the rotation angle about the boresight is poorer by about a factor of 5. An improvement of this situation can be achieved by combining the readings from the two camera heads which are separated by an inter-boresight angle of about 102°.

The ASC on the spacecraft body provides attitude data primarily for the three component STAR accelerometer and the Digital Ion Driftmeter. This information is however also required for the proper reduction of GPS data, laser ranging data and attitude control.

Due to the nadir orientation of CHAMP the Sun will blind one or two of the CHUs on one side of the spacecraft over certain parts of the orbit depending on the orbit constellation wrt the Sun. The attached baffles provide a Sun exclusion angle of about 40°. The disturbance due to the Moon in the field-of-view is less significant because the ASC software can autonomously discard the Moon from image processing. In worst case a full Moon within 10° of the field-of-view boresight leads to blinding.

Attitude determination precision (1σ)	4 arcsec dual head 20 arcsec single head
Field of view	18.4° x 13.4°
Sampling rate	1 Hz
Camera Head Unit (CHU) weight dimensions magnetic moment	 200 g (without baffles) 50 x 50 x 45 mm^3 5 - 10 $\mu A/m^2$
Data Processing Unit (DPU) weight dimensions power consumption	 800 g 100 x 100 x 100 mm^3 8 W per unit

Table 4-7: Star camera characteristics

Implementation of the ASCs on CHAMP

The body-mounted CHUs are rigidly fixed to the thermal housing of the accelerometer comprising a 90° inter-boresight angle (IBA) which is determined by the satellite design with its solar panels being tilted 45° versus the horizontal instrument platform. For the boom optical bench a 102° IBA has been chosen in order to provide optimum simultaneous usage of both camera heads (i.e., minimise blinding of both sensors depending on the satellite orbit constellations w.r.t. the Sun, Earth and Moon).

Magnetic cleanliness, size and weight of the CHU make this ASC ideal for use in conjunction with magnetometry instruments on a boom.

All CHUs are equipped with an inner baffle (12cm) and an outer 25cm long baffle. This double-stage baffle is chosen to optimise the Sun exclusion angle for the given baffle length.

4.7 Digital Ion Driftmeter

General Description

The Digital Ion Driftmeter (DIDM) is provided by the Air Force Research Laboratory, (AFRL) in Hanscom, USA. It is an improved version of an analogue ion driftmeter type flown successfully on many upper atmospheric satellites. The purpose of this instrument is to make in-situ measurements of the ion distribution and its moments within the ionosphere. A number of key parameters can be determined from the readings, such as the ion density and temperature, the drift velocity and the electric field by applying the (v x B)-relation. Together with the magnetic field measurements these quantities can be used to estimate the ionospheric current distribution. Knowing these currents will help significantly to separate internal from external magnetic field contributions.

In combination with DIDM a Planar Langmuir Probe (PLP) is operated. This device provides supplementary data needed to interpret the ion drift measurements. Quantities that can be derived from the PLP sweeps are spacecraft potential, electron temperature and density.

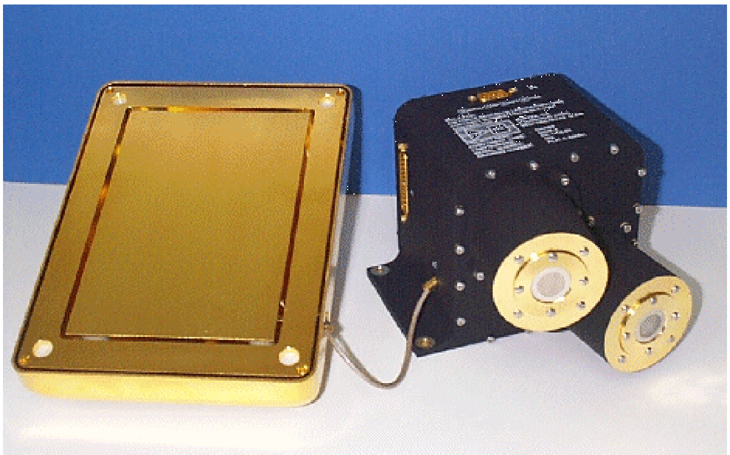

Figure 4-10: CHAMP Digital Ion Driftmeter and Planar Langmuir Probe

Measurement Principle

The sensing elements on DIDM are two ion detectors mounted side-by-side onto the Data Processing Unit (DPU). Ions entering the pin-hole aperture fall into a Retarding Potential Analyser (RPA) cup. Those ions with energies surmounting the settable potential barrier will be guided by an electric field onto a Multi-Channel Plate (MCP). Using an anode which is divided into a 16x128 pixel array the impact location can be detected. By taking into account the ion optics the incoming direction of the particle can be traced back. Accumulating many ion impacts provides an image of the ion distribution in the velocity space. The cross-track components of the ion velocity are well determined by the location of the spot on the anode. The along track component has to be deduced from the effect of varying RPA voltages.

The ion velocities detected by DIDM are dominated by the satellite orbital velocity. To obtain rest frame results great care has to be taken in considering the spacecraft velocity vector correctly. For this purpose it is foreseen to derive precise orbit data from the GPS readings and high quality attitude data from the ASC.

Ion temperatures can be deduced from the width of the distribution on the anode. The total count rate is a measure for the ion density. Images of the pixel map can be returned in order to verify the actual distribution. It is possible to select between partial images centred on the peak count or to retrieve a full image.

The PLP voltage is swept for 1 sec every 15 sec typically between -2.5 and +2.5 V in 32 steps. A selectable bias voltage can be added to account for the S/C potential. By interpreting the measured current/voltage characteristic the above mentioned plasma parameters can be determined. The spacecraft floating potential is measured during the remaining 14 sec.

DIDM Performance Characteristics

Each detector resolves a 35° half-cone of space. The MCP pixel size allows for a gross resolution of about ±1° which can be improved by fitting the results to a theoretical distribution function. Special look-up tables are used to correct for ion optic distortions.

The instrument provides a large variety of selectable modes. Drift measurements can be obtained at rates from 1 to 16 Hz. There are 8 selectable sets of RPA voltage sweeps. They are designed to allow for optimising the measurement modes, either for fast sampling, high resolution, mass resolution etc. Both detectors can be operated fully independently. During launch of the CHAMP satellite one of the detectors was degraded. The scientific return of the mission is reduced marginally by this defect whereas the provided redundancy is lost.

The prime purpose of the PLP is to determine the spacecraft potential. An error of 0.1 V in this quantity is equivalent to an along-track velocity of 75 m/s. The PLP is designed to measure currents drawn from the ambient plasma down to 5 nA.

Range of ion density	10^8 - 10^{12} ions/m^3
Range of ion temperature	200 - 55 000 K
Range of drift velocity	0 - 10 km/s
Range of electric field	0 - 300 mV/m
Resolution of ion velocity	< 1° direction, < 130 m/s speed
Resolution of electric field	< 4 mV/m
Sample rates DM mode RPA mode PLP mode	 0, 1, 2, 4, 8, 16 HZ 0, 8, 16 Hz 0, 1/15 Hz
Power consumption	5 W
Weight	2.2 kg
Dimensions	153 x 150 x 109 mm^3

Table 4-8: DIDM and PLP characteristics

Implementation of DIDM on CHAMP

The DIDM instrument is mounted on a bracket at the ram surface outside the spacecraft body. The two detectors are pointing in nominal flight direction. An accommodation as far down as possible has been chosen to minimise the wake effect caused by the boom. The slanted face sheet behind DIDM is well conducting (aluminium). By pointing into the ram direction it provides a close electrical contact of the spacecraft to the ambient plasma avoiding a charge-up of the satellite.

5 CHAMP ORBIT AND TRACKING

The CHAMP satellite was launched from the cosmodrome Plesetsk (north of Moscow) aboard a Russian COSMOS launch vehicle. The launch took place on July 15, 2000 at 11:59:59.628 UTC.

The CHAMP satellite was injected into an almost circular, near polar (i = 87°) orbit with an initial altitude of 454 km. The 87° inclination is the maximum inclination which can be served from the Plesetsk cosmodrome. The design lifetime of the satellite system is 5 years.

The reason for choosing an almost circular and near-polar orbit is the advantage of getting a homogeneous and complete global coverage of the Earth's sphere with orbit and magnetometer measurements, being important to resolve the gravitational and magnetic geopotentials.

An advantage of the 87° inclined orbit vs. a dawn-dusk sun-synchronous orbit is the local time variation of the satellite ground track which is essential for all three scientific applications in order to enable the separation of constituents of periodic phenomena like tides and day-night variations.

An initial altitude of about 450 km was chosen

(a) to guarantee a multi-year mission duration even under severe solar activity conditions,

(b) to account for the requirement imposed by the atmosphere/ionosphere application to look from the outside through the different atmospheric layers, i.e., an even higher altitude would have been better in this regard, and

(c) because this is the adequate altitude to observe the Earth's magnetic main field. From the gravity and crustal magnetic field's point of view an even lower initial altitude would have been desirable.

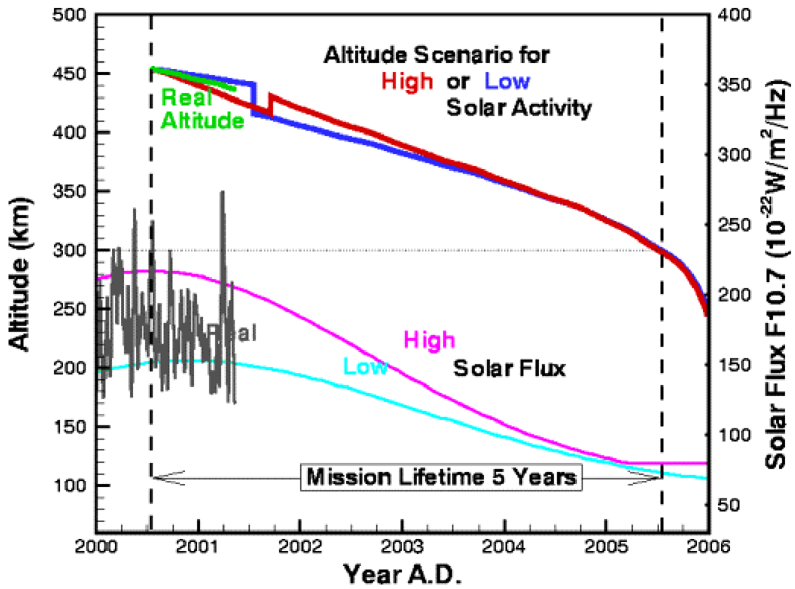

Figure 5-1: CHAMP altitude evolution (status May 18, 2001)

Due to atmospheric drag the altitude will decrease over the 5 years mission lifetime (see Fig. 5-1). As CHAMP is passing through the solar activity maximum later this year, the predicted natural decay depends on the magnitude of the actual solar activity cycle. Simulations before the launch have shown that the predicted decay may amount to more than 200 km or only 50 km within the 5 years. Therefore at least one orbit change manoeuvre is foreseen to correct for orbit injection errors and rising or lowering the satellite orbit to guarantee a 5 years observation period above 300 km and some months of observation time below 300 km altitude towards the end of the mission.

CHAMP is in a free-drifting orbit and is passing through different commensurabilities and resonant regimes, respectively, when decaying over the time. Since launch CHAMP has lost already 17.5 km of its initial orbital height, i.e., about 55 m/day. It has passed through the 46/3 commensurability last year and is near to pass through the 77/5 commensurability with largely enhanced perturbations in the orbital motion.

The CHAMP satellite is continuously tracked by the satellites of the high orbiting GPS constellation through pseudo range and carrier phase observations. From the Earth's surface

CHAMP is tracked sporadically from the global laser network stations of the International Laser Ranging Service (ILRS), the locations of which are shown in Figure 5-2. CHAMP orbit predictions are generated by GFZ and distributed to the network stations through the ILRS data centres. Figure 5-3 shows the global network of high-rate low latency GPS stations, which was established by JPL and GFZ for the rapid GPS and CHAMP orbit determination in connection with the quick generation of CHAMP radio occultation products. This network is planned to be embedded into the infrastructure of the International GPS Service (IGS).

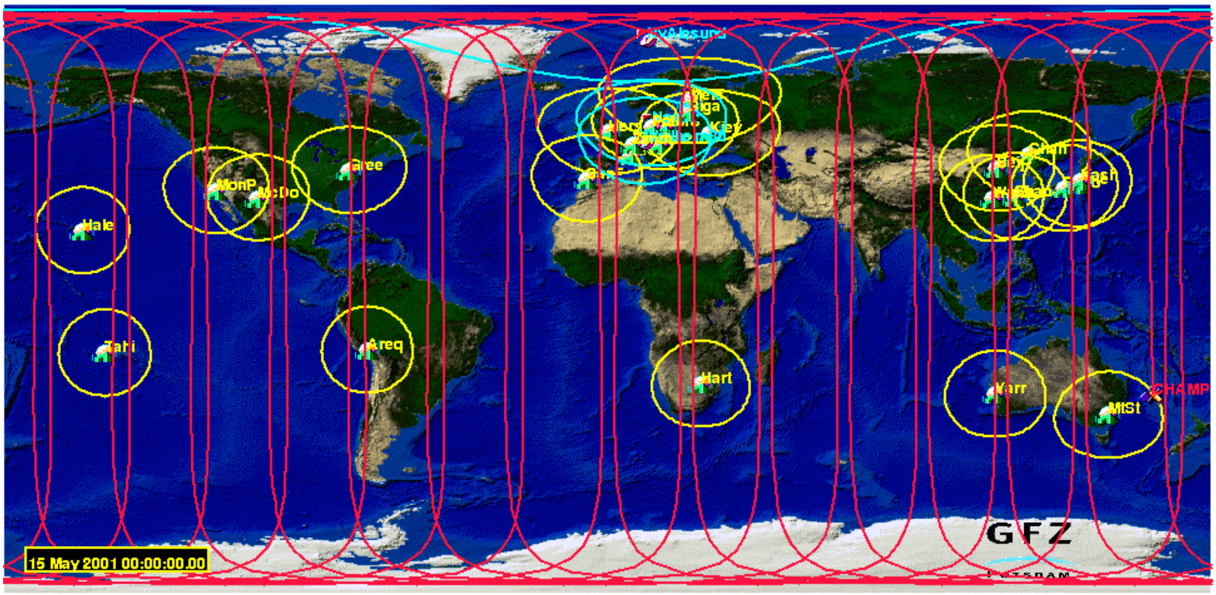

Figure 5-2: Global network of the International Laser Ranging Service (ILRS) (yellow) and CHAMP downlink station coverage (blue)

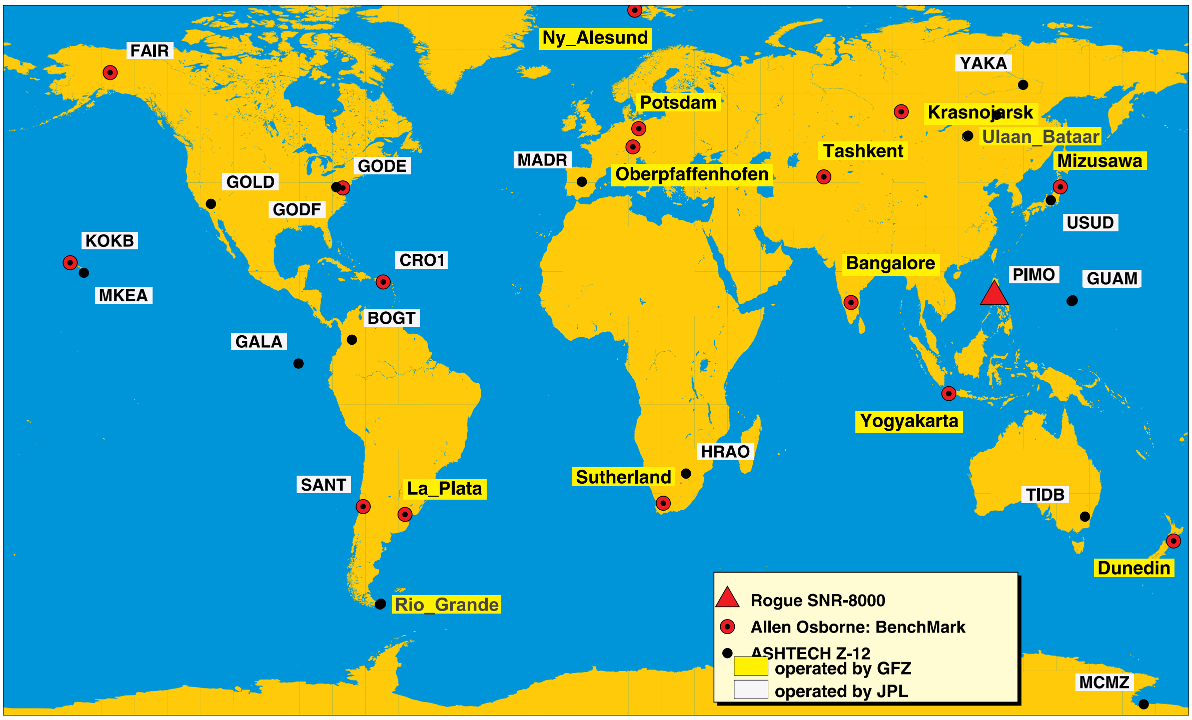

Figure 5-3: Global network of CHAMP mission H/R GPS stations established by JPL and GFZ

A very recent state vector for CHAMP is given in Table 5-1:

Epoch = 2001/05/15 10:00:00 GPS	
Brouwer mean elements in Conventional Inertial System (CIS):	- semi mayor axis = 6806.632 km - eccentricity = 0.003492 - inclination = 87.275 deg - argument of perigee = 216.022 deg - right ascension of the ascending node = 36.352 deg - mean anomaly = 269.343 deg
This leads to:	- true period = 93.21 min - rev/day = 15.45 - nodal period = 957 days - perigee period = 92 days

Table 5-1: State vector for CHAMP

6 GROUND SEGMENT

CHAMP's ground segment comprises all ground-based components which perform the operational control of the spacecraft and instruments, the data flow from the on-board memory and supporting ground networks to the processors and users and standard science product generation. Figure 6-1 shows the general scheme.

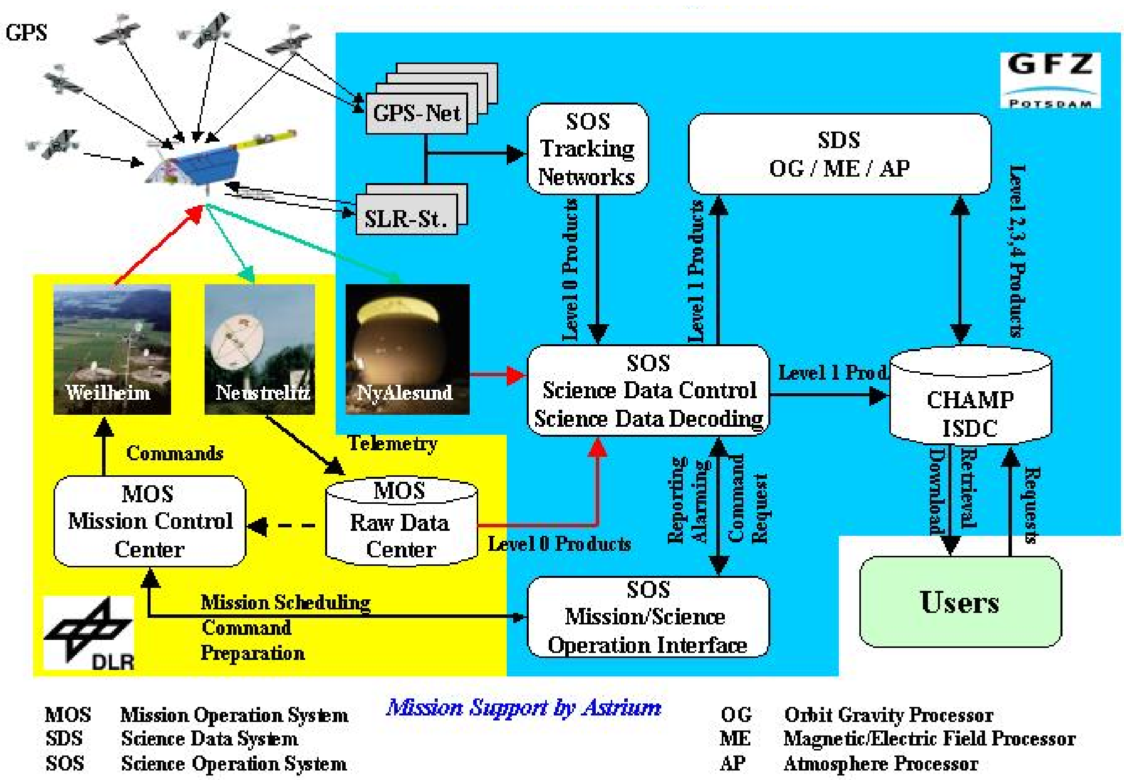

Figure 6-1: CHAMP ground segment

6.1 Mission Operation, Telemetry and Data Flow

DLR runs the *Mission Operation System* (MOS) consisting of the Mission Control Centre (MCC) at DLR's German Space Operation Centre (GSOC), Oberpfaffenhofen, and the Raw Data Centre (RDC) at DLR's German Remote Sensing Data Centre (DFD), Neustrelitz. The *Science Operation System* (SOS) at GFZ constitutes the interface between the science experimenters and satellite operation. It is responsible for mission scheduling, command preparation, and mission and orbit analysis.

CHAMP's on-board instruments continuously produce science and instruments' house-keeping data with an overall rate of 10.8 kbit/s, and the satellite adds 2.2 kbit/s of spacecraft house-keeping data, in total 141 MByte/d, which have to be downloaded to the 7.3 m ground antenna of DLR's receiving station in Neustrelitz (53.5 N, 13 E).

With its telemetry bitrate of 1000 kbit/s and a contact time of 28 min/d at 450 km and 20 min/d at 300 km S/C altitude during the three to five passes per day, Neustrelitz is capable of receiving 210 MByte/d (at 450 km) and 150 MByte/d (at 300 km), respectively, of dump data. A second ground station, DLR-GSOC's ground station in Weilheim (48 N, 11 E), is operated as the commanding and satellite control station. It receives 'real-time' science and H/K data and sends commands at 4 kbit/s. Weilheim also serves as a back-up station to Neustrelitz, then being capable to download the full telemetry data stream.

CHAMP's on-board mass memory unit is organized as a ring buffer and consists of a science data segment of 100 MByte and a H/K data segment of 25 Mbyte storage capacity. The on-board data is written and dumped sequentially controlled by a write and dump pointer. The maximum buffer time (maximum time between two overflights over Neustrelitz) is 13 hours. If, by failure, the buffer runs full, then the oldest data will be overwritten. The on-board clock is synchronized to GPS-time and used for time-stamping the telemetry packets.

CHAMP's *Raw Data Centre* is established at the receiving station Neustrelitz with the following functions: telemetry data reception (Transfer Frames) and long-term storage in the *Raw Data Archive*, demultiplexing and extraction of science and H/K application packets (level-0 data), immediate transfer of H/K packets to GSOC, and temporary storage of all level-0 data in the *level-0 rolling archive* for access by the Decoding Centre of the Science Operation System (SOS-SD) at GFZ Potsdam, where also the *level-0 long-term archive* is located. The instrument providers have immediate access to the level-0 data of their own instruments.

In addition to the spacecraft data, all CHAMP related ground station network data are accessed and archived at GFZ Potsdam: low rate (30 s, 10 s) and high rate (1 s), low latency GPS ground-based observations from individual stations and data centres, and CHAMP laser tracking data from the international laser data centres. The high-rate GPS ground-station data of the GFZ and JPL dedicated CHAMP GPS subnets altogether about 25 stations, are mutually exchanged (about 25 MByte/d in both directions). All data transfer happens via the public Internet network.

6.2 Product Generation

After having decoded CHAMP's level-0 data to level-1 (conversion from telemetry code into user defined physical units), the higher level scientific products are generated within the *Science Data System* (SDS) consisting of the

- Orbit and Gravity Field Processing System (SDS-OG),
- Magnetic and Electric Field Processing Systems (SDS-ME) and
- Neutral Atmosphere Profiling System (SDS-AP),

at GFZ Potsdam, and the

- Ionosphere Profiling System (SDS-IP)

at DLR’s Institute for Communication and Navigation (IKN), Neustrelitz.

Product archiving, administration and retrieval are organized by the CHAMP *Information System and Data Centre* (ISDC), located at GFZ Potsdam, which also is the users' www- and ftp-based interface for access to CHAMP data and scientific products.

7 SCIENCE DATA PRODUCTS

Following the issue of this AO, CHAMP co-investigators will be installed which have access to CHAMP standard data products. The access to internal and intermediate (special) products may be negotiated within the frame of this AO.

CHAMP's standard science products are labelled from level-1 to level-4 according to the number of processing steps applied to the original data. Decommutation and decoding of level-0 data results in level-1 products. These are daily files, associated with each individual instrument and source aboard CHAMP, and the data content is transformed from the telemetry format and units into an application software readable format and physical units. Level-1 products also include the ground station GPS and laser data. Level-2 products are preprocessed, edited and calibrated experiment data supplemented and merged with necessary spacecraft housekeeping data and arranged in daily files. Level-3 products comprise the operational rapid products and fine processed, edited and definitely calibrated experiment data. Finally, level-4 leads to the geoscientific models derived from the analysis of CHAMP experiment data, supported and value-added by external models and observations.

7.1 Standard Science Data Products

Within the three fields of research and application pursued with CHAMP, the following standard products are made available to the general co-investigators’ user community via the ISDC:

(1) Orbit and Gravity Field Processing System (SOS-OG)

- level-1: GPS CHAMP satellite-to-satellite phase and code *tracking observations* (0.1 Hz); GPS ground station phase and code tracking observations (0.1 Hz and 0.033 Hz desampled from 1 Hz high-rate data),
- level-2: preprocessed *accelerometer* observations (0.1 Hz), linear and angular accelerations with attitude information (body star sensors) and thruster firing time events,
- level-3: *rapid science orbits* of CHAMP and the GPS satellites in the Conventional Terrestrial System, and processed with a short time delay (few hours to days) after data download,
- level-4: postprocessed (time delay of several months) *precise orbits* of CHAMP and the GPS satellites and, derived from these, global *Earth gravity field models*, represented by the adjusted coefficients of a spherical harmonic expansion of the gravitational geopotential: period solutions and progressively accumulated solution.

(2) Magnetic and Electric Field Processing System (SOS-ME)

- level-2: *magnetic field;* both scalar and vector field; the latter as well in sensor system as in local coordinates (North, East, Down), all at 1 Hz rate;
  precise attitude derived from Advanced Stellar Compass for the boom instrumentation at a 1 Hz rate,
- level-4: *main field models;* spherical harmonic expansion to degree and order 13 derived from spacecraft data and its secular variation coefficients from space and ground-based observations; updates of the model about every three months,

The magnetic fields in local coordinates rely on an attitude transformation between magnetometer and star tracker as determined during ground testing.

(3) Atmosphere/Ionosphere Profiling Systems (SOS-AP/IP)

- level-1: GPS-CHAMP radio occultation measurements (50 Hz for AP and 1 Hz for IP), GPS ground station phase and code tracking observations (high-rate, low latency network, 1 Hz rate),
- level-2: list of occultation events per day *(occultation tables)*; characterizing information of the occultation (satellite and ground station numbers, begin/end of occultation, approximated location of the point of closest approach for begin/end)
  atmospheric excess path; time tagged atmospheric excess path of the occultation, link annotated with SNR and orbit (position and velocity) information of CHAMP and the occulting GPS satellite for each occultation event,
- level-3: Atmosphere: *vertical profiles* of atmospheric bending angle and geopotential, Abel-inverted profiles of refractivity, *dry air*-density, -pressure and -temperature, and, adopting temperature from global analyses, specific and relative humidity, partial pressure and mixing ratios of *water vapour* in the troposphere, along with total atmospheric pressure, temperature and geopotential, Ionosphere: *link related TEC data* (uncalibrated TEC data along the occultation ray trajectories) and *vertical profiles* of electron density.

The GPS radio occultation capability with CHAMP was established only in Feb. 2001. Therefore, the release of data and products related to this subsystem will be resumed later (except high-rate ground station observations) after the end of a special commissioning phase (about autumn 2001).

7.2 Special CHAMP Data Products

Requests for internal and non-standard CHAMP data products, which are needed as input for studies proposed in reaction to this AO, are reviewed and, if feasible, fulfilled on the basis of individual agreements.

Non-standard data products, including CHAMP's house-keeping sensor data, are not yet defined and depend on the users' requirements and responses to this AO.

Examples for internal CHAMP data products, which are routinely generated but not publicly available, are as follows:

(1) Orbit and Gravity Field Processing System (SDS-OG)

- level-1: accelerometer observations (1 Hz), unprocessed,
- level-2: body star cameras attitude quaternions (1 Hz), preprocessed,
- level-3/4: CHAMP/GPS orbits in celestial system,
- level-4: grid value representations of the gravity field (gravity anomalies, geoid), ocean tide potential, station coordinate solutions, correlation matrices.

(2) Magnetic and Electric Field Processing System (SOS-ME)

- level-2: *external magnetic field,* full rate vector data (50 or 10 Hz) main field subtracted, transformed into a mean-field-aligned coordinate system;
  ion drift and electric field vector, ion density and temperature all at variable rates 1 to 16 Hz;
  rapid magnetic activity index, rate: twice per orbit,
- level-3: *fully calibrated magnetic field vectors* (5 Hz),
- level-4: *lithospheric magnetic field model* based on shorter wavelength terms comprising spherical harmonic expansion from degree and order 15 to 65, progressively improving with mission duration;
  magnetic activity indices: ring current, polar electrojet and global magnetic activity indices, rate: once per orbit (3).

The calibration/validation phase of the DIDM instrument is not completed by the time of AO release. Therefore, the data products related to this subsystem will be made available at a later time.

(3) Atmosphere/Ionosphere Profiling systems (SOS-AP/IP)

A number of specialized and value added products are envisaged to be generated within the neutral atmospheric and ionospheric profiling systems. They will be available as level-4 products on specific request only and depending on data availability. These include:

- weekly and monthly zonal mean temperature and water vapour distributions obtained from CHAMP measurements,
- weekly and monthly mean maps of the global temperature, geopotential height and water vapour distribution at selected vertical levels,
- weekly and monthly error statistics of CHAMP measurements w.r.t. operational meteorological analyses and radio sondes,
- tropopause parameters (lapse rate and cold point pressure, temperature, potential temperature, water vapour saturation mixing ratio),
- gravity wave parameters (wave amplitudes, potential energy due to temperature fluctuations, global maps of gravity wave activity, vertical gravity wavenumber spectra) for various latitude and altitude regions,
- monthly mean maps of the global distribution of the peak electron density for selected local times,
- monthly mean maps of the global distribution of the height of the peak electron density for selected local times,

- imaging of the vertical electron density distribution of the topside ionosphere/plasmasphere ($h > h_{CHAMP}$) in the CHAMP orbit plane during selected events.

8 ANNOUNCEMENT OBJECTIVES

8.1 Scope

This announcement solicits proposals for co-investigations regarding the further calibration/validation of the CHAMP instruments and regarding the analysis of data and the use of higher level products from the CHAMP mission. Investigations are solicited for the three categories described below:

- CHAMP instrument and sensor performance analysis and data preparations,
- CHAMP scientific product generation,
- Scientific modelling, interpretation and application.

For selected investigations in these areas, CHAMP data will be made available to the CHAMP co-investigators by remote access through the CHAMP-ISDC. User facilities are prepared at GFZ Potsdam for making short working visits of CHAMP co-investigators effective. Through GFZ's visiting scientist program it will be possible to invite a limited number of foreign CHAMP co-investigators to closely co-operate with the CHAMP team. To further foster the cooperation of teams and coordinate the activities of co-investigations annual CHAMP workshops will be organized at GFZ Potsdam.

8.2 Topics of Investigation

The following enumerations intend to stimulate investigations dealing with CHAMP mission data and making use of CHAMP's higher level geoscientific products. Ideas for other studies and topics mentioned here are welcome.

8.2.1 CHAMP Instrument and Sensor Performance Analysis and Data Preparations

These investigations aim at a complete understanding of the on-board science instrument and house-keeping sensor performance within the CHAMP satellite environment, and the proper preprocessing (reduction, calibration, filtering) of the measurements for an optimal use in geoscientific data exploitation.

8.2.1.1 Orbit and Gravity Field Instrumentation

The Blackjack GPS receiver on-board CHAMP measures at each 10 s observation epoch dual-frequency carrier phases and pseudo-ranges simultaneously from (presently) up to 8 GPS satellites for use in CHAMP's precise orbit restitution. Additional tracking information comes from ground-based satellite laser ranging.

The three-axes STAR accelerometer measures the non-gravitational linear accelerations perturbing CHAMP's orbit, and angular accelerations. A precise calibration, orientation and reduction of the raw accelerometer measurements is a prerequisite for CHAMP's precise dynamic orbit restitution and the extraction of the purely gravitational orbit perturbation signals for gravity field recovery. The accelerometer data is also going to be used for air density determination in CHAMP's altitude. The inertial orientation of the accelerometer axes is measured using CHAMP's 'Advanced Stellar Compass (ASC)' star cameras.

Studies related to the GPS/accelerometer/stellar compass instrument package which help to improve the data quality, interpretation and (pre)processing approaches may cover the following items:

- error budget (spectral and time domain),
- preprocessing (screening, filtering),
- calibration and reduction (environmental and satellite control impacts),
- observation equations (parametrization and error models).

8.2.1.2 Magnetic and Electric Field Instrumentation

The star trackers (ASC) on the boom optical bench provide the precise attitude for the fluxgate magnetometer. A detailed assessment of the ASC's performance, stability and dependences on temperature and orbit local time may help to introduce further corrections and thus improve the overall quality of the magnetic field vector data. Comparisons of attitudes derived from dual or single head mode are particularly welcome.

The dual-Fluxgate configuration on CHAMP can be used to verify the magnetic cleanliness features of the spacecraft in orbit. Magnetic signatures detected by this technique may be corrected and will help to improve the absolute accuracy of this mission.

The digital Ion-Drift-Meter (DIDM) is a novel instrument. Its advanced design allows for a wide range of different kinds of measurements of the ion dynamics in the ionosphere. Proposals are solicited aiming at a better understanding of the instrument and providing suggestions for corrections of the data. In particular we could think of the following topics:

- calibration of RPA counts against PLP readings,
- investigation of the influence of S/C potential,
- validation and improvement of ion mapping function on the MCP,
- determination of instrumental and angular biases,
- validation of DIDM results in comparison with incoherent scatter radar data and other ground-based facilities.

8.2.1.3 Radio Occultation Instrumentation

Based on configurable scheduling CHAMP's BlackJack GPS receiver performs GPS measurements in occultation mode to record dual frequency carrier phase (50 Hz) measurements from GPS satellites. In addition a second ("reference") satellite is tracked in occultation mode to eliminate the CHAMP satellite clock error by forming single differences of GPS measurements. Studies related to the tracking characteristics of the GPS receiver may relate to the following points:

- error budget of the precise phase measurements,
- preprocessing of the high rate data (screening),
- open-loop tracking,

- GPS receiver tracking simulations.

8.2.2 CHAMP Scientific Product Generation

These investigations aim at improvements concerning accuracy, performance and reliability in CHAMP’s target geoscientific products and at alternative approaches not covered by the CHAMP standard product processing.

8.2.2.1 CHAMP Orbit and Gravity Field Recovery

The purpose of CHAMP's precise orbit determination is twofold: (1) for operational near real-time use in GPS radio occultation data evaluation to derive the excess path delays, and (2) for off-line orbit perturbation analyses to model the Earth's gravity field. Whereas for application (1) the knowledge of the geometric trajectory is sufficient, the second task relies on orbit dynamics, in particular on the extraction of the gravity-induced orbit perturbation spectrum and its relation to the gravity field parameters.

Due to the low altitude of the orbit, the continuous tracking and the direct measurement of the surface forces, the long- to meso-scale Earth's gravity field will be recoverable from CHAMP's orbit perturbation analyses with an unprecedented accuracy and, concerning the long-wave gravitational constituents, from CHAMP data only. This requires new approaches for the solution and quality evaluation, the combination with other gravity data and the resolution of temporal field variations.

Studies related to the following items may be conducted to exploit CHAMP's tracking data (GPS, accelerometry, SLR) for precise orbit determination and to properly model the unique set of new gravity information:

- dynamic vs. reduced dynamic and kinematic orbit determination approaches,
- orbit accuracy and reliability testing procedures,
- long-arc orbit analyses and long-term evolution of orbital parameters,
- translation of orbit perturbation spectrum into Earth's gravity field parameters (alternative approaches and parametrizations),
- parametrization and solvability of tidal and non-tidal temporal gravity field variations,
- combination of CHAMP data with other satellite tracking, altimeter and terrestrial gravity data,
- methods for internal calibration and external validation of the gravity field solution's accuracy and quality: static gravity field, tidal and non-tidal temporal field variations.

8.2.2.2 CHAMP Magnetic and Electric Field Modelling

CHAMP is measuring the magnetic field with an unprecedented accuracy, but this does not automatically imply that the field models will also be improved. Equally important is an effective separation of the contributions from various field sources. In the area of main field modelling we would like to initiate the following studies:

- test the effect of various data selection criteria, e.g., magnetic indices,
- make use of different basis functions for the field modelling,
- try different approaches for model parameterisation,

- determine the time dependence of the spherical harmonic coefficients.

Due to the low orbit and long mission life-time CHAMP is particularly well suited to map the lithospheric magnetisation. Here again one is confronted with the fact that the spacecraft at its descent is approaching the ionospheric E region, with its currents, relatively faster than the Earth surface. Studies related to this topic could be:

- test the efficiency of global vs. regional anomaly modelling,
- determine and model ionospheric current systems,
- find suitable parameters describing the intensity of the current systems,
- develop comprehensive models.

A whole suit of global mapping studies related to ionospheric dynamics and in particular to the measurements of the Digital Ion-Drift-Meter (DIDM) may be conducted:

- construct models of the electron/ion density and determine their dependence on local time, season, magnetic activity and solar flux,
- map the global electric field distribution depending on solar wind parameters and other factors,
- determine the spatial and temporal occurrence of Pointing flux into and out of the ionosphere and relate it to magnetospheric regions and magnetic activity levels.

8.2.2.3 Atmospheric /Ionospheric Profiling

Neutral Atmosphere

The aim of CHAMP's GPS radio occultation processing is to analyse the recorded occultation events and to provide the main data products: (1) calibrated atmospheric excess path of the occultation link and (2) vertical profiles of atmospheric parameters for the individual occultation events. The data products will be automatically generated. The first version of the processing software uses standard methods for the occultation data processing. The atmospheric excess path is derived using a double differencing technique, the atmospheric profiles are calculated assuming geometric optics approach and applying Abel Inversion. Studies related to the following items may be performed to exploit CHAMP's occultation data and to improve the data analysis and processing:

- applying of various GPS processing strategies (Non-, Single-, Double-differencing) for the calibration of the atmospheric excess path and precise determination and comparison of the error budget for each method,
- characterization and correction of ionospheric influence to the retrieval of neutral gas profiling during maximum of solar activity , usage of CHAMP's Langmuir Probe (PLP) and Digital Ion Drift Meter (DIDM) data to get additional "in situ" information for ionospheric correction,
- data analysis in the lower troposphere taking into account multipath wave propagation,
- application of variational retrieval methods in the retrieval of atmospheric and ionospheric parameters from CHAMP radio occultation measurements,
- characterization of the error budget of the derived atmospheric parameters.

Ionosphere

The occulted GPS signals travelling through the ionosphere/plasmasphere system are used to derive the total electron content (TEC) along the ray path by measuring differential phases on L1/L2 carrier frequencies that are sampled with 1 Hz.

The retrieval technique for deriving vertical electron density profiles is based on a model assisted tomographic approach using a spherically layered pixel structure. This has the advantage that additional information deduced from ground based GPS measurements, models and/or other sources can easily be included in the reconstruction of the electron density profiles.

Combining RO data with slant TEC data derived from world wide ground based GPS stations three-dimensional structures of the ionosphere/plasmasphere system can be reconstructed.

Ionospheric sensors onboard CHAMP such as the Planar Langmuir Probe (PLP) and the Digital Ion Drift Meter (DIDM) provide additional information that will help to define the upper boundary condition for retrieving electron density profiles.

Considering the capabilities of ionospheric RO-measurements onboard CHAMP, the following scientific topics and objectives could be addressed:

- Improvements of RO retrieval techniques, i.e., development and test of powerful tomographic and data assimilation techniques,
- Comprehensive error budget analysis for different geophysical conditions,
- Modeling the ionosphere and plasmasphere, i.e., improvement of models that can be used for model assisted retrieval techniques.

8.2.3 Scientific Modelling, Interpretation and Application

These studies aim at the use of CHAMP's higher level products in science and application, exploring the benefits and contributions for multidisciplinary scientific modelling, Earth monitoring and reference systems.

8.2.3.1 CHAMP Global Gravity Field

With the enhanced new quality w.r.t. accuracy and homogeneity of the long- to mesoscale gravitational field models and temporal field variations derived from CHAMP's observation data, contributions to the following fields of investigation and application are addressed:

- implications of CHAMP's Earth gravity field model (static part) on global models of the Earth's interior (isostatic and dynamic modelling, combination with seismic models of crust and mantle and joint inversion),
- use of CHAMP derived geoid as a new reference surface for altimetric sea surface topography and ocean circulation recovery,
- constraints from observed long-term variations in low degree gravitational coefficients for post-glacial rebound and Earth's viscosity modelling, recent ice/water mass balance changes, and core-mantle interaction theories,
- separability, evaluation and integrated modelling of seasonal and inter-annual variations due to atmosphere, ocean circulation, continental water and snow coverage, and long-period tides,

- use of a CHAMP based gravity field and geoid model in geodetic applications: height datum unification, large scale digital terrain model (DTM) reference and combination with regional high resolution gravity data (national or regional geoid/gravity field) for GPS-levelling and small scale DTM reference),
- application and benefit of CHAMP's gravity field model for a most precise orbit determination as required in satellite altimetry and SAR-interferometry.

8.2.3.2 CHAMP Magnetic and Electric Field Models

A number of investigations can be conducted using the advanced CHAMP models together with data from other sources. We would like to stimulate scientific studies in the following fields:

- interpretation of secular variation in terms of core flow, mantle conductivity, length of day variation, etc.,
- interpretation of lithospheric magnetisation maps in terms of geological structures, temperature profiles, conductivity structures, remanent vs. induced magnetisation, magnetic and gravity field joint inversion,
- study of the ring current variability, its implication for main field modelling and its use for induction studies of the Earth's interior,
- joint interpretation of electric and magnetic field measurements in terms of ionospheric current systems, dynamic response of ionosphere to storms/substorms, I/M coupling, coupling between high and low latitude, Joule heating rate, etc.,
- construction of a CHAMP candidate model for the 2005 International Geomagnetic Reference Field (IGRF), participation in the design of the Definitive Geomagnetic Reference Fields for the epochs 2000 and 2005.

8.2.3.3 CHAMP Atmosphere and Ionosphere

With CHAMP's high quality temperature, geopotential height and humidity profiles in the troposphere and stratosphere, contributions to the following fields of investigation and application are addressed:

- seasonal climatologies from CHAMP atmospheric data products,
- cross validation with other remote sensing (both ground and space based) and in-situ instrumentation,
- development and improvement of data assimilation techniques for the use of radio occultation measurements in operational Numerical Weather Prediction (NWP) systems,
- general scientific studies in atmospheric sciences, e.g.
  - investigations regarding atmospheric dynamics, transport and microphysics around the tropical and extratropical tropopause,
  - characteristics of atmospheric waves on various spatial and temporary scales, ranging from extratropical planetary waves to small scale gravity waves, and their coupling to ionospheric processes,
- Climatology of the ionosphere, i.e., study of long-term variation of electron density and TEC on global scale,

- Ionospheric perturbations, i.e., study of large scale ionospheric storms and medium scale phenomena (e.g. TID's),
- Modeling the ionosphere and plasmasphere, i.e., improvement of the corresponding data base for developing, testing and improving models,
- Monitoring of the ionosphere, i.e., operational use of current CHAMP data products for providing signal quality information to operational radio systems such as satellite communication and navigation systems and for providing input parameters for space weather now- and forecasting.

8.2.4 OTHERS

Special investigations which are not directly connected to CHAMP's primary mission goals, but address the broad application potential of CHAMP's instrumentation and sensor equipment may be related to the following topics:

- extraction of the air drag component in the accelerometer measurements for air density variation and fluctuation studies, combination with magnetic and ionospheric perturbations,
- monitoring of space weather conditions at ionospheric/thermospheric level,
- study of magnetic ELF/ULF wave signatures in the ionosphere,
- exploitation of two-colour satellite laser ranging experiment for atmospheric parameter determination,
- detection of ocean circulation induction signals,
- use of CESS (Course Each and Sun Sensors) on-board CHAMP for Earth albedo determination.

9 GUIDELINES FOR PROPOSAL PREPARATION

The following guidelines apply to the preparation of proposals in response to this Announcement of Opportunity and aim at making the proposal process as efficient and comparative as possible for both the proposers and the reviewers.

9.1 Proposal Content and Submission

Proposals shall comprise the following three parts:

- Cover letter
- Proposal summary
- Proposal description

9.1.1 Cover Letter and Submission

Authors of proposals should enclose a covering letter, signed by the scientist leading the proposed investigation. The proposal should be submitted to the CHAMP Project Director at GFZ Potsdam:

Prof. Dr. Christoph Reigber
CHAMP Project Director
GeoForschungsZentrum Potsdam
CHAMP Project Office
Telegrafenberg
D-14473 Potsdam
Germany
Tel.: +49 331 288 1100
Fax: +49 331 288 1732
e-mail: champ@gfz-potsdam.de

French proposers should also send a copy of the proposal to:

Dr. Pascale Ultré-Guérard
Centre National d'Etudes Spatiales (CNES)
Programmes Directorate
2 Place Maurice Quentin
F-75039 Paris Cedex 01
France
Tel.: +33 1 44 76 75 33
Fax : +33 1 44 76 78 67
e-mail: pascale.ultre-guerard@cnes.fr

U.S. proposers should also send a copy to:

Dr. John L. LaBrecque
Mail Code YS
NASA Headquarters
Washington, DC 20546-0001
USA
Tel.: +1-202-358-1373
Fax: +1-202-358-2770 x 342
e-mail: jlabrecq@hq.nasa.gov

and for DIDM related proposals also to:

Dr. David Cooke
Air Force Research Laboratory
AFRL/VSBXR
29 Randolph Rd
Hanscom AFB, MA 01731-3010
USA
Tel: +1-781-377-2931
Fax: +1-781-377-3160
Email: david.cooke@hanscom.af.mil

9.1.2 PROPOSAL SUMMARY

The proposal summary should be concise and **not exceed two pages**. It should contain the following information

(a) Theme of investigation

(b) Proposing lead co-investigator
- name und title
- affiliation
- address
- telephone, fax, e-mail

(c) Proposal co-investigators. For each co-investigator:
- name und title
- affiliation
- address
- telephone, fax, e-mail

(d) Abstract of proposal. This short abstract shall provide in a very concise form the investigation goals, the data and product requirements and the duration of the planned investigation.

9.1.3 PROPOSAL DESCRIPTION

In this part some more detailed description of the proposed investigation and the investigators background shall be given. **This part should not exceed 5 pages**. It should contain a brief description of the objectives of the investigation, the methods to be employed in data analysis or interpretation, a short summary on CHAMP data and/or data product requirements and some description of the expected outcome of the proposed investigation in terms of scientific significance or application potential. The special expertise of the proposing individual or team in relation to the announced topics of investigation (section 8.2) should clearly be described.

9.2 Evaluation and Selection of Proposals

Proposals received in response to this AO will be reviewed by the CHAMP Science Advisory Board (c.f. Section 2) according to the following criteria:

- Science and application merit of the investigation,
- Relevance to the specified topics of the CHAMP AO,
- Competence and relevant experience of the proposing lead co-investigator and his co-investigators.

Final selection of CHAMP co-investigators will be coordinated with NASA, CNES and AFRL. Finally selected proposals will be supported by the CHAMP project to the maximal possible extent with a password protected access to all data and products needed for the proposed investigation.

9.3 Submission of LOI and Proposal Due Date

Individuals or parties interested in proposing a CHAMP mission investigation in response to this Announcement of Opportunity are requested to immediately resubmit the attached Letter of Intent (LOI) form (c.f. separate file and Annex 10.3) to the given CHAMP Project Office address. After having received this LOI, a provisional ISDC Public Account (c.f. Annex 10.1) will be provided to the LOI sender for realizing immediate access to the CHAMP ISDC data archive.

- Due date for the reception of CHAMP proposals in response to this AO is

July 16, 2001

- All those having submitted a proposal to this AO will be informed on the review result until

August 17, 2001

These due-dates apply for the first round of establishing CHAMP co-investigatorships. Subsequent rounds will be opened later on.

Opportunities will also be offered by the partner agencies NASA and CNES.

9.4 Points of Contact

The CHAMP Project Director and the CHAMP Principal Investigators may be contacted regarding further information on the CHAMP system, data and experiments.

CHAMP Project Director

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10 ANNEX

10.1 Data Access Description

The CHAMP data products and the associated metadata (product information) are accessible using the **CHAMP Information System and Data Center** (CHAMP-ISDC). The CHAMP-ISDC consists of operational system components for the input and output of CHAMP products, the clearinghouse modules offering catalogue services and different data warehouse applications in order to get access to the products. The CHAMP-ISDC provides a user-friendly graphical WWW interface to the scientific community. Both the newer versions of the Netscape Browser and the Internet Explorer are supported explicitly by the CHAMP-ISDC applications. The WWW or URL address of the CHAMP-ISDC is:

http://gesis.gfz-potsdam.de

The graphical user interface of the CHAMP-ISDC WWW application consists of two main frames, the navigation frame on the left hand side and the appropriated content frame on the right hand side (Fig. 10-1). This frame design enables to navigate easily and successfully across all CHAMP-ISDC applications.

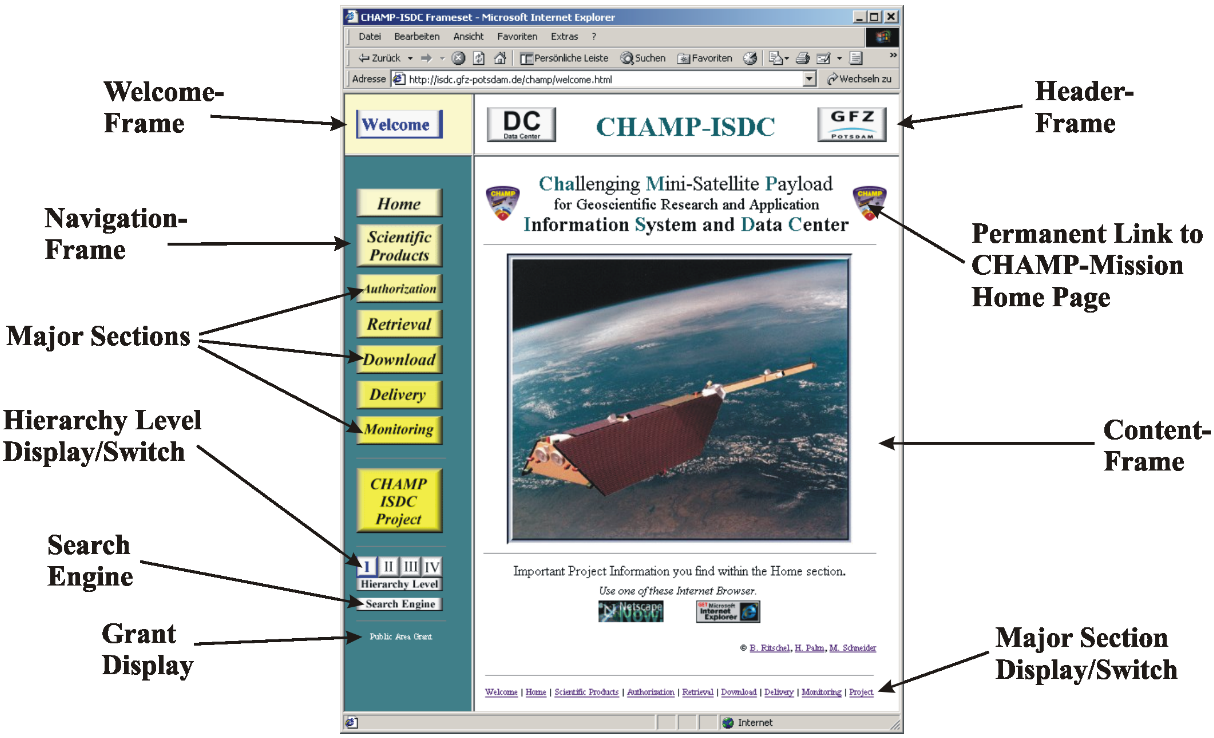

Figure 10-1: CHAMP-ISDC graphical user interface

In order to guarantee a high availability level of all CHAMP-ISDC features, users have to authorize themselves using user-specific accounts and passwords. These user specific IDs are provided by the CHAMP-ISDC using the **First Time Registration** within the *Authorization* section of the CHAMP-ISDC where also the user's requests for products are declared. Simultaneously to the on-line delivery of the CHAMP-ISDC **Guest Account** ID,, the CHAMP product clearingsite checks the personal user requests for public CHAMP products. After a successful off-line verification of the user ID and product request, the user will be informed that the CHAMP-ISDC Guest Account will be changed into a CHAMP-ISDC **Public Account**. This account enables the metadata retrieval of all public CHAMP products within the CHAMP-ISDC clearinghouse and additionally the access and download of the requested products using the CHAMP-ISDC data warehouse features.

10.2 Standard Product Fact Sheets

The following fact sheets for the standard products (c.f. Chapter 7.1) give the basic information on the products content, retrieval attributes and the links for a detailed format description.

```
Product identifier:
-------------------
CH-OG-1-SST

Name/Definition:
----------------
Decoded Low Rate CHAMP GPS-SST Data

Content:
--------
- time tag
- GPS Code and Carrier Phase data records

Data format/reference:
----------------------
Rinex 2.10


Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 10 second

Volume:
-------
10.1 MByte per day

Retrieval attributes:
---------------------
generation date
mission = CHAMP
data access = public
processing facility = GFZ
software package = CHAMP-DECOD 1.0
start_date = time epoch of the first measurement
stop_date = time epoch of the last measurement
revision
satellite_id = 0003902
```

```
Product identifier:
-------------------
CH-OG-1-GPS-30S

Name/Definition:
----------------
GPS ground tracking data, 30 sec sample rate


Content:
--------
- time tag
- GPS phase and Code measurements

Data format/reference:
----------------------
Rinex 2.20, Hatanaka & Unix compressed

Spatial coverage and resolution:
--------------------------------
ground station

Time coverage/resolution:
-------------------------
1 hour / 30 second

Volume:
-------
5 kByte per hour and station, compressed

Retrieval attributes:
---------------------
generation date
mission = CHAMP
data access = public
processing facility = GFZ
software package = CHAMP - tb2binex & bx2rxo
start_date = time epoch of the first measurement
stop_date = time epoch of the last measurement
revision
station_ID
location
```

```
Product identifier:
-------------------
CH-OG-1-GPS-10S

Name/Definition:
----------------
GPS ground tracking data, 10 sec sample rate

Content:
--------
- time tag
- GPS phase and Code measurements

Data format/reference:
----------------------
Rinex 2.20, Hatanaka & Unix compressed

Spatial coverage and resolution:
--------------------------------
ground station

Time coverage/resolution:
-------------------------
1 hour / 10 second

Volume:
-------
45 kByte per hour and station, compressed

Retrieval attributes:
---------------------
generation date
mission = CHAMP
data access = public
processing facility = GFZ
software package = CHAMP - tb2binex & bx2rxo
start_date = time epoch of the first measurement
stop_date = time epoch of the last measurement
revision
station_ID
location
```

```
Product identifier:
-------------------
CH-OG-2-ACC

Name/Definition:
----------------
preprocessed STAR accelerometer data incl. preprocessed attitude data
(Body ASC) and thruster firing events

Content:
--------
- time tag
- linear and angular acceleration vectors
- corrections and calibration parameters for the acceleration vectors
  (i.e. Lorentz force correction)
- thruster firing events
- quaternions from the body mounted Advanced Stellar Compass
- satellite mass values


Data format/reference:
----------------------
CHAMP data format, version 1.0
http://op.gfz-potsdam.de/champ/

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 10 second

Volume:
-------
2.5 MByte per day

Retrieval attributes:
---------------------
generation date
mission = CHAMP
data access = public
processing facility = GFZ
software package = CHAMP-DECOD 1.0
start_date = time epoch of the first measurement
stop_date = time epoch of the last measurement
revision
satellite_id = 0003902
```

```
Product identifier:
-------------------
CH-OG-3-RSO+CTS-CHA_<YYYY>_<DOY>_<HH>

Name/Definition:
----------------
- CHAMP project Rapid Science Orbit (RSO) for the CHAMP satellite
in the Conventional Terrestrial reference System (CTS) starting
year YYYY on day of year DOY and hour HH

Content:
--------
- header infos
- time tag
- position and velocity vector
- attitude angles
- neutral gas density
- manoeuvre flag
- land/water flag
- ascending/descending arc flag
- eclipse flag


Data format/reference:
----------------------
CHAMP orbit format CHORB, version 1.4
http://op.gfz-potsdam.de/champ/

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
14 h / 30 s

Volume:
-------
0.4 MByte per day

Retrieval attributes:
---------------------
processing facility = GFZ-DIV1
generation date
mission = CHAMP
data access = PUBLIC
software package = EPOS-OC <version no.>
revision
start_date
stop_date
satellite_id = 0003902
reference frame = CTS
satellite short name = CHA
```

```
Product identifier:
-------------------
CH-OG-3-RSO+CTS-GPS_<YYYY>_<DOY>_<HH>

Name/Definition:
----------------
- CHAMP project Rapid Science Orbits (RSO) for the GPS satellites
  in the Conventional Terrestrial reference System (CTS) starting
  year YYYY on day of year DOY and hour HH

Content:
--------
- sp3 header info
- time tag
- position and velocity vectors
- clocks

Data format/reference:
----------------------
sp3 format
http://op.gfz-potsdam.de/champ/

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 d / 300 s

Volume:
-------
1.0 MByte per day

Retrieval attributes:
---------------------
processing facility = GFZ-DIV1
generation date
mission = CHAMP
data access = PUBLIC
software package = EPOS-OC <version no.>
revision
start_date
stop_date
satellite_id = <PRN>
reference frame = CTS
satellite short name = GPS
```

```
Product identifier:
-------------------
CH-OG-4-PSO+CTS-CHA_<YYYY>_<DOY>_<HH>

Name/Definition:
----------------
- CHAMP project Precise Science Orbit (PSO) for the CHAMP satellite
  in the Conventional Terrestrial reference System (CTS) starting
  year YYYY on day of year DOY and hour HH

Content:
--------
- header infos
- time tag
- position and velocity vector
- attitude angles
- neutral gas density
- manoeuvre flag
- land/water flag
- ascending/descending arc flag
- eclipse flag

Data format/reference:
----------------------
CHAMP orbit format CHORB, version 1.4
http://op.gfz-potsdam.de/champ/

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
14 h / 30 s

Volume:
-------
0.4 MByte per day

Retrieval attributes:
---------------------
processing facility = GFZ-DIV1
generation date
mission = CHAMP
data access = PUBLIC
software package = EPOS-OC <version no.>
revision
start_date
stop_date
satellite_id = 0003902
reference frame = CTS
satellite short name = CHA
```

```
Product identifier:
-------------------
CH-OG-4-PSO+CTS-GPS_<YYYY>_<DOY>_<HH>

Name/Definition:
----------------
- CHAMP project Precise Science Orbits (PSO) for the GPS satellites
  in the Conventional Terrestrial reference System (CTS) starting
  year YYYY on day of year DOY and hour HH

Content:
--------
- sp3 header info
- time tag
- position and velocity vectors
- clocks


Data format/reference:
----------------------
sp3 format
http://op.gfz-potsdam.de/champ/

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 d / 300 s

Volume:
-------
1.0 MByte per day

Retrieval attributes:
---------------------
processing facility = GFZ-DIV1
generation date
mission = CHAMP
data access = PUBLIC
software package = EPOS-OC <version no.>
revision
start_date
stop_date
satellite_id = <PRN>
reference frame = CTS
satellite short name = GPS
```

```
Product Identifier:
-------------------
CH-OG-4-EGM

Name/Definition:
----------------
CHAMP Global Earth Gravity Field Model

Content:
--------
Files:
(a)   spherical harmonic coefficients and standard deviations (standard
      product)
(b)   correlation matrix of solved-for parameters (special product)
(c)   grid data values: mean gravity anomalies, geoid undulations related
      to a tbd equal angular grid (special product)

Data format/reference:
----------------------
(a)   shm-format
(b)   corregm-format
(c)   grid_data-format (self-explanatory)

Spatial coverage:
-----------------
global

Volume:
-------
(a)   1 MByte
(b)   5 Mbyte (compressed)
(c)   1 Mbyte

Retrieval attributes (selection):
---------------------------------
solution type = CHAMP MISSION ONLY (derived from CHAMP tracking data only),
= SATELLITE ONLY (derived form CHAMP and other satellite tracking data),
= COMBINED CHAMP ONLY (derived from CHAMP tracking data plus surface data),
= COMBINED (derived from CHAMP and other satellite tracking data plus
surface data), resp.

start date/stop date = (e.g.) 2000-08-01/2000-08-31 (period covered by
CHAMP data in the gravity field model solution)

revision = (e.g.) 1

parameter type = SHM (spherical harmonic coefficients), = CORREGM
(correlation matrix), = UND05P0 (5 x 5 deg geoid undulations), = ANO05P0 (5
x 5 deg gravity anomalies), = UND02P5 (2.5 x 2.5 deg geoid undulations), =
ANO02P5 (2.5 x 2.5 deg gravity anomalies), resp.
```

```
Product Identifier:
-------------------
CH-OG-4-OTI

Name/Definition:
----------------
CHAMP Ocean Tide Potential Model
(from simultaneous solution with CH-OG-4-EGM)

Content:
--------
Files:
(a)   C,S coeff. and amplitude, phase of ocean tidal wave constituents and
      standard deviations (special product)
(b)   correlation matrix of solved-for constituents (special product)

Data format/reference:
----------------------
(a)   oti-format
(b)   corroti-format

Spatial coverage:
-----------------
global

Volume:
-------
(a)   0.5 MByte
(b)   1 Mbyte

Retrieval attributes (selection):
---------------------------------
solution type = CHAMP MISSION ONLY (derived from CHAMP tracking data only),
= SATELLITE ONLY (derived form CHAMP and other satellite tracking data),
= COMBINED CHAMP ONLY (derived from CHAMP tracking data plus surface data),
= COMBINED (derived from CHAMP and other satellite tracking data plus
surface data), resp.

start date/stop date= (e.g.) 2000-08-01/2000-08-31 (period covered by CHAMP
data in the OTI solution)

revision = (e.g.) 1

parameter type = OTI (spherical harmonic coefficients), = CORROTI
(correlation matrix), resp.
```

```
Product Identifier:
-------------------
CH-OG-4-STA

Name/Definition:
----------------
Tracking Station Position Parameters
(from simultaneous solution with CH-OG-4-EGM)

Content:
--------
Files:
(a)   3-D geocentric cartesian coordinates and rates of change,
      standard deviations (special product)
(b)   correlation matrix of solved-for constituents (special product)

Data format/reference:
----------------------
SINEX format

Spatial coverage:
-----------------
global

Volume:
-------
(a)   <0.5 MByte
(b)   <1 Mbyte (compressed)

Retrieval attributes (selection):
---------------------------------
solution type = CHAMP MISSION ONLY (derived from CHAMP tracking data only),
= SATELLITE ONLY (derived form CHAMP and other satellite tracking data),
= COMBINED CHAMP ONLY (derived from CHAMP tracking data plus surface data),
= COMBINED (derived from CHAMP and other satellite tracking data plus
surface data), resp.

start date/stop date= (e.g.) 2000-08-01/2000-08-31 (period covered by CHAMP
data in the OTI solution)

revision = (e.g.) 1

parameter type = STA (spherical harmonic coefficients), = CORRSTA
(correlation matrix), resp.
```

```
Product identifier:
-------------------
CH-ME-2-OVM

Name/Definition:
----------------
- preprocessed OVM (scalar magnetometer) data

Content:
--------
- GPS time
    1) full second
    2) and 1/10 milliseconds
- Position
    1) GEO_LAT
    2) GEO_LON
    3) GEO_ALT (above reference sphere)
- Quality word
- Scalar field (in 1/100 nT)

Data format/reference:
----------------------
CDF, see
   CHAMP ME: Preliminary Documents
      Descriptions of Formats
Addendum for the Science Product Manual

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 1 second

Volume:
-------
3.6 MByte per day

Retrieval attributes:
---------------------
generation date,
mission = CHAMP,
processing facility = GFZ
data access = public,
satellite id,
start_date, stop_date,
revision

Remarks:
--------
now whole day in one file
```

```
Product identifier:
-------------------
CH-ME-2-FGM-FGM

Name/Definition:
----------------
- preprocessed FGM (vector magnetometer) data,
  all local corrections with latest available parameter set,
  in FGM1 sensor system

Content:
--------
- UTC Time, CDF Epoch
- Position
    1) GEO_LAT
    2) GEO_LON
    3) GEO_ALT (above reference sphere)
- Quality word
- Calibrated
  Vector field in FGM1 sensor system

Data format/reference:
----------------------
CDF, see
   CHAMP ME: Preliminary Documents
      Descriptions of Formats
Addendum for the Science Product Manual

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 1 second

Volume:
-------
< 20 MByte per day

Retrieval attributes:
----------------
generation date, mission = CHAMP, software package,
processing facility = GFZ, data access = public,
satellite id, start_date, stop_date,
revision

Remarks:
--------
now whole day in one file
```

```
Product identifier:
-------------------
CH-ME-2-FGM-NEC

Name/Definition:
----------------
- preprocessed FGM (vector magnetometer) data,
  all local corrections with latest available parameter set,
  transformed into ECEF NEC (north-east-center) system,
  attitude angles between sensor system and Star Imager
  rely on ground calibration (TMO) results.

Content:
--------
- UTC time, CDF EPOCH
- Position
    1) GEO_LAT
    2) GEO_LON
    3) GEO_ALT (above reference sphere)
- Quality word
- Calibrated Vector field in NEC system

Data format/reference:
----------------------
CDF, see
   CHAMP ME: Preliminary Documents
      Descriptions of Formats
Addendum for the Science Product Manual

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 1 second

Volume:
-------
< 20 MByte per day

Retrieval attributes:
---------------------
generation date, mission = CHAMP,
software package, processing facility = GFZ
data access = public, satellite id,
start_date, stop_date, revision

Remarks:
--------
now whole day in one file
```

```
Product identifier:
-------------------
CH-ME-2-ASC-BOOM

Name/Definition:
----------------
- Magnetometer attitude data
  (processed Advanced Stellar Compass readings)

Content:
--------
- UTC time
- Quaternions

Data format/reference:
----------------------
CHASC (ASCII)

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 1 second

Volume:
-------
< 10 MByte per day

Retrieval attributes:
---------------------
generation date,
mission = CHAMP,
software package,
processing facility = GFZ
data access = public,
satellite id,
start_date, stop_date,
quality,
delta_t,
sensor_flag,
revision
```

```
Product identifier:
-------------------
CH-ME-4-MOD

Name/Definition:
----------------
- coefficients for magnetic model

Content:
--------
- magnetic model coefficients,
  for main field, secular variation, etc.

Data format/reference:
----------------------
ASCII

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
various (see remarks)

Volume:
-------
depends, typical approx. 80kByte.

Retrieval attributes:
---------------------
generation date,
mission = CHAMP,
software package,
processing facility = GFZ
data access = public,
satellite id,
start_date, stop_date,
period,
order, type, model,
ref_altitude
revision

Remarks:
--------
time coverage depends on the
availability of quiet days for
main field modelling .
```

```
Product identifier:
-------------------
CH-AI-1-HR

Name/Definition:
----------------
Decoded High Rate CHAMP GPS-SST Data (Occultation Data)

Content:
--------
- time tag
- GPS Code and Carrier Phase data records

Data format/reference:
----------------------
Rinex 2.10, gzip-compressed


Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 50 Hz

Volume:
-------
170 MByte per day (uncompressed)

Retrieval attributes:
---------------------
generation date
mission = CHAMP
data access = public
processing facility = GFZ
software package = CHAMP-DECOD 1.0
start_date = time epoch of the first measurement
stop_date = time epoch of the last measurement
revision
satellite_id = 0003902
```

```
Product identifier:
-------------------
CH-AI-1-MR

Name/Definition:
----------------
Decoded Medium Rate CHAMP GPS-SST Data (Occultation Data)

Content:
--------
- time tag
- GPS Code and Carrier Phase data records

Data format/reference:
----------------------
Rinex 2.10, gzip-compressed

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 day / 1 Hz

Volume:
-------
10 MByte per day (uncompressed)

Retrieval attributes:
---------------------
generation date
mission = CHAMP
data access = public
processing facility = GFZ
software package = CHAMP-DECOD 1.0
start_date = time epoch of the first measurement
stop_date = time epoch of the last measurement
revision
satellite_id = 0003902
```

```
Product identifier:
-------------------
CH-AI-1-GPS-01S

Name/Definition:
----------------
High rate GPS ground tracking data, 1 sec sample rate

Content:
--------
- time tag
- GPS phase and Code measurements

Data format/reference:
----------------------
Rinex 2.20, Hatanaka & Unix compressed

Spatial coverage and resolution:
--------------------------------
ground station

Time coverage/resolution:
-------------------------
1 hour / 1 second

Volume:
-------
450 kByte per hour and station, compressed

Retrieval attributes:
---------------------
generation date
mission = CHAMP
data access = public
processing facility = GFZ
software package = CHAMP - tb2binex & bx2rxo
start_date = time epoch of the first measurement
stop_date = time epoch of the last measurement
revision
station_ID
location
```

```
Product identifier:
-------------------
CH-AI-2-PD

Name/Definition:
----------------
- Calibrated atmospheric excess path of a single occultation
  event

Content:
--------
- time tag
- Signal to Noise Ratios (C/A, P2)
- Position and velocity of CHAMP and occulting GPS satellite
- atmospheric excess phase (LC, L1, L2)
- Flywheeling flag

Data format/reference:
----------------------
ASCII (tbd)

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 occultation event (about 1 min)
50 Hz resolution

Volume:
-------
1 MByte per file (about 230 files per day)

Retrieval attributes:
---------------------
generation date; starttime; endtime; data access; gps anomaly;
antispoofing=1; doy; end latitude; end longitude; instrument
software version; mission ;revision; method of reconstruction;
occultation number; occultation satellite; occultation satel-
lite channel; processing facility; quality flag; reference
ground station number; reference satellite; reference satellite
channel; revolution; start latitude; start longitude; software
package
```

```
Product identifier:
-------------------
CH-AI-2-TAB

Name/Definition:
----------------
- Table of occultation events per day (duration > 20s),derived
  from CHAMP HR (50 Hz) data

Content:
--------
- occultation and LEO identifier
- time interval covered by the occultation
- Number of occulting and referencing GPS satellite and
  fiducial ground station
- estimated positions (altitude, longitude, latitude) of the
  point of closest approach at occultation start and end
- identifier for rising/setting and forward/backward
  occultation
- elevation of occulting and referencing GPS satellites at
  fiducial ground station site

Data format/reference:
----------------------
ASCII (tbd)

Spatial coverage:
----------------
global

Time coverage:
--------------
daily

Volume:
-------
150 kByte

Retrieval attributes:
---------------------
generation date; processing facility; data access; software
package; mission identifier; day of the year; start time; end
time; orbit file LEO; orbit file GPS; method of reconstruction
```

```
Product identifier:
-------------------
CH-AI-3-ATM

Name/Definition:
----------------
- Vertical profiles of atmospheric parameters (assumption of
dry air)

Content:
--------
- altitude above mean sea level, latitude, longitude
- refractivity, bending angle and impact parameter
- density, pressure, temperature for dry air assumption
- Signal to Noise Ratio (C/A; P2), geopotential
- quality index
- characterization of the occultation plane

Data format/reference:
----------------------
ASCII (tbd)

Spatial coverage and resolution:
--------------------------------
0-60 km; 0.2 km height resolution

Time coverage/resolution:
-------------------------
1 occultation event (about 1 min)

Volume:
-------
50 kByte per file (about 230 files per day)

Retrieval attributes:
---------------------
generation date; viewangle; correction methods; model for
statistical optimization; method of reconstruction; occultation
direction; maxdeviation refractivity from model; height of
maxdeviation refractivity from model; altitude earth surface
above mean sea level; inversion quality stratosphere; inversion
quality troposphere; occultation number; occultation satellite;
occultation satellite channel; reference satellite; reference
satellite channel; gps anomaly; reference ground station
number; day of the year; quality flag; antispoofing; diffrac-
tion correction; start time; end time; local radius of curva-
ture; start altitude; start latitude; start longitude; end
altitude; end latitude; end longitude; casnr at 40km; p2snr at
40km; elevation sun at end lat/end lon; processing facility;
data access; mission; software package; revision;
```

```
Product identifier:
-------------------
CH-AI-3-WVP

Name/Definition:
----------------
- Vertical profiles of atmospheric parameters for moist air

Content:
--------
- altitude above mean sea level, latitude, longitude
- atmospheric parameters for dry air assumption from CH-AI-3-
  ATM
- temperature, density, pressure, specific and relative
  humidity for wet air
- geopotential
- quality index

Data format/reference:
----------------------
ASCII (tbd)

Spatial coverage and resolution:
--------------------------------
0-20 km; 0.2 km height resolution

Time coverage/resolution:
-------------------------
1 occultation event (about 1 min)

Volume:
-------
20 kByte per file (about 230 files per day)

Retrieval attributes:
---------------------
File attributes from CH-AI-3-ATM and
meteorological analysis time, latitude, longitude;
meteorological analysis file; refractivity smoothing type and
width
```

```
Product identifier:
-------------------
CH-AI-3-TCR

Name/Definition:
----------------
link related TEC from Turbo Rogue Receiver onboard CHAMP

Content:
--------
time tag (UTC seconds of the day)
uncalibrated TEC data along ray trajectories
CHAMP & GPS position (ECEF),
GPS Sat Nr.
L1, L2, P1, P2

Data format/reference:
----------------------
ASCII table
http://op.gfz-potsdam.de/champ/

Spatial coverage and resolution:
--------------------------------
global

Time coverage/resolution:
-------------------------
1 hour / 1 second

Volume:
-------
2 Mbyte

Retrieval attributes:
---------------------
total length of gaps
number of gaps
generation date
start time
mission
data access
processing facility
software package
doy
quality flag
samprate
revision
satellite
product identifier

Remarks:
--------
starttime corresponds with full hours 0,1,2 .. 23 UT
```

```
Product identifier:
-------------------
CH-AI-3-IVP

Name/Definition:
----------------
ionospheric vertical profile / vertical profile of electron density

Content:
--------
time tag (UTC), latitude, longitude, altitude of PCA, electron density

Data format/reference:
----------------------
ASCII table
http://op.gfz-potsdam.de/champ/

Spatial coverage and resolution:
--------------------------------
~ 1000 km / 5-20 km (height)

Time coverage/resolution:
-------------------------
5-20 min / 20 s

Volume:
-------
5 kByte

Retrieval attributes:
---------------------
start altitude & latitude & longitude,
end altitude & latitude & longitude,
region of closest approach of the ray latitude & longitude
model
occultation number, satellite, satellite channel,
viewangle
total length of gaps
number of gaps
generation date
start time
mission
data access
processing facility
software package
doy
quality flag
samprate
revision
product identifier

Remarks:
--------
region of closest approach of the ray is defined where the ray enters the
F2 region (height fixed at 300 km)
```

10.3 Letter of Intent (LOI) Form

Please fill out and send the below form to the address given at the bottom. See also the separate attachment.

LETTER OF INTENT

In response to the CHAMP Announcement of Opportunity, issued on 28 May 2001, I (my group) intend(s) to submit a proposal to become a CHAMP Co-Investigator.

Name: ______________________________

Affiliation: ______________________________

____

Address: ______________________________

____

Email: ______________________________

Phone: ______________________________

Fax: ______________________________

Areas of interest:

- ☐ **Orbit and Gravity Field**
- ☐ **Magnetic and Electric Field**
- ☐ **Atmosphere Profiling**
- ☐ **Ionosphere Profiling**
- ☐ **others:** ______________________________

Tentative title of the proposal: ______________________________

____

____

Date, Signature: ______________________________

Please send this form to:

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