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CHAMP

CHAllenging Minisatellite Payload (Fig. 1) is a satellite mission dedicated to improving gravity and magnetic field models of the Earth. CHAMP was proposed in 1994 by Christoph Reigber of GeoForschungsZentrum Potsdam in response to an initiative of the German Space Agency (DLR) to support the space industry in the "New States" of the united Germany by financing a small satellite mission. The magnetic part of the mission is lead by Hermann Lühr. CHAMP was launched with a Russian COSMOS vehicle on July 15, 2000 onto a low Earth orbit. Initially planned to last 5 years, the mission is now projected to extend to 2008 (Fig. 2). The official CHAMP website is at http://op.gfz-potsdam.de/champ/.

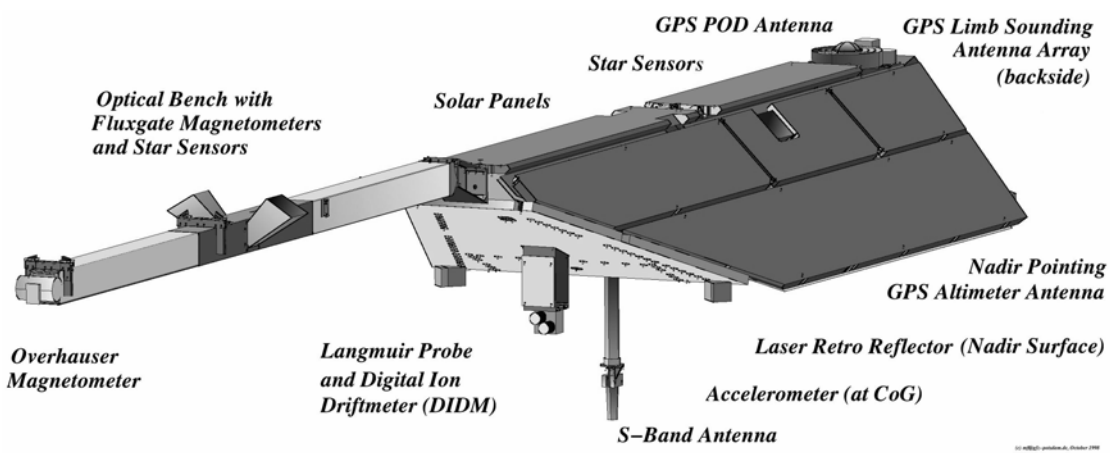

Fig. 1: Front view of the CHAMP satellite (courtesy GFZ Potsdam)

Satellite and orbit

A limiting factor for low Earth satellite missions is the considerable drag of the atmospheric neutral gas below 600 km altitude. This brought down Magsat (qv) within 7 months, despite of its elliptical orbit, and necessitated the choice of a higher altitude orbit for Ørsted (qv). To achieve long mission duration on a low orbit, CHAMP was given high weight (522 kg), a small cross section (Fig. 1) and a stable attitude. It was launched onto an almost circular, near polar (i = 87.3°) orbit with an initial altitude of 454 km. While Magsat was on a strictly sun synchronous dawn/dusk orbit, CHAMP advances one hour in local time within eleven days. It takes approximately 90 minutes to complete one revolution at a speed of about 8 km/s.

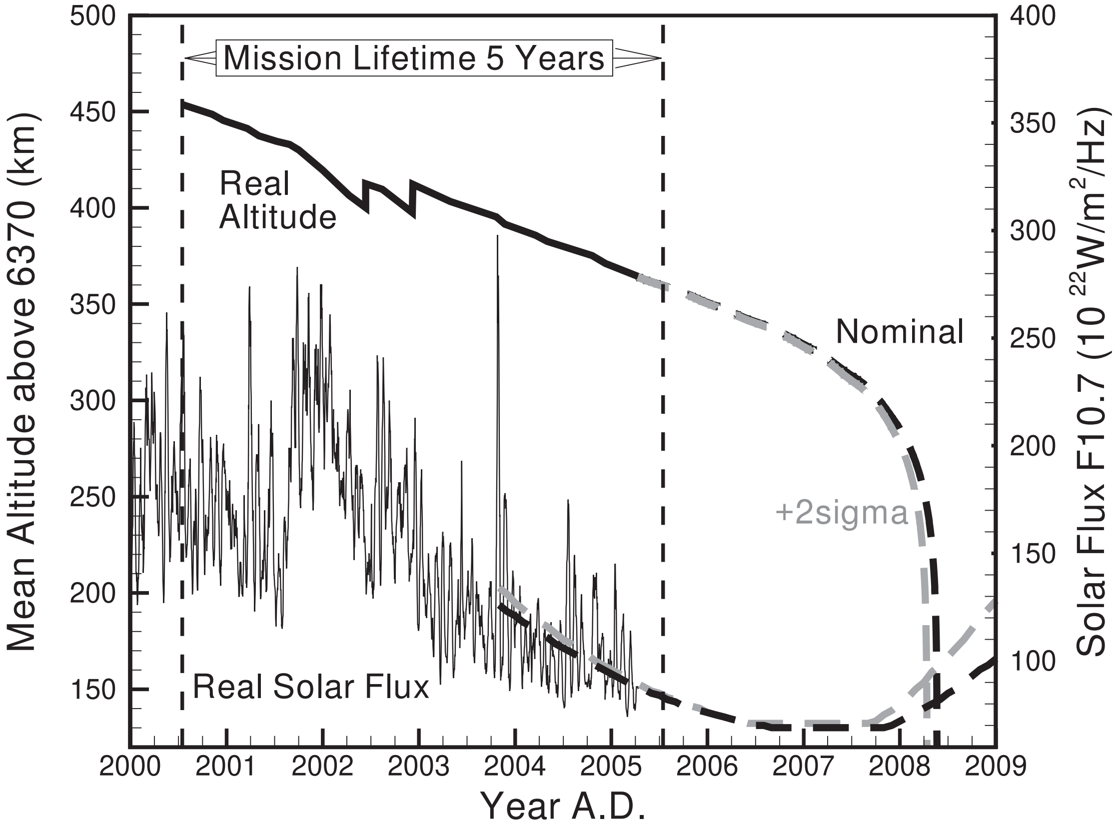

Fig.2: The decay of CHAMP's orbital altitude (left scale) depends on the neutral gas density, which is enhanced by solar activity (right scale). CHAMP's orbit has been raised twice to prolong the mission, which is predicted to end after the solar activity minimum in 2008 (courtesy of F.-H. Massmann, GFZ Potsdam)

Magnetic mission instrumentation

MAGNETOMETERS

At the tip of the 4m-long boom, a proton precession Overhauser magnetometer (qv), measures the total intensity of the magnetic field (qv) once per second. This instrument, which was developed by LETI, Grenoble, has an absolute accuracy of <0.5 nT. Its measurements are used in the absolute calibration of two redundant vector magnetometers, located mid-boom on an optical bench. These fluxgate magnetometers were developed and supplied by DTU Lyngby, Denmark. They sample the field at 50 Hz with a resolution < 0.1nT.

STAR CAMERAS

The orientation of the optical bench in space is given by a star camera which was developed and supplied by DTU Lyngby, Denmark. Attitude uncertainty is the largest source of error in satellite vector magnetic data. Star cameras are often blinded by the sun or moon and provide unreliable attitude with regard to rotations about their direction of vision (boresight). For this reason, CHAMP was equipped with a dual head star camera, improving relative attitude by an order of magnitude to 3 arc seconds, corresponding to around 0.5 nT accuracy for the vector components. Since this high accuracy is only achieved in dual head mode (62% of CHAMP data), future magnetic field missions (e.g. the European Space Agency mission *swarm,* scheduled for launch in 2009) will have triple head star cameras. A further, redundant dual head star camera on the body of CHAMP is of limited utility for the magnetic field measurements, due to the flexibility of the boom.

ELECTRIC FIELD, ELECTRON DENSITY AND TEMPERATURE

A Digital Ion Drift Meter (DIDM) and a Planar Langmuir Probe (PLP) were provided by the Air Force Research Laboratory, USA. The DIDM, designed to measure the electric field from ion velocities, partly failed due to frictional overheating during the launch phase of CHAMP. The PLP, which was not damaged, provides the spacecraft potential, electron temperature and electron density, once in 15 seconds. As discussed below, these quantities can be used to correct magnetic field measurements for the diamagnetic effect of the plasma surrounding the satellite. The PLP measurements have thus turned out to be essential for accurate geomagnetic field modelling.

GPS RECEIVER

Apart from providing the accurate position of CHAMP, the Black Jack GPS receiver (supplied by NASA) has the important task of providing an absolute time frame. A pulse delivered every second is used to synchronize all of the instruments on board. Furthermore, it provides a stable reference frequency for the proton precession magnetometer readings, giving them absolute accuracy.

Data products

CHAMP's standard science products are labelled from level-0 to level-4, according to the amount of pre-processing applied to the original data. Scientific utility starts with level-2 products, which are calibrated, flagged and merged with accurate orbits and are supplied as daily files in Common Data Format (CDF). Level-3 products comprise the final processed, edited and calibrated data, as well as the rapid delivery products. Derived products such as the initial CHAMP main field model CO2 (Holme et al., 2003) are classified as level-4. The level-2 to level-4 products are archived and distributed by the Information System and Data Centre (ISDC) at GFZ Potsdam (http://isdc.gfz-potsdam.de/champ/).

Early science results

MAIN FIELD MODELS

Combined analysis of measurements from the three magnetic satellite missions (CHAMP, Ørsted (qv) and SAC-C) has lead to a breakthrough in main field model accuracy (Holme et al., 2003). While models from ground based observations are limited in resolution to about 5000 km wavelength, the new combined satellite models resolve the main field (qv) and its secular variation (qv) to 3000 km. Shorter wavelengths of the main field are masked by the crustal magnetic field (qv).

CRUSTAL FIELD MODELS

With its low altitude, circular, polar orbit, CHAMP is particularly suited for mapping the field caused by the magnetic minerals in the Earth’s crust. The first CHAMP crustal field model (Maus et al, 2002) - extending to spherical harmonic degree 80, corresponding to a wavelength of 500 km - shows that the Earth’s crustal magnetic field is weaker than indicated by earlier observations from Magsat.

MAGNETIC SIGNAL OF OCEAN FLOW

The flow of electrically conducting sea water through the Earth’s magnetic field acts as a global dynamo, inducing electric fields which drive electric currents and thus give rise to secondary magnetic fields. Focussing on the dominant semi-diurnal lunar tide, periodic ocean flow magnetic signals were clearly identified in CHAMP satellite data (Tyler et al., 2003).

DIAMAGNETIC EFFECT OF IONOSPHERIC PLASMA

A diamagnetic substance responds to an applied magnetic field by circular currents that produce a magnetisation opposing the applied field. Such a diamagnetic response, which is a well-known property of plasma in the outer magnetosphere and the solar wind, was until recently thought to be negligible in the ionosphere. However, bands of enhanced plasma density on both sides of the magnetic equator have been found to cause depressions of the order of 10 nT in the geomagnetic field intensity (Lühr et al., 2003). With the electron density and temperature acquired by the PLP instrument, CHAMP's magnetic field readings can be corrected for this effect. A related phenomenon is the formation of surface currents on plasma cavities. The CHAMP satellite has made it possible for the first time to directly observe these currents in their magnetic field signature (Lühr et al., 2002).

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Cross references

Ørsted, Magsat, magnetometer, main field, secular variation, crustal field.