Multiprobe High-Precision Geomagnetic Field Mission

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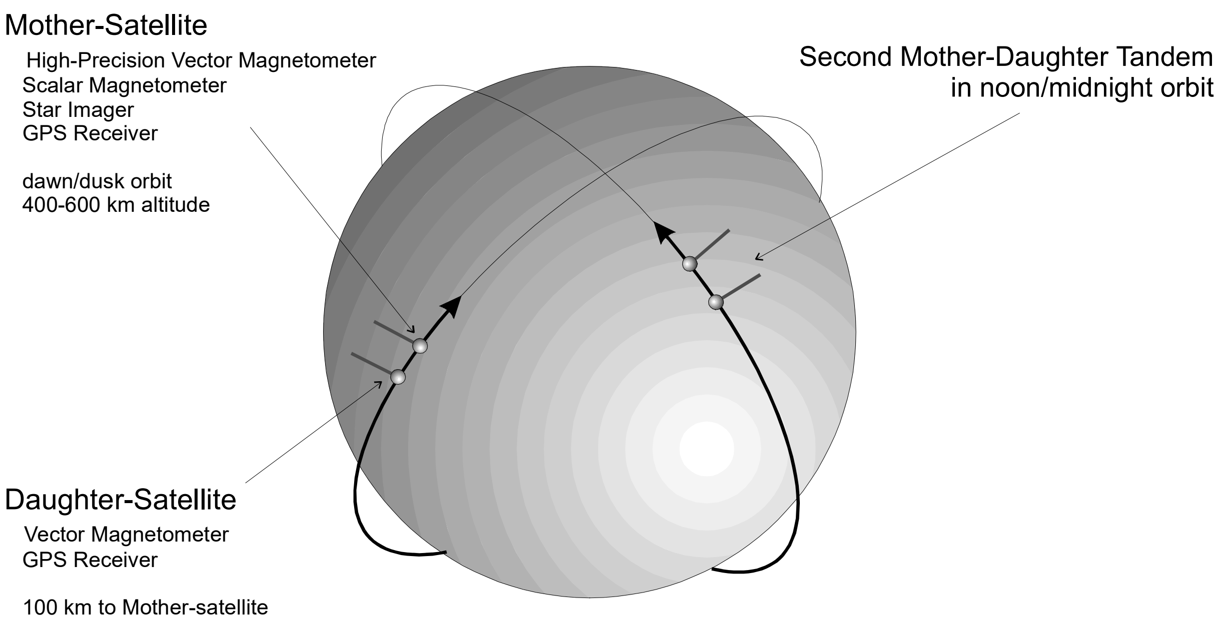

1. Scientific Objectives and Basic Payload Concept

The proposal intends to take advantage of the scientific and technical knowledge acquired in Denmark during the Ørsted mission and to use this as a platform for new and exciting studies of the geomagnetic field and its variations.

One of the limiting factors in determining the main field of the Earth is the dynamical behavior of the external current configuration. Single satellite experiments will never be sufficient to provide a good description of this part, regardless of the accuracy of the measurements.

We therefore propose two pairs of mother-daughter-satellite combinations, each consisting of one satellite with high-precision vector magnetometer, scalar magnetometer, star imager and GPS receiver, followed by a second satellite - in a separation of few hundred kilometers or less - carrying a vector magnetometer and a GPS receiver.
The two mother-daughter tandems will fly in almost sun-synchronous polar orbits at altitudes of 400 - 600 km at different local times, namely in a noon/midnight-orbit and a dawn/dusk-orbit, respectively .

The proposed constellation of these four satellites is optimal for investigating magnetic sources both internal and external to the Earth and can be used for studying the following topics:

1. Modeling of the geomagnetic core field and its secular variation;
2. Determination of the crustal field with hitherto unknown precision;
3. Investigation of the day-to-day variability of ionospheric currents at middle and low latitudes;
4. Estimation of the time-space structure of the equatorial and polar electrojets; analysis of their variability, for example with the solar wind;
5. Study of small-scale Field-Aligned Currents at high latitudes, and of high-latitude current systems during geomagnetic quiet conditions;
6. Tomography of the electron density in the ionosphere from the GPS receivers onboard the four satellites.

In addition to these geomagnetic applications, the GPS receivers enable an atmospheric profiling of temperature, humidity and other meteorological parameters.

2. Science Case

Recent progress in modeling the Earth's magnetic field indicates that one of the limiting factors in the accuracy of present geomagnetic models is the dynamic behavior of the external current configuration. This disadvantage can be partly accounted for by making assumptions about the time-development of ionospheric and magnetospheric contributions based on statistical models, and by including groundbased geomagnetic observations, which, however, are very sparse and non-uniformly distributed. Nevertheless, this allows for determining geomagnetic models with an accuracy not better than a few nT, which is much more than the expected accuracy of the magnetometers. However, single satellite missions are not able to describe the dynamical behavior of external contributions, and since all planned forthcoming high-precision geomagnetic space observations are single satellite missions - like the previous missions -, similar limitations are likely to apply to the analysis of their data.

Hence single satellite missions are not able to take advantage of the enormous improvement in the accuracy of magnetometers and attitude determination systems which has been achieved during the last years, especially by scientists in Denmark. Multiple satellite missions with instruments measuring simultaneously over different regions of the Earth offer the only way to take full advantage of this new generation of instruments. Such a multi-satellite mission enables a *monitoring* of the time-variability of external sources, which is much more convenient than using *extrapolations* based on statistics and on ground observations at selected sites, as it is necessary now.

The proposed two pairs of a mother-daughter-satellite combination will overcome the above mentioned shortcomings of single satellite missions and will contribute to geomagnetic investigations in a threefold way:

1. Data from each of the two mother-satellites will continue long-term geomagnetic observations from space after missions like Ørsted, SAC-C and CHAMP;
2. Combining the high-precision measurements of the two mother-satellites enables a determination of large-scale ionospheric and magnetospheric field contributions *at individual time instants;*
3. Comparing the magnetic fields between the mother-satellites and the closely following daughter-satellites allows for a separation of temporal variations and spatial variations at intermediate scale-lengths of approximately 100 km, which is especially helpful when studying phenomena at high-latitudes.

The proposed mission allows for an analysis of the spatial structure of the time evolution of Earth's magnetic field at large scalelengths (of several thousands of km) as well as at intermediate scalelengths (tens to hundreds of km) and timescales between seconds and months. These new possibilities of geomagnetic observations will drastically enhance the signal-to-noise ratio, will enable a better separation of the different sources, and will open new perspectives for geomagnetic research.

Current **Geomagnetic Field Models** include contributions in the core, crust, ionosphere and magnetosphere and are derived by a joint analysis of groundbased and satellite magnetic observations. In doing so, a separation of the magnetic field contributions *at particular time instants* is necessary, and their inadequate separation is one of the limiting factors for a more accurate determination of the core field, of the secular variation, and of the lithospheric field.
The proposed mission will contribute to solve some of the problems in current geomagnetic field modeling, like (a) the unknown day-to-day variability of large-scale external sources, which has a distorting effect especially on the determination of the low degree spherical harmonic coefficients of the core field and of the secular variation; and (b) the unknown contamination of the main-field coefficients by high-latitude ionospheric current systems with scale-lengths of tens to hundreds of km. New simulations have indeed shown that their influence even during geomagnetic quiet conditions might be much larger than hitherto expected, but their exact determination is difficult due to lack of information about quiet-time high-latitude current systems. Their consideration will undoubtedly enhance the models, and will lead to a better determination of the lithospheric field and of core-field motion.

Recent model studies of induction gave evidence for a contamination of present **Crustal Field** maps by induced currents, especially in the oceans. Correcting for ocean induction is straightforward (since conductivity of sea-water and the bathymetry is well known) but requires knowledge of the structure of large-scale external contributions *at particular time instants* which, however, can be obtained with the proposed multi-satellite mission.

Beside of induction in the oceans, studying heteregoneities in **Deep-Mantle Conductivity** will be possible by comparing the actual measurements with predictions based on models of mantle conductivity.

The proposed mission will also greatly enhance our knowledge of **External Field** contributions. The day-to-day variability of the ionospheric dynamo currents at middle and low latitudes and their possible relation to upward propagating gravity waves are examples for investigation topics. The space-time structure of polar and equatorial electrojets will be studied more accurately, especially concerning their variability with parameters of solar radiation and the solar wind. Small-scale field-aligned current systems, especially at polar latitudes, will be investigated with hitherto unknown resolution.
The question of how solar wind plasma, momentum and energy is transferred to the magnetosphere is one of the fundamental problems in **magnetospheric physics**. A major obstacle for reaching this understanding is the lack of sufficient amount of simultaneous observations of these regions and their ionospheric projections. The proposed multi-satellite mission will also contribute to solve the intriguing question of possible merging between magnetic fields of different origins like the solar and terrestrial fields.
In addition to that, the proposed configuration with two mother-daughter systems will be used as wave telescopes for detecting and studying **Plasma Wave Phenomena**, especially in the frequency range between 0.1 and 10 Hz.

3. Payload Concept

Configuration of the mother-satellites (in analogy to the specifications of CHAMP):

Vector magnetometer:	< 0.5 nT absolute accuracy, sampling rate 20 - 100 Hz;
Scalar magnetometer:	< 0.5 nT accuracy;
Stellar Compass:	< 5" attitude accuracy;
GPS receiver.	

Configuration of the daughter-satellites:

Vector magnetometer:	< 10 nT accuracy, sampling rate 20 - 100 Hz;
GPS receiver.	

4. Science Interests

Scientific collaborators in Denmark:

Copenhagen University - Geophysical Department,
Danish Space Research Institute,
Danish Meteorological Institute - Solar Terrestrial Physics Division,
Danish Technical University.

The great interest of the international geomagnetic community in a geomagnetic high-precision missions becomes evident when recalling that over 50 scientific research groups from 14 countries have been selected in the Ørsted project. It is anticipated that this collaboration to a large extent will continue with the proposed multi-satellite mission.

5. Mission Requirements:

Orbit: The two mother-daughter tandems will fly in sun-synchronous polar orbits in heights of 400-500 km. One mother-daughter pair will be launched into a dawn/dusk orbit, and the other pair into a noon/midnight orbit. The daughter satellites will follow their corresponding mother-satellites in a separation of, say, 100 km.

Launch-time: 2003 as a continuation of the CHAMP mission (1999-2003)

Lifetime: Two years.

6. Relation to Other Missions

The planned launch date and the expected lifetime of two years will continue geomagnetic observations by missions like Ørsted, Sunsat, SAC-C, CHAMP and others. Such a continuous magnetic field observation from space is necessary for example for studying secular variation, the dynamo in the Earth's core and the solar cycle variability of external sources. The expected lifetime of two years enables a study of the seasonal variability of external sources, and of the short-time fluctuations of secular variation, a topic much in discussion now.
The mission fits with the upcoming "International Decade of Geopotential Research" as proposed by the International Association of Geomagnetism and Aeronomy (IAGA) and with other international efforts for studying polar cap physics and the solar-tessestrial environment.

The simple (vector magnetometer only) satellites should be considered as a possible Danish contribution to the recently proposed NASA "Magnetospheric Constellation" project consisting of 10 to 500 small satellites deployed at various locations in the magnetosphere in order to acquire "pixels" of a magnetospheric image. In this case the payload should be augmented with simple measurements of particles and electric fields.

7. Science Operation and Archiving, Technical Feasibility, Management and Funding

The concept of magnetic missions as regards their technical implementation has already been successfully demonstrated in the Ørsted project. The proposed mission suggests to make use of this experience and, in addition, of the substantial improvements to the scientific instrumentation that has occurred since the design for the Ørsted mission.
If selected, this experiment should be offered as a joint project with foreign groups for cost sharing reasons and because it would have a great international interest. We suggest that the experience and facilities established for the Ørsted project could find a natural continuation in this new mission, in the same way as they are expected to provide a basis for danish involvement in other planned and suggested missions in the intervening period. This concerns both practical facilities as for example a scientific data centre, and organisational facilities, as the constitution of a science advisory committee and international science teams and working groups.

For an indept discussion of all of the above points regarding operation and management we should like to refer to the Ørsted Project Documents, the final report on the Study on Geomagnetic Space Observatories (GSO), and the SAC-C Technical Notes and Project Management Plans. In all of these the proposers have leading parts, and thereby have demonstrated the ability to manage and operate the scientific part of satellite missions similar to the one proposed here.