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Swarm

Satellite trio on voyage through the Earth‘s magnetic field

The Swarm mission was initiated by the European Space Agency (ESA) with the main aim of studying the Earth’s magnetic field, i.e. its strength, orientation, and temporal changes. The mission is one of ESA’s Earth Explorer Missions, within the frame of ESA’s Living Planet Programme, intended to study system Earth. Swarm is unique among geomagnetic field missions. As a constellation mission it consists of three identical spacecraft circling Earth at different polar orbits.

The Swarm fleet will return multipoint measurements of the geomagnetic field and gravity field. Other objectives of the mission are to investigate magnetospheric-ionospheric currents, and the characteristics of the thermosphere-ionosphere system. The obtained data are of interest for basic research of global dynamics, but they are also of relevance for practical purposes, i.e. improved orbit predictions, better space weather forecast and reliable GPS navigation data.

Swarm fleet, artist view (ESA/AOES Medialab).

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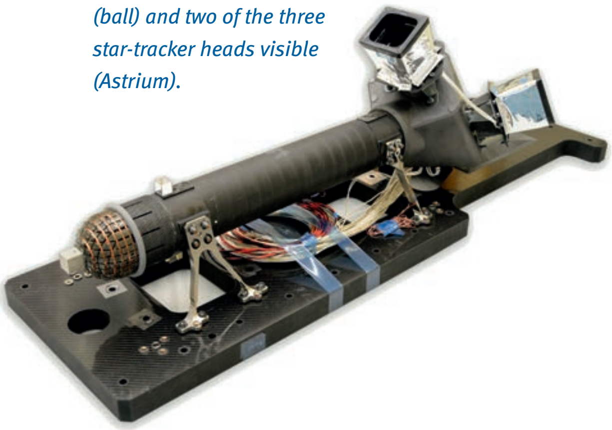


Optical bench carrying the vector magnetometer (ball) and two of the three star-tracker heads visible (Astrium).

Swarm Science Instrumentation

In order to accomplish the scientific objectives of the mission the Swarm satellites are equipped with a complementary set of instruments. For performing high-resolution magnetic field measurements a helium vapor scalar magnetometer is mounted at the tip of a 4-m boom. At about the middle of the boom an optical bench is installed carrying the vector magnetometer and a set of 3 star trackers, which provide the orientation of the satellite with a precision of 1/1000 of a degree. The optical bench assembly can be regarded as the centerpiece of the mission.

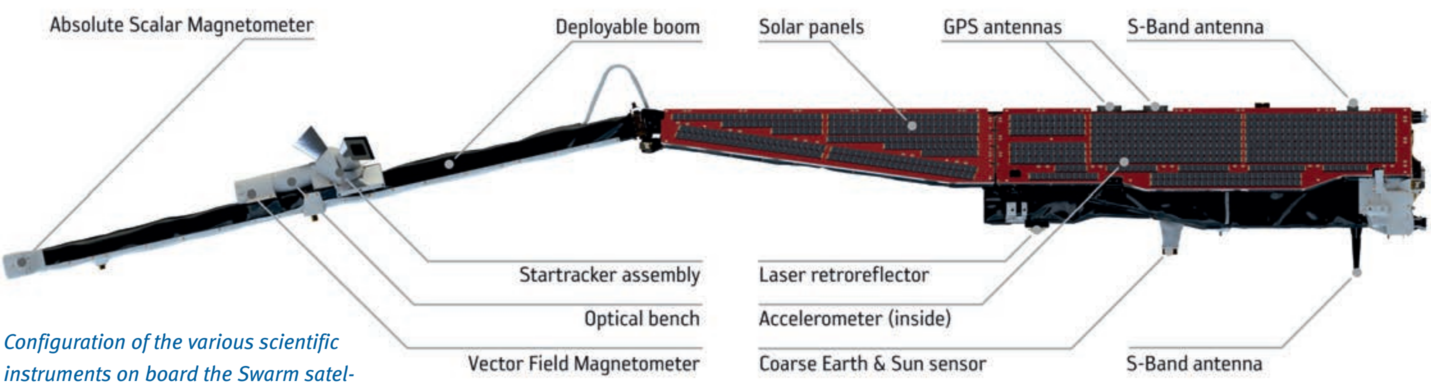
For the purpose of gravity studies a sensitive triaxial accelerometer is mounted at the center of mass inside the satellite. This position ensures that the accelerometer is not influenced by the orbit dynamics, but just measures the forces acting on the spacecraft body, e.g. air drag and radiation pressure from the sun. For this reason the accelerometer serves also as device for recording the air density and for sensing the wind.

Ionospheric measurements are performed by the electric field instrument package. Central part is an ion drift imager that will measure the direction and energy of the incoming ions. From these readings the ion drift vector, the ambient electric field, and the ion mass and temperature can be deduced. Two additional Langmuir probes sense the electron density and temperature.

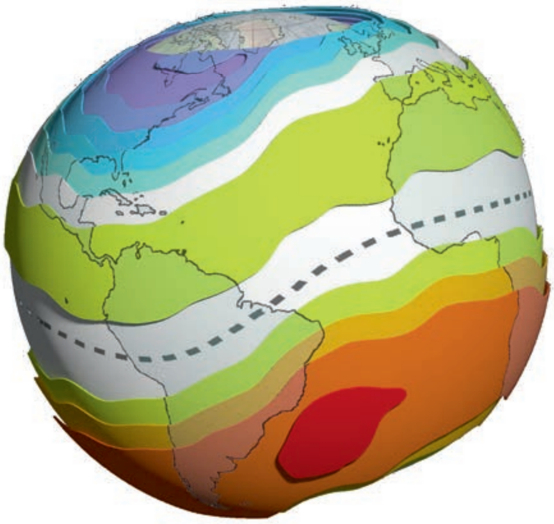
Precise orbit determination is accomplished with the help of a GPS receiver. A laser retro-reflector on the bottom side is used for highly accurate distance measurement from ground in support of the orbit reconstruction.

The 3-axes stabilized spacecraft will fly with the boom pointing backward. The slim satellite shape with a small cross-section area in ram direction allows for a long mission life time in low altitude.

All three Swarm satellites are launched together by a single rocket. After simultaneous injection the single spacecrafts are manoeuvred into their individual orbits. Deployment of the boom with the magnetometers will be one of the first actions (Astrium).



Configuration of the various scientific instruments on board the Swarm satellites (ESA/AOES Medialab).



Visualization of the air density distribution at 400 km altitude during equinox months. Highest densities are not observed at the subsolar point, but along two bands north and south of the magnetic equator (dashed line). (CHAMP, GFZ)

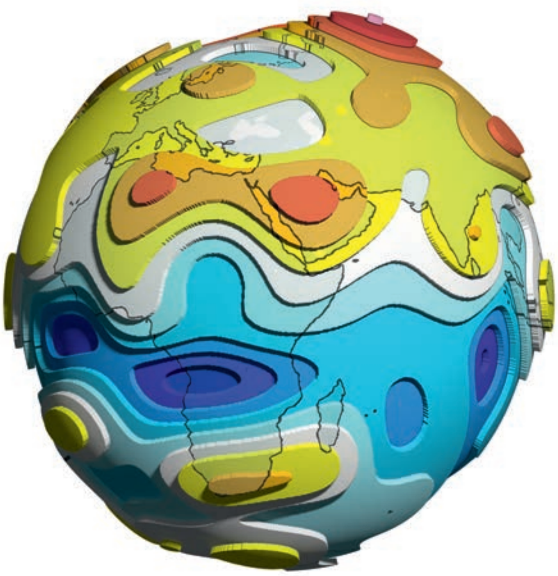
Earth's magnetic field and its variations

The geomagnetic field is composed of internal and external parts. The main internal field source is the geodynamo in the liquid iron core. To a lesser extent the magnetized rocks in the crust contribute to the Earth's magnetic field. The field from the core is subject to continuous changes, so-called secular variations. Sharp changes of secular variations are termed geomagnetic jerks. They are indications for important modifications within the geodynamo. The Swarm fleet of satellites with its high-resolution measurements will be used to map the field dynamics at the core/mantel boundary, close to the source. In combination with numerical dynamo simulations it is planned to elucidate the processes that are responsible for the field evolution.

The two Swarm satellites flying side-by-side will be very efficient in mapping the crustal magnetization. This information is most useful for characterizing geological provinces, but is also helpful for exploration of minerals and ore deposits.

Ionospheric-magnetospheric currents

Electric currents in the planetary environment generate magnetic fields that are characterized by rapid changes. These external fields can severely disturb the core and crustal field analysis. Ionospheric currents are particularly strong at high latitudes in the auroral region. Here, electrical energy driven by the solar wind is channeled from outer space along the geomagnetic field lines into the upper atmosphere. The lower pair of Swarm satellites will be used to measure these important field-aligned currents unambiguously by means of the curl-B method. The results are of relevance for atmospheric research, but also for correction in main field studies.



Radial magnetic field component at the core-mantle boundary. Yellow/red colors represent the field polarity in the northern hemisphere, bluish colors in the south. There are some yellow patches in the southern hemisphere with reversed polarity. Their evolution should be studied (CHAMP, GFZ).

Upper atmospheric research

The Earth's atmosphere is subject to rapid changes. Opposed to a global warming of the troposphere, higher layers are cooling and shrinking. The Swarm satellites will monitor the change rates at orbital heights. Recent results have shown that climate and weather phenomena do affect the dynamics of the ionosphere and thermosphere. The waves and tides propagating across the various layers of the atmosphere shall be recorded by the Swarm fleet. The geomagnetic field is known to control the dynamics of the ionospheric particles. Now there is evidence that also the neutral atmosphere is significantly influenced by this field. The complementary instrumentation on board Swarm will allow a detailed inspection of this unexpected dependence.

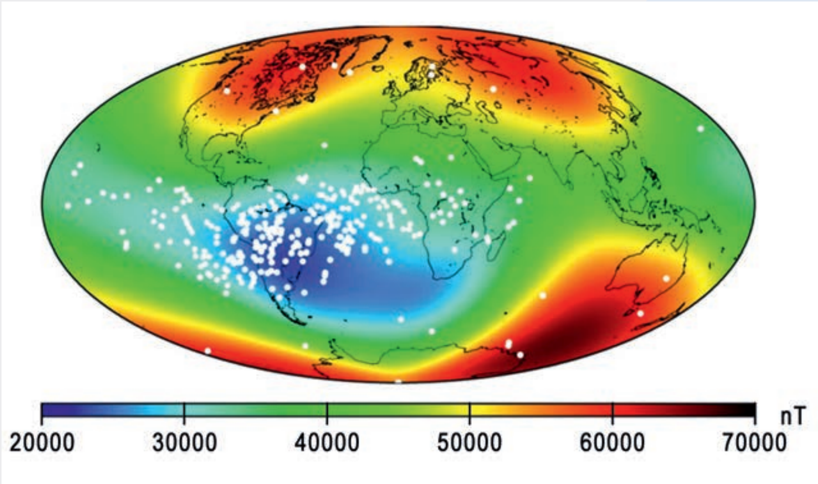
Space weather

The geomagnetic field is an effective shield against high-energetic radiation from space. In some regions, e.g. the South Atlantic, the field strength is weak. Here, spacecraft suffer frequent malfunctions. One task for Swarm will be to monitor and predict the evolution of the South Atlantic Anomaly (SAA). Strong ionospheric currents, as observed in connection with northern lights, induce parasitic currents in power grids and pipelines. Swarm will help to identify the coupling mechanisms. Radio waves going through the ionosphere can be badly disturbed by plasma irregularities. This effect can degrade satellite communication and GPS navigation signals. Swarm will map the irregularities and provide probabilities for the occurrence of the disturbance for a given time and location.

Interaction between the geomagnetic field and charged particles from the solar wind cause auroras (northern lights) at high latitudes. They are associated with strong electric currents that can cause problems in power grids and pipeline systems (image credit: Jouni Jussila).

Swarm mission profile

Launch:	March 2013 (Plesetsk, Russia)
Mission duration:	4 yrs (nominal)
Carrier system:	Rockot
Satellite mass:	~500 kg each
Orbit type:	circular, polar
Altitude:	Sat. A, B: 450-300 km
	Sat. C: 530 km
Inclination:	Sat. A, B: 87.3°
	Sat. C: 88.0°
Separation:	Sat. A-B: 1.4° in geogr. longitude



The geomagnetic field strength is unevenly distributed over the Earth (CHAMP, GFZ). The shielding effect is rather weak in the South Atlantic region. The white dots mark regions where spacecraft frequently experience functionally anomalies (TOPEX/Poseidon).

Swarm Project Office Germany

The Swarm Project Office at GFZ, Potsdam, coordinates the scientific and technical use of the mission products by German companies and research institutions. It initiates funding lines and programs. Furthermore, it provides information about the Swarm mission and is engaged in public outreach. Sponsor of the Swarm Project Office is the Federal Republic of Germany, Initiator: the Space Agency of the German Aerospace Center through funds of the German Federal Ministry of Economics and Technology, following a decision of the German Federal Parliament (grant code 50EE0916).

European Space Agency (ESA) http:
http://www.esa.int/esaLP/LPswarm.html

EADS-Astrium
http://www.astrium.eads.net/de/programme/swarm.html

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