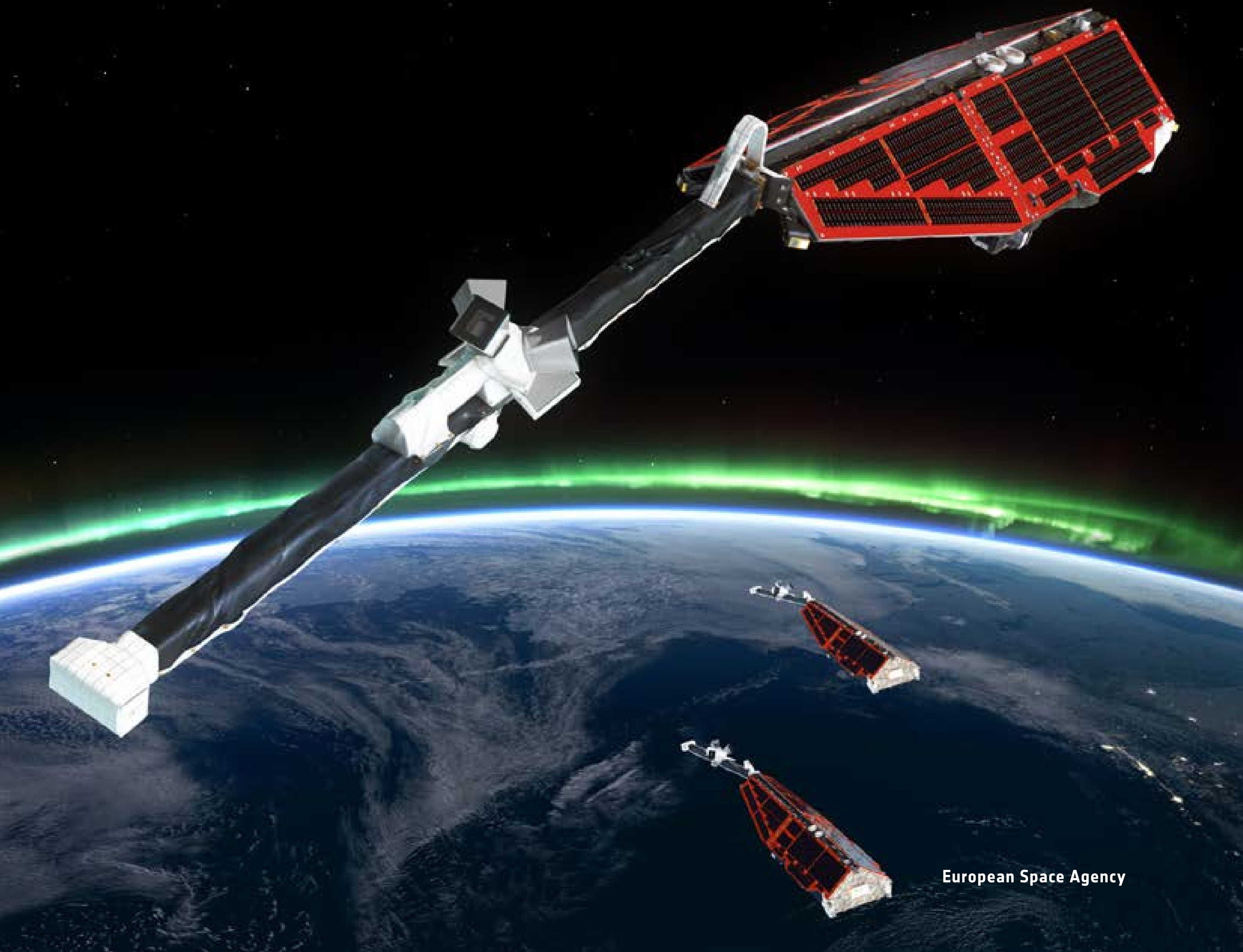
swarm

→ ESA'S MAGNETIC FIELD MISSION

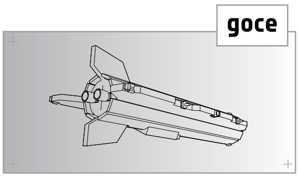


European Space Agency

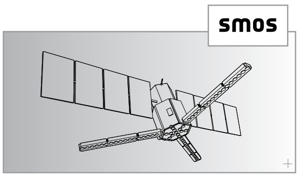
ESA'S EARTH EXPLORER MISSIONS

Earth Explorer missions focus on the science and research elements of ESA's Earth Observation Living Planet Programme. Developed in response to issues raised by the scientific community, these novel missions improve our understanding of how Earth works as a system and the impact human activity is having on natural processes. Earth Explorers also demonstrate breakthrough technologies and remote-sensing techniques, and, together with the scientific questions addressed, provide the basis for the development of new applications for Earth observation data.

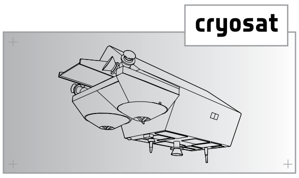
As a result of the continuing, user-driven approach for realising Earth Explorers, six missions so far have been selected for implementation:



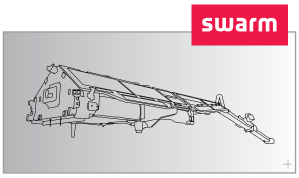
GOCE (Gravity field and steady-state Ocean Circulation Explorer) Launched in 2009, GOCE is dedicated to measuring Earth's gravity field with unprecedented accuracy and spatial resolution. The resulting model of the geoid – the surface of equal gravitational potential defined by the gravity field – is advancing our knowledge of ocean circulation, sea-level change and Earth-interior processes. GOCE is also making advances in geodesy and surveying.



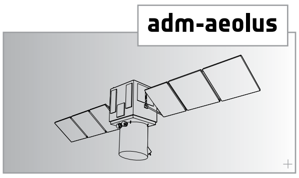
SMOS (Soil Moisture and Ocean Salinity) Launched in 2009, SMOS is making global observations of moisture in the soil and salinity in the oceans. This is resulting in a better understanding of the water cycle and, in particular, the exchange processes between Earth's surface and the atmosphere. Data from SMOS are helping to improve weather and climate models, and also have practical application in areas such as agriculture and water resource management.



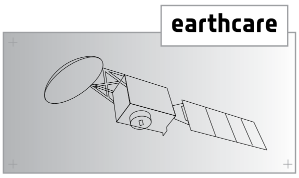
CRYOSAT Launched in 2010, CryoSat is determining variations in the thickness of sea ice so that seasonal and interannual variations can be detected. The satellite is also surveying the surface of continental ice sheets to detect small elevation changes. This information is furthering our understanding of the links between ice, climate change and sea level.



SWARM Swarm is a constellation of three satellites to measure precisely the magnetic signals from Earth's core, mantle, crust and oceans, as well as the ionosphere and magnetosphere. The resulting models will give insight into Earth's interior. Along with measurements of atmospheric conditions around the orbiting satellites, this will further studies into Earth's weakening magnetic shield, space weather and radiation hazards.



ADM-AEOLUS (Atmospheric Dynamics Mission) ADM-Aeolus will be the first mission to measure wind profiles from space on a global scale. The mission will provide near-realtime observations to improve the accuracy of numerical weather forecasting and climate prediction, advancing our understanding of tropical dynamics and processes relevant to climate variability.



EARTHCARE (Earth, Clouds, Aerosols and Radiation Explorer) EarthCARE will improve our understanding of the role that clouds and aerosols play in reflecting incident solar radiation back out to space and trapping infrared radiation emitted from Earth's surface. The mission will lead to more reliable climate predictions and weather forecasts. EarthCARE is being developed in cooperation with the Japan Aerospace Exploration Agency.

Further information about ESA's Earth Explorer missions can be obtained via:
www.esa.int/livingplanet

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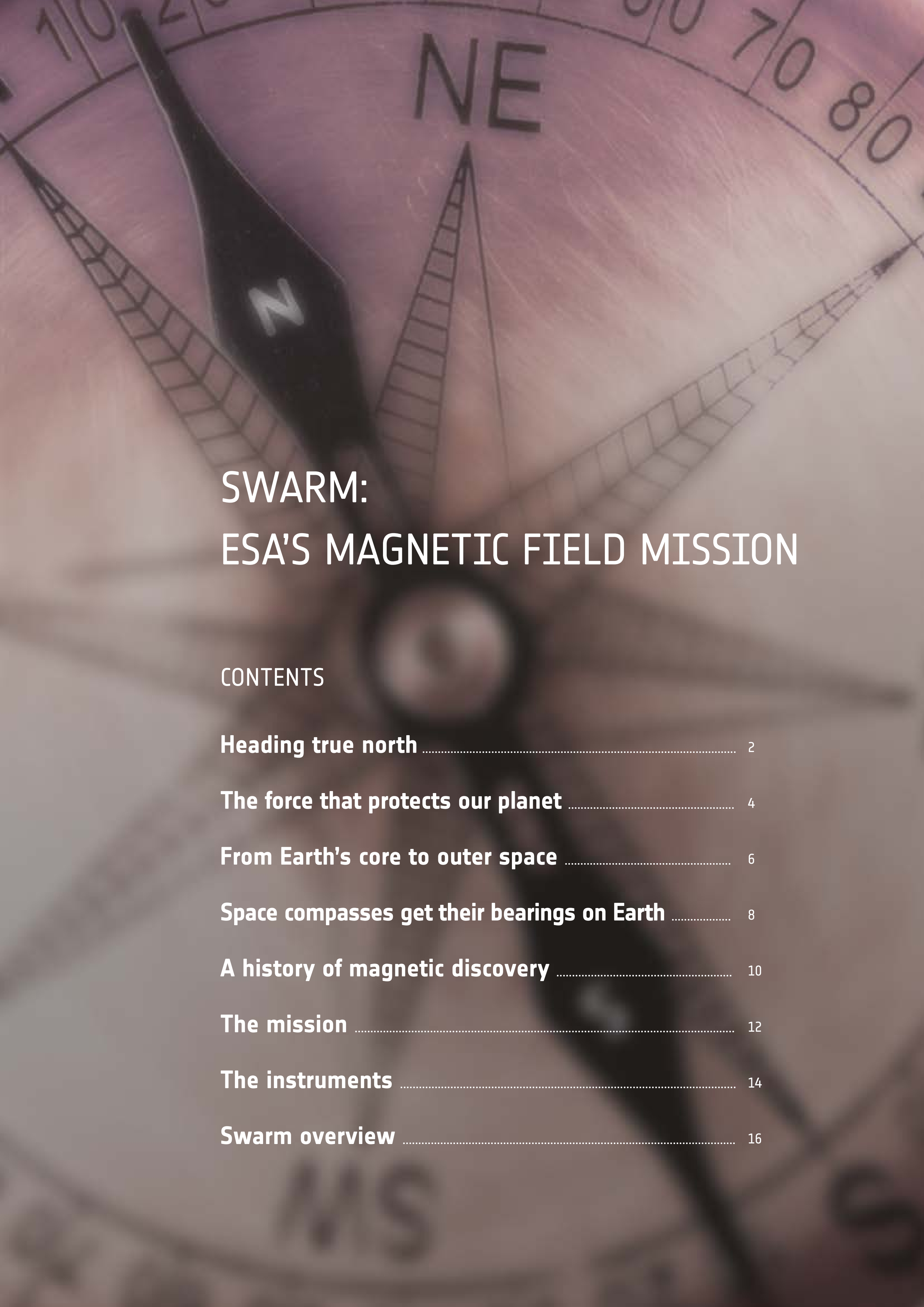


SWARM:
ESA'S MAGNETIC FIELD MISSION

CONTENTS

→ HEADING TRUE NORTH

The Swarm mission will unravel one of the most mysterious aspects of our planet: the magnetic field.

Although invisible, the magnetic field and electric currents in and around Earth generate complex forces that have immeasurable impact on everyday life. The field can be thought of as a huge bubble, protecting us from cosmic radiation and the charged particles that bombard Earth in 'solar winds'. Without this protective shield, the atmosphere as we know it would not exist, rendering life on Earth virtually impossible.

Even as it is, strong solar storms have the potential to cause power and communication blackouts and can also damage satellites orbiting Earth. A visible display of what happens when charged particles collide with atoms and molecules in the upper atmosphere can be seen as waves of luminous green light in the polar skies – the aurora borealis and aurora australis.

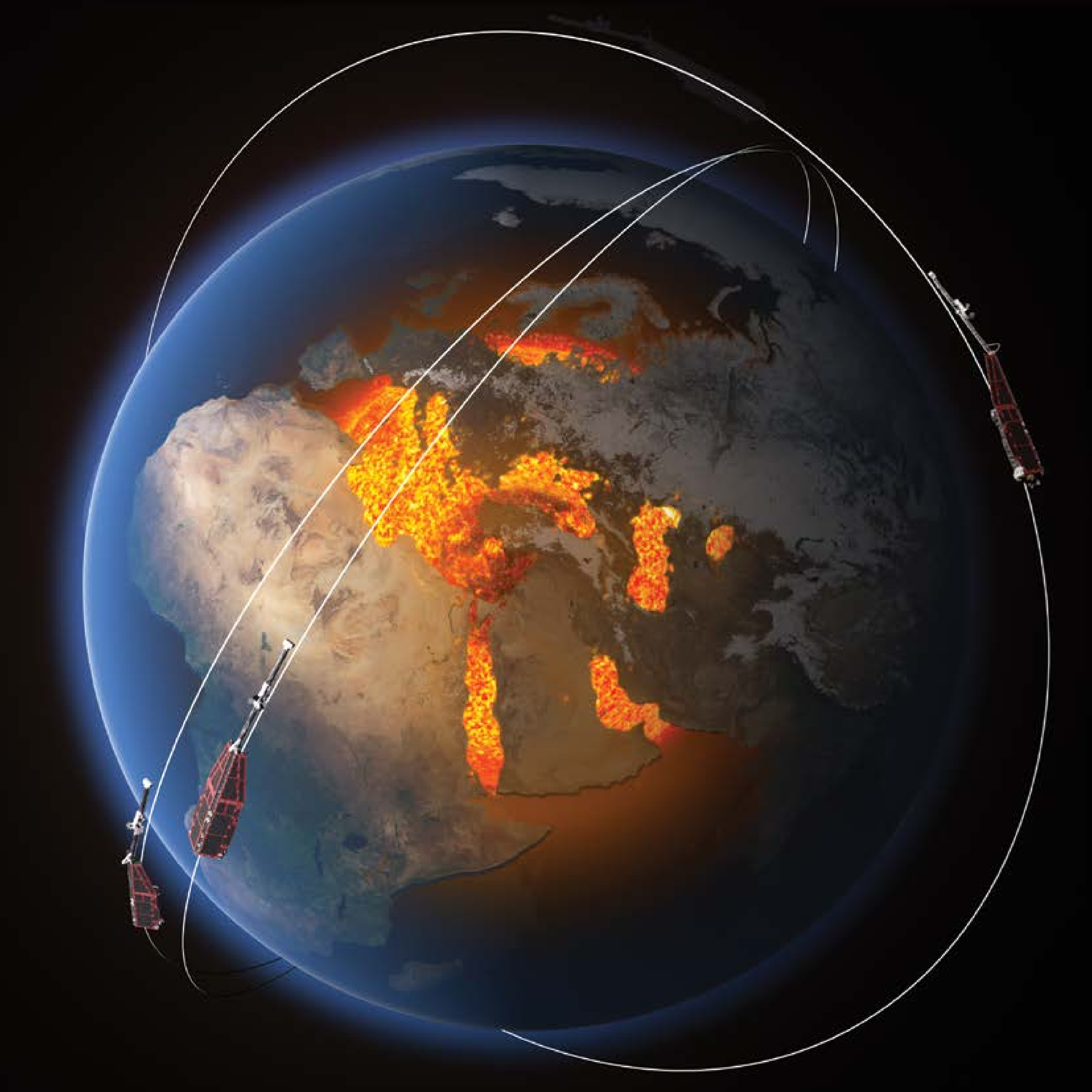
Earth's magnetic field is in a permanent state of flux. Magnetic north wanders, and every few hundred thousand years the polarity flips so that a compass would point south instead of north. Moreover, the strength of the magnetic field constantly changes – and it is currently showing signs of significant weakening.

Following on from GOCE, SMOS and CryoSat, Swarm is the next in the series of pioneering Earth Explorer missions. It is also ESA's first constellation of satellites to advance our understanding of how Earth works. Harnessing European and Canadian technological excellence, the three innovative Swarm satellites are designed to identify and measure precisely the different magnetic signals that make up Earth's magnetic field.

By analysing the different characteristics of the observed field, this state-of-the-art mission will lead to new insight into many natural processes, from those occurring deep inside the planet, to weather in space caused by solar activity. In turn, this information will yield a better understanding of why the magnetic field is weakening.

As well as furthering science, the measurements delivered by the three Swarm satellites will be valuable for a range of applications. For example, the data will be put to practical use to help improve the accuracy of navigation systems including those systems carried on satellites. The data will also improve the efficiency of drilling for natural resources.

The aurora borealis offers a visual display of charged particles from the Sun interacting with Earth's magnetic field.



Earth's magnetic field is largely generated deep within our planet.

→ THE FORCE THAT PROTECTS OUR PLANET

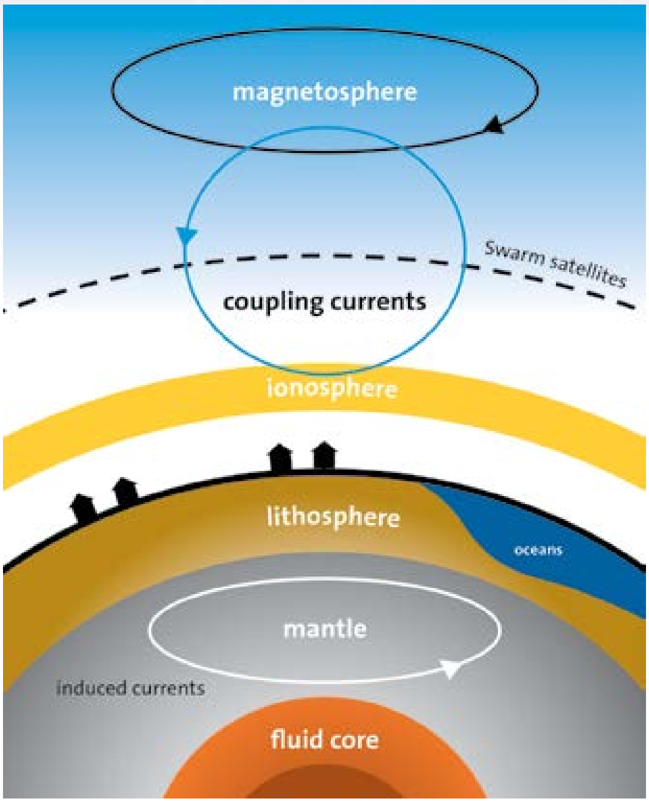
In simple terms, Earth's magnetic field behaves as if there were a powerful bar magnet at the centre of the planet, tilted at about 11° to the axis of rotation. In reality, however, the processes involved in generating the field are far more complex. The magnetic field is thought to be largely generated by an ocean of superheated, swirling liquid iron that makes up the outer core 3000 km under our feet. Acting like the spinning conductor in a bicycle dynamo, it generates electrical currents and thus the continuously changing electromagnetic field.

Other sources of magnetism are the minerals in Earth's mantle and crust, while the ionosphere and the magnetosphere also play a role. Since salt water is conductive, oceans make an additional, albeit weak, contribution to the magnetic field.

Although the Ancient Chinese invented the compass and so were aware of a magnetic force 2000 years ago, our understanding of how Earth's dynamo has been sustained for billions of years and why it changes is still limited.

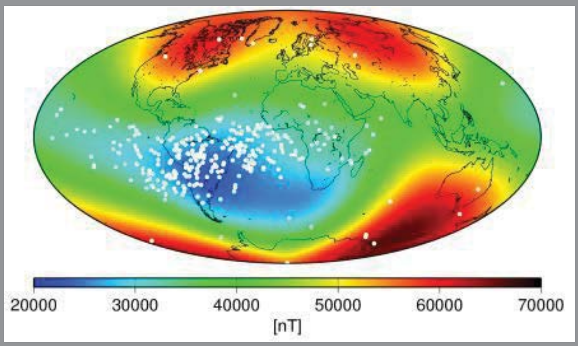
Today, there are concerns that this force that protects our planet is weakening and may even be on the verge of reversing polarity. Over the last 150 years, the magnetic field has lost about 15% of its strength. In addition, the gap between magnetic north and geographic north is not only getting bigger, but the gap is widening at an increasing rate. Prior to 1994, it was estimated that the magnetic north pole was moving at about 10 km a year, but since 2001 this has increased to around 65 km a year.

Pole reversals are a natural phenomenon, evidence of which comes from the ocean floor. When new crust is created though volcanic activity, atoms of iron in the molten rock act like compasses, aligning themselves with the magnetic field and retaining their orientation once the rock has solidified. These magnetic 'fingerprints' in sediments reveal that over the last 200 million years the poles have reversed, on average, about once every 200 000–300 000 years. Reversals are a slow process and do not happen with any regularity. Nevertheless, the last time this happened was about 780 000 years ago, so we are now overdue for a reversal.



The different sources that contribute to the magnetic field measured by Swarm. The coupling currents or field-aligned currents flow along magnetic field lines between the magnetosphere and ionosphere. The ionosphere is 85–600 km above Earth, while the magnetosphere is 60 000–120 000 km from Earth. (ESA/DTU Space)

A weakening magnetic field poses a threat to power supplies and communication links and also affects the use of global navigation satellite systems.



The 'South Atlantic Anomaly' refers to an area where our protective shield is weak. The white spots on this map indicate where electronic equipment on the TOPEX/Poseidon satellite was affected by radiation as it orbited above. (ESA/DTU Space)

DID YOU KNOW?

- Airport runway numbers correspond to compass headings, so they have to be repainted periodically as magnetic north shifts.
- The first measurement of the magnetic north pole was made in 1831. Since then it has wandered 2000 km.
- In 1989, a strong geomagnetic storm knocked out the power grid in Quebec, Canada, plunging the entire province into darkness. The aurora from the storm could be seen as far south as Florida and Cuba.
- The South Atlantic Anomaly is an area where the magnetic field is weak – in fact, it is only half as strong as in Europe. This is problematic for satellites orbiting Earth, and the majority of technical faults occur when they pass through this region.
- The magnetic north and south poles are not antipodal, meaning that a line drawn from one to the other does not pass through the geometric centre of Earth.
- The concept that migratory animals might navigate using Earth's magnetic field was first proposed by the Russian naturalist Aleksandr Middendorf in the 1850s.
- Magnets could be used to avoid shark attacks! It is thought that they use the electrical sensors on their snouts to sense prey and navigate using Earth's magnetic field. A spinning magnet might overwhelm these sensors and repel a shark on the attack.

→ FROM EARTH'S CORE TO OUTER SPACE

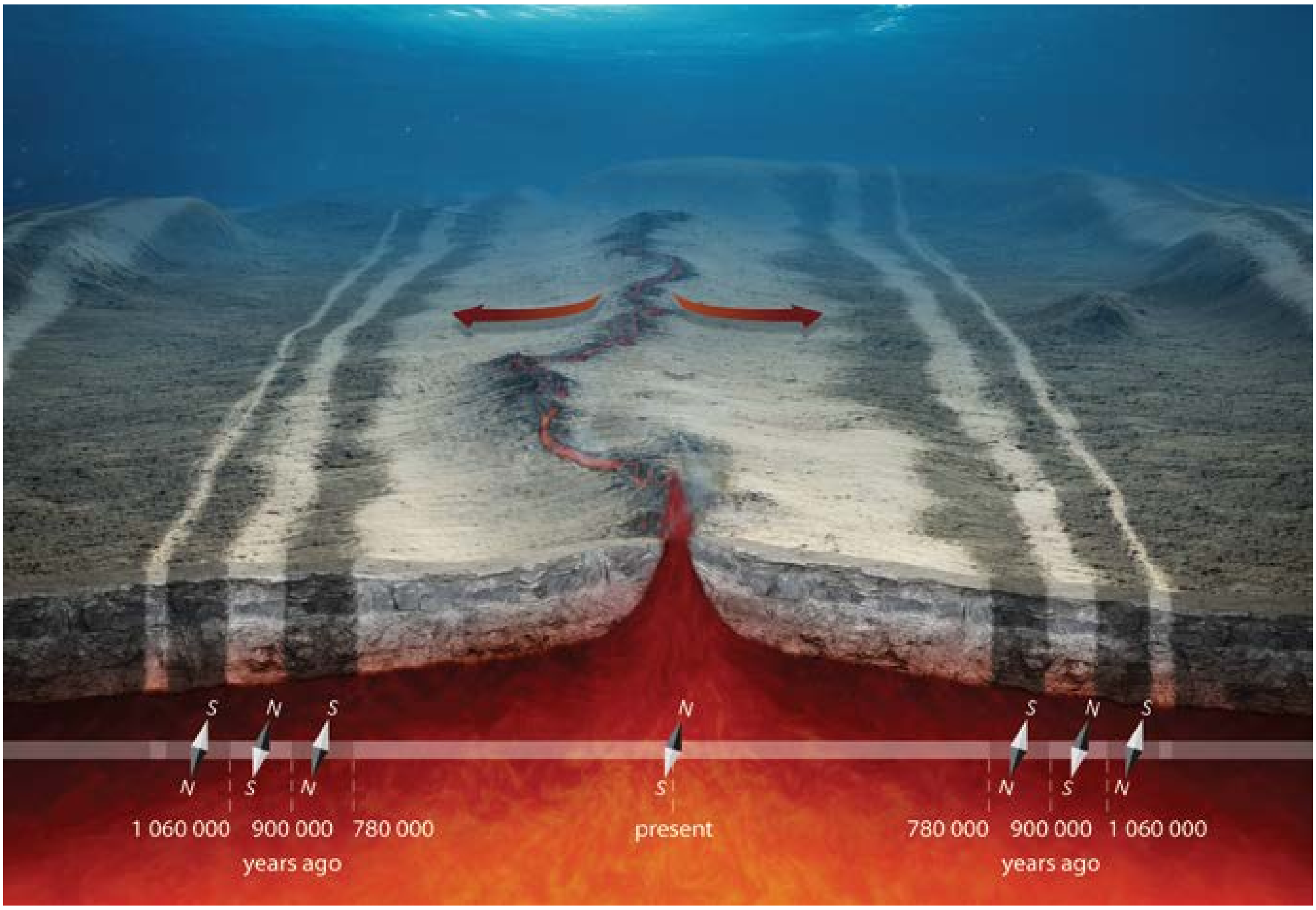
By making key observations to untangle and model the many sources and strengths of Earth's continuously changing magnetic field, the Swarm mission is set to advance many areas of Earth science.

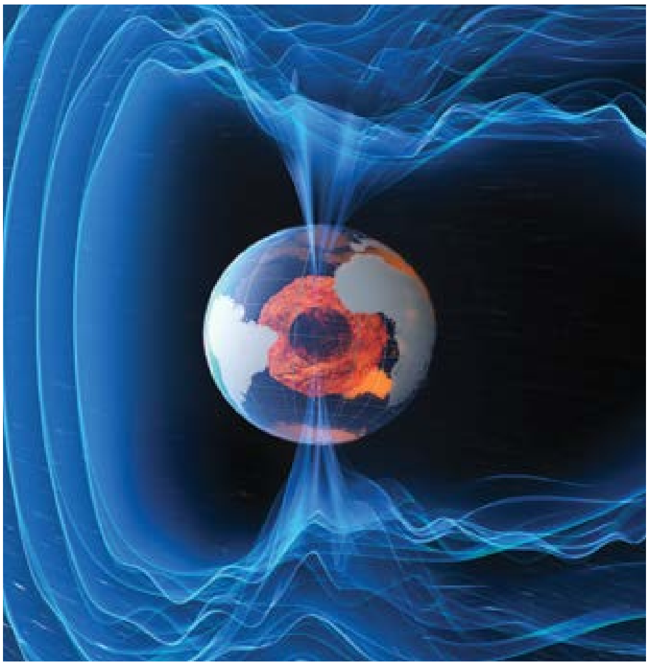
One of the very few ways of probing Earth's liquid core is to measure the magnetic field it creates and how it changes over time. Since variations in the field directly reflect the flow of fluid in the outermost core, new information from Swarm will further our understanding of the physics and dynamics of Earth's stormy heart.

The constellation of Swarm satellites will produce, for the first time, global 3D images of electrical conductivity in the mantle. This will yield evidence of its chemical composition and temperature, which will complement seismic analysis and observations of gravity such as those from ESA's GOCE mission.

We can learn more about the history of the magnetic field and geological activity by studying magnetism in the lithosphere. For example, by analysing the magnetic imprints of the ocean floor, past core-field changes can be reconstructed. This also helps to investigate tectonic plate motion. Magnetic signals from the crust need to be determined from space in much higher resolution than currently available. By complementing the spatial scales observed by Swarm with magnetic surveys from aircraft, our understanding of Earth's crust will be improved.

Pole reversals are imprinted in the seafloor. As new oceanic crust is created through volcanic activity, iron-rich minerals in the upwelling magma are oriented to magnetic north at the time. These magnetic stripes are evidence of pole reversals. High-resolution observations from Swarm will fill gaps in our knowledge about Earth's geological history.





By taking observations of Earth's magnetic field, Swarm will offer essential data for a better understanding of processes occurring deep inside the planet.

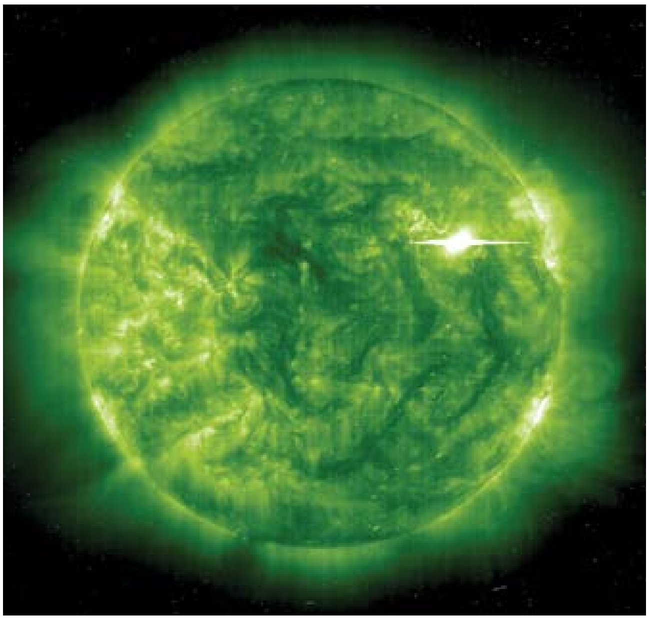
The crust also holds clues about how the field may have affected climate in the past through the escape of atmospheric gases to space.

The ocean produces a relatively weak magnetic signature, which contains information on tides and circulation patterns. Although it is difficult to isolate this signal from all the other sources contributing to the magnetic field, the observations from Swarm will be unique and will complement other types of satellite data.

The magnetosphere is the region in space about 60 000 km to 120 000 km from Earth. It comprises complicated current systems, similar to the ring current around the magnetic equator relative to the magnetic poles on Earth. There are indications that the density of the air in the lower ionosphere relates to geomagnetic activity, but the underlying processes are not well understood. Furthermore, the magnetic field acts as a shield against high-energy particles from the Sun and deep space. Swarm will lead to a much better understanding of this complicated system that connects Earth and the Sun.

Swarm's highly accurate and frequent measurements will provide new insight into our planet's formation, dynamics and environment stretching from Earth's core to the Sun. In short, no other single quantity can be used for such a variety of studies related to the planet.

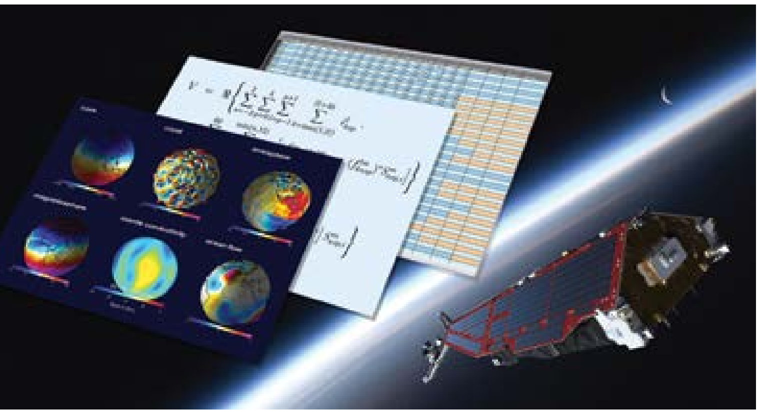
With evidence pointing to a weakening magnetic field, it is more important than ever to understand how Earth's complex magnetic field is generated and the processes causing it to fluctuate. This is important for adopting precautionary measures and developing new technologies to cope with solar storms.



Although Earth's magnetic field protects us from solar winds, strong solar storms can still cause havoc with modern-day technology. This image of the Sun from the SOHO mission shows a powerful solar flare. Swarm will help us to understand more about space weather and provide practical value in building new technologies to withstand the effects of solar activity. (SOHO/EIT)

→ SPACE COMPASSES GET THEIR BEARINGS ON EARTH

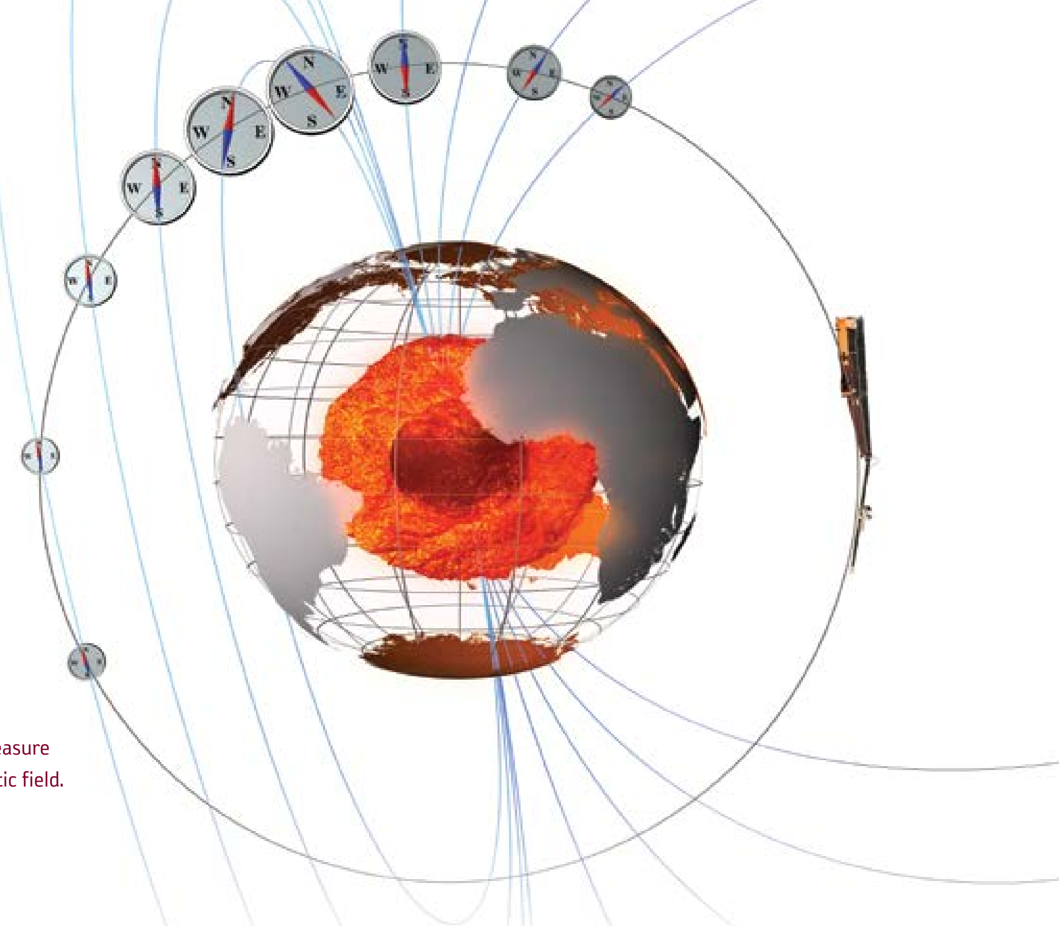
The Swarm constellation comprises three identical satellites, each equipped with what can be thought of as a 3D compass. Each provides precise and detailed measurements of the strength and direction of the magnetic field.



Data from all three satellites are used to derive global models of the core and crust fields, and conductivity maps of the mantle for the study of Earth's interior.

Magnetic sensors measure a tangle of the core field with other signals from magnetised rocks in the crust, electrical currents flowing in the ionosphere, magnetosphere and oceans, and currents inside Earth induced by external fields. The challenge is to separate the different sources of magnetism. GPS receivers, an accelerometer and an electric field instrument deliver supplementary information to study the interaction between Earth's magnetic field and the solar wind.

As well as the advanced technology the satellites carry, their carefully selected orbits are essential to the success of the mission. At the start of life in orbit, the three satellites are relatively close to each other. Two orbit almost side-by-side at the same altitude – initially at about 460 km, but descending to around 300 km over the life of the mission. The lower the satellites are, the more sensitively they can measure small magnetic features in the crust. The third satellite remains in a higher orbit, initially at 530 km, and at a slightly different inclination. The satellites' orbits drift, resulting in the upper satellite crossing the path of the lower two at an angle of 90° in the third year of operations.



Like ‘3D compasses’, the Swarm satellites measure the strength and direction of Earth’s magnetic field.

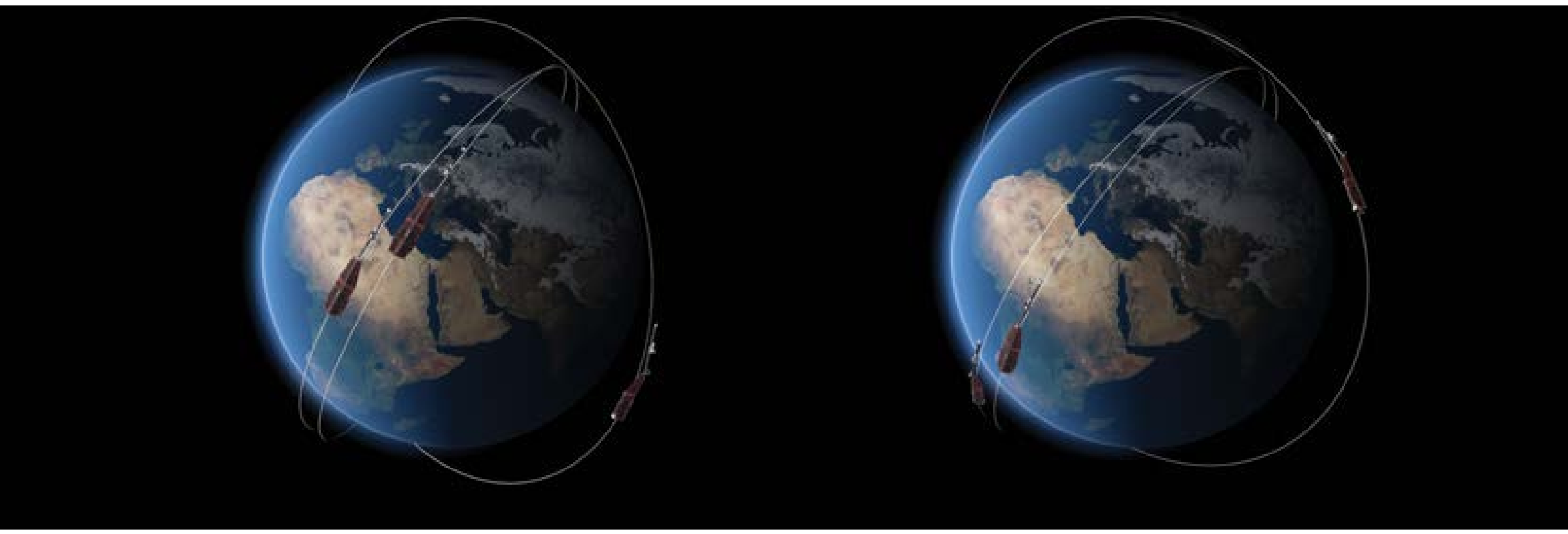
These drifting orbits mean that all the magnetic signals originating from Earth and those caused by the Sun are captured.

The Sun generates typical day and night patterns in the ionosphere between the satellites and Earth. Magnetic storms resulting from solar activity also cause irregular disturbances in the ionosphere and magnetosphere.

Essentially, the constellation optimises the measurements of relevant phenomena. This helps to distinguish between the effects of different sources of magnetism. For example, global field models of the core and crust and conductivity maps of the mantle are needed to study the interior of Earth. These can only be obtained from a combination of selected observations from all three satellites over time.

For studies of the upper atmosphere, each satellite provides information such as ion speed, direction and temperature. Density and winds around each satellite can be derived by using data from the different instruments. Combining observations of the lower pair of satellites will lead to a new way of quantifying the currents that flow along geomagnetic field lines connecting the magnetosphere to the high-latitude ionosphere. It is therefore essential to have the constellation of satellites to offer new opportunities for science.

A unique mixture of local and global products will allow data users to address some of today’s open scientific questions related to global change. Swarm will also benefit a broad range of applications in Earth sciences and space weather.



→ A HISTORY OF MAGNETIC DISCOVERY

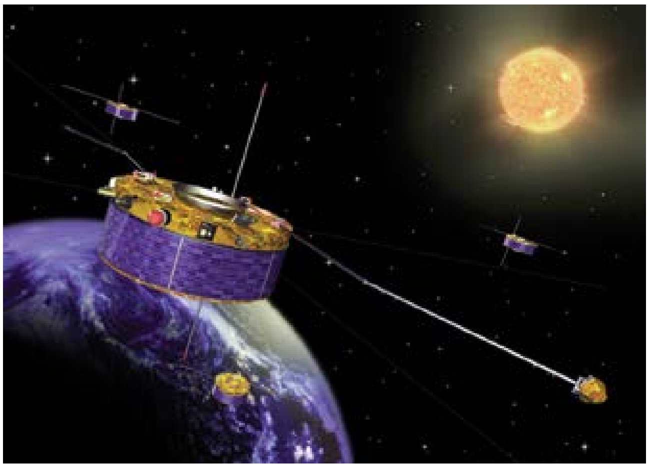
Scientists have been fascinated by Earth's magnetic field for hundreds of years, but it is only since the advent of the space era that we have really been able to get to grips with this complex force. Building on heritage from earlier satellites, Swarm is the most advanced magnetic field mission to date and is set to make a step change in our understanding of Earth.

Satellites dedicated to Earth's magnetic field go back to 1979, when NASA launched its Magsat mission. It carried two magnetometers, which gave it capabilities beyond other spacecraft, until the mission ended in 1980. Almost 20 years later, in 1999, Denmark launched the Ørsted satellite which also carried two magnetometers. Based on data from Ørsted and from studying the changes since Magsat, scientists confirmed that the magnetic poles are moving and that the magnetic shield showed signs of significant weakening.

In 2000, Germany launched the CHAMP satellite that carried a suite of instruments to study variations in magnetic and gravity fields as well as for atmospheric research. Orbiting at a relatively low altitude, CHAMP's design was more aerodynamic than earlier missions. Among other achievements, CHAMP contributed to the current model of the magnetic field generated by Earth's crust.

The scientific and technical experience gained from these three missions has been crucial in the development of Swarm.

In 2000, ESA launched the Cluster mission: four satellites, each carrying 11 instruments, to study the interaction of solar wind with the magnetosphere. They orbit relatively far from



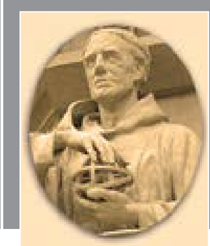
Cluster investigates the interactions between the Sun and Earth's magnetosphere.

1st century AD

Earliest known magnetic compass invented by the Chinese.

1269

Petrus Peregrinus describes a floating compass and writes about the polarity of magnets.



1600–1800

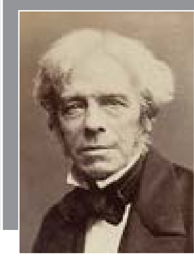
William Gilbert concludes Earth is magnetic, Henry Gellibrand documents the magnetic field changes with time, Edmund Halley and Alexander von Humboldt carry out magnetic surveys.

1819

Danish physicist Hans Christian Ørsted discovers the relationship between electricity and magnetism.

1821

Michael Faraday establishes the first basis for the magnetic field concept in physics.



1840

Carl Friedrich Gauss publishes the first geomagnetic field model demonstrating the dipolar nature of Earth's magnetic field.

The Swarm mission will make a step change in our understanding of Earth's magnetic field.

Earth, close to the magnetosphere. Since Swarm orbits much closer to Earth, the two missions are complementary. This offers new opportunities to study the energy input into Earth's magnetosphere from space and the development of magnetic storms, or space weather.

Much experience has been gained from single-satellite missions as well as ESA's Cluster mission. However, the fact that Swarm is a constellation is key to measuring and separating the different sources of magnetism and to making models in unprecedented detail and accuracy. The constellation also means that, for the first time, mantle conductivity can be mapped in 3D from space. The satellites also offer a new way of studying the effect that solar particles have close to Earth.

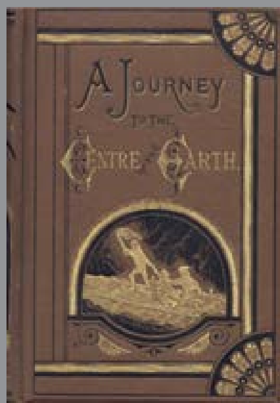
Journey to the centre of Earth

Classic science-fiction writer Jules Verne imagined an exciting expedition to the centre of Earth, but the reality is less romantic. The heart of our planet remains inaccessible to direct observation. While Verne's story describes a passage to Earth's core through an extinct volcano in Iceland, in fact, the deepest hole ever drilled by humans is on the Kola Peninsula in Russia.

The Kola Superdeep Borehole was started in 1970 with the aim of reaching the 'Mohorovičić discontinuity', or 'moho', which is where the crust and mantle intermingle at an average depth of 35 km. The borehole was never completed and the hole is currently 12 km deep, a mere scratch in the surface of the planet.

Although Earth's centre remains inaccessible, it is not completely invisible, as other methods can be used to study the internal structure. Seismology has allowed us to map Earth's interior, leading scientists to believe that there is a liquid-iron outer core and a central, solid-iron nucleus. Gravity data have also advanced our understanding of internal processes.

But no other single physical quantity can be used for a such a variety of studies related to our planet as the variation of its magnetic field. Swarm will provide a unique map of mantle conductivity and a new view of the core field.



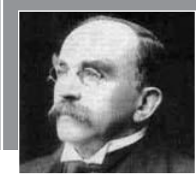
This virtual picture of Earth can be compared to Jules Verne's rich imagination more than 100 years ago.

1909

The Carnegie, a yacht made almost entirely of wood and other non-magnetic materials, sets sail to gather oceanic magnetic data.

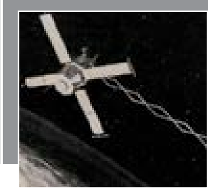
1919

Joseph Larmor suggests that dynamos could naturally sustain themselves in conducting fluids, explaining how the geomagnetic field originates deep inside Earth.



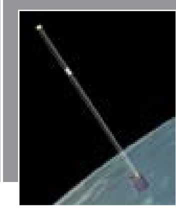
1979

NASA launches Magsat to map Earth's magnetic field.



1999

Denmark launches the Ørsted to measure Earth's magnetic field. Scientists conclude that the magnetic poles wander.

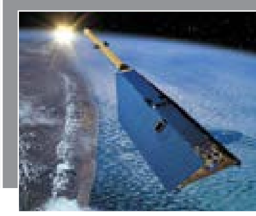


2000

ESA launches Cluster mission to study interaction of solar wind with the magnetosphere.

2000

Germany launches CHAMP satellite to study variations in magnetic and gravity fields.



→ THE MISSION

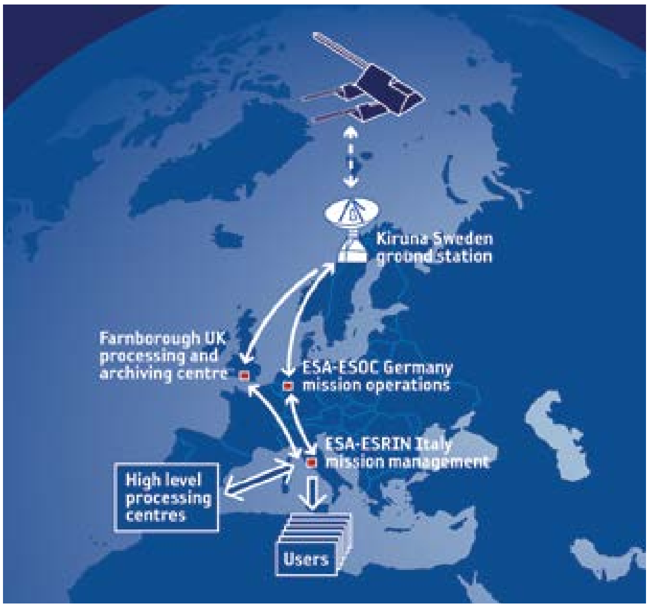
Swarm is ESA's first constellation satellites for of Earth observation. The three identical satellites have a rather unusual shape: trapezoidal with a long boom that is deployed once they are in orbit. Their design is a result of overcoming a number of challenges in accommodating the instrument package, and, since they are launched together on a single rocket, they have to be compact enough to all fit into the launcher fairing.

Developed on behalf of ESA by an industrial consortium led by EADS Astrium GmbH, each satellite is about 9 m long, including the boom, with the surface at the front only measuring about 1 m^2. This is to reduce the effect of air drag and to cut down on the amount of propellant needed to stay at the correct altitude. Below around 500 km, air drag tends to slow satellites down and lower the orbit.

The boom, which accounts for almost half the length of the satellite, trails at the back. This is because the front surface is needed for the electric field instrument so that it can collect and measure the speed and direction of incident ions along the orbital path.

Once the boom has deployed, which happens soon after injection into orbit, the satellite has no moving parts. This ensures that there are no vibrations that could influence the measurements made by the accelerometer, which is fixed at the very centre of the satellite. Likewise, the solar panels are fixed, forming the satellite 'roof'.

Magnetic cleanliness is of paramount importance to the mission, so the sensitive scalar magnetometers are mounted at the end of the boom, far away from any magnetic disturbance that the electrical units on the body may cause. The optical bench holding the vector field magnetometer and the three startrackers is mounted halfway along the boom.



Swarm data flow and ground segment.

One of the Swarm satellites, with boom deployed, undergoing tests at IABG's Magnetic Field Simulation Facility in Germany. The tests are carried out in a magnetically clean environment, hence the wooden floor. (ESA/IABG)

Throughout the design and manufacturing phases, magnetic cleanliness has been a priority, with many tests carried out on almost every unit and final testing of the assembled satellite taking place in a special facility.

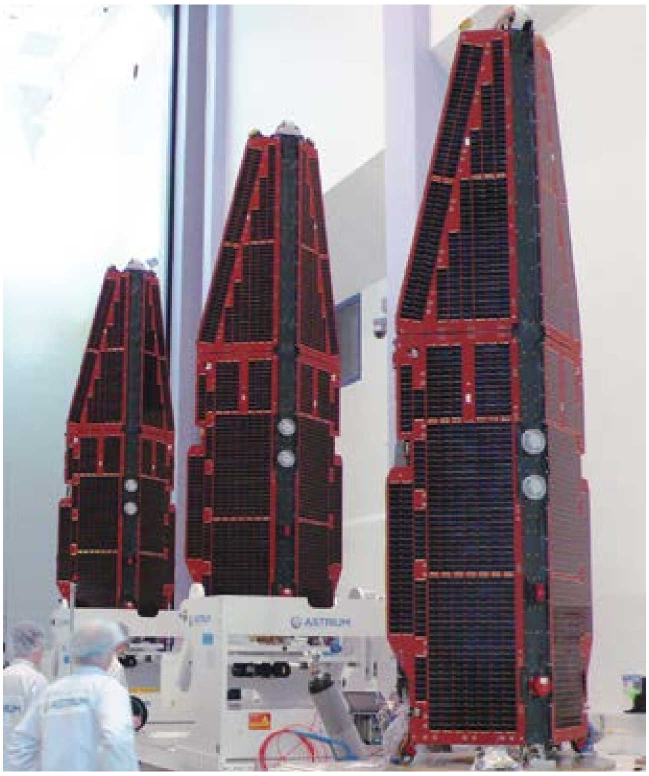
The development of Swarm, which was carried out through ESA's European Space Research and Technology Centre ESTEC, in the Netherlands, also included extensive testing of the optical bench out in the field. Intercalibration campaigns took place in southern Spain at the German–Spanish Calar Alto Astronomical Observatory. The main purpose was to establish precisely the relative orientation of the vector magnetometer and the three startrackers by taking simultaneous measurements at night.

Swarm lifts off on a Rockot launcher, which is a converted SS-19 intercontinental ballistic missile, from the Plesetsk Cosmodrome in northern Russia. The three satellites are placed on a Breeze-KM upper stage with a tailor-made dispenser for simultaneous separation.

Engineers from Astrium GmbH and the Technical University of Denmark preparing for the optical bench intercalibration at the Calar Alto Observatory in Spain. (ESA/DTU Space/Astrium GmbH)

The mission is operated by ESA's European Space Operations Centre ESOC, in Germany, via the primary ground station in Kiruna, Sweden. The critical launch and early orbit phase lasts about three days, during which the booms are deployed and all the satellite units are switched on. This is followed by a three-month commissioning phase to ensure all the instruments are working correctly. To increase daily contact with the satellites during this phase, complementary ground stations in Norway, Antarctica and Australia are also used.

ESA's Centre for Earth Observation, ESRIN, in Italy, manages the scientific data, with processing and archiving in the UK.



The three Swarm satellites standing to attention during testing at IABG's facility in Germany. (ESA/IABG)

→ THE INSTRUMENTS

Benefiting from the technological excellence Europe and Canada have to offer, the Swarm satellites carry a comprehensive range of new-generation instruments to deliver extremely accurate data to advance our understanding of Earth's magnetic field.

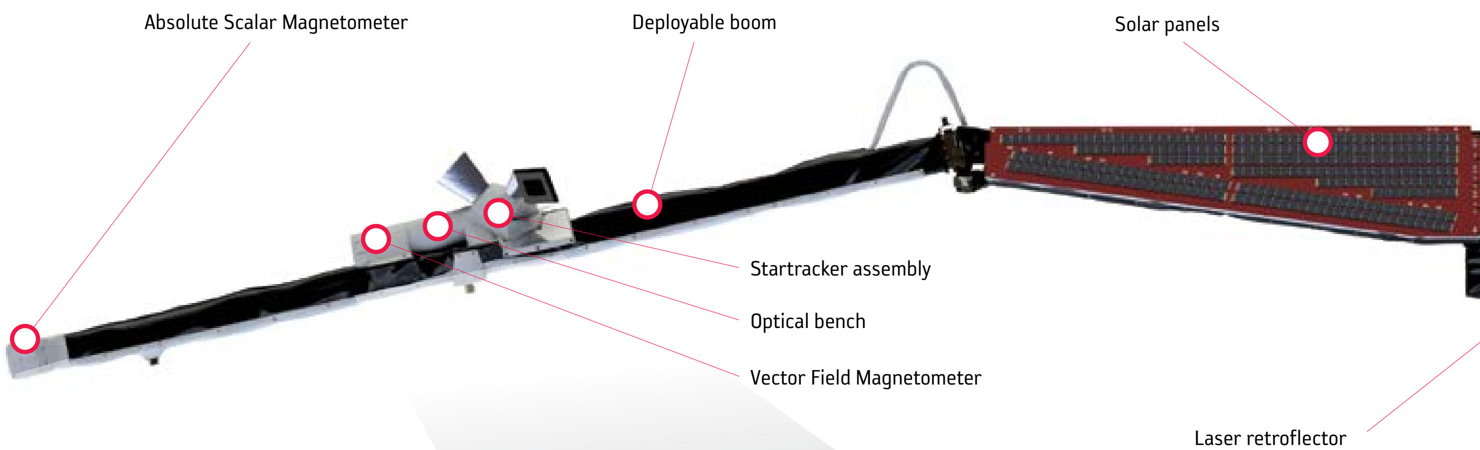
Absolute Scalar Magnetometer

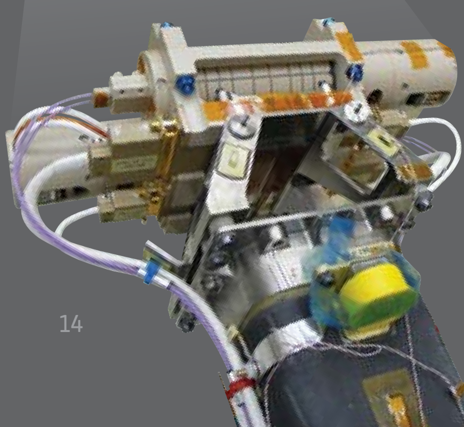
This novel instrument measures the strength of the magnetic field to greater accuracy than any other magnetometer. The Absolute Scalar Magnetometer is an 'optically-pumped metastable helium-4 magnetometer', developed and manufactured by CEA-Leti in France under contract with the French space agency, CNES. It provides scalar measurements of the magnetic field to calibrate the Vector Field Magnetometer.

Vector Field Magnetometer

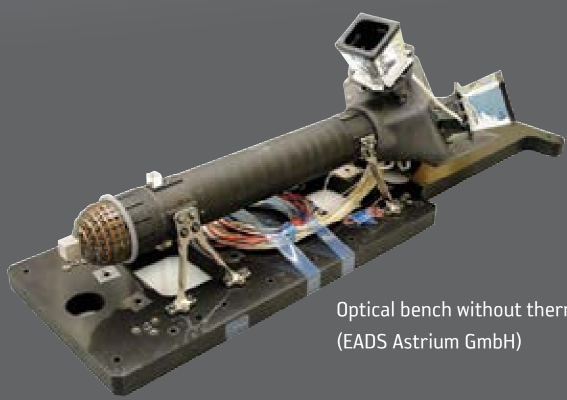
This magnetometer is the mission's core instrument. It makes high-precision measurements of the magnitude and direction of the magnetic field, i.e. the field's vector. The orientation of the vector is determined by the startracker assembly, which provides attitude data. The Vector Field Magnetometer and the startrackers are both housed on an ultra-stable structure called an optical bench, halfway along the satellite's boom. The design of the bench and carefully selected material make it possible to keep the instruments aligned to 1 arcsec.

Achieving this level of stability posed a particular design challenge, because the instruments have to withstand huge swings of temperature as the satellite passes in and out of sunlight. This latest generation of instruments was developed and manufactured at the Technical University of Denmark.





The Absolute Scalar Magnetometer (EADS Astrium)



Optical bench without thermal cover. (EADS Astrium GmbH)

Accelerometer

This unit measures the satellite's non-gravitational acceleration in its respective orbit and, in turn, provides information about air drag and wind around the satellite. Air density models will be derived from these products and will be used with the magnetic data for new insights into how solar wind affects upper-atmosphere dynamics. The instrument was designed and manufactured by the Czech Republic's Aerospace Research and Test Establishment, VZLU – the first time that ESA has placed a contract for an instrument of this complexity with Czech industry.

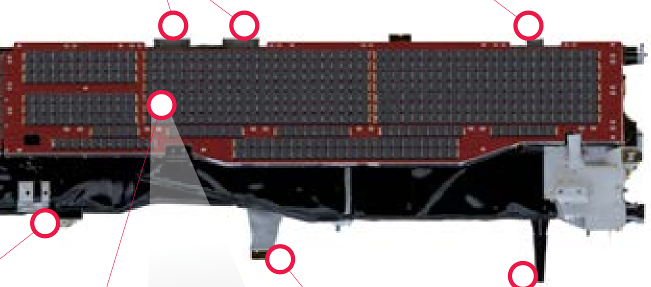
GPS receiver and laser retroreflector

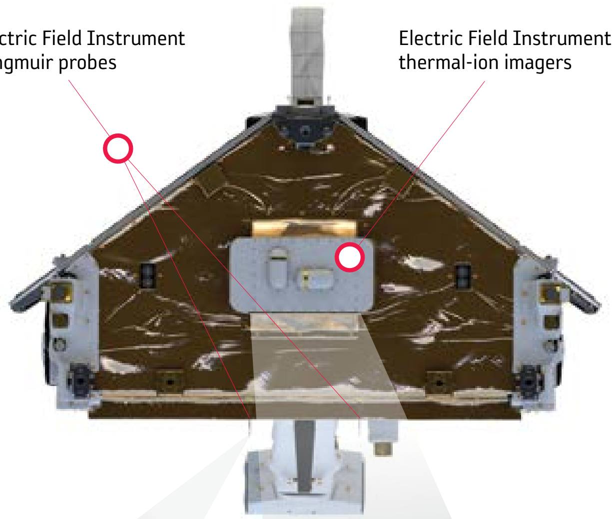
Precise orbit determination relies on the data from the GPS receivers, which were developed by RUAG Space in Austria.

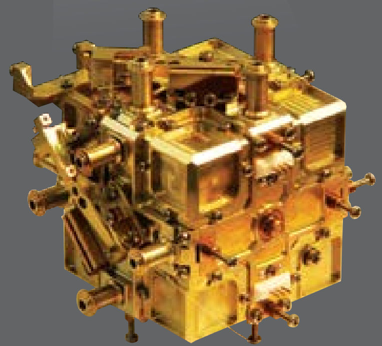
Each satellite is equipped with a laser retroreflector from the German GFZ Research Centre for Geosciences to validate the GPS system.

Electric Field Instrument

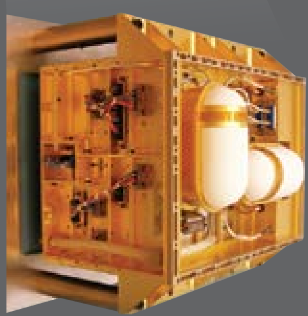
This instrument, positioned at the front of each satellite, measures plasma density, drift and velocity in high resolution to characterise the electric field around Earth. Developed by COM DEV in Canada, this instrument is the first 3D ionospheric imager in orbit. It carries an ingenious thermal-ion imager from the University of Calgary (Canada). The Swedish Institute of Space Physics, IRFU, developed a unique concept for the sensors in the Langmuir probe. This probe provides measurements of electron density, electron temperature and the electric potential of the satellite.






The Accelerometer (VZLU)


Novel Langmuir probe, part of the Electric Field Instrument. (IRFU)


The Electric Field Instrument comprises two thermal-ion imagers (shown) and two Langmuir probes. (EADS Astrium)

→ SWARM OVERVIEW

The Swarm mission is designed to measure the magnetic signals that stem from Earth's core, mantle, crust, oceans, ionosphere and magnetosphere. This will lead to better understanding of the processes that drive Earth's dynamo, which currently appears to be weakening. By studying the complexities of Earth's protective shield, Swarm will provide a clear insight into processes occurring inside the planet. Along with measurements of conditions in the upper atmosphere, a better knowledge of the near-Earth environment and the Sun's influence on the planet can be realised.

Mission
Launch: 2013
Duration: 4 years (following 3-month commissioning phase)

Objectives
A unique view inside Earth to study:
- Core dynamics, geodynamo processes and core–mantle interaction
- Magnetism of the lithosphere and its geological context
- 3D electrical conductivity of the mantle related to composition
- Magnetic signature related to ocean circulation

To study the Sun's influence on the Earth system by:
- Analysing electric currents in the magnetosphere and ionosphere
- Understanding the impact of solar wind on dynamics of the upper atmosphere

Orbit
Type: low Earth; near-polar
Constellation of three identical satellites: two orbiting side-by-side, decaying naturally from an initial altitude of 460 km to 300 km over 4 years; the third maintains an altitude of about 530 km. The inclination difference of 0.6° between the lower pair and the higher satellite ensures a 90° difference in orbital plane by the third year of operations.

Payload
Vector Field Magnetometer, Absolute Scalar Magnetometer, Electric Field Instrument, Accelerometer, GPS receiver, startrackers and laser retroreflector.

Configuration
Three identical satellites, 9.1 m long (including a 4-m deployable boom), 1.5 m wide and 0.85 m high

Mass
Each 468 kg at launch, including 99 kg of Freon propellant

Power
GaAs solar cells, 48 AH Li-ion batteries
Consumption: instruments 50 W; platform units 140 W

Attitude Control
- 3-axis stabilised, Earth-oriented
- Startrackers, magnetometers, magnetotorquers
- Cold-gas (Freon) propulsion: 20 mN thrusters for attitude control and 50 mN thrusters for orbit control

Command and Control
Integrated data handling and Attitude and Orbit Control System computer with communication via a 1553 bus and serial links

Onboard Storage
- 2×16 Gbit solid-state mass memory unit
- Payload data generated on board: 1.8 Gbit/day

Communication Links
Once per day to ground station at Kiruna (SE)
S-band (2 GHz): 6 Mbit/s downlink; 4 kbit/s uplink rate

Flight Operations
Mission control from ESA's European Space Operations Centre, ESOC, in Darmstadt (DE), via ground stations in Kiruna (SE)

Data Processing
Science data downloaded to the Kiruna ground station
Data processing, distribution and archiving managed by ESA's Centre for Earth Observation, ESRIN, in Frascati (IT)

Launch Vehicle
Rockot (with Breeze-KM upper stage) from Plesetsk (RU), provided by Eurockot Launch Services GmbH (DE).
The constellation is launched on one rocket and injected into orbit simultaneously at 490 km and 87.55°.

Prime Contractor
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Illustrations: ESA/AOES Medialab

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