SOLAR ORBITER MAGNETOMETER: OVERVIEW, SCIENCE GOALS AND STATUS

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INTRODUCTION

The magnetic field is a fundamental plasma parameter and is therefore key to processes such as wave particle interactions, coronal mass ejections, turbulence and shocks, all of which are central to Solar Orbiter science. In addition, the magnetic field provides the connection between solar phenomena and those measured at the spacecraft, making the magnetometer central to the principal mission goal of linking solar processes to their signatures in the heliosphere.

SCIENCE QUESTIONS

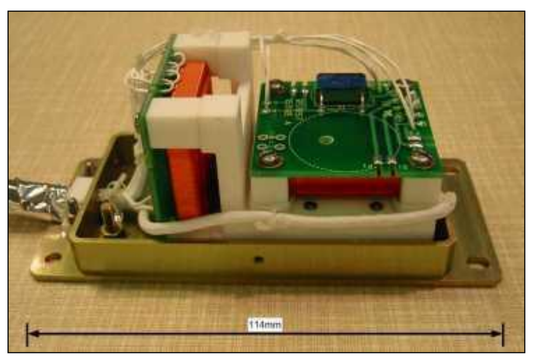
Science topics of the magnetometer team include:

- How does the Sun's magnetic field link into space?
  - The magnetic field is a crucial diagnostic of solar wind connectivity. In addition, Solar Orbiter will provide important information on how the magnetic field disconnects from the Sun as it is carried by the solar wind
- How are the corona and solar wind heated and accelerated?
  - Wave-particle interactions are central to coronal heating. The magnetometer will measure the remnants of these waves, as well as diagnosing how turbulence dissipates and heats the solar wind
- How are particles accelerated near the Sun and how do they travel through space?
  - Complex magnetic field structures control the propagation of energetic particles: the magnetometer allow better calculations of diffusion coefficients

DIGITAL MAGNETOMETER DESIGN

Measurement Principle: Second harmonic detection – the field proportional signal appears as an oscillation at twice the drive frequency. This design is a **mass optimised 2 core design** – only 2 cores are used to measure all 3 axes.
Tuned: A tuning capacitor is used to amplify the field proportional signal at the second harmonic, $2F_0$.

Closed Loop: The magnetometer uses feedback to null out the field in the core, this improves linearity. The proposed fluxgate has **common sense and feedback windings.** This reduces the mass of the sensor and the sensor harness, compared to a sensor with a separate feedback coil.
Digital: The sensor signal is immediately amplified and digitised using an ADC (analogue-to-digital converter). The magnitude and phase of the signal at $2F_0$ is determined in the digital domain, this gives the magnitude and direction of the measured field. This measurement is also converted to a feedback voltage via a DAC (digital-to-analogue converter) to null out the field in the core.



Double Star Fluxgate Magnetometer Sensor

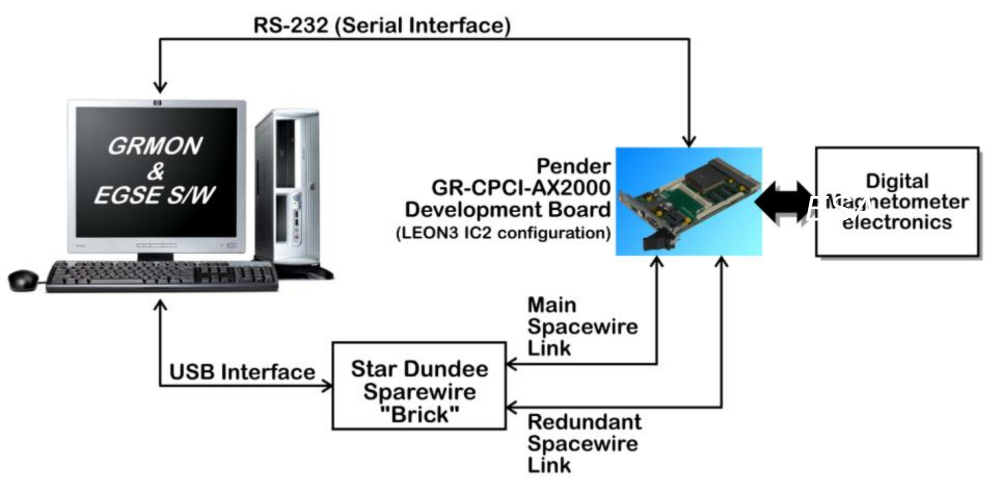
FPGA based: The ADC, field calculation algorithm and DAC are all embedded in a Field Programmable Gate Array. Target device, Radiation tolerant Actel RTAX2000S, rated to total ionising dose of 200krad.

For more information see A radiation tolerant digital fluxgate magnetometer, O'Brien et al, Meas. Sci. Technol. 18 (2007) 3645–50

INSTRUMENT CONTROL UNIT

We have selected the Aeroflex-Geisler RTAX 2 FPGA as the instrument control unit and have purchased a development board, as well as a SpaceWire "brick" from StarDundee.

We have a fully operational chain, from the digital magnetometer measuring induced fields, to the ICU breadboard and then via SpaceWire to a PC.



MAGNETOMETER SCIENCE TEAM

The magnetometer team comprises Co-Investigators covering a wide range of science topics, from heliospheric structures and turbulence to theory and simulations. We share Co-Investigators with a number of other instrument teams.

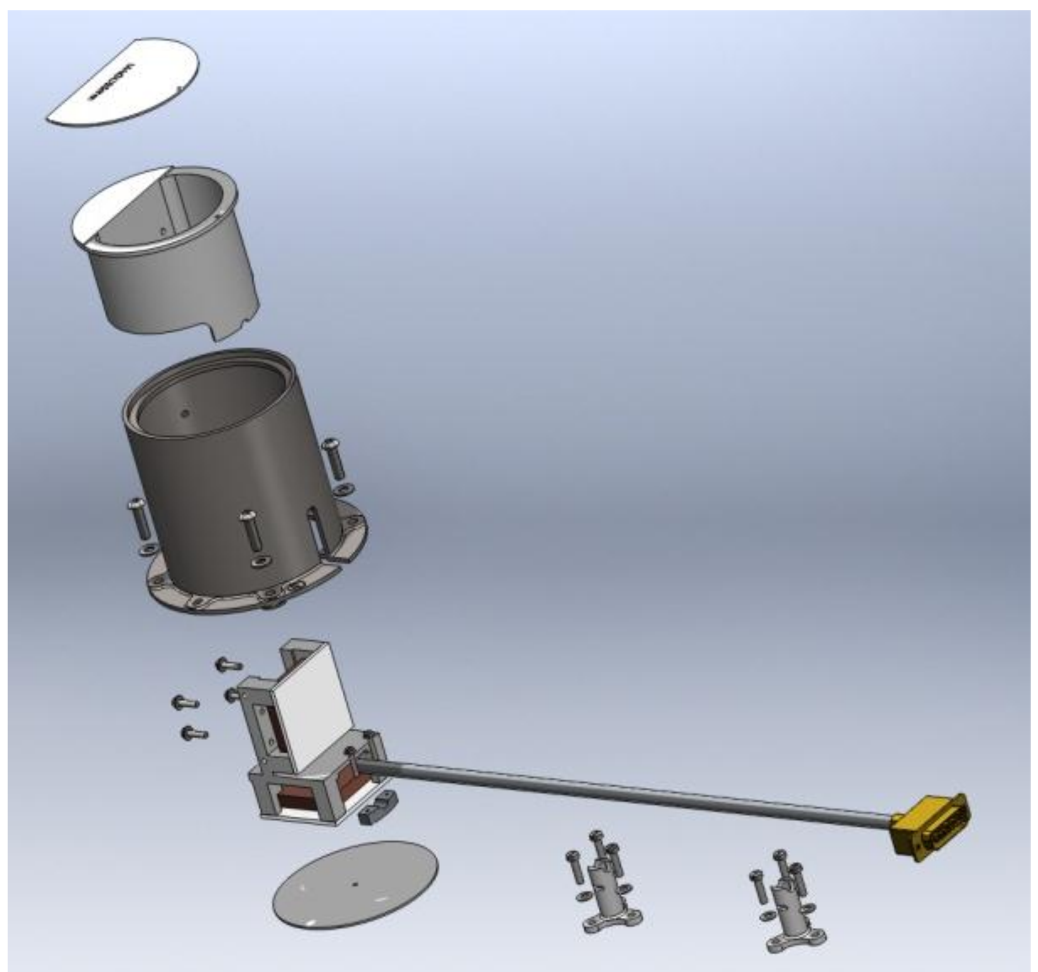
S. Bale, W. Baumjohann, B. Bavassano, D. Burgess, V. Carbone, P. Cargill, N. Crooker, G. Erdos, L. Fletcher, R. Forsyth, J. Giacalone, K.-H. Glassmeier, M. Goldstein, T. Hoeksema, T. Horbury, M. Lockwood, W. Magnes, M. Maksimovic, E. Marsch, W. Matthaeus, N. Murphy, V. Nakariakov, J. R-Pacheco, H. O'Brien, J.-L. Pincon, I. Richter, P. Riley, C. Russell, S. Schwartz, M. Thompson, R. Vainio, M. Velli, S. Vennestrom, R. Walsh, R. Wimmer-Schweingruber and G. Zank

MAGNETOMETER SUMMARY

- Two 3-axis fluxgate sensors mounted on boom in spacecraft shadow
- Measures magnetic field at 16 vectors/s (normal mode) or 128 vectors/s (burst mode)
- Provides data in real time to other instruments (SWA, EPD)
- Passed Preliminary Design Review in January 2012
- Current developments focus on a fully functioning lab model and finalising the mechanical design

THERMAL DESIGN

- Sensors are on boom in shadow: can get very cold
- Boom interface can reach -190ºC!
- Sensors will have heaters to maintain temperature within required range
- Housing of sensors has been completely redesigned to minimise thermal losses
- Baseline design is minimum operational temperature of -40ºC
- We also aim to qualify sensors down to -100ºC to reduce heater power required

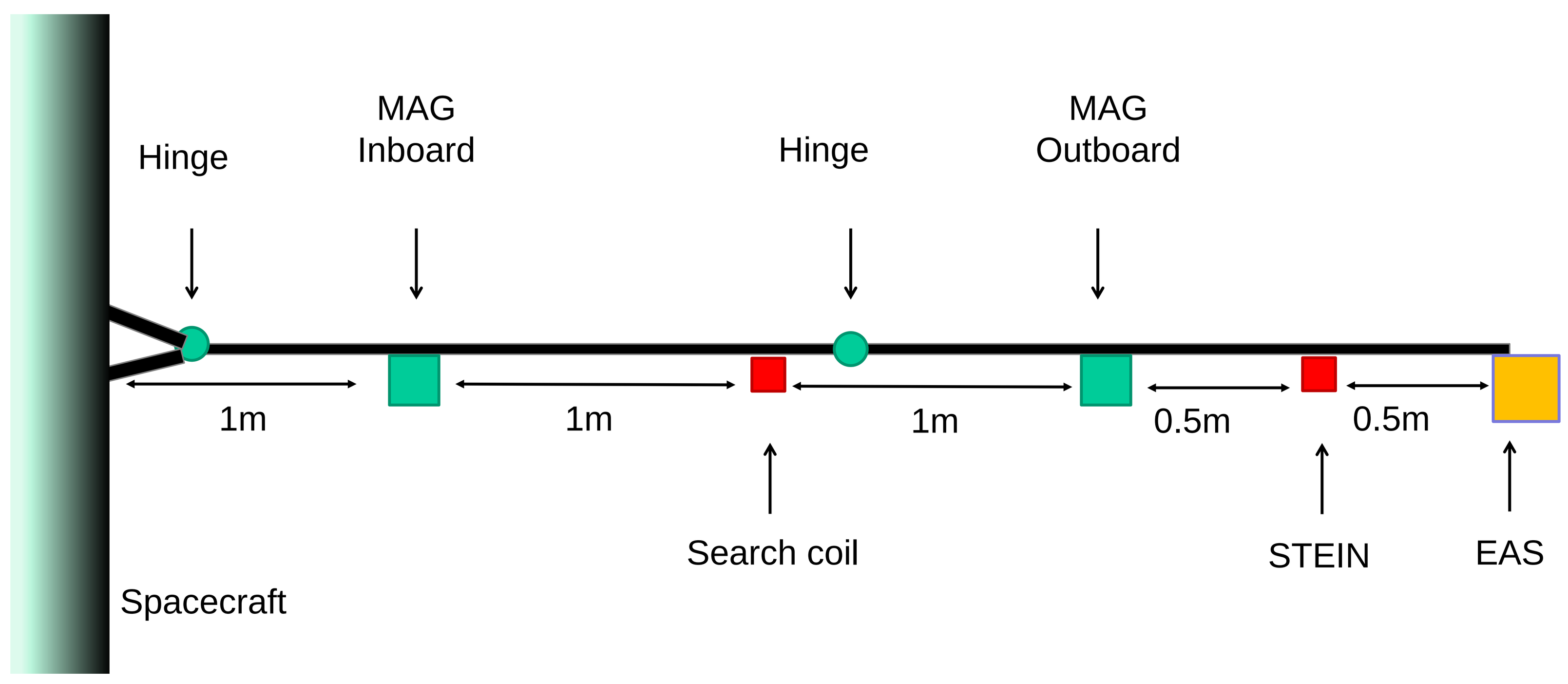


New sensor thermal housing design, which minimises heat losses

MAGNETIC CLEANLINESS

Solar Orbiter is a particularly challenging spacecraft for magnetic cleanliness: it does not spin (making calibration harder); it has a short boom; and there are instruments both between and outside of the two magnetometer sensors. This makes it hard to use some standard techniques such as the dual sensor technique for identifying spacecraft interference.

Boom accommodation is a major concern: interference from other instruments, particularly STEIN and EAS, could jeopardise magnetometer measurements. We are working with other instrument teams, Astrium and ESA to solve these issues.



INTER-INSTRUMENT COMMUNICATION

The magnetometer will provide data in real time via the SpaceWire bus to other instruments as required. It will also participate in coordinated burst mode triggering, based on events such as shocks and solar flares. These activities are being planned and coordinated through the In Situ Working Group.

GET IN TOUCH!

Success of the Solar Orbiter magnetometer depends on it providing data which are useful to the scientific community. The magnetometer team welcome all comments and suggestions regarding the instrument, including burst mode triggering, calibration and coordinated operations with other instruments. Please contact Tim Horbury, t.horbury@imperial.ac.uk

ACKNOWLEDGEMENTS

Solar Orbiter development at Imperial College London is supported by the UK Space Agency