Tessella
Technology & Consulting

Attitude Control and Measurement

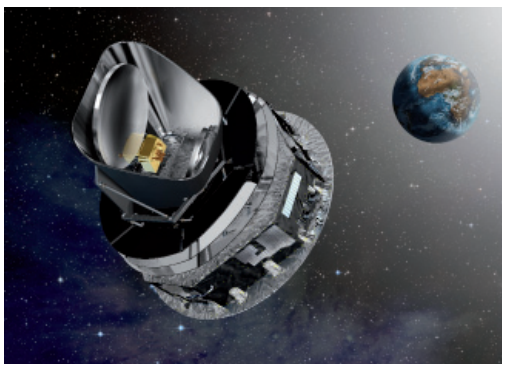
Herschel and Plank, two of the largest and most complex scientific spacecraft ever developed by the European Space Agency, were launched in May 2009. Tessella was a key member of the team that designed the Attitude Control and Measurement Subsystem for the two missions.

The Herschel infrared space telescope and the Planck cosmic microwave mapping mission seek to answer some of the fundamental questions about the origin and composition of the universe. The two spacecraft are cornerstones of ESA's 'Horizon 2000' science programme. Between them they represent significant advances in scientific spacecraft design, yet they are in many ways very different, each presenting a distinct set of challenges.

Herschel is the largest infrared space telescope ever built; at 3.5 m in diameter, its collecting mirror is the largest mirror ever flown in space. It is the first mission able to look at sub-millimetre wavelengths that cannot be seen from the Earth as they are absorbed by the atmosphere. This gives astronomers a new window into the universe, allowing them to study the formation of stars and galaxies, and the chemical composition of objects in our solar system.

Planck, the most sensitive mission ever designed by ESA, will map the cosmic microwave background to an unprecedented degree of accuracy. This radiation is the 'first light' from the universe, formed as soon as the universe cooled enough to allow light to be transmitted. By observing it, astronomers hope to answer some of the fundamental questions about the origin and fate of the universe, to which earlier missions only gave partial answers.

ESA assembled a large industrial consortium to build these two spacecraft. The prime contractor for the mission is Thales Alenia Space France, with Thales Alenia Space Italy being responsible for the service module. The Attitude Control and Measurement Subsystem (ACMS) was selected by competitive tender, and won by a consortium led by Dutch Space, including Tessella and SENER.



Planck © ESA

The Rosette molecular cloud, seen by Herschel © ESA

Herschel © ESA

Tessella's contribution

Within the consortium, Tessella's responsibilities covered three critical areas:

Herschel controller design

Tessella was responsible for design and analysis of the attitude controller for Herschel's observation mode. The accuracy required is equivalent to focusing on a tennis ball 150 km away. To look at objects within our solar system, such as planets or comets, the controller must achieve this accuracy while performing a raster scan and tracking a moving target. Parts of the telescope are extremely sensitive to sunlight, and so a special path planner had to be created to allow the spacecraft to slew from one target to another without exposing any sensitive components to direct sunlight, while still meeting demanding requirements on slew times. Tessella selected the controller methods, performed the system analysis needed to derive the requirements on the attitude measurement and control algorithms, designed the algorithms, and assessed their performance through a comprehensive suite of simulations.

Pointing accuracy

There are standard techniques to estimate the accuracy with which a spacecraft can point at a target by combining the statistical distributions of all contributing errors. Tessella provided these 'pointing budgets' for both spacecraft. As Planck is designed to spin about its axis once every minute, with the telescope boresight following the required track across the sky, the standard pointing budget techniques used on Herschel cannot be used, as it is not possible to define a single 'target direction'. Tessella analysed Planck's pointing requirements, devised new pointing error metrics to quantify the errors, and determined how to combine individual error sources to find the overall pointing error.

Modelling the control hardware

It is not possible to fully test a spacecraft's control system on the ground. Instead, simulations are used, with numerical models of the sensors and actuators interfacing with the real on-board software. In this case, the models of the hardware needed to be sufficiently accurate to be able to study how the hardware and software will interact. Tessella created and maintained these models for both spacecraft, liaising with the other members of the consortium to keep up to date with the hardware development.

A standard library of models was developed in MATLAB®/Simulink® for use by the whole consortium. Tessella defined the model repository architecture and coding standards, and developed, implemented and tested the models, from the interface definition to the detailed underlying mathematics. Tessella was also responsible for porting the same validated models onto the test bench using the MATLAB® Real-Time Workshop® and the MOSAIC tool, to support real-time hardware-in the-loop subsystem testing in the EUROSIM real-time environment.

Results

The ACMS passed all of its design reviews and tests. The two spacecraft were launched together in May 2009, and are currently operating successfully and taking a wide range of scientific observations.

Tessella plc 26 The Quadrant, Abingdon Science Park, Abingdon, Oxfordshire OX14 3YS, UK
T: +44 (0)1235 555511 | F: +44 (0)1235 553301 | E: info@tessella.com

Tessella Inc 233 Needham Street, Suite 300, Newton, MA 02464, USA
T: 1 617 454 1220 | E: info@tessella.com

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