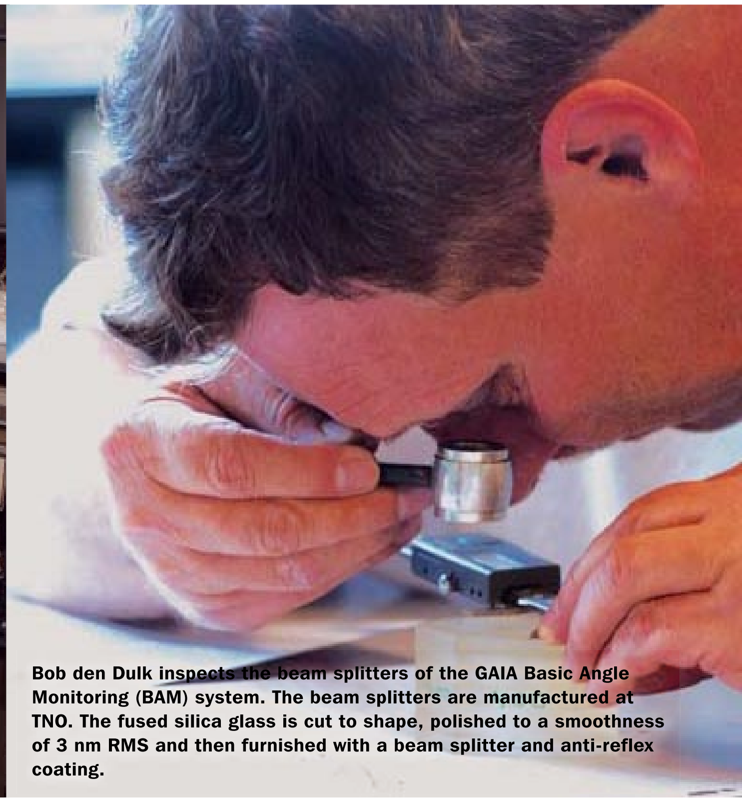
Biggest ever challenge

Olivier Malek assembles the beam splitters of the GAIA Basic Angle Monitoring (BAM) system on a vibration table. The launch loads are simulated during the vibration test.



Bob den Dulk inspects the beam splitters of the GAIA Basic Angle Monitoring (BAM) system. The beam splitters are manufactured at TNO. The fused silica glass is cut to shape, polished to a smoothness of 3 nm RMS and then furnished with a beam splitter and anti-reflex coating.

Photos: Fred Kamphues

INSTRUMENTATION FOR GAIA

The ambition is plain and simple. In 2011 the European GAIA satellite will start its mission to make a three-dimensional map of a large number of star systems, and show the position and movement of a billion stars with unprecedented precision. One of the aims is to find out more about the origins of the Milky Way, something that requires extremely precise instrumentation, built in silicon carbide. TNO is developing key components for the instrument.

Most satellites contain a variety of instruments for collecting all kinds of data. GAIA is different. It will have just one instrument, also called GAIA. Ben Braam, business developer of the ESA Science programme at TNO: 'The instrument needs to be so free of vibration that this precludes the presence of other instruments whose cooling, for instance, may generate too much interference. The required stability of the instrument is in the order of picometers. The size of the telescopes and the stability of the construction also make the instrument so big that there is no room for other instruments in the satellite.'

Once GAIA enters orbit in 2011, it will turn around its own axis and chart the sky every six hours from its position at that moment in time. A series of successive pictures will record earlier observed stars and newly observed stars. Braam: 'What is especially new to GAIA is the precision of the position and path of the stars that the mission will chart. The astrometry will be so accurate that from the star's position we will be able to tell whether it is being influenced by the gravity of planets. The sensitivity is so great that for many of the billion stars we will be able to know whether there is a planetary system.'

Silicon carbide

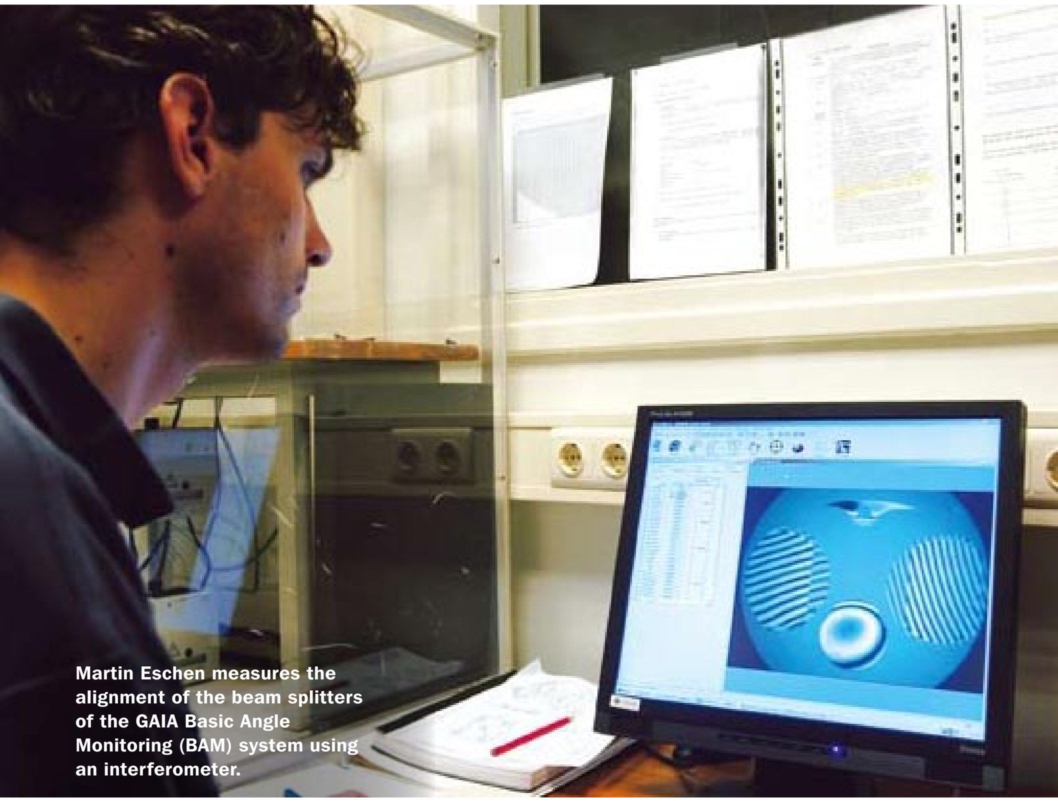
The instrument that is required is a double telescope. Because the satellite turns around its axis, the two telescopes see the same shortly after each other. The light that both telescopes receive goes via mirrors to a detector, a *Focal Plane Array* with more than a hundred CCDs (Charge Coupled Devices) where the stars appear. The image is then recorded and a spectral analysis of the stars is made. The software ensures that each new image is incorporated into the general picture of the Milky Way and that any change in position is registered. This will result in a three-dimensional map of the universe, with unprecedented accuracy.

'The demands made on the precision of the instrumentation are so high that a new material had to be sought to make the instrument,' Braam says. 'Up until now we had often worked with aluminium, which combines lightweight properties with good conductivity and is easy to manipulate. However, the expansion coefficient causes too much interference to be able to comply with the demands of GAIA, so we turned instead to ceramic silicon carbide, an extremely stiff, light, very stable material with good conductivity and hardly any expansion. However, the hardness and brittleness make the material very difficult to manipulate. While aluminium is able to absorb material stresses by being able to deform somewhat, silicon carbide just breaks, which means that the whole design of the instrument has to remain below the breaking limit. And clever design tricks have to be used to integrate individual components into the instrument in line with the required level of accuracy and construction tolerances.'

BAM system

The *Basic Angle Monitoring system*, or BAM, is

e to precision



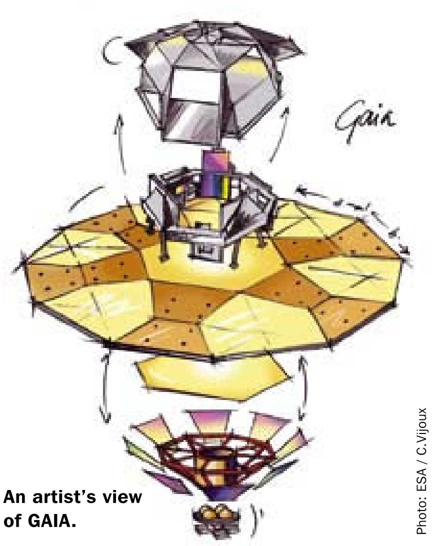
Martin Eschen measures the alignment of the beam splitters of the GAIA Basic Angle Monitoring (BAM) system using an interferometer.

PARTICIPATION IN GAIA

The prime contractor for the 600 million euro GAIA project within the scientific programme of the European Space Agency (ESA) is EADS Astrium in Toulouse. In addition, many parties from various European countries are involved, with the work package per country equivalent more or less to the financial commitment being made to the programme. EADS subsidiary Boostec will be responsible for manufacturing of the TNO designed silicon carbide components, with TNO looking after the polishing, coating, assembly and testing.

The Basic Angle Monitoring system of GAIA.

GAIA charts the Milky Way (artist's impression).



An artist's view of GAIA.

also made from silicon carbide. TNO is designing the system under the supervision of Jan Nijenhuis. Braam: 'The BAM system has to be able to accurately measure the mutual position of the two telescopes to the picometer during recordings. That means absolute material, temperature and construction stability. So precise are the conditions that the GAIA system cannot really be tested for stability on Earth. Test results will need to be extrapolated to the real in-orbit conditions. What you are measuring with the BAM metrology system is the change in range of light via the two telescopes to the detector.'

The principles of BAM were already demonstrated years ago by TNO using the GAIA test bench, a BAM system in aluminium. By using a clever combination of materials and geometry, this instrument is only minimally affected by differences in expansion. The sturdy construction, strict temperature control, tough vacuum and multiple damping for Earth vibrations have enabled 'proof of principle' of the stability at picometer level to be demonstrated for a period of several seconds. 'That is vital because if the BAM system does not work, the whole satellite will not work,' Braam points out.

Precision technology

A second TNO project has just as extreme levels of accurate measurement as the BAM. Systems engineer Amir Vosteen and his colleagues are building a *Wave Front Sensor* that can measure whether the second mirror of the telescope is properly positioned in relation to the satellite's main mirror. The measurements form the basis for controlling the stability of the adjustment mechanism that regulates the second mirror.

The third project for GAIA involves testing the *Focal Plane Array* sensor for which systems engineer Ellart Meijer and his team move a simulated star – a light spot via a special large mirror – in nanometers per second in a stable and well registered way to and fro over the sensor surface. This is the method that is used to test and calibrate the sensor.

'During a meeting at the prime contractor EADS Astrium in Toulouse, this was referred to as one of the most difficult engineering feats in engineering history,' Braam recalls. 'It underlines once again the position of the Netherlands in the field of precision technology.'

TNO stands to benefit from pushing forward the frontiers of precision. 'The level of precision and stability requirements of space exploration can be used in our work in the semi-conductor industry. And the material knowledge can go straight into nanotechnology. We are also looking at the possibilities of using this knowledge in medical technology and methods of inspection. The precision tolerances could, for instance, contribute to techniques for error-free operations. Precision technology is becoming increasingly important in a whole range of applications.'

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