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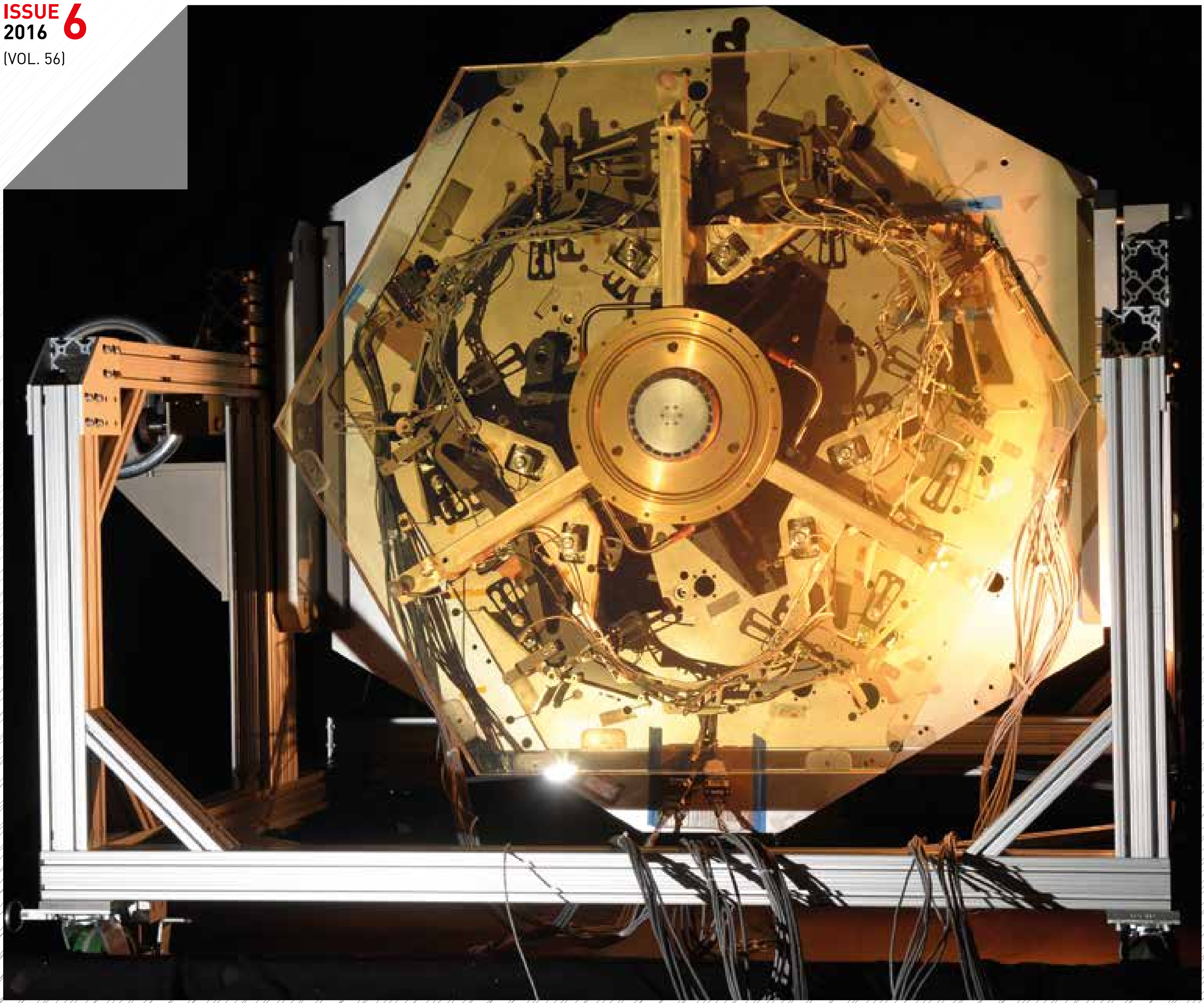

■ THEME: **ASTRONOMICAL INSTRUMENTS** ■ **MOUSE** PRECISION
■ **2016 PRECISION FAIR** IMPRESSIONS ■ **VIBRATION-'FREE'** CRYOGENICS

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The main cover photo (featuring a segment of the Thirty Meter Telescope) is courtesy of TMT/Harris/Fred Kamphues. Read the article on page 10 ff.

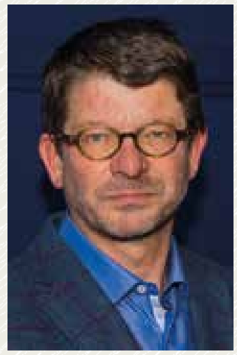
IN THIS ISSUE

ISSUE 6 2016

FEATURES

EDITORIAL

ASTRONOMICAL INNOVATION



The theme of this issue of Mikroniek is 'Astronomical instruments'. Astronomy is associated with huge-scale, high-performance, precision work and ideas. Humans' interest in space and what lies beyond our planet has made our lives more comfortable in lots of ways. Without space research, we would not have satellites, which we use for GPS navigation when driving, or for satellite telephony. Space research also has also given us a better insight in how our world was formed and may have helped us to believe that we are not the only living beings in the universe.

Precision technology is making a substantial contribution to astronomical research, and the competence thus developed is finding application in other areas of technology. This is a typical characteristic of precision technology: applying competences acquired in one area to other areas. This was clearly apparent at the 2016 Precision Fair: I was able to visit different companies from the Eindhoven region and was amazed to see how many technology enterprises have been initiated using the research conducted by, and hence the competence built up by, Philips. One example of this was the winner of the ir. A. Davidson Award (announced during the Precision Fair) Wouter Aangenent, who is working at ASML Research as senior architect for mechatronic systems.

In the 1950s, Antoon Davidson and his successor Hein Post took the initiative within Philips to document and distribute technology throughout the whole company. This unique knowledge sharing has become normal practice within the precision engineering community in the Netherlands, with DSPE acting as a binding element.

Talking about Philips and awards, let's not forget Wim van der Hoek. At the age of 92 years, Wim attended the Precision Fair to witness the granting of the Wim van der Hoek Award 2016 to Niels Giessen. The influence of Wim's design principles is still recognisable in modern precision designs.

Another knowledge sharing activity, in collaboration with Brainport Industries, was the visit to the Precision Fair of Optence (one of the eight photonic clusters in Germany, located in the Wetzlar area). Ahead of the Fair, DSPE organised company visits for them to Sioux, Tegema, Demcon, BKB, NTS, ASML and FEI (Thermo Fisher). A return visit will be scheduled during the W3+ Fair 2017 in March in Wetzlar.

Sharing is also for season's greetings. DSPE wishes you and your relatives a happy New Year, and for you and your company an astronomical 2017.

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EXTREMELY LARGE, HIGHLY ACCURATE

The E-ELT is the European Extremely Large Telescope with a primary mirror of 39 meters that is being developed by ESO for the European astronomical community and ESO members. For the realisation of the E-ELT, TNO Space and Scientific Instrumentation proposes several technical contributions. These are, among others, the mirror support structure, the actuators required for these mirror segments, and optical metrology to control the alignment or phasing. This overview shows how E-ELT technologies are cutting edge while also needing to be robust and low cost for a facility of this size.

JEROEN HEIJMANS, JAN NIJENHUIS AND ARJO BOS

AUTHORS' NOTE

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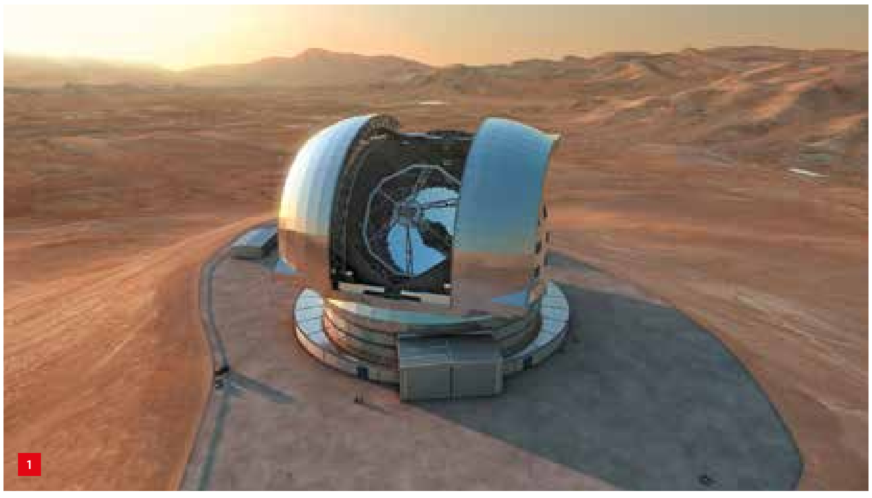
The E-ELT [1] will be based in Chile near the other ESO (European Southern Observatory) telescopes and is the largest of the three giant optical telescopes (the Giant Magellan Telescope, GMT, the Thirty Meter Telescope, TMT, and the E-ELT) that are currently being developed in the world (Figure 1). Besides some healthy competition there also exists a cooperative attitude between the developers as can be read from the following article (page 10 ff.), on the TMT. Up to now, 8-10m sized telescopes have been the largest available telescopes for many years and the limited number of telescopes that exist are in high demand worldwide. As observation times are often long and availability is limited the competition is fierce to get access to telescopes.

The segmented-mirror technology has achieved a breakthrough in creating even bigger telescopes that enable completely new science. Large telescopes mean high-resolution imaging, especially in combination with adaptive optics (AO), which has been the second technology enabler to realise these large telescopes. Resolution can be limited by atmospheric conditions and AO technology is capable to compensate for these conditions making the necessity to go into space for clear skies no longer a requisite.



1 *The proposed design of the E-ELT situated in Cerro Armazones, Chile. (Illustration courtesy of ESO)*

The giant telescopes that can be realised on Earth have a great collective area that enables observing faint objects, looking deeper into the universe, or direct imaging of distant objects or even exoplanets. The imaginable (and imageable) new science that these telescopes create is extensive and so will the number of surprises be that have not yet been predicted.

This year, a contract was assigned for the enormous 79m high dome to the Italian Ace consortium and, not insignificant, the final design of TNO for the primary mirror (M1) support structure was approved by ESO. This is the kind of progress needed to achieve the planned first light of this telescope in 2024.

The Netherlands makes a significant contribution in the European astronomy programme, both on the scientific level and in the technical developments. TNO has developed instrumentation for ESO since 1997 with the delay line for the Very Large Telescope 's interferometer (VLTi) together with Airbus (formerly Fokker Space). From then on a large number of instruments have been developed by TNO for ESO, in recent years with partners such as the Dutch consortium NOVA and currently with VDL.

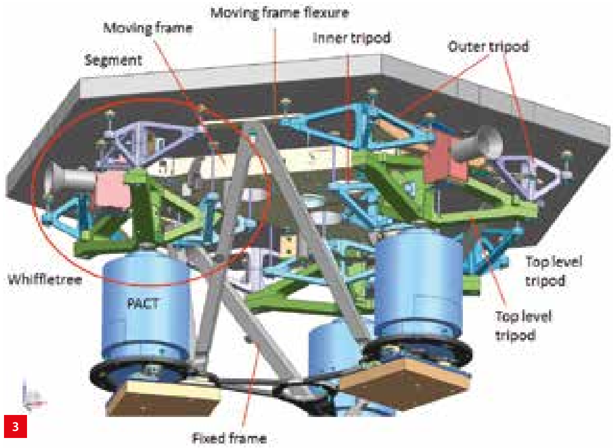
For the realisation of the E-ELT, TNO proposes several technical contributions. These are the mirror support structure, the actuators required for these mirror segments and optical metrology to control the alignment or phasing. The laser guide stars that have been developed for the VLT are also designated for the E-ELT. TNO has proposed in the past to also develop the large deformable M4 mirror and more recently the M2 and M3 mirrors. The latter have been awarded to other European companies in a competitive bidding process as is common for these large European facilities.

M1 support structure

In 2010, TNO delivered three prototypes for the M1 segment support structure to ESO. These prototypes have been tested extensively in a specific test set-up. This has resulted in an updated specification requiring improvements concerning performance, maintenance and cost reduction.
In February 2015, the contract was signed between ESO and the Dutch consortium VDL/TNO/NOVA to design and build an engineering model and four qualification models for the M1 segment support structures. TNO is responsible for the design and testing assisted by NOVA while VDL ETG, as the prime contractor, is responsible for the total development, manufacturability and possible future series production.

It was decided not to just upgrade the design but push for a new design based on the proven principles of the prototype but with much improved maintenance characteristics and improved performance. Furthermore, bringing down the production cost was felt as an urgent need. This has led to a new design that indeed meets these goals. Figure 2 shows the first engineering model that has been designed by TNO and realised by VDL and will be put to the test by NOVA Astron.

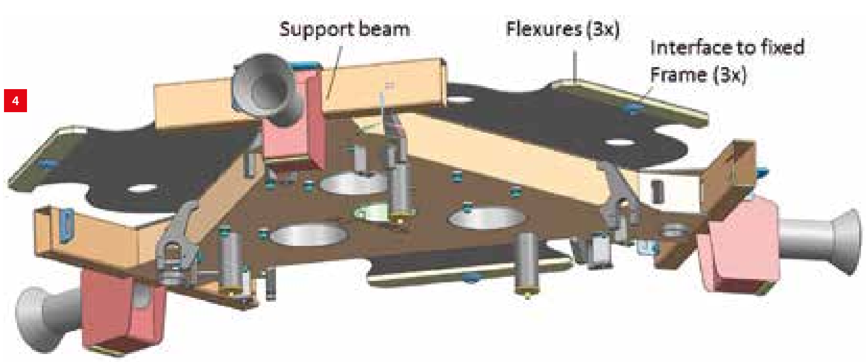
All 798 segments are supported by the same support structure consisting of three whiffletrees (Figure 3). In the lateral direction each segment is supported by an identical membrane. The whiffletrees and lateral support are connected to the Moving Frame (MF) which acts as an intermediate body before being connected to the telescope structure itself. With the addition of a clocking strut between the MF and the segment, a statically determined connection between segment and MF is realised. Combined this is called the Segment Assembly (SA).



Three segment position actuators (PACTs) are placed in between the telescope structure and the Moving Frame to control the segment height and tip/tilt rotations. While changing the elevation angle of the telescope the combined mirror shape of the 798 segment should not change during deformation of the telescope structure. Finally, three flexures connected to the Fixed Frame (FF) make sure that the MF can only move in piston and tip/tilt mode, i.e. lateral motions and rotations around the optical axis are prevented.

To sum up, the main functions of the MF are:
1. Intermediate body between the telescope and the segment, minimising the impact of the PACT operation on the surface form error.
2. One of the most important elements in the stiffness chain from segment to telescope structure, determining the natural frequencies for Tx, Ty (lateral modes) and Rz (clocking).

The MF is made of 1.5mm thick stainless steel plates (Figure 4). The plates are welded together mainly using laser welding. This provides a continuous connection between the sheet metal parts while the laser guarantees that heat transfer to the box is minimised. This results in a box that does not warp due to differential thermal expansion during the welding process.



2 *The first engineering model of the M1 segment support structure.*

3 *The definition of the various sub-assemblies of the segment support structure.*

4 *The new design for the Moving Frame.*

IN SEARCH OF MULTI-FUNCTIONALITY

While functionality is naturally one of the most important features of precision technology products, multi-functionality can be a valuable property for machining aids to have in order to acquire this functionality. When examining trends in machining technology, multi-functionality is certainly a conspicuous one, and there were many signs of it at the, once again, highly interesting 2016 Precision Fair, which attracted nearly 300 exhibitors and 3.650 visitors.

FRANS ZUURVEEN

True, the Precision Fair may not the most obvious venue for finding multi-functional machining centres. Nevertheless, hard-cutting specialist Hembrug Machine Tools demonstrated how multi-functionality can work in its hydrostatic precision-cutting machines, which can be equipped with grinding or polishing units (see Figure 1). (The specifics of these machines are explained more fully in an article on Hembrug in the forthcoming issue of Mikroniek.) An interesting exercise in different approaches to multi-functionality is to contrast Hembrug's precision-maching tools with Schaublin precision lathes (also profiled in Mikroniek [1]). This renowned Swiss company has also integrated a grinding unit in their turning machines, but Schaublin lathes have conventional mechanical slides instead of hydrostatic ones.

2016 Precision Fair impression. (Photo: Mikrocentrum)

AUTHOR'S NOTE

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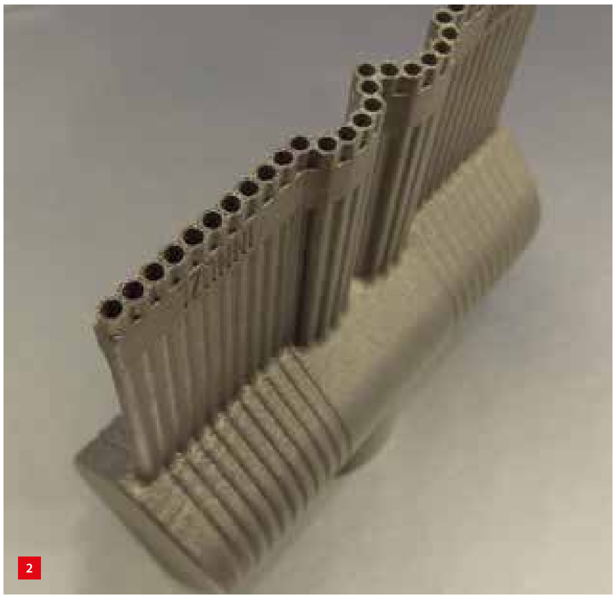
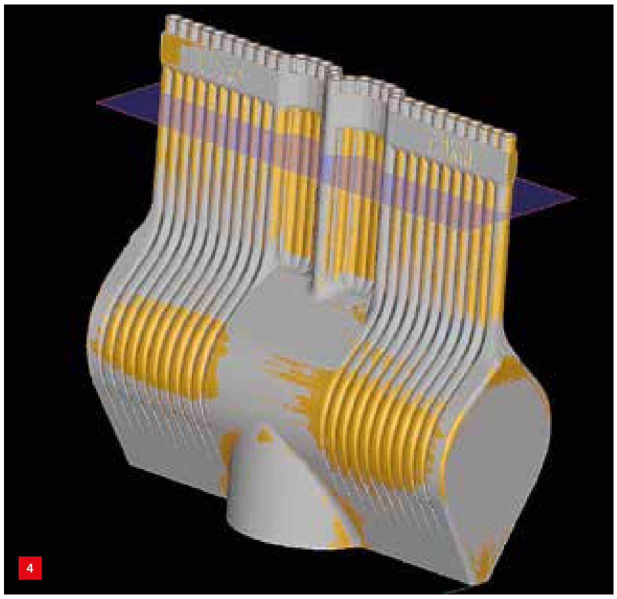
1 *The turntable of the Hembrug vertical hydrostatic turning machine Mikroturn V4 with a run-out accuracy of 0.2 μm. This machine can be equipped with a grinding or a polishing unit.*





2 A product from AAE additively manufactured using an SLM Solutions 3D printing machine.

3 CT working principle: an X-ray point source generates an image on a flat X-ray sensor. The object rotates, after which a computer calculates a 3D image from successive 2D images on the sensor.

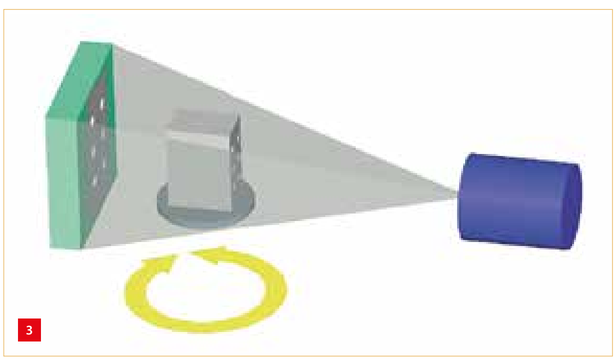
4 A Tomoscan measurement result of the AAE product shown in Figure 2. The colour yellow indicates deviations from CAD values.

Multi-functional co-operation

Another kind of multi-functionality displayed at the fair was a co-operation of precision measuring specialist Werth and mechatronics specialist AAE. AAE has installed a 3D printing machine from SLM Solutions in their High-Precision Parts department and showed in the stand, which they shared with Werth, a 3D-printed part with complicated internal channels (see Figure 2). This is a cooling unit developed by Innogrind for the prevention of grinding burn.

Figure 2 makes it clear that additive manufacturing (AM) enables the production of products that are nearly impossible to make using conventional metal-cutting operations. AAE admits, however, that there may be small problems related to 3D printing, as the channels in this product showed some minor leaks. Werth's Tomoscan measuring machine reveals the why and where, as this instrument can 'look' with its X-rays inside objects and perform accurate measurements, unlike conventional measuring instruments that only observe the exterior.

Figure 3 shows schematically the working principle of the Tomoscan: an X-ray point source generates a 2D image on a flat X-ray sensor with a square pattern of pixels. This is somewhat comparable to the medical application of computer tomography (CT), the difference being that in the latter the human body stays static, while in industrial CT the object rotates. A 3D image can be calculated from 2D images at various rotational positions. In this 3D image precision measurements can be taken. Figure 4 shows how the Werth Tomoscan helped to discover the position of the leaks in the AAE product: a good example of multi-functional co-operation.



Multi-functional 3D printers?

Essentially, AM is a cleverer method of producing a precision product than the subtractive way of conventional machining, which uses sharp tools or cutters to remove all parts or particles that are not needed from a large block of solid material. Nevertheless, combining AM with conventional machining in one hybrid machine would be an excellent example of multi-functionality.

The Precision Fair offered the opportunity to investigate the existence of such a combination. A specialist who was showing the precision capabilities of his conventional workshop reacted, "combining 3D printing with conventional cutting is virtually impossible because the technologies 'bite' each other. 3D printing particles may damage the precision slides of the cutting section, while the cooling and cutting fluids endanger the 3D deposition process."

But the 3D printing specialist at AAE was less sceptical. He recalled an example of an application of 3D printing added to a multi-axis machining centre: specifically, the hybrid five-axis machining centre Lasertec 65 3D sold by the American company DMG Mori. In this machine, a nozzle-based metallic particle-depositing laser head can rapidly replace a spindle with a rotating end-mill. Obviously, the milling head finishes a product surface or