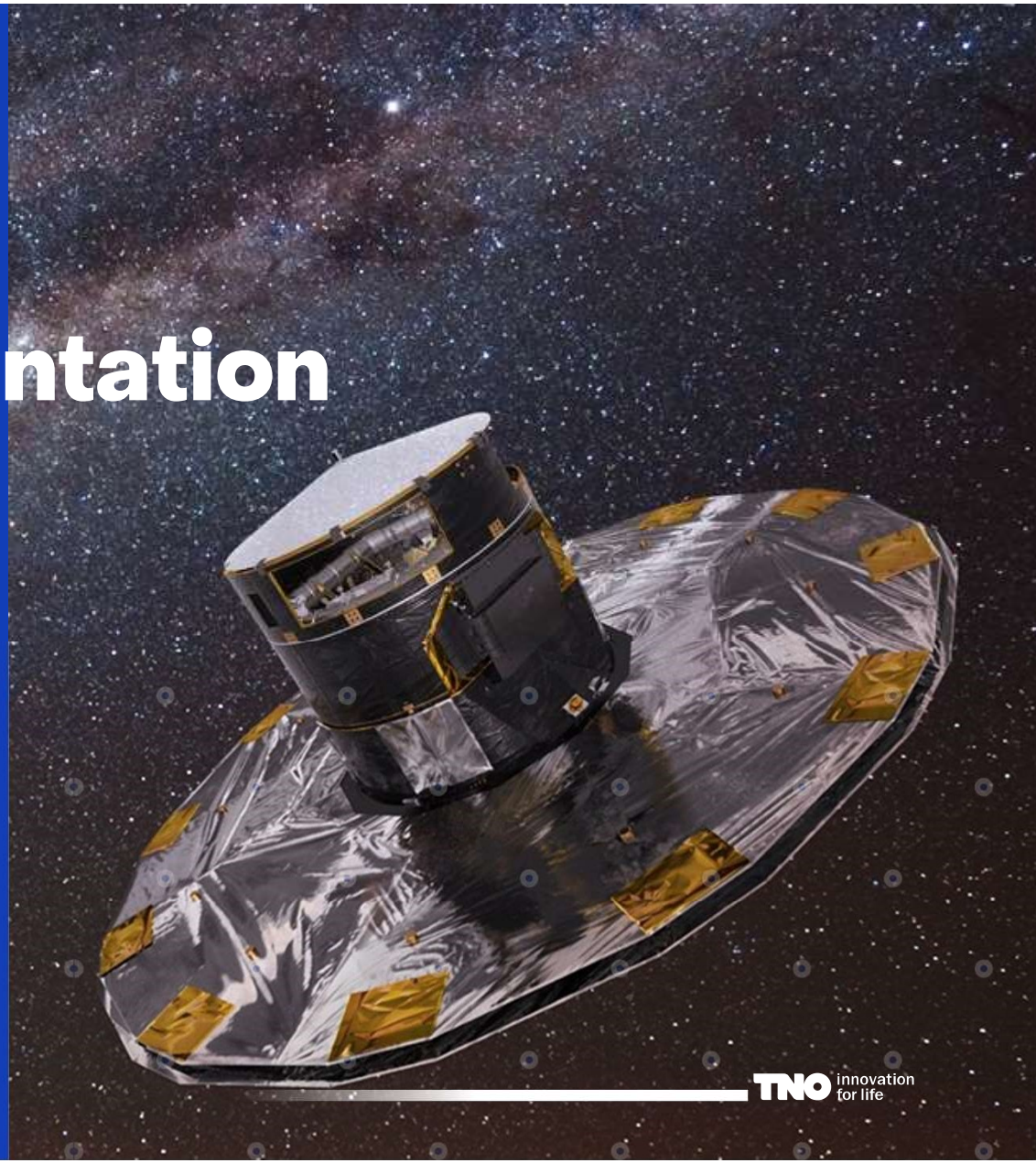
TNO Space & Scientific Instrumentation

Kees Buijsrogge
Director TNO Space & Scientific Instrumentation



We are TNO

TNO connects

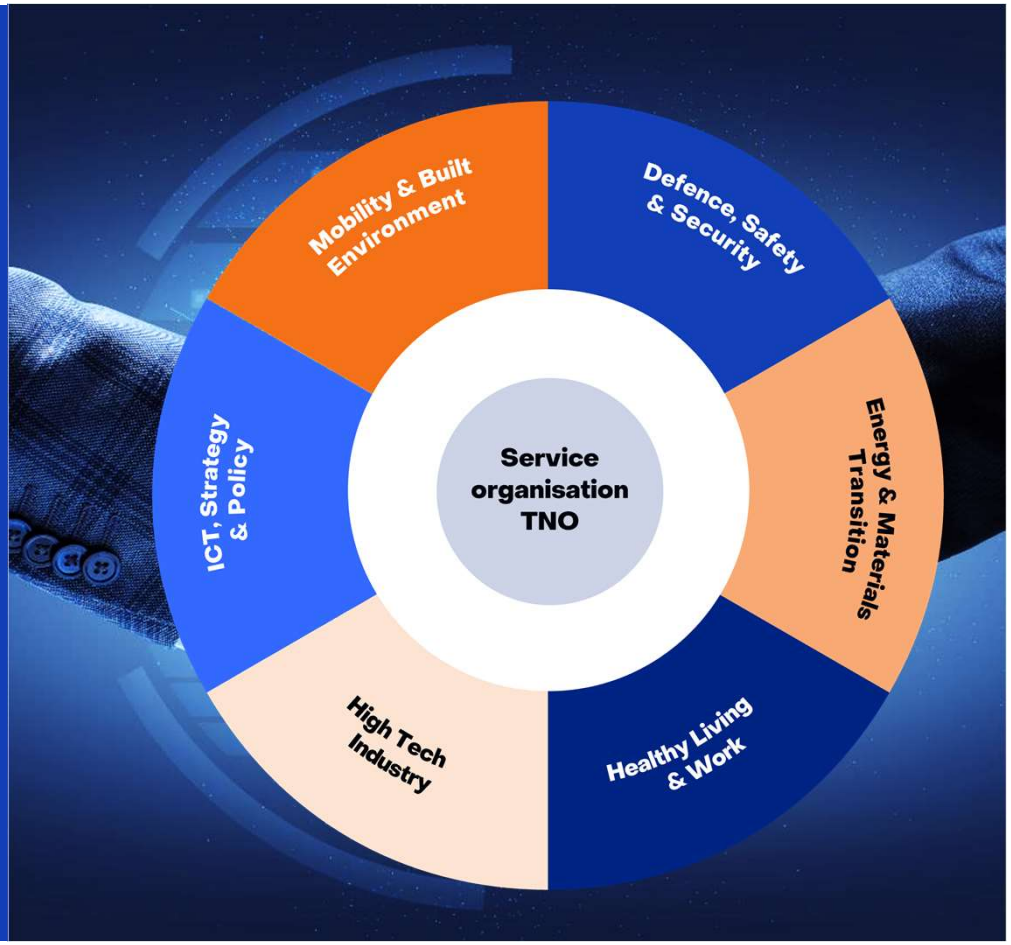
people and knowledge

to create innovations that

1/ boost companies' competitiveness and

2/ sustainably increase well-being across society.

90 years of innovation



TNO Unit High Tech Industry

- TNO's unit High Tech Industry realizes groundbreaking technological and systemic innovations in high-tech industrial value chains in order to safeguard and improve societal well-being and strengthen our national earning capacity.
- We believe the Dutch high-tech industry holds and will continue to hold a leading position in both new and existing markets, powered by TNO technologies.
- 4 innovative roadmaps combining market demands and technology based solutions:

Space & scientific instrumentation

Smart Industry

Semicon & Quantum

Flexible electronics

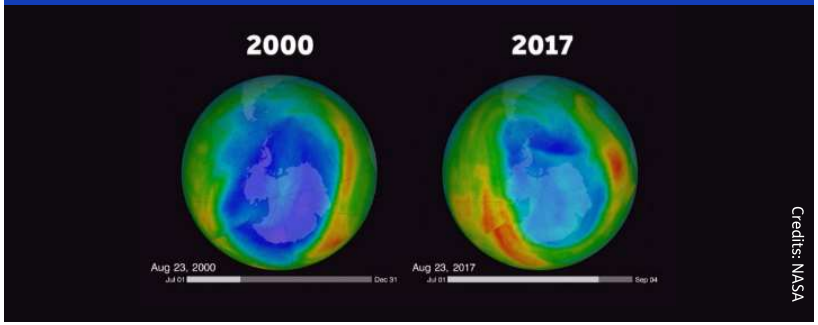
Space & Scientific instrumentation

Why TNO Space & Scientific Instrumentation?

13 CLIMATE ACTION

3 GOOD HEALTH AND WELL-BEING

Prevent climate change & air pollution



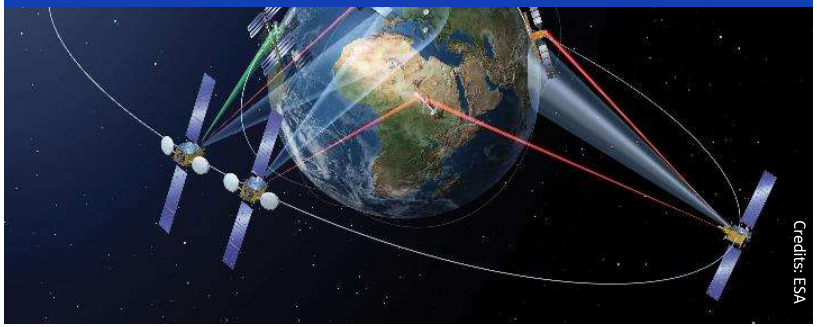
Credits: NASA

15 LIFE ON LAND

14 LIFE BELOW WATER

11 SUSTAINABLE CITIES AND COMMUNITIES

Enable secure broadband connectivity



Credits: ESA

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

4 QUALITY EDUCATION

7 AFFORDABLE AND CLEAN ENERGY

Help understand the universe

Credits: ESA

8 DECENT WORK AND ECONOMIC GROWTH

Safety and security in and from Space

Credits: Northrop Grumman

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

Economic growth in the Netherlands and Europe

Space & Scientific instrumentation

Why TNO Space & Scientific instrumentation?

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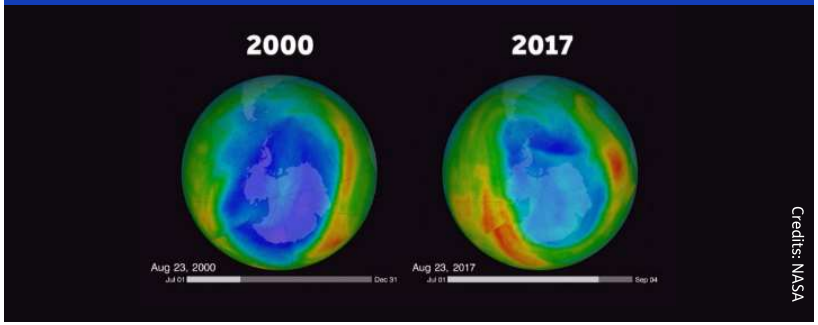

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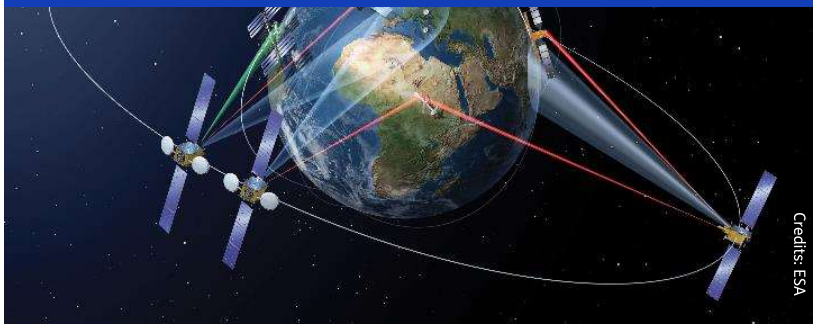

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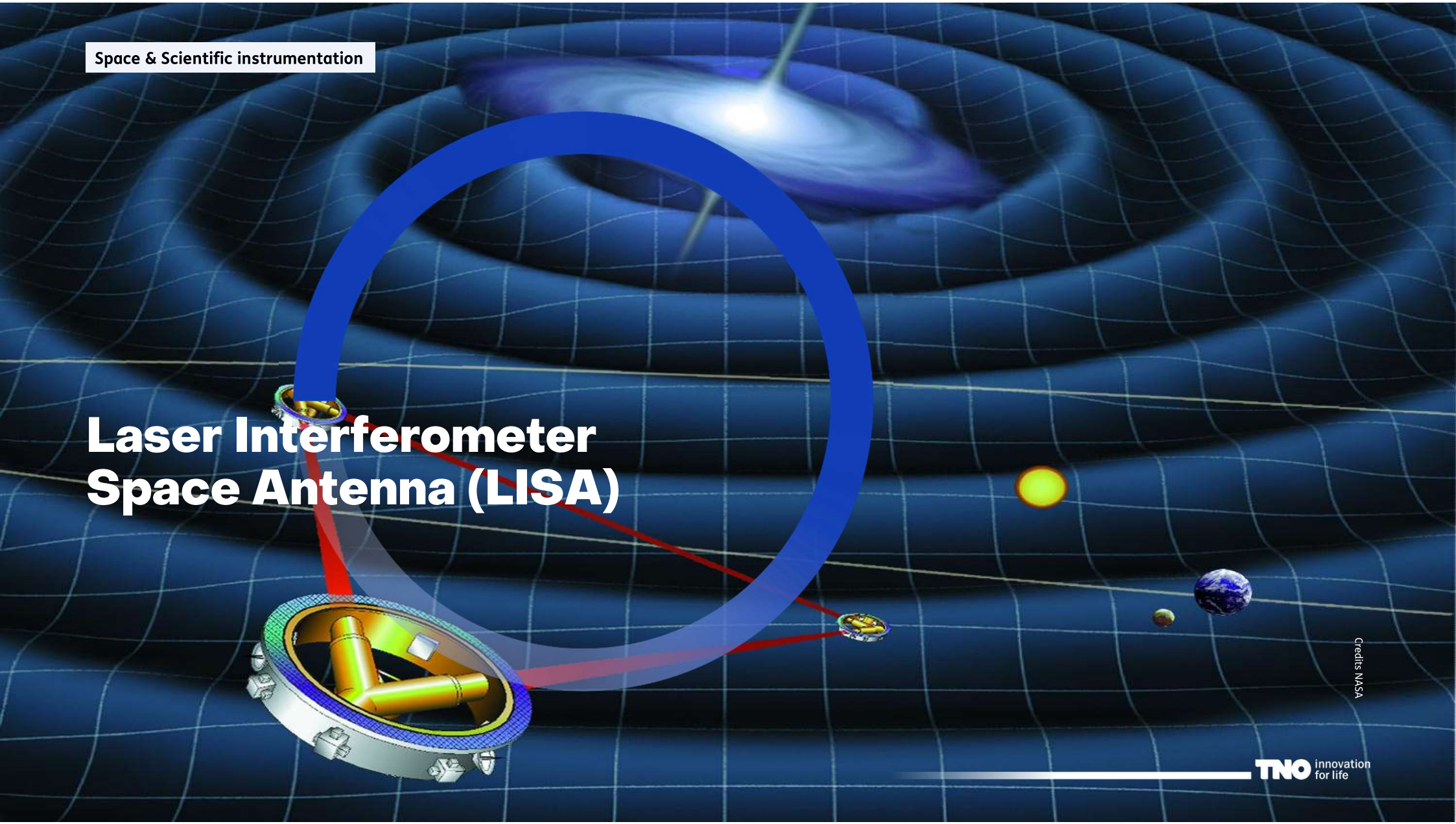
Space & Scientific instrumentation

Instruments for Space based Astronomy

TNO innovation for life

Space & Scientific instrumentation

Laser Interferometer Space Antenna (LISA)

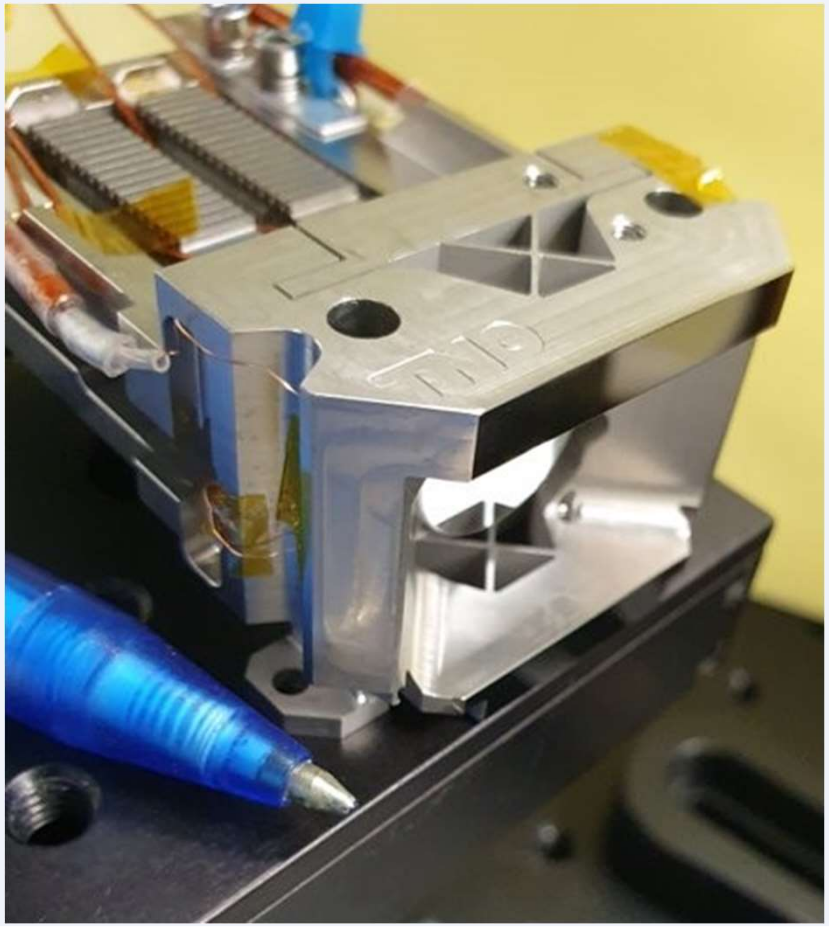


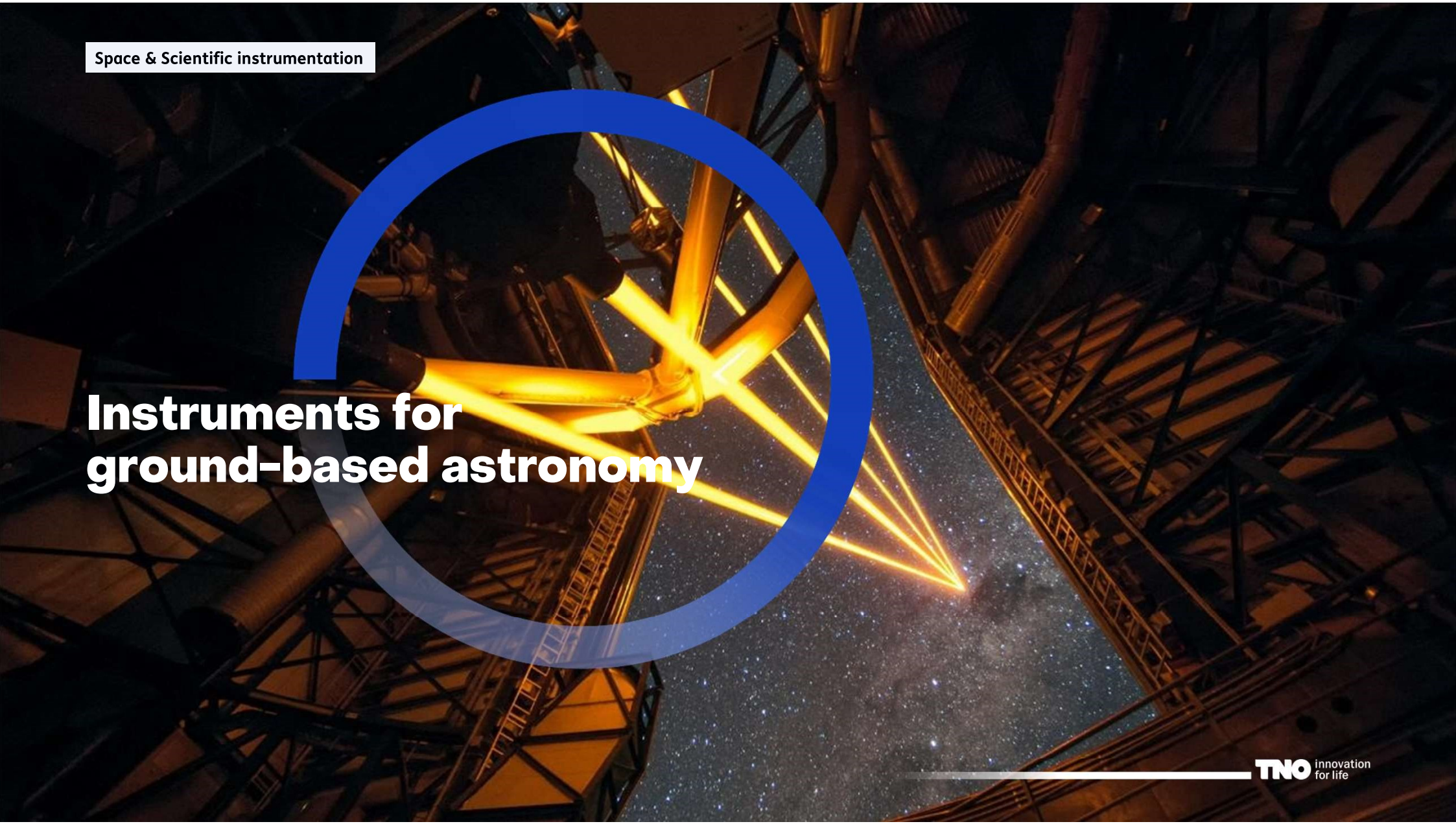
Credits NASA

TNO innovation for life

LISA

- Detection of Gravitational Waves
- TNO is working on Pointing Mechanisms
  Focus on Point Ahead Angle Mechanism
- Measure distance changes with picometer accuracy over 2.5 million km
- Measurement band:
  30 micro Hz to 1 Hz




Space & Scientific instrumentation
Instruments for ground-based astronomy
TNO innovation for life

Space & Scientific instrumentation

Ground-based astronomy at TNO

Societal goal

Answering the Big Questions:

Understanding the universe and our place in it, the hunt for exoplanets, international collaboration and the advancement of human knowledge

Industry goal

Potential for series production allows to involve industry, boosting their expertise, international visibility and business. Spin-off to aerospace, medical and ICT.

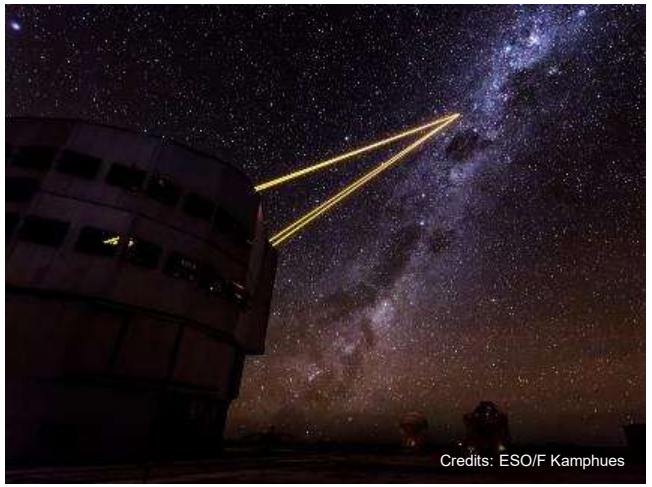
The Netherlands

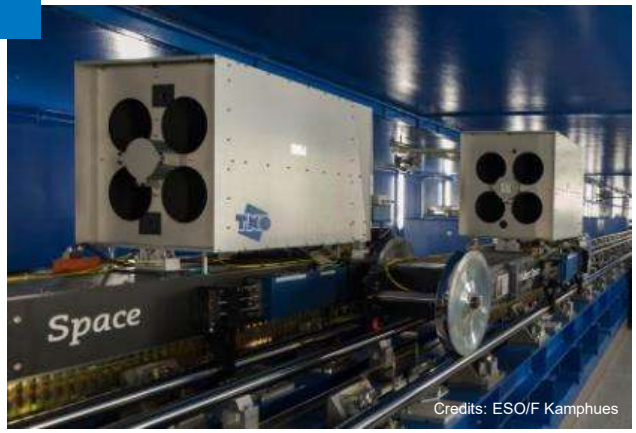
The Netherlands has a strong and long standing position in astronomy

TNO

TNO has a 100% success rate of delivering complex instruments for space and science, and a world class knowledge position: optics, optomechanics, (space) systems engineering

GROUND BASED ASTRONOMY - HERITAGE





VLTi Delay Lines

PRIMA Star Separators

Laser Launch Telescopes for 4LGS Facility

Space & Scientific instrumentation

Ground-based astronomy

Support structures

Laser Guide stars

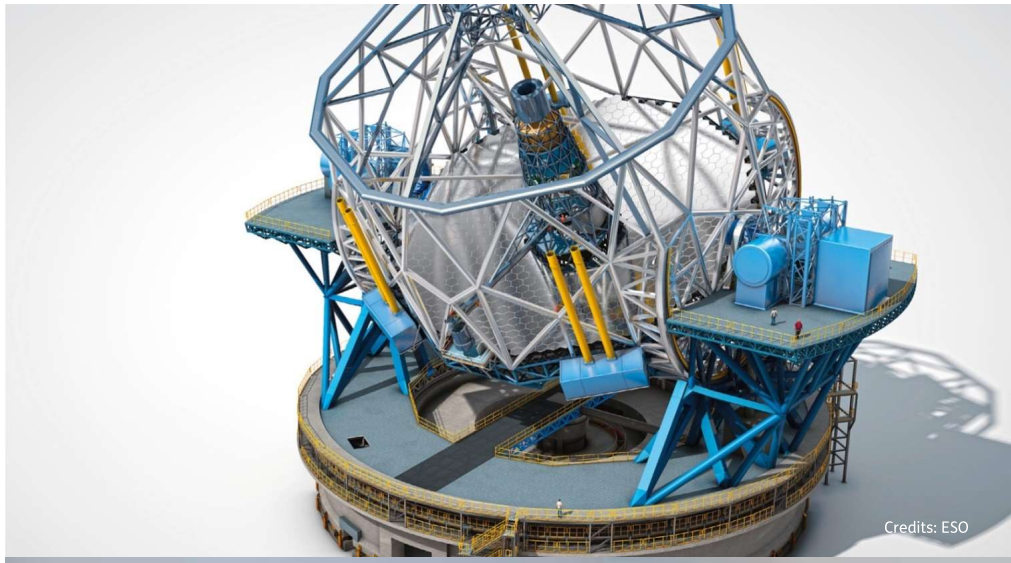
Adaptive Mirrors

Targeting large adaptive optics systems with potential for series production for Dutch industry

Space & Scientific instrumentation

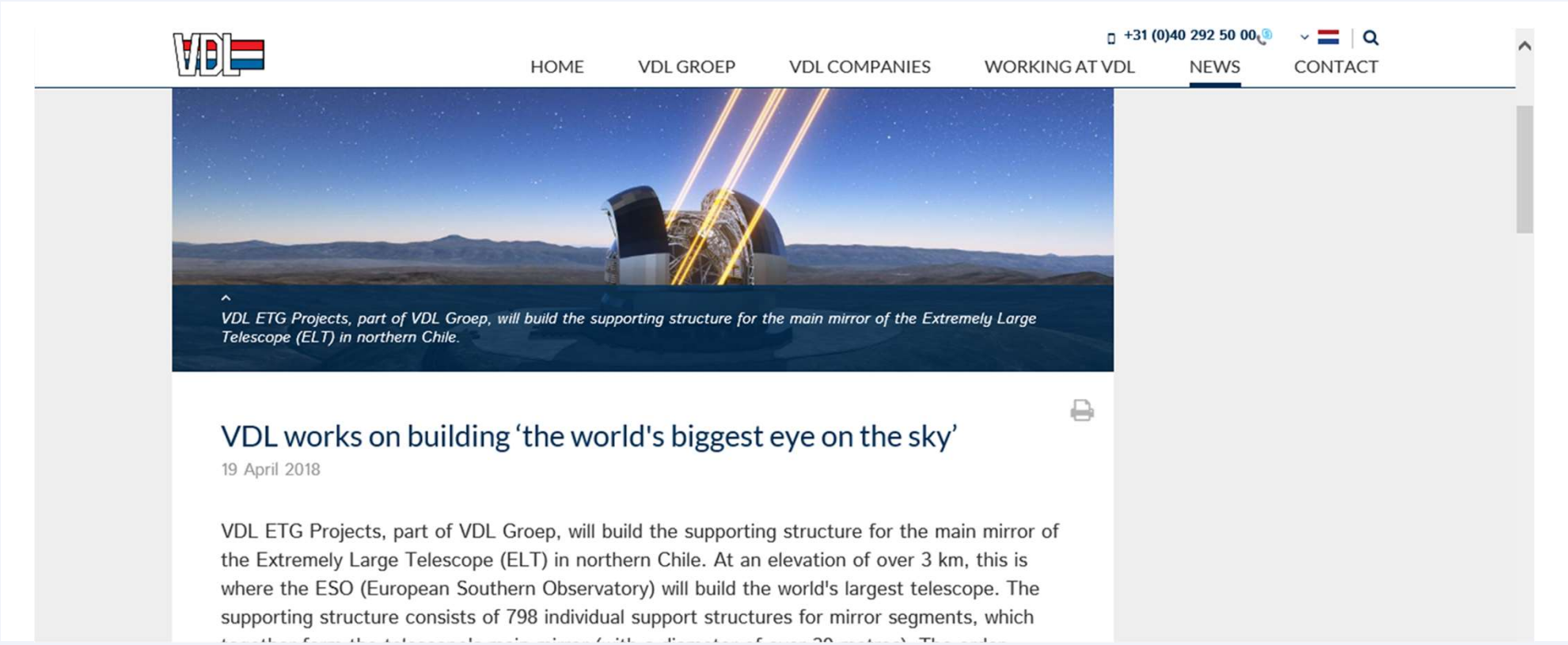
ELT M1 support structure

- ESO's Extremely Large Telescope has a 39m diameter primary mirror, consisting of 798 hexagonal 1.4m segments
- The M1 support structure keeps each segment of each shape within 22nm surface form error, regardless of segment shape and gravity vector
- TNO together with VDL developed 6 prototypes meeting all specs
- Goal of prototype phase: qualify NL for > 30MEUR volume manufacturing contract from ESO for VDL



Space & Scientific instrumentation

VDL ETG wins ESO M1 project



VLT
laser launch telescope

- Laser launch telescopes project an artificial ‘star’ by exciting sodium atoms on the upper atmosphere.
- Observation of this star allows for the characterization of atmospheric turbulence, which can then be compensated for using an adaptive deformable mirror.
- This allows ground-based telescopes to have the clear vision of space telescopes like Hubble
- TNO delivered the laser launch telescopes for ESO’s VLT observatory

Credits: ESO/F Kamphues

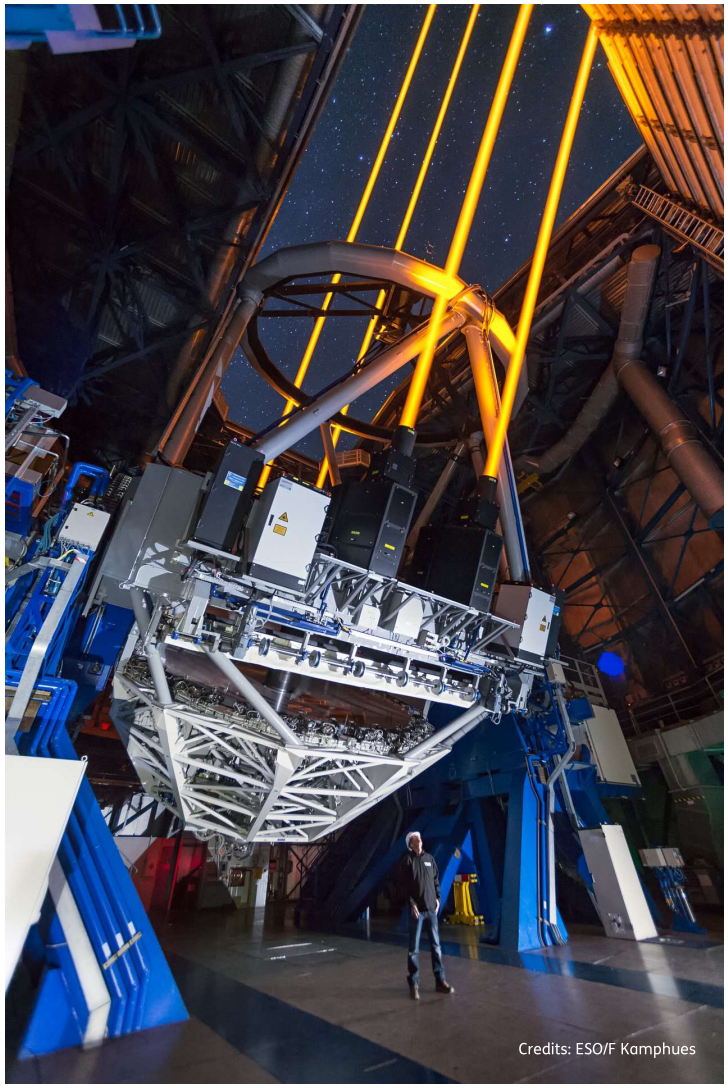
Space & Scientific instrumentation

VLT laser launch telescopes

TNO delivered 4 Laser Launch Telescopes for ESO's 4LGSF in 2012

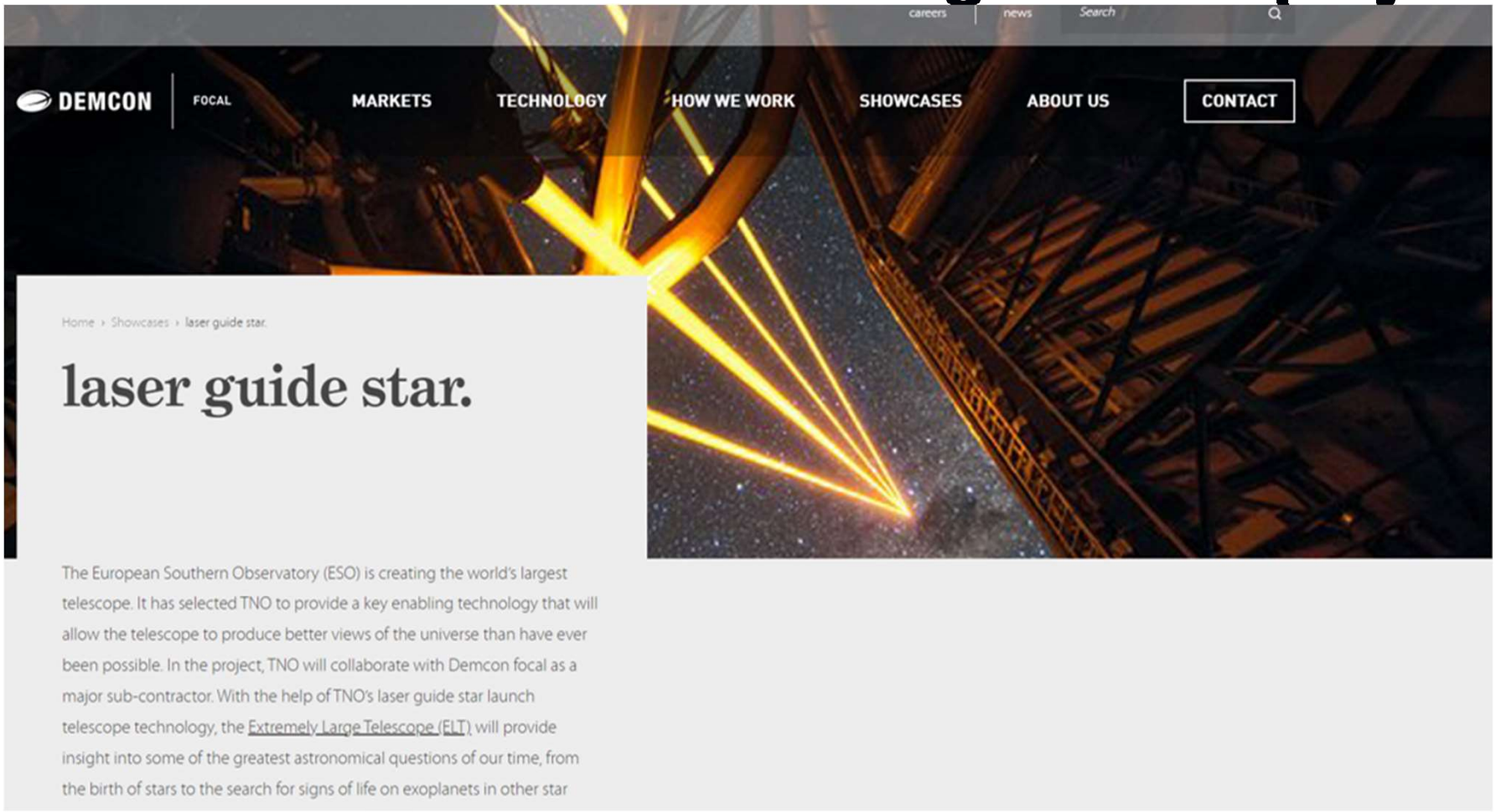
- Large, highly aspheric optics with 17nm transmitted wavefront error
- Fully a-thermal for temperatures (0-150C) & all gradients (0.70C/hr) with <0.2 waves defocus
- Custom in-field pointing with Field Selector Mechanism: 4.8' radius with <0.1" accuracy (3σ)
- In-house (with TU Eindhoven & VSL) developed freeform optics metrology system is now a commercial product (DUI, Dutch sme)

Credits: ESO/F Kamphues


Credits: ESO/F Kamphues

Space & Scientific instrumentation

Demcon & TNO win ELT laser guide star project



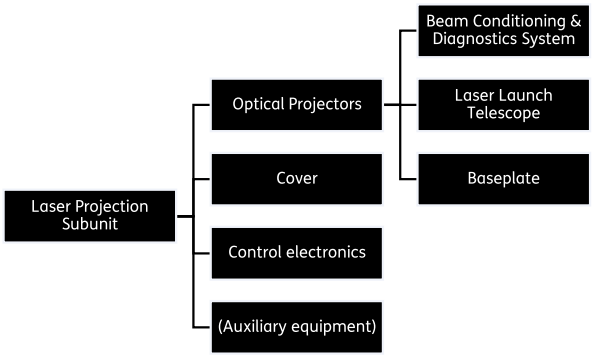
DEMCON TNO innovation for life

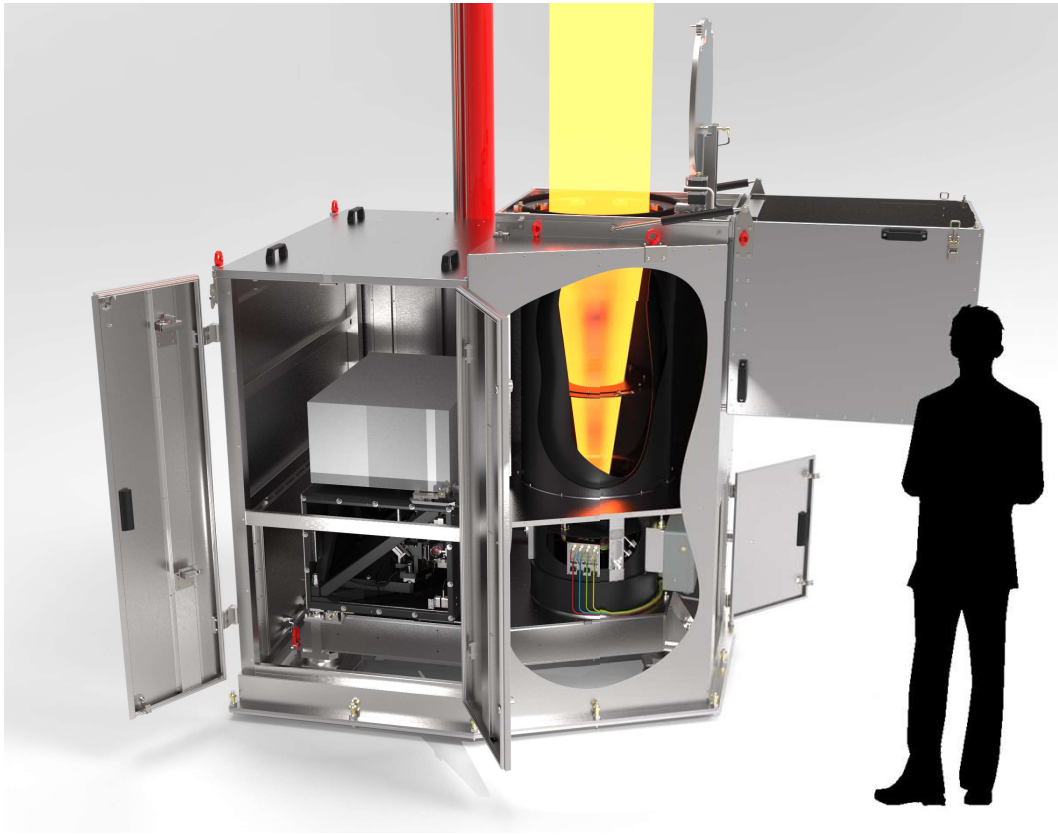
TNO innovation for life

Space & Scientific instrumentation

Laser projection system – 9 units for ELT and VLT Gravity+

- Laser Launch Telescope is passive a-thermal across operational temperature range including gradients
- Variable beam expander controls focus and corrects non-thermal error sources
- Building 9 Laser Projection Subunits (include 3 for VLT upgrade)
- With Dutch company Demcon – took over new BCDS from ESO
- Spare parts, documentation & models
- Future training for observatory personnel





DEMCON TNO innovation for life

Space & Scientific instrumentation

ELT laser projection system – current status

- The first of 9 systems is fully integrated at Demcon HQ.
  - After Test Readiness Review on January 11, the system will be shipped to ESO HQ where TNO will perform verification testing.

- Formal delivery to ESO is scheduled for June 2024.
  - The first 3 units will go to the VLT Gravity+ instrument, the next 6 are for ELT itself.

Above right: ELT OTA1 subsystem integration ready at TNO
Below right: The complete first LPS – prior to EMC testing at Demcon


TNO - DEFORMABLE MIRROR TECHNOLOGY
TNO innovation for life

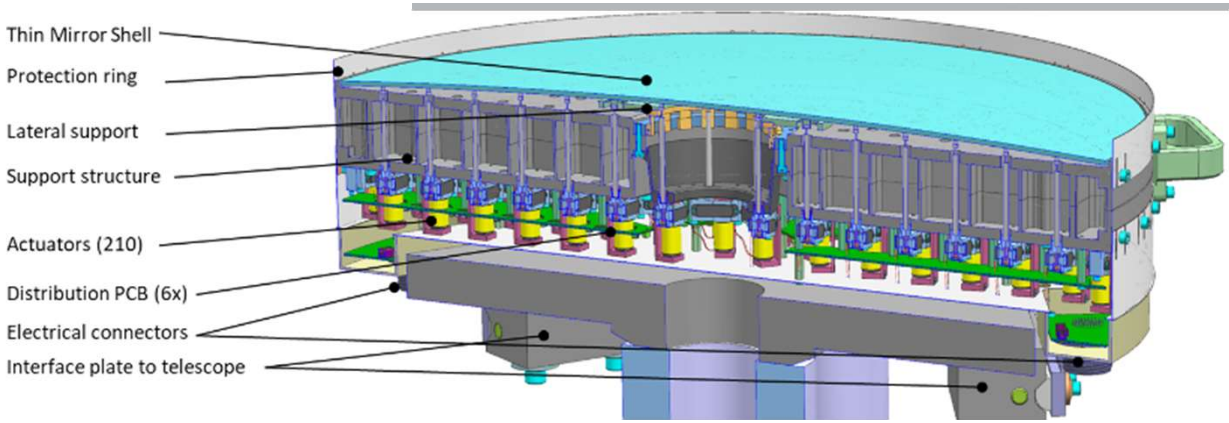
Space & Scientific instrumentation

Adaptive M2 for University of Hawai ʻi 88-inch Telescope

- TNO concept offers far higher reliability at lower cost to user
- Funding: 1,5MEUR including partner investments
- Status: finalizing, on-sky demonstration by 2024

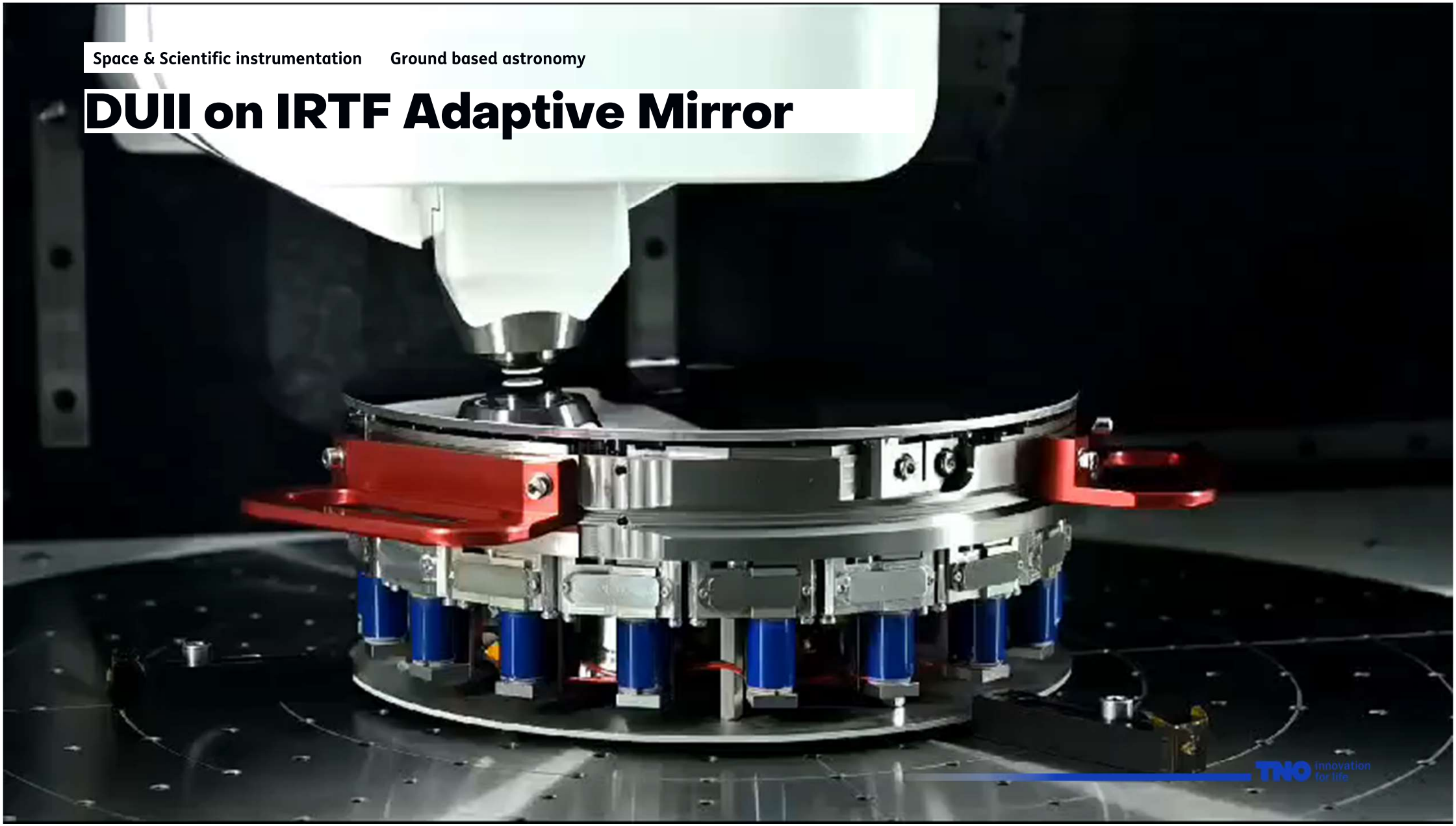
Consortium partners

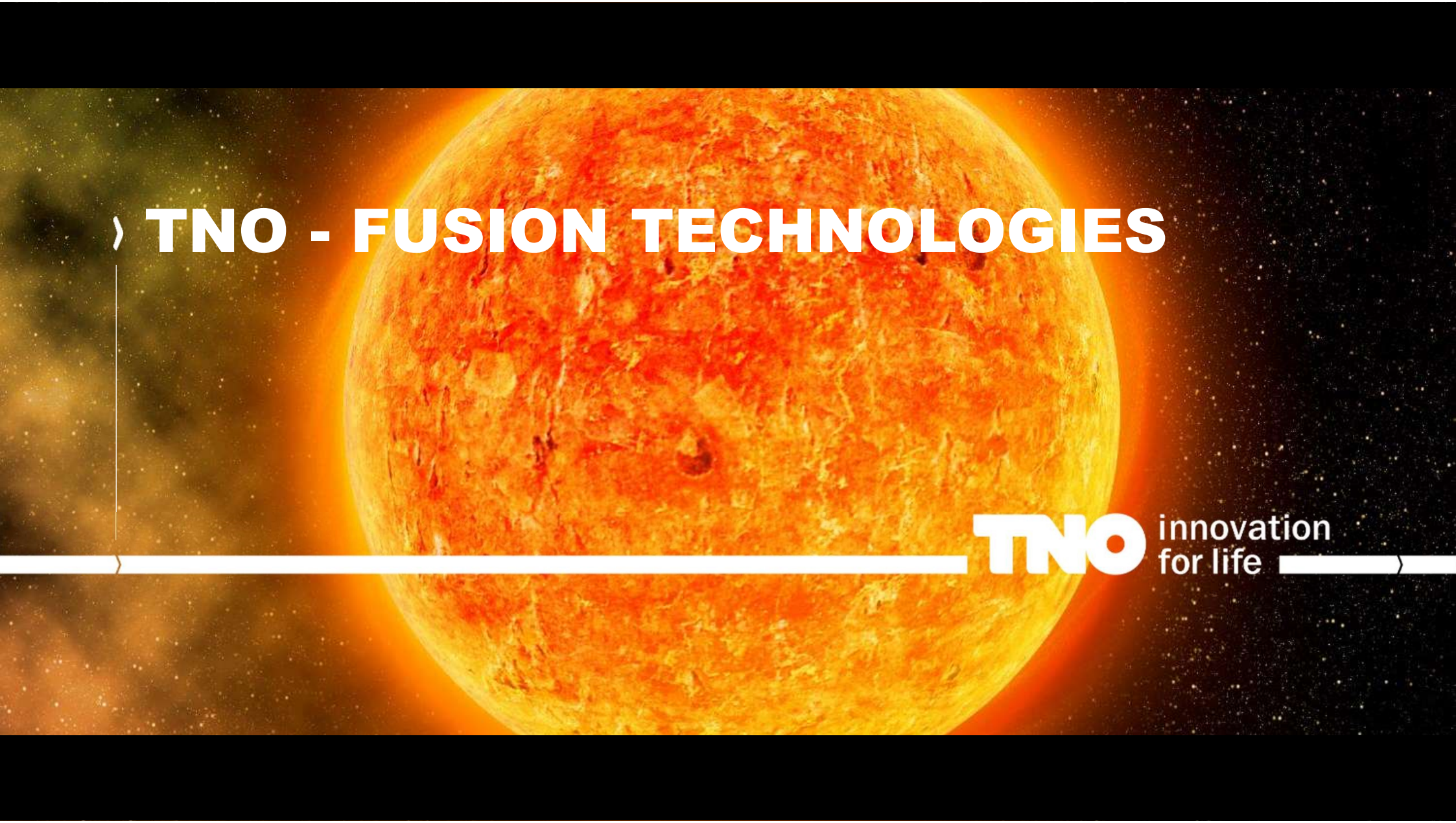
- University of Hawaii (US): advisor and launching customer
- University of California (US): test and research partner
- TNO (NL): development and performance testing
- VDL (NL): actuators & support structure manufacturing
- AAC Clyde Space (NL): electronics development
- Fraunhofer (DE): facesheet pre-forming
- NOVA (NL): facesheet finishing



Space & Scientific instrumentation Ground based astronomy

DUII on IRTF Adaptive Mirror

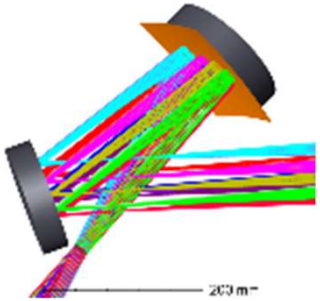


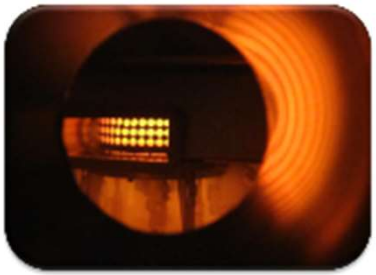

TNO - FUSION TECHNOLOGIES
TNO innovation for life

OVERVIEW OF FUSION ACTIVITIES

Key Product Market Combinations (PMCs)

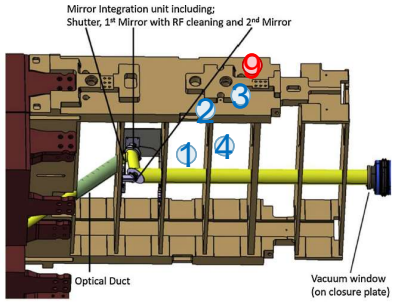
- Diagnostic System Design and Engineering
- Plasma Cleaning Systems

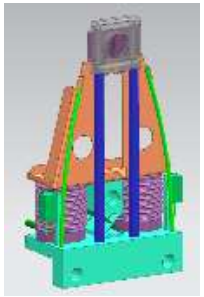


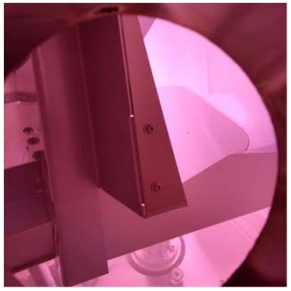


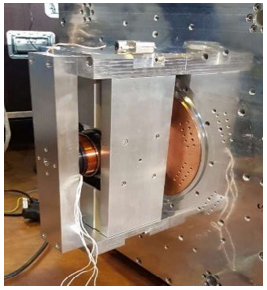
Co-operations

- ITER-IO, ITER-NL, ITER-Japan
- DIFFER, AST-NL, ChromoDynamics
- General Atomics, Princeton Plasma Physics Law
- IDOM









Space & Scientific instrumentation

Questions?

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