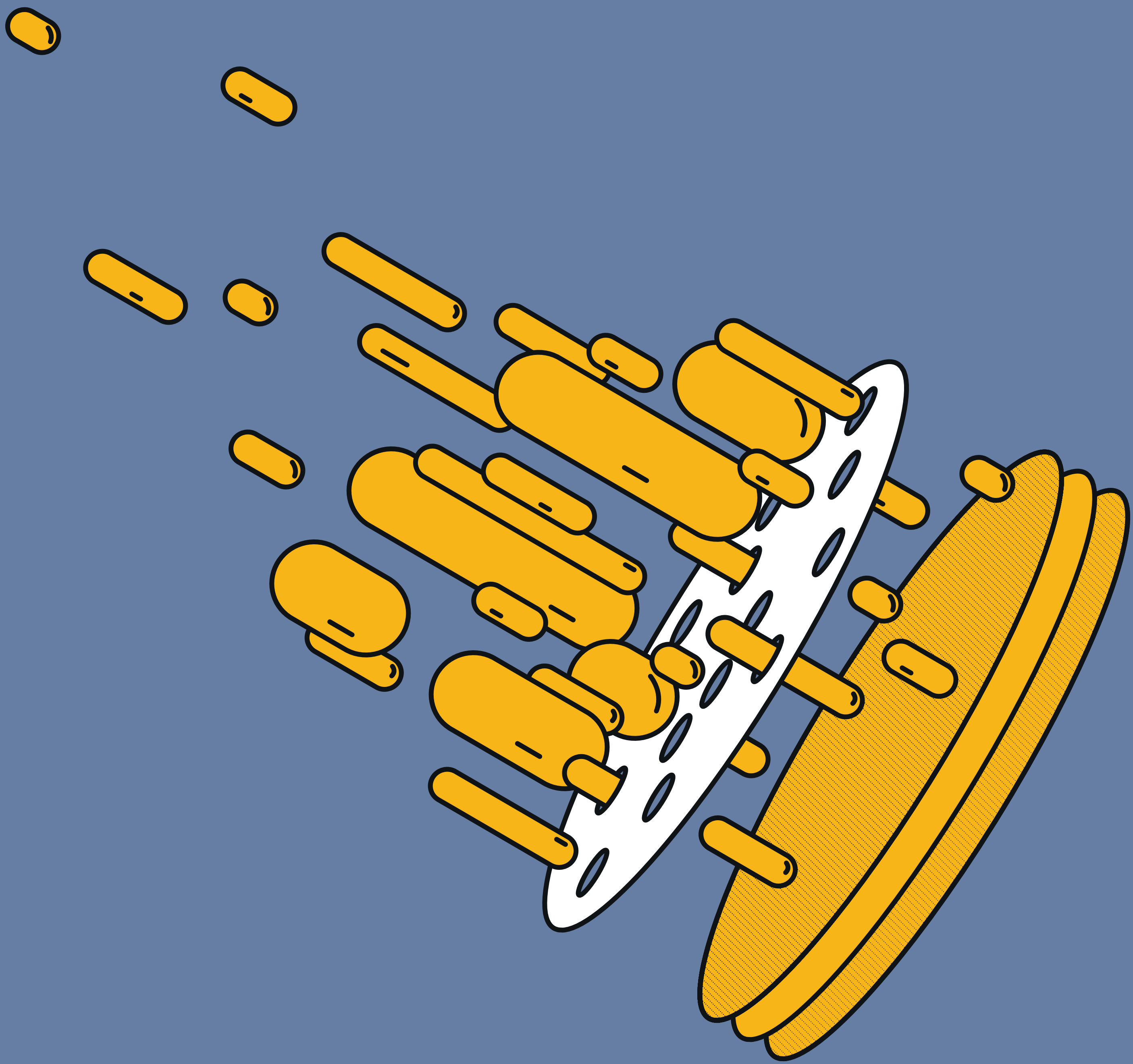
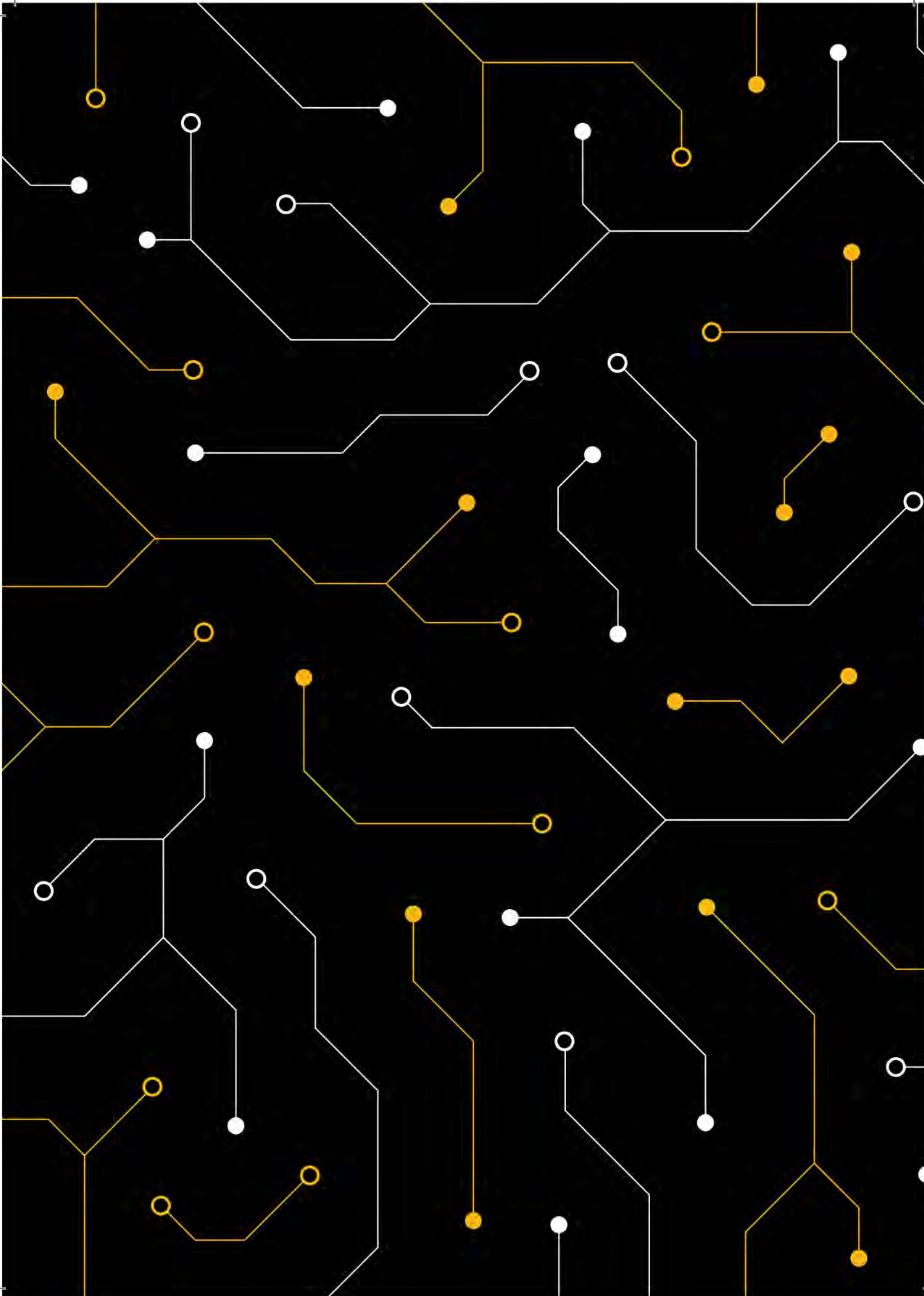
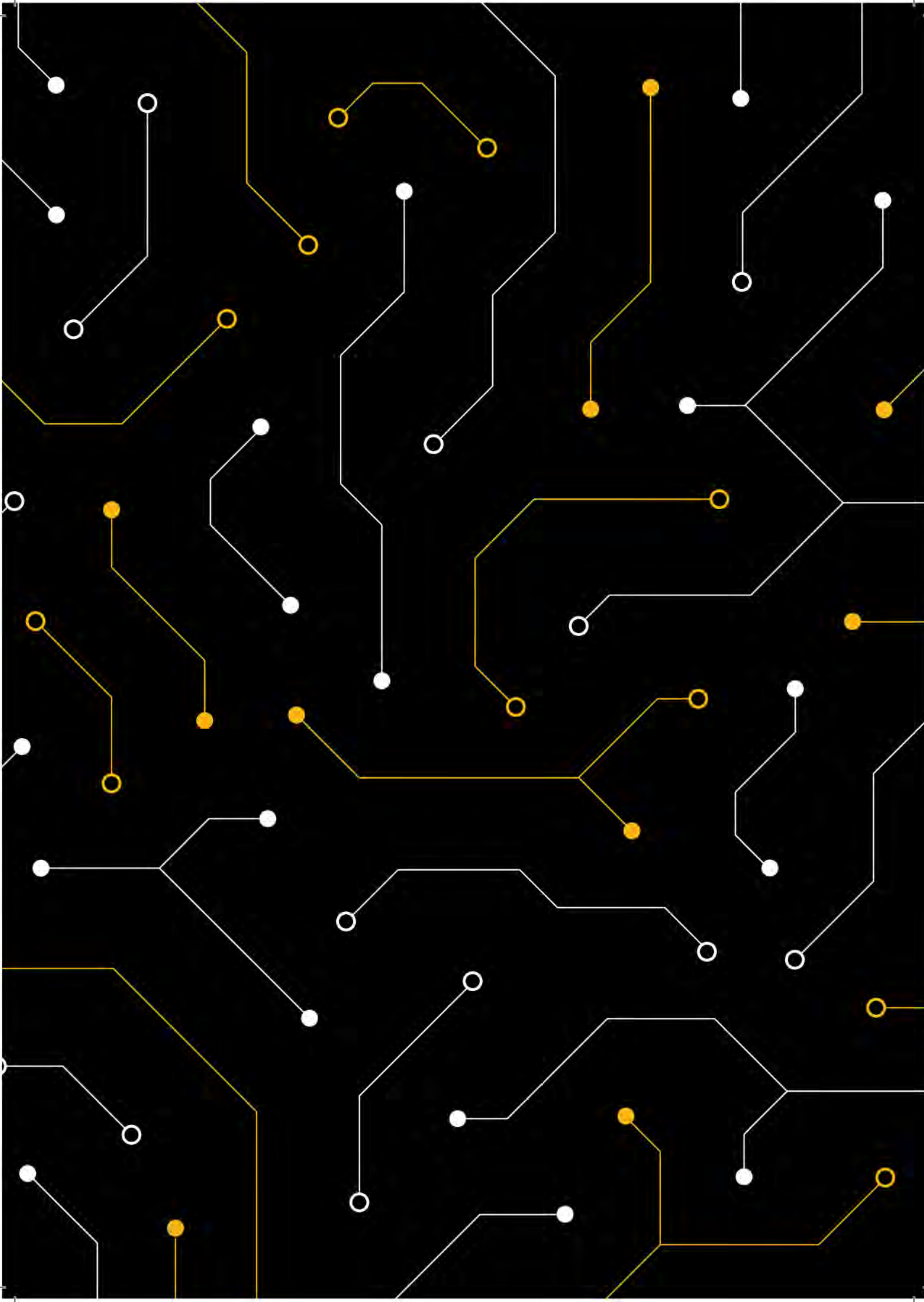


ESA'S TECHNOLOGY STRATEGY





CONTENTS

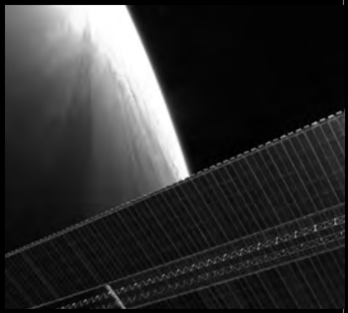
05/ FUTURE MISSIONS TECHNOLOGY NEEDS

06/ PRIORITY TECHNOLOGY THEMES

07/ TECHNOLOGY DEVELOPMENT TARGETS

08/ COMPETENCE DOMAINS

09/ TECHNOLOGY PORTFOLIO



ESA'S TECHNOLOGY STRATEGY IN NUMBERS

01

ESA'S TECHNOLOGY STRATEGY IN NUMBERS

30 %

improvement in spacecraft development time by 2023

We develop key technologies to allow ESA to reduce the time from Phase B2 to launch.

2030

target year for inverting Europe's contribution to space debris

We develop technologies that allow us to leave the space environment in a better state for the next generation.

10 x

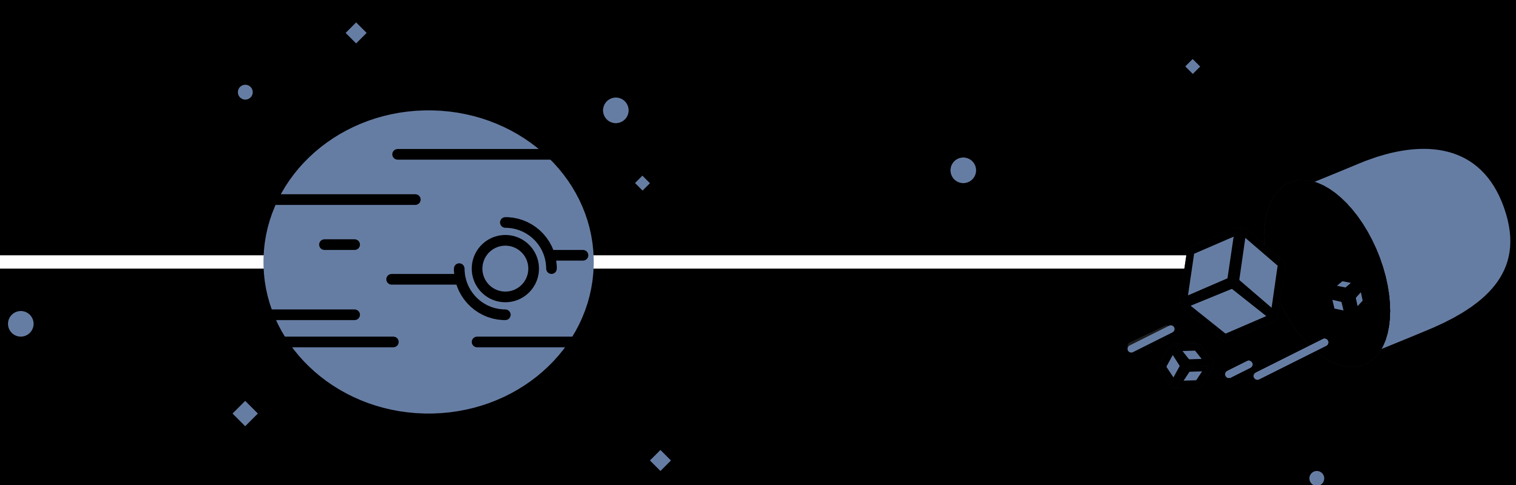
improvement in cost efficiency with each new generation

We develop key technologies to allow Europe to achieve a one order of magnitude improvement in cost efficiency with every space system generation.

30 %

faster development and adoption of innovative technology

We develop processes, methods and technologies to allow Europe to more quickly take full benefit from the early introduction of new technologies into space systems, thus enabling new applications.



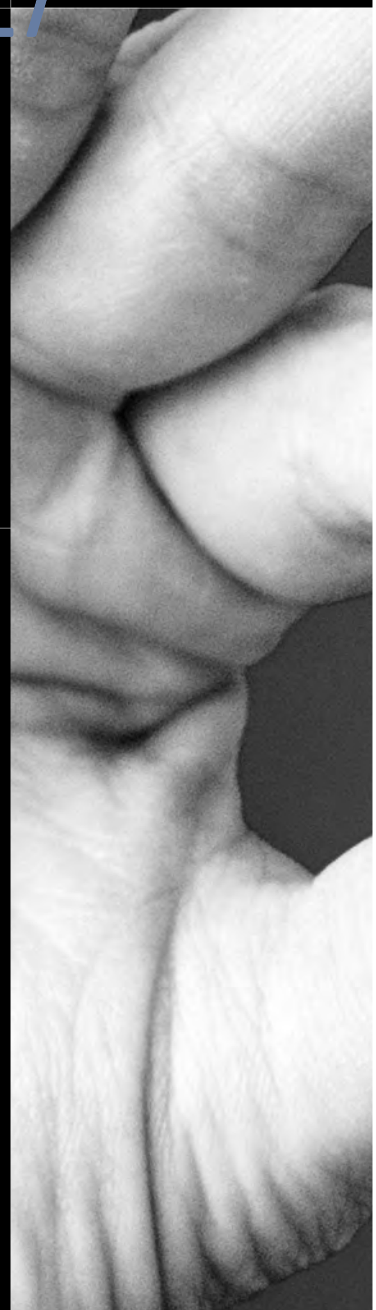
MEET ESA’S RESEARCHERS AND DEVELOPERS

02

MEET ESA'S RESEARCHERS AND DEVELOPERS

1/

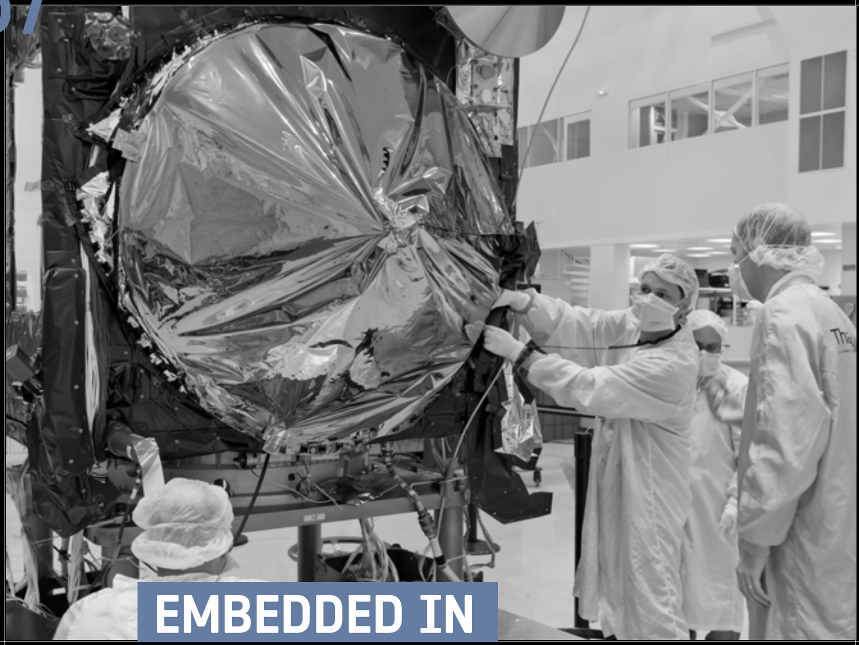
2/



MAKING ESA MISSIONS POSSIBLE

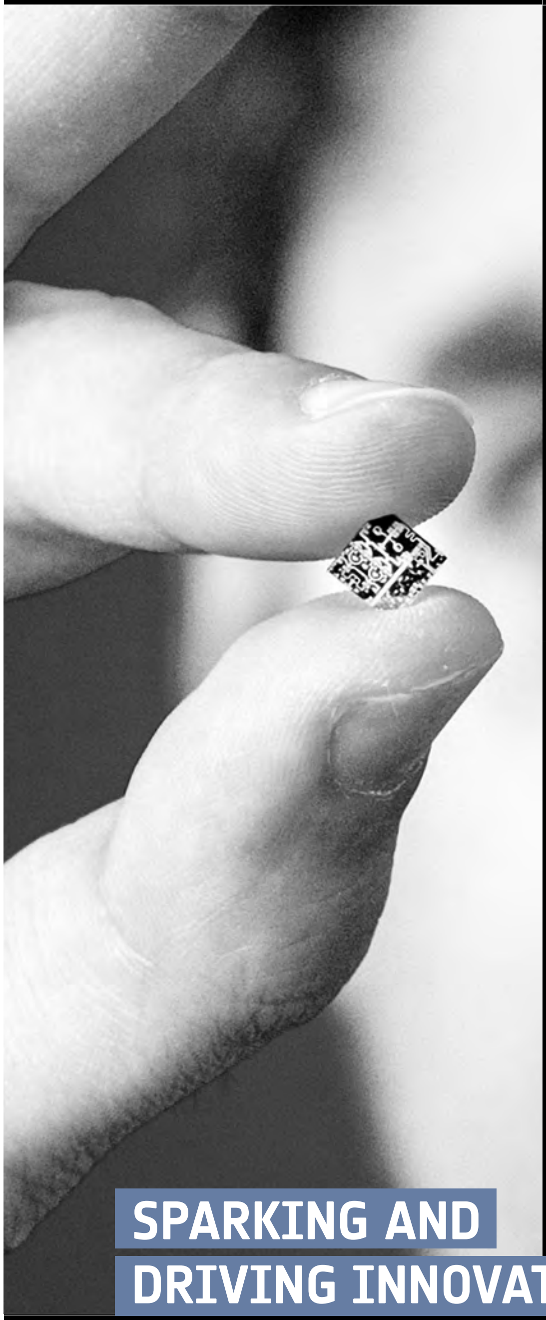
- adapting to a changing space market and changing user needs
- developing technological building blocks that will provide flexibility and modularity to reduce development times
- leveraging downstream commercial technological developments
- using off-the-shelf devices and components smartly

3/



EMBEDDED IN MISSION TEAMS

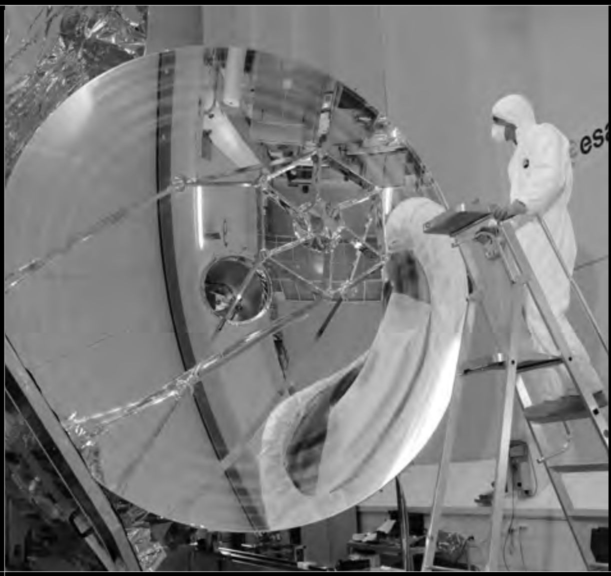
- developing critical technology that enables ESA missions
- developing technology to enhance ESA missions
- creating innovative data processing and analysis tools
- enabling technologies on the frontier of what is technically and scientifically achievable



SPARKING AND DRIVING INNOVATION

- fostering novel technology that encourages unique capabilities
- investing in joint lab facilities for faster spin-in of terrestrial technologies to space applications
- investing in high-risk, high-gain technologies that encourage innovative partnership approaches with academia and industry

PUSHING THE BOUNDARIES: ESA MISSIONS MADE POSSIBLE



01/

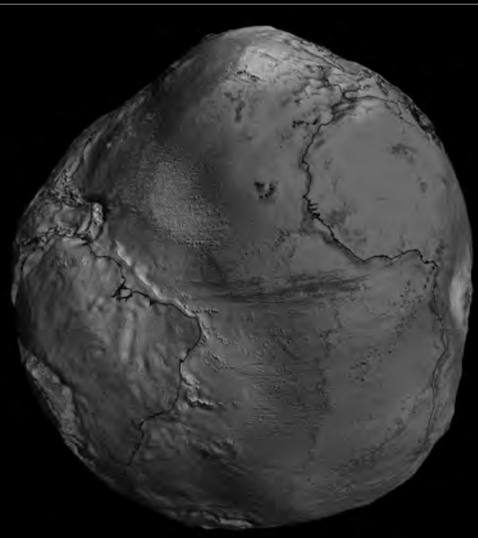
LARGEST TELESCOPE IN SPACE (3.5 METRE MIRROR)

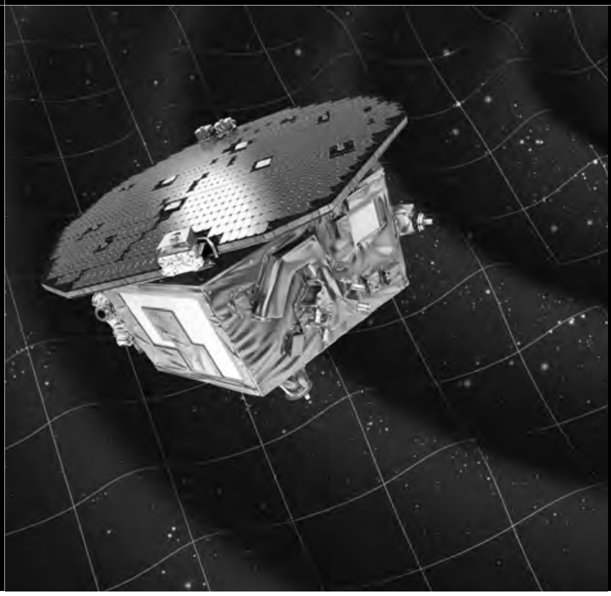
ESA's 2009-launched Herschel infrared telescope used the largest single reflecting mirror ever flown: measuring 3.5 metres across, it had twice Hubble's collecting area.

02/

MOST ACCURATE GRAVITY MAP OF EARTH

ESA's GOCE mission delivered the most accurate model of the 'geoid' ever produced, which will be used to further our understanding of how Earth works.





03/

QUIETEST PLACE IN SPACE

LISA Pathfinder is paving the way for gravitational wave detection by testing novel technologies including an ultra-stable laser metrology system and an ultra-precise micro-propulsion system.

04 /

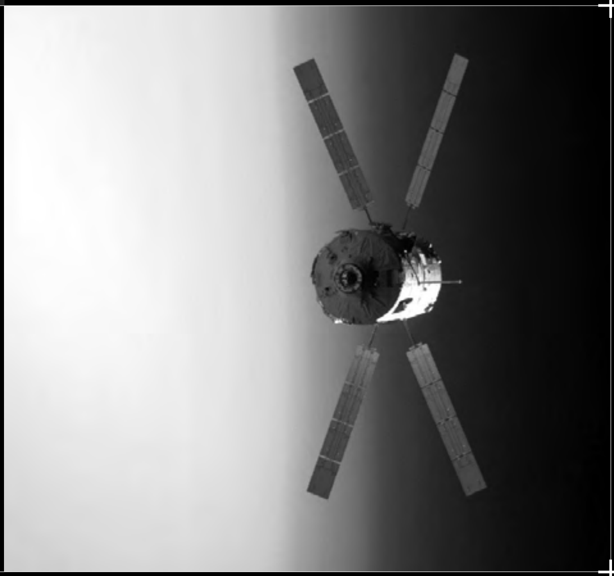
COLDEST OBJECT EVER IN SPACE (-273.25°C)

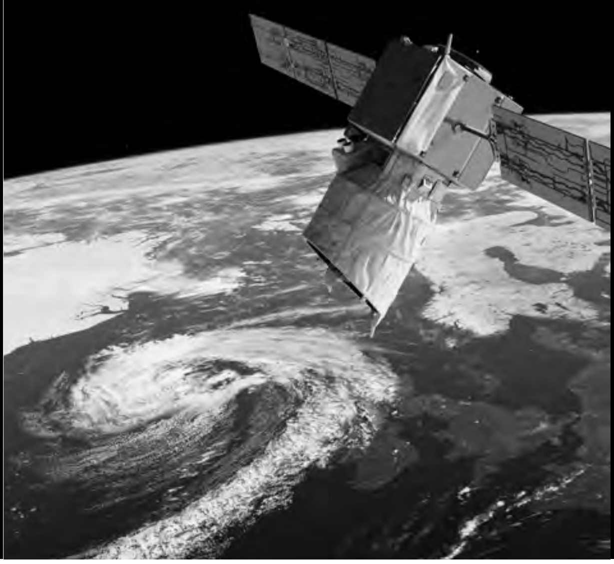
In 2009, ESA's Planck mission to measure the cosmic microwave background radiation included a detector cooled to just a tenth of a degree above absolute zero.

05 /

FIRST FULLY-AUTOMATED DOCKING WITH THE INTERNATIONAL SPACE STATION (2008)

Astronauts only watched as ESA's Automated Transfer Vehicle undertook its first ISS docking in 2008.





06 /

FIRST DIRECT MEASUREMENT OF THE WIND ON A GLOBAL SCALE

Launched in 2018, ESA's Aeolus mission uses unique and revolutionary laser technology to address one of the major deficits in the Global Observing System.

CHANGING SPACE

03

CHANGING SPACE

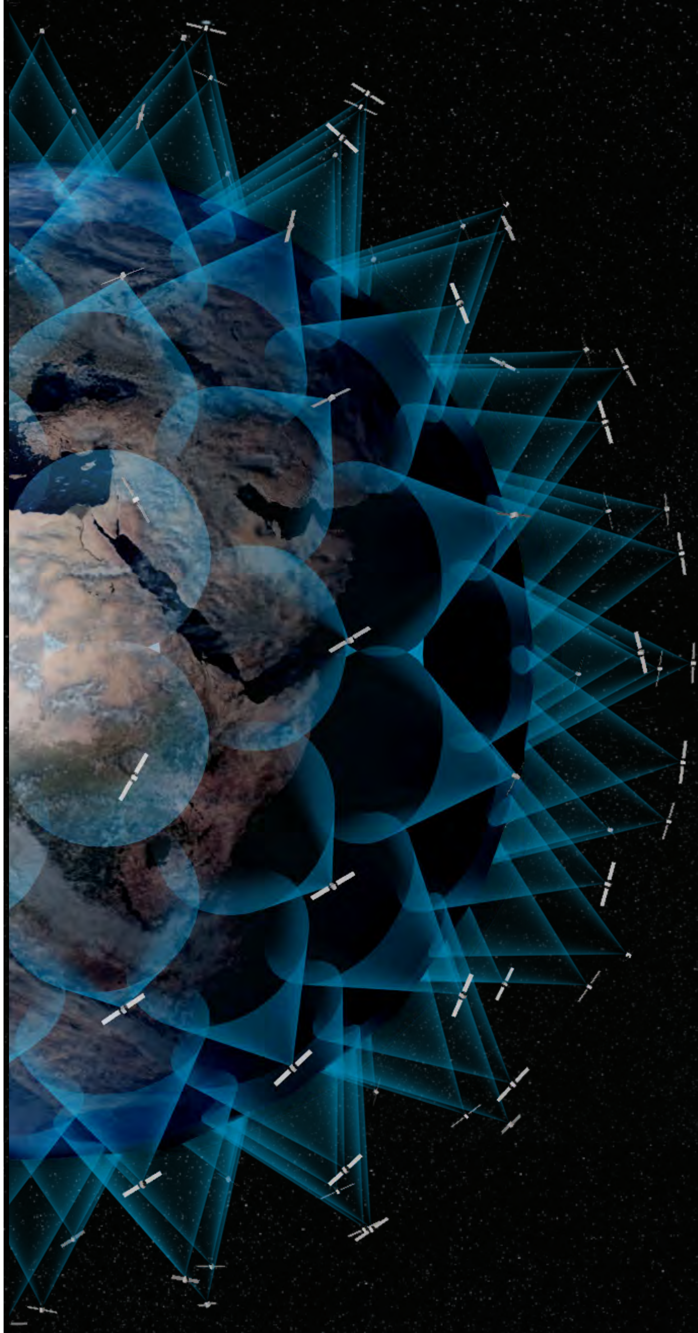
"RARELY HAVE THERE BEEN SUCH EXCITING TIMES IN THE HISTORY OF SPACE TRAVEL AS TODAY. START-UPS WITH SERIOUS PLANS FOR THE COMMERCIAL EXPLOITATION OF SPACE ARE LITERALLY SHOOTING UP OUT OF THE GROUND EVERYWHERE." - Marco R. Fuchs, Chief Technology Officer, OHB SE

"OUR WORLD TODAY IS MOSTLY DRIVEN BY DATA, IN PARTICULAR THE NEED TO GENERATE AND TRANSMIT MORE AND MORE DATA AND GENERATE USEFUL INFORMATION OUT OF THEM." - Patrick Mauté, Chief Technology Officer, Thales Alenia Space

"THIS PART OF THE MARKET WANTS A FLEXIBLE PRODUCT AT AN AFFORDABLE PRICE, WITH MUCH FASTER DEVELOPMENT AND DELIVERY, CONSTANTLY HARNESSING TECHNOLOGY BREAKTHROUGHS." - Arnaud de Rosnay, Chief Technology Officer, Airbus Defence and Space

With more and more space products being integrated into modern economies, the space sector is maturing quickly. There is increased private sector investment by those who have never before set foot in the world of space. Such commercial approaches to space activities are contributing to the overall competitiveness of the European space sector.

This means that cost-effectiveness and time to market are assuming a more central role in the development of space systems, resulting in the need to speed up and reduce costs for satellite design, manufacturing, assembly, integration and testing. In addition to this, the global economy is becoming ever-more data dependent and there is an increasingly widely shared vision that space could be transformative for humanity. Terrestrial technological advances are also creating expectations of more cost-effective space activities.



"THAT MEANS CREATING OUR MANUFACTURING FROM SCRATCH, FOLLOWING A 'DIGITAL FACTORY 4.0' APPROACH." - Herve Gilibert, Chief Technology Officer, ArianeGroup

"THE SPACE SECTOR WORLDWIDE IS GOING THROUGH RAPID EVOLUTIONS AND ON TOP OF THAT, SPACE POWERS ARE DEVELOPING OFFENSIVE STRATEGIES THAT CHALLENGE EUROPE'S POSITIONS IN SPACE." - Jean Loic Galle, Chief Executive Officer, Thales Alenia Space | Eurospace President

"INCREASED USE OF COMMERCIAL-OFF-THE-SHELF ITEMS IS PROBABLY THE MOST IMPORTANT THING." - Arnaud de Rosnay, Chief Technology Officer, Airbus Defence and Space

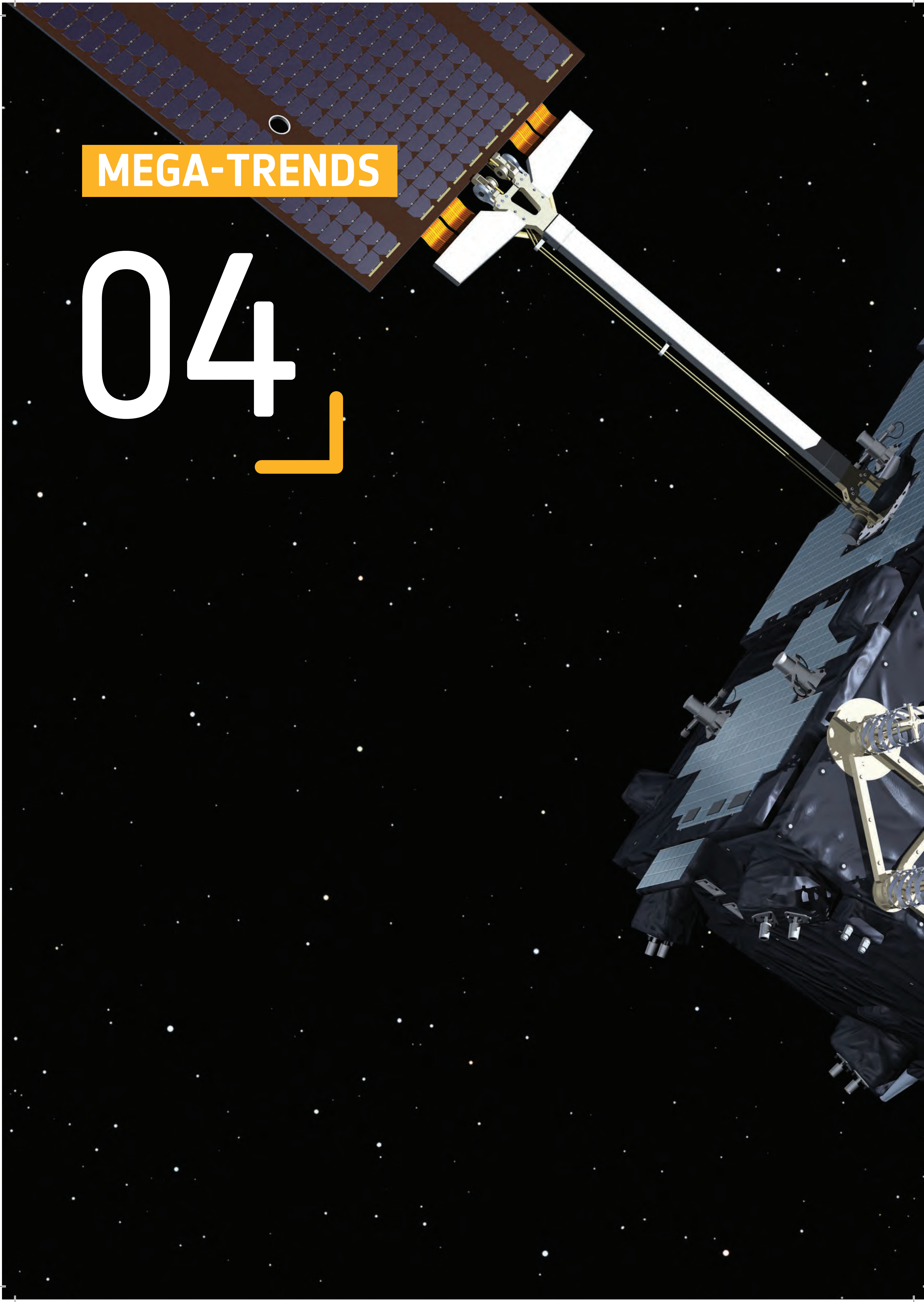
"IN SPACE, WE ARE INCREASINGLY REACHING THE LIMITS OF WHAT IS TECHNOLOGICALLY POSSIBLE. THE THINGS THAT ARE CURRENTLY NOT YET POSSIBLE MUST FIRST BE DEVELOPED OR INVENTED. THE REQUIREMENTS ARE EXTREME, INTENSIVE AND CHALLENGING." - Carsten Borowy, Head of the Department for Future Telecommunications Projects, OHB SE

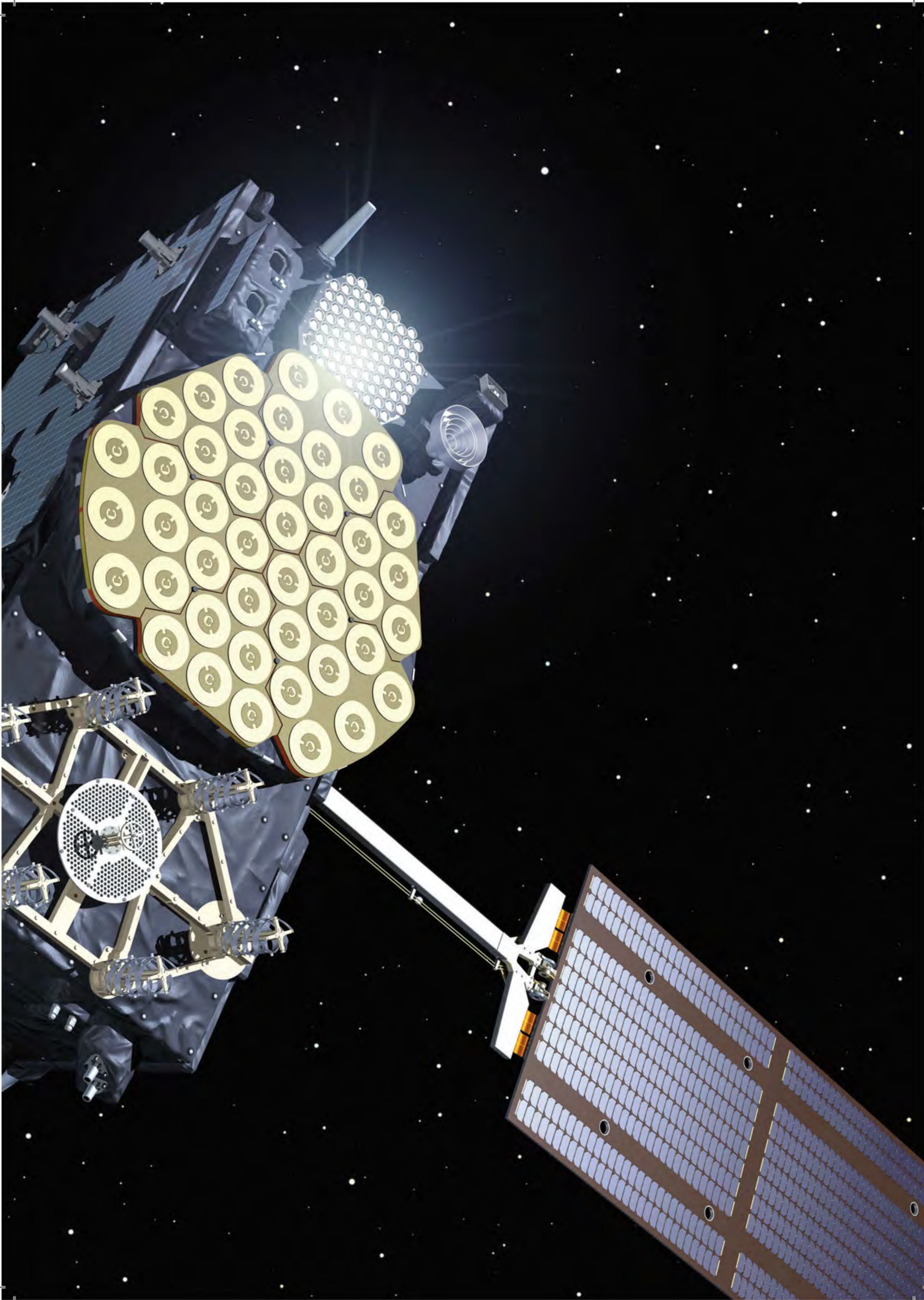
Therefore, ESA needs to support industry with technology that helps reduce production costs and increase production rates, while fostering novel technology that encourages unique capabilities.

Venture capital and seed investment in space start-ups is steadily increasing. The ESA technology development portfolio will take advantage of this evolving space market and will put ESA into a supporting, structuring and directing role.

MEGA-TRENDS

04





MEGA-TRENDS

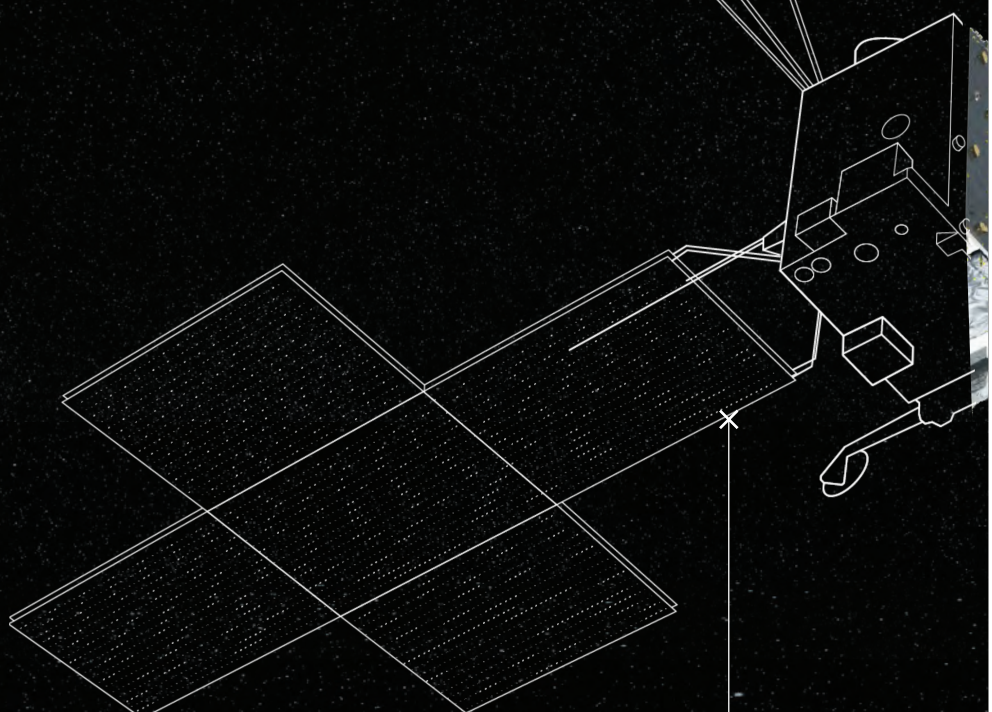
Space is changing, and technology is enabling and driving the change. The maturation of the space sector and the integration of new space products into modern economies implies the serving of new customers and design of new space systems. ESA needs to support industry with technology that helps reduce production costs and increase production rates, while fostering novel technology that encourages unique capabilities.

CYBERSECURITY

Global annual cybercrime costs are estimated to be on the scale of a trillion dollars and are expected to substantially increase over the coming years. Space systems, now interwoven with terrestrial infrastructure, are not immune to cyberattacks. Cybersecurity therefore has become a critical requirement for the next generation of space systems.

QUANTUM TECHNOLOGIES

Quantum technology makes use of the properties of quantum mechanics for practical applications such as computing, sensors, cryptography, metrology and imaging. Many of these are currently moving from laboratory testing to early applications, and promise to spark revolutionary advances in the performance of existing systems, as well as create completely new ones.

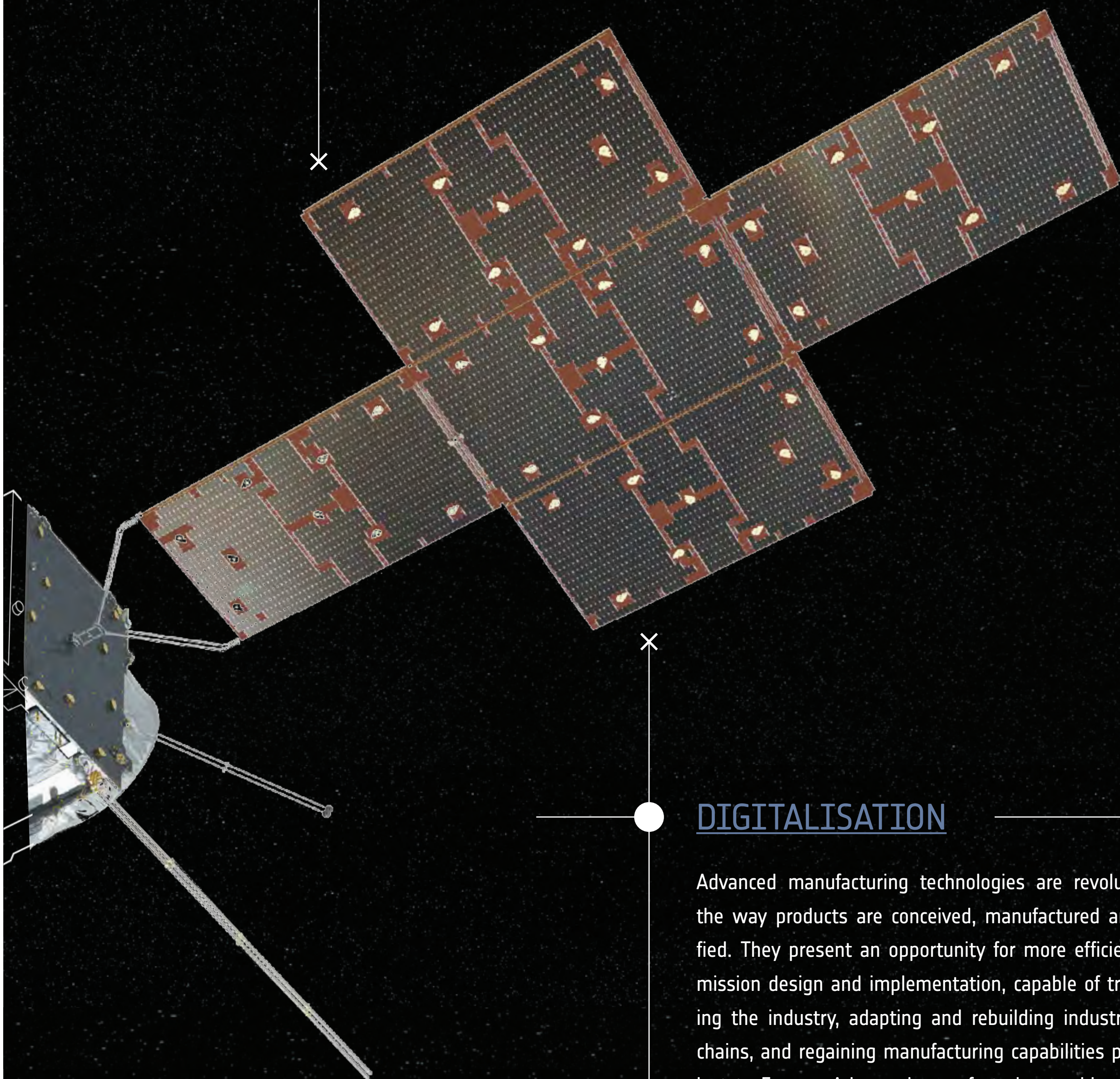


ARTIFICIAL INTELLIGENCE

Considered to be at the core of the next wave of digital disruption, artificial intelligence is accelerating competition and speeding up digital transformations. ESA has long been at the leading edge of space-related artificial intelligence research. European space industry and services capitalise on previously academic-driven research, with first applications already operational.

BIG DATA

The exponential increase in affordable computing power and ubiquitous sensors has led to extremely large datasets that reveal trends, patterns and associations based on machine learning. Data management tools are particularly useful for Earth observation datasets, which are large by nature.



DIGITALISATION

Advanced manufacturing technologies are revolutionising the way products are conceived, manufactured and qualified. They present an opportunity for more efficient space mission design and implementation, capable of transforming the industry, adapting and rebuilding industry supply chains, and regaining manufacturing capabilities previously lost to Europe. Advanced manufacturing enables a transition from a traditional 'design, build and test' approach to a more agile 'analyse then build' approach.

FUTURE MISSIONS TECHNOLOGY NEEDS

05


STOP

FUTURE MISSIONS TECHNOLOGY NEEDS

01/

OPERATIONS

With rapid commercialisation and the high demands of new missions, innovation in operating spacecraft is needed. Key technology needs include innovative concepts for ground segments and operations processes, the introduction of artificial intelligence, data analytics and augmented/virtual reality that result in a faster time to market and reduced duplication.

SPACE TRANSPORT

ESA's Space Transportation programmes guarantee independent, reliable, available and competitive launch services for European missions. Key technologies to be developed include those that enable low-cost propulsion systems, lightweight structures, advanced avionics, reusable systems, recurring launch services, orbital manoeuvrability and transport solutions for exploration missions.

TELECOMMUNICATIONS

Consumer demands include increased connectivity, a ten-fold reduction of cost per bit, a 50% reduction of time to market, higher data rate broadband, low latency solutions and communication security. To satisfy these needs, new technology solutions are required, including millimetre-wavelength communications, digital processing, optical communications and smart antennas. In addition, large telecommunications constellations require extra attention in the context of using space sustainably.

NAVIGATION

Satellite navigation allows a person to determine their position as well as to map a course from one place to another. Developments are required in technologies that focus on precise and low energy positioning, hybridisation of different positioning systems, security, network timing and synchronisation and better exploitation of GNSS data for interference monitoring and scientific applications.

Applications

Enabling & Support

EARTH OBSERVATION

ESA's world-class Earth observation missions address many scientific and societal issues. The main technology thrusts for future Earth observation missions are higher performance, higher lifetime, increased flexibility, miniaturisation, constellations, lower costs, fast-to-market ability, adaptability and flexibility.

SPACE SAFETY

Space is a hazardous environment, and the growing importance of space infrastructure puts additional focus on potential risks. Technologies to manage such risks can be classified into those that detect and analyse threats, those for prevention, protection and mitigation, and those that respond to any dangers that do occur.

EXPLORATION

We are on the verge of an international drive to send robots and humans to the Moon and Mars. Sustainable exploration needs technological advances in the fields of advanced propulsion, life support, autonomy/navigation, energy and in-situ resource utilisation technologies.

SCIENCE

ESA's Science missions require the development of emerging, enabling technologies at the frontier of what is technically and scientifically achievable. These missions have high requirements, for example stability, accuracy, precision and processing, that push technical feasibility to enable cutting-edge science.

08/

- Science & Exploration
- Safety & Security
- Applications


05/
06/
07/

PRIORITY TECHNOLOGY THEMES

06

PRIORITY TECHNOLOGY THEMES

01 ADVANCED MANUFACTURING

There is a need for more flexibility to adapt late in the space system design and development process to react quickly to market needs. ESA is identifying and spinning-in disruptive materials and manufacturing processes already available in non-space sectors. This allows for faster development, shorter lead times for components, increased flexibility and associated cost benefits.

Novel advanced manufacturing technologies include additive manufacturing, solid state joining, processing of advanced composite materials and forming technologies of large structures to create new high-performance space products. Some of these processes are readily available but need to be matured to a level suitable for space use, placing the focus on the verification and qualification process.

ESA will stimulate the space industry supply chain, improving cost, scheduling and sustainability, while maximising the performances of the final space products. The final goal is to revitalise and consolidate European leadership in advanced manufacturing for space applications.

02 DIGITAL DESIGN TO PRODUCE

Digital engineering is currently enabling a revolution in the way spacecraft are designed, developed, tested and operated. Processes are becoming more focused on an integrated, digital model-based approach. This model-centric (rather than the traditional document-centric) analyse and build process is more suited to the new space environment.

At the heart of the initiative is to design space systems towards manufacturability, integration and verification, with the end result being that development time is reduced and manufacturing, assembly, integration and testing is simplified. To achieve these goals, ESA is supporting the space industry to set up partnerships and pilot projects with specialised non-space actors.

ESA will spin-in and demonstrate the core technologies to design space systems to be fully integrated into modern economies.

03

CLEAN SPACE

ESA's CleanSpace initiative focuses on securing the future of space activities by leaving the space environment in a better state for the next generations.

ECODESIGN: ESA has been pioneering life cycle assessments for missions, from understanding the impact of launches, to the environmental footprint left by satellites and ground segments. This has led to innovative solutions that decrease environmental impact.

CLEANSAT: ESA aims to mature technologies necessary for space debris mitigation. CleanSat will bring technologies for uncontrolled or controlled re-entry closer to their systematic use in future missions. Priority areas are power and propulsion passivation, design for demise and effective controlled re-entry.

ACTIVE DEBRIS REMOVAL: Satellites reaching the end of their lives need to be removed from congested orbits, but further technology developments are needed to ensure all future spacecraft can be removed from orbit. In-orbit servicing is maturing but achieving it will require advancements in several technology fields.

04

CYBERSECURITY

An increasingly hostile and aggressive cyber environment at a time when connectivity is ubiquitous raises the importance of cyber security. Spacecraft are becoming increasingly integrated within larger ground systems, opening up a new vulnerability to cyber-attacks.

There is a need to address cybersecurity threats originating in space which endanger space assets and their Earth-based supporting infrastructure. Many technology developments are required to tackle such threats, including those that can monitor cyber threats, detect and report threats, analyse incidents, and manage cyber defence.

The importance of defending space assets and activities from cyber attacks will increase as space becomes more strongly integrated in other sectors.

TECHNOLOGY DEVELOPMENT TARGETS

07

TECHNOLOGY DEVELOPMENT TARGETS

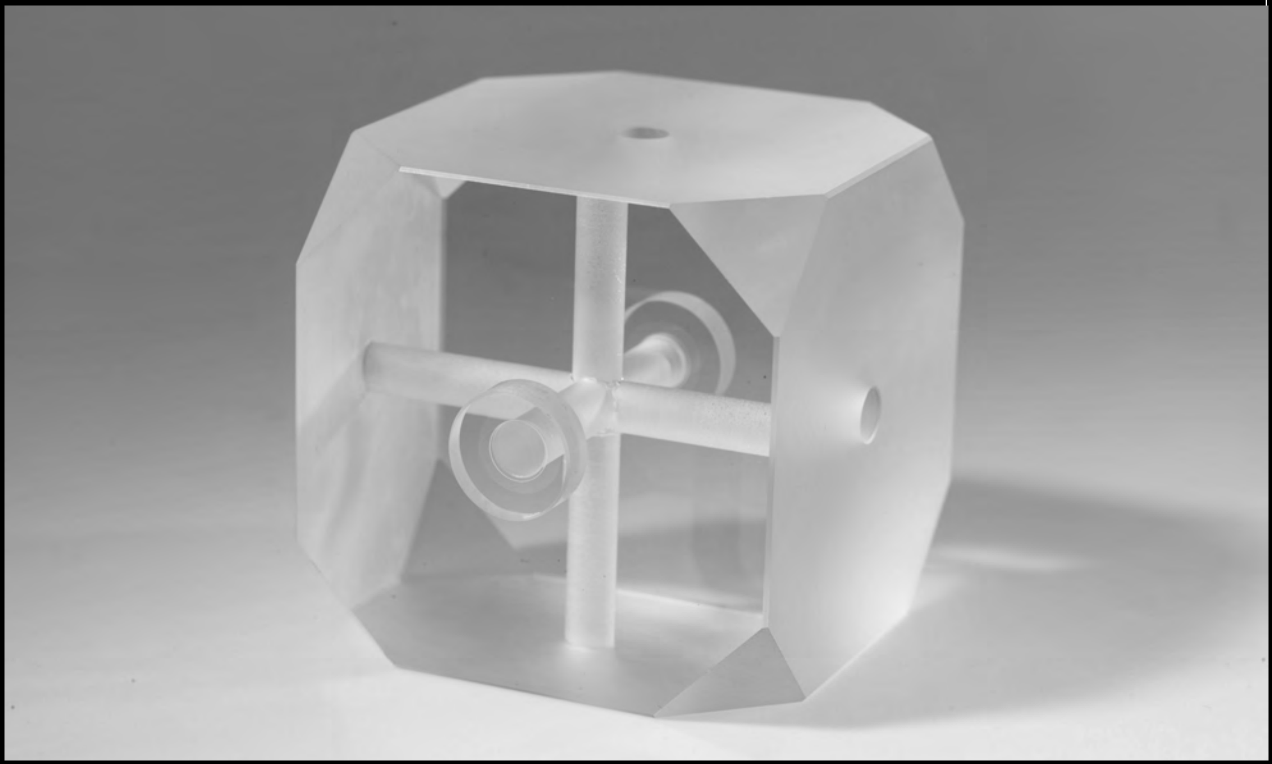
30% IMPROVEMENT IN SPACECRAFT DEVELOPMENT TIME BY 2023

We are developing key technologies to reduce the time between the adoption of ESA missions and their launches. Compared to more traditional technologies, these will digitalise workflows, and increase flexibility, scalability and adaptability. Technology developments from all competence domains will be critical to achieving this goal. Developing processes that quickly introduce terrestrial technology into the space industry is vital.

Reaching this target will largely depend on the success of introducing digital engineering and advanced analytics based on big sensory data, automation and artificial intelligence. The design-to-produce and advanced manufacturing initiatives will be essential in developing relevant technology and processes.

- Developing technologies that digitalise workflows
- Advancing technologies for increased flexibility, scalability and adaptability
- Developing processes that quickly introduce terrestrial technology into spacecraft

30% FASTER DEVELOPMENT AND ADOPTION OF INNOVATIVE TECHNOLOGY



We are developing processes, methods and technologies to allow Europe to introduce new technologies into space systems at an early stage. Specifically, we will double the number of new technologies ready for test, launch and operations by 2021 and quadruple this number by 2024. We will also speed up the development of technologies selected for in-orbit demonstration by 50%, and double the use of commercial off-the-shelf products in ESA spacecraft by 2021.

To achieve this goal, we will focus on technologies that enable new space-based capabilities and services, and offer fast and systematic qualification and in-orbit demonstration opportunities.

Key technologies include quantum technologies, on-board artificial intelligence algorithms, advanced optics and detector technologies, in-orbit robotics, in-orbit manufacturing and assembly technologies and cybersecurity-related technologies.

· Focusing on technologies that enable new space-based capabilities and services

· Investing in joint lab facilities with industry and research centres for faster spin-in from terrestrial sectors to space

· Increasing opportunities for technology demonstration and verification payloads

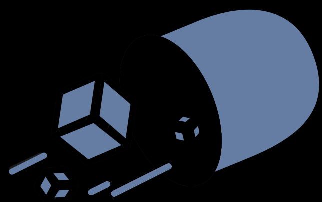
· Doubling the number of new space system technologies demonstrated at TRL 8/9 each year by 2021 and quadrupling this number by 2024

· Reducing the time taken to go from TRL 4/5 to TRL 7/8 by 50% for technologies selected for in-orbit demonstration

· Doubling the use of COTS in ESA spacecraft by 2021 via a dedicated COTS strategy

TECHNOLOGY DEVELOPMENT TARGETS

2030 TARGET FOR INVERTING EUROPE'S CONTRIBUTION TO SPACE DEBRIS



We are developing technologies that will allow us to leave the space environment in a better state for the next generation. Specifically, ESA will ensure all its missions are environmentally neutral by 2020, develop the technologies necessary for the successful active remove of space debris by 2024, and develop the technology that allows all ESA missions to be risk neutral by 2030.

To achieve this target, we will develop technologies to eliminate the creation of new debris, for active space debris removal, for in-space servicing, and for space debris surveillance and characterisation.

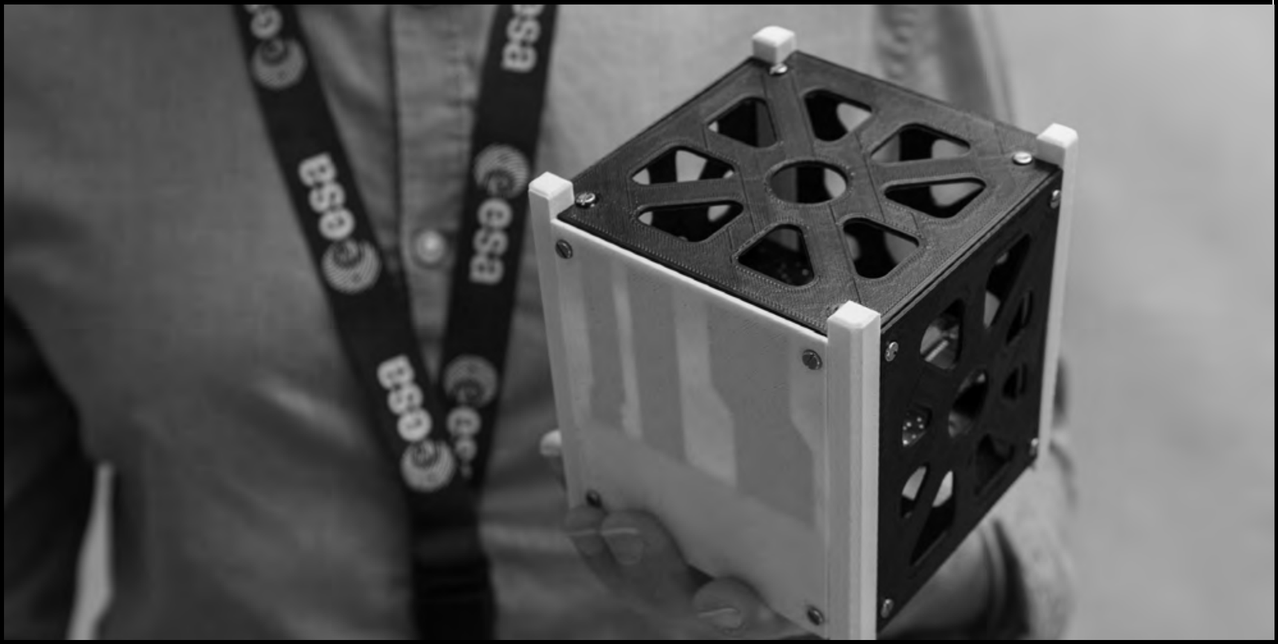
The investment into clean space technologies will provide a competitive edge in the future in-space servicing markets.

· Ensuring that all ESA missions are environmentally neutral by 2020

· Developing the technologies necessary for the successful active removal of space debris by 2024

· Enabling all ESA missions to be risk neutral by 2030

10X IMPROVEMENT IN COST EFFICIENCY WITH EACH NEW GENERATION



We are developing key technologies for Europe to improve cost efficiency by one order of magnitude with every space system generation, both by improving mission performance and reducing costs.

To achieve this goal, we will leverage downstream commercial technological developments, the use of modular architecture for space systems, adapted standardisation, advanced manufacturing and lightweight structures, low cost propulsion concepts and the smart use of commercial off-the-shelf devices and components.

Special attention will be given to big data analytics technologies, end-to-end system design optimisation, on-board intelligence for smart processing, miniaturisation of instrument technologies and payloads, and technology advancements in the domain of optics and

· Reducing the cost per useful bit transmitted by telecommunications satellites by at least one order of magnitude

· Providing 100% service availability of positioning, navigation and timing services and making systems resilient to spoofing attacks by 2025

· Improving the resolution, accuracy, revisit time and product delivery time of remote sensing missions before 2023

· Allowing transformational science and increasing science performance

· Improving remote sensing mission performance in terms of resolution (4x), accuracy (4x), revisit time (10x), tasking and product delivery time and distribution (10x) overall by at least one order of magnitude cost ratio by 2023

COMPETENCE DOMAINS

08

COMPETENCE DOMAINS

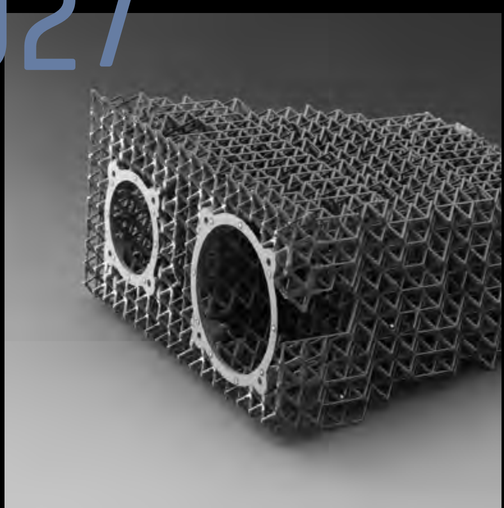
Technical competence is at the core of ESA's added value. It is organised into ten Competence Domains, each complemented by expertise in system engineering and quality assurance. Via the Competence Domains, we structure, plan and coordinate our R&D activities to achieve our strategic technology and engineering targets.

01/

ELECTRIC, ELECTRONIC, (MICRO-)ELECTRO-MECHANICAL AND PHOTONIC SYSTEMS

· Covering all electronic and photonic systems.
· Enabling European non-dependence within the parts marketplace.
· Enabling the use of commercial off-the-shelf components for space projects.
· Enhancing missions by pushing key technology (e.g. GaN microwave technology and processes), enlarging product families (power MOSFETs), and facilitating space usage of ESA qualified processes (capacitors for 65 nm process and new power architectures).

02/



STRUCTURES, MECHANISMS, MATERIALS, THERMAL

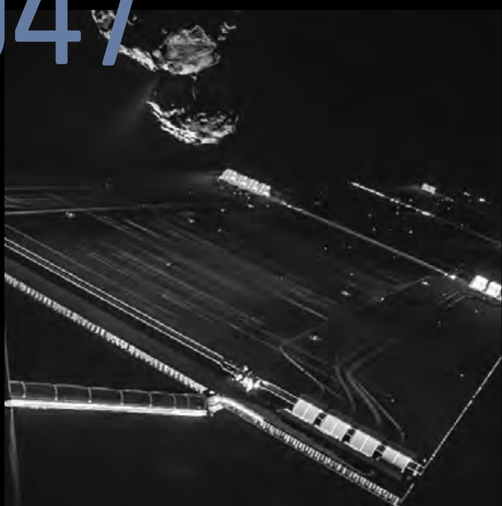
· Covering mechanical structures, mechanisms and thermal systems and their materials.
· Enabling reduced life cycle cost of space products, and shorter schedules with innovative mechanical architectures.
· Enhancing future missions through novel mechanical architectures based on new materials and manufacturing methods, such as additive manufacturing and virtual design.

03/

AVIONIC SYSTEMS

- Covering on-board processors, sensors and data handling systems.
- Enabling ambitious future missions and cost and schedule reduction by streamlining the delivery of avionics to projects through product lines.
- Enhancing science and commercial returns via new time-to-market avionic products.
- Advanced processors, more complex and flexible software, and (smart) high-performance sensors to create more reliable networks.
- Developing technologies for game-changing space system autonomy (e.g. control systems, sensors, onboard data systems).

04/



ELECTRIC ARCHITECTURE, POWER AND ENERGY, ELECTRO-MAGNETIC COMPATIBILITY

- Covering electrical architecture, power generation/management/distribution, energy storage, electromagnetic compatibility and space harness.
- Enabling new technologies for space exploration (e.g. fuel cells and nuclear power systems).
- Enhancing mission performances and reducing costs via record-breaking new solar cell efficiency, doubling the solar array power-to-mass ratio and reducing the in-orbit solar array costs by 30%.
- Developing and spinning-in enabling technologies for novel methods of power management, electricity generation and energy storage, as well as predictive technology for electric, electro-mechanic and electronic reliability.

05/

RADIOFREQUENCY AND OPTICAL SYSTEMS

- Covering the satellite component of telecommunications, navigation and remote sensing applications, with attention on the convergence of data provision, accurate and reliable positioning, timing and big data support.
- Developing microwave, digital and photonics technologies for payload and antenna equipment, improving front-end modems and networking techniques for ground segments, and developing advanced technologies for user terminals.

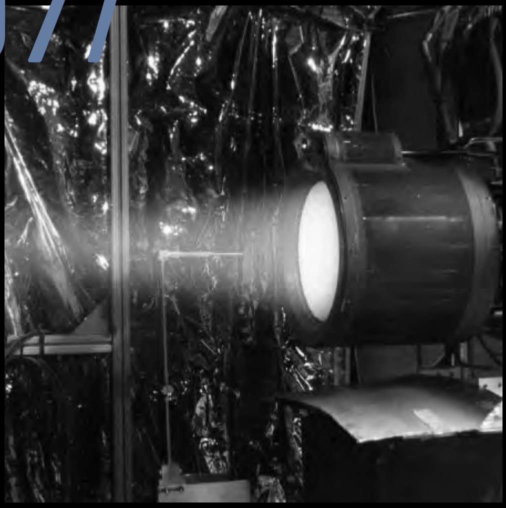
COMPETENCE DOMAINS

06/

LIFE AND PHYSICAL SCIENCE PAYLOADS, LIFE SUPPORT, ROBOTICS AND AUTOMATION

- Covering biological processes, automation and robotics, autonomy, science instrumentation, environmental control and life support systems and in-situ resource utilisation.
- Advancing technologies in the fields of automation and robotics, autonomy, science instrumentation, environmental control and life support systems, and in-situ resource utilisation.
- Enabling technologies for active space debris removal and orbital support services, including in-orbit assembly and robotic modular systems.

07/



PROPULSION, SPACE TRANSPORTATION AND RE-ENTRY VEHICLES

- Covering propulsion for space transportation and orbital applications, as well as operational (re)entry capability.
- Enabling low-cost propulsion systems, advanced avionics, light-weight structures and reusability. These technologies include multi-disciplinary vehicle design, multi-physics simulation and analysis tools, and advanced and fault tolerant GNC systems for autonomous precision flight and precision landing.
- Developing game changing tools and technologies e.g. new aerodynamics shapes that allow near equilibrium glide efficient flight.

08/

GROUND SYSTEMS AND MISSION OPERATIONS

· Covering all ground system and mission operations infrastructure technology, including technologies in tracking, telemetry and command, payload data transmission systems, space debris detection, radio science and telemedicine applications.
· Enabling operations automation and cost reduction, for example using artificial intelligence and data analytics, which will result in reduced operational cost. These also enable very large satellite constellations and data rates.
· Enhancing operations with new optical communications and radar/laser ranging capabilities and technologies for large optical antennas for day and night operations (segmented optical mirrors made of aluminium for cost efficiency, photon counting detectors, high photon efficiency modulation and coding, and high-power laser up-links with associated safety systems).

09/

DIGITAL ENGINEERING

· Covering the consistent use of digital methods and tools throughout the development process, targeting an enhanced planning, quality and process control capability across disciplines, application domains and project lifecycles. This includes spining-in digital engineering and data exploitation techniques to make a shift from documents to models.
· The paradigm shift from documents to models will enable the reduction of costs.
· Enabling technologies for the cost-saving paradigm shift from documents to models include big data analytics, artificial intelligence, virtual and augmented reality, advanced computing, and human-machine interfaces. This will centre the entire space system life cycle around digital models, based on the seamless integration of authoritative data sources.

10/

ASTRODYNAMICS, SPACE DEBRIS AND SPACE ENVIRONMENT

· Measuring, modelling, understanding and mitigating risks induced by the natural and human-influenced space environment, developing technology to survey artificial objects and determine their dynamics and methods for mission analysis and flight dynamics.
· Developing technologies to identify and remove tiny pieces of space debris, enable automated collision avoidance, collect information about the space environment, and precisely determine orbits.

TECHNOLOGY PORTFOLIO

09

TECHNOLOGY PORTFOLIO

More than half of the €740 million invested in European public sector space technology R&D activities in 2016 was done through ESA programmes. This has been imperative to maintaining Europe's competitive edge, and means that ESA's technology development activities are embedded within the wider European R&D landscape.

The management of technology development activities is guided by two structuring parameters: technological readiness and innovation. These determine how activities are funded, appropriate risk levels, and how industry and academia are involved in the development. ESA develops technology at all readiness levels.

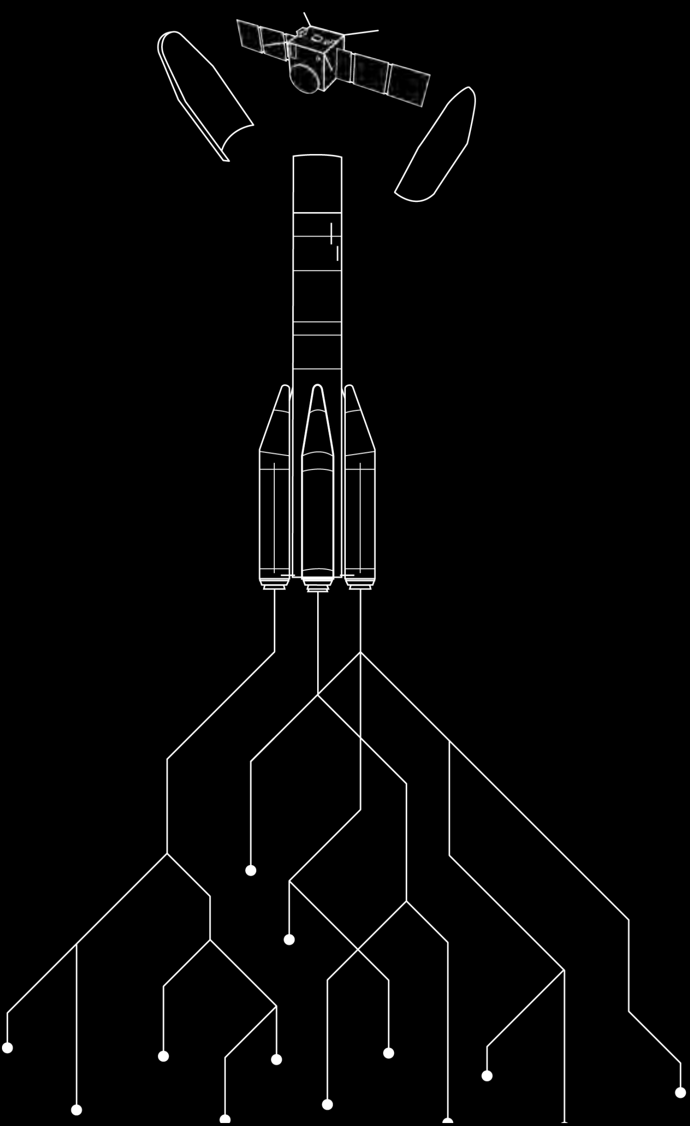
Early-stage technology is developed as part of ESA's Basic Activities, whilst more advanced technology is typically developed within optional programmes. The range of early-stage technology developed is naturally larger to allow for exploration of new concepts and preparing new missions. ESA also supports technology knowledge management, promoting the further development and use of such technologies inside and outside the space sector.

ESA's technology portfolio ensures cohesion and effectiveness between the different technology development programmes, fast implementation of technology development activities, and transparency and accountability to ESA Member States, space projects and industry. ESA also supports critical core technology needs while investing sufficiently in technology that can substantially enhance mission performance or introduce game-changing capabilities.

ENABLING

Developing enabling technology represents the majority of ESA's technology investment. These developments ensure that technology critical for planned missions is ready on time. Work is typically driven by clear deadlines and integrated into development plans and roadmaps.

The development of enabling technologies is time-critical and missions depend on their availability. As they are funded within space projects, the development risk needs to be kept in line with mission budgets.



ENHANCING

ESA invests in enhancing technologies when these promise substantial improvements in performance. Developments are either performed directly within mission projects or via the General Support Technology Programme.

The development of these technologies allows higher risks to be taken, enables the use of different contractual approaches and gives greater freedom to innovate for space industry.

GAME-CHANGING

ESA investment into game-changing technology enables European industry to identify and assess technology developments that promise to introduce entirely new capabilities.

Research and development activities for game-changing technology are typically high-risk, high-gain activities, which allow innovative partnership approaches with academia and industry. They are performed via generic technology development activities, e.g. Basic Activities or the General Support Technology Programme.