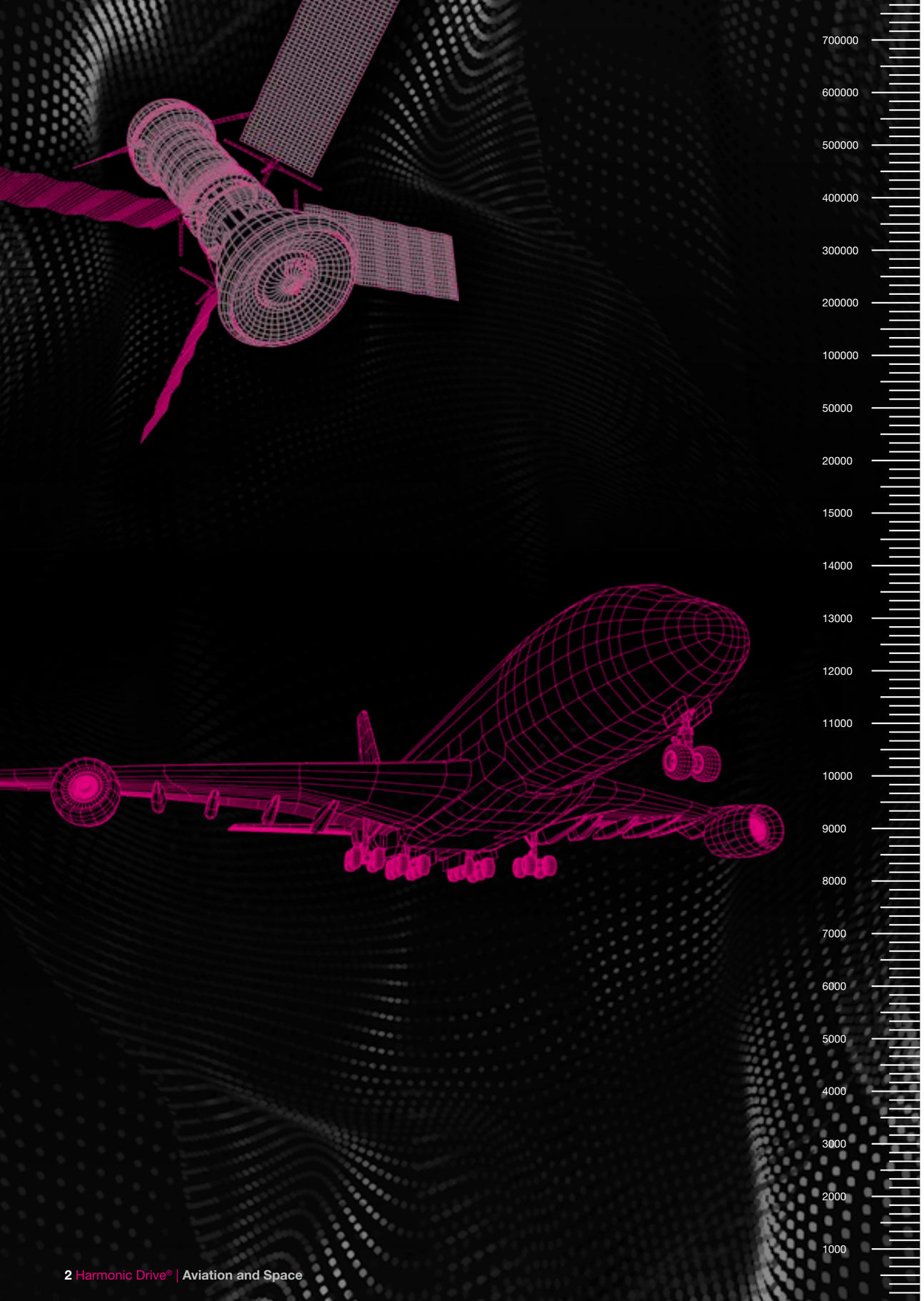
Aviation & Space

Harmonic Drive SE

Fly further.
Explore deeper.
Define new horizons.



Our heritage, your future

The Harmonic Drive® Strain Wave Gear principle of operation was invented in 1955 by Clarence Walton Musser. This extraordinary inventor was also credited with more than 250 inventions. Nothing among the human technique was out of his interest.

“It is never a question as to whether it can be done. It is only whether one cares to spend the time and effort.”
Clarence Walton Musser, Inventor of the Harmonic Drive® Strain Wave Gear

The Japanese company Harmonic Drive Systems Inc., Tokyo, was the first company to foresee the large potential of precision gears. From the lunar rover in the mission Apollo 15 to the martian rover Mars 1, Harmonic Drive® Products have conquered space always improving this technology.

“As with anything, I believe there are no limits.“
Mitsumasa Ito, Chairperson of the Board of Directors of Harmonic Drive Systems Inc., Tokyo, Japan

Our satisfied customers: The measure of our success

AIRBUS · sener · TESAT · BAE SYSTEMS · esa · VINCORION

In 1970, the German headquarter is established.
Today, Harmonic Drive SE is leading the global aerospace segment.

Our inspiration

With either Apollo 15 on the moon or in the depths of the rough oceans, for more than 50 years, we have been providing significant applications across the planet and beyond with our drive solutions. We, as an industry leader in high precision drive technology, have not only continued to expand our portfolio based on the unique Harmonic Drive® Strain Wave Gear but have also recognised the requirements of modern, trend setting markets and applications: The future of drive technology is intelligent, sustainable and efficient.

Thanks to their special characteristics, which have been continuously developed over decades, Harmonic Drive® Gears and Actuators are perfectly suited to important key industries, including robotics, handling & automation, medical technology, special environments, aviation & space and mechanical engineering.

Highest precision and quality for our customers are key principles of our corporate culture. Eighty percent of the products that leave our factory in Limburg/Lahn are customised versions and are therefore specially developed, designed and manufactured according to customer specifications - from space saving gear component sets to intelligent drive systems.

Due to the high complexity in the configuration of suitable drive technology components, we partner and advise our customers comprehensively. The proposed solution for the drive task to be realised is developed in close cooperation to enable the subsequent integration into the application environment without any problems. Vital for this are, on the one hand, the high flexibility and, on the other hand, the customised scope of services and the integration level. The result is an optimal, highly individualised drive solution.

Successfully shaping the future together with, and for our customers, in demanding industries is a sign of our innovative strength in the field of high precision drive technology.

Production and development sites at the highest technological level in Germany, Japan and America, as well as subsidiaries in Europe and Asia, ensure that we can offer highly specialised and intelligent drive solutions as well as mechatronic systems worldwide.

Mars Rovers

Moving space exploration forward

Harmonic Drive® Gears have embarked on an incredible journey through the solar system, frequently landing on Mars and will continue to play a vital role in supporting space exploration on the red planet in the near future.

The exceptional reliability of Harmonic Drive® Gears significantly minimises the risk of failure in maintenance free applications, even under the most extreme environmental conditions, as proven by the Perseverance rover.

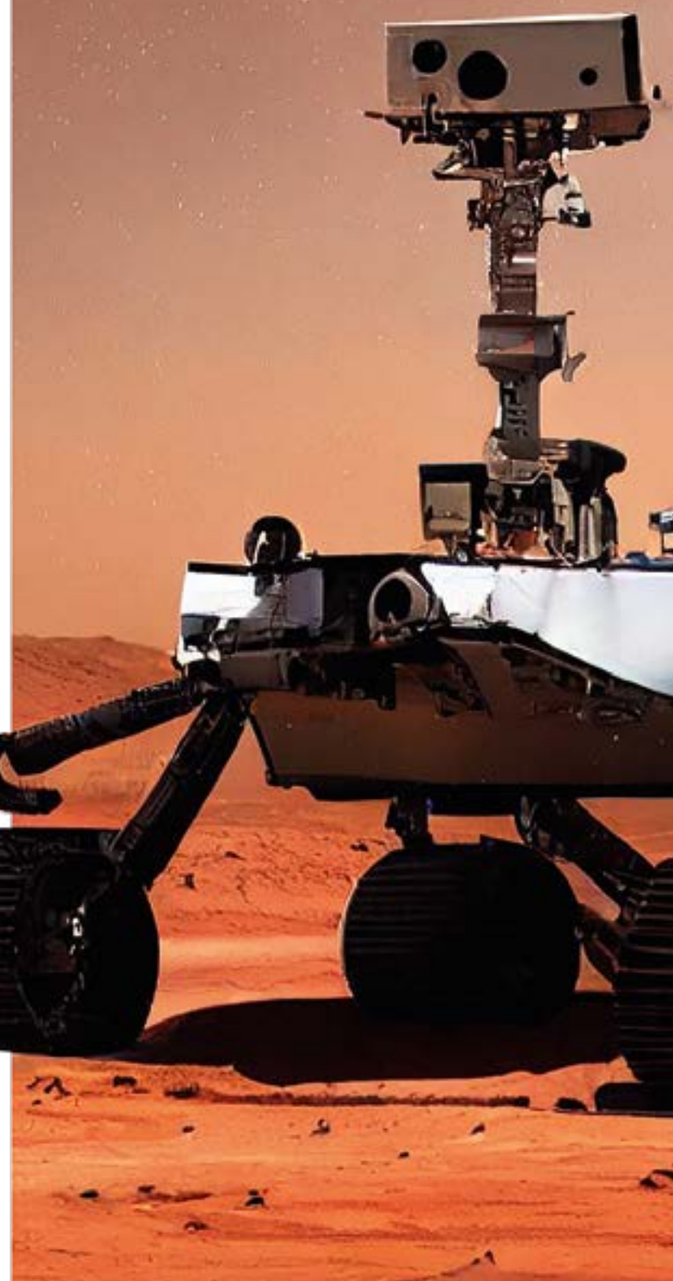
Over the course of more than 740 Martian days, the Perseverance rover has successfully collected samples thanks to the precision of five Harmonic Drive® Gears.

This remarkable precision, achieved over vast distances and under the challenge of delayed remote control, would have been impossible without these products, which exhibit zero backlash and high accuracy throughout their entire operational lifespan.

CPL Series Gear Component Sets

Ratio	30 … 160 in a single stage
Temperature	-100 °C … 150 °C
Humidity	0% … 95%
Customisation	Dry lubrication (0% relative humidity)

Harmonic Drive® Gears: NASA trusted choice to conquer Mars since 2003!



Moon Rovers

Pioneering Space Rover Technology

Among all the missions in the solar system utilising by Harmonic Drive® Gears, Apollo 15 set the path to the future of drive systems in space. It was the first mission specifically designed to test the long term capability of the lunar rovers for the transportation of people and samples. The results went beyond NASA expectations setting a new scientific record, covering 28 km at a top speed of about 13 km/h.

Working in a tight space envelope with significant weight restrictions, it was necessary to couple the wheels of the rover to the high speed motor using a gear ratio of 80:1, to achieve the desired torque and speed. Only Harmonic Drive® Gears were able to provide such a challenging ratio in a single stage. The success of the mission confirmed the leading role of the company in the market of drive systems for space exploration.

Space CPL

Basic product	CPL-2A Gear Component Set
Temperature	-100 °C … 150 °C
Pressure	Up to 10^{-9} Pa
Transmission accuracy	< 1.0 arcmin
Traceability	Full documentation according to ECSS-Q-ST-70C-Rev.2
Design characteristics	Extreme lightweight Circular Spline design and spline connection of Wave Generator

Apollo 15’s Lunar Roving Vehicle, powered by Harmonic Drive® Technology, set a scientific speed record on the moon. Harmonic Drive® was there, moving the wheels of the first lunar car.

Space critical systems

Performance tested in all the environments

Harmonic Drive® has a successful heritage in space that is supported by some long lasting partnerships which cover entire space programs. When a satellite is in orbit, there are some primary systems whose failure would compromise the entire mission.

The operational integrity of vital systems like solar panel deployment or antenna pointing is paramount during a mission. These components are often bulky and lack redundancy. Yet, any compromise in their functionality could lead to the satellite being deemed “lost,” resulting in mission failure.

Harmonic Drive® Gears are the first choice of the aerospace industry to assure the operation of these critical systems in extreme environmental conditions. Materials and lubrication assure the performance in any condition.

The space qualified lubricants are characterised by a very low outgassing under vacuum condition, which ensures high performance and a longer operating life. Additionally, Harmonic Drive® Gears can also be dry lubricated, when required by some particular mission operative conditions.

Space PMG

Basic product	PMG Gear with output bearing
Weight	0.43 kg
Size	11
Transmission accuracy	< 2 arcmin
Outer diameter	40 mm
Repeated peak torque	7.9 Nm
Design characteristics	Integrated output support bearing

In low orbit, a satellite is moving at 8 km/s and must sometimes point the antenna to other satellites at a distance of about 73 km or with ground stations at 600 km.

Space robotics

Compact gear design for space

The Harmonic Drive® Component Set comprises three key parts: the Wave Generator, the Flexspline, and the Circular Spline. Together, they provide the maximum torque to weight ratio achievable for a gear of a given size.

The component set is the core of all the Harmonic Drive® Products. The main characteristic is the total absence of backlash, which increases the accuracy of the mechanical transmission.

If the zero backlash, low hysteresis, minimum motion loss are the reasons behind the success of Harmonic Drive® Gears, the compactness is the reason why these products are the only viable solution in to space robotics, where the space envelope is constrained and the maximum weight limited.

Space CPL

Basic product	CPL Gear with output bearing
Weight	1.20 kg
Size	20
Operative temperature	-60 °C … 120 °C
Outer diameter	115 mm
Design characteristics	Integrated input and output bearings, weight reduced by 25%

In space robotics, space is often limited. Harmonic Drive® Gears, compact and versatile, fit seamlessly into any mission.

Fuel control system

Highest precision, unmatched quality

Harmonic Drive® Actuators are the choice of the leading industries manufacturing launchers.

The fuel control systems operate at very low temperatures down to -60 °C and under vacuum conditions. They demand exceptional precision to prevent even minor fluctuations in combustion, which could lead to missed orbits or detrimental shifts in launcher attitude, resulting in catastrophic consequences.

Within the aerospace industry, meticulous analysis and engineering are paramount. Even minor oversights can lead to critical failures. Our commitment to high quality standards and rigorous engineering processes is essential for preventing latent issues resulting in disasters.

Harmonic Drive SE takes this responsibility with extreme seriousness and provide fully qualified and tested systems that can withstand extreme environmental conditions.

Besides the precision and the high ratio, beyond the reliability in extreme conditions, Harmonic Drive® Actuators are chosen for their low weight and minimised envelope.

Space AlopexDrive

Basic product	AlopexDrive Servo Actuator
Sizes	14 ... 40
Repeated peak torque	18 ... 647 Nm
Transmission accuracy	< 2 arcmin

Harmonic Drive® Actuators powering European launchers for unparalleled fuel management.

Nozzle control system

Unparalleled motion transmission

The nozzle control system is a critical application ensuring the directional stability of the thrust with the highest precision. Harmonic Drive® Gears can transfer the actuation with very high accuracy lower than one arcmin.

For new micro launchers and avio launchers, precise thrust control is the defining factor for the success of this emerging market. Harmonic Drive SE is an active partner with companies in this sector providing them with compact and reliable solutions.

Harmonic Drive® Gears are characterised by zero backlash and low elastic deformation, resulting in a low hysteresis and no loss of motion transmission. These characteristics make these products the first choice when it comes to applications where the precision is a crucial aspect.

Customised AlopexDrive Actuator

Weight	3.0 kg
Size	17
Temperature	-50 °C … 70 °C
Dimensions	300 x 300 x 15 mm
Design characteristics	IP 65 rated

Harmonic Drive® Products ensure a precise thrust control for successful launches.

Harmonic Drive® Gears for electromechanical actuators

The trusted choice for critical applications

Harmonic Drive® Gears are the go to solution in applications where safety and fault tolerance are non negotiable. Their unique design, with limited components and zero backlash, ensures precision and reliability, reducing the risk of sudden mechanical failures.

This robustness is especially crucial in mission critical sectors such as aviation. Therefore, when stringent regulations on electro-mechanical actuation (EMA) were introduced, to regulate more electric systems, the aviation industry turned to Harmonic Drive® Gears.

Nowadays, the actuation systems of many aircraft of the Airbus family are powered by our products. From the high lifting surfaces to the position pick-off units, from the landing gears to the trolley lift, Harmonic Drive® Gears have been qualified for these applications through intensive failure mode and effects analysis.

When reliability matters most, Harmonic Drive SE delivers.

Aviation HFUC

Basic product	HFUC-2A Gear Component Set
Temperature	-100 °C … 150 °C
Momentary peak torque	Up to 1300 Nm
Design characteristics	Up to ratio 400 in a single stage, axial spline at output side

Experience the Skies Safely with Harmonic Drive®: Powering Aircraft Control Surfaces and Landing Gear for Seamless Journeys.

Auxiliary control systems

Enhancing the flight experience

Harmonic Drive® Gears have established themselves as an essential component in the force feedback systems of cutting edge military control systems, such as those found in advanced fighter jets. These gears play a pivotal role in translating the pilot's input into precise control surface movements, ensuring rapid response and optimal manoeuvrability.

Their unique characteristics, including exceptional precision, compact design, and zero backlash, make them an ideal choice for critical applications where split second decisions and accurate control are imperative.

Harmonic Drive® Gears enhance the force feedback experience, allowing pilots to maintain control in the most demanding and dynamic scenarios. As a result, these gears continue to be part of the technology empowering unmatched performance.

Customised HFUC-2UH Gear with output bearing

Weight	0.32 kg
Size	14
Ratio	Up to 100 in a single stage
Temperature	-50 °C … 85 °C
Design characteristics	Integrated output support bearing

From 5G communications to Force Feedback Actuators, Harmonic Drive® Gears Enhance Auxiliary Systems Across Civil and Military Aviation.

Auxiliary systems

Ensuring Helicopter Safety: Harmonic Drive® Precision in Auxiliary Systems

Harmonic Drive® stands as the essential backbone of many auxiliary systems in helicopters, supporting critical functionalities such as rescue hoists. This intricate application demands precision, reliability and robust performance in a very compact space.

The Harmonic Drive® Gear, with its impeccable zero backlash and torque transmission, is the essential component of these systems, assuring the correct rolling and unrolling of the rope.
When lives are on the line in search and rescue operations, Harmonic Drive® Gears come through ensuring that every movement is executed with pinpoint accuracy, again and again.

Aviation PMG

Basic product	PMG Gear with output bearing
Weight	0.45 kg
Size	8
Outer diameter	44 mm
Design characteristics	Flexspline with integrated output shaft and input shaft with support bearings

Elevating Helicopter Performance: Harmonic Drive® Gears Redefining Support Systems.

Control systems

The gears for high manoeuvrability

Harmonic Drive® Gears play a pivotal role in controlling the swashplate, a critical part of the rotor system that enables precise manoeuvrability even after shocks and vibrations.

Harmonic Drive® Gears translate pilot inputs into nuanced swashplate adjustments. In the dynamic and high stakes world of aviation, where split second decisions matter, these gears offer the essential precision required for safe and controlled flight.

Whether it’s search and rescue, aerial filming or military missions, the control of the swashplate by Harmonic Drive® Gears ensures that helicopters respond with accuracy, enhancing both safety and operational capabilities.

Fully integrated solutions

Experience the unparalleled craftsmanship of Harmonic Drive SE, where precision meets customisation. Our tailor-made solutions seamlessly integrate gears, motors, bearings, sensors, and personalised interfaces, culminating in a uniquely qualified product tailored to exceed our customers‘ every need.

Driving Helicopter Precision: Harmonic Drive® Gears at the Core of Control Systems.

Rotor tilting

Leading the urban mobility

Harmonic Drive® Gears are at the forefront of the revolution in urban air mobility, where they play a pivotal role in the tilting motors and jet flaps. Their exceptional precision is a game changer for controllability, enabling these futuristic vehicles to take off, land and navigate urban skies with unparalleled accuracy.

The seamless motion and zero backlash provided by Harmonic Drive® Gears are vital for safe and efficient flight, making split second adjustments in response to complex urban environments.

With these gears at the heart of the tilting motors and jet flaps, air taxis are not just a vision of the future; they're a reality, offering a transformative transportation solution that's as precise as it is revolutionary. Harmonic Drive® Gears ensure the smooth and controlled flight that's the hallmark of this next generation mobility.

Aviation Actuator

Basic product	BHM Frameless Motor, CSG-2A Gear Component Set
Weight	1.75 kg
Size	25
Continuous torque	110 Nm
Repeated peak torque	275 Nm

Harmonic Drive® Products are paving the Way for Urban Mobility's Green Revolution.

Flight controls

The cornerstone of safety and flight controls

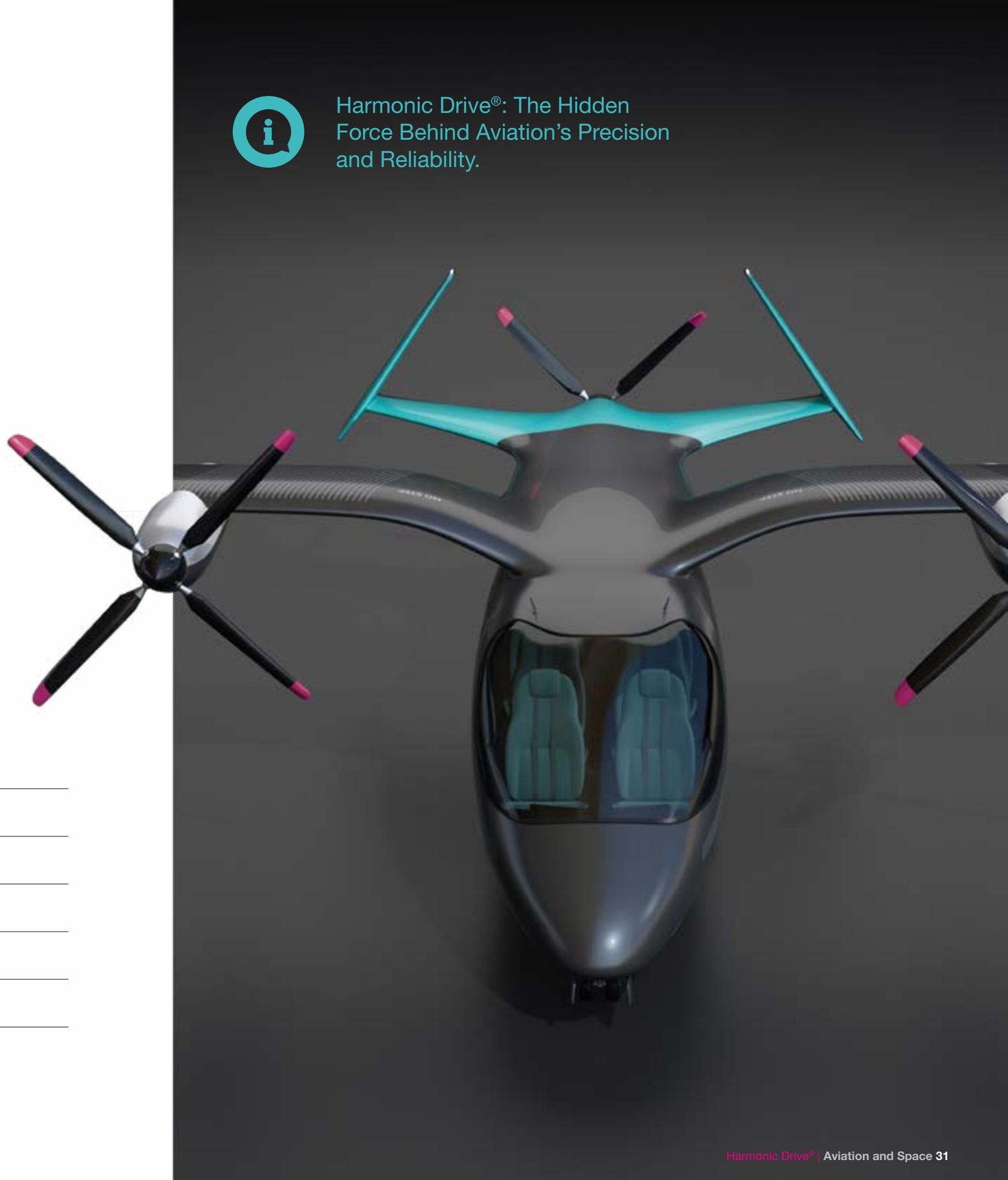
When a pilot manoeuvres an aircraft, every degree of movement in control surfaces, such as ailerons, elevators, and rudders, must be precise. This is particularly true when it comes to EVTOLs whose flight scenarios includes the urban skies where the manoeuvrability is the key element on which the trust of the final customers is based.

Harmonic Drive® Gears excel in providing this level of precision, ensuring the vehicles respond accurately and swiftly to pilot commands. Their zero backlash and compact design mean that even in the most challenging conditions, from the turbulent skies to the rapid manoeuvres around the skyscrapers, the control surfaces maintain exact positions.

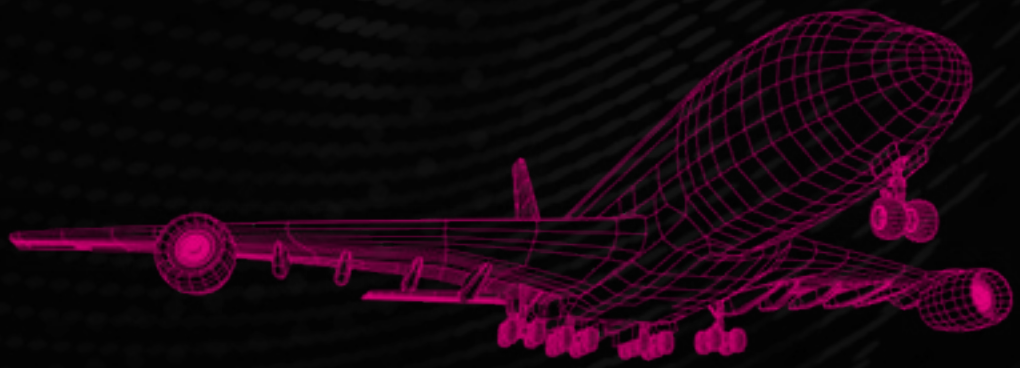
As enabling technology behind this level of controllability, Harmonic Drive® Gears are opening the path to autonomous flights in our skies. In fact, by reducing the error margin at each manoeuvre, the guidance and navigation systems can accurately identify the position of the vehicles during the flight.

Aviation CSG

Basic product	CSG-2A Gear Component Set
Weight	0.09 kg … 3.2 kg
Sizes	14 … 50
Ratio	30 … 200
Repeated peak torque	4.9 Nm … 1534 Nm



Harmonic Drive®: The Hidden Force Behind Aviation’s Precision and Reliability.



PASSION GENERATES THE HIGHEST QUALITY

Harmonic Drive SE
Hoenbergstraße 14
65555 Limburg/Lahn
Germany

T +49 6431 5008-0
info@harmonicdrive.de
www.harmonicdrive.de

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