



# Defence and Aerospace



Harmonic  
Drive AG



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For all products, you will find Quicklinks which easily leads you to more detailed information on our website. Just simply input the code in the field for the quick link into [www.harmonicdrive.co.uk](http://www.harmonicdrive.co.uk) , e.g. 3030 for the CPL-2A Series Component Set – and you'll go straight to the page you want.

**QUICKLINK**  
**[www.harmonicdrive.co.uk/3030](http://www.harmonicdrive.co.uk/3030)**

You can find other publications on our website, under Downloads.

**[www.harmonicdrive.co.uk](http://www.harmonicdrive.co.uk)**



## Our inspiration

Since its inception over 40 years ago Harmonic Drive AG, with nearly 400 staff at the Limburg / Lahn site, has transformed itself into the company offering the solution of choice for high precision drive technology. Whether for servo drives, direct drives, gears following the strain wave principle or planetary gears: the more demanding the task, the better!

The focus of our efforts is the joint development of the best possible solution for you – using high technology components, delivered on time and cost effective.

Overall we currently offer more than 25,000 different products, of which more than 80% are customer specific solutions which can be manufactured from a lot size of 1.

Any questions you may have, please direct them to our sales staff and to our technical customer services. It does not matter whether you want advice, check the current status of your order, start to use our products or simply purchase spare parts – we are happy to help you.

Our products are sold throughout the world. Harmonic Drive AG is the contact for customers in Europe, Asia, Africa and South America. North America and the Far East are looked after by our partner companies in those areas, with whom we constantly exchange our knowledge.

### **Group of companies – we can offer more**

*Ovalo GmbH and Micromotion GmbH use the Harmonic Drive® Technology in combination with special production technology for large scale production and in the field of micro systems technology.*

### **Quality assured!**

*With our EN 9100 certification we meet both industrial requirements and even more demanding requests from the aerospace industry and defence technology.*

*We also comply with other requirements, for environmental management and safety at work which are reviewed annually.*

**QUICKLINK**

[www.harmonicdrive.co.uk/0010](http://www.harmonicdrive.co.uk/0010)





## Defence

Particularly in the defence industry, security conditions alter constantly. The security situation is subject to constant change as the complexity of new forms of threat has increased. The highest demands on precision, performance and state of the art equipment are therefore placed on products and system solutions for defence technology.

Request our expertise in developing and consulting to deliver you world class products, which ensures the success in new operational areas with the highest possible protection of individuals.

We invite you to develop technologically superior and innovative solutions in a close partnership with us. Especially where highest accuracy and reliability is of paramount importance, Harmonic Drive® Products stand for pioneer technology.



## Remote Weapon Station

A Remote Weapon Station (RWS) is a remotely operated station mounted on vehicles. The PROTECTOR® weapon station is designed for small and medium caliber weapons and can be installed on any type of platform. It is fully stabilised, combat proven and is qualified for global operations. The system is operated from inside the vehicle, providing full protection for the operator. The PROTECTOR® weapon station is currently in use in 17 countries.

Harmonic Drive AG supplies gears and actuators for use in azimuth & elevation axes of the weapon station and in the pan & tilt axes of the camera. Important factors for the selection of Harmonic Drive® Gears are high accuracy, low weight, hollow shaft for implementing a slip ring and high power density. Due to challenging demands, close dialogue with our customer was necessary when specifying the special lubricants and materials used in this application.

Table 6.1

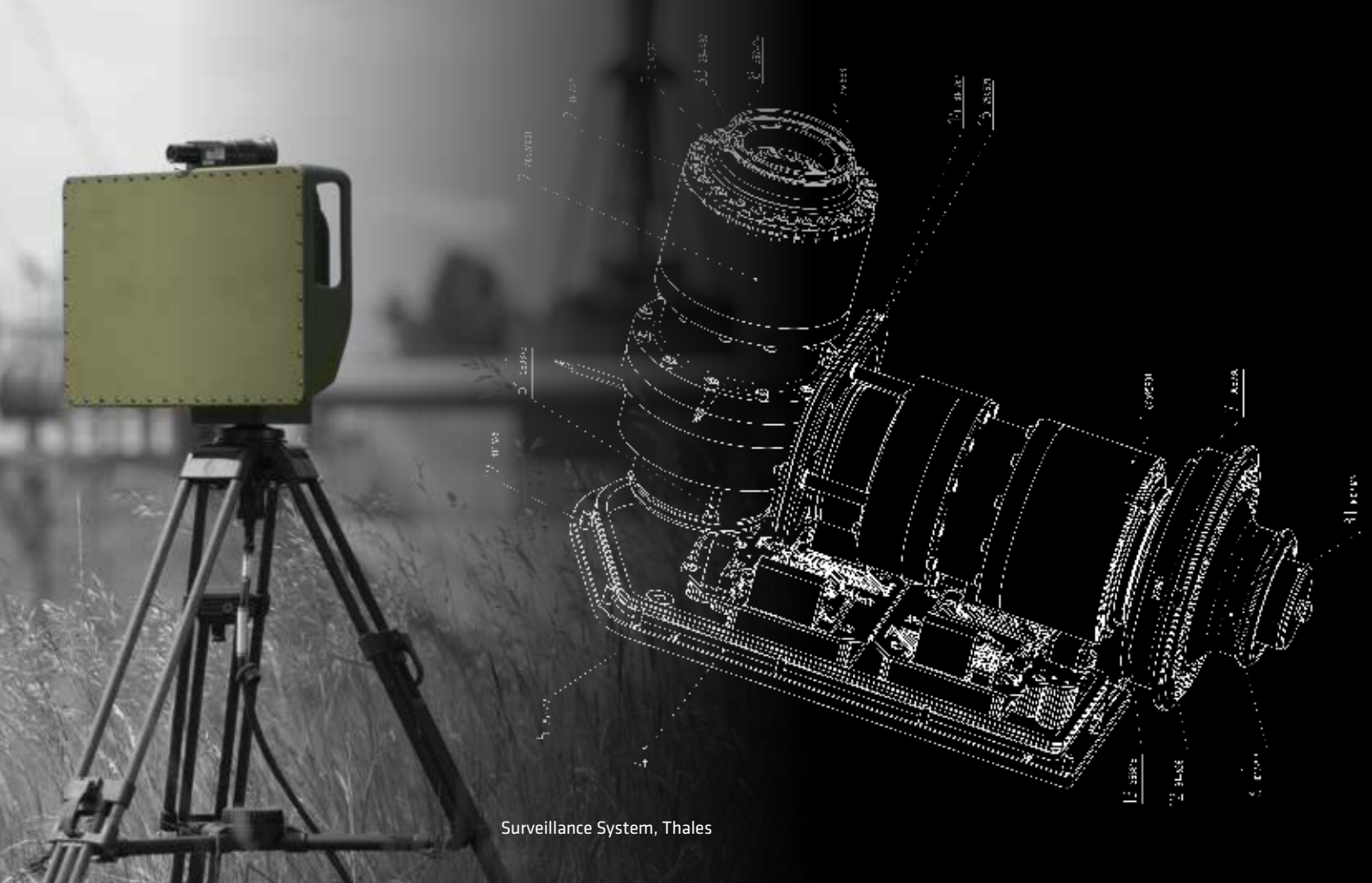
HFUS-2UH Units				
Size	Ratio	Outer diameter [mm]	Max. repeated peak torque [Nm]	Max. hollow shaft diameter [mm]
14	30 ... 100	70	9 ... 28	14
17	30 ... 120	80	16 ... 54	19
20	30 ... 160	90	27 ... 92	21
25	30 ... 160	110	50 ... 176	29
32	30 ... 160	142	100 ... 372	36
40	50 ... 160	170	402 ... 647	46
45	50 ... 160	190	500 ... 882	52
50	50 ... 160	214	715 ... 1180	60
58	50 ... 160	240	1020 ... 1840	70

QUICKLINK [www.harmonicdrive.co.uk/2060](http://www.harmonicdrive.co.uk/2060)



PROTECTOR® weapon station, Kongsberg





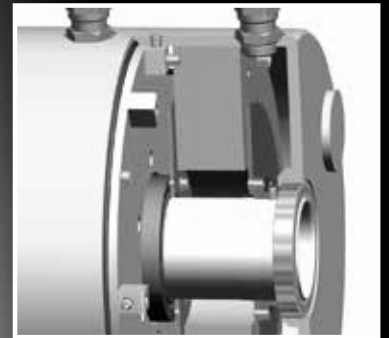
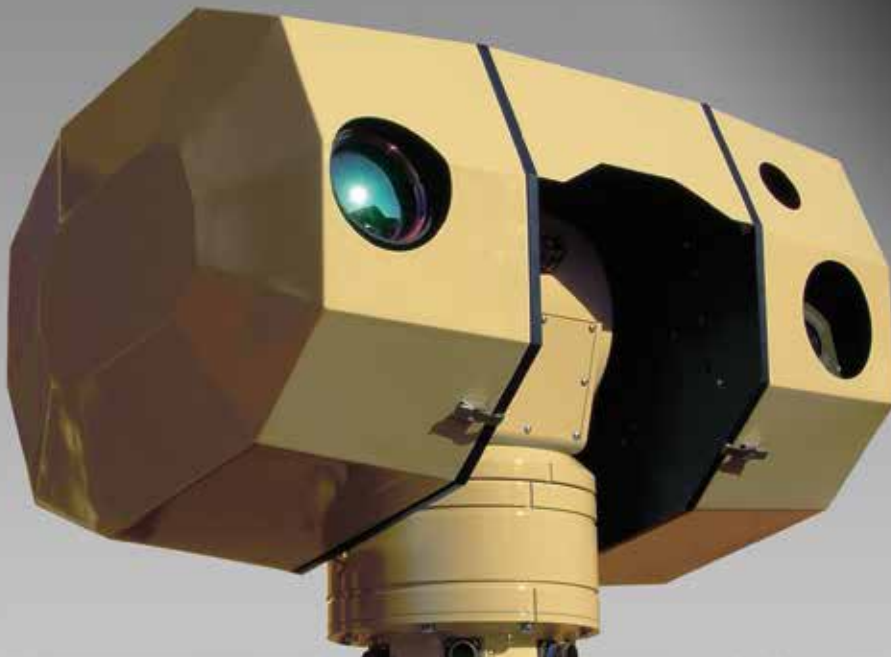
## Ground Surveillance Systems

A range of flexible ground surveillance systems are centred on our high accuracy, zero backlash AlopexDrive® Series Hollow Shaft Servo Actuators.

Applications range from security and surveillance through high performance systems for stabilised target tracking and acquisition systems for Army and Navy. These high performance stabilised systems rely on high stiffness and low losses in the system making Harmonic Drive® AlopexDrive® Series the best solution.

Table 7.1

	Unit [Symbol]	AlopexDrive® 14A	AlopexDrive® 17A	AlopexDrive® 20A	AlopexDrive® 25A	AlopexDrive® 32A	AlopexDrive® 40A
Ratio	$i$ [ ]	30 ... 100	30 ... 120	50 ... 160	50 ... 160	50 ... 160	50 ... 160
Maximum output torque	$T_{max}$ [Nm]	9 ... 28	16 ... 54	56 ... 92	98 ... 176	216 ... 372	402 ... 647
Maximum output speed	$n_{max}$ [rpm]	85 ... 283	61 ... 243	41 ... 130	35 ... 112	30 ... 96	25 ... 80
Continuous stall torque	$T_0$ [Nm]	6.8 ... 11	12 ... 39	19 ... 49	38 ... 108	44 ... 216	125 ... 420
Brake holding torque	$T_H$ [Nm]	9 ... 28	15 ... 54	27 ... 92	54 ... 176	54 ... 288	225 ... 647
Weight without brake	$m$ [kg]	2.0	3.0	3.2	4.9	6.6	11.7
Weight with brake	$m$ [kg]	2.1	3.2	3.9	6.1	7.8	13.8
Hollow shaft diameter	$d_H$ [mm]	12	16	18	27	32	39
Transmission accuracy	[arcmin]	1.5 ... 2.0	1.5 ... 2.0	0.8 ... 1.5	0.8 ... 1.5	0.8 ... 1.5	0.5 ... 0.7
Ambient operating temperature	[°C]	-40 ... 65					



## Optic Surveillance Systems

Chess Dynamics designs and manufactures a range of flexible optic surveillance systems centred on our high accuracy, zero backlash AlopexDrive® Servo Actuators. Their products are designed for land, sea or air vehicles, and can be fitted with a selection of thermal imagers, CCD cameras, laser range finders and laser pointers, tailored to the customer's requirements.

With a main focus of optical surveillance and on-board stabilisation for marine applications, our customer is relying on the highest precision.

These actuators allow also the integration of slip rings. The entire arrangement is housed in a precision quality aluminium alloy housing. The surface is coated by Surtec 650 or similar protection possibilities in order to fulfil the EMI/EMC requirements.

Table 8.1

CHA-32C							
Ratio	i [ ]	30	50	80	100	120	160
Maximum output torque	T <sub>max</sub> [Nm]	100	216	304	333	353	372
Temperature range	[°C]	- 30 ... 50					
Supply voltage	[VDC]	24 ... 48					
Motor feedback system		A + B / 1Vpk-pk					
Position measurement		Absolute encoder with SSI interface					





## Force Feedback Actuator

Compact dimensions, low weight and high reliability are key criteria for applications in the aerospace industry. So it is not surprising that precision gears from Harmonic Drive AG are used in the Force Feedback Actuator of the F-35 Joint Strike Fighter (JSF). This fifth generation supersonic fighter jet is designed for operation with the U.S. Air Force, Navy and Marine Corps as well as for the British Navy and Royal Air Force.

For the man machine interface, the aircraft is equipped with active inceptors to provide force feedback to the pilot. Developed by BAE Systems, Active Stick technology provides the pilot with better situational awareness in vertical take-off and landing, subsonic and supersonic flight.

Modified gears of the HFUC Series are used in the three axes, equipped with force feedback. These gears are characterised by excellent sensing characteristics due to their precision and linear operating behavior under load. Furthermore, detailed information about reliability, failure types and probabilities enabled the design to be realised. This drive solution has been developed by Harmonic Drive AG, based on more than 40 years' experience in the aerospace industry and was optimised in close dialogue with the manufacturers and pilots.

Table 9.1

Customised HFUC			
		HFUC-14	HFUC-17
Breakout torque	[Nm]	< 0.8	< 1.2
Ultimate peak torque	[Nm]	118	206
Weight	[g]	300	430
Torque/Weight ratio	[Nm/kg]	383	48
Operating temperature	[°C]	-50 ... +80	



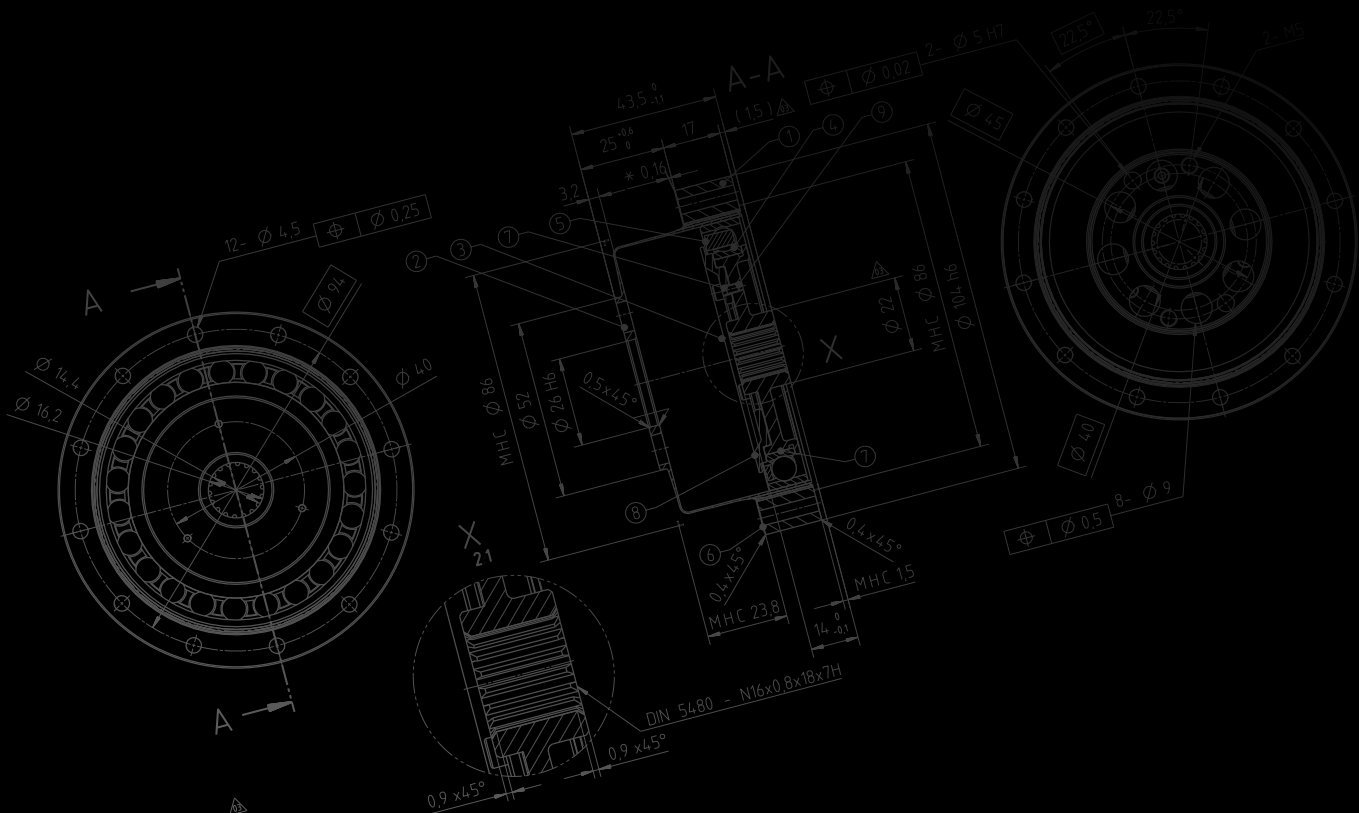


## Aerospace

Today's modern aircraft make it possible to reach almost any region of the world under almost any condition. Going even higher into space or planetary exploration precludes any chance of repair or maintenance. The highest levels of technology reliability and precision are therefore prerequisites for assignments in aviation and space.

Harmonic Drive® Products reach the highest levels of reliability and safety, and are thus ideally suited for this industry. In addition, we ensure special diligence in the development process by our highly qualified engineers - this is also confirmed by our certifications in the field of aerospace.

Benefit from our experience and our many years of process know-how!  
Design with us the aviation and space products of tomorrow - because above the clouds there is no room for compromise!





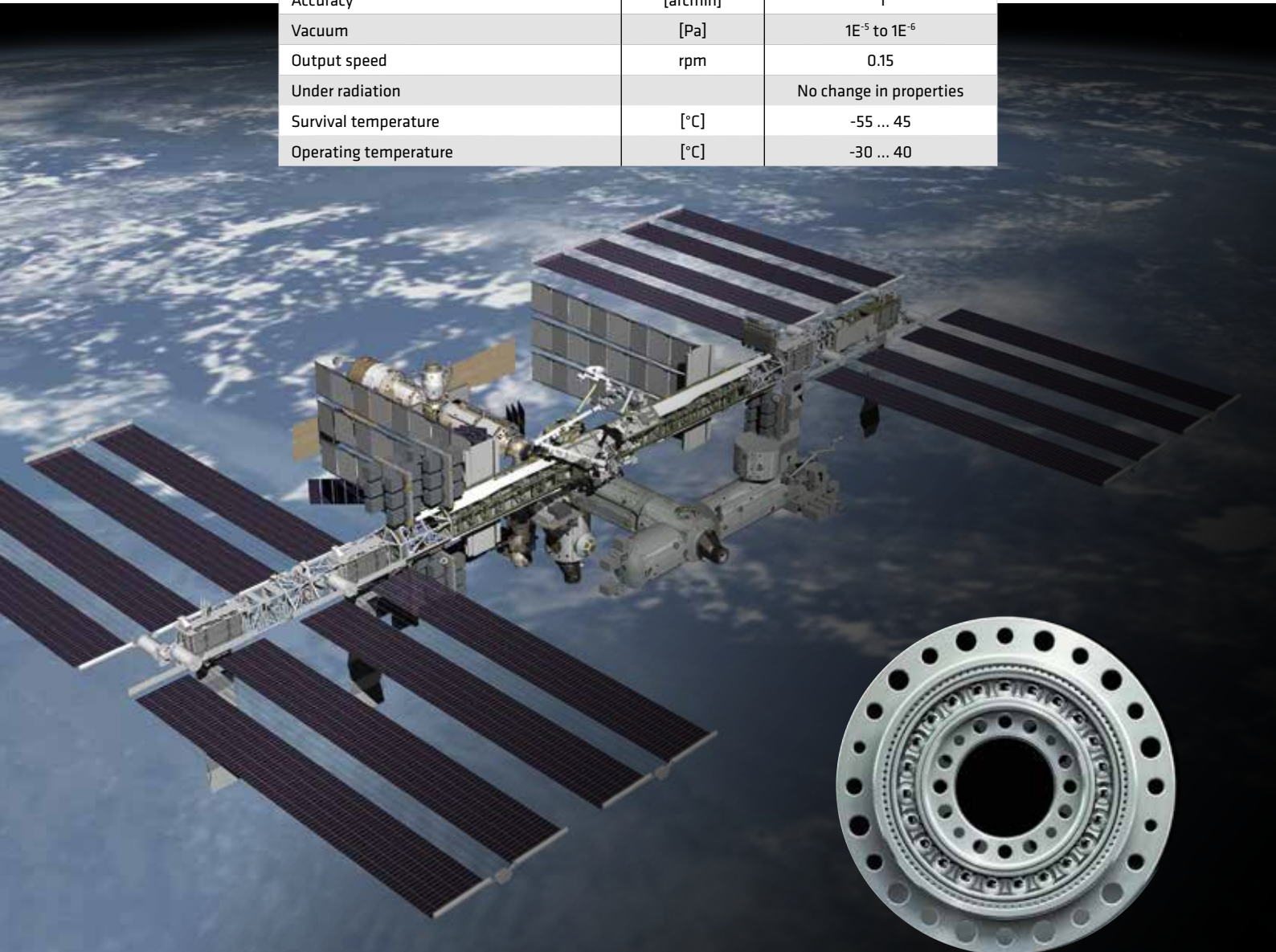
## Stereo Vision Measurement System (SVMS)

Harmonic Drive AG has developed fully space rated gears for the Stereo Vision Measurement System (SVMS) used for cartography and planetary exploration in the external ISS environment. In order to do this, a twin camera system is installed on a pan and tilt head in order to orient the cameras towards the objects under observation.

Because of the experience of Harmonic Drive AG in high positioning accuracy and homogeneous motion at slow speed, two Harmonic Drive® Gears are used to orient the camera in pan and tilt directions. HFUC-14 Component Sets, manufactured in stainless steel, are used for both axes. A full space documentation according to ESA standards is included.

Table 12.1

Customised HFUC		
Accuracy	[arcmin]	1
Vacuum	[Pa]	1E <sup>-5</sup> to 1E <sup>-6</sup>
Output speed	rpm	0.15
Under radiation		No change in properties
Survival temperature	[°C]	-55 ... 45
Operating temperature	[°C]	-30 ... 40







MASCOt by DLR



## Mobile Asteroid Surface Scout (MASCOt)

*By the way: Harmonic Drive® Strain Wave Gears were first invented for space applications.*

Since the dawn of space travel, Harmonic Drive® Gears have been used successfully in space and planetary exploration. Harmonic Drive® Technology has been to the Moon, visited Mars, travelled past gas planets, and is now exploring space beyond the confines of our solar system. The Limburg-based technology will also be on board an asteroid explorer which will be investigating a near-earth asteroid in 2018.

*MASCOt has four devices: A combination of a special infrared spectrometer and a microscope will explore the asteroid's mineralogy. A radiometer and a magnetometer will measure magnetic field and flux density and investigate the thermal properties on the surface of the asteroid. A specially designed wide-angled camera will provide striking pictures of the asteroid itself.*

The Mobile Asteroid Surface Scout (MASCOt) is an asteroid exploration device. The movement mechanism of MASCOt consists basically of a metal rocking arm. A relatively small weight made of tungsten is fixed on the arm and by rotating the eccentric flywheel an angular momentum is generated which lets the rover jump from A to B. HFUC-2A Component Set Series with a special surface coating are used to drive this mechanism.

Table 13.1

HFUC-2A					
Size	Ratio	Outer diameter	Length	Limit for repeated peak torque	Limit for momentary peak torque
		[mm]	[mm]	[Nm]	[Nm]
5	30 ... 100	20	7,5	0.5 ... 1.4	0.9 ... 2.7
8	30 ... 100	30	17	1.8 ... 4.8	3.3 ... 9
11	30 ... 100	40	19.5	4.5 ... 11	8.5 ... 25
14	30 ... 100	50	23.5	9 ... 28	17 ... 54
17	30 ... 120	60	26.5	16 ... 54	30 ... 110
20	30 ... 160	70	29	27 ... 92	50 ... 147
25	30 ... 160	85	34	50 ... 176	95 ... 314
32	30 ... 160	110	42	100 ... 372	200 ... 686
40	50 ... 160	135	51	402 ... 647	686 ... 1180
45	50 ... 160	155	57	500 ... 882	950 ... 1910
50	50 ... 160	170	63	715 ... 1180	1430 ... 2450
58	504 ... 160	195	73	1020 ... 1840	1960 ... 3430



ROKVISS – Robotics on the International Space Station  
© DLR/Institute of Robotics and Mechatronics

## Robotics on the International Space Station (ROKVISS)

The technology project ROKVISS was a project for qualification, in-flight verification and demonstration of light-weight robotic components. These components, developed by the Institute for Robotics and Mechatronics of the German Aerospace Centre (DLR), represent one of the most advanced robotic axes world-wide.

The main components of the technology demonstration are a manipulator with two representative axes, a control computer, the storage box for the control electronics, lighting, power supply, cabling and a mechanical contour to verify the manipulator functions.

As operational modes both an automatic mode and telepresence mode are implemented. The telepresence mode is possible during a direct radio link with the German Space Operation Center (GSOC) ground station, which is the case for 5-7 minutes during fly-over.

### Features

- Good dynamic capabilities
- Zero backlash
- Small dimensions
- Low friction
- Corrosion protection
- High repeatability
- High reliability
- High ratio
- Maintenance free

Table 14.1

HFUC-25		
Weight	[g]	190
Vacuum	[Pa]	1E <sup>-5</sup> to 1E <sup>-6</sup>
Under radiation		No change in properties
Survival temperature	[°C]	-55 ... 45
Operating temperature	[°C]	-30 ... 40

## Solar Array Drive Mechanisms (SADM)

A major application area for Harmonic Drive® Gears in satellites is the orientation of the solar panels towards the sun. One example is the use of HDUC Series Gears, which are extremely reliable, maintenance free and installed in the Septa 31 drives from RUAG Switzerland AG. In other Solar Array Drive Mechanisms, the extremely lightweight Harmonic Drive® CPL-2A Component Sets are used, which are available in different sizes and ratios. These drive mechanisms are used in small satellites which are equipped with weights of up to 500 kg and operate in low to medium orbits. Another member of the family is SARA 21, which uses components from the CSD Series.





## Position Pick-off Unit (PPU)

Since the first flight of the Airbus A310 in 1982 more than 50,000 Harmonic Drive® Gears have been applied in the flaps angle measurement system giving information about the flap position. This is used in all single-aisle Airbus aircraft, wide-body and long range versions. Four gears are integrated in each wing, two in the wing flaps root, and two in the wing flaps tip to check asymmetry while they are extended. The compact design associated with low weight and high accuracy were the key factors which convinced the customer to integrate Harmonic Drive® Gears in their systems.

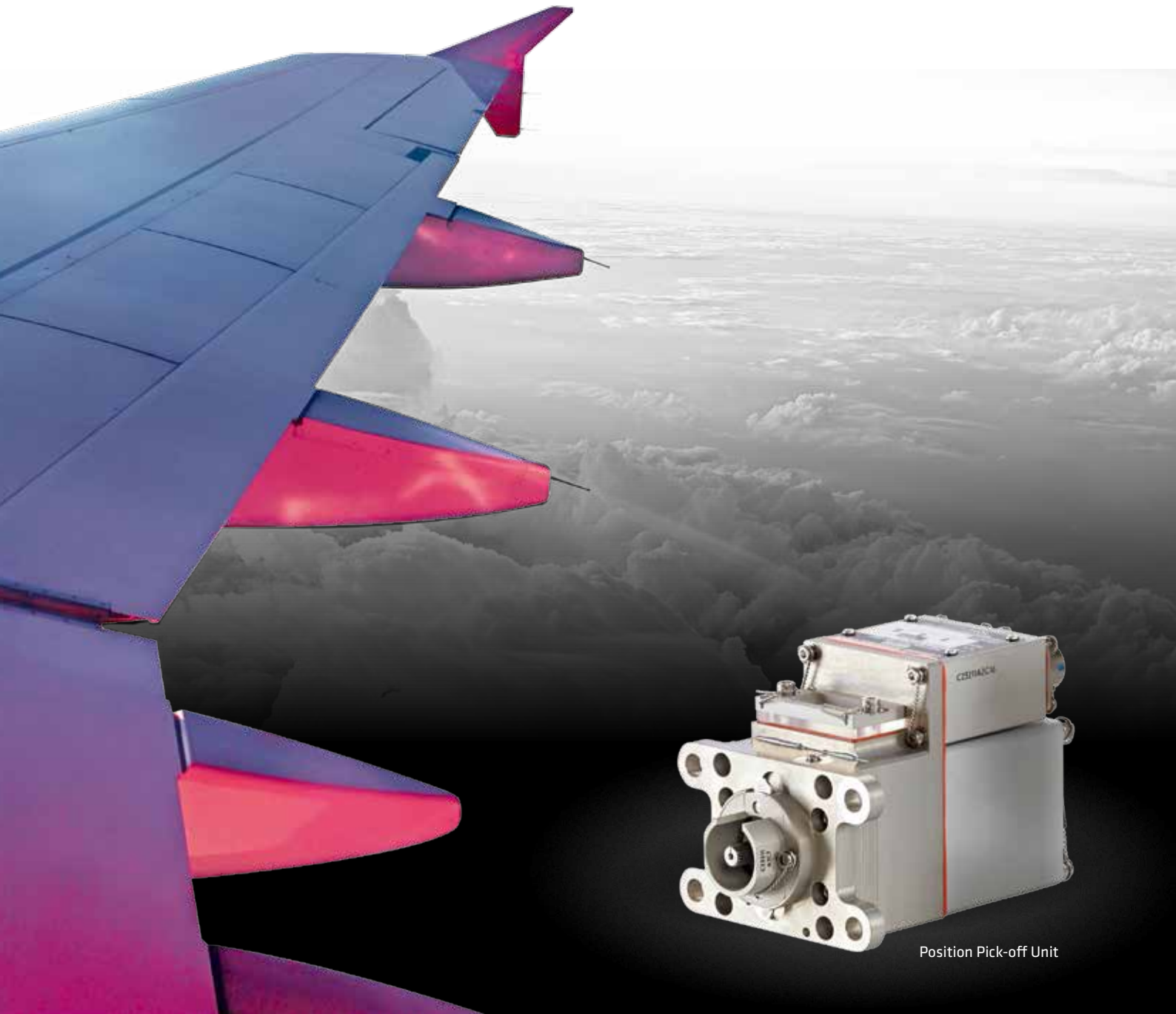
### Features

- Zero backlash
- High reliability
- Low weight
- Small dimensions
- Low friction
- Corrosion protection
- Growth potential
- Long-term availability

- High accuracy
- High ratio in one stage

### Special features of the Harmonic Drive® Gear:

- Optimised interface for easier integration and maintenance
- Made from stainless steel



Position Pick-off Unit





Trolley Lift for Airbus

## Trolley Lift

On board the Airbus A380 special elevators are used in order to transport the catering trolleys between the levels of the aircraft. These elevators have been developed by Jenoptik AG. Harmonic Drive® Gears are used for actuation - because of their compactness and reliability. Special attention was given to a noise reduced integration in order to reflect passenger demands with respect to comfort. The lift itself is a safety-critical element.

The trolley lifts have first been used on the A340-600. The Harmonic Drive® Gear used is a modified unit made in stainless steel, which takes into account the special requirements with respect to available space and environmental conditions.

### Features

- Circular Spline and gear housing in one part
- Optimised interface for easier integration and maintenance
- Made from stainless steel

Table 171

HFUC-40-50		
Reliability factor		1E <sup>-10</sup> /FH
Ultimate peak torque	[Nm]	685
Weight	[kg]	4.7
Torque/Weight ratio	[Nm/kg]	145.7
Storage temperature	[°C]	-55 ... +85
Operating temperature	[°C]	-15 ... +55

Due to the special requirements in the defence and aerospace sector, our drives are developed based on our standard products and are modified according to your needs and application requirements.

Harmonic Drive AG uses the latest 3D-CAD software to design its products. Data is available for standard products via the Internet and files can be made available in a variety of formats at customer request.

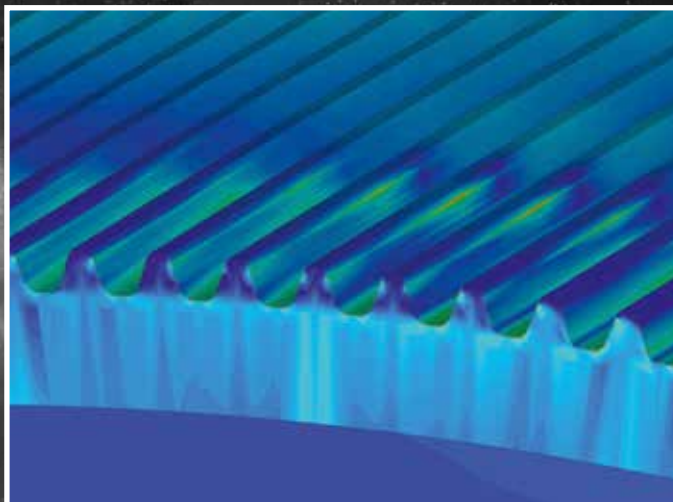
In order to meet the requirements for configuration management and traceability, relevant data is documented in our data system.

FEA software is used not only for the development and for optimisation of mechanical components but also for the electromagnetic and thermal analysis of motor components.

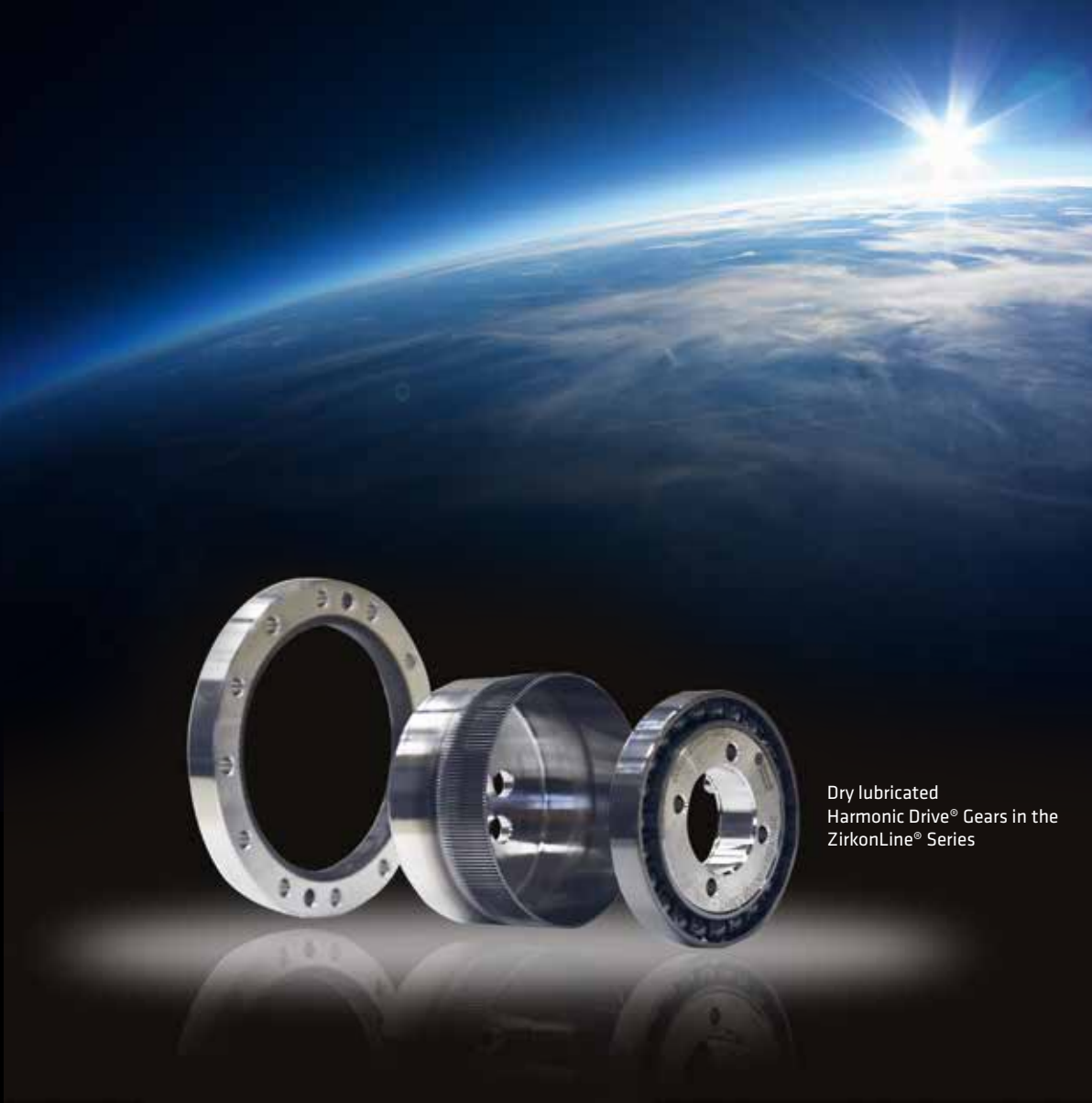
In order to accelerate the development and design of complex mechatronic solutions, Harmonic Drive AG applies modern simulation software such as MATLAB/Simulink, Dymola and Modelica. Models of mechanical and mechatronic products can be made available upon request and can be integrated with your system.

This also applies to the analysis of reliability and endurance. Performing failure analysis (FMEA) or the determination of failure rates and calculating the MTBF also belongs to the capacity of our development team. When required the results can be verified on our test rigs with application-specific life cycles.

In our laboratories and in collaboration with widely recognised institutions, we can perform tests under extreme environmental conditions. Performance tests in thermal vacuum, under space conditions or in the cryo-temperature range are possible.



Representation of the contact pressures in the Flexspline toothings determined by FE analysis



Dry lubricated  
Harmonic Drive® Gears in the  
ZirkonLine® Series

## Lubricants

Depending on product and on requirements coming from your application a proper lubrication configuration and sealing concept will be selected. The selection for defence and aerospace applications is mainly driven by the special tribological needs of the Harmonic Drive® Gear. The drivers for Space flight applications and Cryogenic applications are the environmental conditions such as vacuum and operating temperatures against the required lifetime.

Especially for applications in the low temperature range, we have developed simulation tools to calculate, e.g. the efficiency as a function of torque, speed and temperature. The results from simulation can be verified in our climate chambers and on the different test stands. These include tests with a reduced amount of lubricant and specially developed lubricant types in order to expand the range of applications and to increase the efficiency at low temperatures.

Table 19.1

Lubricants for special operating demands			
Application	Type	Manufacturer, Designation	Operating temperature range [°C]
Broadband temperature range	Grease	Harmonic Drive, Flexolub-A1	-40 ... +120
Low temperature	Grease	Harmonic Drive, Flexolub-M0	-70 ... +150
Vacuum	Grease/Oil	Braycote 601EF/Fomblin Z25	-80 ... +90
Cryo	Solid lubrication	Dicronite®/DL5 Balinit® C/MoS <sub>2</sub>	below -150

## Features

- Standard voltage range 24-48 VDC
- Large hollow shaft
- Compact design
- Low cogging torque
- Smooth operation
- High overload capacity
- Maintenance free
- Variable housing design
- Speed up to 6,500 rpm
- Rated torque capacity up to 45 Nm within the linear range
- Corrosion protected design
- Sinusoidal back EMF
- Ripple torque < 1 %
- Brake 18-32 VDC

## Motor Technology

Our many years experience in the field of motion control as well as our adaptation to continuously changing markets have increased the specialist knowledge at Harmonic Drive AG. In addition to the ongoing development of the Harmonic Drive® Gear we have expanded our core competencies to include the development, design and production of customised servo motors.

Our main focus lies in the development of motors for extreme ambient conditions which are available as a standard or as a customised motor and are equipped with motor feedback systems for both speed and position control. They provide the optimal solution for integration into your application.

These motors have a very low cogging torque due to the optimised winding and magnetic flux path, which when combined with a symmetrical, sinusoidal three-phase system means the AlopexDrive® Motor runs at very low noise and with a very smooth running characteristic.

The compact design combined with the central hollow shaft helps to solve many design problems resulting in minimum design effort.

### Output Bearing

- cross roller bearing or four point contact bearing
- high stiffness
- developed to withstand high axial and radial forces as well as high tilting moments
- HD Protect: corrosion protected

Table 20.1

Type	Synchronous servo motor
Insulation class	F (EN60034-1)
Insulation resistance	100 M [ $\Omega$ ] at 500 VDC
Insulation voltage	500 VAC (10 s)
Ambient temperature	Operation: -40 °C to +65 °C Extended temperature range on request
Vibration resistance	10 Hz to 500 Hz, max. 5 g DIN IEC 68 part 2-6 Adaptable to the application
Shock resistance	30 g, 18 ms DIN IEC 68 part 2-27 Adaptable to the application
Temperature sensor	PTC 116-K13-145 °C



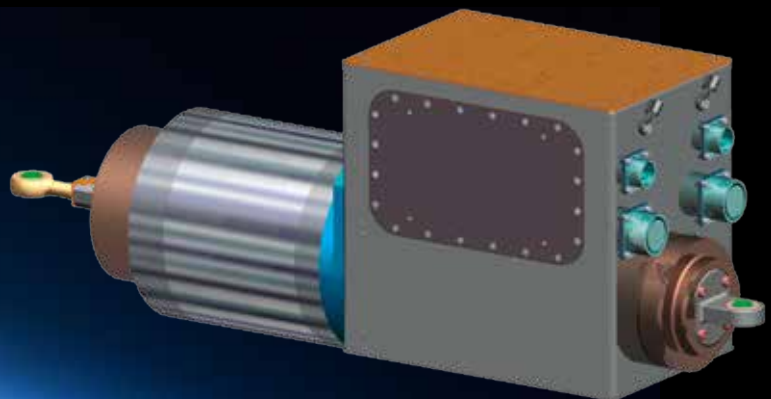
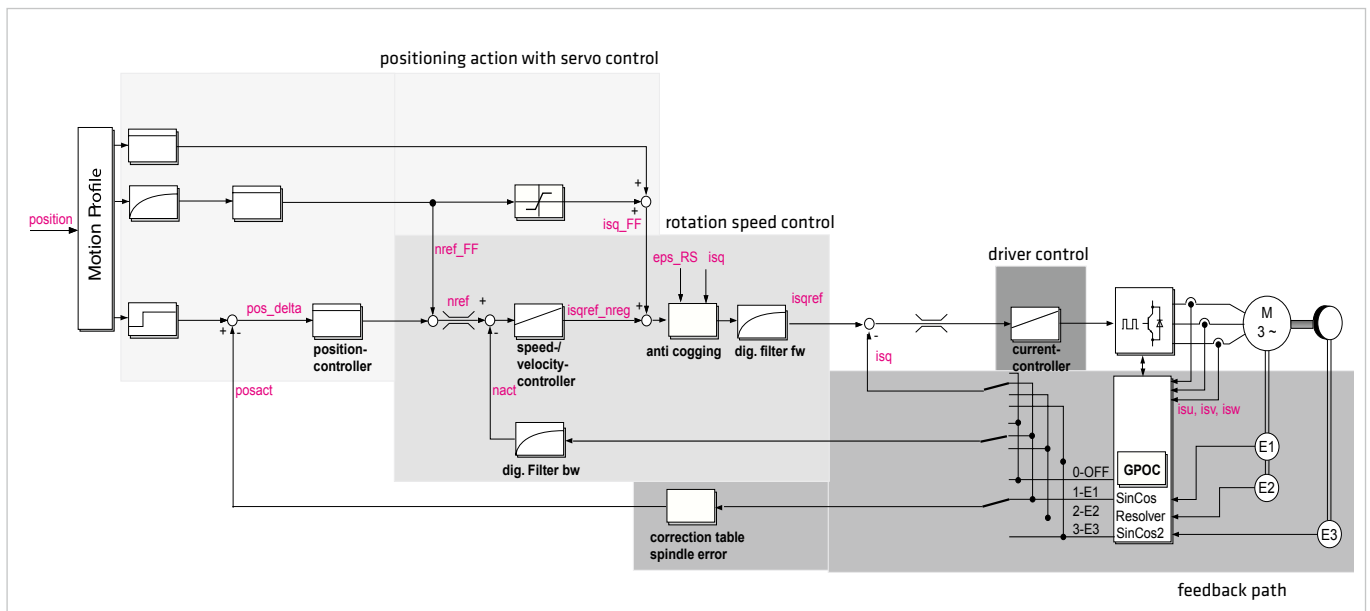
## Systems

Regardless of your control concept our servo actuators with predefined controllers allow easy integration into your system. They therefore offer comprehensive solutions for your motion request.

Our experience includes not only technology, but also reliable partnerships with companies active in this field.

The generation of motion profiles, well suited for highly dynamic movements, can either be implemented directly into the drive or into the primary control.

Figure 21.1



Harmonic Drive® Gears have successfully been designed against the following requirements:

- High reduction ratios in a single stage
- High torque/weight ratio
- High repeatability
- Zero backlash
- Maintenance free
- MTBF greater than 2 Mio. FH
- Failure rates below  $1 E^{-8}$  ...  $1 E^{-10}$  / FH

Harmonic Drive® Products have been qualified according to:

- RTCA DO-160
- MIL-STD-810
- DEF-STAN 00-35
- ECSS-E-30 Part 3A
- ECSS-Q-70B
- JAR 25 / FAR 25
- ABD 100 / ABD 200
- GRESS



The export of goods may be subject to legal regulations, which are regulated by the EC Regulation and national export regulations (CHP), the Foreign Trade Act (AWG) and the Foreign Trade Regulation (AWV).

The products manufactured by Harmonic Drive AG are currently not covered by the EC Regulation No. 428/2009 dual-use goods list.

Non-listed items could be subject to approval for export due to their application.

Compliance with the statutory export jurisdiction lies with the exporter.

## Labelling, Guidelines and Regulations

### CE Marking

With the CE marking, the manufacturer or EU importer declares in accordance with EU regulations, that by affixing the CE mark the product meets the applicable requirements within the harmonisation legislation established in the Community.



### REACH Regulation

REACH is an European Community Regulation on chemicals. REACH stands for Registration, Evaluation, Authorisation and Restriction of Chemicals.



### RoHS EU Directive

The RoHS EU Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment.





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We reserve the right to make technical changes  
 and modifications without prior notice.



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