

## phySPACE™

### Stepper Motor Series for SPACE applications, Standard and Customised Solutions

With 25 years of space heritage and over 1000 motors in space we know how to optimise weight, power consumption, thermal dissipation and stray magnetic flux without sacrificing precision or reliability.

phySPACE™ represents a standard stepper motor series for SPACE applications. This series comes with features essential to usage in extreme environments. Beyond that it is also the basis for customised projects - to optimise motor-load coupling.

Our phySPACE™ stepper motors are cost-efficient, clean and reliable even within extreme environments. The phySPACE™ series is developed and built to resist vacuum, vibrations, low/high temperature and radiation while maintaining high performance, precise positioning, long life.

#### In Focus



vacuum



radiation resistance

#### Standard

- 2-phase stepper motors
- Holding torques from 3.1 to 420 mNm without gearing
- Diameters from 20 to 57 mm
- 200 steps (1.8° per full step)
- Designed for high shock and vibration loads
- 4 leads parallel
- Preconditioned, protection IP 20
- Embedded K-type thermocouple
- Ambient temp. -40 °C... +120 °C
- Up to +200 °C (winding)
- Radiation up to 10<sup>6</sup> J/kg
- Bake-out temperature up to 200 °C (24 h)
- Outgassing TML <1 %, CVCM <0.1% (at <125 °C)

#### Options

- "Light weight" upgrade (Titan)
- "Space-testing" upgrade (vibration, shock, thermal cycling)
- Winding cold redundant
- For Cryo applications up to -269 °C

#### Customised Solutions

- Special designs based on the phySPACE series
- Gear

#### Highlights



#### Performance & Lifetime

Phytron phySPACE™ motors are based on a technology that can also be found in the most challenging projects of our time. From a variety of satellites up to the Mars rover Curiosity: Phytron motors drive applications in distant worlds - highly accurate, reliable and durable. Driven within their specification range, high-quality components and a proven design make sure: These motors won't let you down!



#### Cleanliness

Phytron motors for use in space contain only materials that also meet the requirements of the ECCS (European Cooperation for Space Standardisation). Thus, each material has a maximum TML (Total Mass Loss) value of 1% and a maximum CVCM (Collected Volatile Condensable Materials) value of 0.1 %. You will receive your space motor, double-wrapped and vacuum-sealed.

Space

phySPACE™ Stepper Motor



**Structure design**

The structure design of the phySPACE™ motors presents an optimum of lightweight, stiffness and surface protection. As is commonly done in high-vacuum class all structural elements such as housing, flanges and shafts are made of stainless steel. Even the standard version in stainless steel is optimised in terms of weight: The quadratic flange is reduced to flange lugs and the flanges are hollowed to save additional weight. In order to save even more weight the phySPACE™ comes with the option for a „light-weight“-material like titanium.



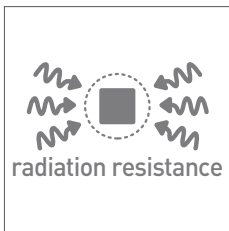
**Bearings**

The shock and vibration loads of a rocket launch can stress or damage the ball bearings significantly - resulting in reduced life under certain circumstances - when the motor hasn't even been put into operation. The phySPACE™ standard motor is equipped with special ABEC 7 bearings. A duplex bearing assembly in the front flange dissipates the vibration loads safely into the housing structure. Especially when in a vacuum, unlubricated ball bearings can be affected by „cold welding“, and thus degrading and even binding the bearings.



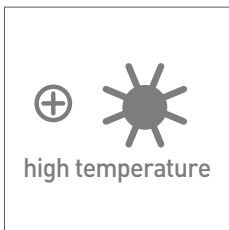
**Adhesives**

The adhesives used are qualified for space applications according to ECSS Q-70-02A. They represent an optimum of strength, ductility, low outgassing rates and thermal resistance. The outgassing rates (TML, CVCM) comply with the European Space Standards and American space standard.



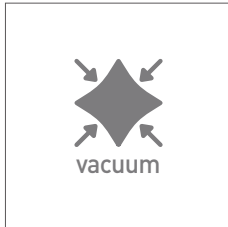
**Radiation Resistance**

The phySPACE™ motors are designed for radiation of up to  $10^6$  J/kg for use in space applications. A motor not designed for radiation will not only suffer degradation of the insulation and the adhesives - especially the grease of the ball bearing reducing the efficiency and will eventually cause the motor to fail.



**Temperature Management**

All materials selected for the phySPACE™ motors can withstand a short-term winding temperature of up to 200° C. Due to the lack of convection in a vacuum, the motors can heat up very quickly and often work at a high temperature level - depending on the duty-cycle. In our phySPACE™ motors we integrate a thermocouple to allow monitoring of the exact winding temperature. This is how you protect your motors from overheating.



### Preconditioning

The selected materials and components are outgassed by a Phytron process at up to 200 °C in vacuum chambers, so that outgassing materials cannot deposit in the ball bearings or inside the motor. This way we provide a minimum molecular contamination of the surrounding system so that the motors can even operate close to optical systems.



### Handling and Storage

phySPACE™ motors are primarily designed for use in a vacuum. For this reason the motors must always be handled under controlled conditions: On the ground at 20 °C +/-10 °C and relative humidity <=50%, in clean rooms and clean boxes. Long-term storage is permitted only in unopened original phytron packaging. After storage, or not rotating for more than 6 months, a „running-in“ is highly recommended in order to distribute the grease evenly again. The motors are to be handled with suitable gloves. Since the rotor is magnetic, it must be handled in a clean environment so that no metal particles can be pulled through the opening at the rear of the motor into the motor. Particles in the motor lead to an impairment of operation, the lifetime, or even failure of the motor due to binding.

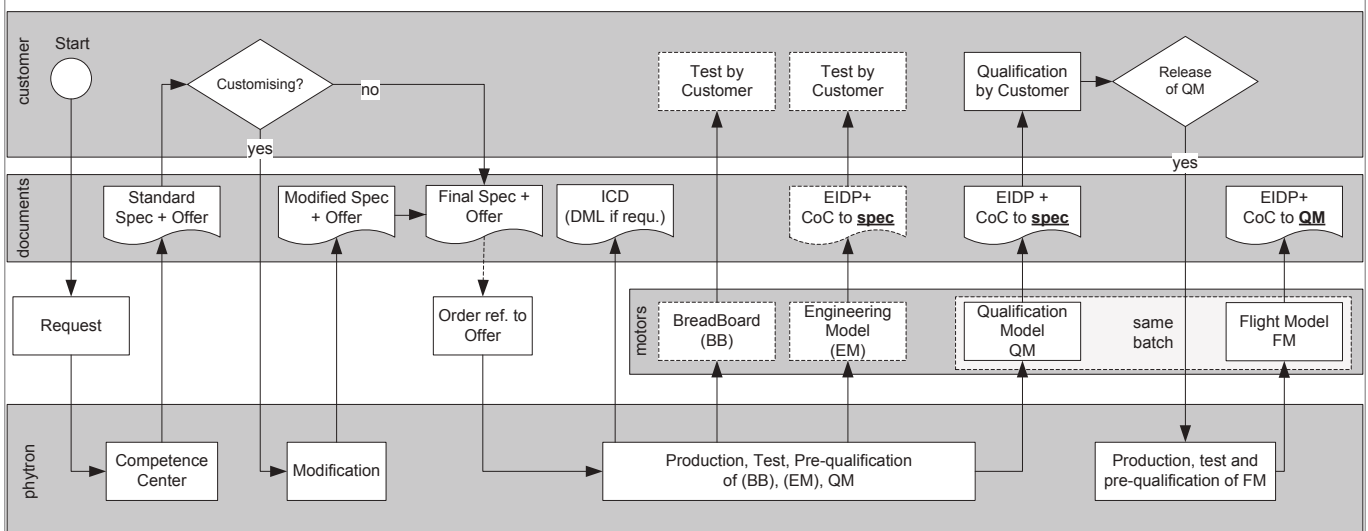


### Service, Consulting and Customising

Of course we are happy if our standard already fulfills your application's needs! Although our phySPACE™ series integrates our application experience of the last decades - sometimes the standard is just not enough. We offer to create customised solutions to make our motor a perfect fit for your application, because sometimes even small changes make the difference.

## Road-Map & Milestones

Phytron project partnership: receive the perfect space motor for your application.

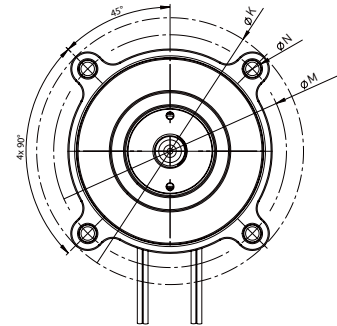
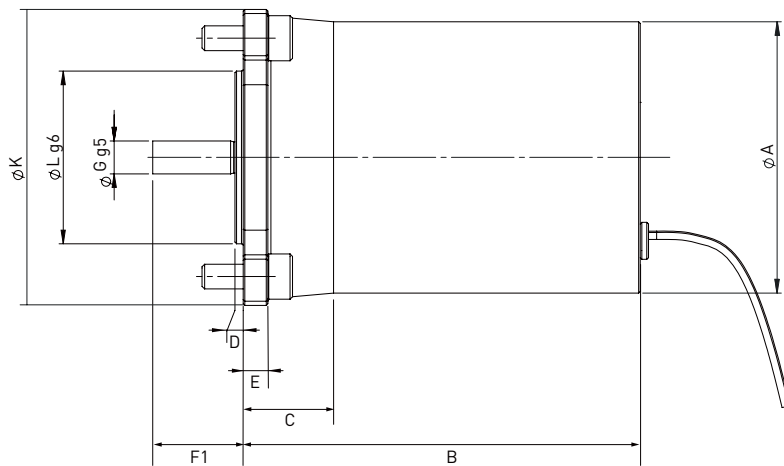


Space

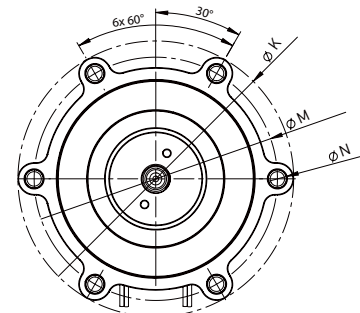
Technical Characteristics

		Standard	Upgrade Options
General Characteristics	Number of steps / step angle	200 / 1.8 °	
	Physical step accuracy (non accumulating)	3 to 5 %	
	Speed (typical for continuous operation)	400 rpm	
	Preferred direction	clockwise (facing the motor shaft)	
	Bearing quality / arrangement	ABEC7 / Duplex (front)+ floating bearing (rear)	
	Lubrication	space grade compatible	non / dry
	Housing	stainless steel	„light weight“ titan
	Protection class	IP 20	
	Expected lifetime (typical)	20 x 10 <sup>6</sup> revolutions	
Electrical	Operating voltage	up to 48 V	
	Control	bipolar	
	Leads: amount / wiring / wire exit	4-leads bipolar / parallel / axial	cold redundant
	Lead insulation	Kapton	
	Temperature sensor	type K	
	Dielectric strength	>500 V <sub>AC</sub> with 50 Hz	
	Insulation resistance (depending on diameter)	>100 MΩ with up to 500 V <sub>DC</sub>	
Cleanliness	Pre-Conditioning	first outgassing by phytron	
	CVCM (Collected volatile condensable materials) at 125°	< 0,1 %	
	TML (Total Mass Loss) at 125°	<1 %	
	Magnetic emission	upon request	
Environmental	Surrounding Environment	vacuum (UHV)	
		atmosphere (with restrictions)	
	Radiation resistant up to a dose of	10 <sup>6</sup> J/kg	
	Environment temperature (operating)	-40...+120 °C	higher temperature upgrade/ Cryo temperature upgrade
	Environment temperature (non operating)	-70...+140 °C	
	Temperature max. (winding)	max. +200 °C	
	Environment (storage)	+10...+50 °C; original packing	
	Humidity (max.)	<=50 %	
	Vibration GRMS	20	
Test	Test: electric / mechanic / dynamic / climate	standard	
	Test: Vibration / Shock / Thermal Vacuum Cycling	-	„space-testing“
	EIDP (End Item Data Package)	standard	

phySPACE™ 19-2 to 56-2 Stepper Motors



phySPACE™ 19-2 to 42-2



phySPACE™ 52-2 and 56-2

Dimensions / Electrical and Mechanical Characteristics

phySPACE™ Standard 200-step 4 lead parallel bipolar	Electrical characteristics				Mechanical characteristics						Dimensions in mm										
	Current/ phase I <sub>N</sub>	Resistance/ phase <sup>4)</sup>	Max. operating voltage <sup>5)</sup>	AWG	Holding torque <sup>1)</sup>	Power-OFF torque	Rotor inertia	Loads <sup>2)</sup>		Mass <sup>3)</sup>	A	B	C	D	E	F1	G <sup>95</sup>	K	L <sup>96</sup>	M	N
								axial	radial												
A	Ω	V <sub>DC</sub>		mNm	mNm	kg cm <sup>2</sup>	N	N	g												
19-2	0.6 1.2	2.1 0.63	48	28	3.8	0.9	0.0009	10	15	70	20	34	10.5	1.5	2	7.5	2.5	32	14	27	2.2
25-2	0.6 1.2	3.25 0.95		28 26	13	2	0.0025	15	25	100	26	36	10.5	2.5	2.5	9.5	3	38	14	33	2.7
32-2	0.6 1.2	4.6 1.25		26	50	3	0.01	30	45	211	33	48	11	2.5	3	11	4	47	18	42	3.2
42-2	1.2 2.5	1.7 0.34		24 22	140	5	0.045	30	50	425	43	60	16	2.5	3.5	16	5	62	22	54	4.2
52-2	1.2 2.5	2.6 0.6		24 22	450	12	0.15	65	100	900	53	75.5	17	1	5	21	6	75	38	66	5.2
56-2	1.2 2.5	3.9 0.8		24 22	500	50	0.24	50	80	970	57	70	16.5	2.5	4.5	22	6	77	38	68	5.2

<sup>1)</sup> Holding torque in bipolar mode with parallel windings. Two phases on at rated current

<sup>2)</sup> Axial radial loads are for mounting purposes only. A flexible coupling must be used in operation.

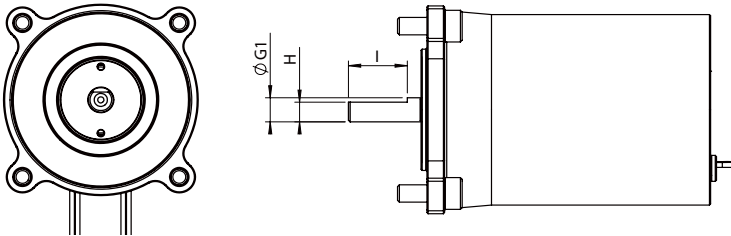
<sup>3)</sup> The use of titanium parts reduces the overall weight by 20 %.

<sup>4)</sup> Differently with redundant winding

<sup>5)</sup> Max. operating voltage of the power stage (intermediate circuit voltage)  
All values given above refer to room temperature and atmospheric pressure. Other sizes available upon request

Space

Option: Shaft Design



More shaft options upon request.

Dimensions

Stepper motor	Dimensions in mm		
	G1	H	I
phySPACE 19	2.5	2	4.5
phySPACE 25	3	2.5	6.5
phySPACE 32	4	3.5	8
phySPACE 42	5	4	13
phySPACE 56	6	5	18.5

Derating - Duty-Cycle-Design for Applications in Vacuum

Motors operating in a vacuum heat up very quickly depending on their duty cycle. Driven with nominal current the maximum temperature will be reached within several minutes. Therefore it is necessary to monitor the motor's temperature (K-element) or to design a duty cycle with enough off-time to always keep the motor a safe temperature level.

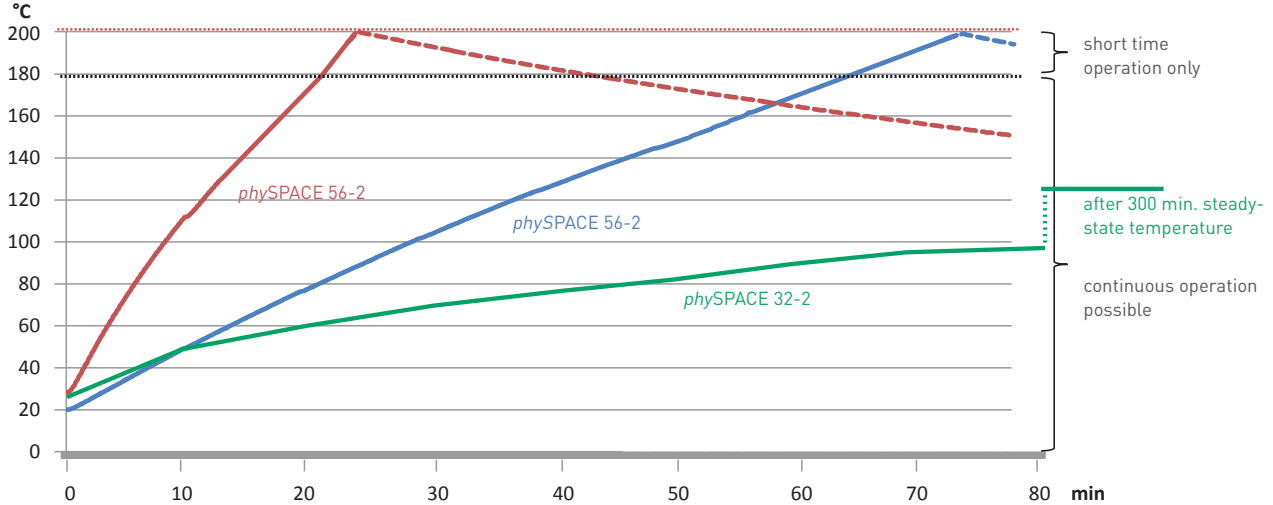
The shown curve is set at an environmental temperature of 20 °C. To give you an idea of how the chosen current influences the motor temperature we drew two curves of a motor similar to the phySPACE™ 56. Driven with 400 rpm at 50 % of the nominal current, the motor takes longer to heat up due to less ohmic losses than driven with the full nominal current.

The third curve (phySPACE™ 32-2) with 0.5 nominal current and 200 rpm only leads to a steady state temperature within the safe temperature limits.

A higher rotational speed increases the magnetic losses. Therefore high speeds should be avoided as far as possible to reduce heat losses and to protect the bearings.

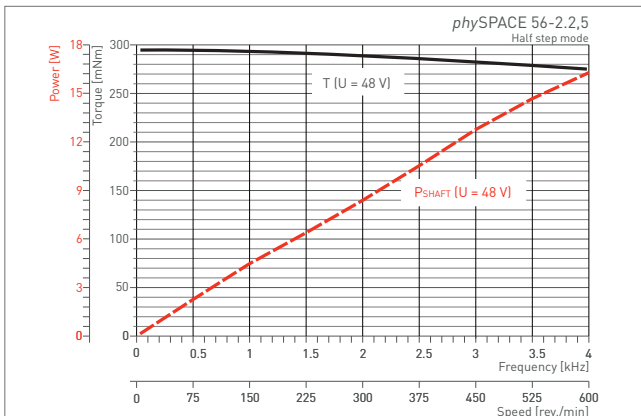
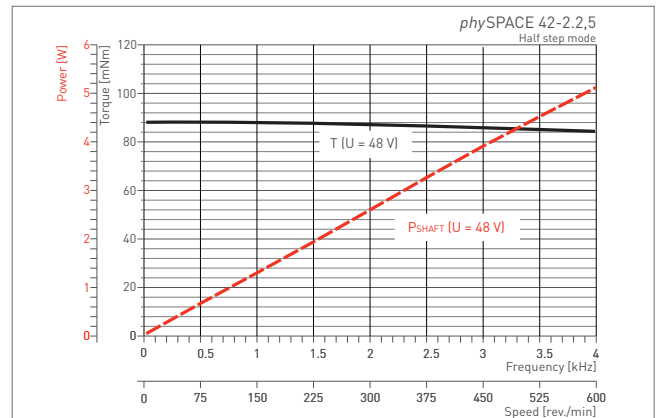
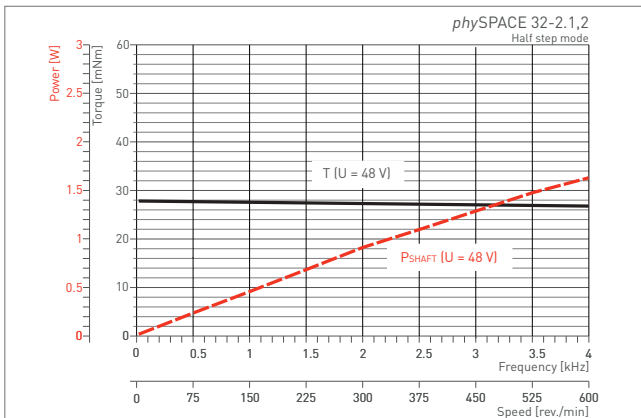
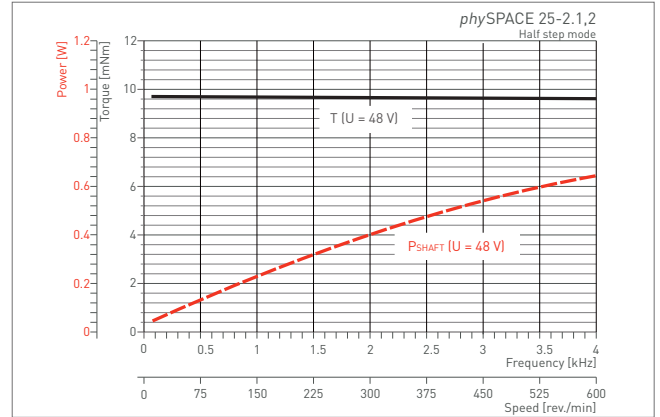
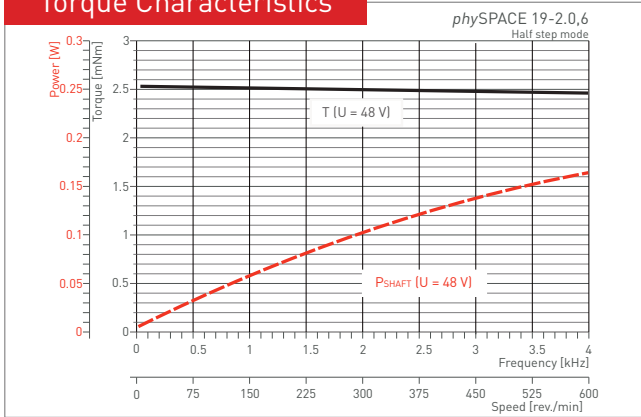
The cooling down speed during the off-time depends on the temperature delta in between the current motor temperature and the environmental temperature and the connected structure's thermal capacity.

Winding temperature (in vacuum), environment 20 °C



- 1/1 nominal current, 48 V, 400 rpm      cooling down
- 1/2 nominal current, 48 V, 400 rpm      cooling down
- 1/2 nominal current, 48 V, 200 rpm

## Torque Characteristics



## Motor Temperature Sensors: K-type Thermocouple

The insulated temperature sensor in Phytron motors is integrated in the motor windings. The response time to temperature changes of the winding is very short, compared to temperature sensors mounted outside the motor housing. The temperature is measured all the time (even if only one motor phase is powered at a time), because the sensor is always mounted between the phases.

Efficient Customising - the Perfect Fit

We proudly contribute to projects of:



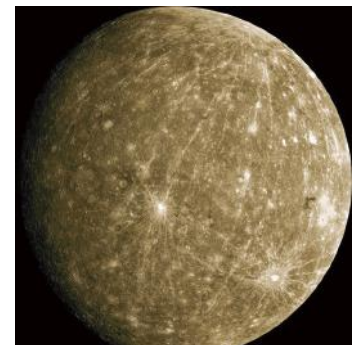
Tailored Stepper Motors for Space Applications



**BepiColombo - MERTIS (due to launch in 2015)**

MERCURY Radiometer and Thermal Infrared Spectrometer

- Instrument: <http://www.dlr.de/os/desktopdefault.aspx/tabid-6956/>
- Mission: [http://www.esa.int/Our\\_Activities/Space\\_Science/BepiColombo\\_overview2](http://www.esa.int/Our_Activities/Space_Science/BepiColombo_overview2)
- For: Polish Academy of Science (PAS), DLR, ESA



Bepi Colombo image: NASA



**MAVEN (2013)**

Launch date: Nov. 18, 2013; mission target: mars - explore its upper atmosphere; orbit insertion date: Sept. 22, 2014

- Grating flip mechanism, 90° deflecting angle moving in hard end stops
- Cleanliness for optics
- Motor: size 25, hybrid stepper 200 steps/rev
- Gear: integrated planetary gear ratio 50:1, 90 deg travel
- Structural parts titanium, hybrid bearings, lubrication
- Titanium coupling: compensation of an axial length reduction during deformation without additional stress
- For LASP / NASA



LASP MAVEN image: NASA/Goddard Space Flight Center

Tailored Stepper Motors for Space Applications

**Mars rover CURIOSITY for NASA (2011)**

Phytron stepper motor focuses laser and the analysis camera

- Focuses the laser light and the analysis camera inside the ChemCam instrument on the sample.
- Excels in reliability, durability, vacuum compatibility and minimal outgassing rates.
- Optimised for mechanical friendly smooth running and is capable of precise positioning even without feedback or complex electronics



Mars rover CURIOSITY - ChemCam image: NASA



**JUNO (2011)**

Mirror rotation in Ultraviolet Imaging Spectrograph

- Phytron's stepper motor : VSS 32
- Instrument: <http://adsabs.harvard.edu/abs/2008AGUFMSM41B1678G>
- Mission: [http://www.nasa.gov/mission\\_pages/juno/main/index.html](http://www.nasa.gov/mission_pages/juno/main/index.html)
- NASA / ESA



Juno image by NASA/JPL



**MIRIS (2010)**

Multi-purpose infrared imaging system (MIRIS)

- Instrument: [http://www.isas.jaxa.jp/home/rikou/kogata\\_eisei/symposium/2nd/koto/07.pdf](http://www.isas.jaxa.jp/home/rikou/kogata_eisei/symposium/2nd/koto/07.pdf)
- For: Astronomy and Space Technology R&D Division, Korea Astronomy and Space Science Institute

Tailored Stepper Motors for Space Applications



**EnMAP mission**

Shutter calibration mechanism as part of the scientific payload of the German EnMAP mission.

- Customised titanium gear shaft for low weight and strength
- Tailored magnet arrangement to minimise stray magnetic flux
- Redundant windings cater for loss of primary coils
- Harmonic Drive gears for space conditions
- Duplex bearings to better absorb shock and vibration
- Central housing configuration for optimised force transmission (hybrid assembly technology)
- For: Kayser-Threde and HTS



**A perfect fit for EADS Astrium.**

High precision positional actuator for the X-Band Downlink Antenna for the KOMPSAT S/C:

- Customised titanium main structure for low weight and optimal strength
- Integrated Harmonic Drive gear unit
- Duplex bearings to withstand shock and vibration
- Special lubrication system to prolong lifetime
- Customised leadwire exit to meet project constraints
- Motor model endurance tested in vacuum and N<sub>2</sub> atmosphere (bearings, lubrication system, gears)



**SOLACES (2003)**

- Stepper motor with 200 steps/revolution (1,8°)
- Designed for 300 N axial force
- Holding torque 70 mNm / driving torque 60 mNm
- Spindle system, non-magnetic
- Special grease; designed for ultra high vacuum at -50 °C to +40 °C
- For: IPM Freiburg

## Tailored Stepper Motors for Space Applications

### Rosetta - Cosima (2004)

Cometary Secondary Ion Mass Analyser

- Motor: stepper motor VSS19
- Instrument: <http://www.mps.mpg.de/de/projekte/rosetta/cosima/#instrument>
- Mission: [http://www.esa.int/Our\\_Activities/Space\\_Science/Rosetta](http://www.esa.int/Our_Activities/Space_Science/Rosetta)
- For: Max-Max-Planck-Institut, Extraterrestrische Physik München

### STEREO (2006)

The sun in 3D

- Mission: [http://www.nasa.gov/mission\\_pages/stereo/main/index.html](http://www.nasa.gov/mission_pages/stereo/main/index.html)
- For: NASA + The Johns Hopkins University

### XMM-Newton - EPIC (2000)

European Photon Imaging Camera (EPIC)

- Instrument: <http://sci.esa.int/xmm-newton/31281-instruments/?fbodylongid=774>
- Mission: <http://xmm.esac.esa.int/>
- For: Max-Max-Planck-Institut, Extraterrestrische Physik München, ESA

### Cassini-Huygens (1997)

Exploring Saturn

- Mission: ESA: [http://www.esa.int/Our\\_Activities/Space\\_Science/Cassini-Huygens](http://www.esa.int/Our_Activities/Space_Science/Cassini-Huygens)
- Mission: NASA: [http://www.nasa.gov/mission\\_pages/cassini/main/](http://www.nasa.gov/mission_pages/cassini/main/)
- For: Max-Planck-Institut, Heidelberg, ESA, NASA

### MOS-IRS-P2 (1996)

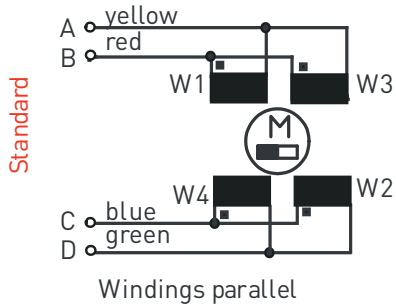
Indian Remote Sensing Satellite-P2

- Mission: <https://earth.esa.int/web/guest/missions/3rd-party-missions/historical-missions/irs-p3>
- For: DLR

Space

Electrical Connection

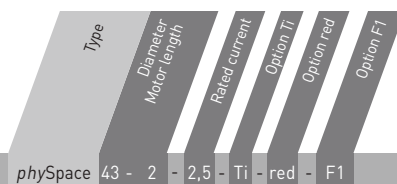
4-lead  
bipolar control



All illustrations, descriptions and technical specifications are subject to modifications; no responsibility is accepted for the accuracy of this information.

Ordering Code

The variable elements of the product are displayed in colour.



Ordering code phySpace 43 - 2 - 2,5 - Ti - red - F1

Options

Diameter - Motor size	19 - 2 25 - 2 32 - 2 42 - 2 52 - 2 56 - 2	
Rated current [A/Phase]	0,6 1,2 2,5	for phySPACE 19 to 32 for phySPACE 19 to 56 for phySPACE 42 to 56
Option	Ti	Titanium housing
Option	red	Winding cold redundant
Option	F1	Shaft design flat (front)

**Morskate®**



Any questions? Please contact us.

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