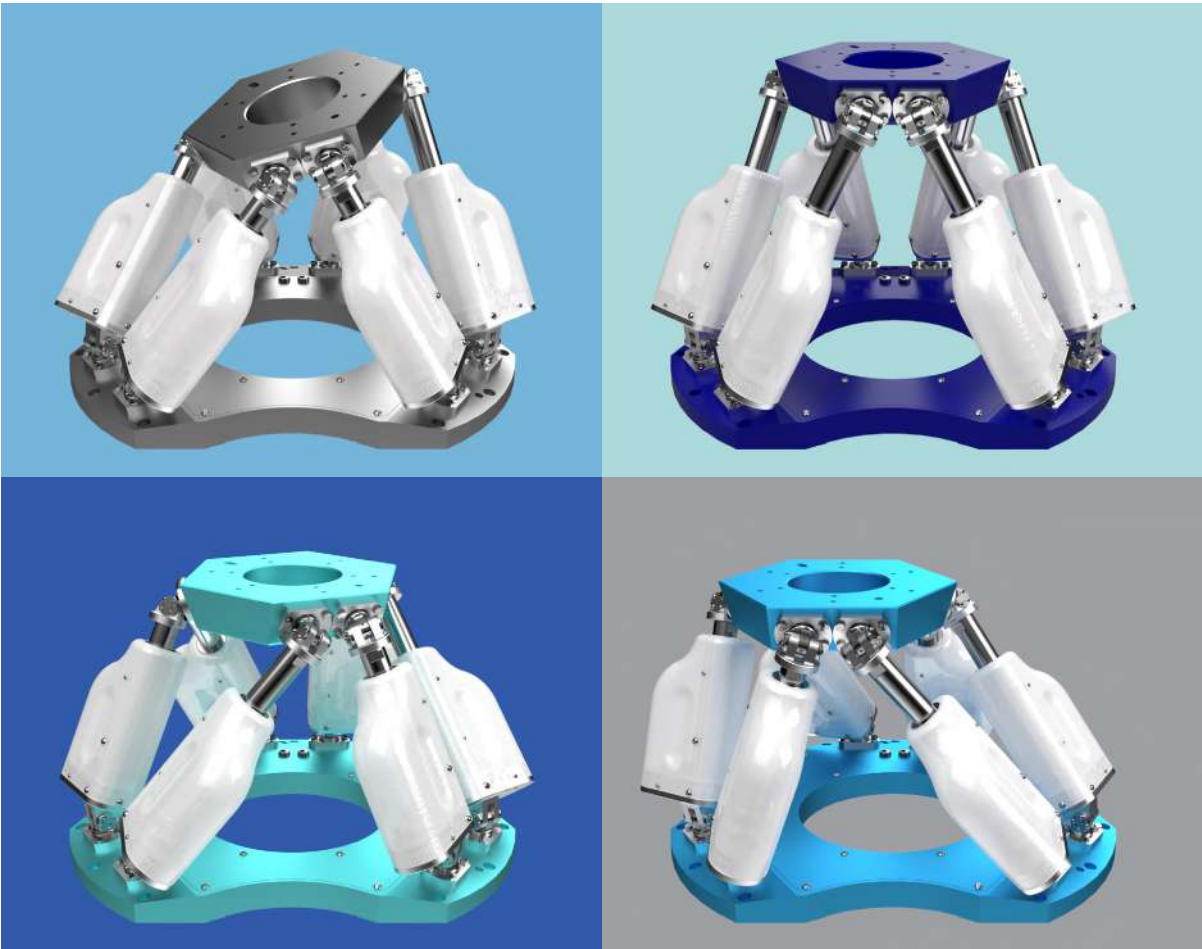# Symétrie

Positioning hexapods catalog

Welcome

In browsing this catalogue, you will find the best possible positioning solutions to cater to your demanding applications.

Always looking to increase the performance of our hexapods, our growing team works hand in hand to integrate the latest available technology.

This is why SYMETRIE is first and foremost a R&D company. Thanks to our experience providing hexapods for industry and research laboratories, we will be able to quickly answer your needs.

Olivier Lapierre & Thierry Roux
Co-founders, CEO & CTO

Contents

SYMETRIE company

Design department

SYMETRIE's engineering office consists of mechanical, electronics and software engineers. Our R&D department is continuously seeking for improvement, with a major effort on control software.

Workshops

All our hexapods and controllers are assembled in our mechanical and electronics workshops using standardized procedures.

Clean room

In our ISO 7 (class 10000) clean room, we mount the hexapods for applications, which are sensible to environmental contamination, such as optics, space or particle accelerators. In a clean room the concentration of particles is controlled and minimized.

Metrology laboratory

To demonstrate high precision performances, SYMETRIE is equipped with a wide range of metrology tools: laser interferometers, laser trackers, coordinate measuring machine (CMM), electronic inclinometers, capacitive sensors, accelerometers.

A promising experience and vision

SYMETRIE's trusted R&D skills led to the birth of the positioning and motion hexapods

SYMETRIE was created in 2001 with the hexapod technology as a baseline. This innovative system was quickly spotted by the highest research institutions which asked SYMETRIE for a high precision hexapod to position the target of the MegaJoule Laser, a high energy inertial confinement fusion device in France.

The following contracts, still more ambitious, trusted the company to add dynamic motion capabilities to its hexapods systems. SYMETRIE succeeded once again in delivering up to 1g acceleration to slosh 10 ton liquid gas tanks for maritime transportation.

The acquired experience and trust built among a nascent network of customers were the beginning of an involvement in a wide array of technological projects, such as the Gaia satellite and the James Webb Space Telescope among others.

Innovation is a key factor of our development. Our R&D department works every day to improve our technologies and control systems using the latest generation components and techniques for higher quality products.
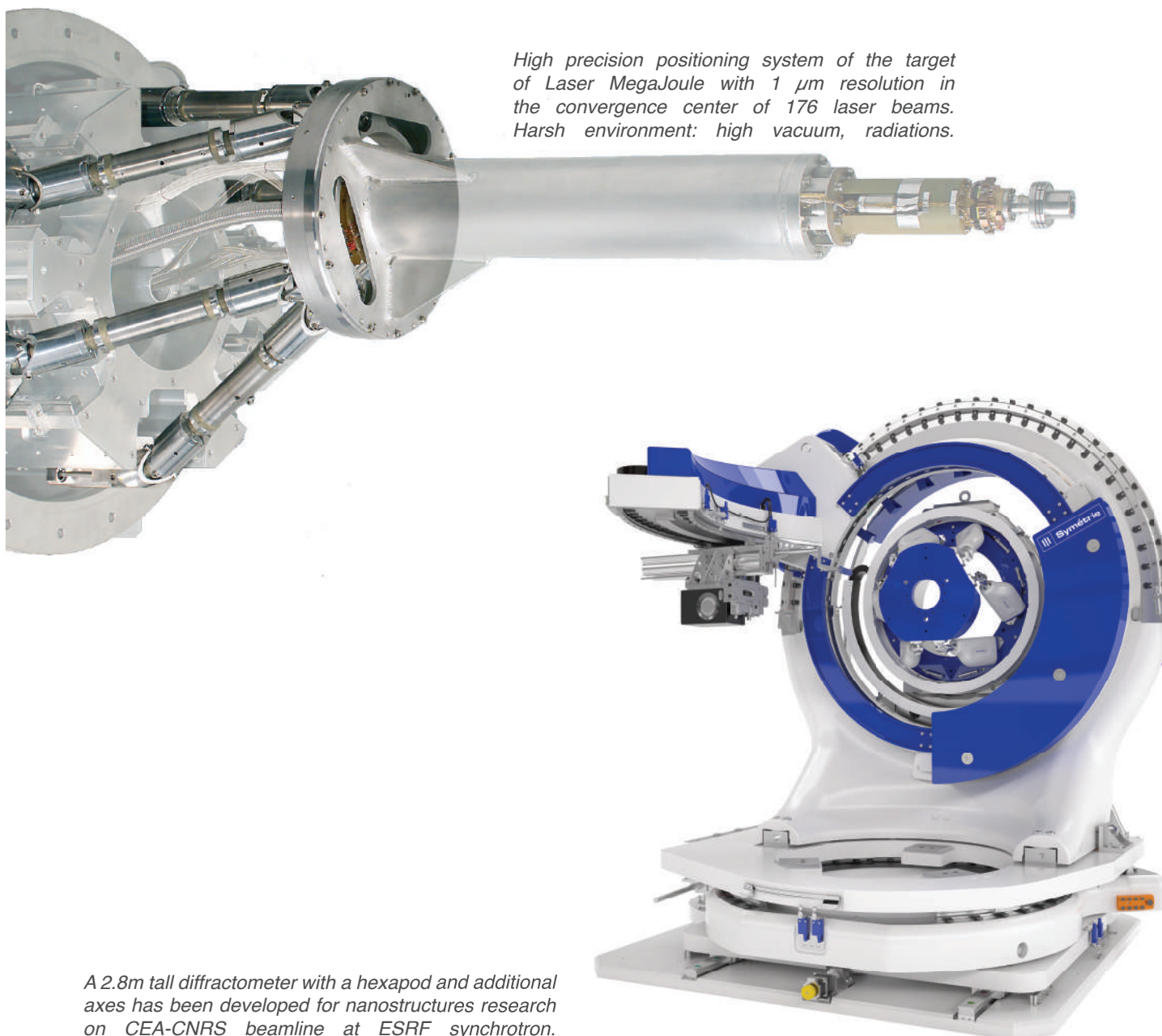
High precision positioning system of the target of Laser MegaJoule with 1 µm resolution in the convergence center of 176 laser beams. Harsh environment: high vacuum, radiations.

A 2.8m tall diffractometer with a hexapod and additional axes has been developed for nanostructures research on CEA-CNRS beamline at ESRF synchrotron.
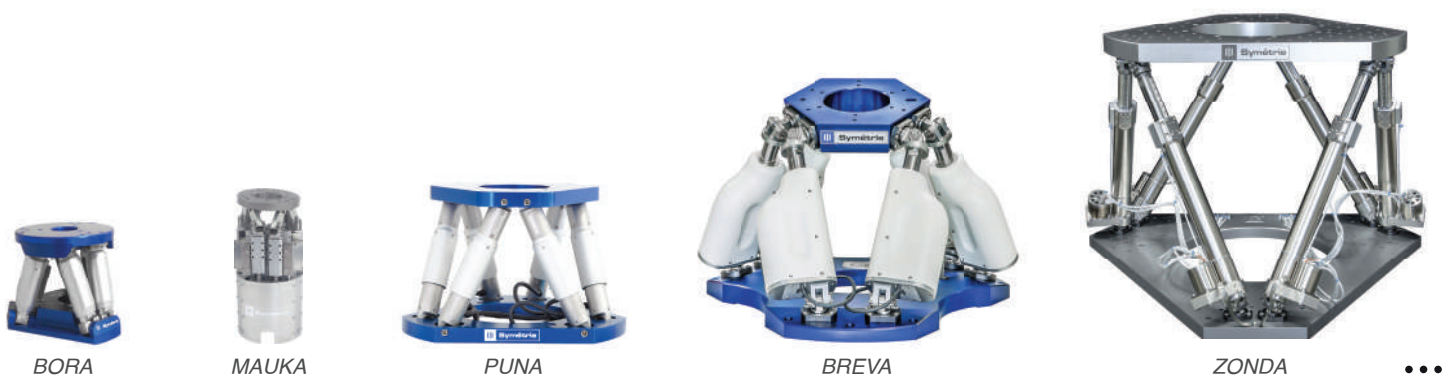
||| **Symétrie**

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From standard hexapods to custom designs

To cater to your needs in the smoothest way, SYMETRIE offers a range of turnkey hexapods.

- ■ Better price and lead time: We look forward to offering hexapods which have already been designed.
- ■ Ease project definition: Offering **a coherent range** where the hexapods differentiate between each other with unique features allows you to easier select and understand the capabilities that you will get.

SYMETRIE remains a trustworthy designer for customized solutions and can provide custom designs in a short time thanks to an in-house software enabling to quickly create a hexapod geometry with respect to the customer's input parameters.

With more than 20 years hexapod background, SYMETRIE is experienced in choosing and using the most adapted technologies in terms of motors, encoders, joints… according to the customer's application.

BORA   *MAUKA*   *PUNA*   *BREVA*   *ZONDA*   •••

Our roots: metrology specialists with innovative minds

The two co-founders of SYMETRIE, Olivier Lapierre and Thierry Roux, were previously working for LNE, the French national metrology and testing laboratory. Specialized in **dimensional metrology**, they were looking for an innovative and efficient 6 DOF measurement system to quickly calibrate machine-tools and thought of the hexapod as a perfect solution.

The dimensional metrology grain remains running through the veins of SYMETRIE at each one of its footsteps. Thanks to an experienced metrology staff, SYMETRIE knows how to qualify and test the hexapods before delivery to validate conformity.

Hexapod technology

6 Degrees Of Freedom

A hexapod is a parallel kinematic structure composed of a mobile platform linked to a fixed platform with 6 actuators.

This design allows to move an object placed on the mobile platform with 6 DOF (Degrees Of Freedom). In other words, the hexapod can move an object along the 3 translations (Tx, Ty, Tz) and the 3 rotations (Rx, Ry, Rz); any combination is possible.
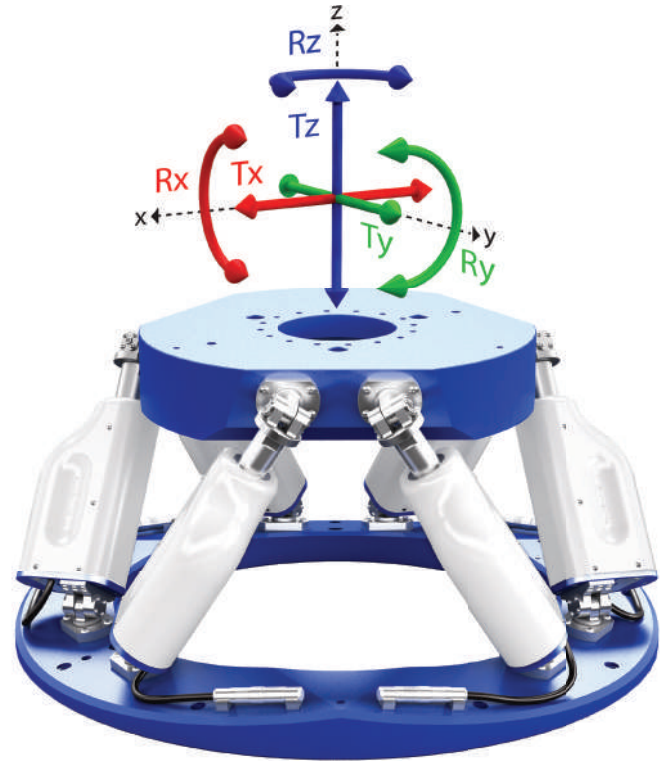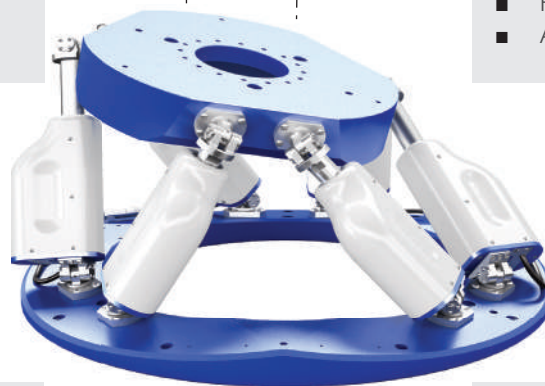

A versatile solution

Environment

- Vacuum (down to 10^{-6} mbar)
- Clean room

Payload

- From few grams to several tons
- Any orientation available

Performances

- Resolution
- Repeatability
- Accuracy
- Stiffness
- Stability
- Speed

Workspace

- From few µm to several hundred mm
- From few µrad to 45°

Workspace

A workspace defines all reachable positions of the mobile platform for specified degrees of freedom. An infinity of workspaces exists depending on which DOF are set to be swept and which DOF are set to be constant among Tx, Ty, Tz, Rx, Ry, Rz.

Available workspace can be easily verified with our software simulation tool HexaSym (cf. p. 9).

Example of two workspaces:
- In yellow, the workspace [Tx=swept, Tz=swept, Ty=0, Rx=0, Ry=0, Rz=0].
- In orange, the workspace [Tx=swept, Tz=swept, Ty=0, Rx=0, Ry=0, Rz=20°].

The orange workspace is smaller than the yellow workspace because the Rz rotation requires extra actuators' length.

Workspace [Tx, Tz, Ty=0, Rx=0, Ry=0, Rz=0]

Workspace [Tx, Tz, Ty=0, Rx=0, Ry=0, Rz=20°]
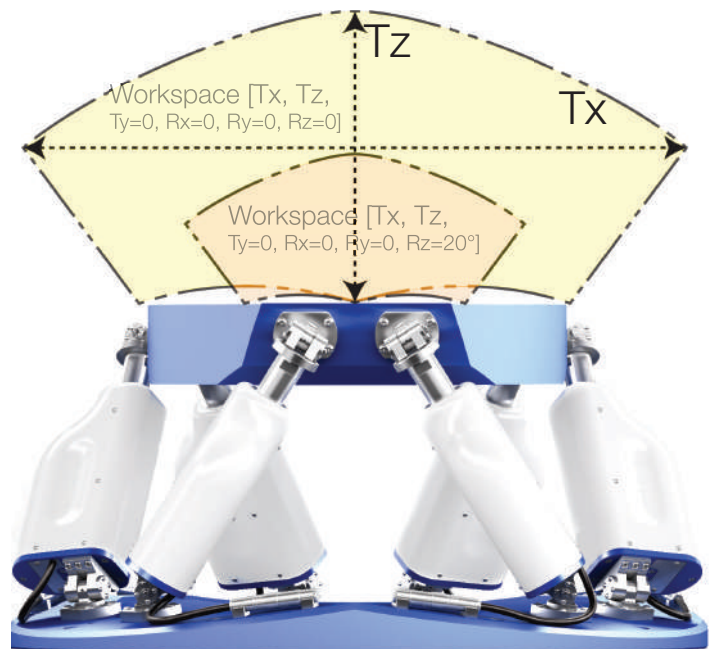
Configurable pivot point

In order to orientate the mobile platform in the desired way, a 3D rotation center has to be defined. This point is not limited to the center of the mobile platform and can be placed wherever the user needs it to be.

Hexapod designed and built for MAX IV Laboratory synchrotron. Special rotation centers have been defined to adjust easily a polarimeter with respect to the beam position.

Pivot point 1   Pivot point 2

Pivot point 0

Symétrie

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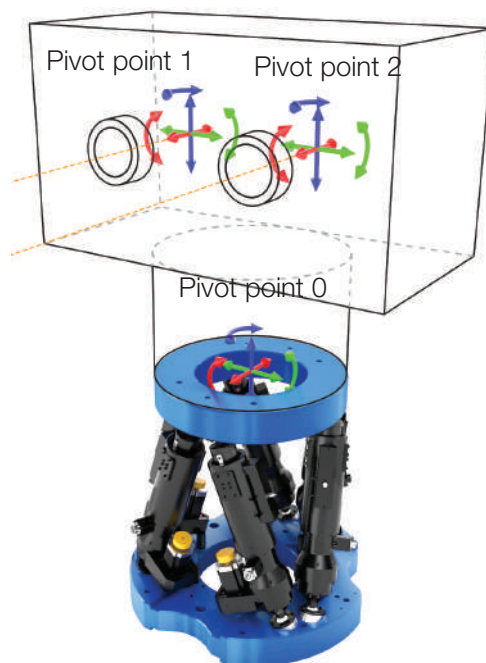
Overview of the product range

	Name	Payload	Linear travel range	Angular travel range	Linear / Angular resolution	Height
	MAUKA	5 kg	± 5 mm	± 8°	0.5 µm / 5 µrad	198 mm
	BORA	10 kg	± 20 mm	± 15°	0.1 µm / 2 µrad	145 mm
	PUNA	25 kg	± 30 mm	± 20°	0.5 µm / 5 µrad	200 mm
	BREVA	200 kg	± 75 mm	± 22°	0.5 µm / 2.5 µrad	350 mm
	ZONDA	400 kg	± 200 mm	± 20°	0.1 µm / 0.5 µrad	360 mm / 640 mm
	SIRIUS	200 kg	± 150 mm	± 20°	5 µm / 10 µrad	750 mm
	KUBAN	500 kg	± 75 mm	± 10°	0.1 µm / 1.5 µrad	600 mm
	JORAN	1 500 kg	± 170 mm	± 18°	0.1 µm / 0.5 µrad	750 mm
	SURES	500 kg	± 8 mm	± 1°	0.1 µm / 1.5 µrad	360 mm

The 3D STEP files of our standard products are downloadable on our website for an easy integration into your environment.

Symétrie

HexaSym simulation software

With HexaSym simulation software, the user can check the hexapod travel ranges and load capacities. It simplifies verifying cumulative travel ranges on several axes simultaneously, while changing :

- ■ the pivot point
- ■ the hexapod orientation (vertical, horizontal, other)
- ■ the payload parameters.

HexaSym simulator includes a 3D visualization, which enables to see how the hexapod moves according to the commanded positions.

This simulation software can be downloaded on our website. HexaSym will help to select the right hexapod model for a particular application.
It is also possible to use HexaSym for a customized hexapod, for which we will provide you with a specific configuration file.
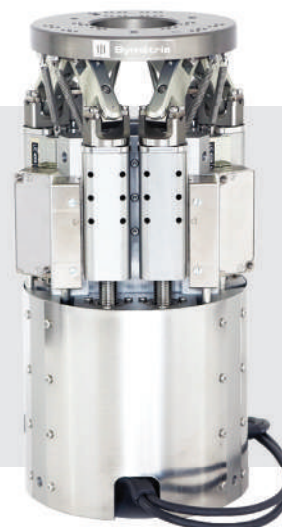
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MAUKA hexapod

High precision in a small diameter
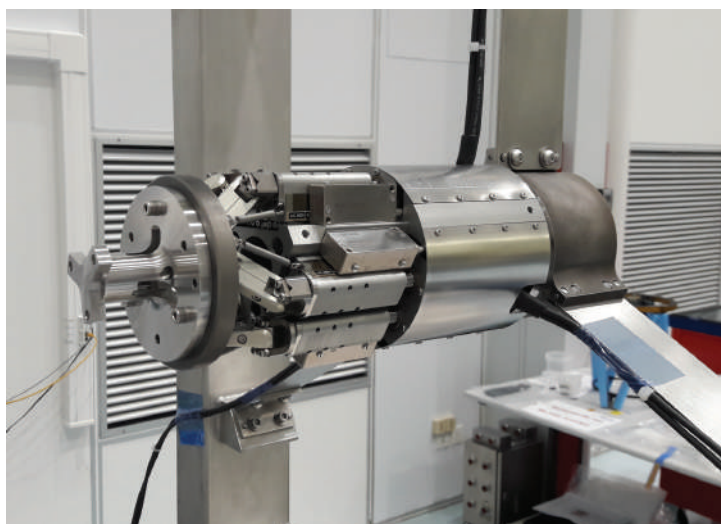
KEY FEATURES

- Small diameter of 107 mm
- Payload capacity up to 5 kg
- Angular travel range ± 8 °
- Absolute encoders

APPLICATIONS

- Optics
- Synchrotrons
- Space
- Astronomy

MAUKA hexapod with the interface to the glue box that will fix a mirror on a space telescope.
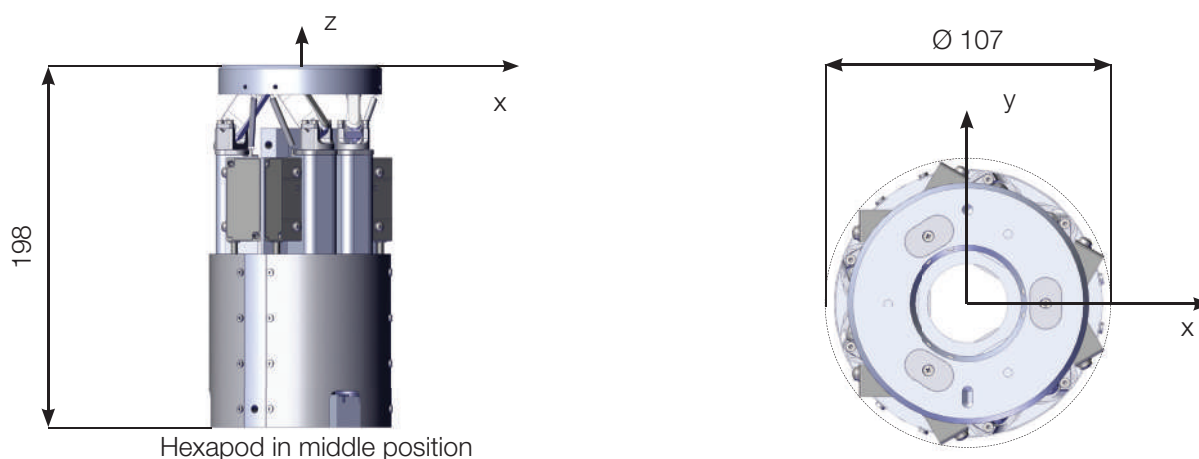
MAUKA hexapod has a very small diameter of 107 mm.

III Symétrie

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	MAUKA
Motion and positioning	
Travel range Tx, Ty (mm)	± 5
Travel range Tz (mm)	± 10
Travel range Rx, Ry (deg)	± 8
Travel range Rz (deg)	± 8
Resolution Tx, Ty, Tz (µm)	0.5
Resolution Rx, Ry, Rz (µrad)	5
Repeatability Tx, Ty, Tz (µm)	± 1
Repeatability Rx, Ry, Rz (µrad)	± 10
Speed Tx, Ty (mm/s)	1.6
Speed Tz (mm/s)	1
Speed (deg/s)	2
Mechanical properties	
Stiffness X, Y (N/µm)	0.7
Stiffness Z (N/µm)	4
Payload capacity (kg) (vertical orientation / horizontal orientation)	5 / 2.5
Motor type	DC motor, gearhead
Encoder type	Absolute linear encoder
Miscellaneous	
Operating temperature range (°C)	0 to + 50
Materials	Aluminum, steel, stainless steel
Mobile platform size (mm)	Ø 90
Fixed platform size (mm)	Ø 100
Central aperture (mm)	Ø 38 for mobile platform ; Ø 30 for fixed platform
Height in middle position (mm)	198
Footprint (mm)	Ø 107
Mass (kg)	3
Cable length (m)	3
Options	Clean room compatibility Vacuum compatibility Customized platform design Hand-held control unit Outdoor use Scalable size
Controller	
Controller type	ALPHA+
Interface	Ethernet
Power supply	110-240 VAC / 50-60 Hz

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.

z

x

198

Hexapod in middle position

Ø 107

y

x

Symétrie

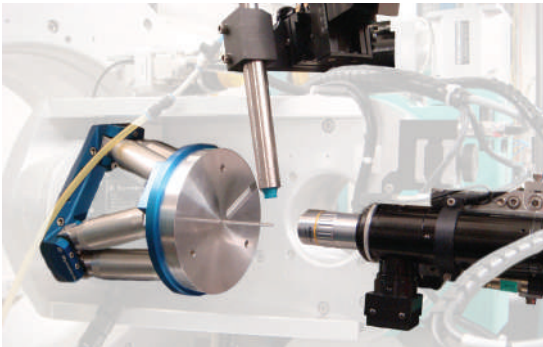www.symetrie.fr

BORA hexapod
High resolution hexapod small size

KEY FEATURES

- Payload capacity up to 10 kg
- Linear travel range ± 20 mm
- Angular travel range ± 15 °
- Height in middle position 145 mm

APPLICATIONS

- Instrumentation
- Aeronautics and spatial
- Optics
- Metrology
- Testing laboratories
- Semiconductors
- Synchrotrons

This hexapod places a sample at the centre of two large rotation stages. With this installation, hexapod mounting orientation varies between 0° and 90°. Advantages of the hexapod are: high stability, stiffness and repeatability of the sample position with respect to the rotation stages independently of their orientations.
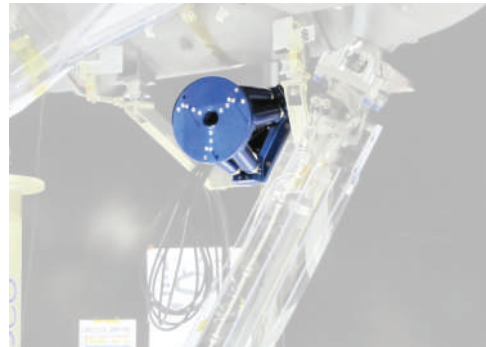
Alignment of a mirror with high precision on a space telescope. When the hexapod has correctly positioned the mirror, the user fixes the mirror and takes the hexapod off the structure.
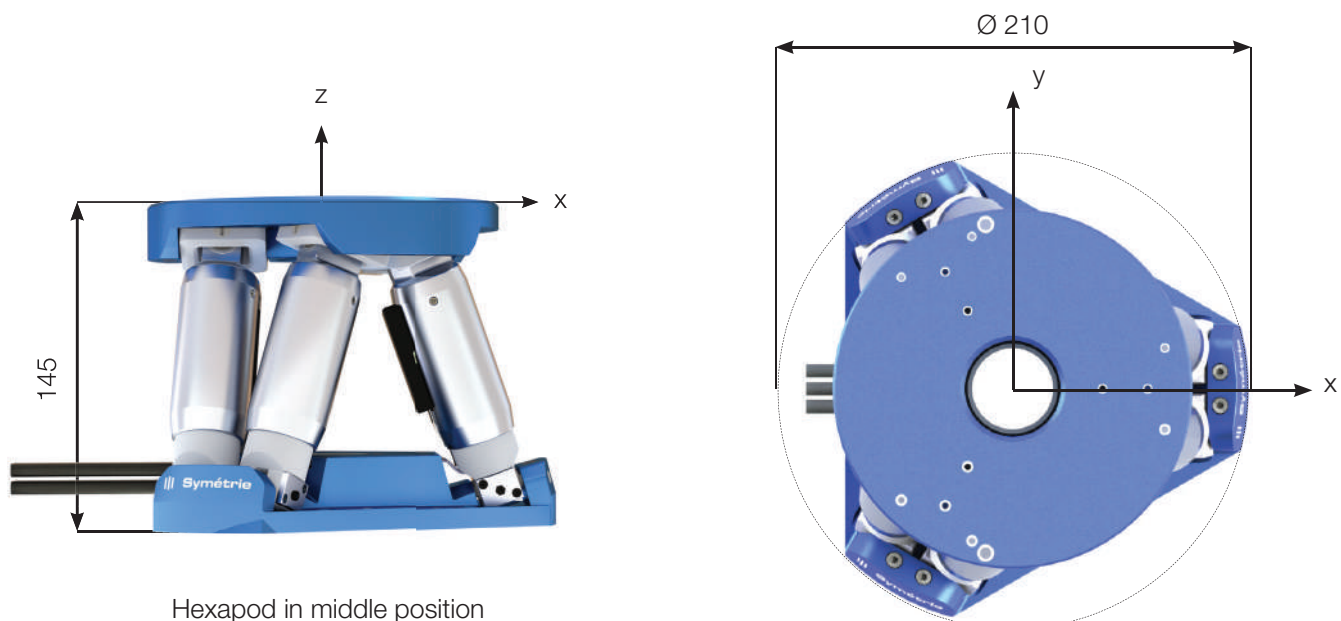

Two BORA hexapods position Kirkpatrick-Baez (KB) mirrors with high stability and resolution to improve the beam quality on a synchrotron beamline.

Some HV BORA hexapods are positioning the high reflectivity mirrors of a Fabry-Perot cavity in order to optimize their alignment and thereby the cavity finesse.

III Symétrie

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	BORA
Motion and positioning	
Travel range Tx, Ty (mm)	± 20
Travel range Tz (mm)	± 10
Travel range Rx, Ry (deg)	± 10
Travel range Rz (deg)	± 15
Resolution Tx, Ty, Tz (µm)	0.1
Resolution Rx, Ry, Rz (µrad)	2
Repeatability Tx, Ty, Tz (µm)	± 0.4
Repeatability Rx, Ry, Rz (µrad)	± 3.2
Speed Tx, Ty (mm/s)	2
Speed Tz (mm/s)	1
Speed Rx, Ry (deg/s)	1
Speed Rz (deg/s)	2
Mechanical properties	
Stiffness X, Y (N/µm)	1
Stiffness Z (N/µm)	10
Payload capacity (kg) (vertical orientation / horizontal orientation)	10 / 5
Motor type	DC motor, gearhead
Miscellaneous	
Operating temperature range (°C)	0 to + 50
Materials	Aluminum, steel, stainless steel
Size mobile platform (mm)	Ø 160
Central aperture (mm)	Ø 43 for mobile platform ; Ø 36 for fixed platform
Height in middle position (mm)	145
Mass (kg)	4.3
Cable length (m)	3
Options	Clean room compatibility Vacuum compatibility Low temperature compatibility down to -40°C Hand-held control unit
Controller	
Controller type	NAOS or ALPHA+ if cable length > 10 m or temperature < 0°C
Interface	Ethernet
Power supply	110-240 VAC / 50-60 Hz

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.

Hexapod in middle position

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PUNA hexapod
Simple and affordable hexapod

KEY FEATURES

- Payload capacity up to 25 kg
- Resolution 0.5 μm
- Linear travel range ± 30 mm
- Affordable

APPLICATIONS

- Instrumentation
- Aeronautics and spatial
- Optics
- Metrology
- Testing laboratories
- Semiconductors
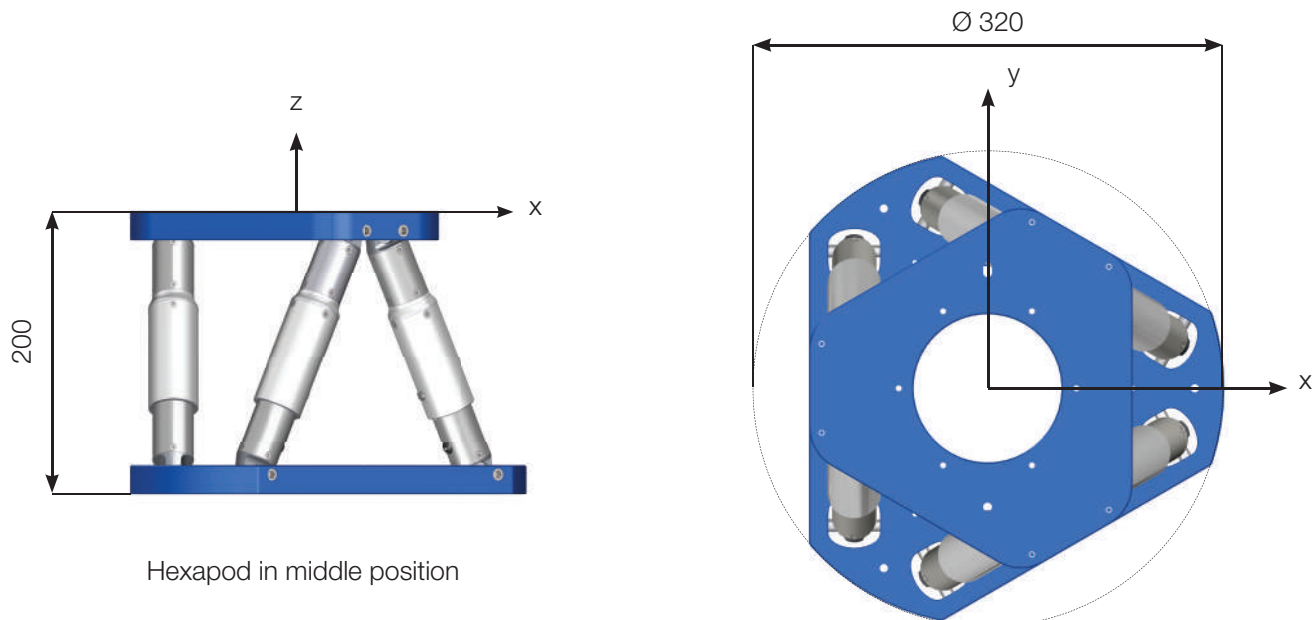- Synchrotrons
- Automotive

Along our standard hexapods, we also offer customized versions. They can carry heavier payloads than a standard PUNA: 35 kg at a 45° orientation, 20 kg in horizontal orientation.
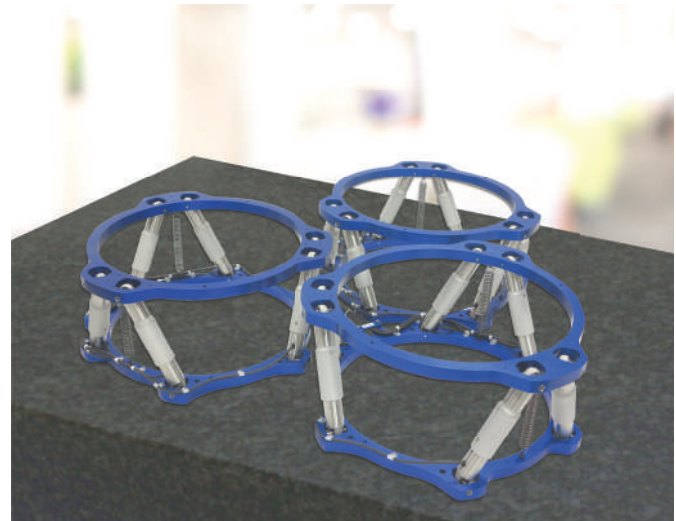
The diameter of these customized PUNA hexpapods has been changed in order to maximize its central aperture (372 mm). The application is mirror alignment.

||| Symétrie

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	PUNA
Motion and positioning	
Travel range Tx, Ty (mm)	± 30
Travel range Tz (mm)	± 20
Travel range Rx, Ry (deg)	± 11
Travel range Rz (deg)	± 20
Resolution Tx, Ty, Tz (µm)	0.5
Resolution Rx, Ry, Rz (µrad)	5
Repeatability Tx, Ty, Tz (µm)	± 0.75
Repeatability Rx, Ry, Rz (µrad)	± 3.5
Speed Tx, Ty (mm/s)	3
Speed Tz (mm/s)	1.25
Speed Rx, Ry (deg/s)	1.25
Speed Rz (deg/s)	0.75
Mechanical properties	
Stiffness X, Y (N/µm)	1.75
Stiffness Z (N/µm)	30
Payload capacity (kg) (vertical orientation / horizontal orientation)	25 / 10
Motor type	DC motor, gearhead
Miscellaneous	
Operating temperature range (°C)	0 to + 50
Materials	Aluminum, steel, stainless steel
Size mobile platform (mm)	Ø 250
Central aperture (mm)	Ø 100
Height in middle position (mm)	200
Mass (kg)	5.6
Cable length (m)	3
Options	Clean room compatibility Scalable size Hand-held control unit Heavier payload
Controller	
Controller type	NAOS or ALPHA+ if cable length > 10 m or temperature < 0°C
Interface	Ethernet
Power supply	110-240 VAC / 50-60 Hz

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.
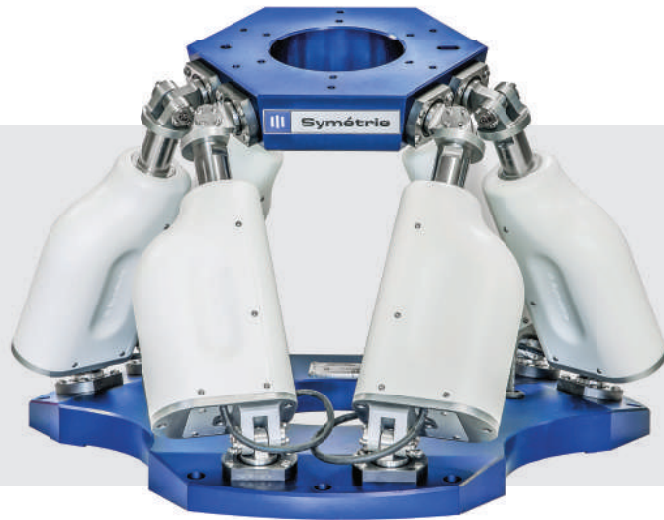

Hexapod in middle position

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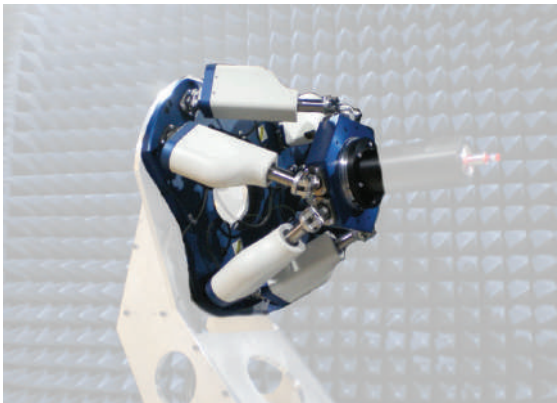# **BREVA** hexapod

High resolution hexapod medium size

KEY FEATURES

- ■ Payload capacity up to 200 kg
- ■ Linear travel range ± 75 mm
- ■ Angular travel range ± 22 °
- ■ Absolute encoders

APPLICATIONS

- ■ Instrumentation
- ■ Aeronautics and space

- ■ Optics
- ■ Metrology

- ■ Testing laboratories
- ■ Synchrotrons

This hexapod integrates a 360° rotation in its mobile platform. It orientates a microwave source to qualify microwave antennas.

Diffractometer with BREVA hexapod on CEA BM32 beamline at ESRF synchrotron for the development and analysis of nanomaterials.

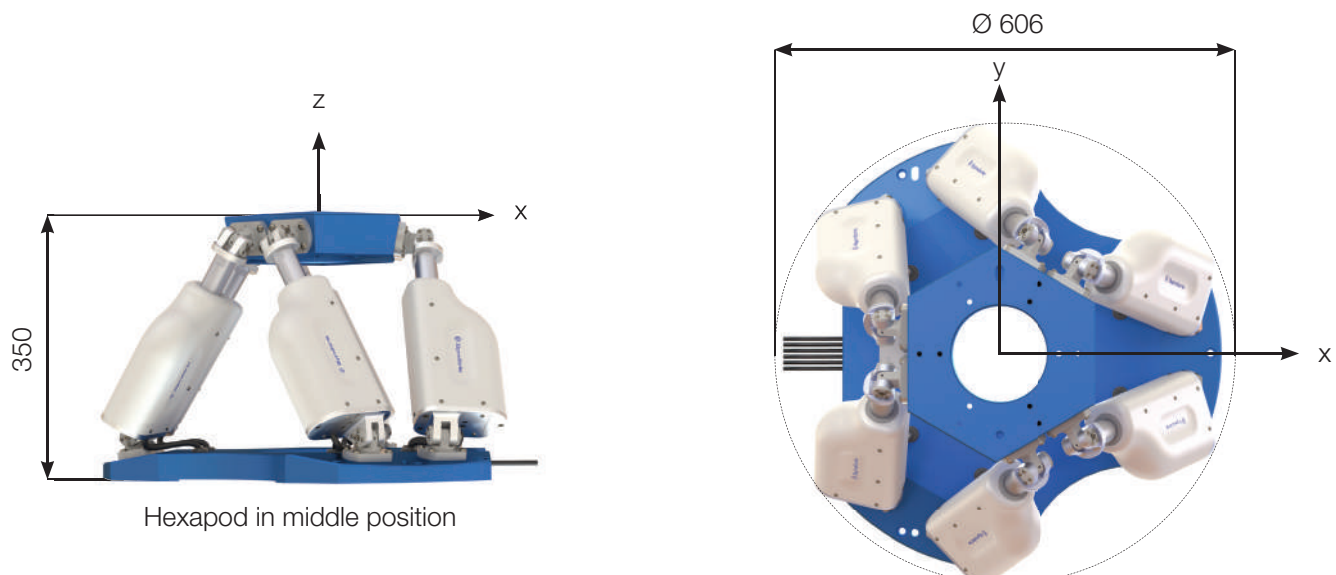*This hexapod positions a vacuum chamber containing a gas sample and offers a ± 20° angular range.*

This hexapod is coupled to a Tz elevation stage in order to achieve larger travel range for space optical calibration..

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	BREVA
Motion and positioning	
Travel range Tx, Ty (mm)	± 75
Travel range Tz (mm)	± 50
Travel range Rx, Ry (deg)	± 20
Travel range Rz (deg)	± 22
Resolution Tx, Ty, Tz (µm)	0.5
Resolution Rx, Ry, Rz (µrad)	2.5
Repeatability Tx, Ty, Tz (µm)	± 0.5
Repeatability Rx, Ry, Rz (µrad)	± 2.5
Speed Tx, Ty (mm/s)	6
Speed Tz (mm/s)	4
Speed Rx, Ry (deg/s)	1.5
Speed Rz (deg/s)	2.25
Mechanical properties	
Stiffness X, Y (N/µm)	5
Stiffness Z (N/µm)	32
Payload capacity (kg) (vertical orientation / horizontal orientation)	200 / 80
Motor type	Stepper motor, gearhead
Encoder type	Absolute encoder
Miscellaneous	
Operating temperature range (°C)	0 to + 50
Material	Aluminum, steel, stainless steel, plastic
Size mobile platform (mm)	Ø 289
Central aperture (mm)	Ø120 form mobile platform ; Ø250 for fixed platform
Height in middle position (mm)	350
Mass (kg)	34
Cable length (m)	3
Options	Clean room compatibility Customized platform design Hand-held control unit Scalable size
Controller	
Controller type	ALPHA+
Interface	Ethernet
Power supply	110-240 VAC / 50-60 Hz

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.
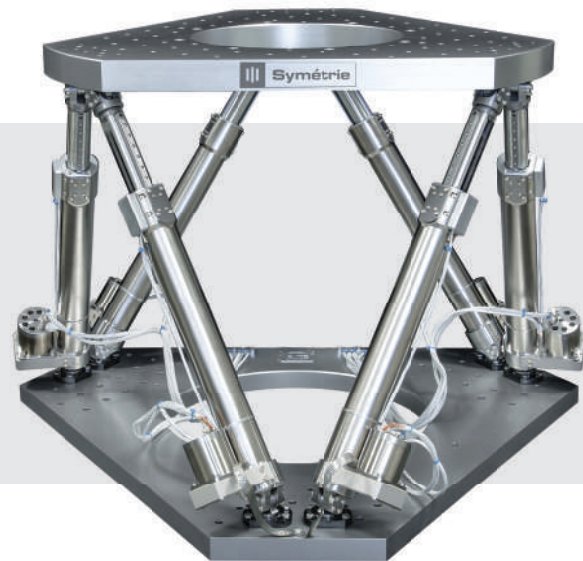

350

z

x

Hexapod in middle position

Ø 606

y

x

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ZONDA hexapod

Very stable hexapod with high precision

KEY FEATURES

- Very high stability
- Payload capacity up to 400 kg
- Vacuum compatibility
- Large travel ranges
- Absolute linear encoders

APPLICATIONS

- Synchrotrons
- Tests laboratories
- Metrology
- Aeronautics and space
- Optics
- Semiconductors
- Instrumentation

ISO5 clean room compatible hexapod to test space optical instruments for MTG (Meteosat Third Generation) satellites at BERTIN Technologies.

ZONDA Hexapod in a vacuum chamber with a mirror for optical calibration at Thales Alenia Space.

This HV ZONDA hexapod is used for the thermal vacuum tests and calibration of some of the cameras of PLATO mission at IAS.

This ZONDA S hexapod aligns two parts of a space telescope in an ISO5 clean room.
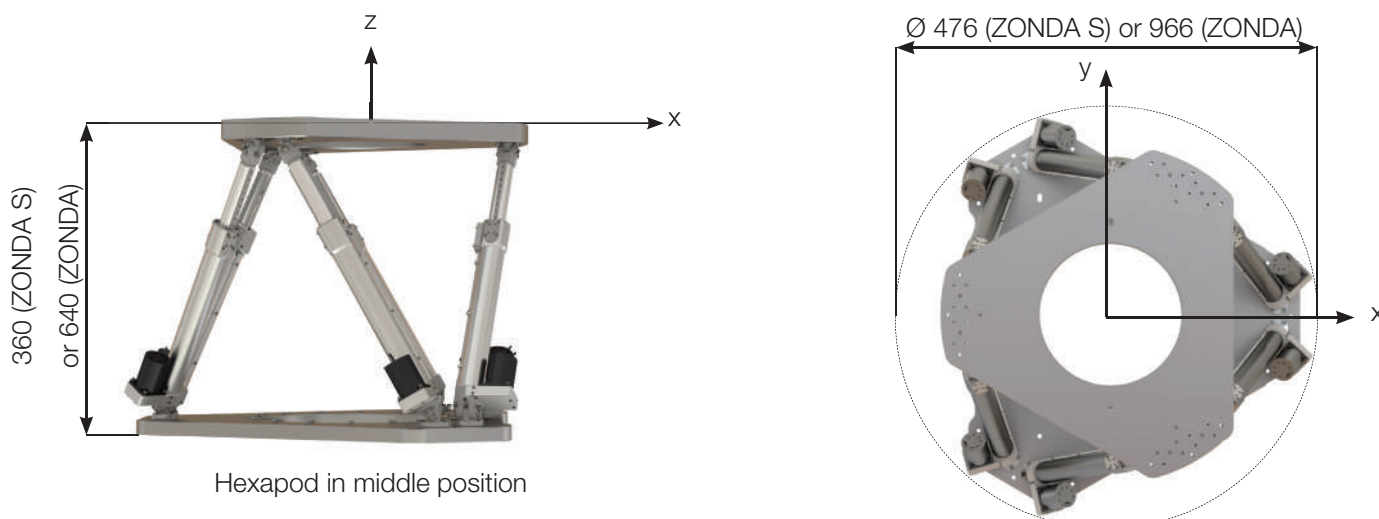

This ZONDA S positions a coronograph in order to characterize it in a vacuum chamber at Liege Space Center (CSL).

This ZONDA hexapod positions a laser interferometer (Zygo) in order to characterize the X-ray mirrors at Synchrotron SOLEIL.

Symétrie

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	ZONDA S	ZONDA
	for small travel range	for large travel range
Motion and positioning		
Travel range Tx, Ty, (mm)	± 50	± 200
Travel range Tz (mm)	± 25	± 150
Travel range Rx, Ry (deg)	± 10	± 20
Travel range Rz (deg)	± 20	± 20
Resolution Tx, Ty, Tz (µm)	0.1	0.1
Resolution Rx, Ry, Rz (µrad)	1.5	0.5
Repeatability Tx, Ty, Tz (µm)	± 0.25	± 0.25
Repeatability Rx, Ry, Rz (µrad)	± 2.5	± 1
Speed Tx, Ty (mm/s)	0.55	0.8
Speed Tz (mm/s)	0.4	0.4
Speed Rx, Ry (deg/s)	0.075	0.2
Speed Rz (deg/s)	0.12	0.4
Mechanical properties		
Stiffness X, Y (N/µm)	5	8.5
Stiffness Z (N/µm)	50	30
Payload capacity (kg) (vertical orientation / horizontal orientation)	400 / 140	400 / 140
Motor type	Stepper	Stepper
Encoder type	Absolute linear encoder	Absolute linear encoder
Miscellaneous		
Operating temperature range (°C)	0 to + 75	0 to + 75
Materials	Aluminum, stainless steel, Invar, Peek	Aluminum, stainless steel, Invar, Peek
Size mobile platform (mm)	Ø 320	Ø 720
Height in middle position (mm)	360	640
Mass (kg)	37	99
Cable length (m)	< 5	< 5
Options	Clean room compatibility Vacuum compatibility Customized platform design Higher speed with brushless or DC motor Hand-held control unit Scalable size	
Controller		
Controller type	ALPHA+	
Interface	Ethernet	
Power supply	110-240 VAC / 50-60 Hz	

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.

Hexapod in middle position

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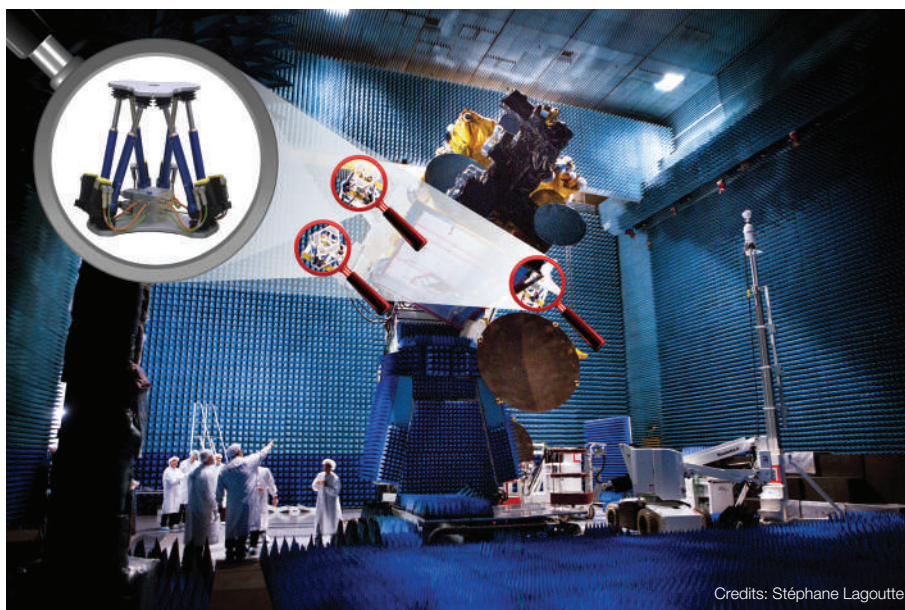
SIRIUS hexapod
High resolution hexapod large size

KEY FEATURES

- Linear travel range ± 150 mm
- Angular travel range ± 20 °
- Absolute encoders

APPLICATIONS

- Optical adjustment
- Antenna qualification
- Aeronautics and space

Credits: Stéphane Lagoutte

Four SIRIUS hexapods orientate the antennas of telecommunication satellite to test their performances before the launch. Thanks to the flexibility and pivot point configuration of these hexapods, this set up is adaptable to different satellite models.
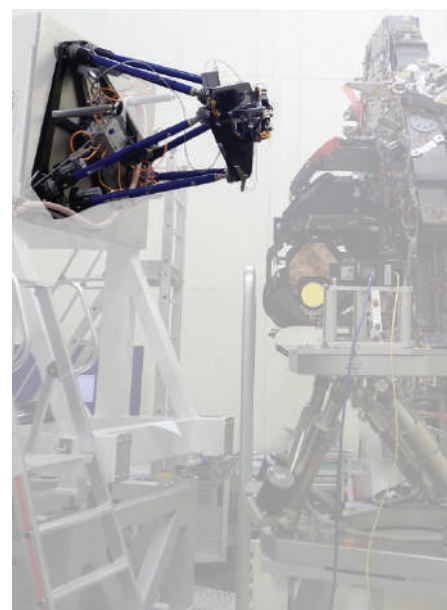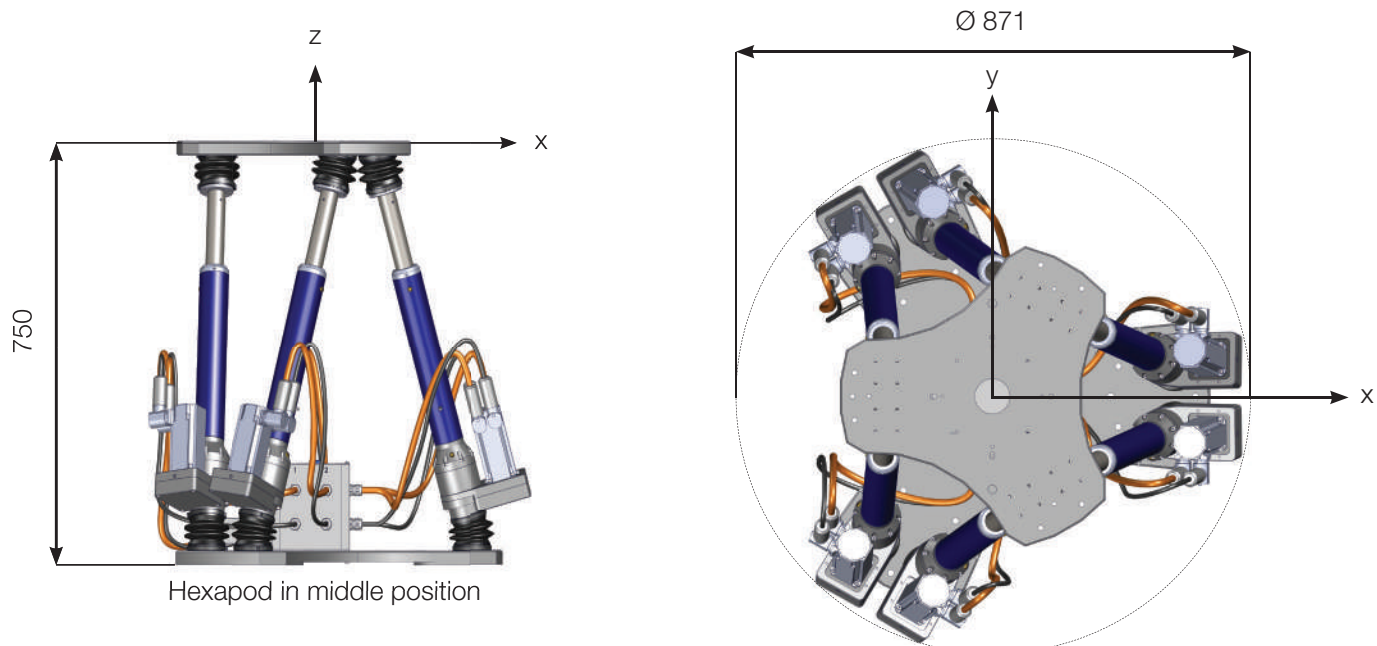
An ISO5 SIRIUS XL hexapod is involved in the optical alignment of the EUCLID space telescope by Airbus Defense and Space.

III Symétrie

	SIRIUS
Motion and positioning	
Travel range Tx, Ty (mm)	± 150
Travel range Tz (mm)	± 100
Travel range Rx, Ry (deg)	± 16
Travel range Rz (deg)	± 20
Resolution Tx, Ty, Tz (µm)	5
Resolution Rx, Ry, Rz (µrad)	10
Repeatability Tx, Ty (µm)	± 3
Repeatability Tz (µm)	± 2
Repeatability Rx, Ry (µrad)	± 10
Repeatability Rz (µrad)	± 17.5
Speed Tx, Ty (mm/s)	8
Speed Tz (mm/s)	4
Speed Rx, Ry (deg/s)	1
Speed Rz (deg/s)	2.5
Payload capacity (kg) (vertical orientation / horizontal orientation)	200 / 80
Motor type	Brushless motor
Encoder type	Absolute encoder
Miscellaneous	
Operating temperature range (°C)	0 to + 50
Materials	Aluminum, steel, stainless steel
Size mobile platform (mm)	Ø 520
Height in middle position (mm)	750
Mass (kg)	82
Cable length (m)	5
Options	Clean room compatibility Customized platform design Hand-held control unit Heavier payload Scalable size
Controller	
Controller type	ALPHA+
Interface	Ethernet
Power supply	110-240 VAC / 50-60 Hz

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.

Hexapod in middle position

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KUBAN hexapod
High resolution heavy payload medium size

KEY FEATURES

- Height 600 mm
- Resolution 1.5 µrad
- Repeatability ± 2.5 µrad
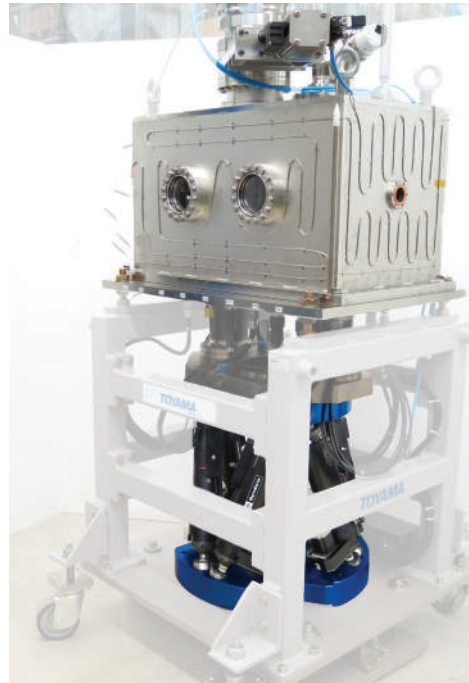- Payload capacity up to 500 kg
- Absolute linear encoders

APPLICATIONS

- Synchrotrons: mirror or chamber supports
- Optics

This KUBAN hexapod aligns a mirror inside a vacuum chamber on LUCIA beamline at Synchrotron SOLEIL. A high stability over time is crucial.
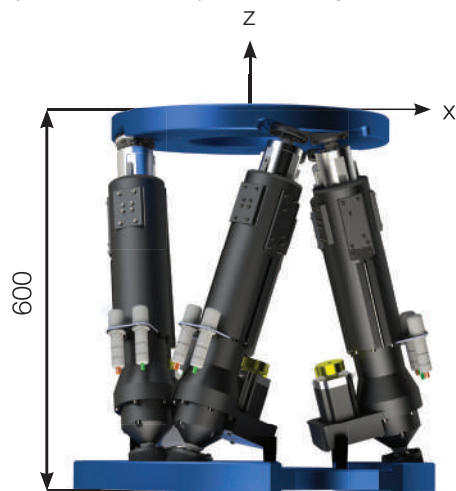

KUBAN hexapod aligns a polarimeter with high precision in a short time. This installation made by TOYAMA can be moved to be used on different beamlines at MAX IV Laboratory synchrotron.
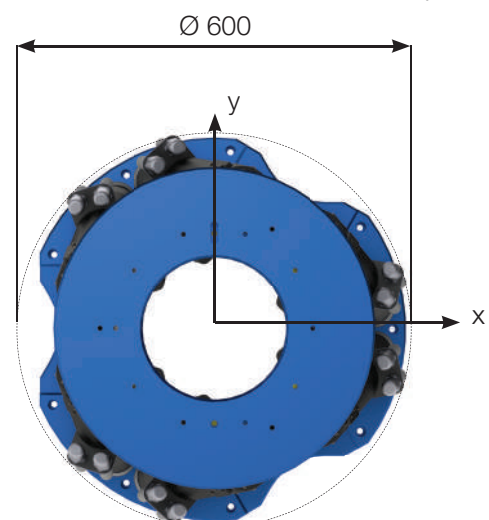

KUBAN hexapod positions a mirror inside of a vacuum chamber with high resolution. To be sure to avoid harming any part due to an unexpected over range, an inclination limit switch is installed under the hexapod mobile platform and stops the motion if the maximum roll angle is reached.

Ⅲ Symétrie

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	KUBAN
Motion and positioning	
Travel range Tx, Ty (mm)	± 75
Travel range Tz (mm)	± 45
Travel range Rx, Ry (deg)	± 5
Travel range Rz (deg)	± 10
Resolution Tx, Ty (μm)	0.2
Resolution Tz (μm)	0.1
Resolution Rx, Ry (μrad)	1.5
Resolution Rz (μrad)	2
Repeatability Tx, Ty (μm)	± 0.5
Repeatability Tz (μm)	± 0.25
Repeatability Rx, Ry (μrad)	± 2.5
Repeatability Rz (μrad)	± 4
Speed Tx, Ty (mm/sec)	0.6
Speed Tz (mm/sec)	0.4
Speed Rx, Ry (deg/sec)	0.045
Speed Rz (deg/sec)	0.07
Mechanical properties	
Payload capacity (kg)	500
Motor type	Stepper motor
Encoder type	Absolute linear encoder
Miscellaneous	
Operating temperature range (°C)	0 to + 50
Material	Aluminum, steel, stainless steel
Size mobile platform (mm)	Ø 450
Central aperture (mm)	Ø200 form mobile platform ; Ø280 for fixed platform
Height in middle position (mm)	600
Mass (kg)	140
Cable length (m)	5
Options	Customized platform design Hand-held control unit Hgher speed Scalable size Heavier payload
Controller	
Controller type	ALPHA+
Interface	Ethernet
Power supply	110-240 V AC 50-60 Hz

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.

Hexapod in middle position

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JORAN hexapod

High resolution ultra heavy payload large size

KEY FEATURES

■ High stability
■ Resolution 0.5 µrad
■ Large payload capacity 1500 kg
(more upon request)
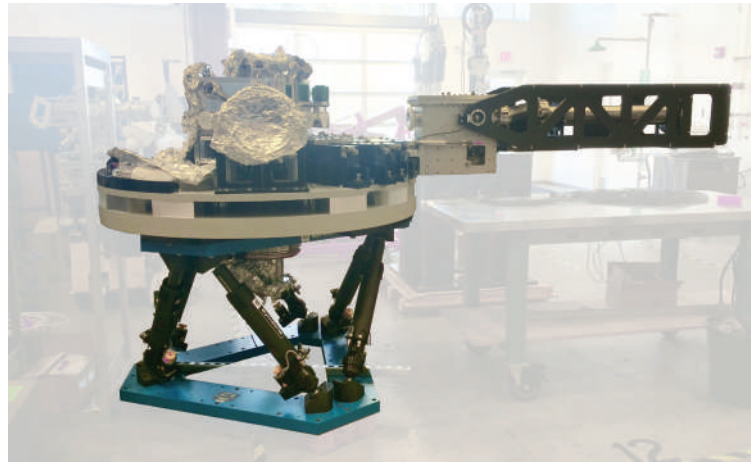■ Absolute linear encoders

APPLICATIONS

■ Synchrotrons: mirror or chamber supports   ■ Optics   ■ Astronomy

JORAN hexapod size has been adapted to the beam height of the Australian Synchrotron.

JORAN actuators at LBL are longer to enable a ± 12.5° rotation around Z. This JORAN hexapod has also been customized to support a 3.2 tons payload.

Customized JORAN hexapods with extra Rz rotations calibrate the segments of the primary mirror of ESO ELT telescope at Safran REOSC.
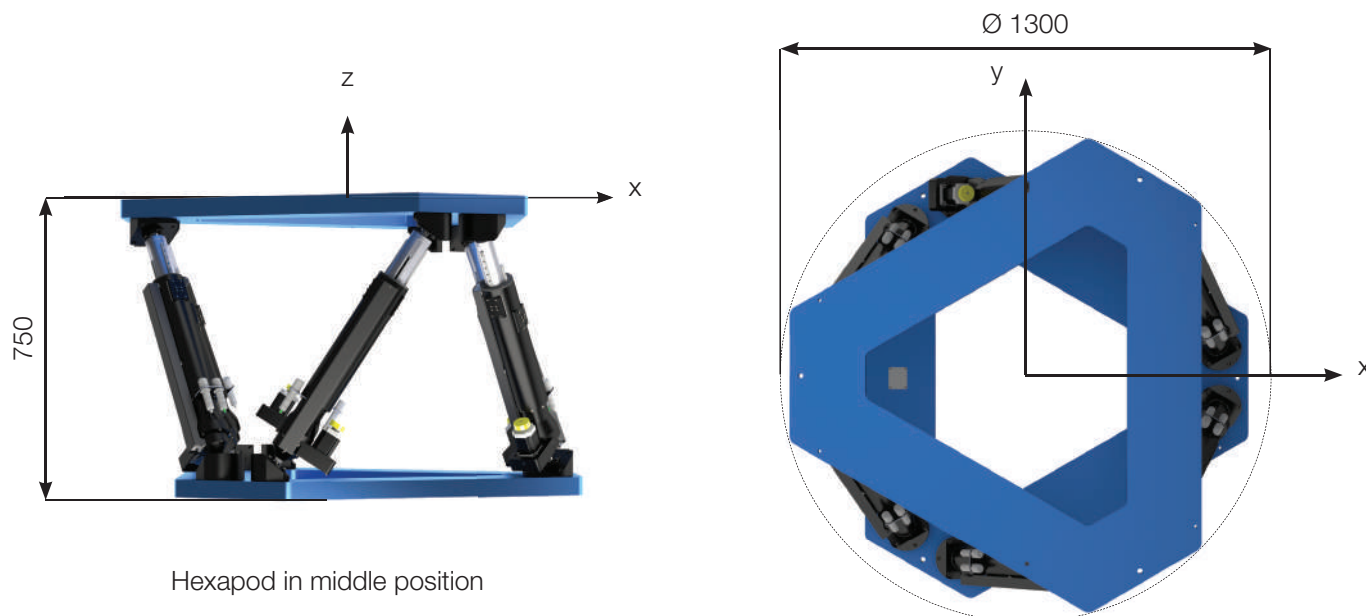

JORAN hexapod has been developed in collaboration with ESRF synchrotron to position mirrors with very high resolution.

Symétrie

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	JORAN BJ	JORAN UJ
	Ball Joints	Universal Joints
Motion and positioning		
Travel range Tx, Ty (mm)	± 75	± 170
Travel range Tz (mm)	± 50	± 100
Travel range Rx, Ry (deg)	± 5	± 10
Travel range Rz (deg)	± 8	± 18
Resolution Tx, Ty, Tz (µm)	0.1	0.1
Resolution Rx, Ry, Rz (µrad)	0.5	0.5
Repeatability Tx, Ty, Tz (µm)	± 0.25	± 0.25
Repeatability Rx, Ry, Rz (µrad)	± 1	± 1
Speed Tx, Ty (mm/sec)	0.6	0.6
Speed Tz (mm/sec)	0.4	0.4
Speed Rx, Ry (deg/sec)	0.045	0.045
Speed Rz (deg/sec)	0.07	0.07
Mechanical properties		
Payload capacity (kg) (vertical orientation)	1500	1500
Motor type	Stepper motor	Stepper motor
Encoder type	Absolute linear encoders	Absolute linear encoders
Miscellaneous		
Operating temperature range (°C)	0 to + 50	0 to + 50
Material	Aluminum, steel, stainless steel, ceramic	Aluminum, steel, stainless steel
Size mobile platform (mm)	Ø 1300	Ø 1300
Height in middle position (mm)	750	750
Mass (kg)	515	515
Cable length (m)	5	5
Options	Customized platform design Hand-held control unit Higher speed Scalable size Heavier payload	
Controller		
Controller type	ALPHA+	
Interface	Ethernet	
Power supply	110-240 VAC / 50-60 Hz	

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.

Hexapod in middle position

Ø 1300

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SURES hexapod

High resolution high rigidity hexapod for astronomy

KEY FEATURES

- Payload capacity up to 500 kg
- Low cross coupling motions
- Operational in any orientation
- Operational at high altitude
- Absolute encoders

APPLICATIONS

- Astronomy
- Positioning of mirror of telescope
- High accuracy positioning
- Antenna qualification
- Optical adjustment

SURES hexapod positions the 450 kg secondary mirror of OAJ T250 telescope in Spain with 0.35 µm linear and 0.5 arcsec angular resolutions. The SURES hexapod for OAJ has a 920 mm diameter.

ARIES telescope is installed in Nainital in India. With a primary mirror of 3.6 m diameter, it is the largest optical centre in the country. Cross-coupling of SURES hexapod is less than 0.7 arcsec in tip-tilt during centering or focus.
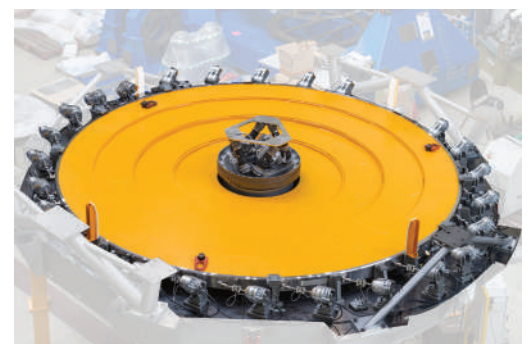
Two identical SURES hexapods position the M2 and M3 mirrors of DAG 4m telescope in Turkey.
They realign the optics in order to compensate relative displacements due to gravity and temperature change during observation. Thus they improve the imaging quality of the telescope.

Symétrie

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	SURES
Motion and positioning	
Travel range Tx, Ty (mm)	± 8
Travel range Tz (mm)	± 6
Travel range Rx, Ry, Rz (°)	± 1
Resolution Tx, Ty, Tz (µm)	0.1
Resolution Rx, Ry, Rz (µrad)	1
Repeatability Tx, Ty (µm)	± 0.25
Repeatability Tz (µm)	± 0.13
Repeatability Rx, Ry, Rz (µrad)	± 0.5
Mechanical properties	
Payload capacity (kg) (with orientation from 0° to 90°)	up to 500
Motor type	Brushless motor
Encoder type	Absolute encoder
Miscellaneous	
Operating temperature range (°C)	-20 to + 40
Humidity level (%)	up to 100
Materials	Aluminum, steel, stainless steel
Size mobile platform (mm)	Ø 690
Height in middle position (mm)	360
Mass (kg)	117
Cable length (m)	10 (longer on request)
Options	Customized platform design Hand-held control unit Scalable size
Controller	
Controller type	ALPHA+ custom
Interface	Ethernet
Power supply	120-240 VAC / 50-60 Hz

The performances are specified for single axis motions, with all other axes at midrange and for a rotation center in the middle of the mobile platform.
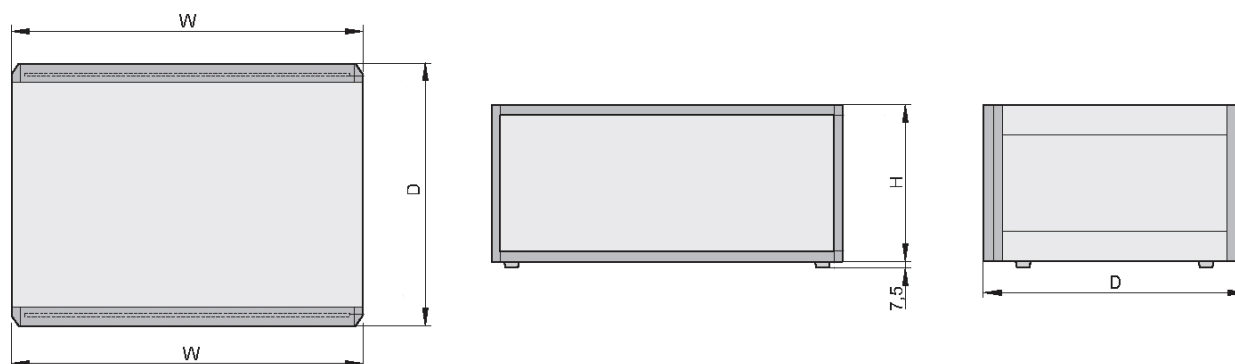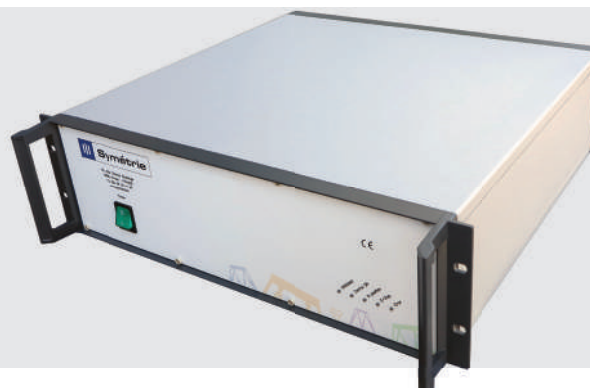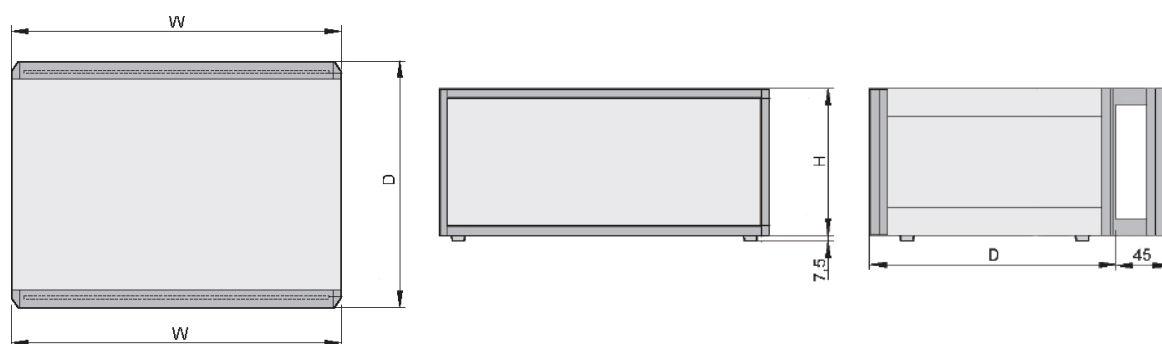
Hexapod in middle position

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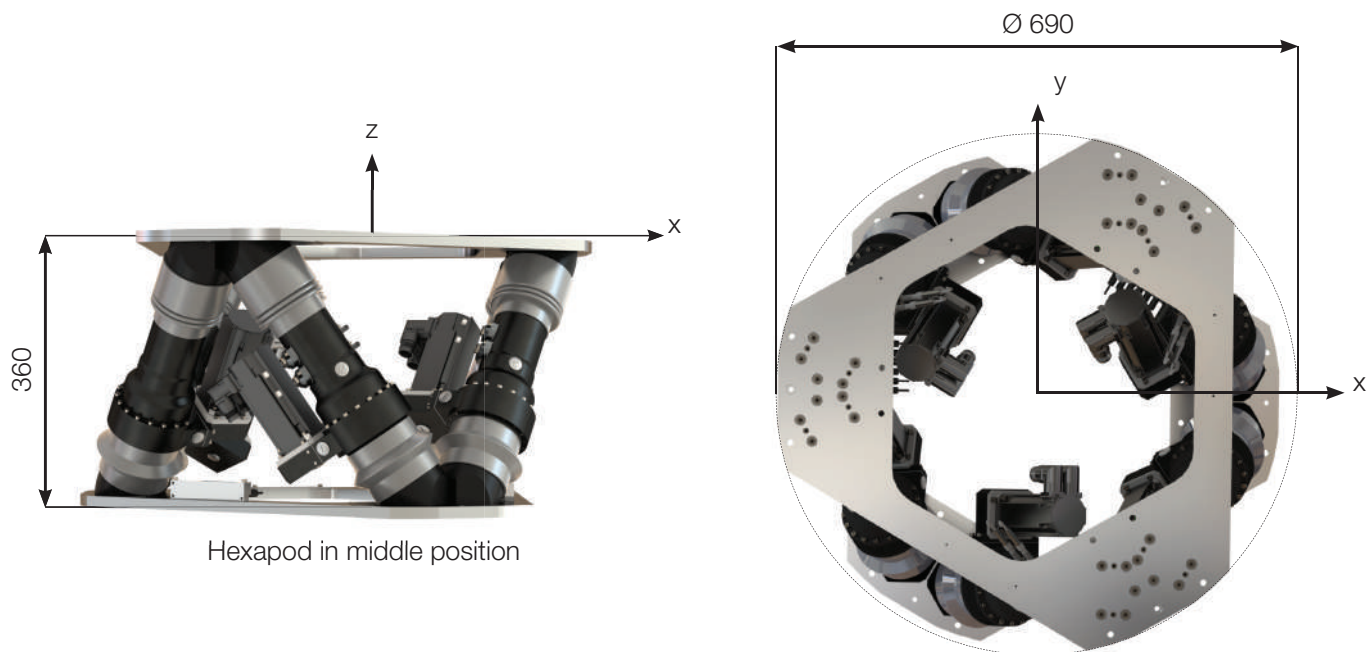
NAOS controller

KEY FEATURES

- Ethernet
- Complete control software
- General purpose inputs / outputs
- Compatible with: BORA & PUNA

Features	
Axis number	6
Motion controller	DeltaTau / Omron controller with SYMETRIE software embedded
Communication	Ethernet
Motor type	DC
Encoder signals	Incremental differential signals (RS-422)
Connectors	6x D-sub 15 pins
GPIO	2 outputs & 1 input optically isolated (D-sub 9 pins) 8 optional inputs and handwheel (D-sub 15 pins high density)
Safety	Emergency stop input
Miscellanous	
Voltage	110-240 VAC / 50-60 Hz
Power	< 250 W
Dimensions	Width (W) / Depth (D) / Height (H) 235.54 (42F) / 375.5 mm / 88.1 mm (2U) + foots 7.5 mm
Mass	3.7 kg
Operating temperature	0 °C to + 40 °C
Storage temperature	- 25 °C to + 70 °C

ALPHA+ controller

KEY FEATURES

- Ethernet
- Complete control software
- General purpose inputs / outputs
- Compatible with: MAUKA, BORA, PUNA, BREVA, ZONDA, SIRIUS, KUBAN, JORAN

Features	
Number of axes	6 + 2 optional
Motion controller	DeltaTau / Omron PowerBrick LV programmed with SYMETRIE hexapod control software
Communication	Ethernet
Motor type	DC, Brushless or Stepper
Encoder signals	Incremental differential signals (RS-422) or high-speed serial protocol for absolute encoders (Endat or BISS)
Connectors	Hexapod model dependant 6 or 12 x D-Sub15 pins or M17/23
GPIO	2 outputs & 1 input optically isolated (D-sub 9 pins) 8 optional inputs and handwheel (D-Sub 15 pins high density)
Safety	Emergency stop input / Safe Torque Off (STO) function
Miscellanous	
Voltage	110-240 VAC / 50-60 Hz
Power	< 300 W for MAUKA, BORA, PUNA < 750 W for BREVA < 1000 W for ZONDA, KUBAN, JORAN with stepper motors < 1500 W for JORAN with brushless motors, SIRIUS
Dimensions	Width (W) / Depth (D) / Height (H) 448.90 mm (84F) / 435.5 mm / 132.55 mm (3U) for model with power < 750 W 448.90 mm (84F) / 495.5 mm / 132.55 mm (3U) for model with power < 1000 W 448.90 mm (84F) / 495.5 mm / 177 mm (4U) for model with power < 1500 W
Mass	Between 10 and 12 kg (model dependant)
Operating temperature	0 °C to + 45 °C
Storage temperature	- 25 °C to + 70 °C

EnDat 2.2

BiSS INTERFACE

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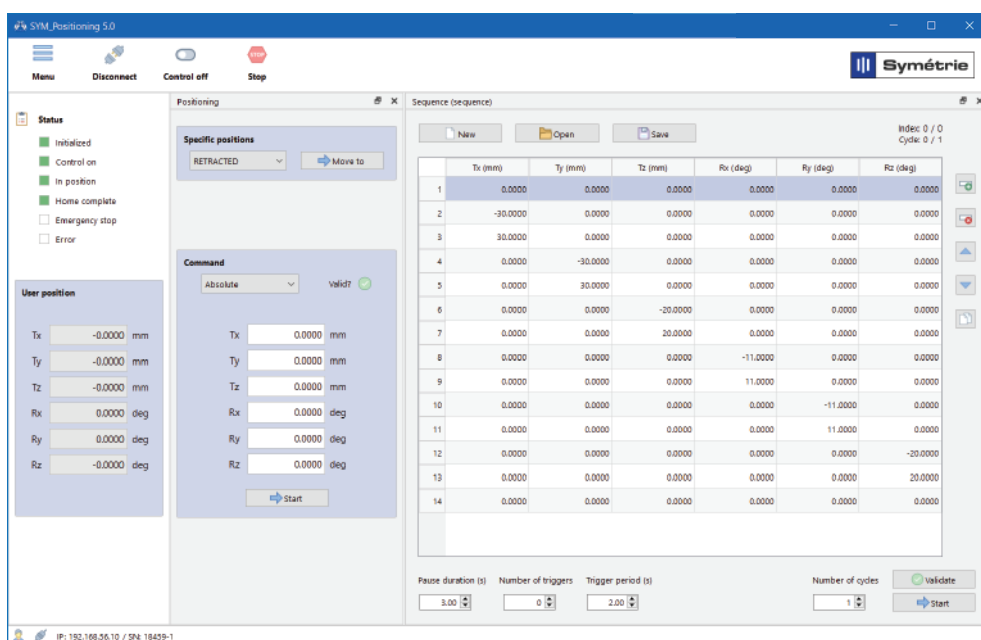
SYM_Positioning software

SYM_Positioning is the main interface software to control the hexapod. It has to be installed on a control computer which will be connected, through an Ethernet connection, to the hexapod controller.

The hexapod control is facilitated by the ergonomic and intuitive graphical user interface (GUI). This software is well suited for the customer who does no need to integrate the hexapod in a more complicated system. All functionalities necessary to control the hexapod are included, even the most advanced and complicated features (pivot point definition, speed, workspace limits...).

The main window of SYM_Positioning software allows the user to set the target position of the hexapod or to create an automated list of points (sequence) for the hexapod.

It also enables the user to constantly witness the current hexapod position.

This synoptic presents the architecture of SYM_Positioning software.

All these features are also available with the Application Programming Interface (API).
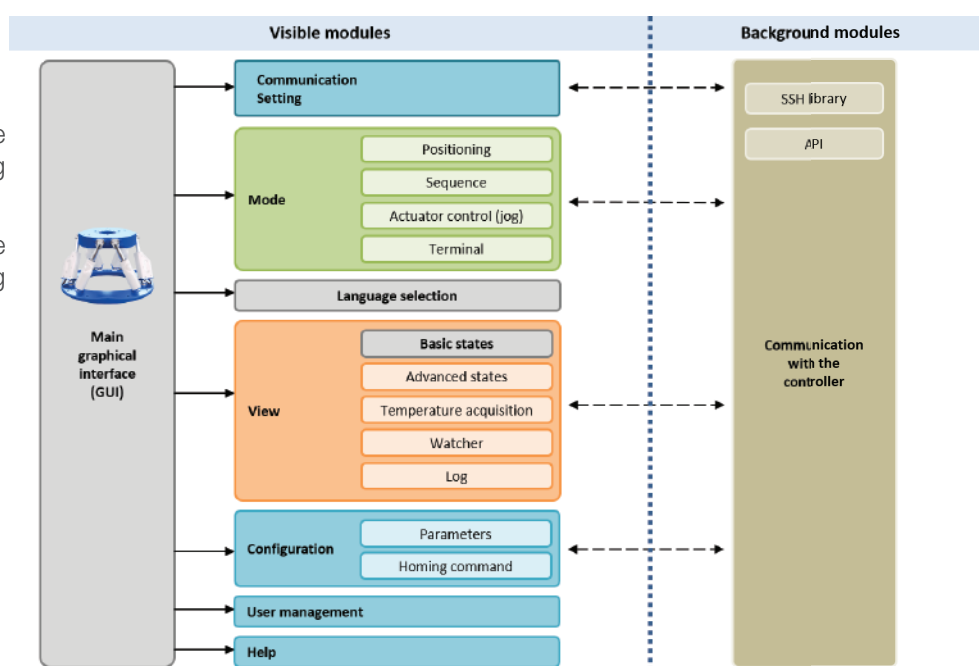
Controller technology

The motion controller is integrated with drive amplifiers and power supplies in an industrial control enclosure. It is the brain responsible for the hexapod control. In particular, the controller:

- **Communication:** communicates with the graphical interface software or a base control system through the Application Programming Interface (API).
- **State machine:** executes a state machine, responsible for the control of the hexapod. The state machine uses the hardware inputs and data received from the Application Programming Interface (API) to determine what to do.
- **Kinematics transformations:** performs the conversion between position expressed in DOF (degrees of freedom) regarding to the defined coordinate systems and actuators' lengths.
- **Coordinate systems:** transformations are calculated inside the motion controller at a low level.
- **Servo loop closure:** ensures that the position error between the target actuator position and the measured position is minimized.
- **Health monitoring:** the motion controller checks the state of hardware inputs and control loop deviations from normal operating conditions.
- **Trajectory profile generation:** the motion controller implements an interpolation algorithm to produce smooth motion with a trajectory control to guarantee low cross-coupling.
- **Validation process:** before each motion the controller checks if the requested motion is valid, considering the hexapod parameters and including safety limits.

From the user to motion:
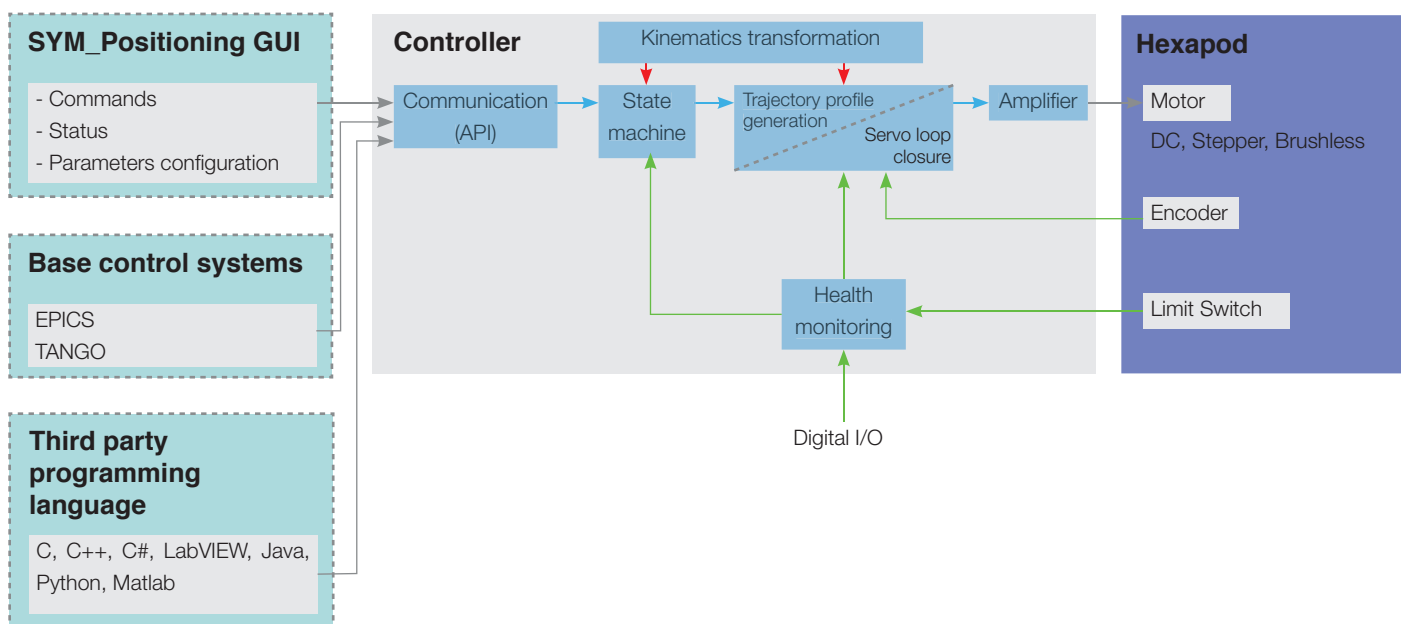
The control software embedded on the motion controller is developed by SYMETRIE. All functionalities necessary to control the hexapod are included, even the most advanced and complicated features. Embedded software programming is easily customizable to integrate the more complex customer application requirements (examples: integrate additional axis control, customize digital outputs, add safety sensors...).

The customers have the choice between several configurations to control the hexapod:

- **Windows Graphical User Interface (GUI): SYM_Positioning software**
- **Application Programming Interface (API):** to integrate the hexapod control into your environment
- **Base control system drivers: EPICS, TANGO**
- **Specific programming library: C, C++, C#, LabVIEW, Java, Python, Matlab…**

Hand-held control unit

A manual control unit is provided optionally with the hexapod. This unit is useful to control fine adjustments, without necessarily using the software.

Features available on this manual control unit are similar to those found on a CNC machine:

- Axis selector: Tx, Ty, Tz, Rx, Ry, Rz

- Increment size selector: 0 (hand-held disabled), x1, x10, x100, +/- (continuous mode)

- J+ button: allow to realize a continuous motion in positive direction

- J- button: allow to realize a continuous motion in negative direction

- Pulse generator: wheel to control incremental motion

Application Programming Interface (API)

With the standalone configuration, in addition to the control enclosure, the system comes with a documentation about the commands necessary to communicate with the hexapod. All functionalities necessary to control the hexapod are available, even the most advanced and complicated features.

The Application Programming Interface and the controller Ethernet protocol (TCP/IP) are highly documented. This open architecture permits to integrate the hexapod control under any third party programming language (C, C++, C#, LabVIEW, Java, Python, Matlab…).

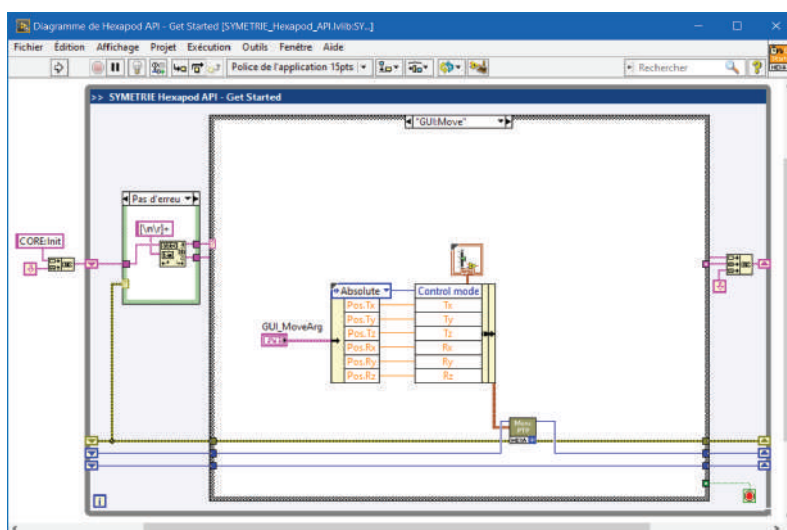Thanks to our recent developments, it is now possible to easily integrate the hexapod into EPICS or TANGO.
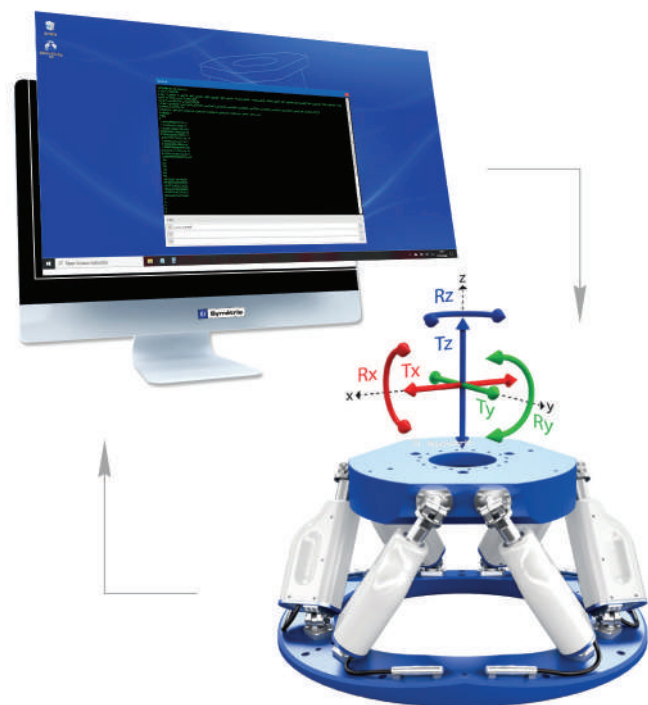
LabVIEW library

The library features easy-to-use native LabVIEW VIs (Virtual Instruments) to control and command SYMETRIE hexapod directly from your favorite graphical development environment. With this library, you can easily and quickly integrate full hexapod control into your application and eliminate complex programming expertise. Using this approach, you do not need to learn specialized software programming skills, which means you can achieve higher performance and better results in less time.

VIs are provided to simplify the programming of the hexapod control into your application. To start using them, we assume a prior knowledge of proper LabVIEW programming techniques. Nevertheless it is not necessary to be a LabVIEW expert to use our library.

C++ library

The C++ library allows the application programmers to control the hexapod with a minimum of programming effort. With this library, the programmer has access to all hexapod controller features to create your own software or integrate it into a more application environment.

Vacuum environment

A vacuum environment is a space empty of matter. The perfect vacuum is an ideal concept and cannot be practically attained. However, it is possible to approach this ideal in laboratory in decreasing the pressure of a system. Indeed, the lower is the pressure of a system, the closer it is to the perfect vacuum.

At SYMETRIE, we provide hexapods that are designed to operate in such environments. Regarding vacuum projects we take a special care during assembly in our clean room and we select specific materials and treatments, in particular:

- ■ Vacuum compatible motor, ball screw, encoder
- ■ Vacuum compatible lubrification
- ■ Use of Teflon or Kapton cables
- ■ Specific roughness of parts
- ■ All holes are vented
- ■ Specific cleaning of parts in an ultrasonic bath
- ■ Assembly in our ISO7 clean room

For several hexapods in this catalog, we can implement vacuum options:
- ■ Low Vacuum Option (10^{-3} mbar)
- ■ High Vacuum Option (10^{-6} mbar)

In our vacuum lab, we can perform RGA testing down to 10^{-8} mbar.

Test preparation in our vacuum lab

Clean room

ISO5 clean room compatible hexapod to test space optical instruments for MTG (Meteosat Third Generation) satellites at BERTIN Technologies.

A clean room is a room where the concentration of particles is minimized. Temperature, humidity and pressure parameters are also controlled.

Clean rooms are used for the industry or research fields, which are sensible domains to environmental contamination (biology, construction of spacecraft, optical manufacturing or semiconductors…).

We can also prepare our hexapods in order to make them compatible with a clean room environment.

Special components, materials and treatments are used. Assembly is done in our ISO 7 (class 10 000) clean room.

In the space sector, we regularly deliver ISO 5 (class 100) compatible systems, for which we follow the design and assembly rules related to the cleanliness of an ISO 5 environment.

Scalable size

The hexapod structure makes it very scalable. The hexapod is constituted of several components (platforms, actuators, motors, joints…) that can be sized differently in order to create a new hexapod.

Our skilled engineers are experienced in optimizing a hexapod in order to match the needs of the customer's application. They rely on a large database of existing components and designs, so that the costs can be closely controlled.
Feel free to ask us if you need any customization.

Hereunder we show three examples of custom hexapods based on PUNA standard product.

PUNA standard product

For this model, we changed the platforms diameter and geometry.

*Here the platforms and the actuator have been modified.*

On this version, only the actuator has been changed.

Modular solution

If there is a need for a very long travel range on one axis, a hexapod can be too limited. In this case, it is sometimes possible to combine a hexapod with an additional translation or rotation in order to obtain a larger workspace.

In order to offer a ready-to-use solution, Symetrie provides a full system integration: mechanics, electronics and software.

Depending on the specifications, Symetrie is able to design custom stages or buys off-the-shelf additional axes.
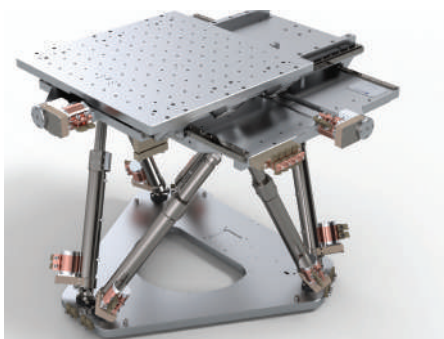
A ZONDA hexapod with two linear stages integrated on top of the mobile platform. The whole system is vacuum compatible.

A custom ZONDA hexapod with a large linear stage mounted on top. The system is ISO5 clean room compatible to test space optical instruments.

A ZONDA hexapod is mounted on a gimbal (two rotations) in order to qualify optical telescopes in a high vacuum chamber.

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Applications: Astronomy

Ground-based telescopes are more and more powerful in order to help astronomers to see further and more accurately. As a consequence, telescopes manufacturers are looking after improved mirror positioning performances. Hexapods are used to realign the secondary mirror relatively to the primary mirror to compensate the mechanical deformations of the telescope structure due to temperature and gravity changes during the night.

Ground-based optical telescopes

The hexapod is installed on Pan-STARRS-2 optical telescope at an altitude of 4267 m on Maui, Hawaii. Pan-STARRS-2 is operated by the Institute for Astronomy of the University of Hawaii. A small version of the SURES hexapod has been adapted as the secondary mirror is 600 mm diameter and weighs less than 110 kg.
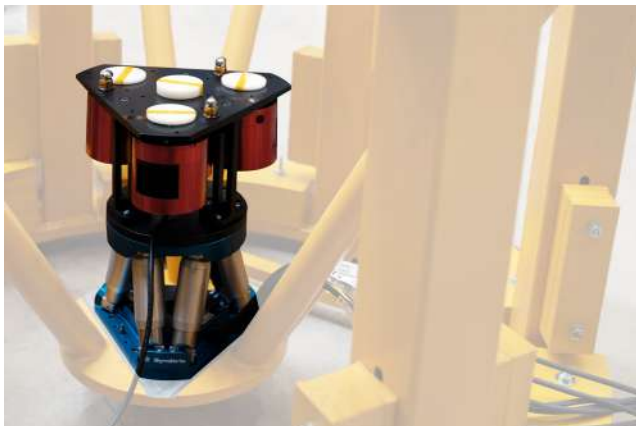
Large ground-based optical telescopes

The compact BORA hexapod is positioning a system made of 4 cameras in order to periodically calibrate some optical parameters on Mount ABU ground-based telescope in India.

It will work vertically and horizontally as the calibration is done at different degrees of elevation of the telescope.

Ground-based radio telescopes

NOEMA is the most powerful millimeter radiotelescope of the Northern Hemisphere. Located in the French Alps, it is operated by the IRAM research institute for radio astronomy. Customized hexapods with light carbon platforms are positioning the 900 mm diameter subreflectors with high precision.

Applications: Optical benches

Hexapods are particularly adequate to precisely align mirrors on satellites or to calibrate and test space optical components during mounting and testing phases.

Mirror adjustment on a satellite

- Environment: high vacuum (10^{-6} mbar)
- Payload capacity: 250 kg / Hexapod height: 2.5 m
- Resolution: less than 1 µm (linear) and 2 µrad (angular)

Thales Alenia Space has to adjust a mirror during its integration on an optical satellite using five degrees of freedom (TX, TY, TZ, RX, RY) with high accuracy.

Bertin Technologies is responsible for the adjustment bench of this mirror and selected SYMETRIE's hexapod proposal. This solution based on a 3-meter-height hexapod is a technological breakthrough compared to the mounting and test equipment previously used in the space industry.


Optical integration and calibration

- High stability thanks to its conception and the use of Invar material with a low coefficient of thermal expansion
- High accuracy
- Customized platform to integrate the payload

Meteosat Third Generation (MTG) is the next fleet of meteorological satellites, which are managed by the European Space Agency (ESA) and Eumetsat.

This high rigidity and high stability hexapod has been made for integration and calibration of a space optical sensor of one of these satellites.
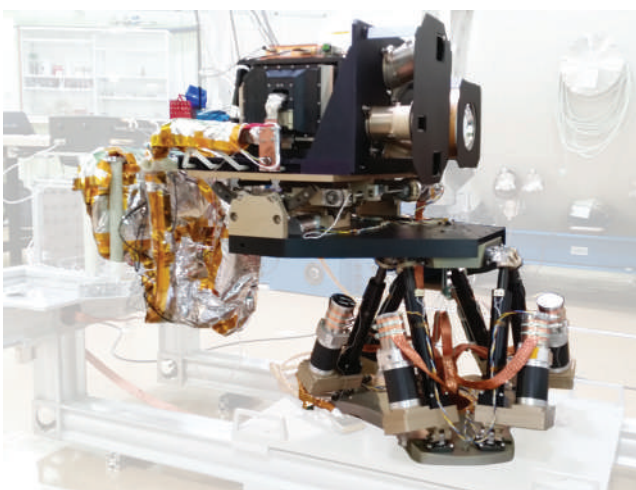

Space optical instrument calibration

- Resolution: less than 0.5 µm (linear) and 2.5 µrad (angular)
- Rigidity
- Environment: high vacuum (10^{-6} mbar)

A customized BREVA hexapod helps IAS Space Astrophysics Institute to calibrate Simbio-Sys space optical instrument, one of the major elements of the BepiColombo ESA mission dedicated to the study of Mercury.

This hexapod integrates an additional translation and a goniometer to pre-align one of the four instruments of Simbio-Sys in front of the optical source. Then the fine and precise positioning for the qualification is achieved thanks to the hexapod.

Applications: Synchrotrons

Scientists need higher precision positioning systems with several degrees of freedomin order to perform more and more demanding experiments.
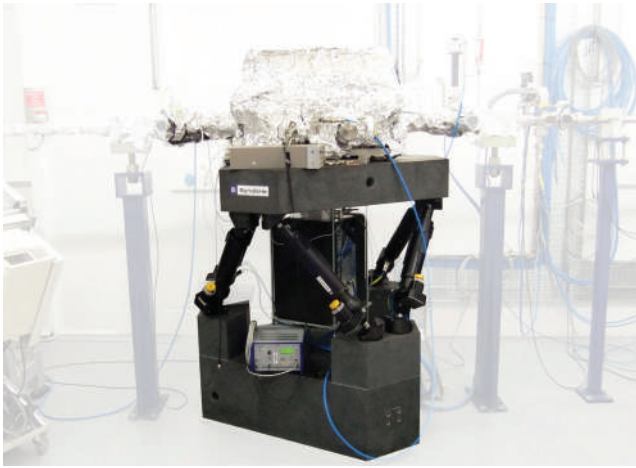
Mirror support

Developed in collaboration with the European Synchrotron ESRF (Grenoble, France), JORAN hexapod is ideal to support mirrors or vacuum chambers on synchrotrons beamlines.

The conception of JORAN, particularly of its actuators, spherical joints and natural granite platforms, ensures a great stability and guarantees the positioning quality over time.

- High angular resolution: 0.5 µrad
- High stability
- Ultra heavy load > 3 tons

HV Diffractometer

To improve their equipment and offer new experimental capabilities, SIRIUS beamline at Synchrotron SOLEIL acquired a 10-6 mbar high vacuum diffractometer, integrating a high precision HV BORA sample positioning hexapod and four HV circles, on top of a bigger customized JORAN alignment hexapod.

- Large sample accessibility whereas the 4 circles can rotate on big travel ranges
- HV slip ring for BORA hexapod to facilitate cable management
- Control with TANGO developed in collaboration with Synchrotron SOLEIL
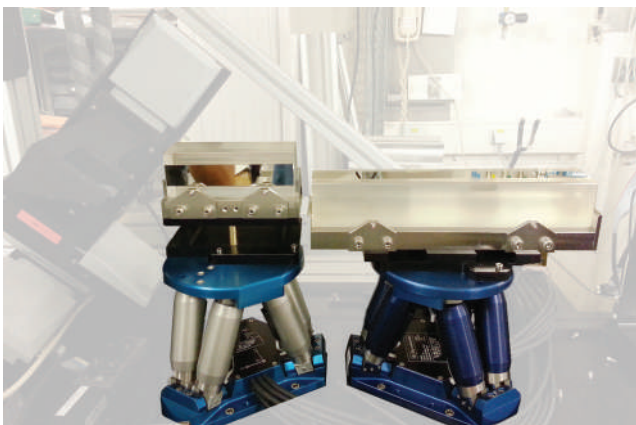
KB mirrors adjustment

The beam has to be as much focused and brilliant as possible and the scientists want to have the maximum beam time for their experiments. Therefore the KB mirrors need to be precisely positioned in a very stable way over a long time to avoid multiple realignments during experiments.
These two BORA hexapods were selected for their high stability over time.

- High resolution: 0.1 µm
- Compact size: 145 mm height
- High stability: 10 nm in Tz over 24 months

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Applications: Light Sources

The precision positioning hexapods of SYMETRIE are particularly adapted for the specific precision positioning needs of particle accelerators and other research institutes.

FEL laser in-coupling

The SwissFEL is a free-electron X-ray laser, which will deliver extremely short and intense flashes of X-ray radiation. These properties will enable novel insights into the structure and dynamics of matter.

A customized JORAN hexapod is positioning the laser in-coupling chamber of the Experimental Station B.

■ High resolution: 0.1 μm ; 0.5 μrad
■ Heavy load: 1130 kg + 5000 N external lateral forces
■ Low amplification of vibrations (Q factor)

EUV Sample positioning

TNO has built an EUV (Extreme Ultra Violet) lithography facility to help the semiconductor industry in testing the EUV effects on the material and components of their future integrated circuits in order to address contamination and lifetime challenges.
A customized JORAN hexapod is positioning the sample via manipulators inside a vacuum chamber.

■ Travel range: ± 110 mm ; 20° with an off-centered pivot point
■ High repeatability with heavy external forces due to the bellows: ± 3 μm ; ± 0.0002°
■ High accuracy : ± 5μm ; ± 0.005°
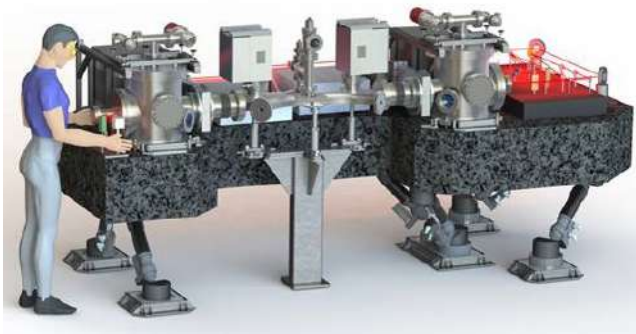
Compton light source

ThomX is a compact light source in which the Compton effect is used to produce "hard" X-rays (a few tens of keV).

A customized JORAN hexapod has been delivered to LAL (Laboratory of Linear Acceleration) in order to position the optical table, on which the cavity and the high power laser are installed.

■ Highly custom asymmetric design
■ Repeatability: ± 0.8 μm
■ Payload: 7 tons (including granite platform)

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Applications: Special projects

Our engineers are experienced to design made-to-measure hexapods with a high level of customization for very specific projects.
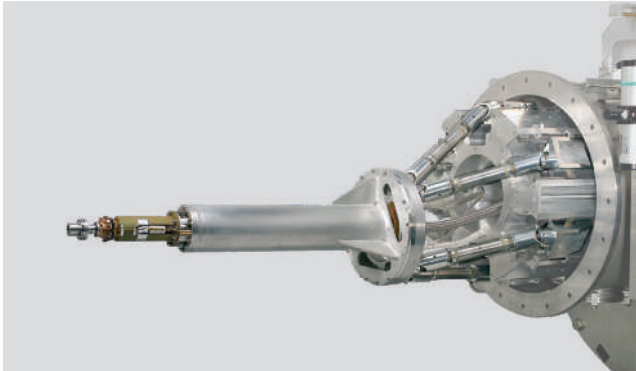
Laser MegaJoule

Laser MegaJoule (LMJ) is a large laser-based inertial confinement fusion (ICF) research device being built near Bordeaux, in France by the French nuclear science directorate, CEA.

- High precision positioning of the target in the convergence centre of 240 laser beams
- Harsh environment: high vacuum and radiations
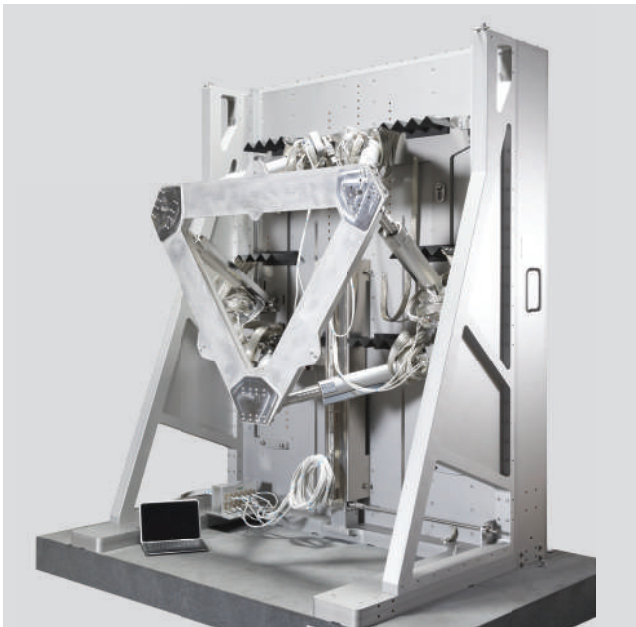
Mirror test bench

Mirrors for observation satellites have improved performances over the years. Therefore test equipment need to be more and more precise.

To qualify a large mirror a hexapod is attached to a Z stage to enable a large vertical travel range.

Actuators derived from ZONDA hexapod are very stable and thermal precautions have been taken to guarantee the thermal stability of the test equipment over time.

This system is compatible with ISO5 clean room and high vacuum.

- High angular resolution: 1 µrad
- Heavy payload: 1 ton horizontally mounted
- Small cross-talk error : ± 5 µrad over 200 mm translations
- Height of the system: 2.5m
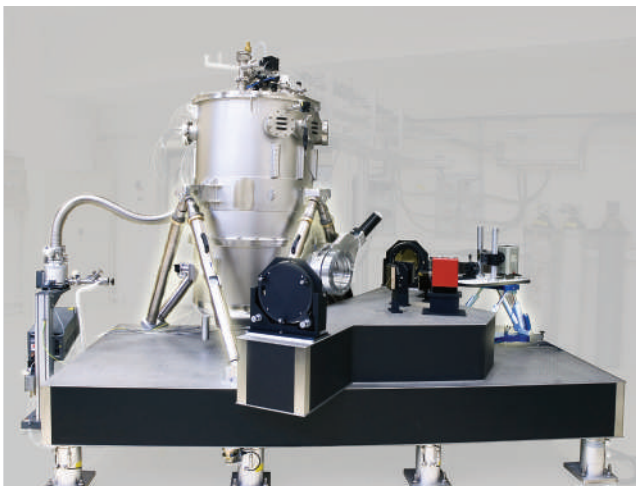
Webb optical test bench of the Webb telescope

The James Webb Space Telescope (JWST) is the successor to Hubble. This telescope is an international collaboration between NASA, ESA and CSA.

This optical test bench was made by CEA to qualify the MIRIM (Mid Infra Red IMager) instrument of JWST.

- Two positioning hexapods: a manual one for the cryostat and a customized BREVA for the light source
- High resolution positioning: 1 µm
- SONORA and BREVA hexapods have been adapted

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Glossary

Abbe Error
A positioning or measurement error caused by parasitic rotations when a misalignment exists between the measurement axis and the point of interest. By reducing either parasitic rotations or the offset of misalignment, or both, the Abbe error can be minimized.

Accuracy
Represents how close the actual position is to the commanded position to which it is expected to move. It is affected by kinematic model error, linearity error, hysteresis, Abbe error, etc. (parameter M or A following ISO 230-2 standard).

Backlash error
Clearance or lost motion in a mechanism caused by gaps between the parts.

Cross coupling
When commanded to move on a single axis, defines the deviation of the hexapod position on the other axes.

Dimensional metrology
Science of calibrating and using physical measurement equipment to quantify the physical size of an object or the distance and angle from any given object.

Drift
A position change over time, which includes the effects of temperature change and other environmental effects. The drift may be introduced from both the mechanical system and electronics.

Hysteresis error
It is a deviation between the actual and commanded position at the point of interest caused by elastic forces and friction forces.

Repeatability
Deviation from the average of actual positions when the system is commanded several times to go at a desired position.
Repeatability is given as unidirectional repeatability in any point of the axis with ± 1 standard deviation (parameter R+ following ISO 230-2 standard).

Resolution
Resolution is seen as minimum incremental motion (MIM). It is the smallest motion increment that the system is able to achieve in a consistent and detectable manner.

Stability
Defines how much the hexapod deviate from its position over time without any new command.

Stiffness
Defines how much the hexapod deforms when subject to an applied force. Stiffness is determinant to increase the natural frequency.

Straightness
Defines the deviation of the hexapod position from its trajectory when commanded to move on a straight line.

Absolute encoder
An absolute encoder maintains position information when power is removed from the system. The position of the encoder is available immediately when applying power.

Application Programming Interface (API)
An API is a set of commands, functions, protocols and objects that programmers can use to create software or interact with the controller. It provides developers with standard commands for performing common operations so they do not have to write the code from scratch.

Graphical User Interface (GUI)
An intuitive interface which allows the user to control the hexapod.

Hexapod
Parallel kinematics system composed of six struts to provide motion and accuracy for positioning in the six Degrees Of Freedom (6 DOF) also called Gough-Stewart platform or Stewart platform.

Invar
Invar is a nickel–iron alloy (Fe36Ni - 64FeNi in the USA) notable for its uniquely low coefficient of thermal expansion. The name Invar comes from the word invariable, referring to its relative lack of expansion or contraction with temperature changes.

Parallel kinematics
A parallel kinematics system is a mechanical system that uses several (at least two) computer-controlled serial chains to support a single platform, or end-effector. Compared to a serial kinematics system in which each degree of freedom is dependent, the degrees of freedom in a parallel kinematics system are interdependent.

Pivot point
Center of rotation around which the hexapod moves. It can be configured virtually via software.

Six Degrees Of Freedom (6 DOF)
It refers to the freedom of movement of a body in three dimensional spaces. The body is free to move forward/backward, up/down, left/right combined with rotation about three perpendicular axes, often termed pitch, yaw and roll.

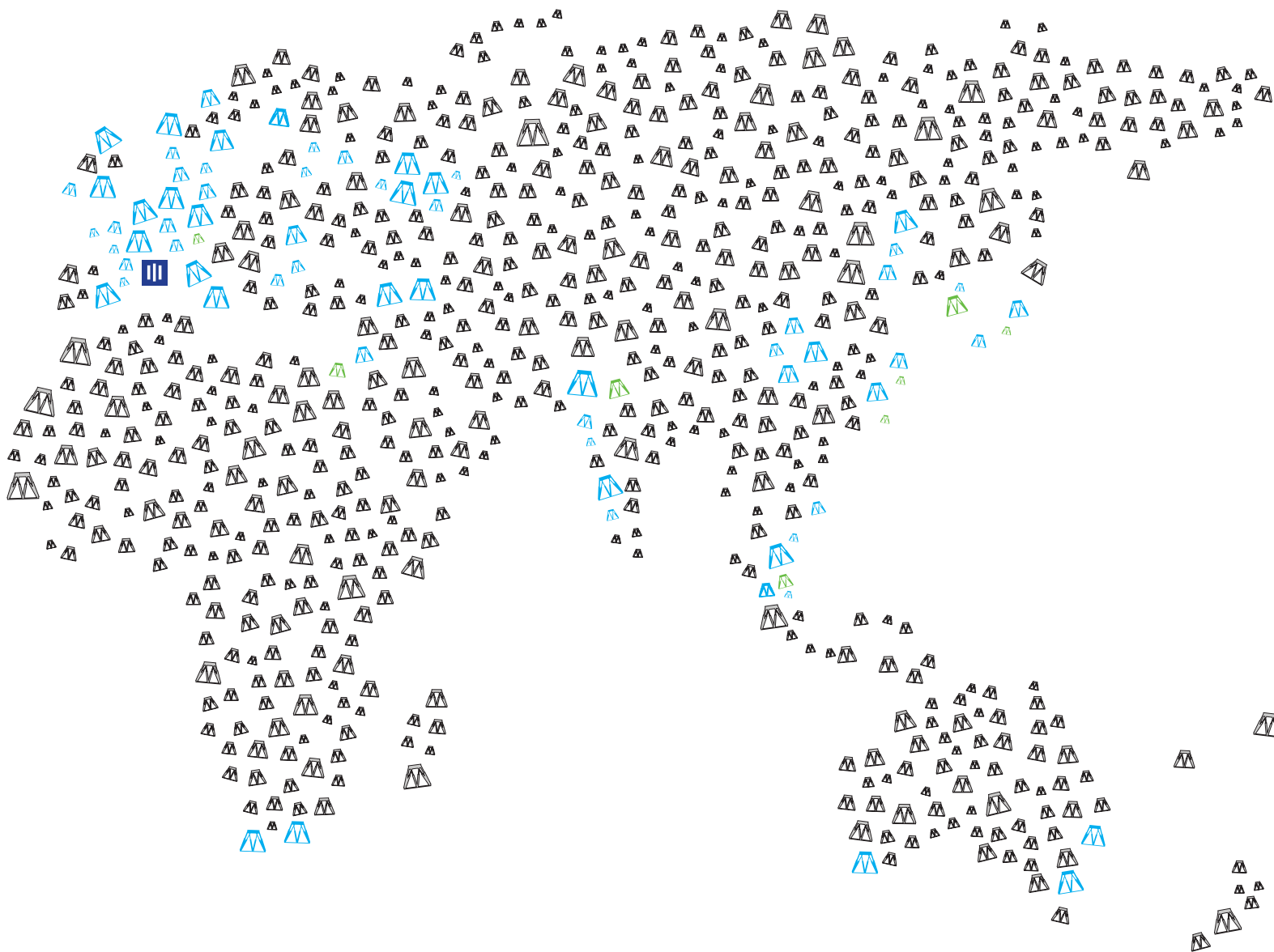# A worldwide presence

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