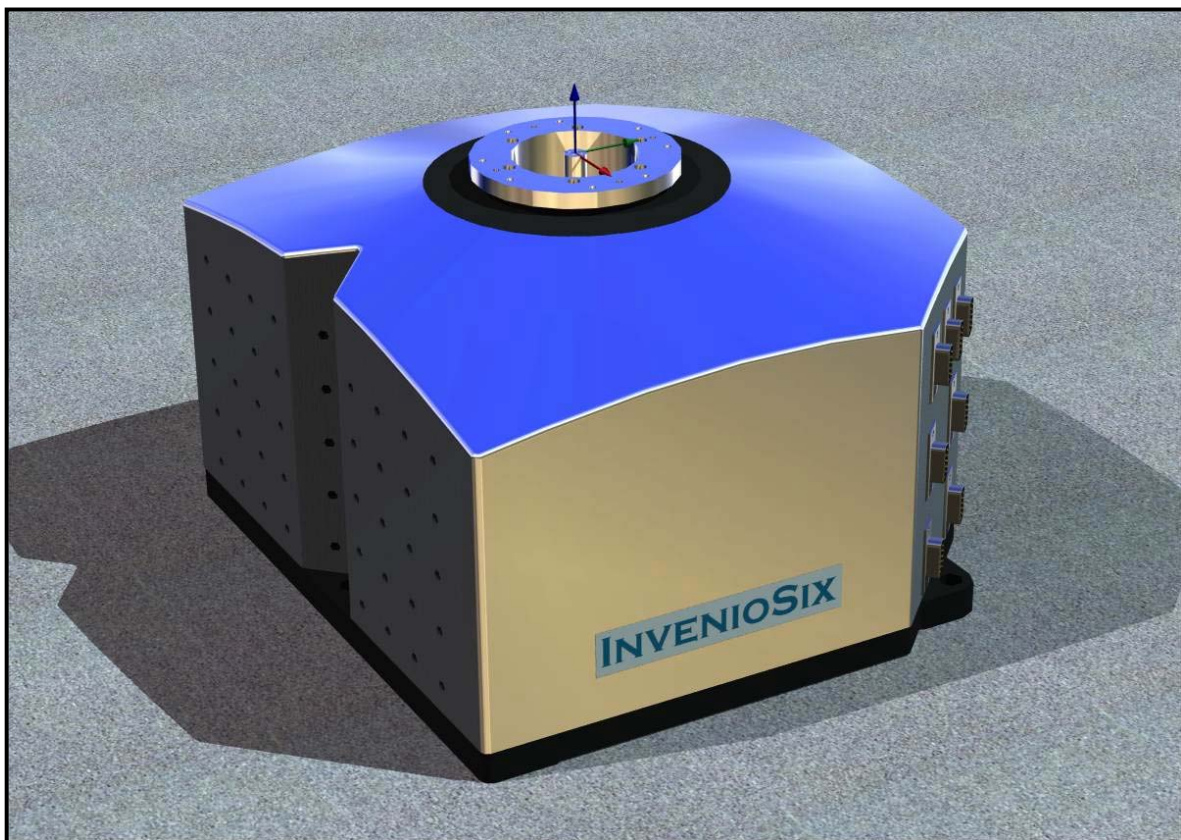


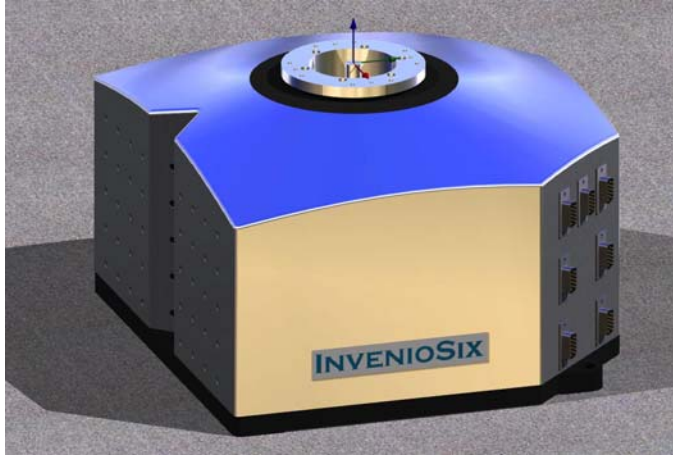
# INVENIOSIX

**The Six Degree of Freedom (6-DOF)  
Sub-Micron Precision Motion Platform**



## BASIC DESCRIPTION

**INVENIOSIX** is a general-purpose, 6-DOF motion platform for manipulating and aligning small payloads with sub-micron precision and high stability.



**INVENIOSIX** uses a revolutionary parallel-kinematics mechanism with significant performance advantages over stacked stage assemblies that have traditionally been used for generating 6-axis motions.

Furthermore, compared to parallel-kinematics systems made by other manufacturers, **INVENIOSIX** has superior robustness, higher thermal stability and higher load carrying capacity. The control software interface (**INVENIOSIX** PC), engineered by one of the world's leading experts in 6-axis robotics, can also be enhanced by adding the optional fully-integrated machine vision.

The powerful **INVENIOSIX** PC software's easy script language, with interpretive editor and code visual simulator, gives the user complete control over motion sequences, coordinate systems, and the location of the pivot point [or tool center point] (i.e. axis of rotation).

Although the **INVENIOSIX** mechanism utilizes a fully closed-loop positioning system via six high-resolution encoders, alignments can be enhanced using additional real-time closed-loop feedback from analog inputs. Also, the optional integrated machine vision system, customer-specified instrumentation (via a GPIB (IEEE) interface), or user provided dll's and hardware, can be used as a secondary sample rate closed-loop control scheme.

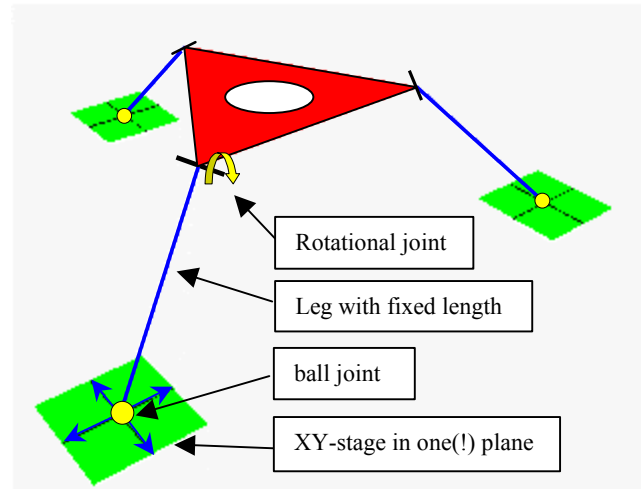
The **INVENIOSIX** is the world's only commercially available six-axis positioning mechanism with a fully closed-loop upper platform, provided as an optional feature. This feature makes the **INVENIOSIX** capable of high-resolution accuracy suitable for metrology

## TYPICAL APPLICATIONS

- Attach detector arrays to imaging systems
- Steer and point laser beams, collimators etc.
- Align secondary mirrors in telescopes
- Auto alignment of optical components
- As a motion platform for six axis dimensional metrology and QA systems
- Micro-fabrication
- High-precision assembly tasks
- Optical tweezers manipulation
- Bio-genetic research

## PRINCIPLE OF THE **INVENIOSIX** PARALLEL KINEMATICS

The Parallel-kinematics architecture is the "cutting edge" of motion control and positioning technology today, and is completely differentiated from the traditional stacked-stages approach.



Internal Configuration of the InveniosSix.

Mounted to the base plate inside the **INVENIOSIX** enclosure are three sets of closed-loop XY linear actuators, each connected via a backlash-free precision strut to the moving top-plate, which carries the payload. Our proprietary non pre-loaded design can easily carry up to 1 kg of payload at a 150mm lever-arm without a reduction in performance, resolution or accuracy. **INVENIOSIX** provides a unique solution to modern parallel stage design.

**INVENIOSIX** has a sophisticated control system to perform real-time coordinate transformations. The controller generates a desired incremental move of the top plate by issuing a parallel real-time stream of commands to the six linear actuators using a dedicated DSP. This implementation allows for accurate contoured moves.

## CHOOSE COORDINATE SYSTEM, PIVOT & PATH

Compared to three or 4-axis systems, a 6-axis mechanism is significantly more complicated. For example, the user is required to consider all of the following:

- Global (lab bench) coordinate system
- Local (tool-tip) coordinate system
- User-defined coordinate system (i.e. “XY” alignment plane tilted by 8 degrees)
- Polarity of each of the motion axes
- Pivot point location for each angular move
- Verifying the absolute location of the pivot point
- The specific path for any given move
- The absolute location of top plate relative to some well-defined reference
- Defining zones of the 6-axis work envelope where the stage is prohibited from going

Fortunately, **INVENIOSIX**-PC software manages all of these aspects in a clear, intelligent manner. In addition, it allows the user to define the pivot point at any location inside or even outside of the mechanism’s motion envelope.

## “REAL-TIME” KINEMATICS

**INVENIOSIX** PC™ software is equipped with highly complete, accurate and advanced forward and reverse kinematics model, which transforms the linear motions of the six motorized actuators into the desired linear and angular motion of the top-plate. As a result, all units are calibrated in mm/ inches/degrees/radians and displayed in user-friendly Cartesian coordinates.

For example, the user just tells the software to roll the top-plate by +1° and the controller does the rest. The movement will automatically be carried out via simultaneous, coordinated movements of all six linear actuators about the currently defined coordinate system.

## SUPERIOR TO “STACKED STAGES”

**INVENIOS** believes that the parallel-kinematics architecture out-performs traditional “stacked-stage” designs.

**INVENIOS**’ architecture offers significant improvements in the following areas:

**Smaller size:** With a 275mm x 290mm (11” x 11½”) footprint and a height<sup>1</sup> of just 180mm (7”), **INVENIOSIX** is smaller than a typical “stack”. Also, the footprint to load carrying capacity ratio is smaller than any other “stack” or “parallel” mechanism with similar load capacity.

<sup>1</sup> With flat tool-flange and Z-value of 0mm.

**No moving cables** [except Flex-limit-switches and cable for customer tools] **or spring pre-loaded mechanisms:** In the sub-micron realm, the non-linear forces exerted by moving cables actually disturb the alignment [isn’t it a term of photonics only?]. **INVENIOS** has eliminated pre-loading mechanisms from the moving platform.

**Maximum speed by elimination of cantilevering:** Long-settling times are usually due to wobbling, cantilevered massed, which are commonplace in stacked-stages designs. **INVENIOSIX** effectively eliminates cantilevering altogether.

**Excellent thermal stability:** **INVENIOSIX**’ fully enclosed mechanism quickly reaches thermal equilibrium and holds a position relative to the fixed center post for hours without thermally drifting.

**Much higher load capacity:** **INVENIOSIX** is equipped with sturdy struts and sophisticated flexure hinges designed to carry loads of 5kg; not compromised by the mounting orientation of the stage. This capacity is not possible with a comparably sized stacked-stage or parallel system.

**More uniformly distributed load:** With **INVENIOSIX**, the payload mass is evenly distributed across the six actuators. Compare this to stacked stages, where each lower stage must carry the weight of the ones above.

**Lower moving mass:** **INVENIOSIX**’ intrinsically smaller mechanism (per kg of payload), more uniform load distribution, and parallel design, translate into a lower moving mass, which means faster step & settle time.

**Simplified tuning:** **INVENIOSIX**’ parallel-kinematics design requires none of the painstaking adjustment and servo-tuning that is associated with that of a stacked-stage assembly.

**More predictable, better-behaved motion:** In a stacked stage assembly, each axis is controlled by an individual stage carrying a different load. Therefore, each axis has a different speed and dynamics property. In contrast, all of the **INVENIOSIX** actuators have the same characteristics, so the system’s motion characteristics are much more uniform.

## INVENIOSIX PC SOFTWARE

INVENIOSIX -PC controls the INVENIOSIX stage system. It is written in Microsoft C++ and runs on the Windows 2000 and XP operating systems.

A comprehensive software manual documents the high-level script commands.

## INVENIOSIX STANDARD SYSTEM COMPONENTS

- 6-DOF mechanism
- Cables
- Controller-amplifier unit (one - 19"rack)
- Pre-configured industrial PC
- INVENIOSIX PC software
- Canned motion & vision routines/algorithms
- PCI motion controller
- GPIB integrated software for communication with customer-supplied instruments

## OPTIONS:

- Metric or English threads and hole patterns
- IEEE-1394 fire-wire vision cameras with lenses
- Camera mounting supports
- Angle bracket for mounting the INVENIOSIX mechanism at 90 degrees.
- Custom tool-flange and tooling for maximum flexibility
- Custom alignment routines and algorithms
- GPIB board for integrated communication with instrumentation
- Completely integrated fiber optics assembly platforms containing two INVENIOSIX systems, for fiber optic waveguide test & assembly

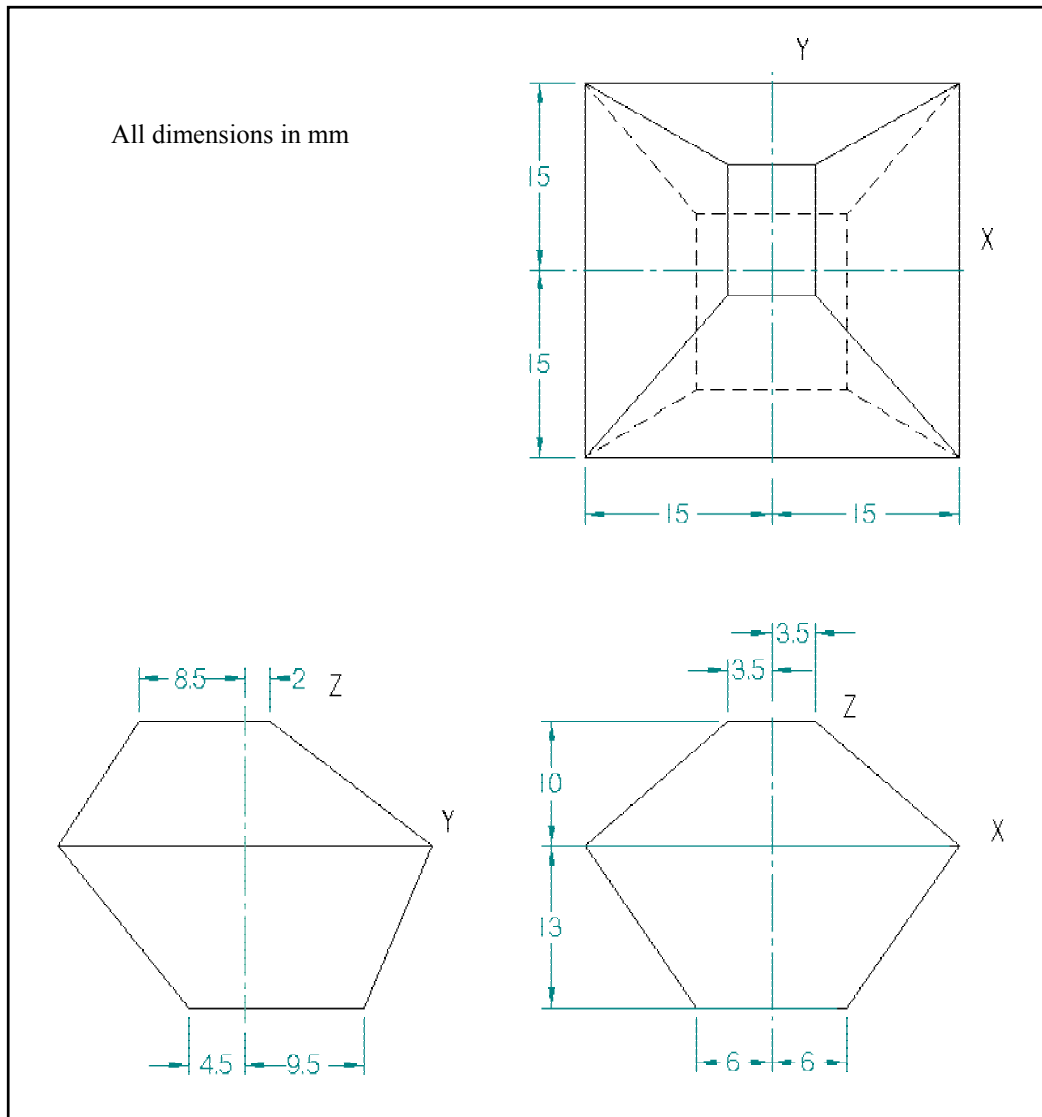
## INVENIOSIX SPECIFICATIONS:

PARAMETER (measured at top-plate)	VALUE
Maximum linear (XY) range of motion	± 15mm
Maximum linear (Z) range of motion	+10 / -13mm
Minimum incremental linear (XY) move	50nm
Minimum incremental linear (Z) move	35nm
Linear (XY) accuracy, standard	± 2µm
Linear (Z) accuracy	± 15µm
Linear (XY) bi-directional repeatability	100nm
Linear (Z) bi-directional repeatability	70nm
Maximum linear (XY) speed	25mm/s
Maximum linear (Z) speed	17mm/s
Flatness/straightness of travel during linear (XYZ) moves	± 1µm
Maximum angular (θx-θy-θz) range of motion	θX, θY: 7° θZ: 9.5°
Minimum incremental angular move	1µrad
Angular accuracy	50µrad
Angular bi-directional repeatability	2µrad
Maximum angular speed	10°/s
Load capacity (load centered on top plate)	4kg
Cantilevered load capacity (load offset 150mm (6 ") from center of top plate)	1kg
Footprint of mechanism (L x W)	275mm x 290mm
Height <sup>2</sup> of mechanism (h)	180mm
Weight of mechanism (base model)	11kg / (24lbs)
Length of cables between mechanism and controller-amplifier	2.4m
Dimensions of controller-amplifier	482mm x 431mm x3u 19" x 17" x 3u
Weight of controller-amplifier	25 lbs / 11.4kg
System line voltage	105-240 VAC 47 to 63 Hz
Analog input range	0-2V 12-bit 0-5V on request 0-10V on request
Maximum line current rating	5 A
Standard operating Temperature:	17 to 25°C (63 to 78°F)
Humidity:	<80%RH
Storage environment Temperature	0 to 32°C (32 to 90°F)
Humidity	<90%RH
Impedance of analog inputs (for connecting power meters)	10 kΩ (standard) 50 kΩ (on request)

<sup>2</sup> With flat tool-flange and Z-value of 0mm.

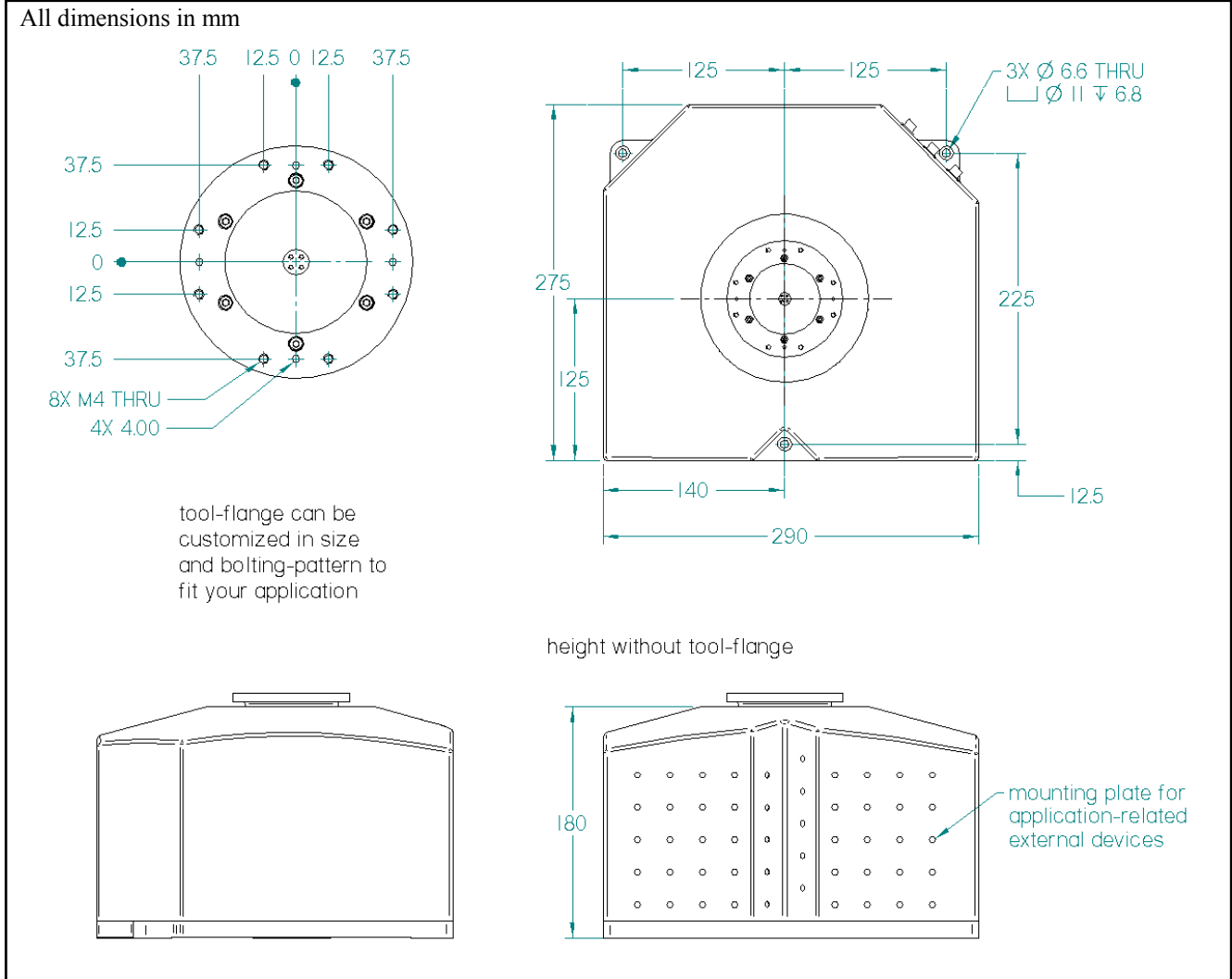
**WORKSPACE INFORMATION:**

This graph displays the translational workspace<sup>3</sup>.



<sup>3</sup> The available angular range decreases towards the limits.

**DIMENSIONAL INFORMATION:**



**FOR MORE INFORMATION, PLEASE CONTACT:**

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