



Advanced Motion Systems for Aerospace, Defense, and National Security



Motion
Simulators



Advanced
Control
Systems



Vacuum
Systems



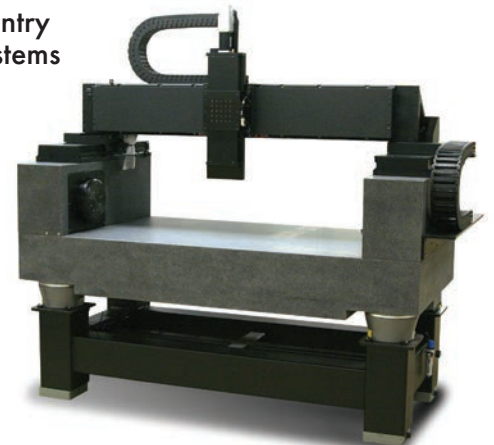
Electro-Optic
Sensor Test
Systems



Prototype Development
Systems



Gantry
Systems

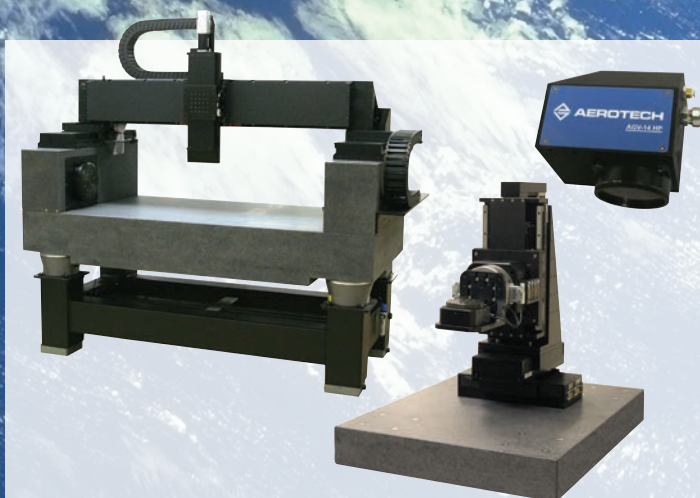


Aerotech

Since 1970, Thousands of Systems Successfully Deployed

Since 1970, Aerotech has designed and manufactured thousands of precision positioning systems for government labs, research centers, aerospace and defense contractors engaged in aerospace and defense manufacturing, testing, and field proof-of-concept demonstrations. Our high-accuracy aerospace and defense solutions have helped customers worldwide to manufacture and test jet engines, aircraft wings, surveillance and tracking electro-optics, directed energy systems, laser communications systems, countermeasures, inertial navigation systems, missile systems, and satellites with their science payloads.

Aerotech is vertically integrated, manufacturing all positioners, electronic controls, and software in our Pittsburgh, Pennsylvania facility. Having all engineering, machining, electronics manufacturing, assembly, and test under one roof allows Aerotech to provide systems engineered and tested to meet the highest performance possible. Our advanced metrology facility can measure and calibrate linear and rotary products to the exceptional performance levels needed in the aerospace and defense industries. Our experienced engineering staff can work with your engineers to customize our extensive product line to meet the most demanding requirements.



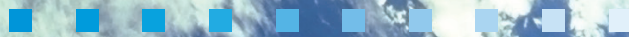
Multi-Axis Motion Solutions for Aerospace Manufacturing

Manufacturing large electro-optics, antenna, and aerospace products to high accuracy is a reality with our high accuracy, large format systems. Sub-micron accuracy and nanometer-level motion are available for laser processing of aerospace materials. Our Cartesian gantries are ideal for dispensing 3D conductive ink onto radomes and other complex surfaces.

Aerospace and Defense Test Systems

Advanced Motion Simulators and Electro-Optic Motion Systems

Aerotech produces many single-axis rotary systems, multi-axis motion simulators, and multi-axis gimbal systems for optical testing, gyro testing, inertial navigation testing and calibration, and target tracking. Aerotech controls can synchronize up to 32 axes to handle the most complex NDT scanning systems, laser processing machines, and ground support equipment applications.



Our products are utilized in the laboratory, on the production floor, and in the field. We specialize in products for cleanroom and high-vacuum operation.

Our talented and dedicated engineering staff has expertise in all core motion technology areas:

- Precision machine design
- Vibration and controls
- System modeling and characterization
- Magnetic circuit design
- Power electronics design
- Servo systems
- Software development

Our linear and rotary air- and mechanical-bearing stages can be assembled into multi-axis systems for payload positioning to sub-arc-second accuracy. Typical linear systems range in travel from 25 mm to 2 meters. Load capabilities of linear and rotary systems are up to 1000 kg (2200 lb). Our facilities include temperature testing capabilities and large system ISO 14644-1 Class 6 (Federal Standard 209E Class 1000) and cell specific ISO Class 5 (Class 100) cleanroom facilities.

Aerotech is committed to continuing the development of new motion technology and products to better serve the defense, aerospace, and national security markets.



Prove Your Equipment in the Field

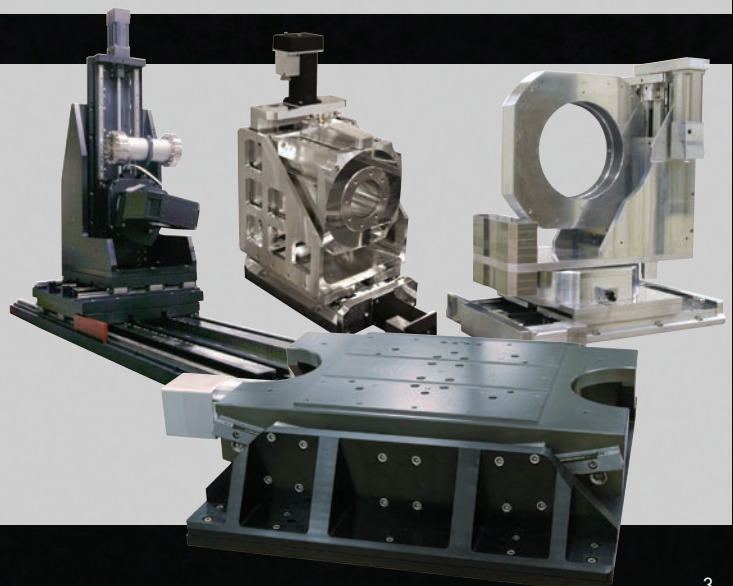
Precision Pointing Systems and IP66-Rated Gimbals and Pedestals

Range tracking, electro-optic beam steering, and surveillance applications regularly use Aerotech rotary systems. Many of our systems can be qualified for operation from -40°C to 70°C. Our direct-drive gimbals provide highly accurate pointing and tracking systems. Customers use our systems to field-qualify their sensors, lasers, and antenna systems.

Reach the Stars

Vacuum-Compatible Motion Systems and Celestial and Satellite Tracking Mounts

Aerotech has provided thousands of axes for high vacuum (up to 10^{-8} Torr) and cleanroom (up to ISO Class 1) environments. Aerotech specializes in configuring our positioners with low outgassing materials to provide automation in space-rated environments.



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Aerospace and Defense Manufacturing Systems



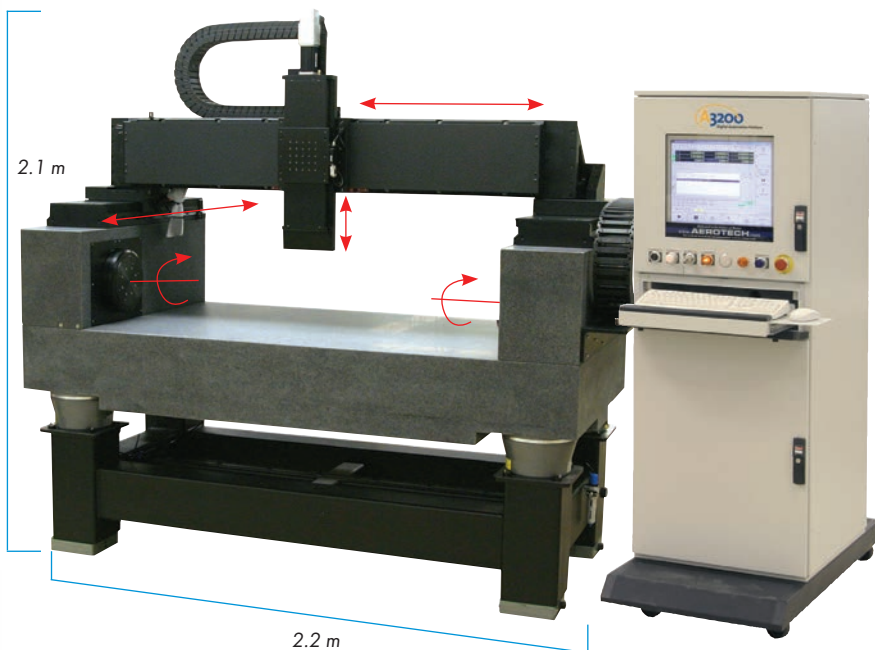
Aerospace and Defense Manufacturing Systems

Laser Processing

The quality and precision required of aerospace and defense components and testing demand highly accurate and repeatable motion systems. For over 40 years Aerotech has developed and deployed exceptionally accurate motion systems that meet and exceed the precision specifications of the aerospace and defense industries.

Laser drilling, welding, and cutting systems used in aerospace and defense manufacturing require motion systems to follow tool-path trajectories with incremental motion and precision much smaller than the actual laser spot. New additive manufacturing processes such as laser sintering and conductive ink writing require the use of precision motion systems to guide the laser or printing heads. Multi-axis tooling heads can be added for eddy current or ultrasonic NDT. Our Nmark AGV-HP galvo scanner can be coordinated with the Cartesian axes to process large format parts with high accuracy.

Not only can Aerotech provide exceptional multi-axis air- or mechanical-bearing positioning systems for this work, but our motion controllers provide easy to use tool-path planning and execution, and also laser/print-head triggering based on the trajectory path vector distance traveled. Our Position Synchronized Output (PSO) feature can trigger laser firing, print dispensing, or data capture events. Our solutions range from individual motion components to fully motorized, multi-axis systems in laser-safe workstations.

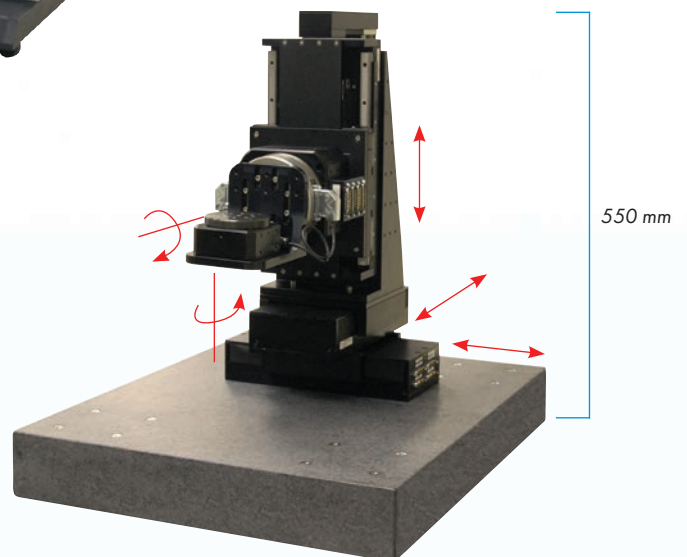


Laser Sintering Gantry

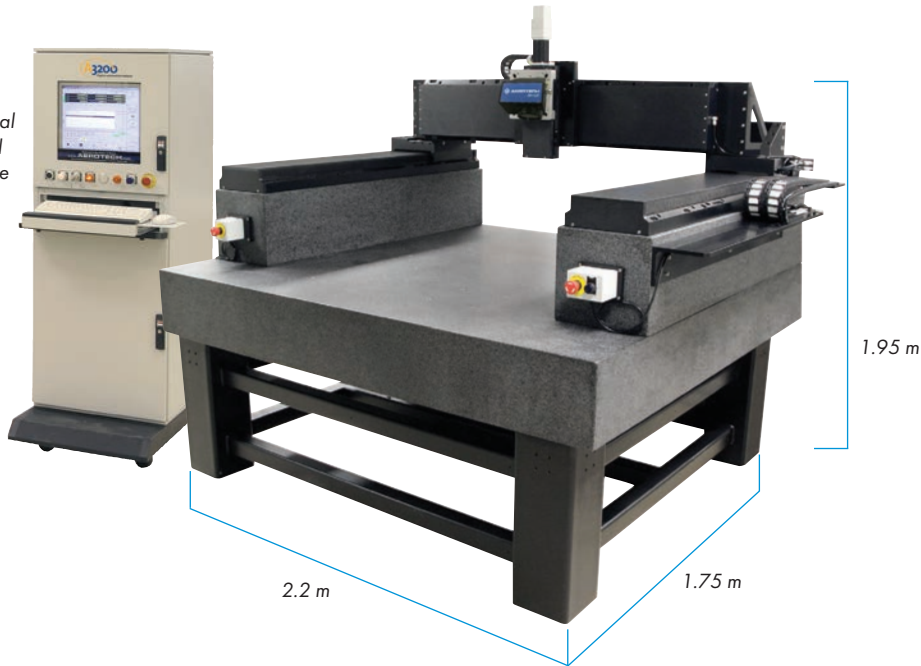
- Position synchronized laser firing
- CNC multi-axis control
- 2 to 32-axis contouring
- Multi-dimensional error correction
- Special sealed connectors to keep metal particles out
- Air purged
- Passive-air vibration isolation
- ALS5000XY/ATS2000LT/ASRT-245
- 450 mm X
- 1300 mm Y
- 300 mm Z
- ASRT-245 cross axis

Five-Axis System for Laser Processing or Optical Sensor Positioning

- Direct linear encoders, direct-drive XYAB, ball-screw Z
- Submicron, sub-arc-sec incremental motion
- Continuous rotation of the AB rotary axes
- 5 kg payload capacity



Optional
Control
Console

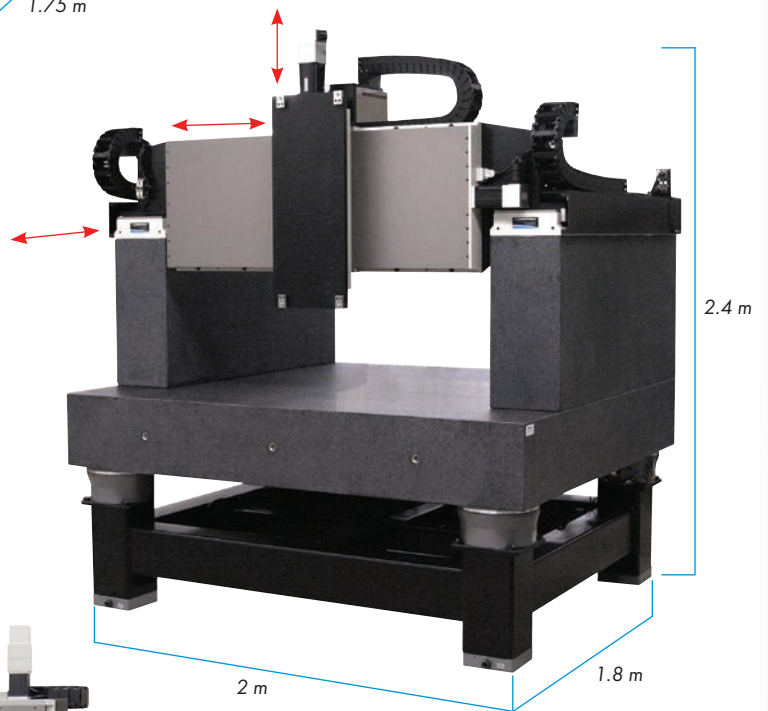


Large Travel Gantry

- PRO280LM XY PRO165 Z
- Laser processing, laser sintering, optical inspection
- 7 μm /axis accuracy
- 1.2 m XY, 300 mm Z travel
- Air-purge input ports to keep out metal dust

Large Travel, High-Performance Gantry

- Optical metrology
- 3-axis ALS5000/ATS5000WB/ATS5000
- 1 m x 1 m XY, 300 mm Z travel
- High load: 80 kg
- <75 arc-sec total angular errors
- Passive air isolation
- 6 ft tall A3200 rack-mount console
- Accuracy: X = 140 μm , Y = 2 μm , Z = 2 μm



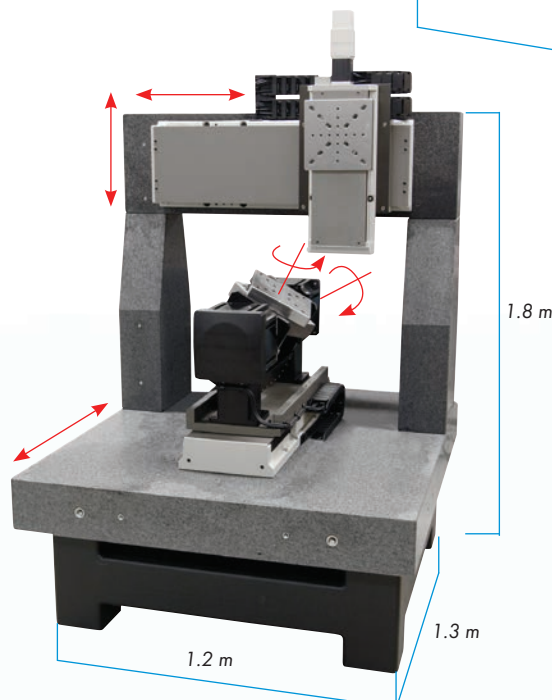
Five DOF (Degree of Freedom) System for Laser Processing or Additive Manufacturing

- XAB part motion
- YZ bridge dispense stages
- Controller position synchronizes output – triggers dispense pump
- $\pm 5 \mu\text{m}$ accuracy



Rack-mount controllers simplify equipment installation

Standard dual redundant emergency stop controls



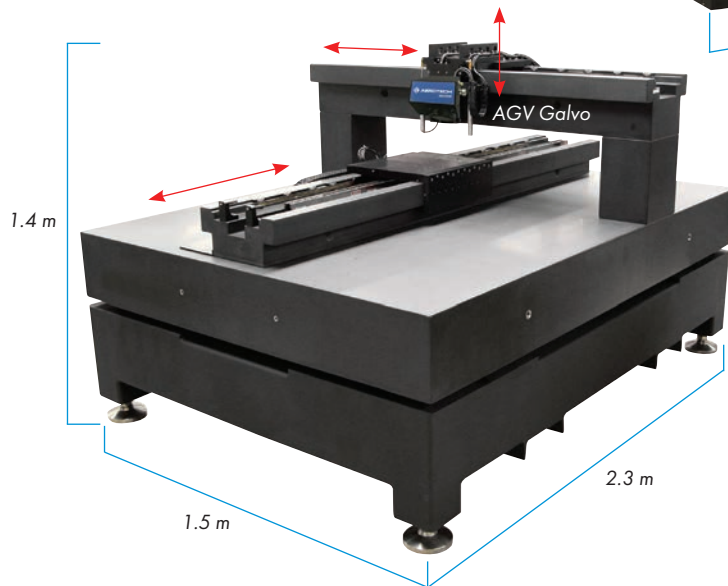
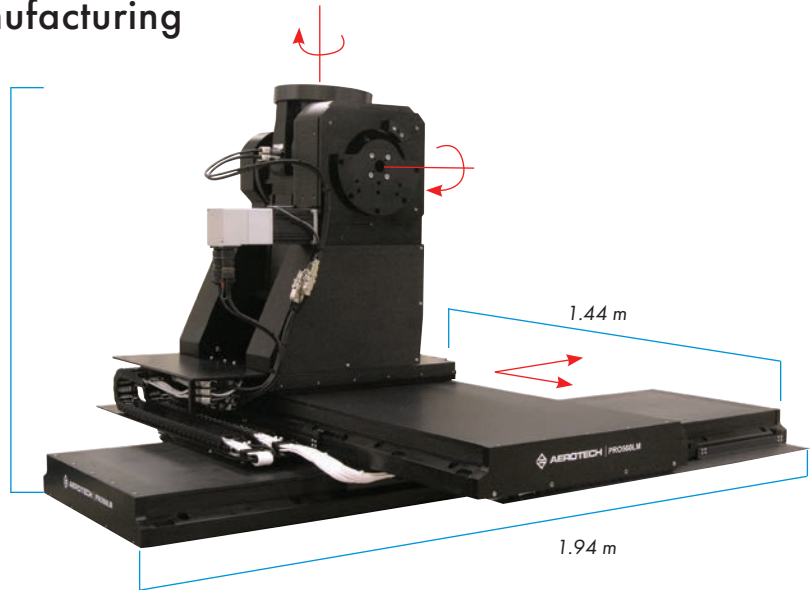
Aerospace and Defense Manufacturing Systems

Laser Processing, Additive Manufacturing

Custom Laser Processing, Heavy-Load, Four-Axis System

- 20 μm tool-point XY accuracy
- 50+ kg load capacity
- XY with AB axis
- Travel 1200 mm X, 900 mm Y
- -25° to $+90^\circ$ pitch
- Continuous 360° yaw

1.1 m

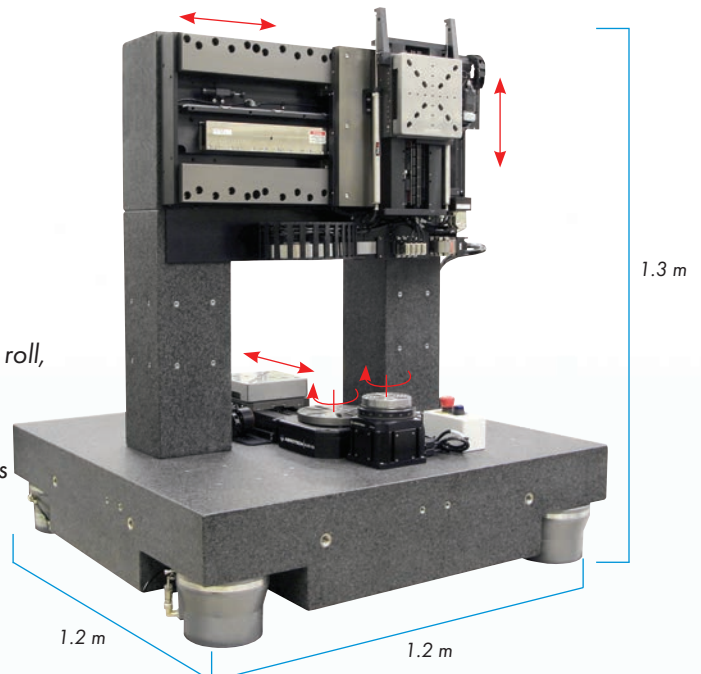


Multi-Axis Air-Bearing System for Laser Writing or Drilling

- Split XY axes
- Accuracy 4 μm X, 4 μm Y, 0.7 μm Z
- Ideal for 5 μm or smaller laser spots
- Travel 1500 mm X, 1200 mm Y, 85 mm Z
- Air-bearing provides submicron flatness/straightness
- <5 μm straightness/flatness
- Single-digit arc-second roll, pitch, and yaw

High Accuracy, Five-Axis System for Laser Processing or Electro-Optics Testing

- Lower stages provide linear X and dual yaw rotation axes
- Upper YZ linear air-bearing axes provide long travel, high stiffness
- Linear air-bearings provide exceptional straightness, flatness, roll, pitch, yaw errors
- Roll, pitch, yaw <10 arc-sec
- Includes base passive air isolation to eliminate floor vibrations from affecting the test results
- All axes are direct-drive providing years of maintenance-free operation
- 400 mm x 150 mm bridge YZ travel, 100 mm X travel
- Two direct-drive rotaries, <1.5 arc-sec accuracy



The ability to form structurally complex parts from plastic, metal, ceramic, or glass powders is an advantage that additive manufacturing continues to exploit over its subtractive manufacturing counterparts. As the industry continues to mature, the level of precision within these processes will increase. Aerotech has the ability to fulfill these high-precision system requirements.



Nmark AGV-HPO



Nmark AGV-HP

Nmark AGV-HP/-HPO Galvanometer Scanner and Controls

- Position synchronized laser firing
- CAD-to-motion command software capability
- Micron-level field of view accuracy achieved by thermally stable feedback sensors
- Direct access is granted to the position sensors of the galvanometer, closing the control loop and virtually eliminating lag and tracking errors typically associated with scanners
- Coupled with controls, the galvanometer can be seamlessly integrated with linear servo stages to create an Infinite Field of View (IFOV) that eliminates stitching errors associated with other scanner systems



Nmark CLS

Aerospace and Defense Manufacturing Systems

Additive Manufacturing

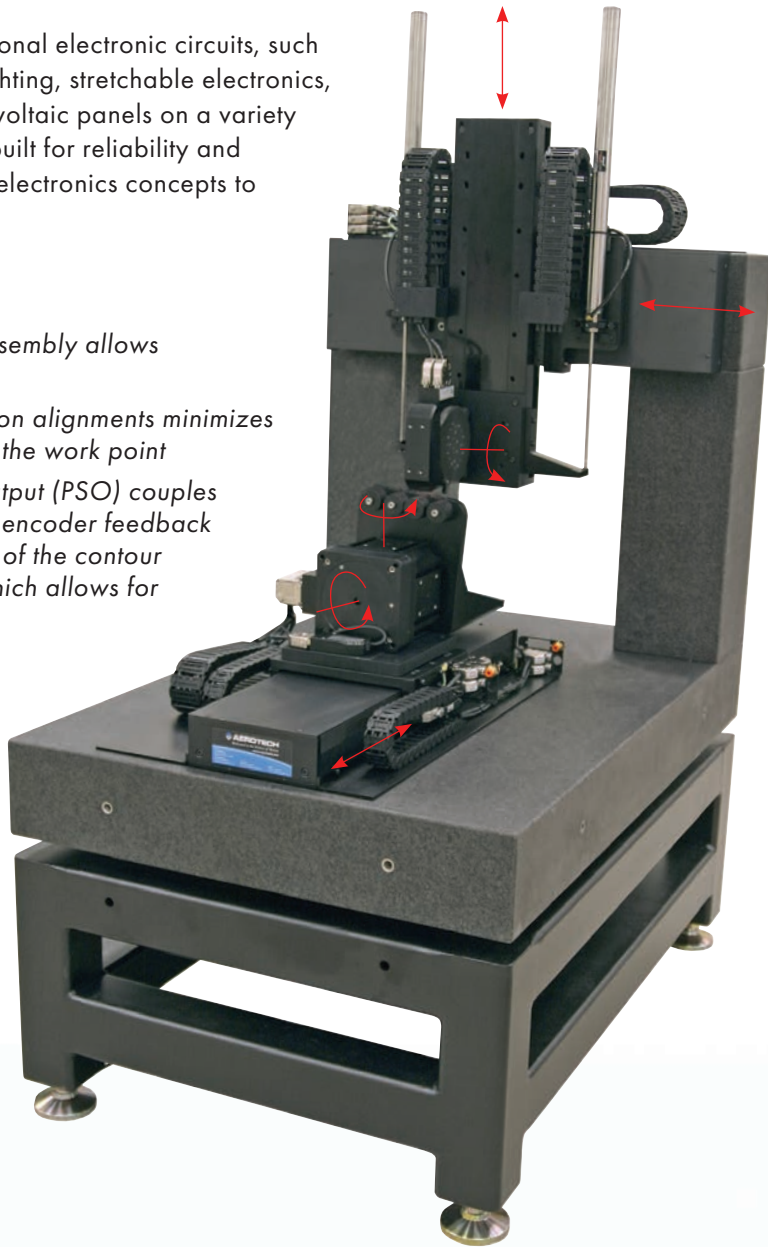
Dispensing involves printing organic and inorganic components on various substrates including paper, plastics, and textiles. Dispensing encompasses applications including printed electronics, 3D printing, and conformal coatings. Overall system accuracy and throughput are important requirements in these applications to dispense along complex contours. Aerotech's product line is specifically designed with these requirements in mind. Common configurations include gantries, split bridge assemblies, and five- to six-axis Degree of Freedom (DOF) systems.

Printed Electronics

Printed electronics involve printing functional electronic circuits, such as OLED displays, electroluminescent lighting, stretchable electronics, wearable sensors, RFID tags, and photovoltaic panels on a variety of media. Aerotech motion systems are built for reliability and flexibility, allowing you to bring printed electronics concepts to reality.

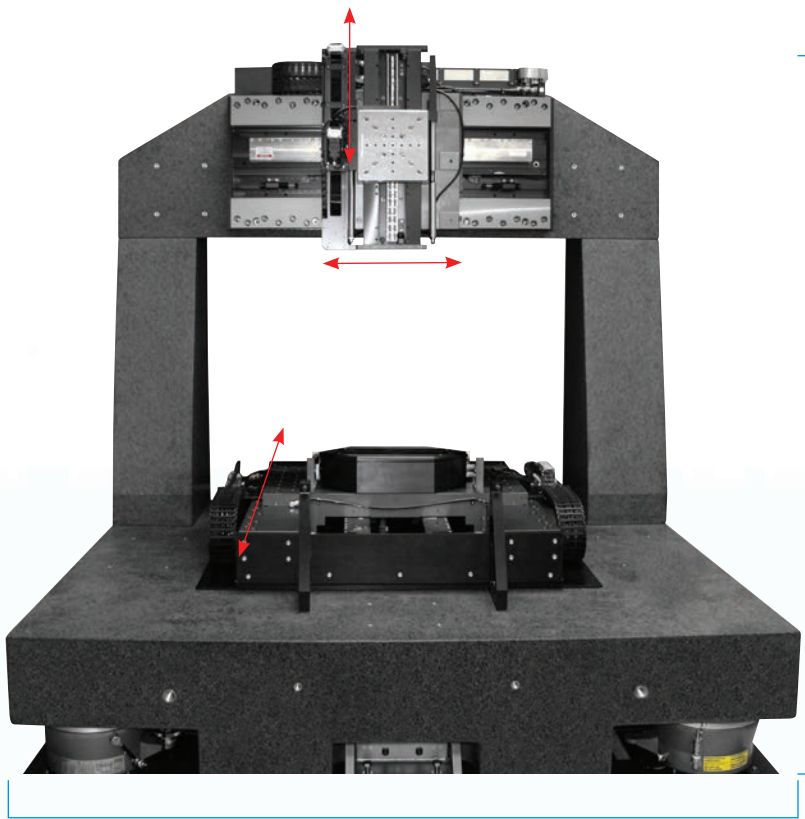
Six-Axis DOF Dispensing System

- Split axis, six degrees of freedom assembly allows dispensing on complex contours
- Precision rotational axis of intersection alignments minimizes three dimensional stack-up errors at the work point
- Multi-axis Position Synchronized Output (PSO) couples your dispensing head directly to the encoder feedback for consistent deposition, regardless of the contour complexity or velocity variability, which allows for the highest possible throughput
- Direct-drive rotary axes exhibit high acceleration and zero backlash for ultra-smooth velocity regulation



Five DOF System for Additive Manufacturing or Laser Machining

- XYAB part motion
- Z axis for dispense head or laser optic
- $\pm 5 \mu\text{m}$ accuracy
- Bridge, laser, and optics mounting patterns



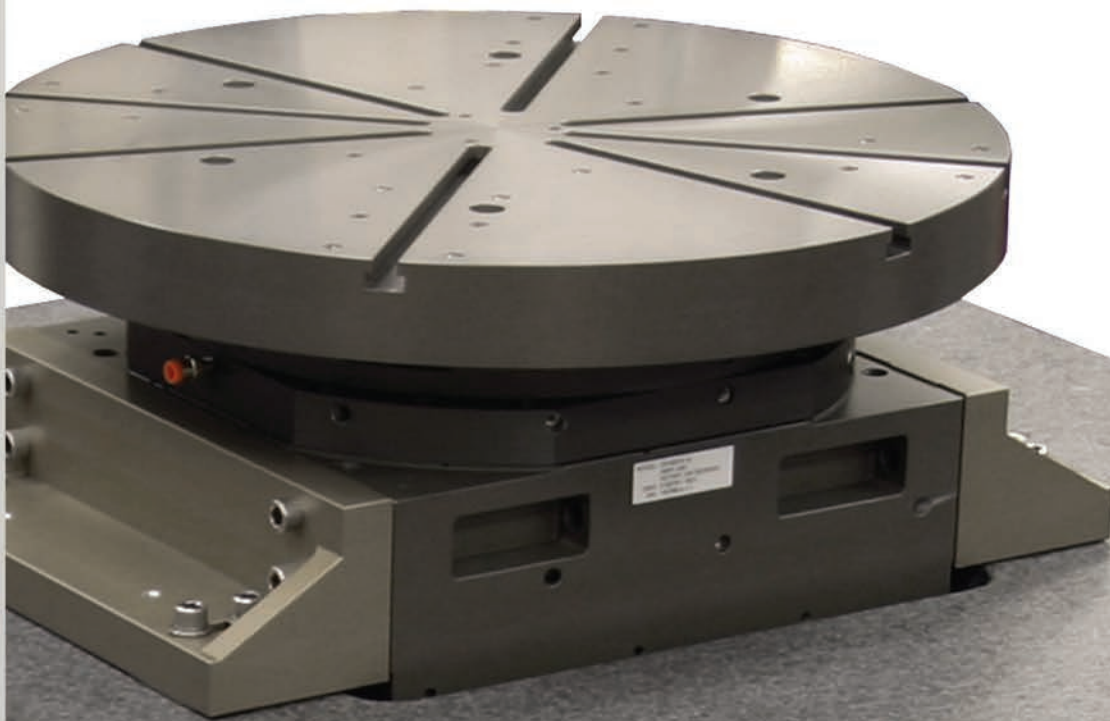
Large Format Air-Bearing XYZ for Laser Processing or Additive Manufacturing

- $< 1.5 \mu\text{m}$ XYZ accuracy
- Additional three-axis rotary option for six DOF processing
- Ideal for $5 \mu\text{m}$ or smaller features
- Travel 500 mm X, 500 mm Y, 280 mm Z
- Air bearings provide submicron flatness/straightness
- Single-digit roll/pitch/yaw errors
- Passive air isolation
- Oversized X air-bearing for high payload capacity
- $< 100 \text{ nm}$ incremental motion

1.7 m

2.2 m

Aerospace and Defense Testing



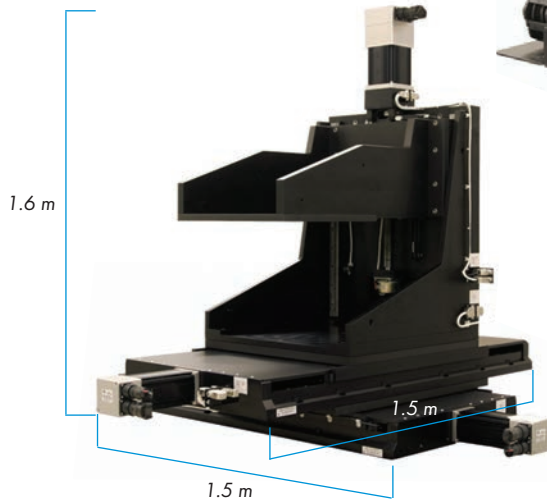
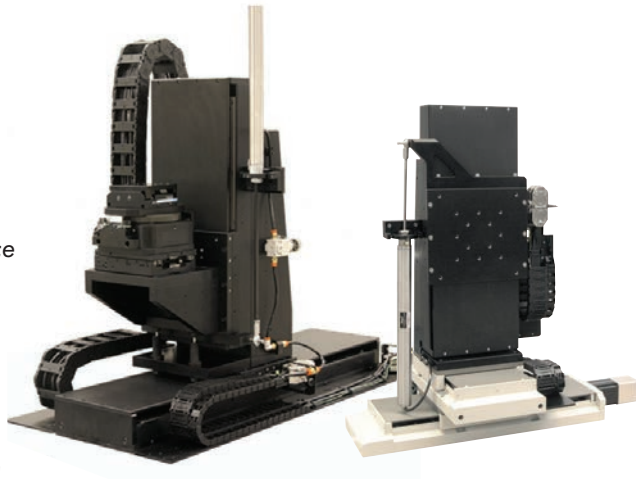
Aerospace and Defense Testing

Large Component Test and Inspection Systems

Aerospace and defense test systems must employ accurate motion to position and test sensors such as interferometers, autocollimators, vision systems, and antennas. Aerotech positioning systems provide motion with higher resolution than the capabilities of electro-optic sensors used in satellites, night vision systems, missile seekers, aircraft heads-up displays, and surveillance and targeting systems. Our systems are engineered for the highest accuracy possible with reliable, long-life performance features to give years of testing with little or no maintenance. Our motion controllers provide up to 32 axes of coordinated motion with high-power linear and PWM amplifiers. Our systems are designed to work in either air or vacuum environments. The pages that follow show many examples of Aerotech's high-accuracy positioning systems used by the aerospace and defense industries for testing and calibration.

Five Axis, XYZ, Tip/Tilt

- *Integrated cable management*
- *Direct-drive, high accuracy*
- *Pneumatic vertical counterbalance*

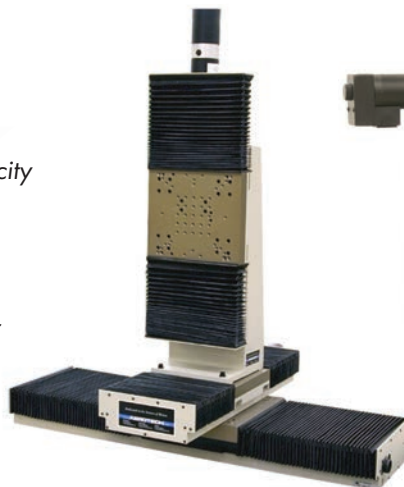


Large Capacity, Heavy Duty, XYZ System

- *227 kg (500 lb) payload capacity, cantilevered 400 mm off Z*
- *200 nm stepping capability*
- *300 mm XYZ travel*
- *4 nm resolution direct encoders*
- *Cleanroom or Vac 10⁻⁶ Torr compatible*

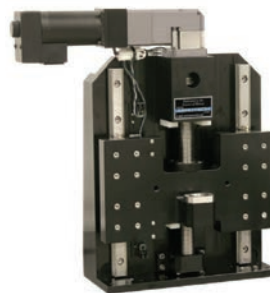
ATS0500 Heavy-Duty XYZ

- *Good for large payloads*
- *114 kg (250 lb) load capacity*
- *Up to 1 meter of travel in all directions*
- *Bellows provide dirt shield*
- *Cleanroom or Vac 10⁻⁶ Torr compatible*



VTS300 High-Load Vertical Stage

- *455 kg (1000 lb) load capacity*
- *No back-driving*
- *Adjustable electrical limits*

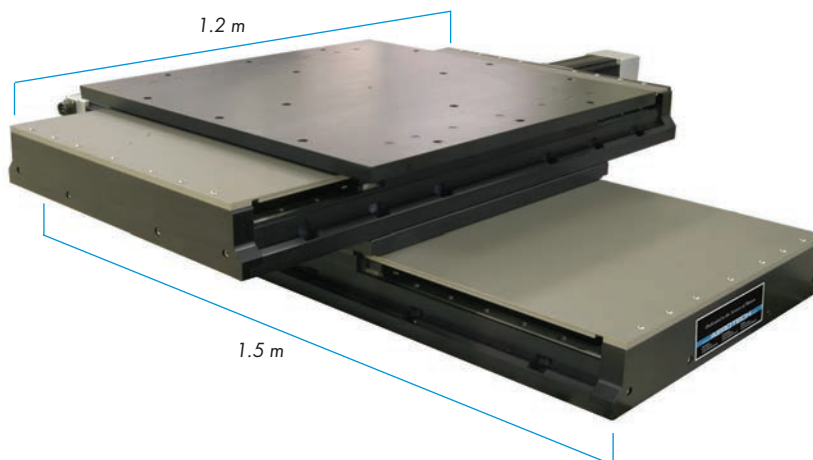


Aerospace and Defense Testing

Large Component Test and Inspection Systems

High Load, Ball Screw, XY Linear Stages

- Payloads up to 682 kg (1500 lb)
- Optional linear encoders for high accuracy and repeatability
- Cleanroom or Vac 10^{-6} Torr compatible
- 600 mm x 300 mm travel
- $\pm 2 \mu\text{m}$ accuracy with linear encoder

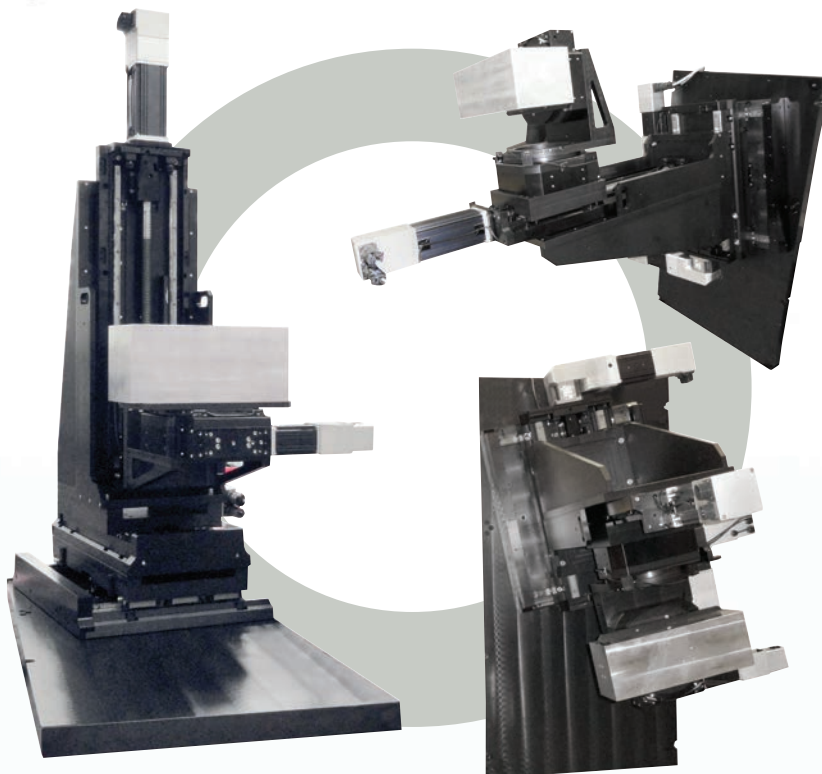


High Load X/Theta

- 350 mm travel
- Continuous 360° rotation
- 682 kg (1500 lb) load capacity
- $\pm 10 \mu\text{rad}$ rotary accuracy
- Cleanroom or Vac 10^{-6} Torr compatible
- Only 200 mm tall

Five-Axis XYZ AZ/EL System Operates at 0°, 90°, 180°, 270° Mounting Configurations

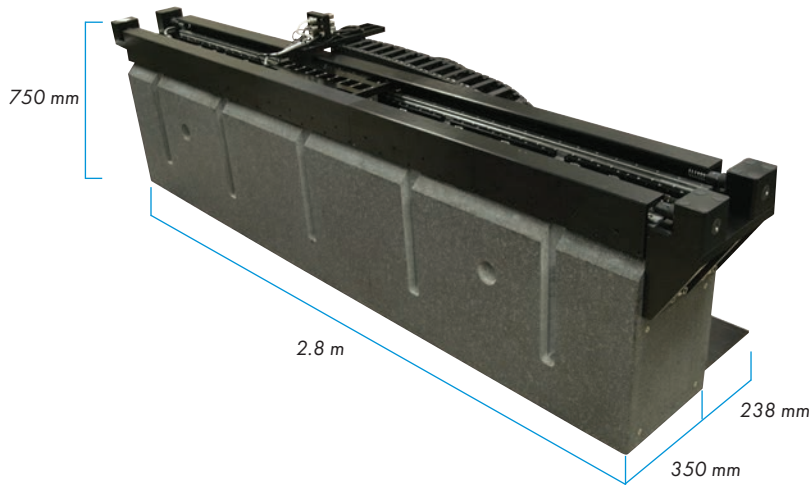
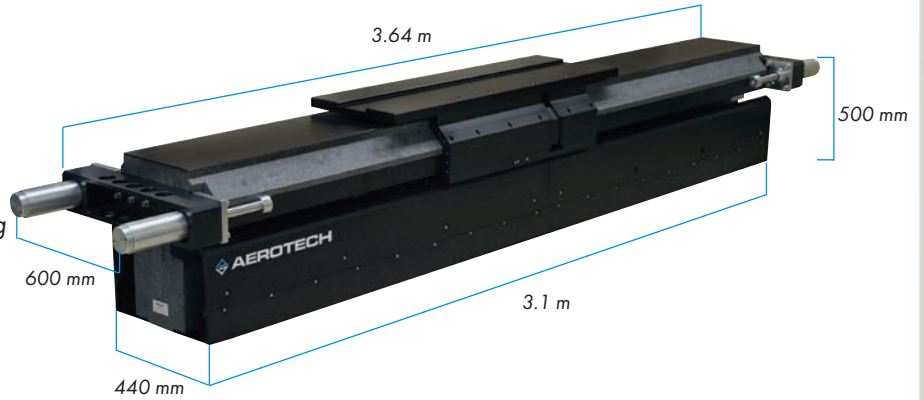
- Can be mounted in almost any orientation relative to gravity
- Cleanroom or Vac 10^{-6} Torr options
- XYZ min incremental motion $< 0.2 \mu\text{m}$
- $1 \mu\text{m}$ linear axis repeatability
- Pitch/yaw min incremental motion $< 2 \text{ arc-sec}$
- Pitch/yaw 5 arc-sec unidirectional repeatability



Aerotech produces specialized linear positioners for high loads, long travels, and high-capacity payloads. Each of these unique positioners has specialized features designed to meet customer requirements and provide years of reliable operation. These mechanical- and air-bearing stages are used for aerospace testing operations, laser processing, and other unique test applications.

High Force, High Load, Direct-Drive Actuator with Mechanical Bearings

- Includes air cooling ports for continuous operation
- Max speed 3 m/s, max acceleration 5 g with 5 kg payload
- Load capacity 150 kg, moving mass 70 kg
- Force 8000 N peak, 1400 N continuous
- 2 m travel, 1.8 m travel at max acceleration and speed
- Accuracy $\pm 2 \mu\text{m}$ calibrated, $\pm 50 \mu\text{m}$ uncalibrated

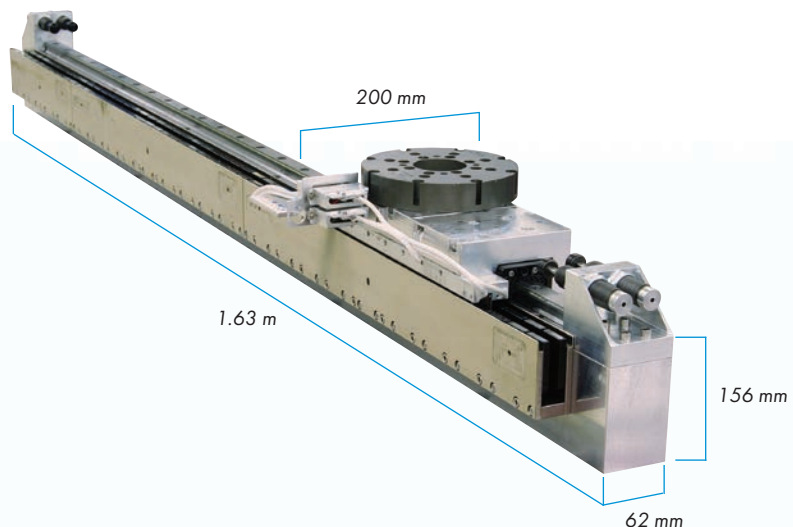


High Force, High Speed, Linear Motion Simulator with Mechanical Bearings

- 5 g, 5 m/s in center 1 m of travel with 5 kg load
- 2 m travel, 1.7 m travel at max acceleration and speed
- $\pm 1\%$ velocity stability at 5 m/s
- 150 kg max load
- Accuracy $\pm 5 \mu\text{m}$ calibrated, $\pm 50 \mu\text{m}$ uncalibrated
- Replaceable e-chain cables

High Acceleration Linear Actuator

- 1 m travel
- 3 m/s, 4 g with 1 kg load
- Mechanical bearings
- 60 kg load capacity
- Accuracy $5 \mu\text{m}$ calibrated, $\pm 50 \mu\text{m}$ uncalibrated
- Vacuum 10^{-6} Torr

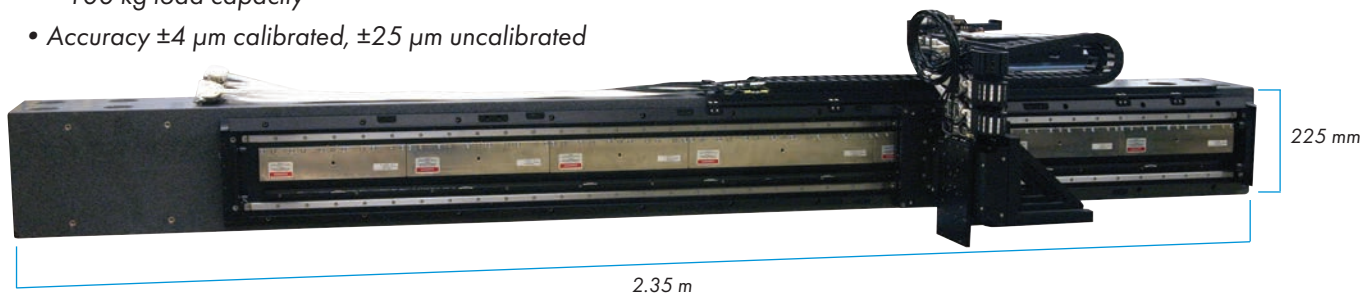


Aerospace and Defense Testing

Large Component Test and Inspection Systems

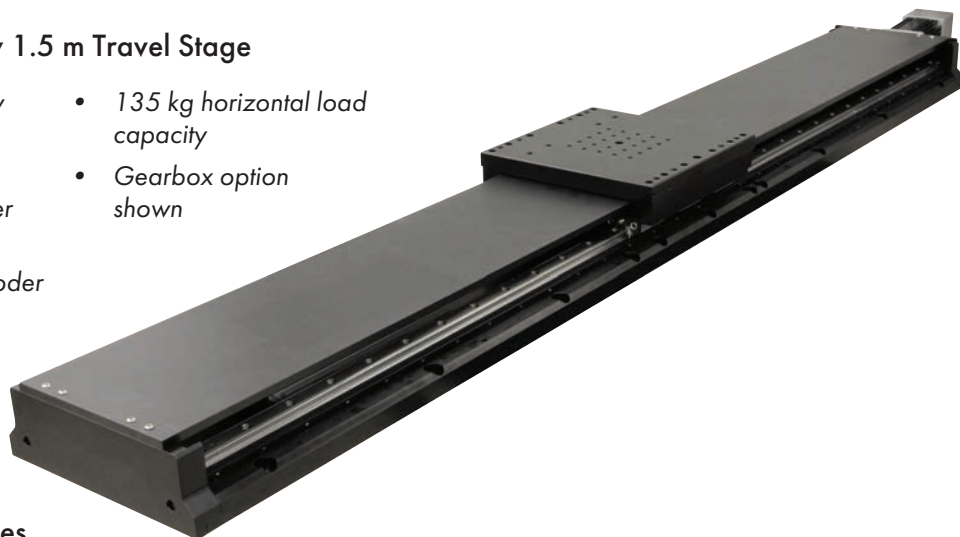
Two-Meter Travel, Direct-Drive PRO225LM

- Shown with optional YZ, two motorized axis head and granite bridge
- 2 m/s, 3 g max speeds with 1 kg load
- 100 kg load capacity
- Accuracy $\pm 4 \mu\text{m}$ calibrated, $\pm 25 \mu\text{m}$ uncalibrated



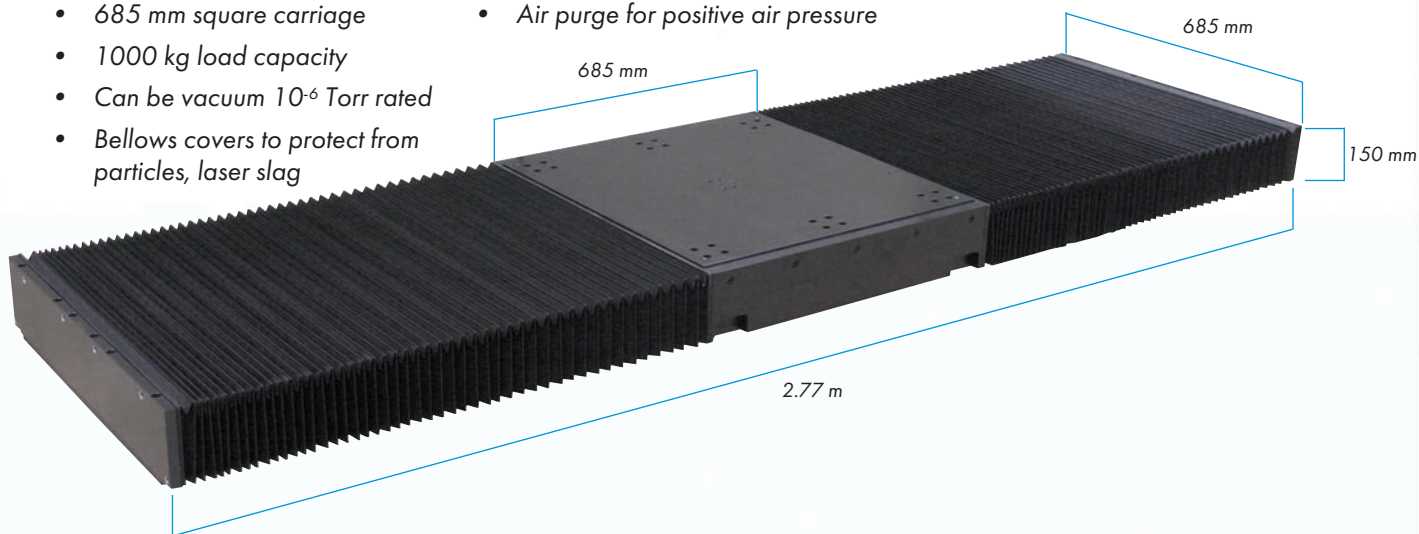
ATS5000 High-Accuracy 1.5 m Travel Stage

- 2 μm calibrated accuracy with linear encoder
- 0.1 μm min incremental motion with linear encoder
- $\pm 40 \mu\text{m}$ uncalibrated accuracy with rotary encoder
- 4 mm ball screw
- Vacuum compatible
- 135 kg horizontal load capacity
- Gearbox option shown



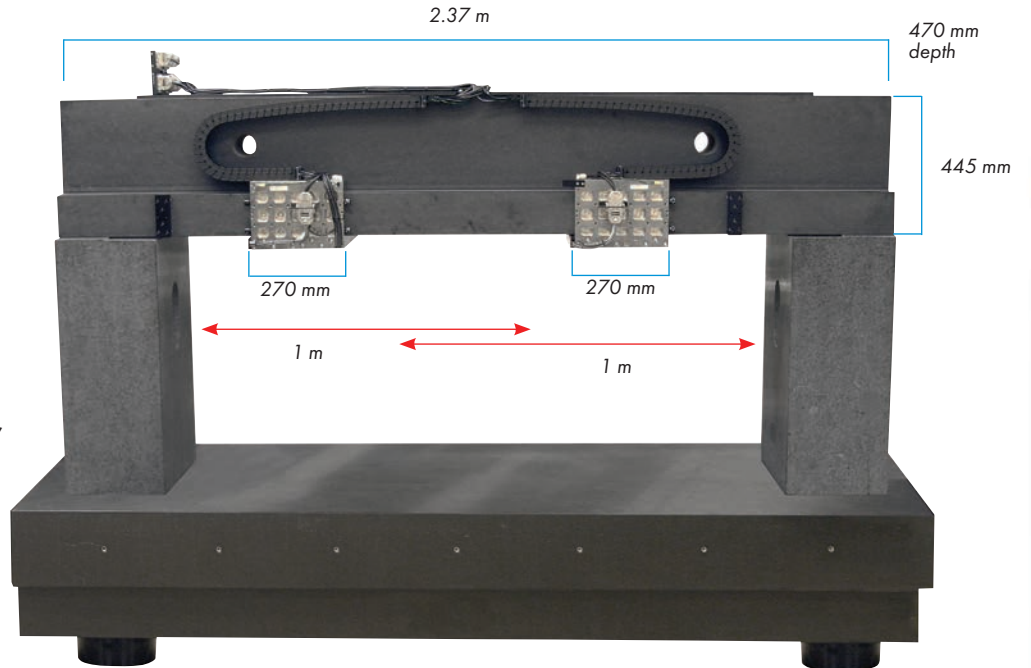
High Load, Ball Screw, Mechanical-Bearing Stages

- 600 mm, 1000 mm, 1500 mm travel sizes
- 685 mm square carriage
- 1000 kg load capacity
- Can be vacuum 10^{-6} Torr rated
- Bellows covers to protect from particles, laser slag
- Accuracy $\pm 8 \mu\text{m}$ calibrated, $\pm 50 \mu\text{m}$ uncalibrated
- Air purge for positive air pressure



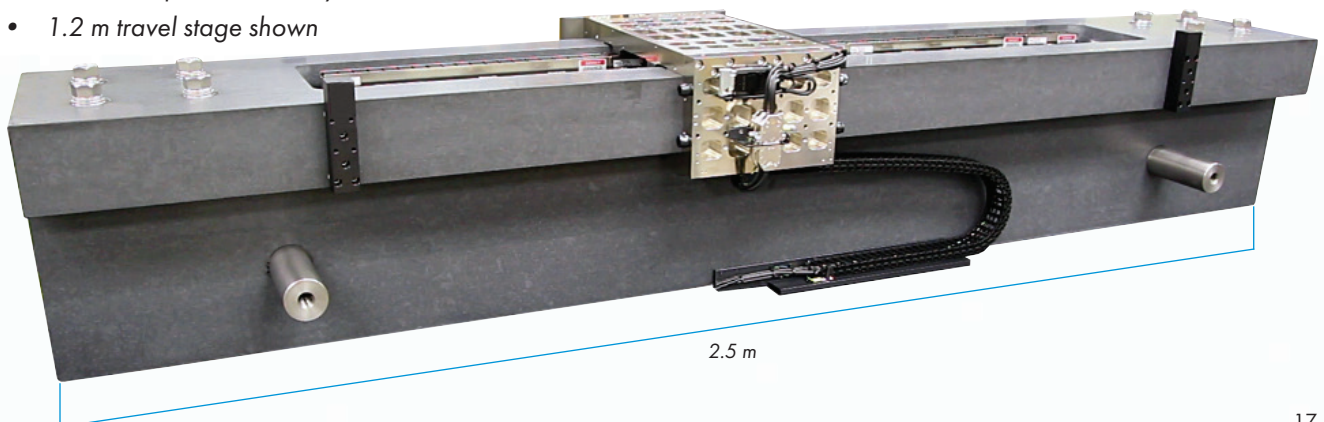
Dual Carriage, Direct-Drive Air-Bearing; Bridge Configuration for Optics Inspection

- Granite stage, stainless-steel carriages
- 1 m travel for each carriage
- 0.25 g, 250 mm/s with 5 kg load
- $\pm 2.5 \mu\text{m}$ straightness, $\pm 5 \mu\text{m}$ flatness
- ± 2.5 arc-sec roll, pitch, yaw
- $\pm 1 \mu\text{m}$ accuracy calibrated, $\pm 0.6 \mu\text{m}$ repeatability
- 50 kg load capacity per carriage



1.5 m Travel, Direct-Drive Air Bearing

- Granite stage, stainless-steel carriage
- 1.5 m/s, 1.5 g with 5 kg payload
- $\pm 5 \mu\text{m}$ flatness, straightness
- ± 5 arc-sec roll, pitch, yaw
- Accuracy $\pm 1 \mu\text{m}$ calibrated, $\pm 0.6 \mu\text{m}$ repeatability
- 35 kg load capacity
- $< 40 \text{ nm}$ in-position stability
- 1.2 m travel stage shown

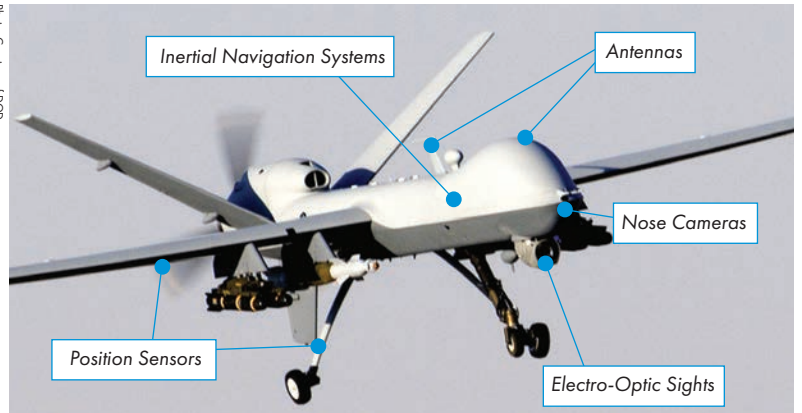


Aerospace and Defense Testing

Electro-Optic Test

These high-accuracy motion systems are designed for superior multi-axis angular testing and calibration of electro-optic sensors, missile seeker gimbals, satellite sensors, inertial navigation guidance units, and are also used as target-tracking gimbal mounts. With our advanced controls and software, customers can rapidly integrate and test their products. Beam-director configurations are possible with 100 mm to 325 mm clear apertures for high-energy beam pointing and testing.

Photo: Courtesy of DOD



Features and Benefits

- High accuracy
- Smooth motion
- Repeatability
- High speed
- Direct drive
- Non-cogging

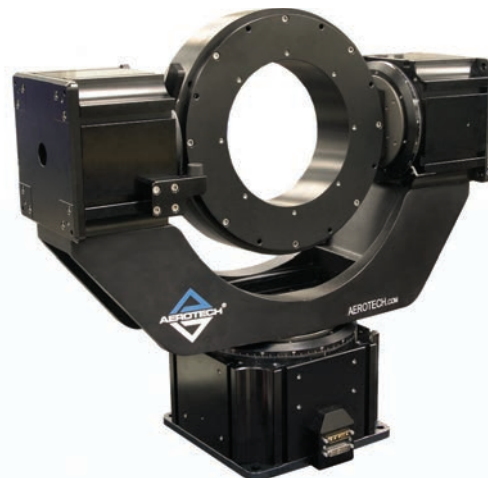
High Accuracy, Two-Axis, Direct-Drive Gimbal Mount

- Continuous 360° rotation of both axes
- High axis-positioning accuracy and repeatability using inductosyn feedback
- $\pm 5 \mu\text{rad}$ accuracy; 0.26 μrad resolution
- Low error motion and axis orthogonality
- Direct drive, brushless, slotless servomotors
- Cog-free design for outstanding velocity stability
- Thermal stability better than 0.4 $\mu\text{rad}/^\circ\text{C}$
- Accommodates loads up to 500 mm diameter
- Vacuum-compatible versions



Ultimate Bearing Precision, Two-Axis, Air-Bearing Motion Simulator/Positioner

- Direct drive, brushless, slotless motors
- $\pm 10 \mu\text{rad}$ accuracy
- Cleanroom compatible
- $< 3 \mu\text{rad}$ tilt error per axis
- 5 μrad repeatability
- 300 mm aperture
- 120 nm axial error motion per axis
- 170 nm radial error motion per axis



Aerospace and Defense Testing

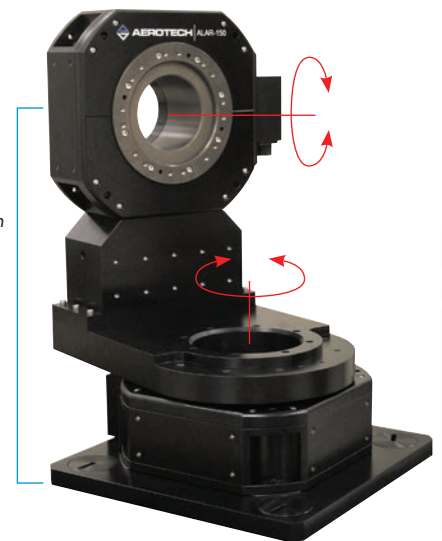
Electro-Optic Test

We provide high-accuracy standard gimbals for many applications, including image and laser scanning. Customers often have unique payload size, shape, and weight requirements that need special design considerations. Our direct-drive and gear-drive rotary products are readily configured into two-axis gimbals as shown in the pages that follow. Many features are available such as travel limits, slip rings for continuous travel, power-off brakes, and adjustable counterbalances. Systems shown include load capacities up to 500 kg. If you do not see an appropriate solution for your application, please contact the factory with your requirements so that we can configure a system for your needs.



Direct Drive, Two-Axis Azimuth/Elevation Positioner

- ALAR-150-SP gimbal
- MS connectors
- Pilot mounting ID on pitch axis 491 mm
- Rear pitch tabletop for counterbalance
- Universal breadboard mounting plate
- $\pm 10 \mu\text{rad}$ accuracy
- 25 kg load capacity
- Min incremental steps 0.01 arc-sec
- Movable travel limits



Large Aperture, Two-Axis Azimuth/Roll Positioner

- Direct drive
- $\pm 10 \mu\text{rad}$ accuracy
- 0.03 μrad resolution
- 100-325 mm apertures available
- Azimuth slip-ring; limited or unlimited travel available
- 150 mm apertures shown



Aerospace and Defense Testing

Electro-Optic Test

High-Load-Capacity Sensor Testing Positioner

- $\pm 14.5 \mu\text{rad}$ accuracy per axis
- Air or vacuum versions available
- Up to 182 kg (400 lb) load capacity
- Limited travel AZ; continuous or limited travel EL
- 0.005 μrad resolution allows super-fine stepping and excellent repeatability



Our gimbals are used to test and verify missile guidance systems.

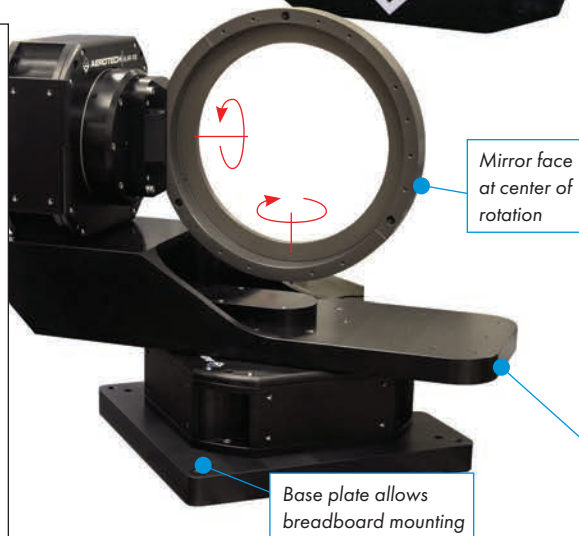


Photo: Courtesy of DOD



We supply full systems...

...or rack-mount drives to operate our positioners.



Mirror face at center of rotation

Foot allows electronics or counterbalance mounting

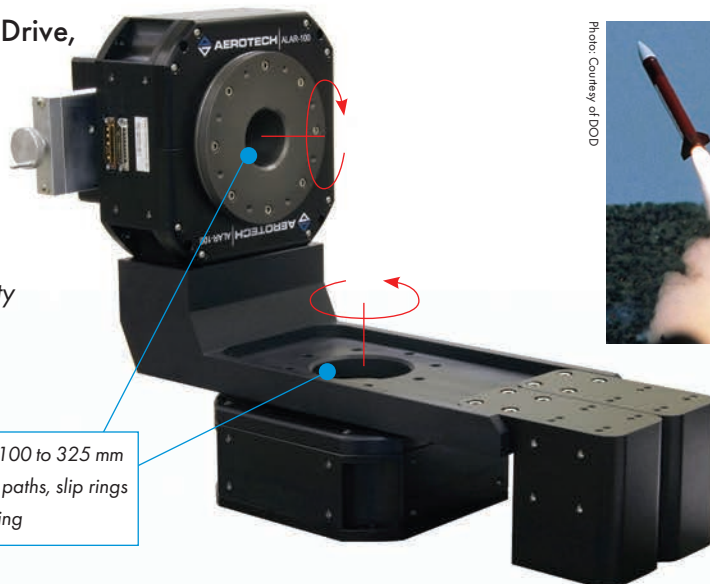
Base plate allows breadboard mounting

Electro-Optic Sensor Calibration Gimbal

- 2-axis direct drive
- 300 mm diameter FSR mirror
- 0.025 μrad resolution
- $\pm 10 \mu\text{rad}$ accuracy

High Accuracy, Direct-Drive, Two-Axis Positioner

- Two-axis positioner
- AZ $\pm 170^\circ$ travel
- EL $\pm 170^\circ$ travel
- $\pm 7 \mu\text{rad}$ accuracy
- $\pm 2.5 \mu\text{rad}$ repeatability



Large apertures of 100 to 325 mm for cables, optical paths, slip rings or payload mounting

Photo: Courtesy of DOD



Missile accuracy depends on seeker and navigation systems. Our gimbals are used to measure and calibrate these systems.



Front Surface Reflecting Mirror Gimbal

- Mirror face is at the AZ/EL center of rotation for minimal optical path error
- AMG gimbal EL axis with ALAR-100/-150 AZ axis



Direct-Drive, Two-Axis Gimbals

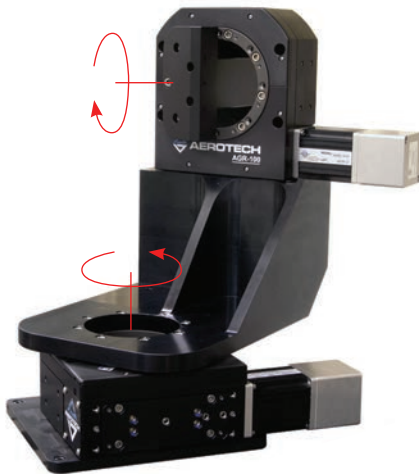
- Continuous 360° rotation of azimuth and elevation including built-in slip ring
- High-accuracy angular position and rate capability
- High axis stiffness for precise pointing
- Direct drive, brushless servomotors result in zero backlash



Low profile AMG LP for loads up to 200 mm in diameter



Heavy-duty AMG for loads up to 600 mm in diameter



Worm-Gear Drive AZ/EL with Counterbalance

- Direct encoder for $\pm 12 \mu\text{rad}$ repeatability
- $\pm 50 \mu\text{rad}$ accuracy with direct encoder
- Economical solution with good performance
- 4.5 to 114 kg (10 to 250 lb) load capacity

Two-Axis, Direct-Drive Mirror Mounts

- Smooth motion for accurate target tracking
- Vac 10^{-6} Torr version available
- Limited AZ/EL travel
- $\pm 5 \mu\text{rad}$ accuracy
- $\pm 2.9 \mu\text{rad}$ repeatability
- 660 mm ID mirror cell shown
- Custom yoke needed for hard stops and limited AZ travel



68 kg (150 lb) load capability

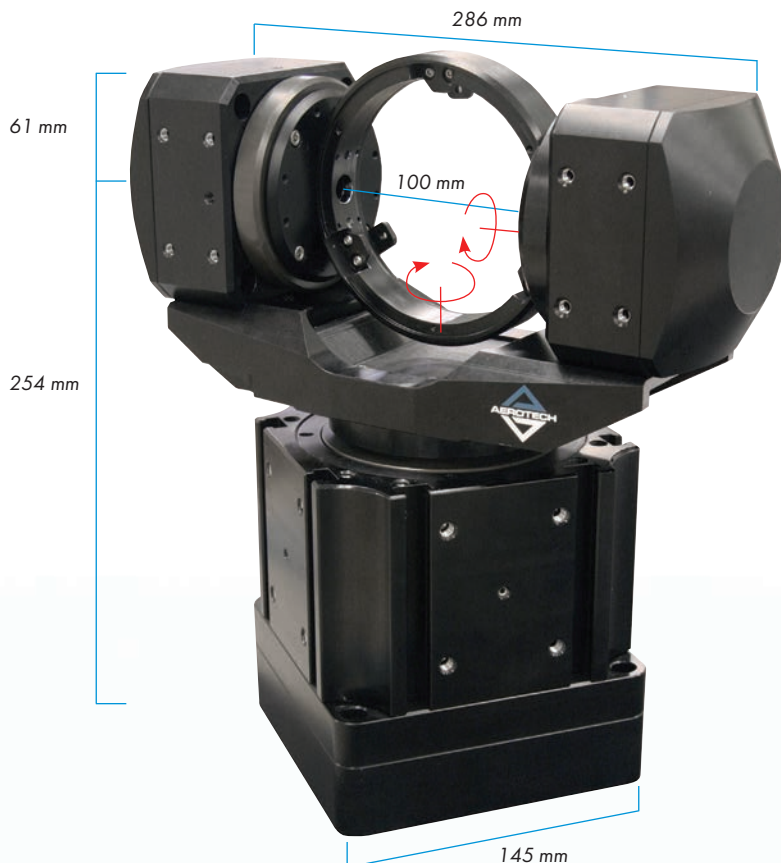
Front surface reflecting mirror for true optical path steering

Aerospace and Defense Testing

Electro-Optic Test

AMG-200LP Custom, Direct Drive, High-Acceleration Gimbal

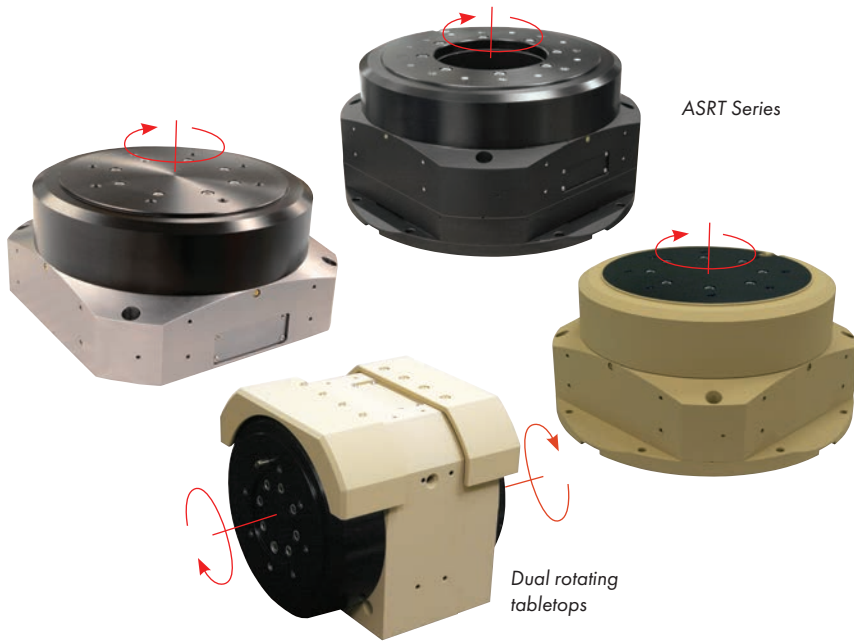
- Raised EL axis allows steep beam angles vertically
- Mirror cell easily removable to add other payloads
- Sub-arc-sec jitter
- AZ slip-ring allows continuous rotation
- 8" ID mirror cell, 14" height to mirror center
- Optional high-load AZ for vertical surface mounting



Beam Scanning, High-Speed Gimbal

- $\pm 7.5 \mu\text{rad}$ accuracy plus high acceleration capability
- Direct-drive motors can operate in any orientation relative to gravity
- Mirror front surface is centered on AZ/EL axes to eliminate off-axis reflection error
- AZ slip-ring allows 360° continuous rotation in both axes
- 4" (100 mm) mirror cells shown, 6" (150 mm) and 8" (200 mm) available





ASRT Series

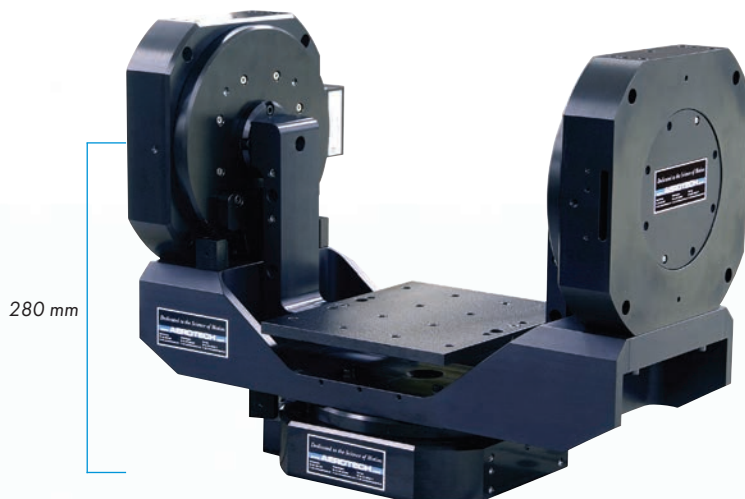
Dual rotating tabletops

Direct-Drive, Sealed Rotary Stages

- IP66 environmental protection
- Optical or magnetic position feedback
- -20 to +70°C operation
- Optional absolute encoder for -40°C to +70°C operation
- Open aperture or solid tabletop
- Up to 182 kg (400 lb) capacity
- Optional slip-ring

AMG-200LP High-Speed Scanning Gimbal for High-Duty-Cycle Oscillation

- $\pm 95^\circ$ electrical limits, $\pm 100^\circ$ hard stops
- No slip-ring allows higher current/torque to EL motor for greater scanning and oscillation speed than possible with standard slip-ring
- Long life with no slip-ring brushes to wear out



High Load, Low-Profile Gimbal for EO Sensor Pointing

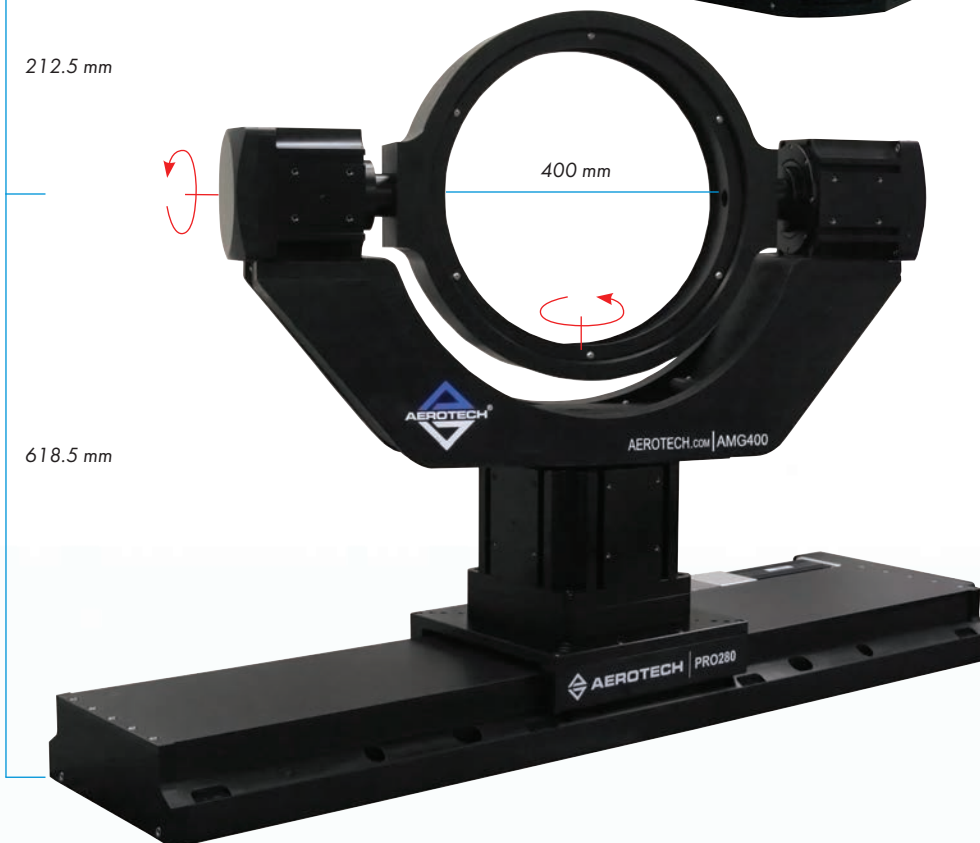
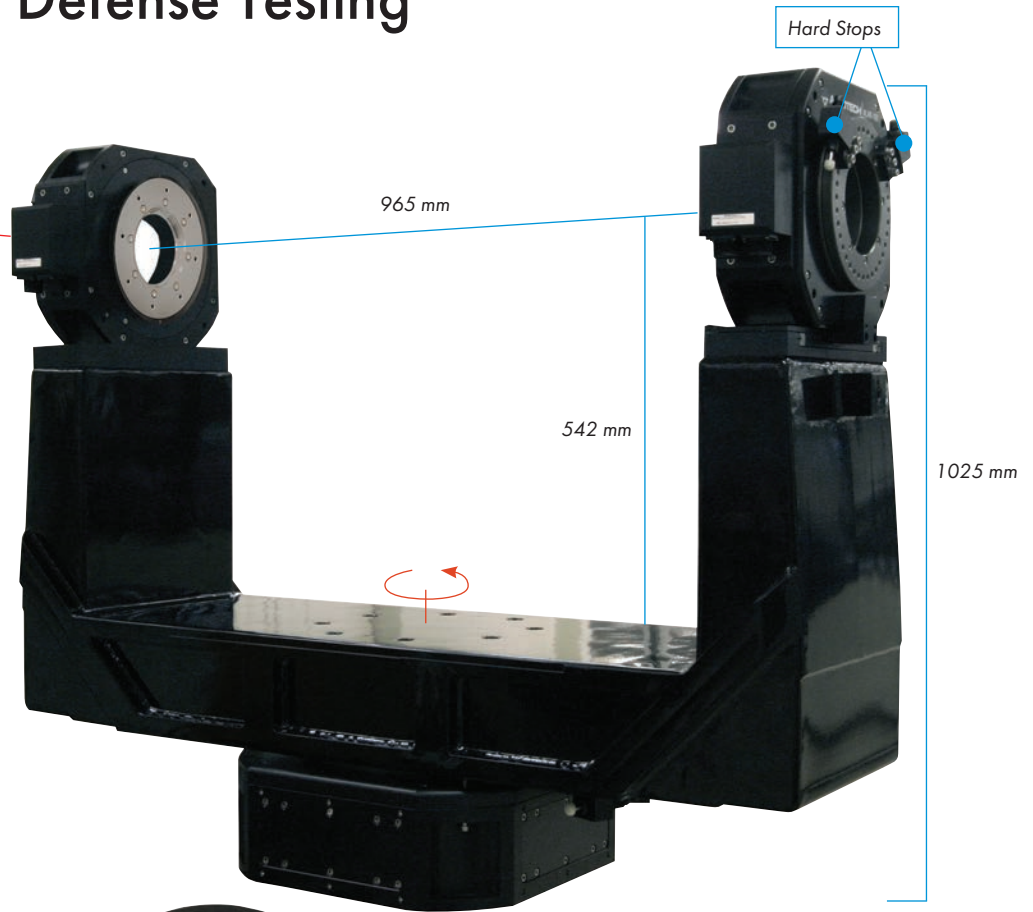
- Two ADRS-200 direct-drive stages, $\pm 7.5 \mu\text{rad}$ calibrated accuracy
- Limited AZ and EL travel to avoid sensor cable wrap-up ($\pm 25^\circ$ AZ, $\pm 15^\circ$ EL)
- Payload size up to 18 kg (40 lb), 10.25 mm wide
- Center of rotation 280 mm above mounting
- Gimbal dims 464 mm wide x 381 mm high x 280 mm deep including cables

Aerospace and Defense Testing

Electro-Optic Test

Direct Drive, High Load, Two-Axis Gimbal

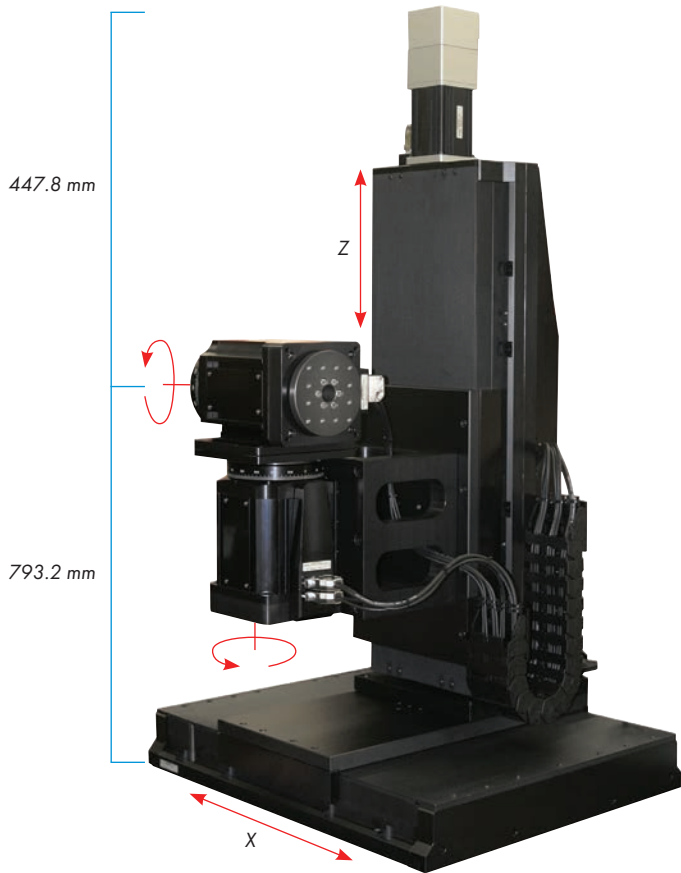
- Up to 500 kg load
- 0.01 arc-sec minimum step size
- ± 1.5 arc-sec accuracy
- Single- or dual-driven pitch axis (dual-drive shown)
- As shown, max load of gimbal 200 kg, 1.32 m swept diameter
- $\pm 150^\circ$ yaw, $\pm 120^\circ$ pitch travel



AMG-400 400 mm Mirror Gimbal on PRO280 1 m Linear Ball-Screw Stage

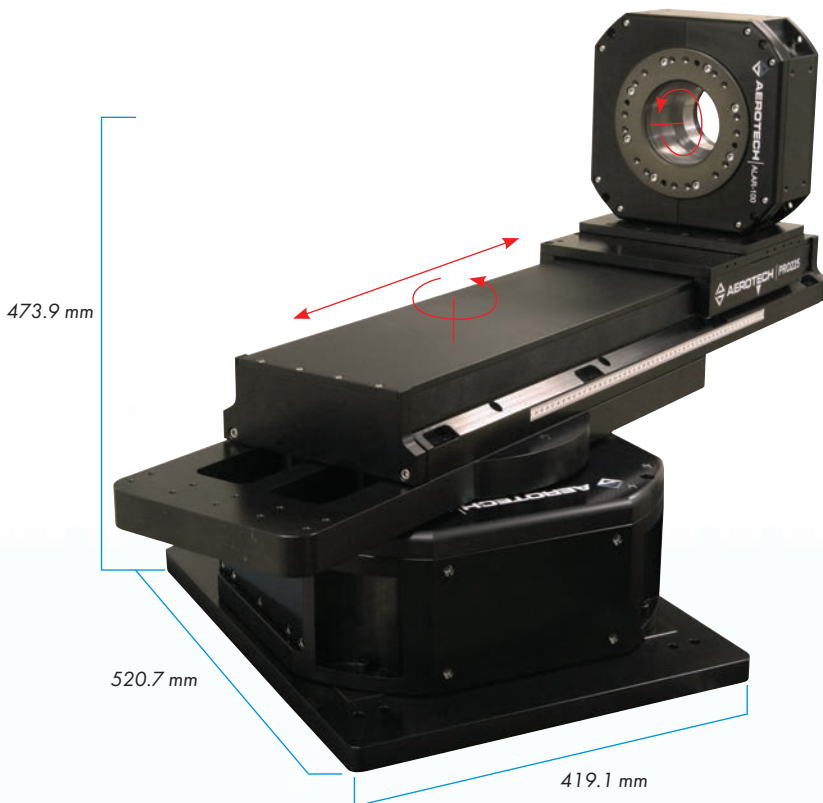
- Allows customer to reposition the gimbal over 1 m for different optical tests
- $\pm 10 \mu\text{rad}$ AZ/EL
- $\pm 3 \mu\text{m}$ linear calibrated accuracy
- Smaller or larger configurations available
- 360° continuous pitch and yaw gimbal travel





High-Accuracy XZ AZ/EL

- XZ 2 μm accuracy, 0.3 μm repeatability
- ± 220 mm XZ travel
- 4.85 μrad accuracy, 1.5 μrad repeatability
- $\pm 12^\circ$ AZ/EL travel
- 20 kg load capacity



High-Accuracy AZ/ROLL Gimbal with Adjustable Linear Axis

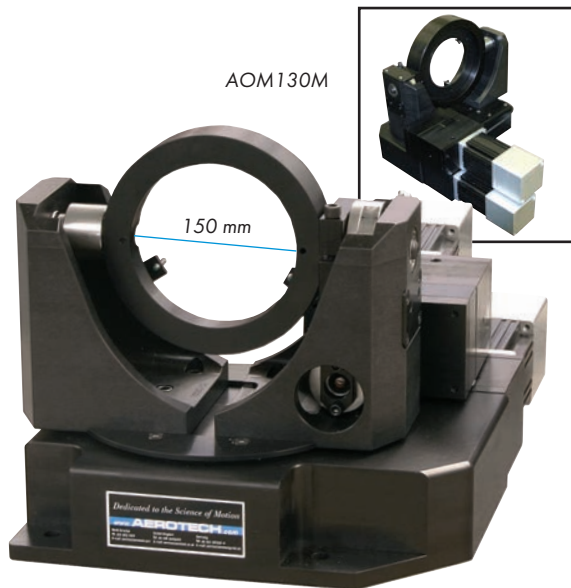
- Precise AZ and ROLL positioning combined with an adjustable PRO225 0.25 in/rev lead-screw axis allows easy centering of payload over AZ axis regardless of the payload length
- ALAR-200-SP AZ, ALAR-80-SP, PRO225-500 manual lead-screw stages
- ROLL: 80 mm aperture with front and back rotating tabletops and mounting holes
- AZ/ROLL calibrated accuracy of ± 10 μrad , 0.5 μrad min incremental step size
- 25 kg load capacity, larger load configurations available
- Max speed: AZ 36°/s, ROLL 360°/s with linear amplifiers
- Includes breadboard mounting plate
- Roll 360° continuous or 340° limited travel
- Yaw 210° limited travel
- Linear X 500 mm manual travel
- 1.52 m swing radius

Aerospace and Defense Testing

Electro-Optic Test

Mechanical Drive AZ/EL Mirror Gimbal with Direct Encoders

- $0.5 \mu\text{rad}$ minimum incremental motion
- $\pm 50 \mu\text{rad}$ accuracy, $\pm 2 \mu\text{rad}$ repeatability with direct encoder
- $\pm 4^\circ$ travel, holds position with power off
- 16–24 in (400–600 mm) mirror sizes
- Air or vacuum 10^{-6} Torr rated

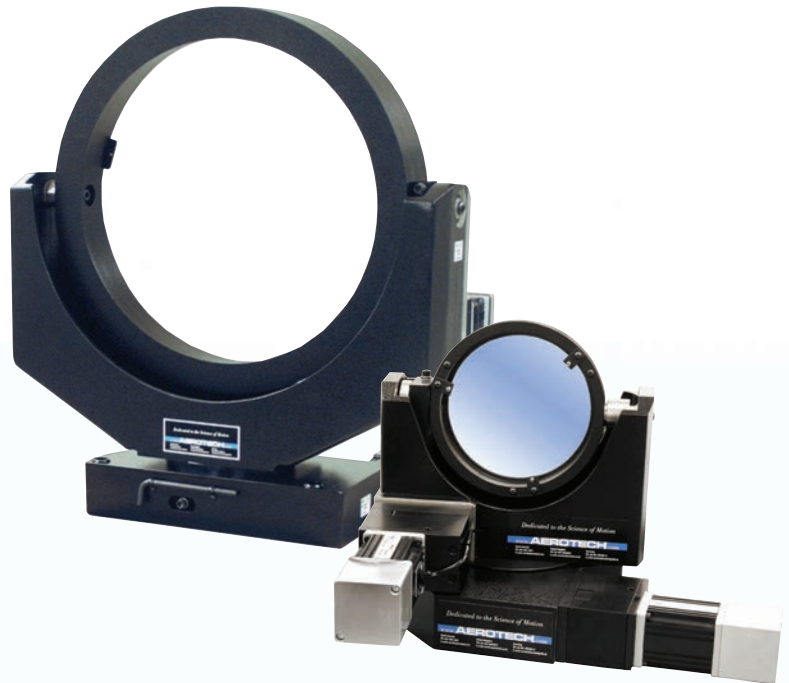


Direct Encoder Tangent-Arm Gimbal

- Direct encoder provides $\pm 38 \mu\text{rad}$ accuracy, vacuum compatible
- $\pm 2.5 \mu\text{rad}$ repeatability
- 4–24 in mirror cells
- Air or vacuum rated

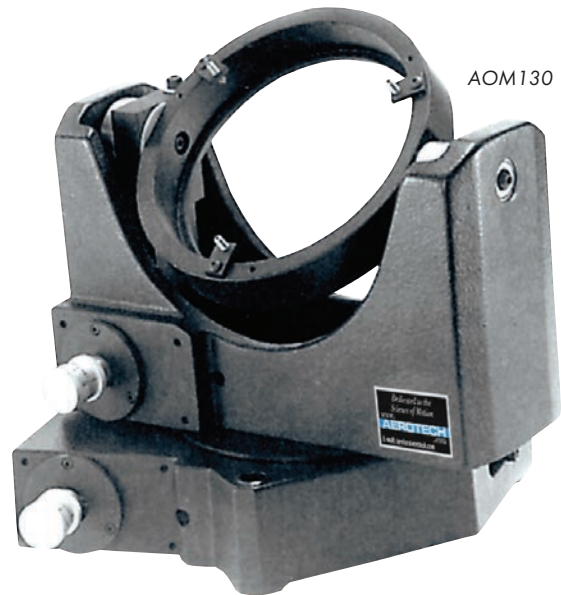
AOM130M Two-Axis, Motorized-Drive Optical Mount

- $\pm 4^\circ$ motorized travel
- 360° rotation in azimuth and elevation coarse travel
- Excellent thermal stability and vibration stability
- Standard models accept 152.4 mm through 609.6 mm optic diameters
- Air or vacuum rated



Two-Axis, Manual-Drive Optical Mount

- $\pm 4^\circ$ fine adjustment travel
- 360° rotation in azimuth and elevation coarse travel
- Excellent thermal and vibration stability



AMG-200GR



AMG-GR Two-Axis, Gear Drive, Optical Mount

- Choice of high-resolution microstepping or servomotors
- Rectangular and circular cell models
- 100, 150, 200, 300 mm mirror cells
- AZ 315° , 90° travel
- EL continuous 315° , 90° travel
- Direct encoder option

High Precision, Large Angular Range, Azimuth, and Elevation Manual Optical Mounts

- Patented drive provides sub-arc-second resolution
- Excellent thermal stability
- Non-marring set screws and rotating clips



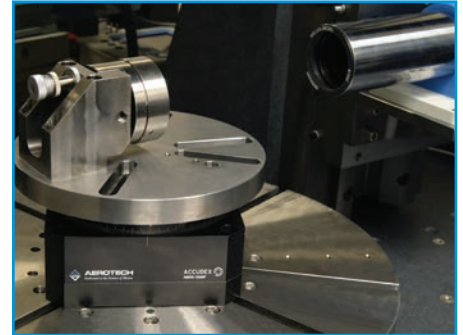
Aerospace and Defense Testing

Rotary and Linear Sensor Test



Specifications

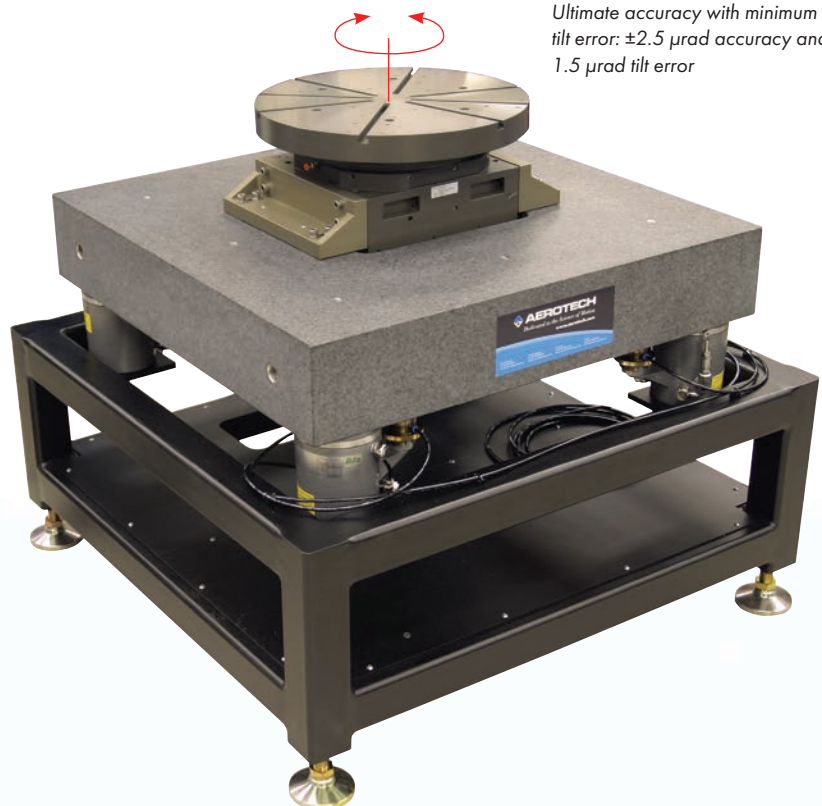
- Master-axis accuracy: <0.6 microradian (<0.12 arc-second)
- Minimum incremental step: 0.035 microradian (0.007 arc-second)
- Angular measurement uncertainty: <0.73 microradian, $k=2$ (<0.15 arc-second expanded uncertainty, $k=2$)
- 200 kg load capacity



- Resolver/Encoder Tester
- Rotary Stage Tester
- Bearing Tester

Ultra-Precise, High Accuracy, Heavy Load, Direct-Drive, Air-Bearing on Isolation System

- ABRT-400 air-bearing
- Used for testing rotary stages, motors, resolvers, encoders, bearings
- ± 2.5 μ rad accuracy
- 1.5 μ rad tilt error
- 136 kg (300 lb) load capacity
- Passive air-isolation base
- 70 nm axial/radial error motion



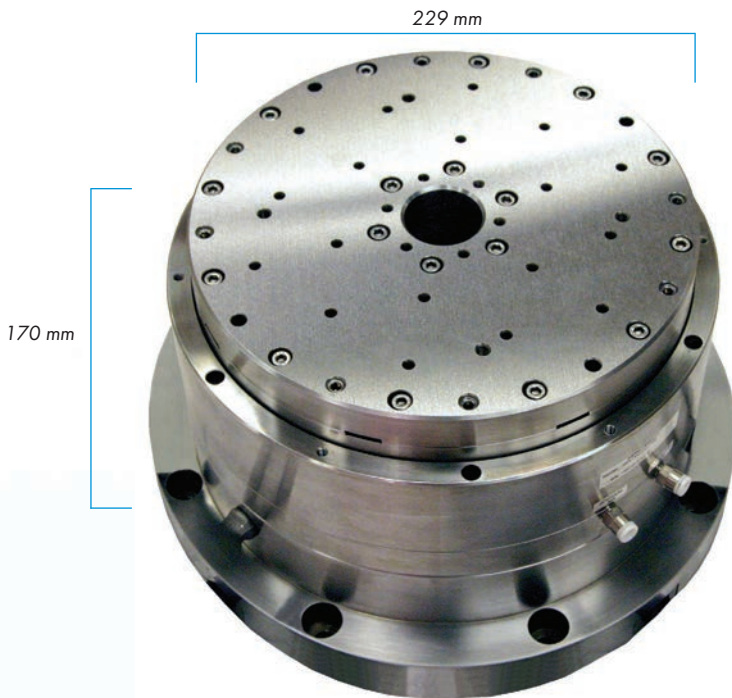
Ultimate accuracy with minimum tilt error: ± 2.5 μ rad accuracy and 1.5 μ rad tilt error





Stainless-Steel APR260 for Best Tilt and Thermal Stability

- High-accuracy direct drive
- Mechanical bearing
- ± 0.5 arc sec tilt
- ± 0.75 arc sec accuracy
- 230 kg load
- Optional oversized steel tabletop and mounting post



ABRS-250MP High-Accuracy, Stainless-Steel, Rotary Air-Bearing

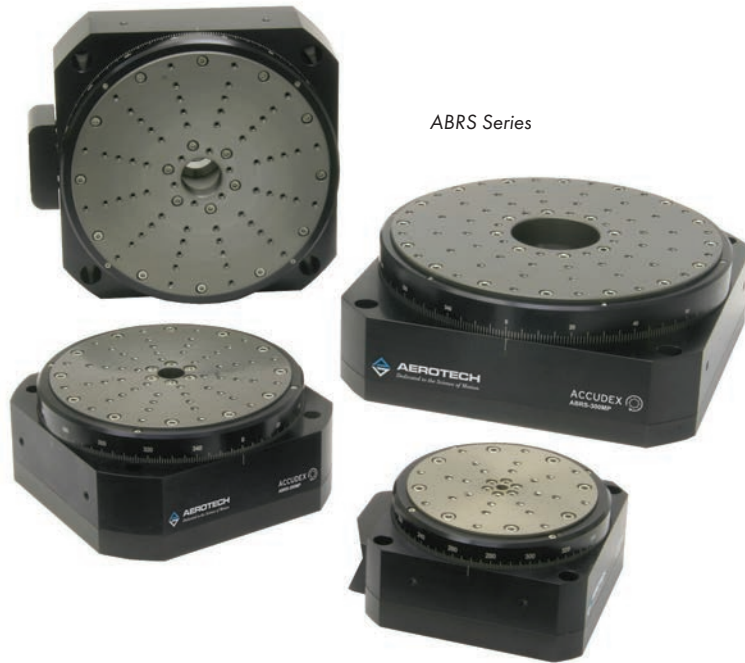
- ± 0.5 arc-sec accuracy
- Stainless-steel construction
- 50 kg axial load
- < 120 nm axial error
- < 270 nm radial error
- 0.6 arc-sec tilt

Aerospace and Defense Testing

Rotary and Linear Sensor Test

Ultra-Precise, Low Profile, Direct-Drive Rotary Air-Bearings

- Excellent radial, axial, and tilt error motions
- Direct coupled, high-accuracy rotary encoder
- Low profile, planar design
- 9 to 100 kg (20 to 220 lb) payload capacity
- Magnetic preload



ABRS Series



Aerotech's rotary stages are used in non-destructive testing of many types of precision engine components.



ABRT Series

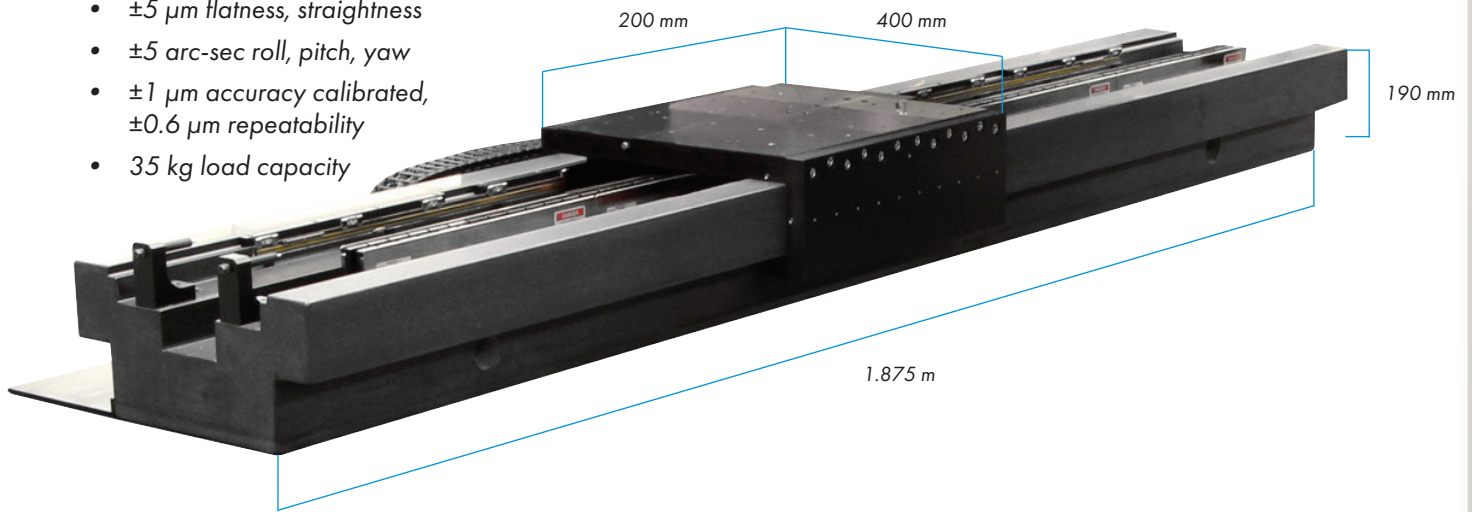
Ultra-Precise, High Accuracy, Direct-Drive Rotary Air-Bearings

- High torque output, direct-drive slotless, brushless servomotor
- Zero-cogging motor for outstanding velocity stability
- Excellent radial, axial, and tilt error motions
- Direct coupled, high-accuracy rotary encoder
- Large diameter clear aperture
- No mechanical contact
- Fully constrained air-bearing can be run upside down or on its side
- 20 to 68 kg (44 to 150 lb) payload capacity



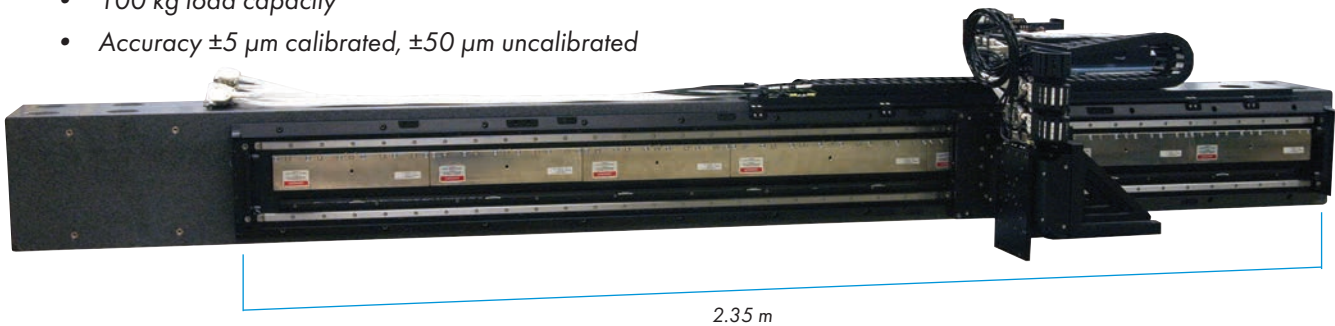
1.5 m Travel, Direct Drive, Air-Bearing Stage

- 1.5 m/s, 1.5 g with 5 kg payload
- $\pm 5 \mu\text{m}$ flatness, straightness
- ± 5 arc-sec roll, pitch, yaw
- $\pm 1 \mu\text{m}$ accuracy calibrated, $\pm 0.6 \mu\text{m}$ repeatability
- 35 kg load capacity



2 m Travel, Direct Drive, Mechanical-Bearing Stage

- Shown with optional YZ, two motorized axes, and granite bridge
- 2 m/s, 3 g max speeds with 1 kg load
- 100 kg load capacity
- Accuracy $\pm 5 \mu\text{m}$ calibrated, $\pm 50 \mu\text{m}$ uncalibrated



High Load, 1.5 m Travel, Linear Motor Stage

- Modified ALS5000WB
- Travels up to 1.5 m
- 350 kg horizontal load capacity
- Solid carriage, thicker base provide higher stiffness
- $0.1 \mu\text{m}$ minimum incremental motion
- $\pm 1.5 \mu\text{m}$ calibrated accuracy

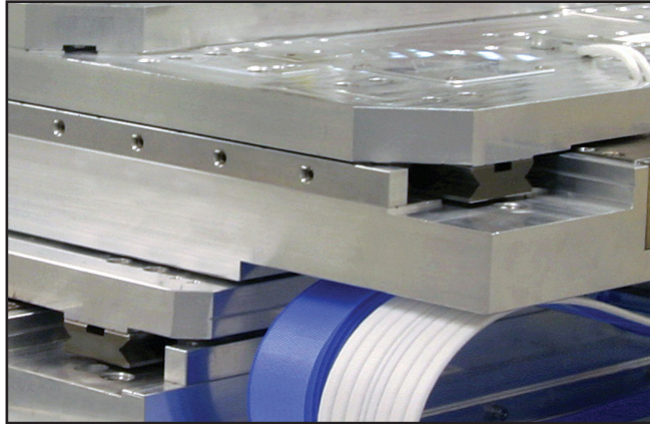


Aerospace and Defense Testing Vacuum Systems

Aerotech specializes in understanding customer vacuum system needs and customizing our product line to provide additional capabilities based on application specific requirements. All Aerotech vacuum-compatible motion platforms minimize pump downtime, chamber contamination, and thermal issues. We offer vacuum systems including all required cables, connectors, and bulkhead feed-through connectors.

A wide variety of standard Aerotech motion products are available in vacuum-prepared versions. In addition to standard platforms, Aerotech manufactures custom systems designed to meet application-specific needs. For example, a key application consideration may be a reduction of magnetic fields or perhaps the system must operate in a space-rated environment. In these cases, we use our in-depth knowledge (see listing at right) to design and produce a system perfectly tailored to our customers' requirements.

Aerotech's vast application experience, unmatched product scope, and extensive engineering capabilities make us the partner of choice for vacuum-compatible motion systems. Since our inception, Aerotech has designed and manufactured the highest-performance motion control and positioning systems available, and our vacuum-compatible platforms are no exception. Aerotech's precision motion control products provide the critical performance for today's demanding vacuum applications in markets such as semiconductor manufacturing and inspection, optics fabrication, and defense/aerospace.



XY linear-motor-driven motion system showing several key design elements that allow stage operation in high vacuum.

Aerotech has specific experience with vacuum-compatible motion platforms for 10^{-3} to 10^{-8} Torr environments:

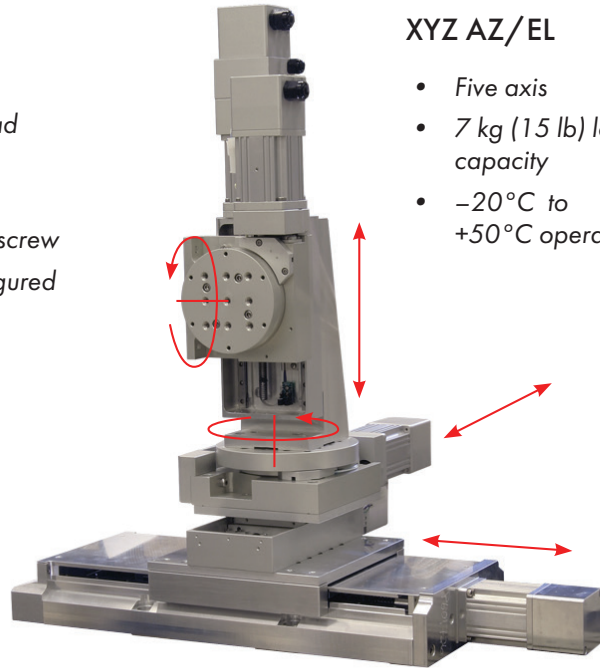
- *Material selection*
- *Surface preparation*
- *Hardware venting and elimination of trapped volumes*
- *Lubricant selection*
- *Cable selection*
- *Thermal management*
- *Magnetic field control*
- *Cleaning*
- *Bake-out*
- *Handling and packaging*





Vertical Stage with Free-Standing Base

- 114 kg (250 lb) load capacity
- Linear encoder
- High precision ball-screw
- Can be easily configured as an XYZ system

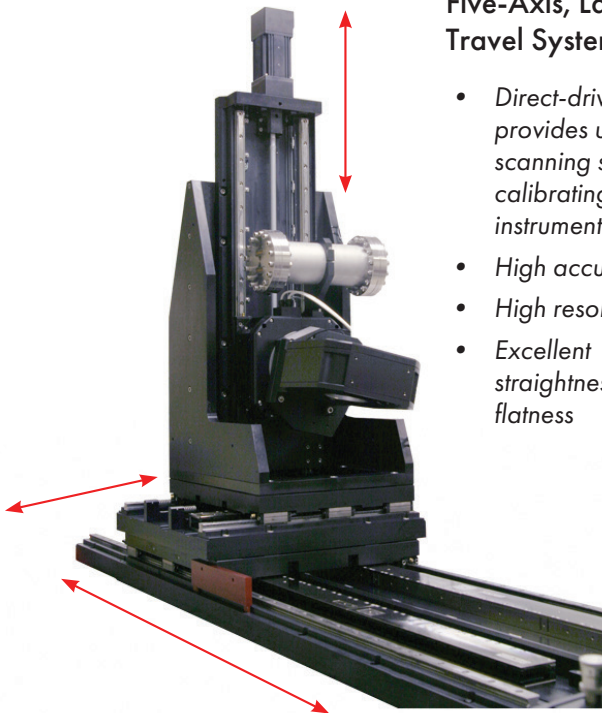


XYZ AZ/EL

- Five axis
- 7 kg (15 lb) load capacity
- -20°C to $+50^{\circ}\text{C}$ operation

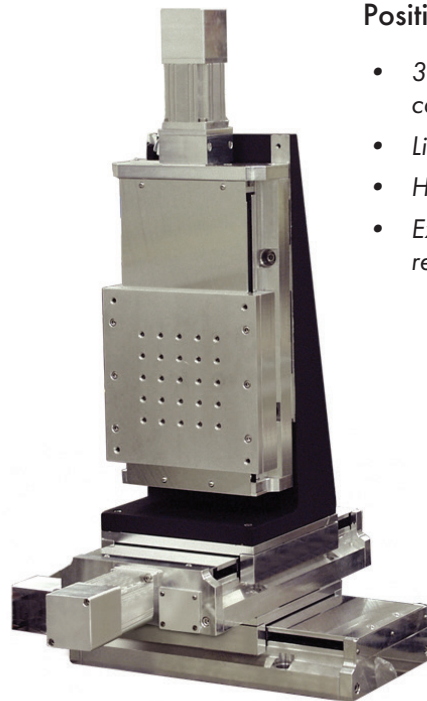
Five-Axis, Large-Travel System

- Direct-drive provides ultimate scanning system for calibrating satellite instruments
- High accuracy
- High resolution
- Excellent straightness and flatness



XYZ Ball-Screw Positioner

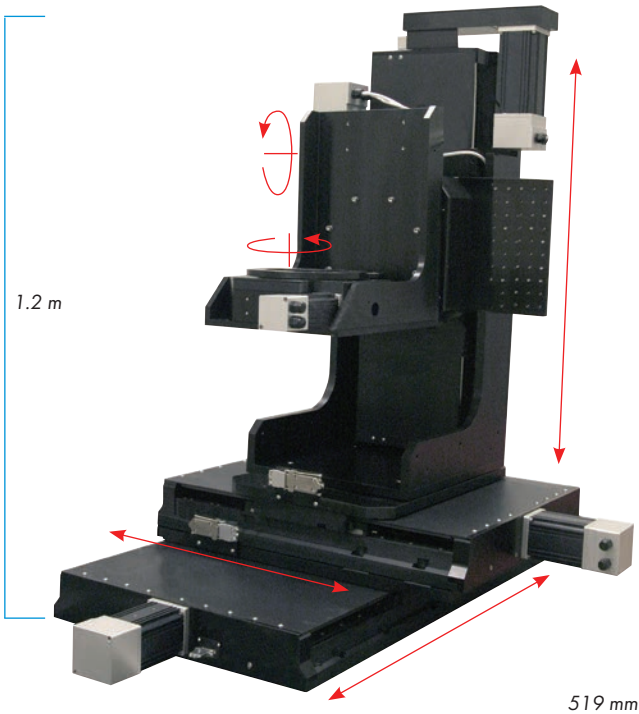
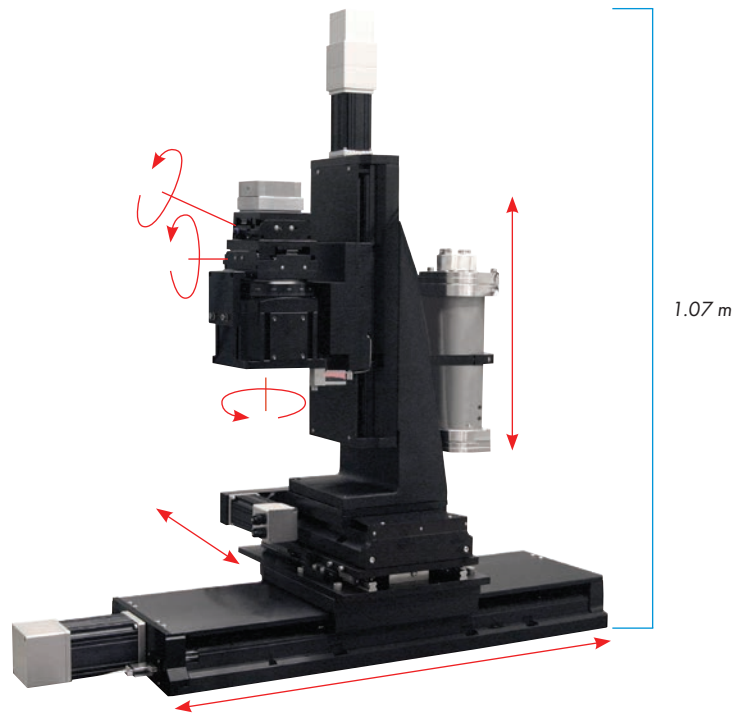
- 36 kg (80 lb) load capacity
- Linear encoders
- High accuracy
- Excellent repeatability



Aerospace and Defense Testing Vacuum Systems

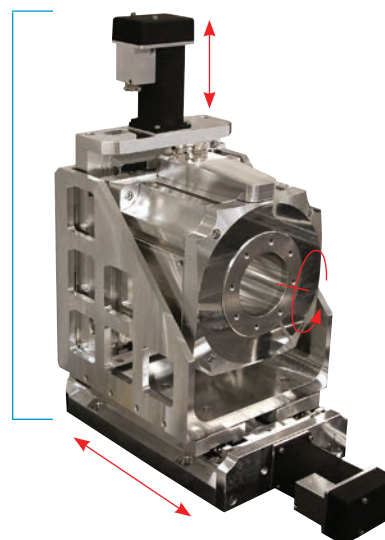
Six-Axis, High-Accuracy System

- 10^{-6} Torr vacuum compatible
- Direct-drive roll, pitch, yaw:
min incremental motion 0.05 arc-sec
- Direct encoder XYZ ball-screw stages:
min incremental motion $0.1 \mu\text{m}$,
 $\pm 5 \mu\text{m}$ XYZ work-point accuracy



XYZ AZ/EL Vacuum System

- 60 kg load capacity
- $0.1 \mu\text{m}$ linear and 0.5 arc-sec
angular minimum incremental
motion
- Direct linear and rotary encoders
- $\pm 5 \mu\text{m}$ XYZ work-point accuracy



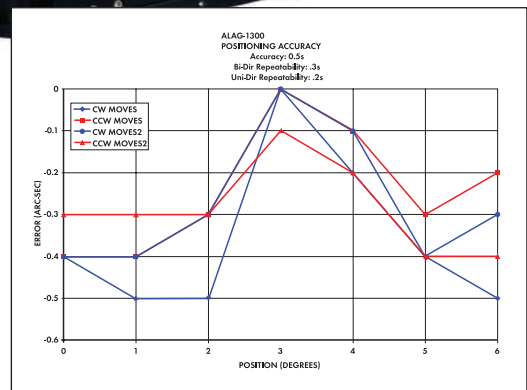
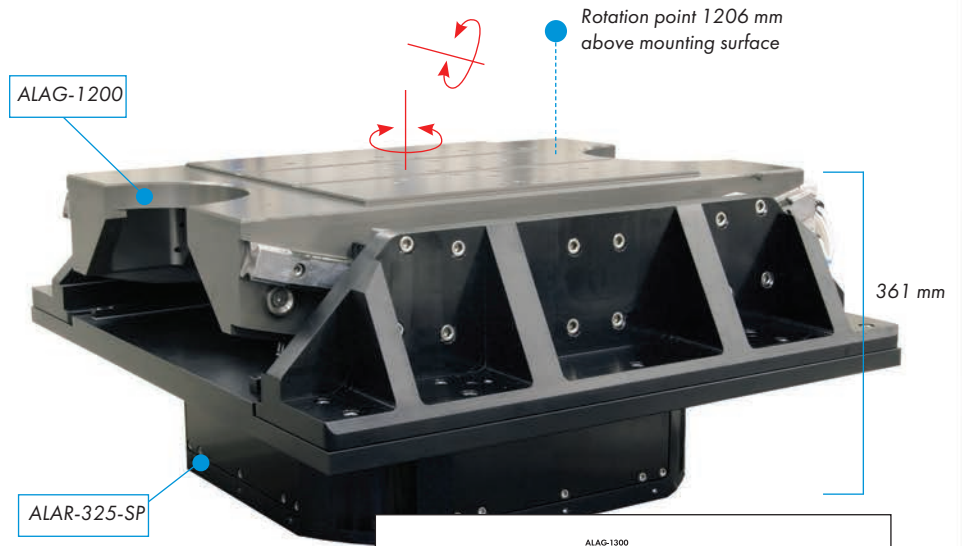
Vac 6×10^{-7} Torr XY Pitch Positioner

- $0.2 \mu\text{rad}$ rotary,
 $0.05 \mu\text{m}$ minimum
incremental steps
- ATS2000/ATS20002/
APR200 DL
- Linear stepper motors
- Servo rotary stage



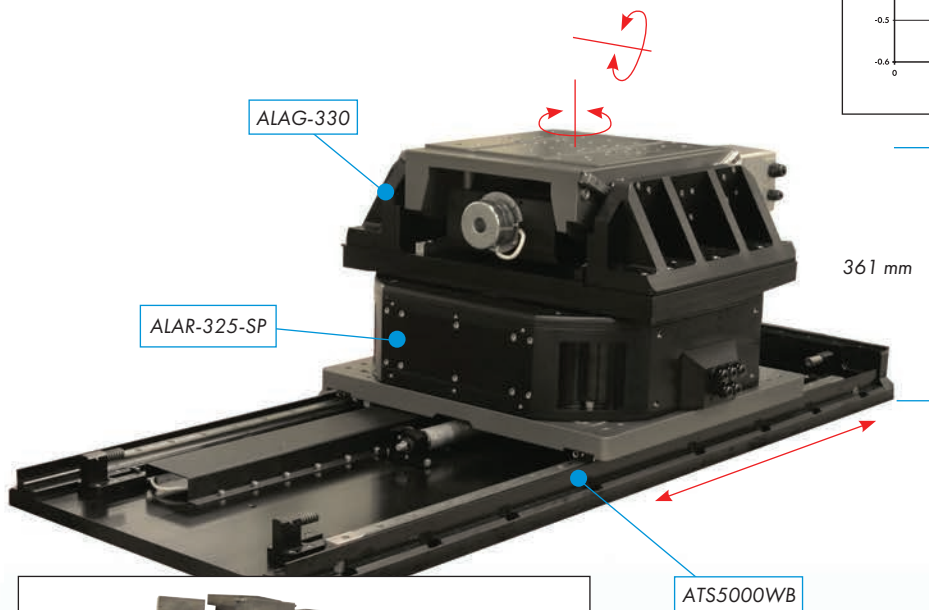
**Large Capacity
Tilt/Rotary Positioner
ALAG-1200/ALAR-325-SP**

- 682 kg (1500 lb) load capacity
- Rotation point is 1200 mm above tilt stage
- $\pm 2 \mu\text{rad}$ repeatability
- $\pm 5 \mu\text{rad}$ accuracy
- Vac 10^{-6} Torr
- AZ direct drive
- $0.025 \mu\text{rad}$ machine resolution
- Goniometer includes direct tabletop feedback
- $\pm 3^\circ$ travel



**Large Capacity
Tilt/Rotary/Linear Positioner
ALAG-330/ALAR-325-SP/
ATS5000WB Vac 6
682 kg (1500 lb)**

- 600 mm linear shown; up to 1.2 m available
- AZ direct drive: $\pm 2.5 \mu\text{rad}$ repeatability and $\pm 5 \mu\text{rad}$ accuracy
- Pitch goniometer 330 mm rotation point
- Goniometer includes direct encoder feedback
- $\pm 5^\circ$ travel



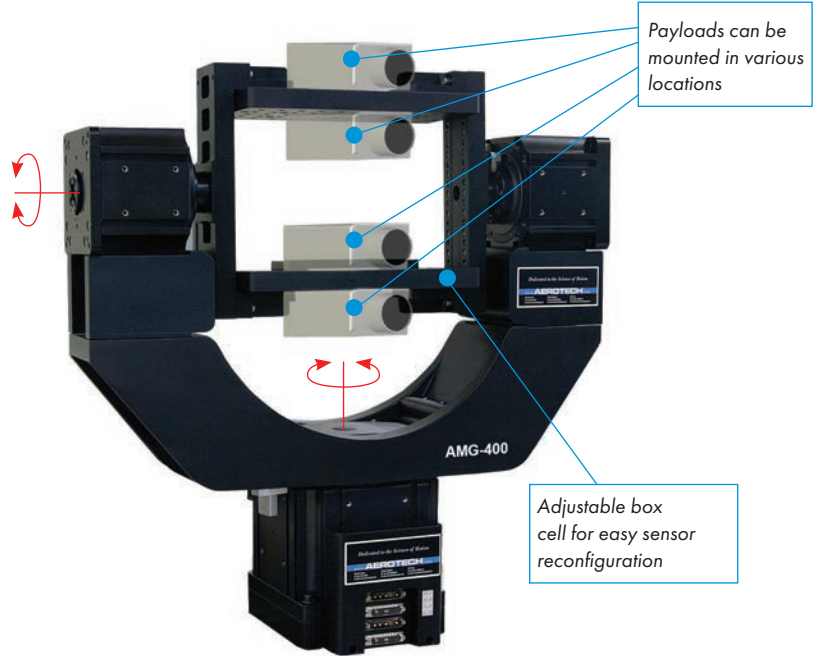
Aerospace and Defense Testing

Electro-Optic Prototype Pointing Systems

Prototype development systems are used to prove our customers' products in real-world environments. Our systems provide precise pointing of customer payloads with easy-to-use controls and software. This allows customers to focus on field qualification of their devices and relieves them from engineering the pointing system. Our experience includes engineering electrical hook-ups, slip rings, mechanical mounting interfaces, distributed control, power requirements, safety electronics, and post-processing of motion events.

Two-Axis, Direct-Drive Positioner

- Continuous 360° rotation of azimuth and elevation including built-in slip ring
- High accuracy angular position and rate capability
- Direct-drive brushless servomotors result in zero backlash
- Cog-free design for outstanding velocity stability
- Box cell provides multiple mounting locations for user flexibility
- Low maintenance and high reliability provide the lowest cost of ownership



IR or Day Camera Pointing

- Direct drive gives rapid motion in a small package
- $\pm 24 \mu\text{rad}$ accuracy
- $\pm 2.5 \mu\text{rad}$ repeatability
- Can be vertically or horizontally mounted
- Rectangular mirror cell
- Limited travel in AZ and EL
- Also useful as antenna steering gimbal



Video Tracker Testing

- T configuration EL over AZ
- Mounting for sensor or laser on both sides of the EL axis
- Limited or unlimited travel
- 36 kg (80 lb) load capability
- Larger size options are available

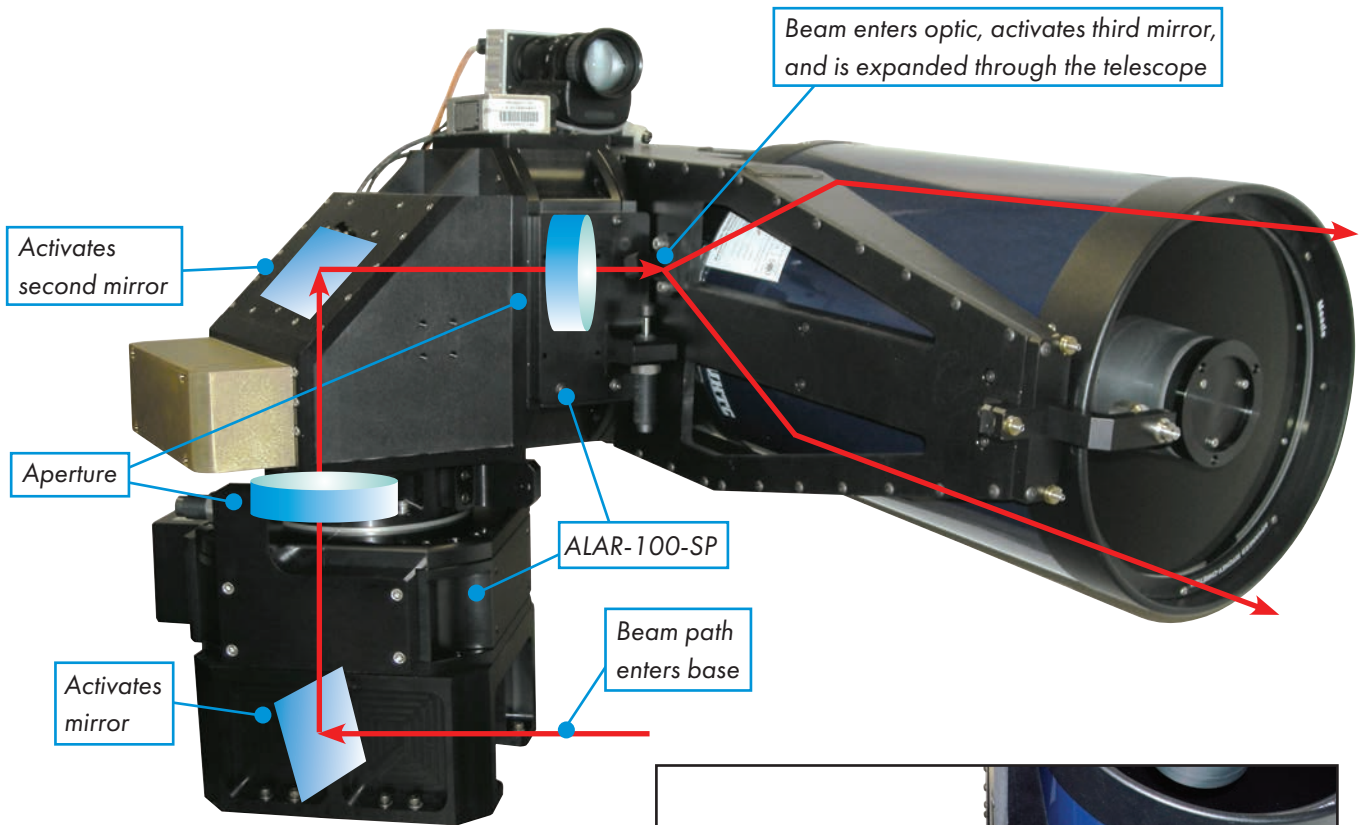
Sensor mounting on both sides



Aerospace and Defense Testing

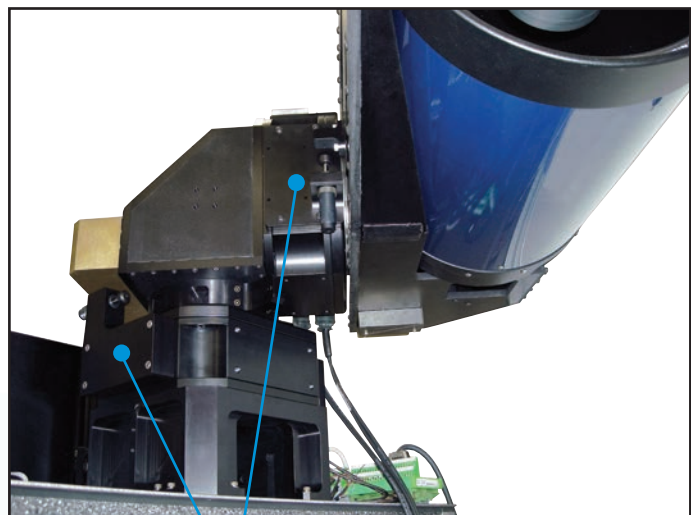
Electro-Optic Prototype Pointing Systems

Aerotech large aperture rotary stages provide high-resolution motion and can be configured into two-axis gimbals with a coudé path to direct laser energy through the stages and out through a telescope. This system shows a custom beam-director built with our ALAR rotary stages.



Two-Axis Beam Director

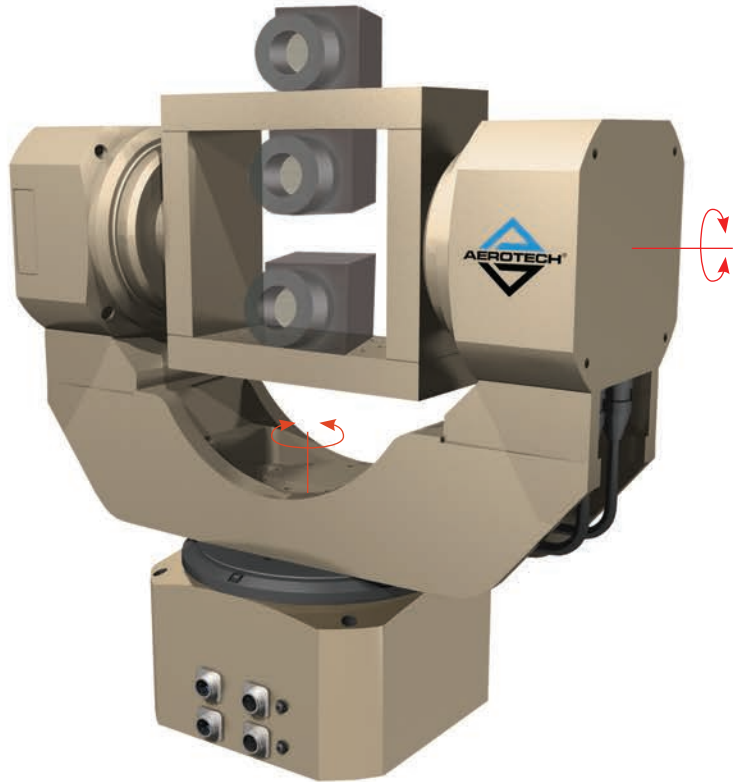
- 100 mm to 325 mm optical apertures available
- Used for star tracking or laser beam pointing
- Active or passive applications



ALAR-100-SP apertures and their high accuracy are what make this system work

Aerospace and Defense Testing

Outdoor Pointing and Tracking Systems

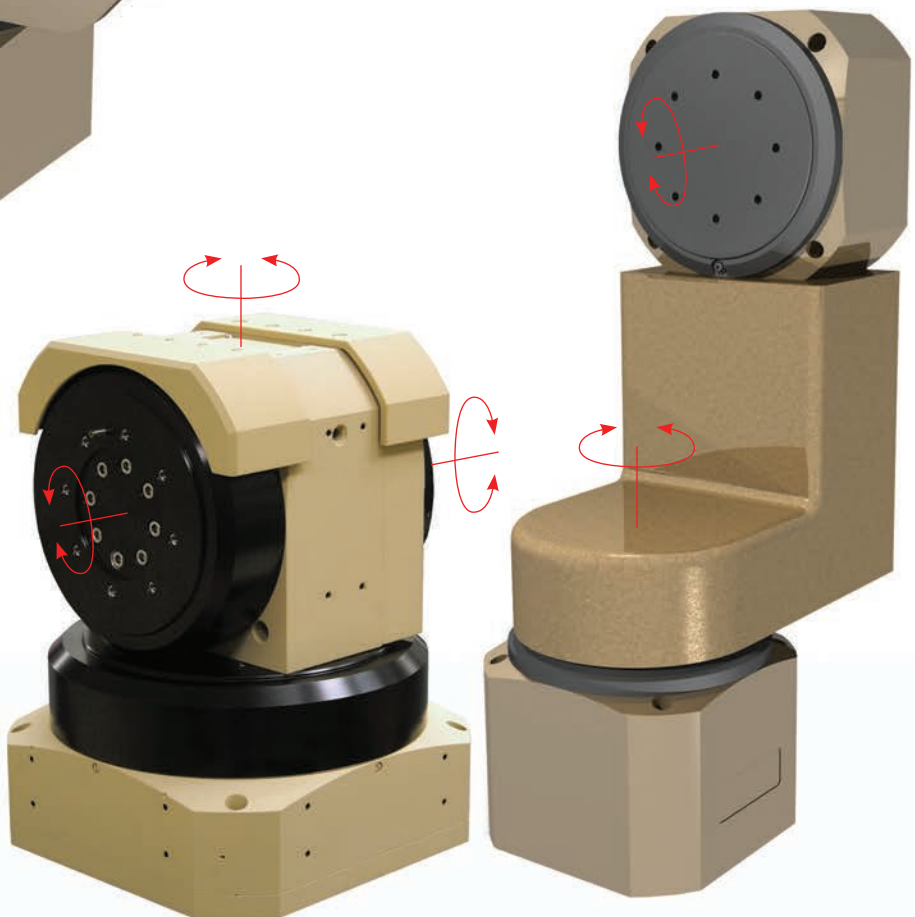


Direct-Drive Outdoor Sensor-Pointing Mount, IP66-Sealed

- Environmentally hardened for field testing
- Provides easy mounting points
- Continuous or limited travel
- Slip-ring options
- Payloads up to 45 kg (100 lb)
- Sealed connectors

Direct-Drive Outdoor Camera or Antenna Mount, IP66-Sealed Pan and Tilt

- Payloads up to 23 kg (50 lb)
- Slip-ring options
- Low maintenance
- Sealed connectors
- Continuous or limited travel



With our extensive line of positioners, we can readily configure a system for unique payloads.

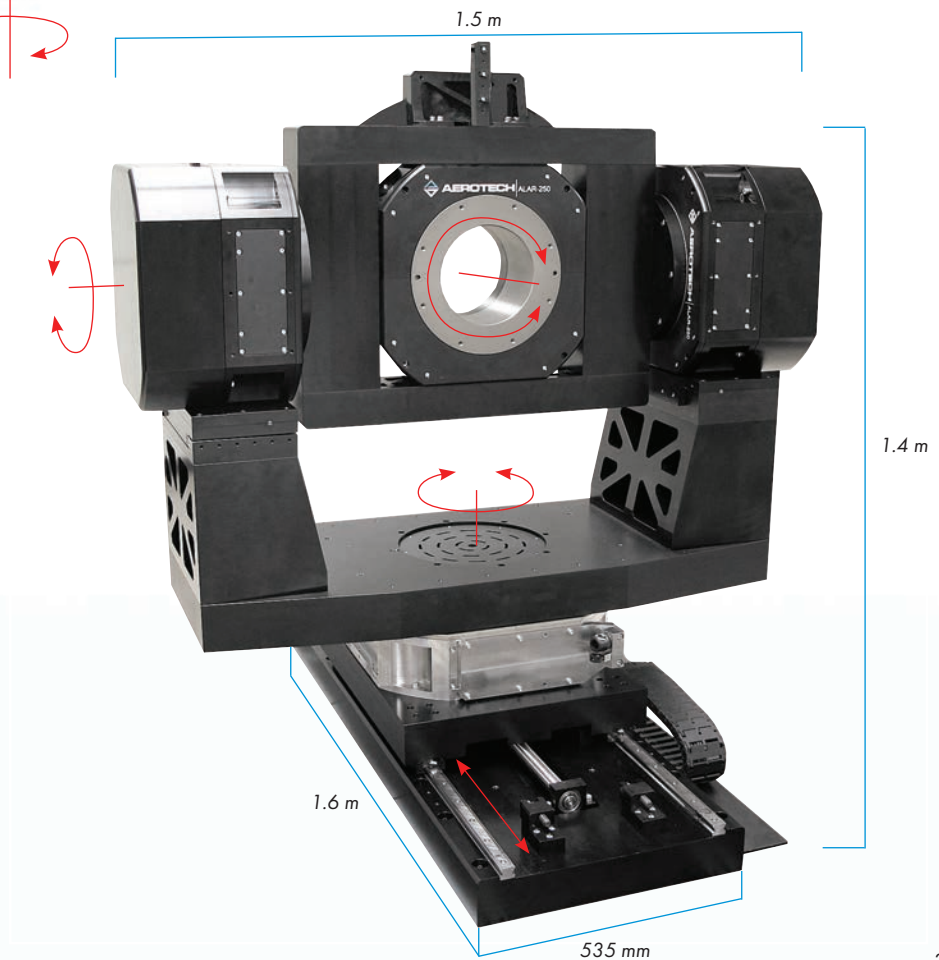


High Performance, Three-Axis, Large Aperture, Direct-Drive, Guidance Test System

- 100 to 325 mm ROLL aperture
- Used for testing or calibration
- Continuous or limited travel versions
- Slip rings for customer signals and power
- High resolution
- $\pm 10 \mu\text{rad}$ accuracy
- $0.03 \mu\text{rad}$ resolution
- Precision angular contact bearings result in low axis-error motions
- No backlash or gear wear

High Load, Three-Axis Gimbal for Precision Pointing

- ROLL, AZ/EL axes shown on linear ball-screw stage
- 350 kg payload capacity
- Direct drive
- Optional brakes



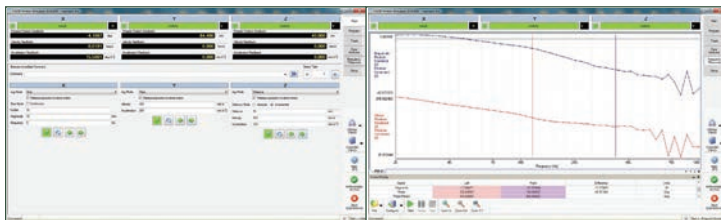
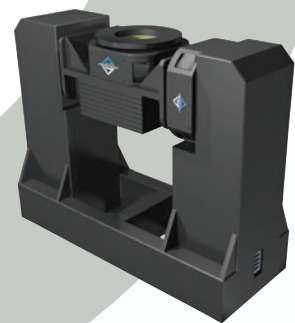
Aerospace and Defense Testing

Rotary and Linear Sensor Test

Aerotech motion simulators are designed for high-accuracy testing and calibration of aerospace and defense systems. The Aerotech family of motion simulators can generate accurate and repeatable acceleration, velocity, or position motion trajectory for angular or linear device testing. Single- and multi-axis solutions are available.

Our motion simulators are used to test inertia sensor components such as MEMS, fiber-optic gyroscopes, and accelerometers. Our multi-axis systems are used to test Inertial Measurement Units (IMU), Inertial Navigation Systems (INS), and Attitude Heading Reference Systems (AHRS) used in missiles, aircraft, spacecraft, stabilized electro-optic payloads, ships, and ground vehicles.

- High accuracy, direct-drive motion simulators
- No cogging
- High torque
- Mechanical or air bearings
- Real-time data collection
- Position, rate, and oscillation modes
- Easy user-profile importing
- Windows®-based programming
- Slip-rings or twist cables feed UUT signals/power
- Solutions range from economical single-axis systems to high-performance three-axis systems



Single-Axis Motion Simulators for Inertial Sensor Testing and Calibration

Single-axis motion simulators are used to induce precise angular or linear acceleration, velocity, or positions to sensors such as gyroscopes, accelerometers, and other inertial sensing equipment. Our single-axis motion simulators are used in laboratories for sensor research or in manufacturing for test of production inertial sensor systems. Electrical slip-rings are included in the rotary tables to connect the

sensors to control and power while allowing continuous rotation with no cable wrap-up. Aerotech employs high-accuracy feedback devices in our motion simulators to provide low- or high-speed trajectory accuracy. Aerotech's single-axis rotary tables have multiple size units to handle a wide range of payload inertias and form factors. Optional features include floor stands with manual tilt for vertical or horizontal axis testing.

Precision Direct-Drive Rotary Position and Rate Tables

- *High-capacity angular contact bearings or air bearings*
- *Highly accurate closed-loop control*
- *Brushless, slotless motor for smooth motion with no cogging*
- *Large selection of integrated, low-noise slip-rings for customer signals and power*
- *Multiple motor types for high speed or high-torque configurations*
- *Excellent error motion performance*
- *Dual liquid or gas ports*
- *Low maintenance design*
- *Position resolution to 0.000006° ($0.1 \mu\text{rad}$) (0.02 arc sec)*



Aerotech products are capable of testing today's top inertial navigation systems.



ARMS-260

ARMS-200

ARMS-LP

Aerospace and Defense Testing

Inertial Testing Motion Simulators

ARMS-260

- 227 kg (500 lb) payload capacity
- Unloaded acceleration $>20,000^\circ/s^2$
- Minimum rate $0.001^\circ/s$

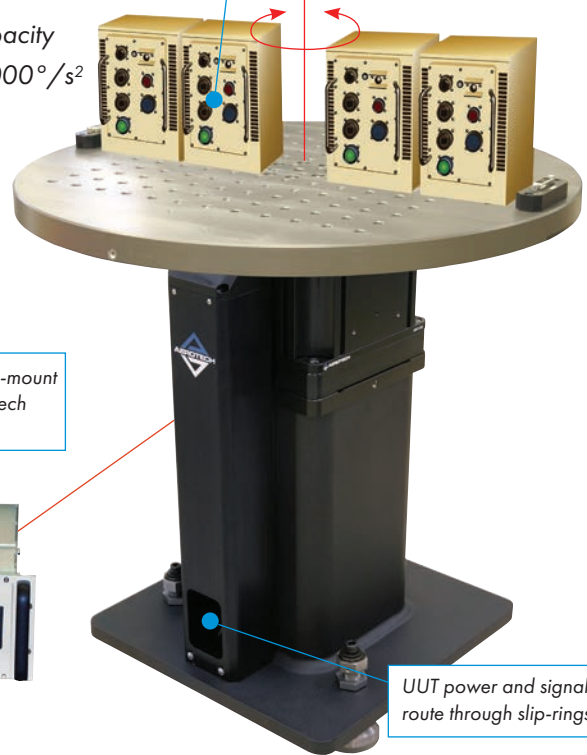
Motion Simulator software can accept trajectories from third-party software such as MATLAB® or CSV position, velocity, acceleration, and time.



PC and Npq® or HLe rack-mount control operation via Aerotech Motion Simulation software



Mount multiple UUTs on our large tabletops for simultaneous testing



UUT power and signals route through slip-rings

High-speed rotation or oscillation



- 146 N·m peak torque
- 24-90 slip-rings standard
- Manual tilt table for vertical or horizontal operation
- 230-600 mm tabletop options (600 mm shown)

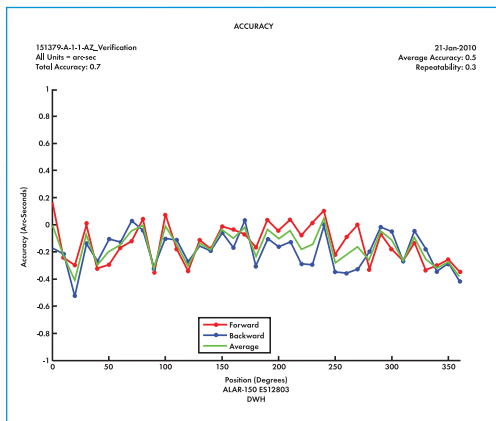
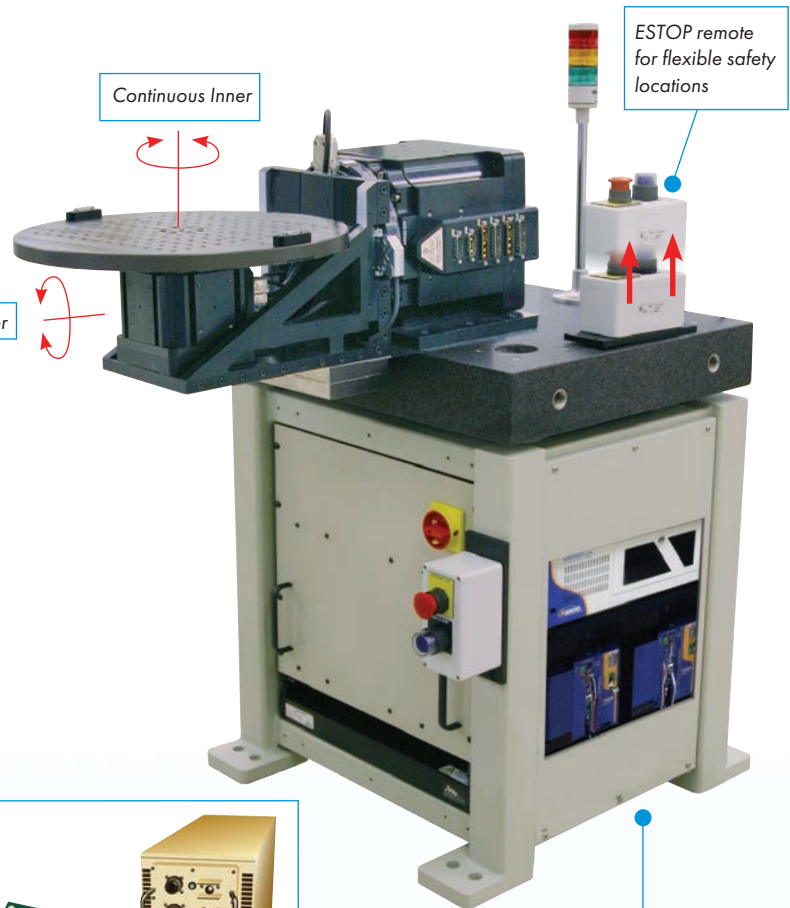
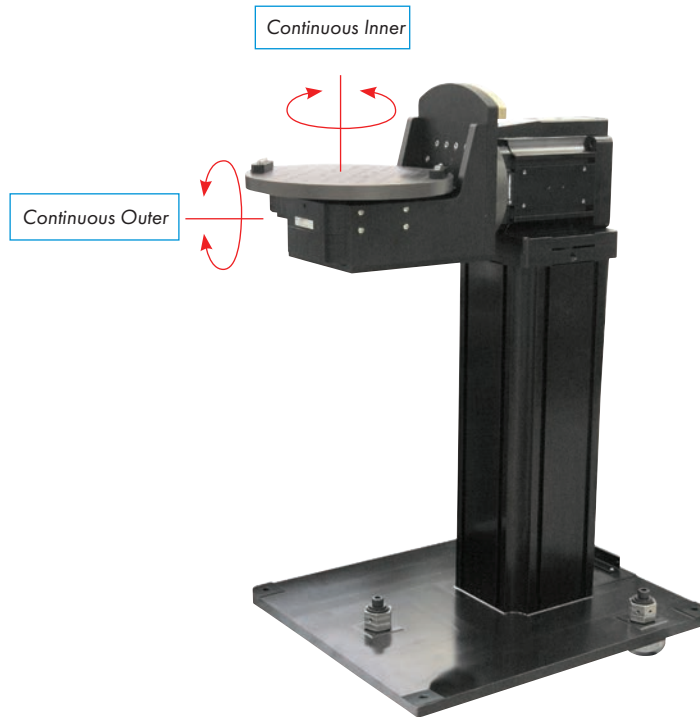
High-Accuracy, Single-Axis Rate Table with Tilt Table

- Allows rate-table performance at multiple inclination angles
- Mounted to a gear-drive rotary for tilt motion
- User adjustable pitch mounting location of the yaw stage to balance the system

Two-Axis Rate Table with Integrated Electronics

Two-axis rate tables are used for point-to-point or continuous motion to excite two-axis sensor systems. Simultaneous acceleration, velocity, or position motion can be produced and repeated for production and qualification testing of inertial measurement and navigation systems. Multiple systems can be tested at once to increase testing throughput.

- Continuous rotation of both axes
- Smooth motion from non-cogging brushless, slotless motors
- Power and signal slip-rings
- Two rotating gas/liquid ports
- Machine base includes motion controller, linear digital amps, and ESTOP safety controls
- Free-standing, post-mounted two-axis systems or integrated control weldment base configurations are available to optimize floor space



Accuracy plot showing better than ± 1 arc-sec accuracy ($\pm 4.85 \mu\text{rad}$)

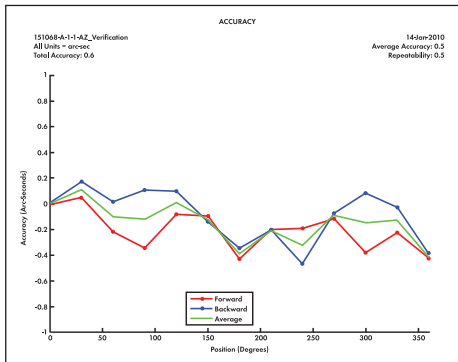


Gyro and inertial navigation testing

Linear amplifiers and ESTOP control integrated into rolling rack-mount shelf to minimize floor space requirement

Aerospace and Defense Testing

Inertial Testing Motion Simulators



Accuracy plot showing better than ± 1 arc-sec accuracy ($\pm 4.85 \mu\text{rad}$)



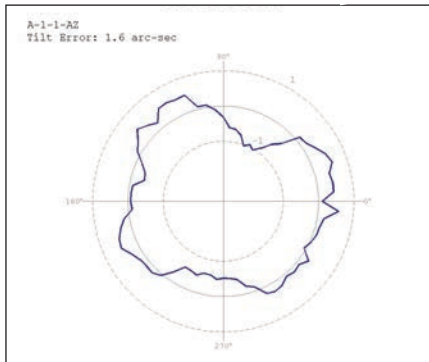
Two-Axis Direct-Drive Motion Simulator

- 91 kg (200 lb) load capacity
- Optional slip-rings
- ± 5 – $10 \mu\text{rad}$ positioning accuracy
- $0.001 \mu\text{rad}$ resolution for high velocity stability and low jitter
- 100 mm–325 mm aperture option
- Limited or continuous travel

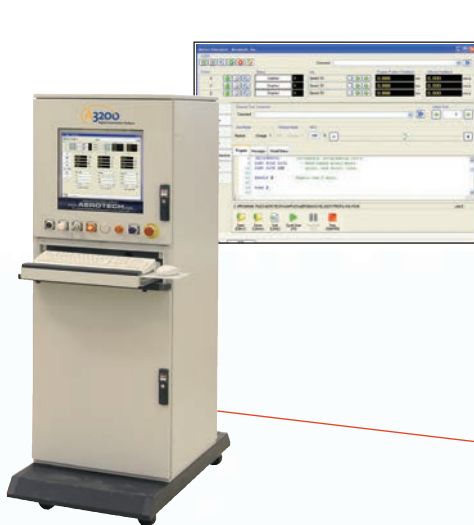
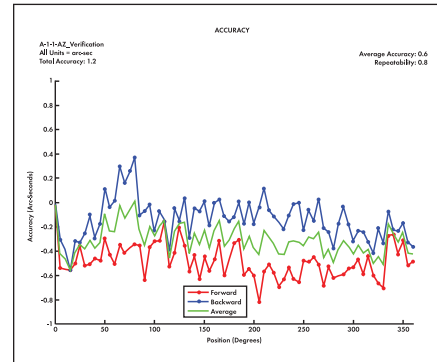
This motion simulator configuration centers payload at the intersection of the rotary axes for true rotation with no linear translation.

Three-axis motion simulators provide roll, pitch, and yaw simultaneous motion for real-world angular velocity profiles.

- Smaller than traditional three-axis simulators to accommodate today's miniature MEMS gyros in a much smaller footprint
- Modular design based on the ARMS rate tables
- Continuous or limited travel options
- Pedestal options



Each motion simulator is tested for accuracy and tilt errors. Typical tilt is below 10 μ rad. Typical accuracy is $\pm 5-10 \mu$ rad.



- High-torque three-axis system for testing INU and autopilot packages
- Continuous or limited travel options
- Base weldment options for free-standing configuration

Aerospace and Defense Testing

Inertial Testing Motion Simulators

Limited travel motion simulators benefit from a more simple system configuration and economical price point. By eliminating slip-rings and restricting the axes' travel range, the payload's native cables can be used during motion testing. This reduces the cost of making special test cables, reduces labor and number of connectors, and eliminates slip-rings, making the system less expensive. Operational longevity is extended as there are no slip-rings to wear-out.



ADRT-150-185/ADRT-260-180 Direct-Drive Stages

- Travel $\pm 165^\circ$ pitch, $\pm 165^\circ$ yaw
- Inner 30 N·m peak torque, outer 146 N·m peak torque
- Can easily add a third axis for limited outer



ADRT-100-85/ADRT-150-135 Direct-Drive Stages

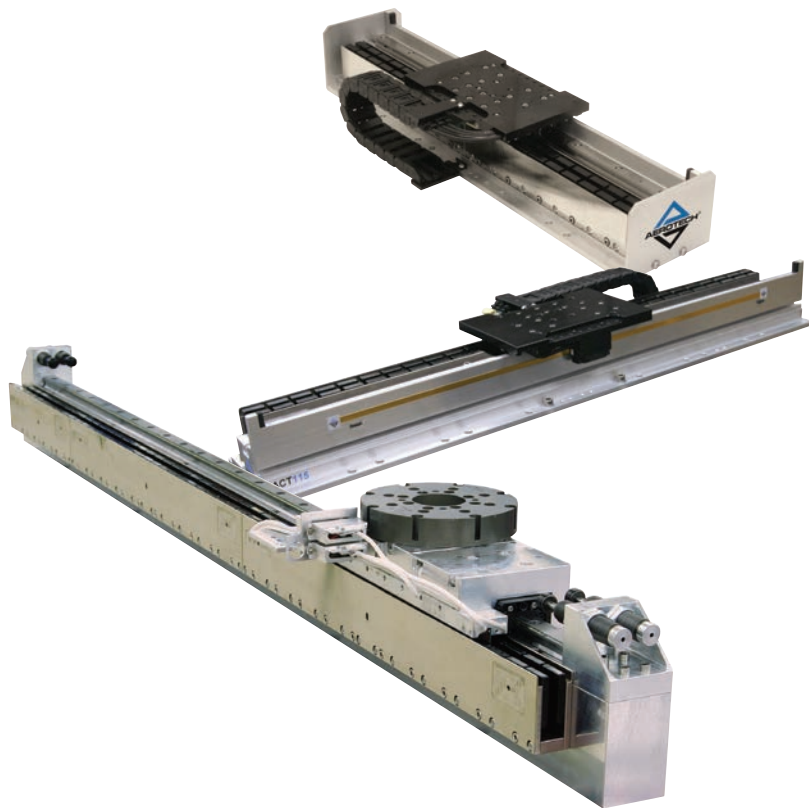
- Continuous inner rotation, limited outer
- Tabletop size with breadboard mounting base
- 3-5 kg load capacity depending on inertia and move profile
- Can be configured with larger rotary stages for more load capacity



ARMS-200 with Removable Hard Stops

- Limited-travel rate table that can be reconfigured from limited travel to continuous travel
- Can test payload with native cables over limited travel or easily changed over to use the internal slip-rings
- Removable hard stop and switchable electrical limits protect INU cables from damage
- 14 inch tabletop, D connectors or circular connectors

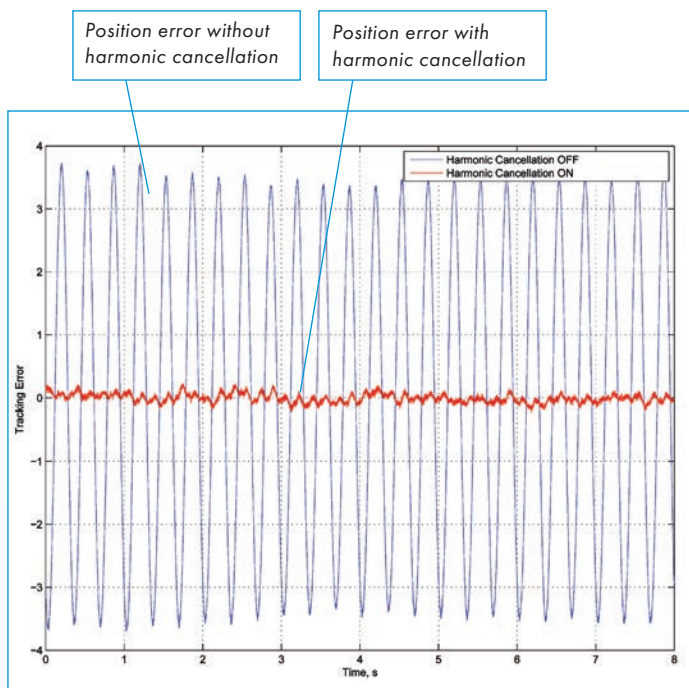




ACT Linear Actuators for Acceleration and Velocity Testing

- High performance, cost-effective actuator
- Travel range from 100 mm to 1.5 m
- Acceleration capability up to 3 g
- Velocity capability up to 5 m/s
- Maximum continuous force output up to 105.5 N
- Maintenance free, direct drive, zero-cogging motor and noncontact optical linear encoder

Harmonic Cancellation Software Greatly Reduces Sinusoidal Position Disturbances



Advanced Control: Harmonic Cancellation

Challenge

Many times a sinusoidal excitation is needed in the testing or calibration procedure of an inertia device. The very nature of this test introduces errors in the motion at the excitation frequency and other higher order harmonics. Left uncorrected, these errors can skew test results, lead to poor calibration, or trigger unnecessary failures in quality assurance.

Solution

Using Harmonic Cancellation, which is part of our Dynamic Controls Toolbox, users easily cancel-out any disturbances caused by the excitation frequency or an unbalanced load. This feature adapts to magnitude and frequency of error source. An easy-to-use setup wizard is provided through the Digital Scope and the Motion Simulator. Understanding that disturbances are undesirable, we developed Harmonic Cancellation for all Aerotech controller lines to eliminate these errors, resulting in the most accurate testing and calibration available.

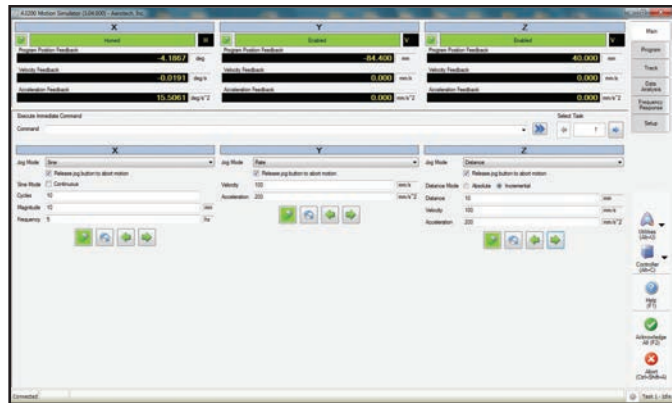
Aerospace and Defense Testing

Inertial Testing Motion Simulators

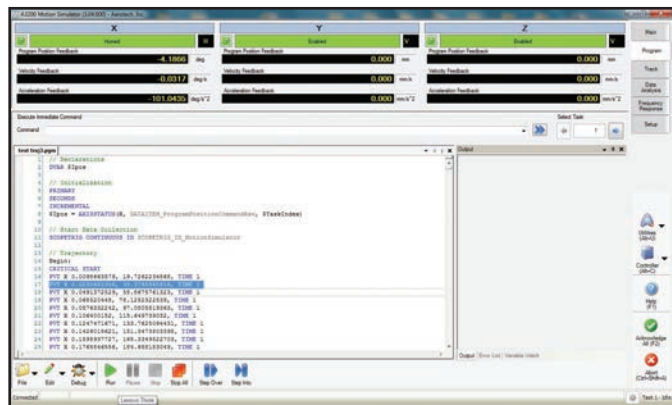
Aerotech's Motion Simulator software is an easy-to-use Windows®-based program for creating simple and advanced motion stimuli for testing and calibrating customer inertial sensors and systems. The Aerotech Motion Simulator software includes all controls for manually or automatically running 1-3 axis motion simulations. The GUI provides a user interface and programming environment that requires no third-party development software. If customers prefer, our motion controllers do have LabVIEW®, Microsoft .NET, or C drivers along with sample code for easy programming in familiar development environments.

Key Features:

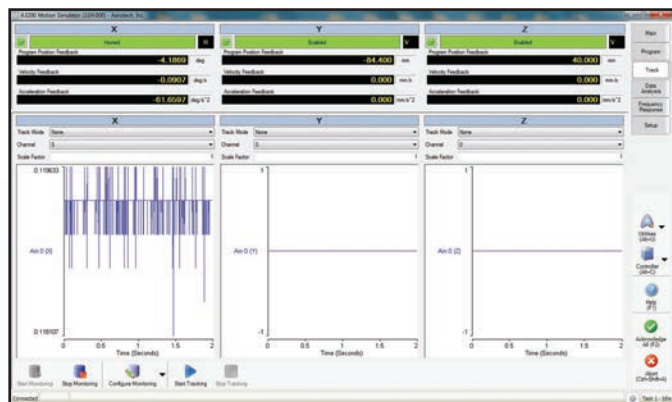
- User-friendly Windows®-based graphical user interface
- Operate 1,2,3 axis motion simulators
- Graphical motion profile PVAT (Position, Velocity, Acceleration, Time) importing
- PVAT GUI profile generation and editing
- Position Synchronized Output for real-time event triggering
- Trajectory tracking from Ethernet, analog or Windows® program inputs
- Frequency response mode allows input sine sweep and UUT performance tests on customer device
- Iterative Learning minimizes position error
- GUI remote client-server mode allows parallel processing capabilities and control via Ethernet network
- Harmonic Cancellation optimizes motion position errors generated by sinusoidal motion
- No dependence on third-party motion controller, amplifier, or software suppliers



Main screen provides manual control



Program screen provides user programming environment

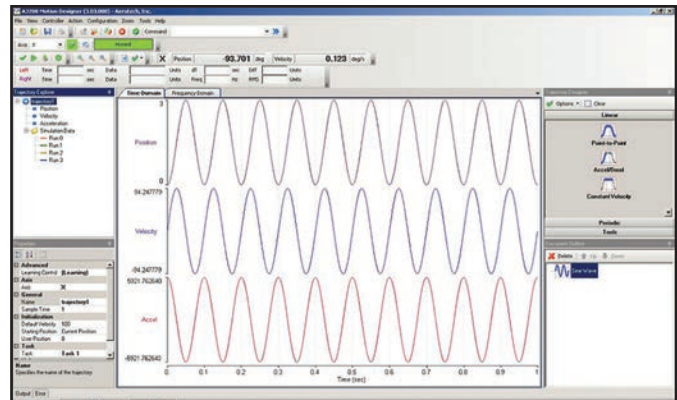


Track page provides real-time input controls for servo tracking of position or velocity inputs

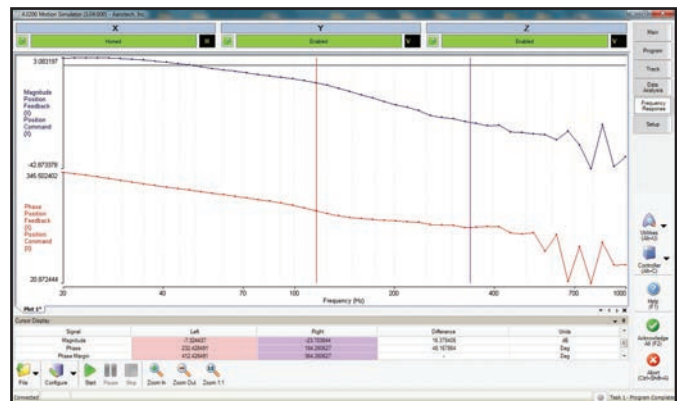
Aerotech Motion Simulator – The Integrated, Easy to Use, Graphical Trajectory Generation, Data Analysis, and Enhanced Machine Performance Toolkit.

Features and Benefits

- Learning algorithms designed to reduce position error between runs lets the system improve the move and settle results.
- Profile Mode allows users to import an existing trajectory from MATLAB® or other programs consisting of position, velocity, and/or acceleration state vectors from an external file to simplify profile input.
- Plot trajectories and use analysis tools in the time or frequency domain to give detailed motion evaluation.
- Create and modify multi-axis trajectories using predefined building blocks to provide rapid motion prototyping.
- Overlap multiple runs of a trajectory to easily see how program changes modify the motion.
- Create and export a trajectory to an AeroBasic™ program for optimized motion function. These saved functions can be combined to run complex motion simulations.
- Perform data analysis such as FFT, max, min, average, rms, and standard deviation from an existing trajectory for diagnosing system performance.
- Data input file formats include Excel, CSV, or MATLAB®. If only partial trajectory information is known, such as position versus time or acceleration versus time, Motion Simulator can calculate the other required state variables.



Motion Designer screen provides import or generation of motion profiles



Frequency response screen allows UUT frequency response testing

Aerospace and Defense Testing

Advanced Controls for Ground Support Equipment

Hardware Features

- Rack-mount controllers, panel-mount or desktop configurations
- Emergency stop safety relays to remove power and stop motion
- Optional discrete drives allow modular controller integration into existing customer equipment
- 115 VAC, 200 VAC, 208 VAC, or 230 VAC single-phase input

Motion Controller

- PC-based or stand-alone motion controllers
- User easily switches between manual and program control
- Digital controller closes PID loops at 8 kHz - 20 kHz
- Servo-loop transmission and autotuning are standard features
- Programmable digital filters to eliminate system resonances and improve bandwidth
- PC motion controller can be expanded to operate up to 32 axes so additional motion requirements can be handled in one program and one integrated hardware solution
- Stand-alone motion controllers can run up to 10 axes

Digital Drives

- Aerotech advanced controls provide 65536x analog encoder multiplication
- Digital amplifiers simplify electrical connections and minimize unwanted electrical noise in critical signals
- Easily retrofit to run motion simulators with brush/brushless motors, and inductosyns, optical analog or digital encoders, or resolver feedback
- Linear or PWM amplifiers
- Real-time digital I/O, 16-bit analog inputs, 18-bit analog outputs
- High-speed position latching for 50 ns angle capture
- 1D, 2D, 3D Position Synchronized Output provides high-speed, vector-based event triggering based on actual simulator position
- Ethernet, USB, RS-232 serial bus



GSE: Ground Support Equipment

- Save time and money with reconfigurable ground support equipment
- Windows®-based motion controllers provide simple, user-friendly software in LabVIEW®, .NET, C, C#, AeroBasic™
- Position Synchronized Output trigger for laser, eddy current, or ultrasonic sensor control
- Easily configured for brushless, brush, and stepper motors
- Reads resolver, inductosyn, incremental, and absolute encoder signals
- Capture all motion performance during testing for quality control
- Loop transmission frequency response testing built-in

Software

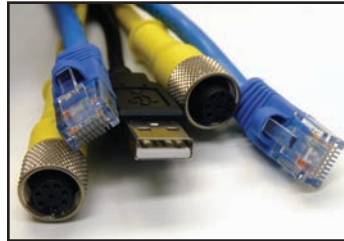
- Use the libraries and example code to develop your own front-end and applications with .NET, C#, C, and LabVIEW®.
- Easy setup with calculators and autotune routine
 - Use state-of-the-art IDE for developing your motion program
 - Second-to-none diagnostics toolkit
 - Conditional 2D error plotting

Linear and Rotary Servo and Torque Motors



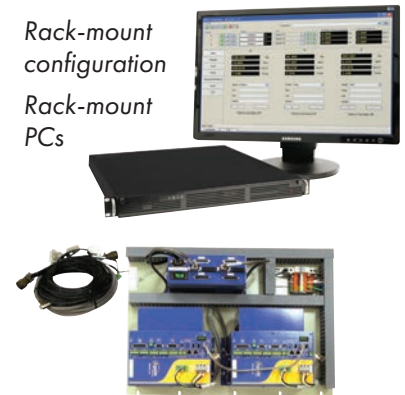
Interfaces

- Ethernet/IP™
- Modbus®/TCP
- DeviceNET
- Ethernet TCP/IP
- USB
- RS-232
- GPIB

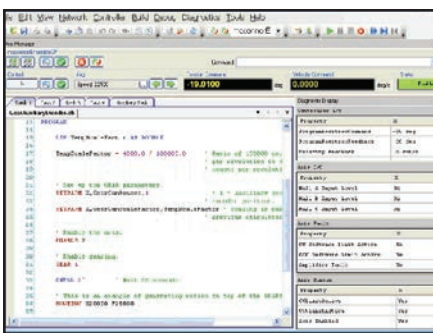


Accessories

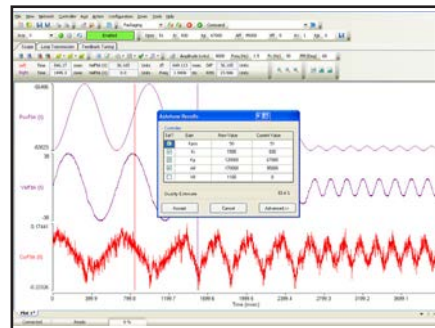
- Linear amps
- ESTOP
- Rack-mount configuration
- Rack-mount PCs



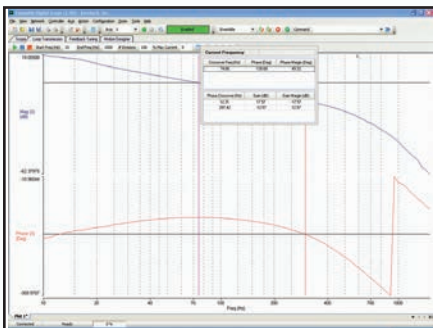
Integrated Development Environment



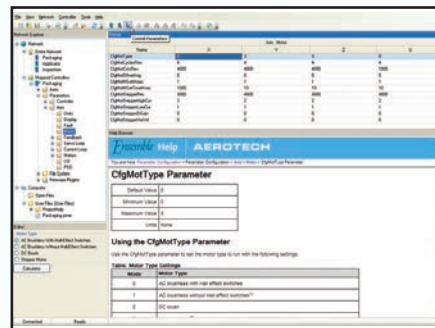
Programming Interface



Autotune



Loop Transmission



Parameter Editor

Aerospace and Defense Testing

Advanced Controls

Automation 3200



- Up to 32 tasks
- PC-based
- RS-274 G-code
- Advanced features for demanding applications
- 1 to 32 axes of coordinated motion
- Scanner control for marking
- Tightly integrated laser functionality
- Retrofit package
- Analog and digital I/O

Ensemble



- Up to 4 tasks
- Stand-alone 1- to 10-axis controller
- Versatile, cost-effective, coordinated motion
- PWM or linear drives (10-200 A peak)
- Brushless, brush, or stepper motors
- Desktop or panel mount
- .NET, C++, or LabVIEW®
- GPIB, Ethernet, USB

Soloist



- Elegant, economical, single-axis controller
- Stand-alone
- PWM or linear drives (10-200 A peak)
- .NET, C#, LabVIEW®
- Ethernet, USB



Virtual Instruments for the LabVIEW® Environment

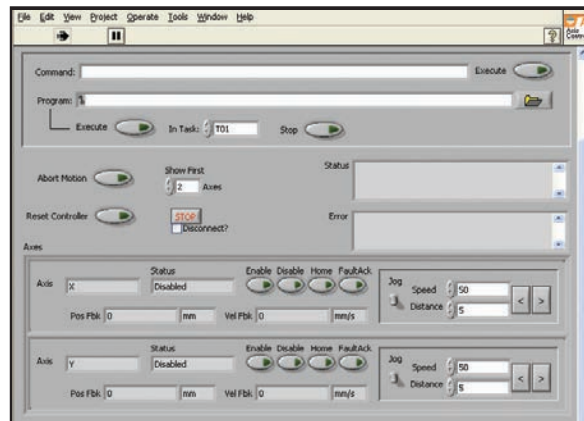
All Aerotech motion controllers have integrated LabVIEW® VIs and LabVIEW® example code for powerful motion capabilities in the Windows® LabVIEW® environment. The LabVIEW® multi-axis HMI front panel easily integrates into your application. Our user-friendly VI library includes tools and examples for initializing the controller, executing simple or complex move functions, status checking, error checking, and fault handling. Now LabVIEW® programmers have a toolbox of advanced motion VIs for rapid prototype work.

These VIs can be used as building blocks or as stand-alone VIs to perform various tasks such as initialization, motion, and status/position updates.

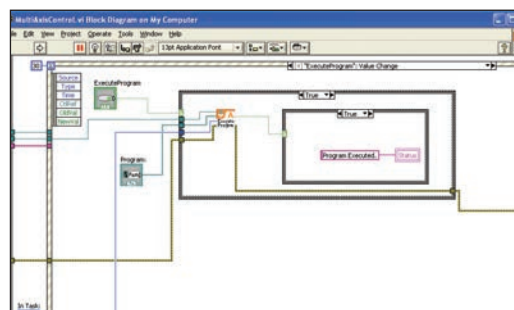
The VIs are organized into the following categories:

- Initialization Functions
- Analog and Digital I/O Functions
- Motion Functions
- Error Handling Functions
- Parameter Functions
- Status and Position Functions
- Global Data Functions
- Run Program Functions
- Utility Functions
- Get and Set Variable Functions

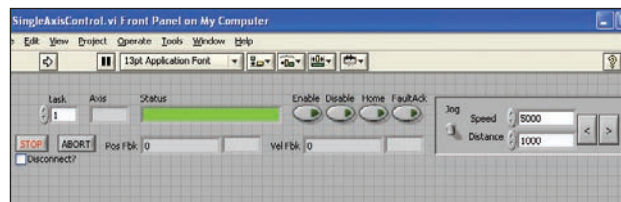
Aerotech's VIs conform to National Instruments' LabVIEW® programming standards. Each VI is simple and intuitive to use.



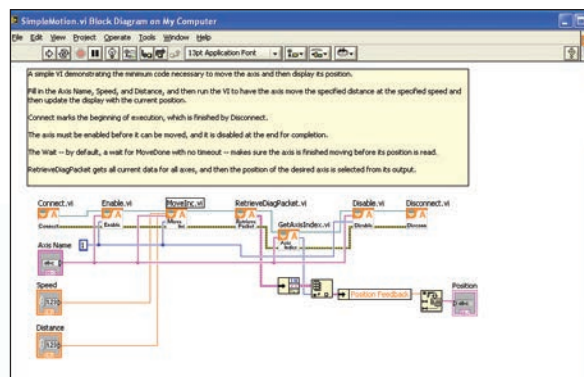
LabVIEW® multi-axis HMI front panel



HMI diagram



LabVIEW® simple two-axis VI



Vector linear move diagram

Aerospace and Defense Testing

Advanced Controls

Linear Servo Amps Now Feature Resolver or Inductosyn Interfaces for High Accuracy and Ultra-Low Jitter Operation

The HLe and Npaq linear servo amplifiers are for motion control applications that require high accuracy drives with no PWM switching noise and zero deadband. Because the HLe and Npaq linear servo amplifiers have no PWM switching noise, they do not induce electrical noise into sensitive electrical measurement devices. Our linear amplifiers have no dead band, and provide smooth current through motion direction reversals.

Resolver or Inductosyn Interface Provides High Accuracy and Ultra-Low Jitter Operation for Direct-Drive AZ/EL and Rotary Positioners

Aerotech's linear digital amplifiers are now available with an optional one- or two-channel resolver or inductosyn interface to read position from absolute encoders. The Npaq with linear amplifiers can have six channels of resolver, inductosyn, or optical encoder feedback. These new features, when combined with the smooth current inherent in a linear amplifier, make the Aerotech motion controllers ideal for high-accuracy position or velocity tracking with direct-drive rotary positioners that use resolver or inductosyn feedback. These features let customers track objects with high accuracy and low jitter — critical performance concerns in applications such as laser steering, target tracking, and star tracking.

Linear Amplifier Advantages

- No switching noise
- Zero dead-band
- $\pm 40\text{ V}$, $\pm 60\text{ V}$, and $\pm 80\text{ V}$ output voltage
- Peak output current up to 20 amps
- Continuous output current up to 10 amps
- Software selectable power amplifier bandwidth
- Linear amps are available with up to 750 watts of power dissipation per amplifier*



Ensemble HLe

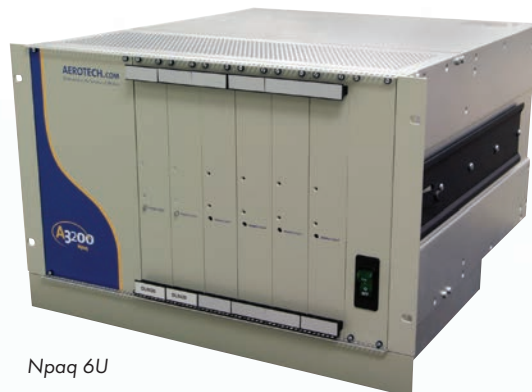
Ndrive HLe

Soloist HLe

Ndrive ML



Npaq 3U



Npaq 6U

*Npaq 6U and linear amplifiers



PWM Amplifiers, 10–200 A Peak Output

Aerotech PWM digital servo amplifiers are capable of controlling brushless, DC brush, and stepper motors over a wide range of operating voltages and currents. Based on a common architecture, these amplifiers perform both current- and position-loop closures digitally.

The use of high-performance double-precision processors allows these drives to generate ultra-smooth motion profiles. Servo system response is optimized with the use of up to eight second-order loop-shaping filters, precise time-aligned feed-forward, and other proprietary techniques with loop closure rates up to 20 kHz.

The PWM family is offered in a number of highly efficient versions. The MP is a low power, small footprint PWM drive ideal for space-sensitive applications. The CP is a medium-power PWM drive capable of running directly from AC mains voltage and is optimized for cost-sensitive applications. The HPe is the highest performance PWM drive providing a host of features not available on the other PWM drives, and is available in output current ranges from 10 A to 200 A peak.

Options for Aerotech PWM amplifiers include integral encoder interpolation, one- to three-axis Position Synchronized Output (PSO), automatic brake control, digital and analog I/O expansion, absolute encoder interface, and one- or two-channel resolver interfaces. An optional dedicated Ethernet port is available on the HPe drives for connection to third-party I/O expansion devices.

Ensemble MP



Soloist CP



Ndrive HPe

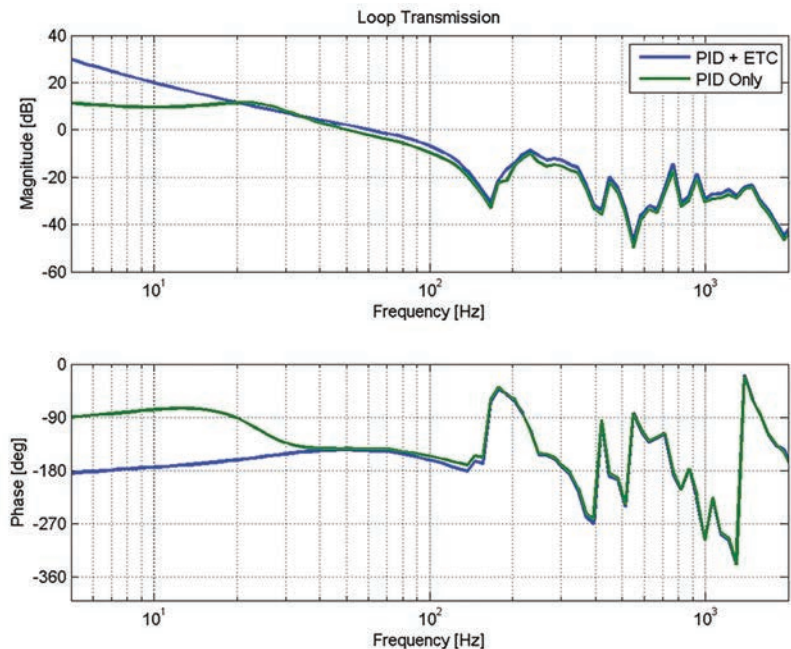


Aerospace and Defense Testing

Advanced Controls

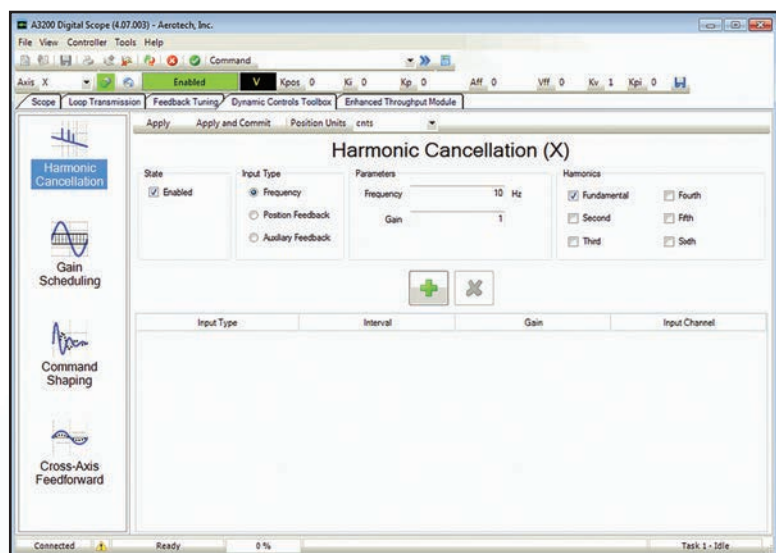
A3200 Enhanced Tracking Control

Aerotech's unique Enhanced Tracking Control (ETC) feature improves move-and-settle times in point-to-point positioning and reduces tracking errors during contoured motion. It is available across our family of controllers (A3200, Ensemble, and Soloist) including our Nmark CLS High-Performance Galvo Controller. The Enhanced Tracking Control algorithm works in parallel with a conventional Proportional-Integral-Derivative (PID) control architecture and increases the ability of the servomechanism to reject disturbances that would otherwise lead to position errors.



A3200 Dynamic Controls Toolbox

The Dynamic Controls Toolbox provides control algorithms that increase system performance such as settle time, accuracy, in-position stability, and/or velocity stability. These include Harmonic Cancellation, Threshold, Dynamic Gain Scheduling, Command Shaping, and Cross-Axis Feedforward.



Standard Products



Standard Products

Rotary Positioners

Ground-Breaking Performance

Aerotech large aperture rotary stages are revolutionary direct-drive stages. Now customers have the combined features of large apertures, direct-drive motors, extremely high resolution and accuracy, low tilt errors, and high bearing-load capabilities. These features give customers new capabilities to make systems with high load-capacity, ultra-precise rotary positioning, and large axis through-holes to pass cables, hoses, payloads, slip rings, or optical paths. The ALARs can also be configured for 10^{-6} Torr vacuum environments. Customers can get these large-aperture, zero backlash stages to test their space-rated instruments and imagers.

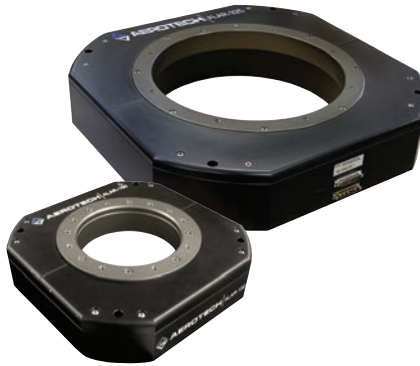
Direct-Drive Advantage

Direct-drive ALAR rotary stages have no gear wear or gear vibration. Another benefit is that direct-drive provides very high speeds, so testing can be completed in less time. In production settings this equates to faster testing, lower-cost manufacturing, and higher profits. From the standpoint of system accuracy and repeatability, the stage will maintain its performance over time with no need for maintenance because there is no gear wear. With high accuracy and no backlash, customers can produce more accurate products because their test system is now more accurate.

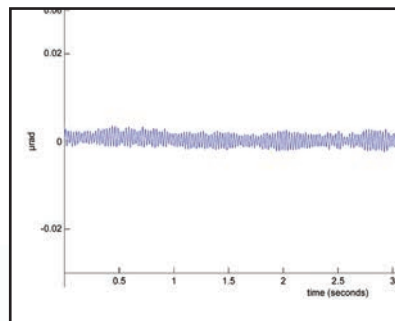
Large Aperture, Direct-Drive Rotary Stages

- 100 mm, 150 mm, 200 mm, 250 mm, and 325 mm apertures
- Axial load capacity of 136-682 kg (300-1500 lb)
- Excellent accuracy and repeatability
- Cog-free motor provides smooth motion
- No gear backlash
- No accuracy change over time from gear wear
- 45-300 rpm continuous rotation speed
- Vac 10^{-6} Torr compatible versions
- High resolution gives excellent stepping and in-position stability
- Optional absolute encoder

ALAR-LP Series

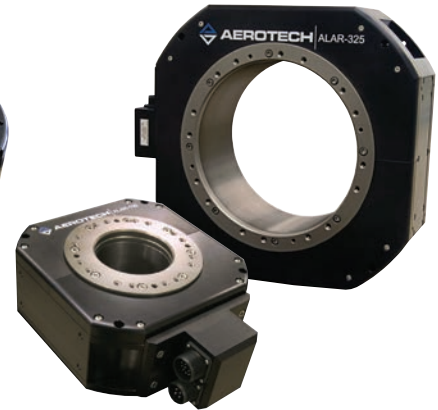


Our ALAR-LP is designed to be mounted with the vertical axis coincident with gravity. The LP is lower profile than the SP for applications that have less space available.

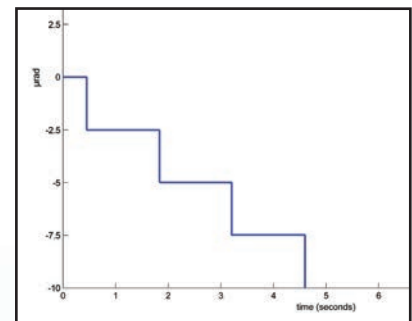


In-position stability of $\pm 0.05 \mu\text{rad}$

ALAR-SP Series



Our ALAR-SP is designed to be mounted in any configuration – vertical or horizontal.



High resolution gives small step capability

Mechanical-Bearing Direct-Drive Rotary Stage

- Accuracies up to 1.5 arc second
- Axial load capacity up to 250 kg
- Incremental or absolute encoders
- Large bearings provide high payload and moment-load capacity
- 375-800 rpm continuous rotation speed
- Seven models are available, each with either 50, 75, or 100 mm clear aperture

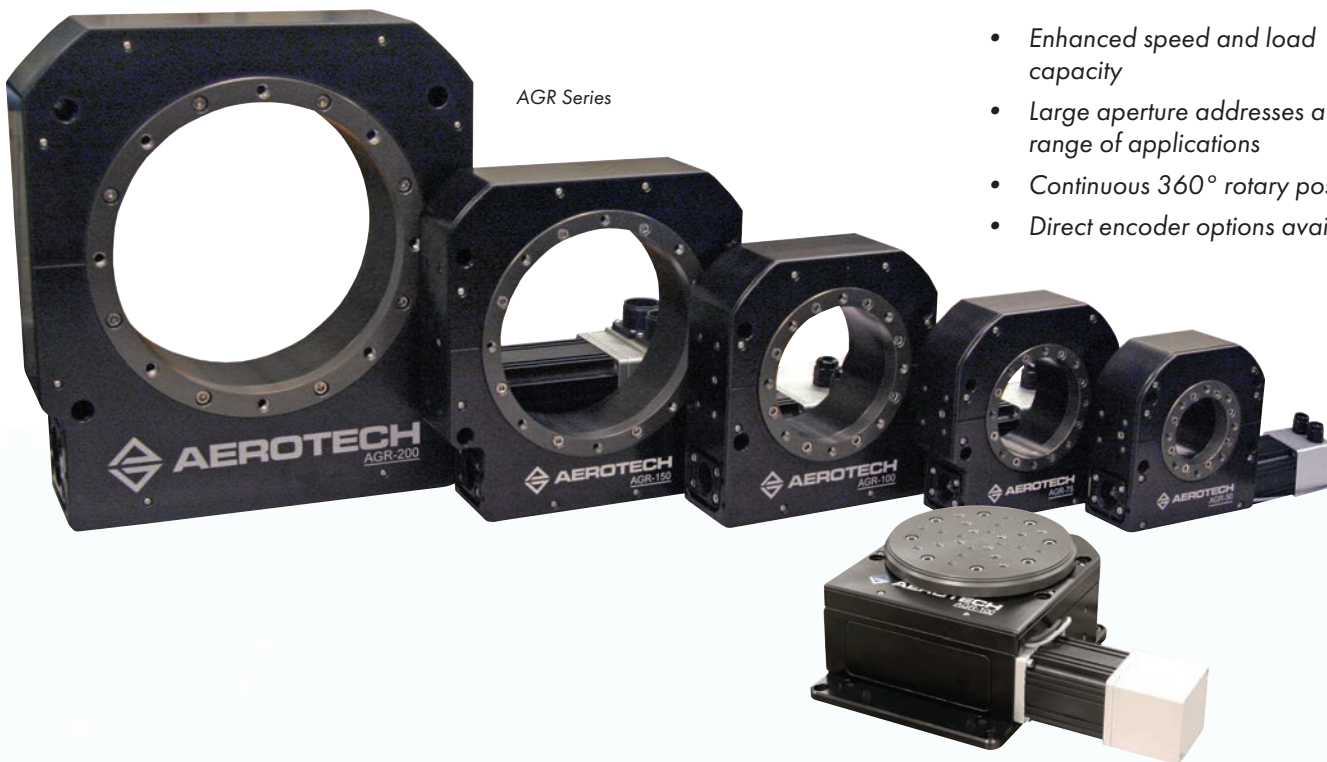
APR Series



Mechanical-Bearing Gear-Drive Rotary Stage

- Enhanced speed and load capacity
- Large aperture addresses a wide range of applications
- Continuous 360° rotary positioning
- Direct encoder options available

AGR Series



Standard Products

Rotary Positioners

Stainless-Steel Direct-Drive Rotary Stages

- High torque, brushless, slotless servomotor produces no cogging torque, allowing for high speed and low stage error motions
- Sealed stages survive harsh environments
- Custom mounting and tabletop options provide flexibility and ease integration
- Construction options include passivated stainless-steel for corrosion resistance and thermal stability



ADRT and ADRS rotary stage family in stainless steel

High Torque Output, Direct-Drive Rotary Stages

- Cog-free brushless servomotor design for outstanding velocity stability
- Large diameter clear aperture
- High load capacity and high speed
- ± 15 to ± 50 μ rad accuracy



ADRT Series



ADRS Series

Low Profile, Direct-Drive Rotary Stages

- High torque output, direct-drive brushless servomotor
- Cog free, slotless motor design for superior velocity stability
- Direct coupled, high-accuracy rotary encoder
- Ultra-low-profile minimizes working height



Standard Products

Linear Positioners

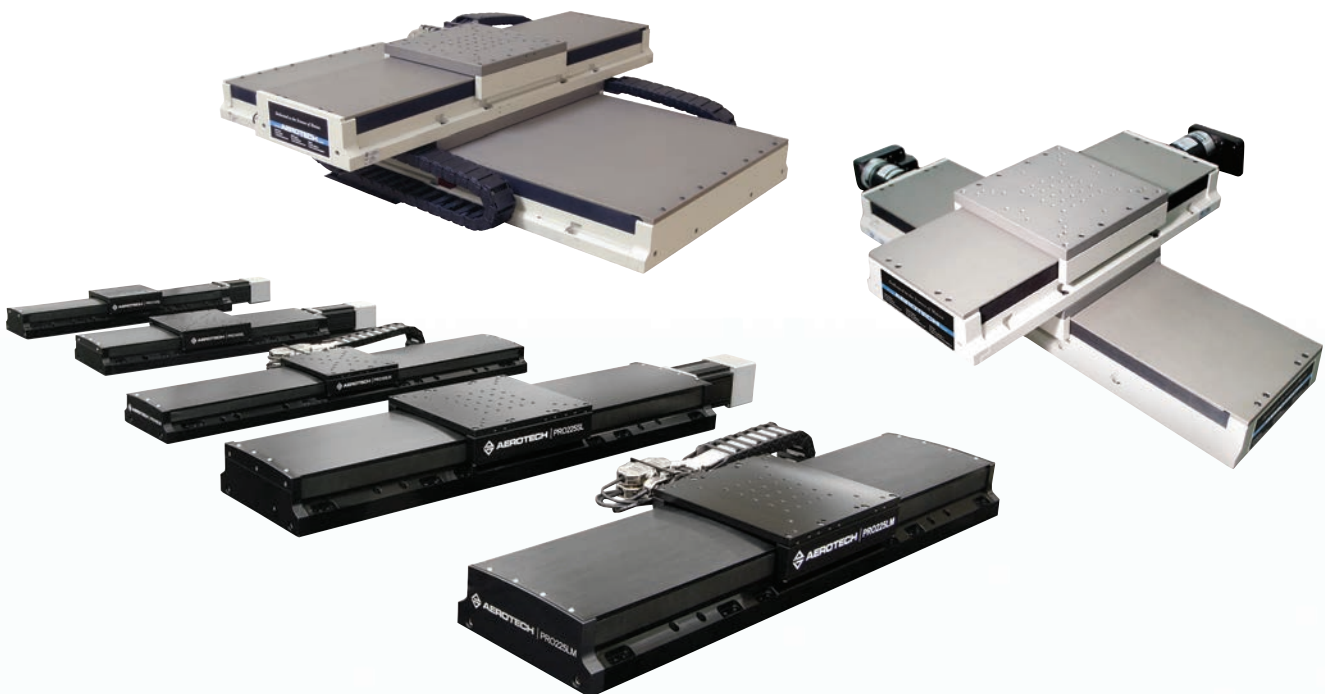
Aerotech manufactures air-bearing linear and rotary stages for testing optical encoders, resolvers, and potentiometers used in aerospace and defense aircraft, ships, and ground vehicles.



ABL1500 Air-Bearing, Direct-Drive Linear Stage

- *Designed for high-performance scanning and inspection*
- *450 mm wafer compatible*
- *Active air preload on all air-bearing surfaces*
- *Linear encoder feedback provides subnanometer resolution*
- *High stiffness for heavy loads and excellent geometric performance*
- *Travel up to 500 mm*

Aerotech manufactures many different linear mechanical-bearing stages. Please see aerotech.com to view the large range of linear stages.

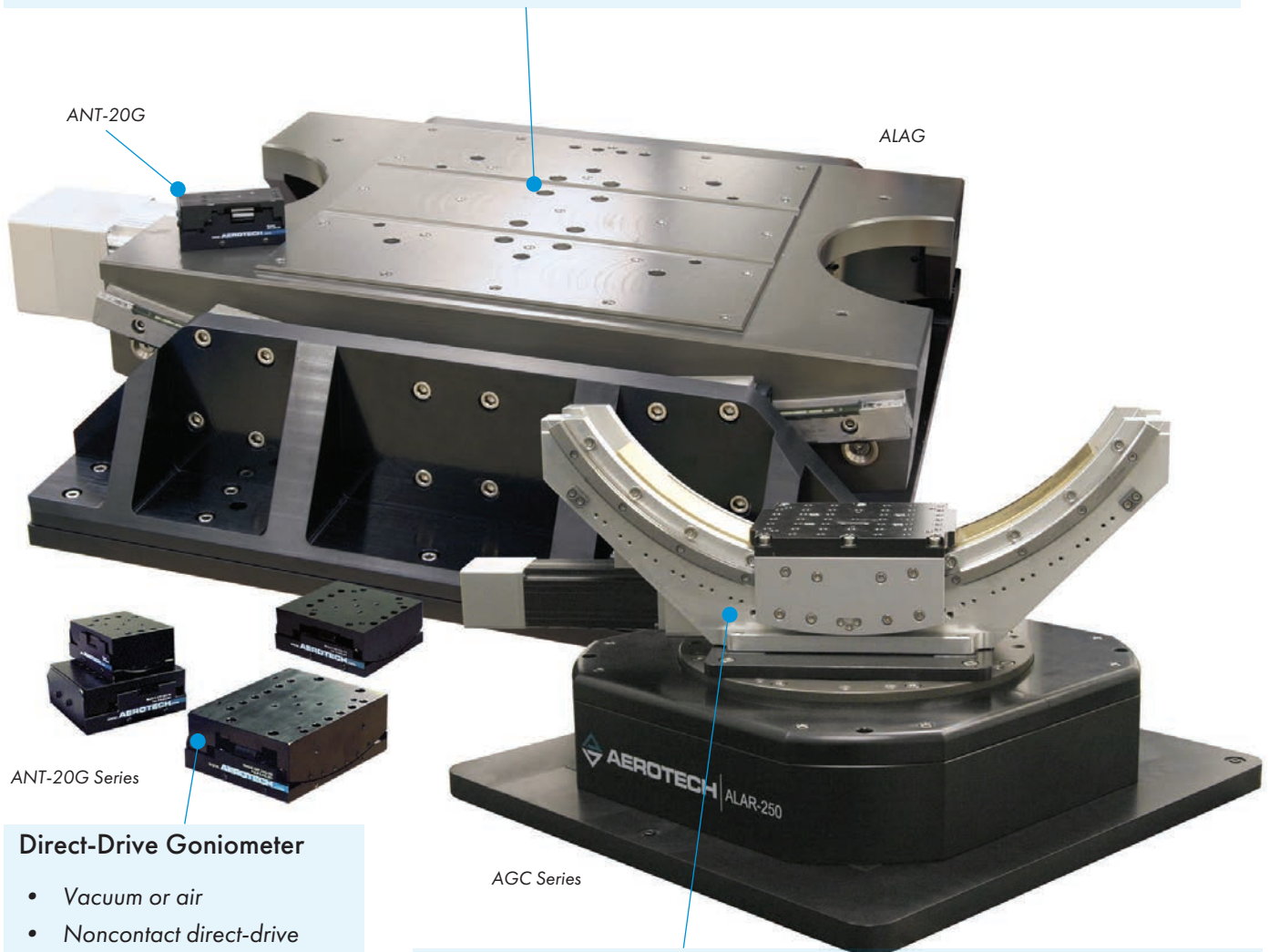


Standard Products

Goniometers

Large Capacity Goniometer

- 682 kg (1500 lb) load capacity
- Rotation point is 330 mm or 1200 mm above tilt stage
- $\pm 2 \mu\text{rad}$ repeatability
- $\pm 5 \mu\text{rad}$ accuracy
- Vac 10^{-6} Torr
- AZ direct drive
- 0.025 μrad machine resolution
- Goniometer includes direct tabletop feedback
- $\pm 3^\circ$ to $\pm 5^\circ$ travel



Direct-Drive Goniometer

- Vacuum or air
- Noncontact direct-drive
- High speed and high resolution
- No maintenance
- 20 degrees of travel
- $\pm 30 \mu\text{rad}$ accuracy
- 1.5 to 5 kg (3.3 to 11 lb) load capacity
- Stackable for pitch/roll

Gear-Drive Goniometer

- $\pm 60 \mu\text{rad}$ accuracy
- $\pm 45^\circ$ rotary positioning with unobstructed 360° view of customer load
- Precision worm-gear-drive for outstanding accuracy and repeatability
- Direct encoder options available
- Horizontal or vertical mounting orientation
- 20 to 50 kg (44 to 110 lb) load
- AZ stage 0.25 μrad minimum incremental motion

Standard Products

Piezo Stages and Direct-Drive Nanopositioners

Aerotech brings you the next generation in piezo nanopositioning. Q-Series QNP piezo nanopositioners and the QLAB multi-axis piezo controller represent a quantum leap in piezo nanopositioning performance.



- Closed-loop travels of 100 μm , 250 μm , and 500 μm available in X, XY, and Z configurations
- High-precision, frictionless flexure guidance system provides nanometer-level geometric errors over full travel
- Sub-nanometer positioning resolutions and nanometer-level accuracy with direct-metrology capacitive sensors
- 1 to 4 axes of high-resolution control in open or closed-loop mode
- Touch-screen with intuitive menu-driven interface for quick and easy access to system functionality

Linear

- 1 nm resolution
- <1 nm in-position stability
- 75 nm repeatability
- 250 nm accuracy
- Up to 160 mm travel

Rotary

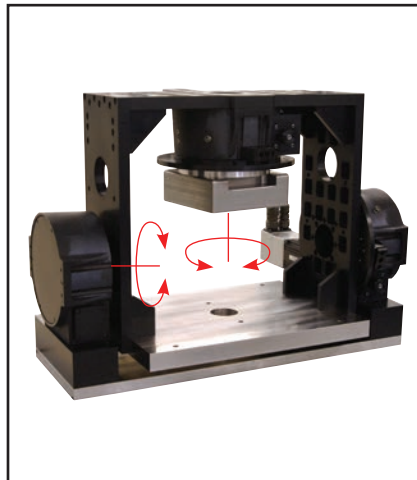
- 0.01 arc-second resolution
- 0.005 arc-second in-position stability
- 1.5 arc-second repeatability
- 3 arc-second accuracy
- 360° continuous or limited travel



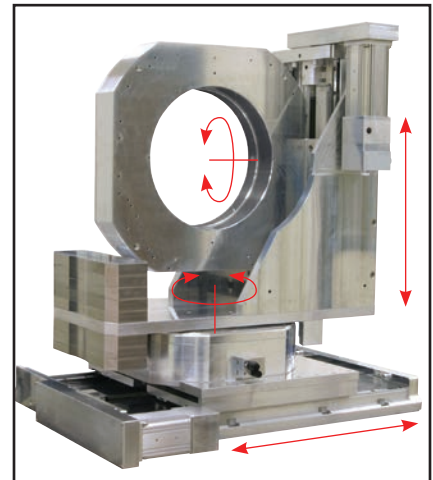
Additional Examples of Custom Engineered Systems



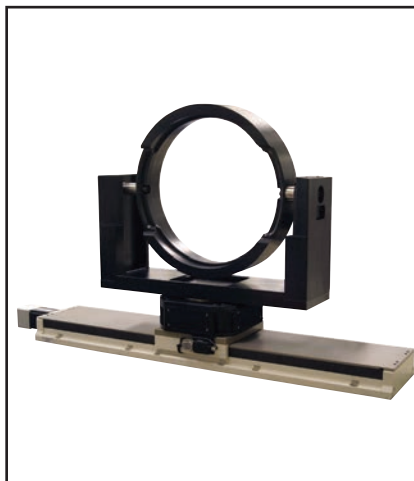
Two-Axis ADRS-200/-150 AZ over EL Direct-Drive



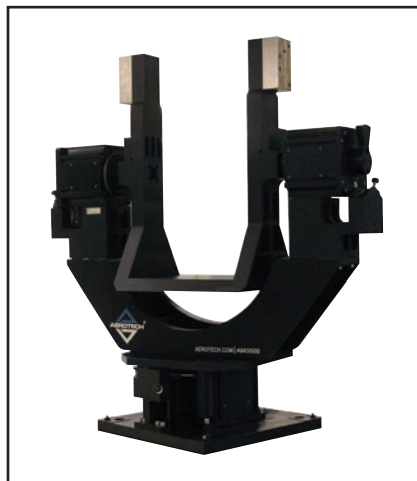
Vac 6 Gear-Drive Gimbal



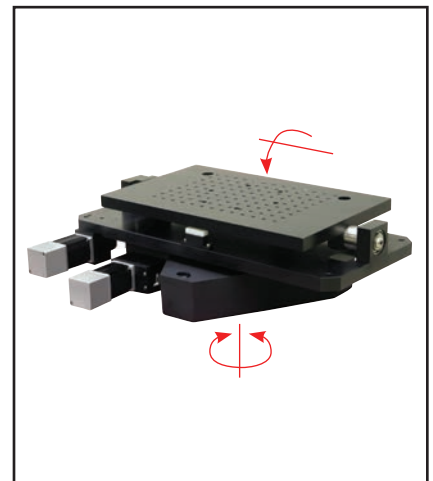
Four-Axis Vac 6 XY with Roll and AZ, ATS5000WB/ALAR-325-SP



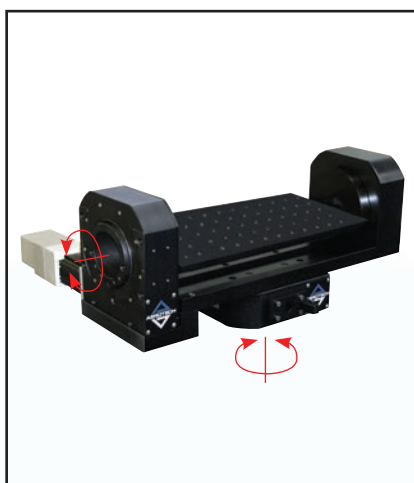
High Accuracy AZ/EL Gimbal with One Meter Linear Translation



Custom Motion Simulator AMG-500 with Payload Swing



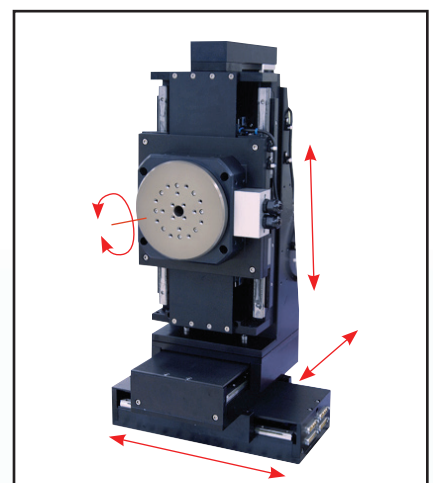
Low Profile $\pm 4^\circ$ Travel AZ/EL



AGR100 Gimbal with Breadboard Swing



Vac 6 Custom Square Cell AMG-300 Gimbal



ALS1000 XYZ Theta, ATS1000, ADRS-150, 10^{-3} Torr

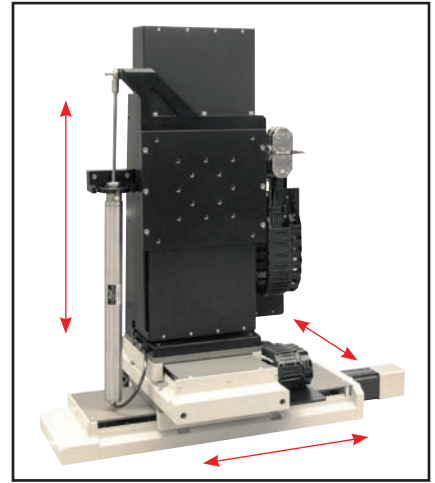




ADRT-260/ADRT-200 Direct-Drive Gimbal



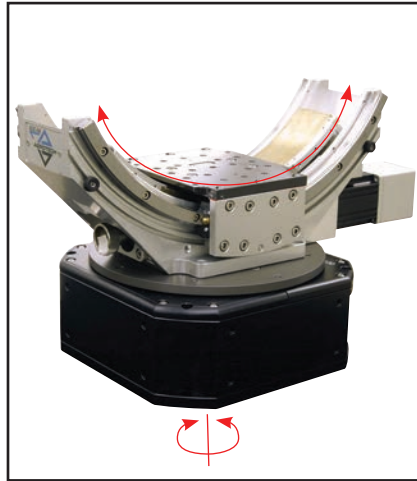
ADRT Direct-Drive AZ/EL



High Accuracy XYZ



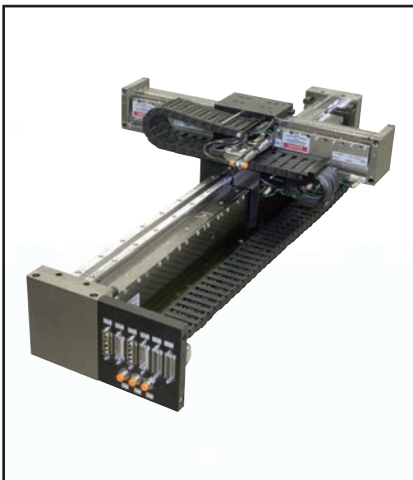
ADR/ANT Direct-Drive AZ/EL



High Accuracy AZ/EL Positioner



ALAR-100/ANT-20G with Mirror Cell



XY LMA Actuators



APR260 Rotary Test Stand



ADRT/AGR AZ/EL Gimbal

Capabilities in Other Markets

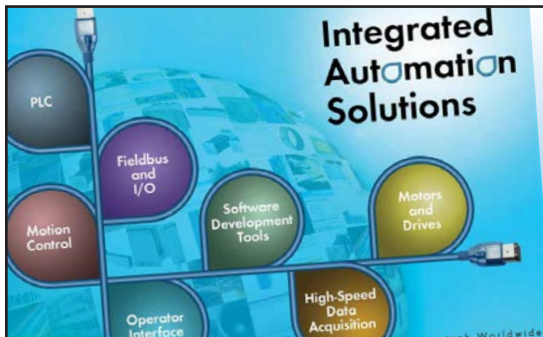
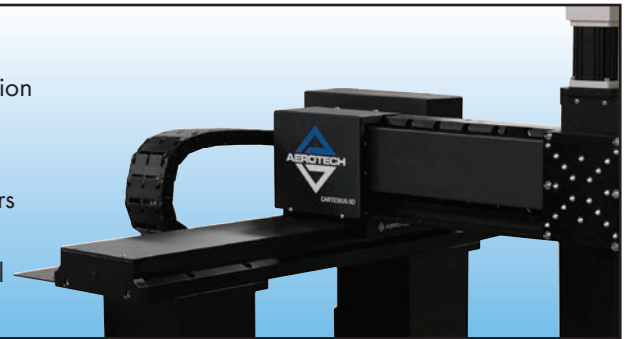


Photonics and Fiber Optics

Aerotech nanopositioners are perfect for the high-volume manufacture of fiber optics and photonics components and systems. Aerotech nanopositioners feature the highest closed-loop resolution available with up to six axes of coordinated motion. With efficient automation in mind, our fiber optics and photonics equipment combines durability and the latest technology to create nanopositioners that fit seamlessly into manufacturing systems and endure nonstop use.

General Automation

Since 1970 Aerotech has been a manufacturer of top-quality automation products. The breadth of our product line, including automated nanopositioners, planar air-bearing systems, high-speed gantries, linear and rotary and lift stages, brushless linear and rotary servomotors and drives, single- and multi-axis motion controllers, goniometers, and gimbals/optical mounts makes Aerotech unique among motion control manufacturers. Aerotech is *Dedicated to the Science of Motion*.

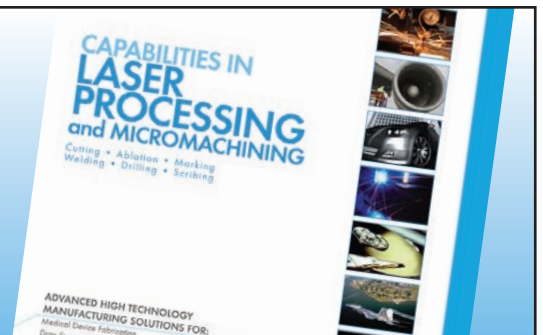


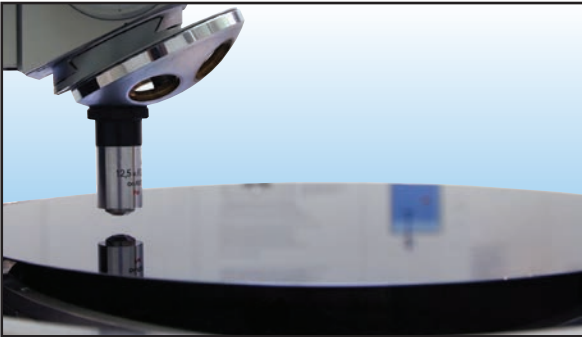
Control Systems

Aerotech motion controllers, motors, and drives are utilized in our own positioning systems and by end users and OEMs worldwide. From our Automation 3200 software-based motion controller that can control up to 32 axes, to the Soloist single-axis servo controller, to the Ensemble multi-axis stand-alone motion controller, we provide a variety of options to suit your application.

Laser Processing

Aerotech has extensive experience in providing motion components and subsystems for laser processes such as cutting, welding, marking, etching, and micromachining. These processes are the key to advancing technology in markets such as photovoltaic manufacturing, aerospace, and medical device manufacturing.



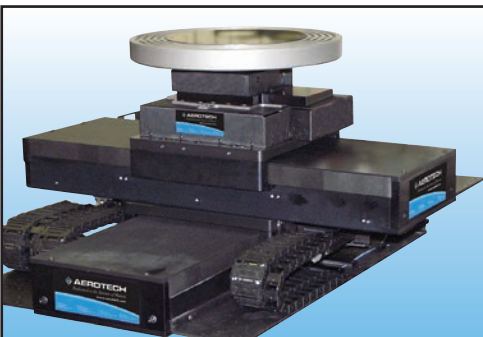
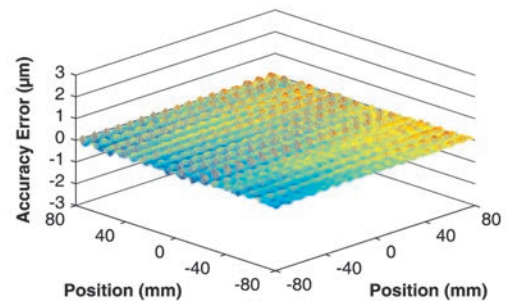


Test and Inspection

Aerotech is involved in test and inspection across a wide array of industries with applications including CMMs, ultrasonic, eddy current, x-ray, optical, and electronic. All of these applications rely on Aerotech products' unmatched precision, accuracy, and durability. Optical inspection solutions range from high-end linear-motor-driven models packaged with all control elements in an optimized machine base, to modular systems specifically designed for cost-sensitive applications.

Government and Educational Research and Development

The breadth of Aerotech's product line offers solutions for the wide-ranging requirements of academic and government R&D. Our nanopositioners provide the accuracy required not only for photonics experiments, but also for micro- and nano-machining workstations. Aerotech's multi-axis rotary positioners and gimbals offer the high precision needed for defense, satellite, and space science research. Unique applications call for unique solutions, and Aerotech can provide custom-engineered systems to meet your needs.

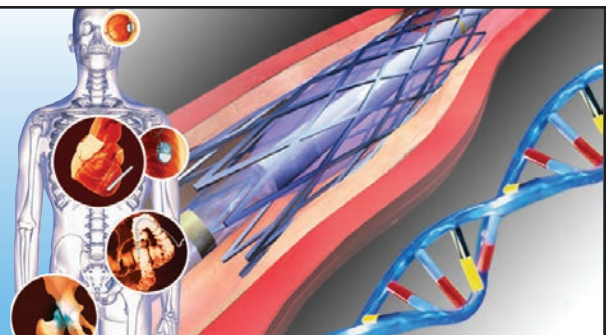


Electronics Manufacturing and Assembly

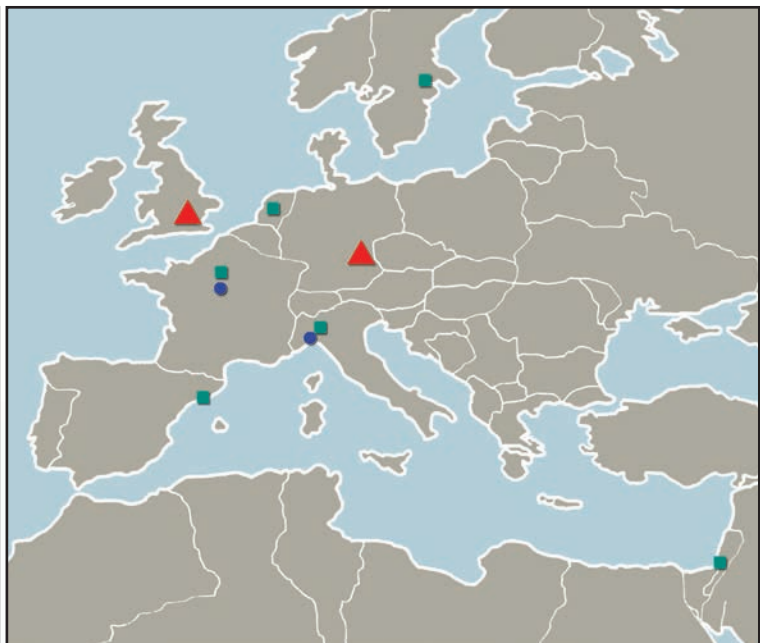
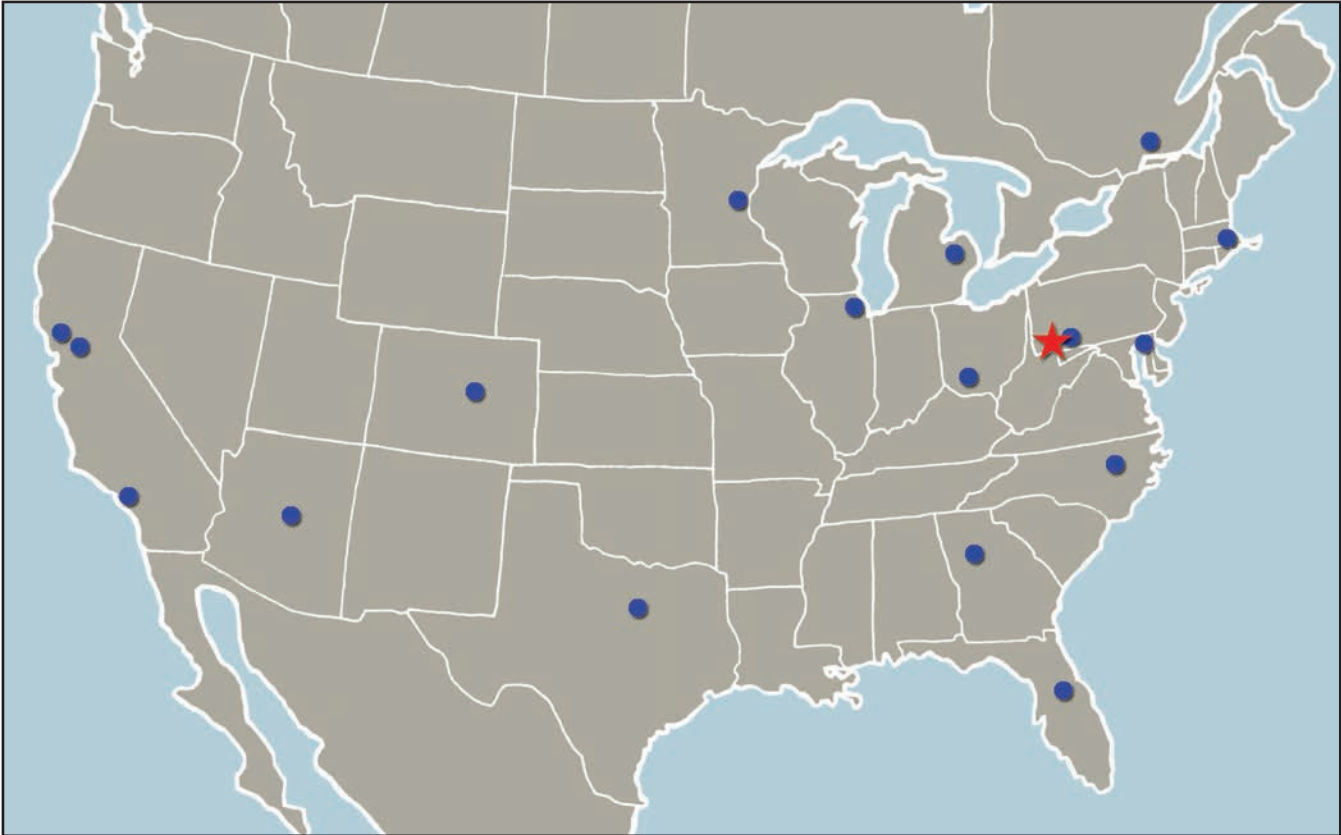
Speed, accuracy, and reliability are the key requirements for pick-and-place machines, stencil cutting machines, printed circuit board assembly, and other electronic manufacturing and assembly equipment. Since 1970 Aerotech has exceeded the most stringent criteria used to judge electronic manufacturing and assembly equipment, and we continue to raise the standard with our advanced motion technologies by addressing industry-specific challenges in pick-and-place machines, stencil cutting machines, and printed circuit board assembly systems.

Medical Device Manufacturing and Life Sciences

Aerotech manufactures high-performance motion systems and components for medical and life sciences applications including stent cutting, medical laser welding systems for cardiac pacemakers and catheters, IOL and contact lens manufacturing, DNA sequencing, blood sequencing, haptic mills and drills, x-ray machines, magnetic resonance scanners and CAT scanners. We can customize a medical laser welding system for any need.



Aerotech's Worldwide Sales and Service Locations



★ - Aerotech Headquarters ● - Direct Field Sales Office ▲ - Aerotech Subsidiary ■ - Representative