AMTI Biomechanics Force Platform Installation Manual Version 4.4

April 2017

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Version 4.4

Advanced Mechanical Technology, Inc.

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PLEASE SAVE YOUR ORIGINAL PACKAGING

If you need to return a force platform to AMTI it must be properly packaged to prevent damage in shipping. Contact AMTI for more information.

OPERATING ENVIRONMENT

For best performance, AMTI force platform systems should be operated in a ventilated, stable environment under the following conditions:

- A temperature range of 5 to 40°C (41-104°F)
- A relative humidity range of 15-90%, noncondensing
- An atmospheric pressure range of 700-1060 mbar (20.7-31.3 in Hg)

AMTI force platform systems should be turned on and allowed to stabilize for at least one hour prior to use. The system may be left on when not in use and this is recommended.

SAFETY ALERTS

DO NOT DROP THE FORCE PLATFORM

The platform is a rugged instrument and should provide years of trouble-free operation when handled correctly. However, dropping the platform even a short distance onto a hard surface can result in significant damage. Please contact AMTI at support@amtimail.com with any concerns.

DO NOT MODIFY THE FORCE PLATFORM

Tampering with any visible fasteners, removing the connector, or making any other modifications to the platform can damage the strain measuring elements. Please contact AMTI at support@amtimail.com for advice on any needed modifications.

STATIC DISCHARGE

The force platform and amplifier are sensitive to static discharge. Avoid possible damage by properly grounding the force platform as described in this manual. It is good practice to touch a grounded surface before inserting connectors.

DO NOT EXCEED THE MAXIMUM SAFE LOAD FOR PLATFORMS

The total load is an aggregate of the stress on each individual sensing element, so there is no single maximum safe load. Please contact AMTI at support@amtimail.com if you think your applied force might greatly exceed these general guidelines:

Force Platform	Estimated Maximum Load
-1000 series	450 N (1000 lb) vertical load **anywhere** on the top surface **AND** 2225 N (500 lb) side load **anywhere** on the platform in the x or y direction
-2000 series	8900 N (2000 lb.) of vertical load **anywhere** on the top surface **AND** 4450 N (1000 lb) side load **anywhere** on the platform in the x or y direction

Warranty, General Terms and Conditions

Advanced Mechanical Technology, Inc. (AMTI) warrants all transducers it manufactures to be free from defects in materials and factory workmanship, and agrees to repair or replace any industrial transducer or amplifier that fails to perform as specified within one year, and any force platform within five years after date of shipment. This warranty shall not apply to any transducer that has been:

i. Repaired, worked on, or altered by persons unauthorized by AMTI in such a manner as to injure, in our sole judgment, the performance, stability, or reliability of the transducer;

ii. Subjected to misuse, negligence or accident or

iii. Connected, installed, adjusted, or used otherwise than in accordance with the instructions furnished by AMTI.

At no charge, we will repair at our plant or at our option or replace any of our products found to be defective under this warranty.

This warranty is in lieu of any other warranty, expressed or implied. AMTI reserves the right to make any changes in the design or construction of its transducers at any time, without incurring any obligation to make any changes whatever in units previously delivered.

AMTI's sole liabilities, and buyer's sole remedies, under this agreement shall be limited to the purchase price, or at our sole discretion, to the repair or replacement of any transducers that prove, upon examination, to be defective, when returned to our factory, transportation prepaid by the buyer, within one year (industrial), or five years (force platform), from the date of original shipment.

Return transportation charges of repaired or replacement transducers under warranty will be prepaid by AMTI.

AMTI is solely a manufacturer and assumes no responsibilities of any form for the accuracy or adequacy of any test results, data, or conclusions, which may result from the use of its equipment.

The manner in which the equipment is employed, and the uses to which the data and test results may be put, are completely in the hands of the purchaser. AMTI shall in no way be liable for damages consequential or incidental to defects in any of its products.

This warranty constitutes the full understanding between the manufacturer and buyer, and no terms, conditions, understanding, or agreement purporting to modify or vary the terms hereof shall be binding unless hereafter made in writing and signed by an authorized official of AMTI.

1. AMTI Biomechanics Force Plate Components

A complete standard system typically consists of a force platform, an amplifier, a computer or data acquisition system, mounting hardware, and interconnecting cables.

AMTI offers three portable solutions in addition to its selection of standard force platform. A complete portable system typically consists of a portable force platform, a computer or data acquisition system, and interconnecting cables.

1.1. Force Plate

A force platform is designed to measure the forces and moments applied to its top surface as a subject stands, steps, or jumps on it. Force plates are regularly used in research and clinical studies looking at balance, gait, and sports performance.

AMTI Biomechanics Force Platforms are available in 1000-lb, 2000-lb, and 4000-lb capacities in a wide range of sizes.

1.2. Signal Conditioners

An AMTI signal conditioner is required for use with each strain gage force platform or force sensor. A signal conditioner amplifies, conditions, and filters the low-voltage output from the platform's sensing elements to create usable data streams. AMTI offers three amplifiers, the Optima Signal Conditioner, the Gen 5, and the AMTI MSA-6.

AMTI Optima Signal Conditioner (OPT-SC)

Exclusively for use with Optima Human Performance System force plates (OPT and OP series)

The Optima Signal Conditioner is an essential component of the Optima Human Performance System, a revolutionary force measurement system that offers a 10-fold improvement in accuracy over any force platform system on the market.

This signal conditioner works exclusively with Optima Force Plates and Optima Precision Calibration files to provide levels of accuracy never before seen in force platform systems:

- Average COP accuracy of just a fraction of a millimeter (typically less than 0.2)
- Crosstalk values typically ±0.05% of applied load
- Measurement accuracy typically ±0.1% of applied load*

The OPT-SC is a medical-grade signal conditioner manufactured under the ISO 13485:2003 and ISO 9001:2008 quality systems. This product meets the standards set by CE Directive 2006/95/EC and has successfully been tested to comply with medical electrical equipment standards regarding basic safety, essential performance and electro-magnetic compatibility.

AMTI Gen 5 Signal Conditioner

Compatible with all AMTI force plates and forces sensors <u>except</u> Optima force platforms (OPT series)

The Gen 5 is an advanced strain gage signal conditioner compatible with all of AMTI's standard force plates and force sensors. It provides industry-leading performance and innovative features in an easy-to-use and cost effective package.

The Gen 5 features state-of-the-art signal conditioning with six independently configurable data channels, built-in cable length compensation, and internal crosstalk correction. It offers multiple, software-selectable gain and excitation voltage settings for each channel. A USB connection is used to control the amplifier and output the data; six analog data streams are also available.

The Gen 5 is a medical-grade signal conditioner manufactured under the ISO 13485:2003 and ISO 9001:2008 quality systems. This product meets the standards set by CE Directive 2006/95/EC and has successfully been tested to comply with medical electrical equipment standards regarding basic safety, essential performance and electro-magnetic compatibility.

AMTI MSA-6 Amplifier

Compatible with all AMTI force plates and forces sensors except Optima force platforms (OPT series)

The MSA-6 is a 6-channel strain gage amplifier designed to work with AMTI multi-component force platforms and transducers. It offers multiple, jumper-selectable gain and excitation voltage settings for each channel. Serial and analog data streams are available. Serial data is via RS-232 protocol, which can be converted to USB with an adapter.

*Minimum applied load of 50 lbs.

1.3. Mounting Fixtures

AMTI offers mounting fixtures specifically configured for each model of force platform. When properly installed these fixtures provide a sufficiently flat and rigid mounting surface for the force platforms to perform properly. The standard mounting fixtures permit single position mounting. Special custom mounting systems can be designed that provide multiple platform mounting positions and configurations with multiple platforms. Contact AMTI for further information.

1.4. Cables

Analog Strain Gauge Signal Cable

The force plate or force sensor is connected to the signal conditioner via a multiconductor, twisted-pair, shielded signal cable designed for low-noise transmission of very low-level signals. Standard length is 30 feet; other lengths are available on request. AMTI manufactures a large variety of cables and connector combinations, including right-angle connectors.

Serial Data Cable

(Ships with AMTI Amplifiers)

USB cables are provided with the GEN 5 and Optima signal conditioners; RS-232 cables are provided with the MSA-6. USB hubs are available for use with multiple Gen 5's and\or Optima's, and a special Y-cable is available to connect two MSA-6 amplifiers to the same RS-232 port on a PC.

Analog Output Cable

Analog output cables with several termination styles (BNC, DB15, or flying leads) are available to mate with a variety of data acquisition input connection types.

1.5. NetForce Software

AMTI's NetForce software for multi-axis force platforms monitors and stores up to 12 channels of real-time selectable data from two RS-232/USB products (MSA-6) **–OR–** four Ethernet or analog products **–OR–** twelve USB Gen 5\Optima signal conditioners. Real-time display mode includes a center of pressure (COP) graph and, with a few mouse clicks, the output of any of the installed multi-axis products.

NetForce provides top-end hardware speed while preserving reasonable performance on lower-end and legacy systems. For more information, please refer to the AMTI NetForce Manual.

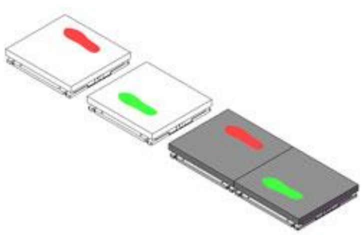
2. Force Platform Installation

AMTI technical support (support@amtimail.com, p: 617-926-6700, f: 617-926-5045) is available for additional assistance in planning your installation.

2.1.Choose a Mounting Configuration

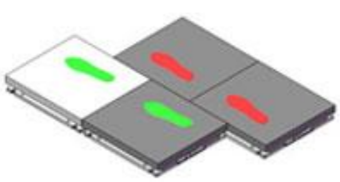
Most gait laboratories use multiple force plates to capture the reaction forces and moments generated throughout a full gait cycle. Two and four-platform setups are the most common installations.

The layout of a gait lab's force plates is largely dependent on the stride length of its subjects; for example, children require closer platform spacing than adults. Some of the most common platform layouts are shown below. The gray platforms indicate the number and position of the minimum platforms for each layout; white platforms show the location of additional recommended platforms. Three- or four-platform installations are generally preferred as they increase the number of foot strikes captured during the patient's gait cycle.



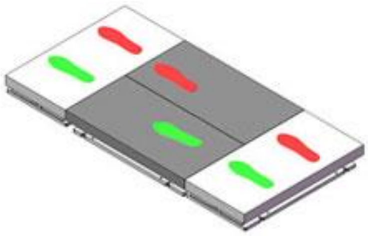
The **Inline Configuration** is used in a large number of gait labs as it provides a "corridor" where patients are less tempted to aim their foot strikes, thus changing their gait patterns. Platform spacing can be adjusted for step length variability, patients' age or application (walking, running, sports, etc). This layout may require the use of customized mounting rails and the thru top mounting option to allow for easy plate repositioning. Platforms located end to end may require a right angle connector on the platform signal cable.

Most common applications and platforms:
Gait – BP400600, OR6-7
Sports – OR6-6, OR6-7



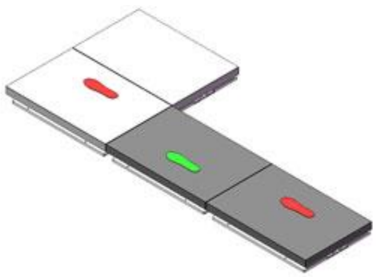
The **Staggered Configuration** is common in the gait community, although it is employed less often than the inline arrangement. It allows for adaptation to different step widths, which is often required when working with elderly patients due to their need for a larger base of support. The thru top mounting option is required when force platforms are located side by side.

Most common applications and platforms:
Gait – OR6-7
Sports – OR6-6



Gait Initiation/Gait Termination/Fall Prevention has become intensively studied protocols intended to test the effect of a central or peripheral disease on the sensorimotor functions. This configuration is used to record patients' COP patterns while initiating or terminating gait, as well as reaction times and movements during postural perturbations or secondary tasks.

Most common applications and platforms:
Neurosciences – BP400800
Aging – BP400800



An **Inline Configuration** using large force plates and is ideal for sport activities that involve multiple foot strikes over a long distance, such as running and jumping. The addition of an adjacent platform allows for the study of side-step cutting and activities that involve a large base of support. AMTI engineers can help design a mounting rail arrangement that allows the plates to translate in order to accommodate for different activities and stride lengths.

Most common applications and platforms:
Sports performance and training, landing, jumping, cutting and sprinting – BP600600, BP600900

2.2. Choose an Installation Method

For the highest-quality data, a Force Platform should be mounted on a surface that is sufficiently flat[1] and rigid[2] for the type of testing to be performed.

The best installation method is the one best suited to the type of testing to be performed:

- **Unmounted Force Platform**
  A platform may be left freestanding for certain activities, such as balance, that have relatively low-frequency dynamic content, low impulse loading, and low side loads. Freestanding installation may provide satisfactory results in these instances but is typically not recommended by AMTI unless using a portable force plate specifically designed for these applications. AMTI does not recommend using unmounted or unsecured force plates for dynamic activities that could result in movement of the platform, potentially injuring a subject.

  If using this method, care must be used to ensure the platform is on a flat surface. If the platform rocks or shakes when a load is applied, noise artifacts may be introduced into the data. Low pile carpeted floors generally work reasonably well under freestanding platforms as they distribute the applied load evenly. On hard floors, it is best to shim the platform until no rocking is evident with paper or metal shims.

- **Mounted Platform**
  For more dynamic test conditions such as running or jumping, you may need to bolt the force platform to a solid foundation using AMTI mounting rails or other customized mounting fixtures. AMTI sales personnel can provide advice and guidance regarding the best type of mounting fixtures for the type of testing you plan to conduct. The standard mounting rails are not in themselves rigid compared to the platform base plate, but the combined force platform and mounting rail structure becomes very rigid when the mounting rails are bonded to a concrete slab or floor. Standard mounting rails or custom mounting fixtures are designed to be bonded to a concrete substrate using epoxy adhesive, creating a permanent installation.

- **Movable Magnetic Mounting**
  The greatest platform placement flexibility can be achieved with AMTI's innovative magnetic mounting system, which allows for specially equipped platforms to be easily mounted and repositioned anywhere on a mounting surface up to several square meters in area.

  The system consists of a ferromagnetic stainless steel sheet bonded to a poured epoxy

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[1] Flat, i.e., flat and level over the area of the force platform to better than .05 mm (.002")

[2] A criterion for acceptable floor vibration can be found in Generic Criteria for Vibration-Sensitive Equipment by Colin G. Gordon. Refer to Proceedings of International Society for Optical Engineering (SPIE), Vol. 1619, San Jose, CA, November 4-6, 1991, pp. 71-85. Vibration levels should be less than the limit appropriate for Operating Theaters.

surface. Compatible platforms are equipped with magnetic hold-downs and air bearing casters, which activate with a simple air pump and allow the platform to be rolled into any position on the mounting stage.

Magnetic mounting systems must be manufactured in place and require considerable expertise. AMTI's sales team can help you determine the cost to install such a system at your site, as well as answer any additional questions you may have.

- **Slab-On-Grade**
  A permanent ground floor (slab-on grade) installation is recommended and should have depth of 15 to 45 cm of concrete (6 to 18") beneath the force platform and mounting plate. The goal is to reduce data errors caused by twisting (as with an unmounted platform on an uneven floor) and vibration (as with a platform mounted on an upper level without proper stabilization).

2.3.Slab-On-Grade Installation

Installation Checklist

- ☐ Make the pit deep enough to accommodate the force platform/mounting plate combination that you will be using. (See Table 2 for dimensions)
- ☐ Make the pit long and wide enough to adequately configure the force platform(s) for their intended use.
- ☐ If the pit is for a single platform, it may be wise to make it large enough to add additional platforms in the future. (This is especially important in new construction where the cost for constructing a larger pit during the initial construction is small compared to enlarging the pit in the future)
- ☐ Allow about 15 cm (6") of free space between the array of platforms and the end of the pit to allow access to the connector.
- ☐ Clearance of 2-3 mm (1/8") should be allowed around the entire platform. It is very important that the top surface of the force platform does not contact the surrounding floor.
- ☐ When larger clearances are provided around a force platform, the open space must be filled in. This can be done using commercially available raised access flooring, or by custom fabricated fillers made from lumber and other readily available materials.
- ☐ Allow for an electrical conduit to be run under the floor from the pit to the area where the computers will be located. This is for the force platform cable(s). The minimum recommended conduit size is 2 inch trade size per 2 cables. This allows the connector ends to be fed through the conduit. Long sweep bends should be used.
- ☐ Provide a way to connect the ground lug on the force platform to an earth ground.

Installation Dimensions

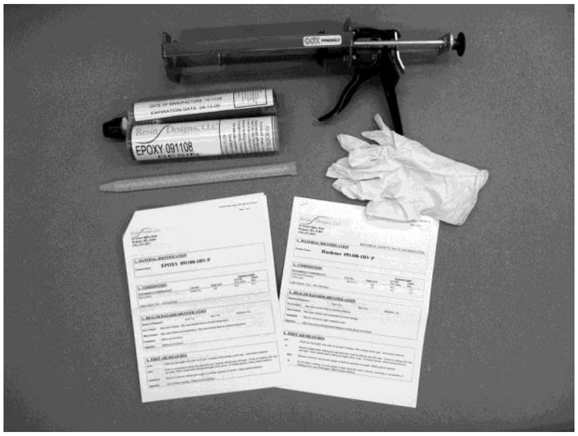
Force Platform Model Number (Capacities)	Force Platform size in mm width X length X height	Mounting Rail* Size in mm width X length X height
OR6-6 (1000, 2000, 4000)	464 X 508 X 82.5	101 X 508 X 25.4 mm rails
OR6-7 (1000, 2000, 4000)	464 X 508 X 82.5	101 X 508 X 25.4 mm rails
BP400600 (1000, 2000, 4000)	400 X 600 X 82.5	101 X 600 X 25.4 mm rails
BP400800 (1000, 2000, 4000)	400 X 800 X 102	101 X 800 X 25.4 mm rails
BP600900 (1000, 2000)	600 X 900 X 102	101 X 900 X 25.4 mm rails
BP600900 (4000)	600 X 900 X 102	101 X 900 X 25.4 mm rails
BP900900 (1000, 2000, 4000)	900 X 900 X 102	101 X 900 X 25.4 mm rails
BP6001200 (1000, 2000, 4000)	600 X 1200 X 102	101 X 1200 X 25.4 mm rails
BP12001200 (1000, 2000, 4000)	1200 X 1200 X 108	101 X 1200 X 25.4 mm rails

*2 mounting rails per force platform, one on each side.

Table 1: Installation Dimensions

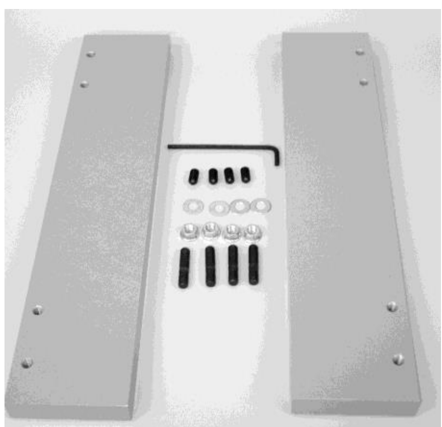
3.Mounting Installation Instructions

The following photos detail the mounting process for an AMTI model OR6-7 Force Platform. The same instructions will apply to any model AMTI Force Platform with the only difference being the length of the mounting rails and the amount of epoxy resin used.



Each resin kit contains:

- Epoxy dispensing device
- MSDS safety sheet
- Rubber gloves
- Epoxy 091108-1M1 cartridge set (includes combined tube of yellow adhesive and blue hardener components)
- Mixing wand attachment

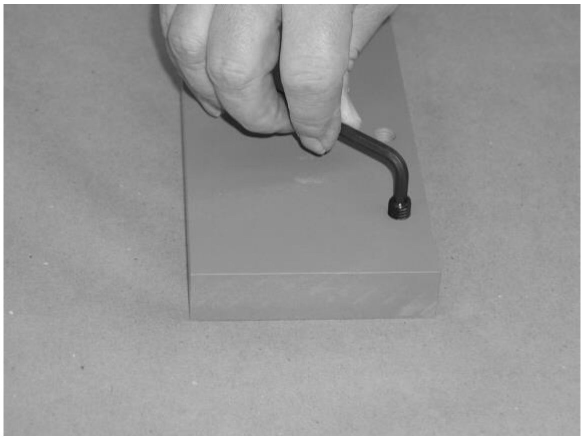


Each set of mounting rails contains:

- 1 Pair of Mounting Rails
- 4 each, 3/8” mounting studs
- 4 each, 3/8” flat washers
- 4 each, 3/8-24 flanged mounting nuts
- 4 each, 3/8-16 X 1” set screws
- 1 each, 3/16 hex key

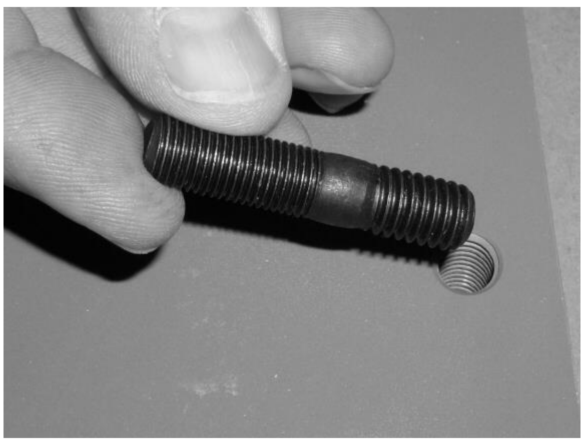
SAFETY NOTE Please read the enclosed MDS safety sheet before proceeding, and observe all safety precautions. Please contact AMTI at support@amtimail.com with any concerns.

1



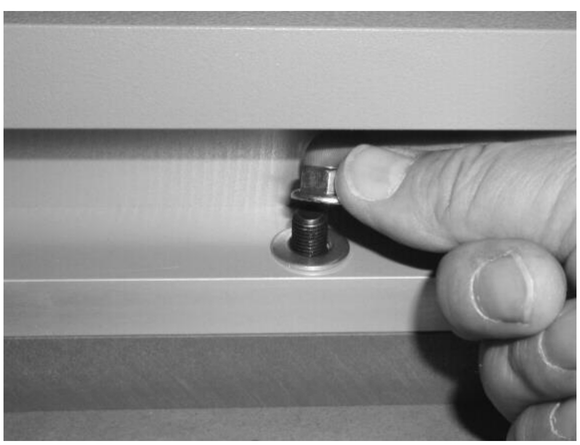
Insert the 3/8-16 set screws into the through holes in the mounting rails.

2

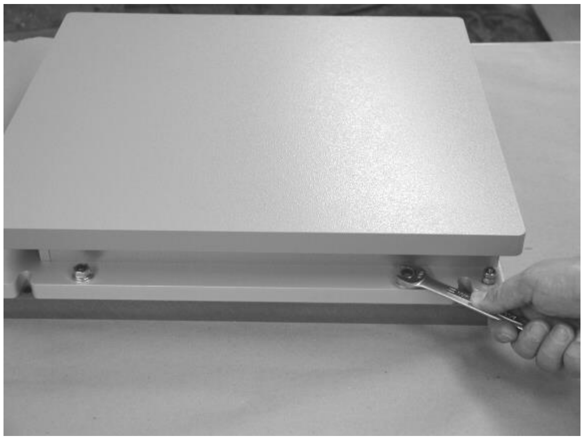


Insert the coarse threaded end of the 3/8 mounting studs into the remaining holes in the mounting rails.

3



Attach the mounting rails to the Force Platform using the 3/8 flat washers and the 3/8-24 flanged mounting nuts.

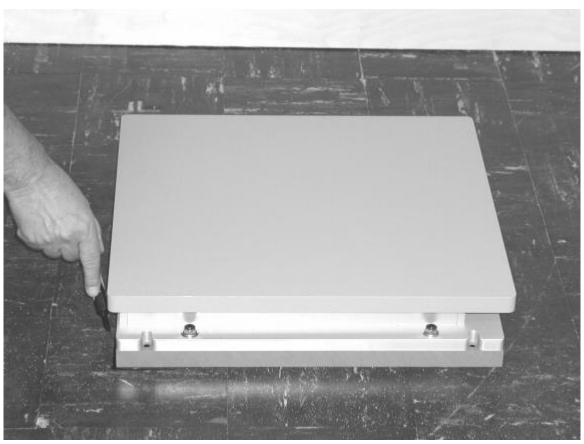


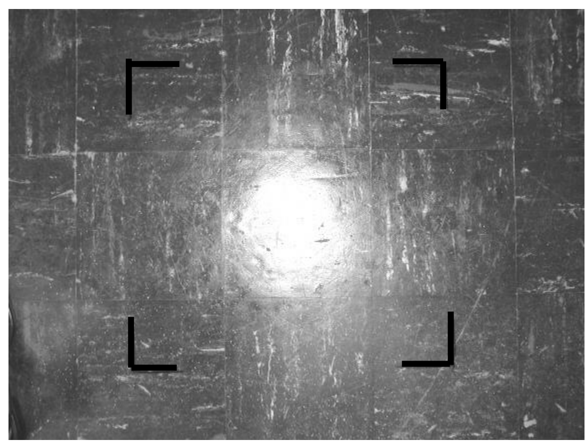
Use a size 9/16 wrench to tighten the mounting nuts to 250-350 in-lb. torque.

NOTE Steps 4–6 show how to install a Force Platform on top of an existing floor. If your installation site is new and has no floor covering, be sure to remove any wax, oil, or other agent that will inhibit the bonding process and skip to step 7.

Please contact AMTI at support@amtimail.com with any questions or concerns.

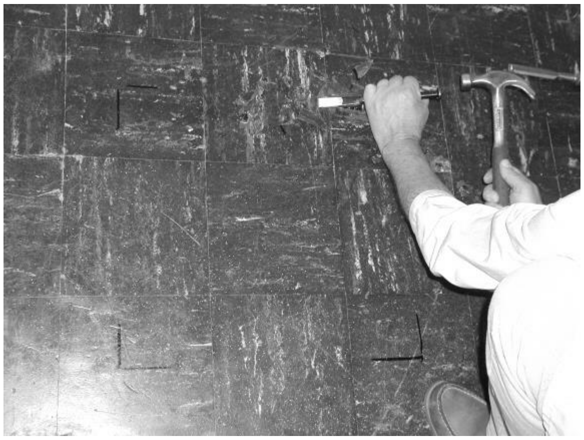
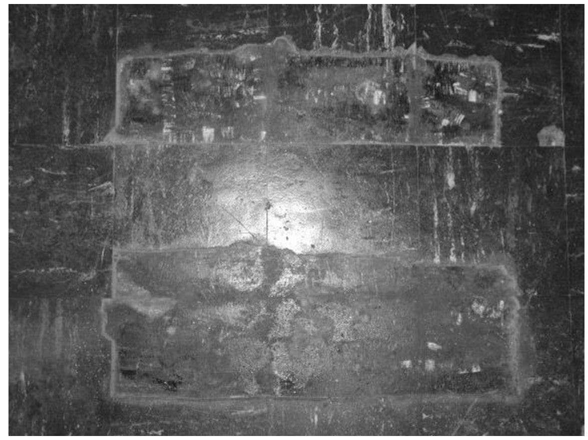
4





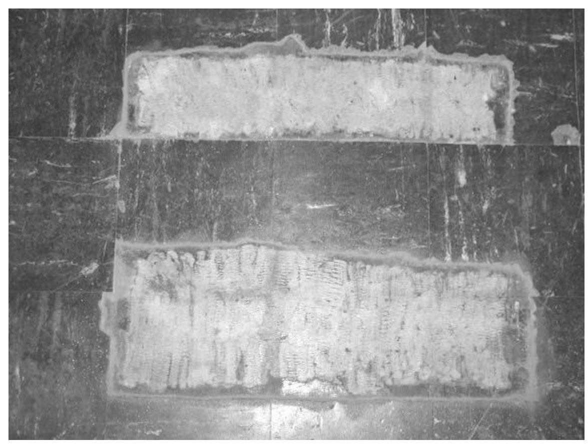
Determine the best location in the laboratory for mounting the Force Platform. Place the Force Platform in that location, and mark the position on the floor.

5

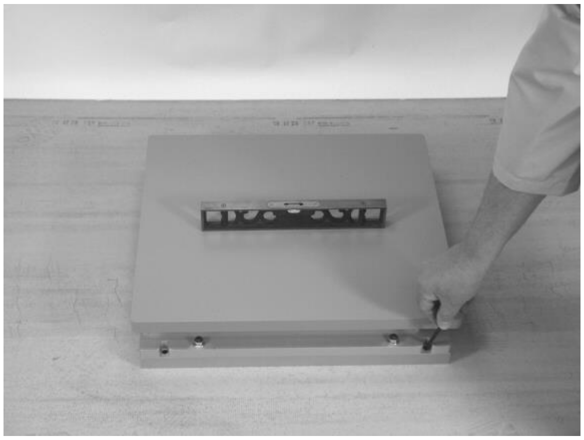
Remove the floor covering to expose the concrete underneath.

6

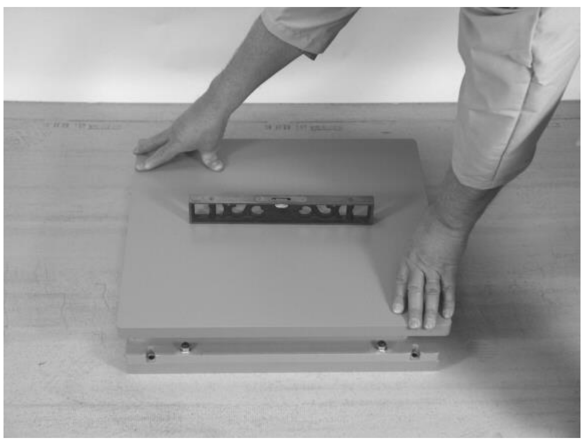



For best bonding results, remove any old tile adhesive and expose the bare concrete surface.

7

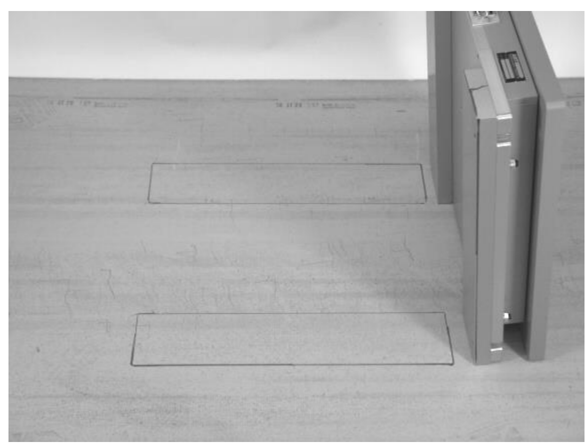


Place the Force Platform in the preferred location. Using the 3/8-16 set screws and the 3/16 hex key, level the Force Platform in both the X and Y directions, and set the appropriate height for your particular installation.



Be sure that the Force Platform is level and does not rock from corner to corner. All four leveling screws should be in contact with the floor surface under the mounting plate.

(At this time make a note of the size of the gap that exists between the bottom of the mounting rails and the mounting surface. This gap will later be filled with resin).

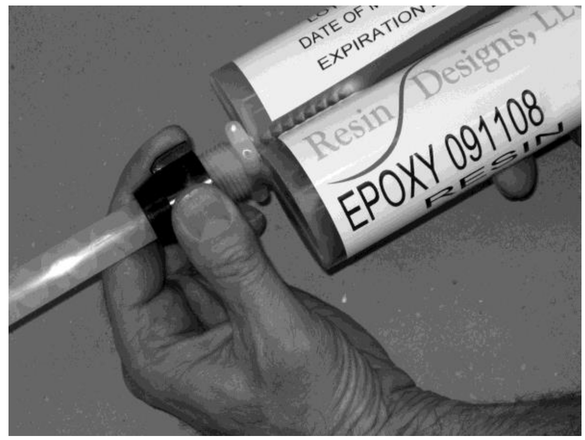


Mark the exact location of the mounting rails on the floor. The platform and attached mounting rails should then be removed so a straight edge can be used to finish marking the rail locations, and the epoxy can be applied to the marked areas. After the epoxy resin has been applied, the Force Platform should be returned to this marked location.

8 Mix the epoxy resin

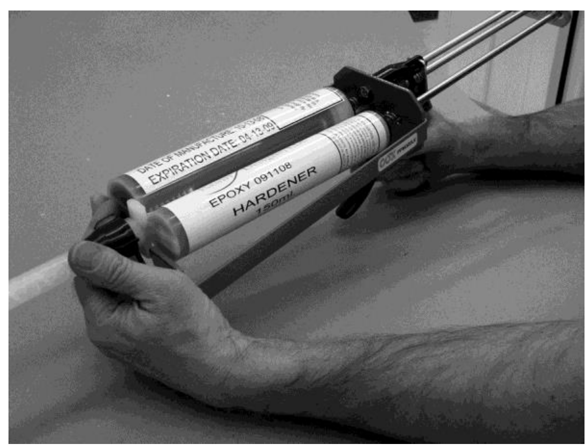
NOTE | The cartridges should be dispensed and cured at a minimum of 65°F. After the epoxy is mixed, it will have a workable life of approximately 2 hours. The epoxy will reach 90% cure in 48 hours at 70°F, and will fully cure in 7 days.

a



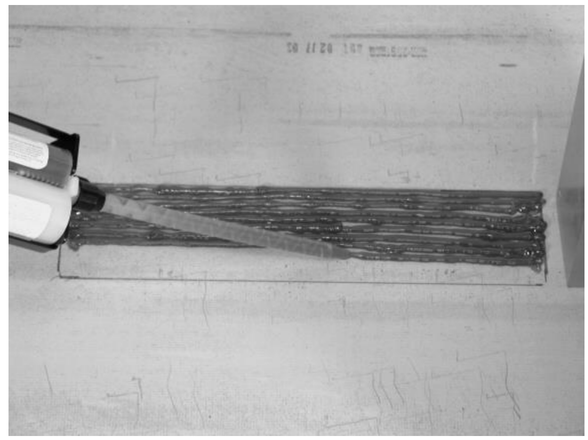
Unscrew the black locknut from the epoxy cartridge, and place to the side. Pull out the 2 small black plugs from the cartridge spouts. Attach the mixing wand to the end of the cartridge by sliding the black locknut over the tip of the nozzle and then screwing it into the end of the cartridge until it is snug.

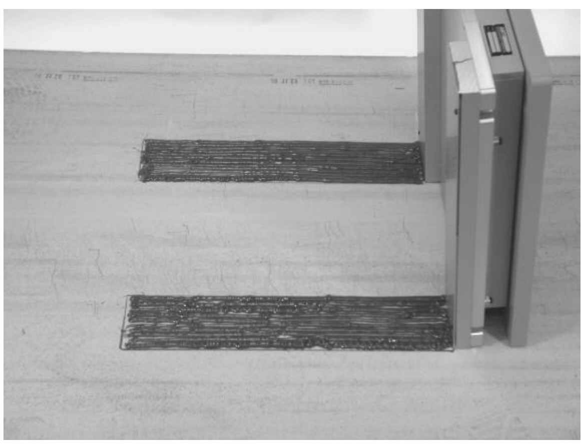
b



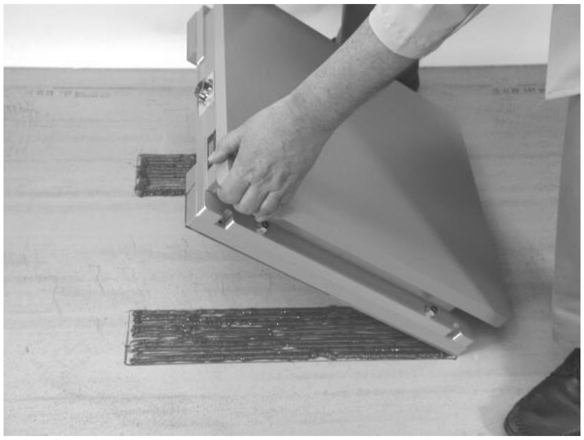
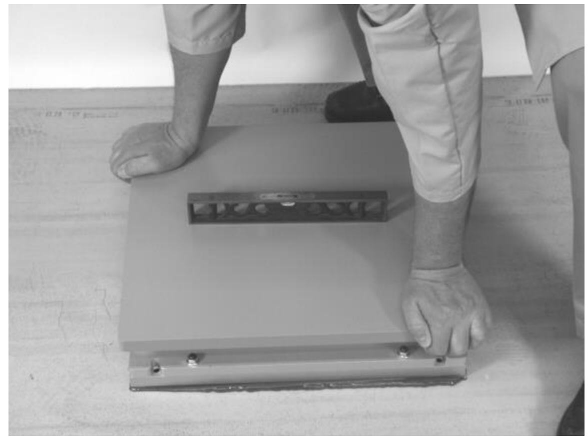
Depress the silver latch on the dispensing device with your thumb while you pull back the black knob. Place the epoxy cartridge so the black depressors fit inside the barrels, and the cartridge tip fits in the notch on the front of the dispensing device frame. Squeeze the handle to get the epoxy flowing through the mixing wand so it turns green. If an additional cartridge is needed, the mixing wand can be transferred to the new cartridge set as long as it is used prior to hardening. It is also possible to mix the epoxy by hand without the mixing wand if necessary.

9





Place a layer of resin on the Force Platform location that was marked in step 8. Make sure that the layer will be thick enough to fill the gap that was noted in step 7. A cartridge set contains 450 mL or 27.5 in^3 of epoxy. The OR6-7 rails are each 4”x20”, so there is enough epoxy in a cartridge set to fill a .172” gap under the rails. If the average gap is slightly more than .172” it is not necessary to fully fill the entire area under the rails. If the gap is more than .2”, it is better to use an additional cartridge set. The suggested nominal gap is .125”, but thicker gaps will still result in a stiff mounting installation.

10  

Return the Force Platform, with the mounting rails attached, to the location marked in step 8. Push the platform down into the resin to make sure that the leveling screws come in contact with the mounting surface.

11 

Recheck the level and location of the platform.

NOTE

DO NOT remove the Force Platform from the mounting rails for at least 48 hours. The resin must be given time to sufficiently harden before the Force Platform is removed from the rails.

4.Ground the Force Platform

Force platforms should be connected to an earth ground, such as the ground lug of a proper electrical outlet. The shield of a platform cable is electrically connected to the connector shell at both ends in the as-shipped configuration. This provides a ground path between the force platform and the amplifier. Depending on the output signal configuration, it is possible to form a “ground loop”, which can lead to an excessively noisy signal. AMTI recommends trying the cable as received. If the signal is noisy, the shield can be disconnected at the amplifier end of the cable by disconnecting the green wire from the connector back-shell clamp.

Appendix A: Force Plate Functional Overview

AMTI utilizes two types of sensing technologies in its products: Hall Effect and strain gage. Each offers distinct benefits and requires a unique hardware setup.

Hall Effect

Hall Effect force plates and force sensors are economical, lightweight, portable instruments that function as standalone systems for specific applications. Their patented design uses Hall Effect sensors to measure all six force components and allows for high overload protection on all axes.

Multiple Hall Effect sensors and magnets are arranged inside the force transducer. The sensors measure magnetic field changes that occur when integrated spring elements deflect due to the forces and moments acting upon the top surface.

Signal amplification occurs inside AMTI’s Hall Effect-based products, eliminating the need for an external amplifier and limiting the necessary system components to an analog or digital data cable. If the digital output is used, an interconnection box may be used to connect two force plates or force sensors to a computer.

Mounting is possible with Hall Effect force plates, but is typically unnecessary for the recommended applications.

Strain Gage

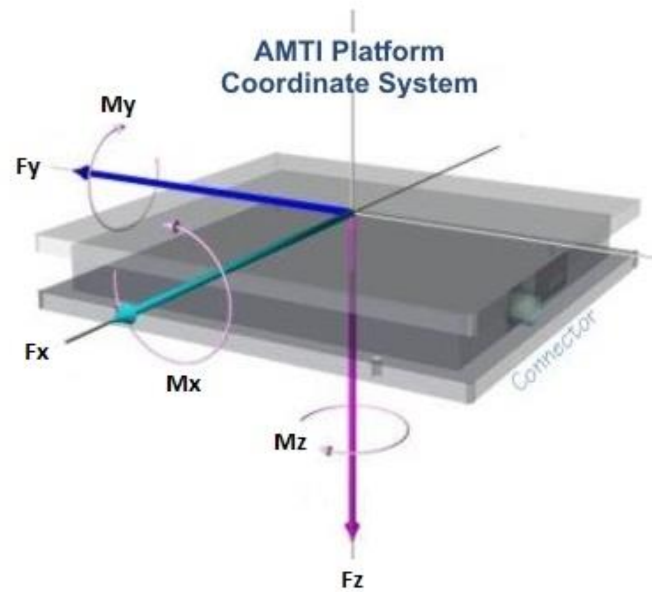
Most of AMTI's products use strain gage technology, which provides the most accurate and flexible force measurement solution. (Hall Effect platforms offer comparable measurement performance when employed for their intended use.)

The working surface of an AMTI strain gage-based product is supported by thin-walled cylindrical sensing elements. Each element is instrumented with strain gages, which are excited by a constant voltage supplied by the connected signal conditioner.

When a load is applied to the working surface of the transducer, strains occur in the walls of the supporting cylinders. This changes the electrical resistance of the strain gages and produces a change in the output voltage that is proportional to the forces being applied. AMTI's proprietary arrangement of strain gages isolates the signals caused by individual forces and moments, allowing them to be accurately and separately quantified.

AMTI Force Platforms sense these forces and moments in relation to a set of XYZ axes. The forces and moments are measured by strain gages attached to proprietary load cells near the four corners of the platform. The gages form six Wheatstone bridges with four active arms each and eight or more gages per bridge.

Three of the bridge output signals are proportional to the forces parallel to the three axes and the other three outputs are proportional to the moments about the three axes. The diagram below shows the three force and the three moment components that are measured as a subject is in contact with the platform.



Fx, Fy, and Fz are the force components and act along the axes of an orthogonal x, y, z-coordinate system. In the diagram, the arrows point in the direction of positive force along each of the axes, following the right-hand rule. Fx and Fy are the horizontal or shear force components, and Fz is the vertical force component.

Mx, My and Mz are the three moment components. Moments are rotations around the corresponding x, y and z axes. Positive moments are determined according to the right hand rule. When looking down an axis (in its positive direction) positive moments have a clockwise rotation.

The measurement origin (x=0, y=0, z=0) lies at X, Y and Z offsets from the top surface geometric center. The X- and Y-axis origins lie approximately in the center of the top plate, but the Z-axis origin is located a significant distance (Z_0) below the surface. The exact location of the measurement origin is provided with the force platform calibration certificate.

Smart Platforms

All AMTI force platforms* with serial numbers ending in 'M' are equipped with Smart Chip technology, which uses an EPROM[3] to store the transducer serial number and other platform data. The function of the Smart chip varies with your amplifier:

Optima Signal Conditioner (OPT-SC): The OPT-SC signal conditioner is used exclusively as part of AMTI's Optima Human Performance System. The Precision Calibration files used by the Optima HPS are so complex they must be stored on the connected PC; however, once the calibration is loaded and matched to the correct force plate, the connection is maintained. Any time thereafter the platform is connected to the PC, the correct Precision Calibration file will be

[3] A memory chip that maintains its data when power is shut off.

automatically applied. Please note that the force platform must be plugged in before turning on the amplifier in order to read the Smart Chip.

Gen 5: When a Gen 5 amplifier is connected to an AMTI Force Platform with Smart Chip technology, the amplifier automatically retrieves the platform calibration data from the Smart Chip, providing a plug-and-play-style system. (Please note that the force platform must be plugged in before turning on the amplifier in order to read the Smart Chip.) The chip can hold up to 8 sets of calibration data, allowing for several recalibrations. In the unlikely event that a customer requests more than eight re-calibrations over the life of the platform, the memory chip can be replaced.

MSA-6: MSA-6 amplifiers do not make use of Smart Chip technology. Each AMTI force platform that contains a Smart Chip is shipped with a calibration CD, allowing the user to save the file to their PC and manually identify the correct calibration. As the Smart Chip is not read using this amplifier, the user is responsible for managing the association between connected platforms and calibration files. If another platform is connected to the amplifier, the user will need to load the correct platform calibration.

* Excluding custom products without a connector

Appendix B: AMTI Biomechanics Force Platform Output Connections

The maximum recommended excitation voltage is 10 VDC.

Pin	Function	Channel	Pin	Function	Channel
A	+ Excitation	Fx	N	+ Excitation	Mx
B	- Excitation	Fx	P	- Excitation	Mx
C	- Output	Fx	R	- Output	Mx
D	+ Output	Fx	S	+ Output	Mx
E	+ Excitation	Fy	T	+ Excitation	My
F	- Excitation	Fy	U	- Excitation	My
G	- Output	Fy	V	- Output	My
H	+ Output	Fy	W	+ Output	My
J	+ Excitation	Fz	X	+ Excitation	Mz
K	- Excitation	Fz	Y	- Excitation	Mz
L	- Output	Fz	Z	- Output	Mz
M	+ Output	Fz	a	+ Output	Mz
			b	Smart Chip SIG	
			c	Smart Chip GNP	

Table B1. Force Platform Output Connections

Appendix C: Standard Force Platform Calibration

The calibration of a force platform involves determining the sensitivity of each channel to all applied load components.

For the standard AMTI calibration process, the platform is bolted to a precision calibration stand. Loads are then applied at various points in the three coordinate directions while the outputs from all six channels are recorded. The location of the XYZ origin is computed from the data. It is given in the calibration report, relative to the geometrical center of the top surface.

The platform's calibration report provides the channel "sensitivities" in a 6 x 6 matrix (shown below. On the calibration report provided with the transducer, the S_{ij} terms are replaced with actual values).

S(I,J)	Fx	Fy	Fz	Mx	My	Mz
Fx'	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}
Fy'	S_{21}	S_{22}	S_{23}	S_{24}	S_{25}	S_{26}
Fz'	S_{31}	S_{32}	S_{33}	S_{34}	S_{35}	S_{36}
Mx'	S_{41}	S_{42}	S_{43}	S_{44}	S_{45}	S_{46}
My'	S_{51}	S_{52}	S_{53}	S_{54}	S_{55}	S_{56}
Mz'	S_{61}	S_{62}	S_{63}	S_{64}	S_{65}	S_{66}

Table C1: Sensitivity matrix

In this matrix, the output for each channel is represented by the left column and the input load is shown on the top row (i.e. the output, in micro-volts/volt-of-excitation, for the Fx channel is Fx'). The main diagonal terms represent the channel sensitivities and the off-diagonal terms are the crosstalk values. Crosstalk is the output on channels not corresponding to the input channel in response to a load on that channel. The units for sensitivity are micro-volts/volt-of-excitation/unit-of-load.

The matrix equation for calculating the transducer outputs for a given input load involved is shown in equation 1.

Equation 1:

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} & S_{15} & S_{16} \\ S_{21} & S_{22} & S_{23} & S_{24} & S_{25} & S_{26} \\ S_{31} & S_{32} & S_{33} & S_{34} & S_{35} & S_{36} \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} & S_{46} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & S_{56} \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{bmatrix} * \begin{bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{bmatrix} * \begin{bmatrix} CF_x \\ CF_y \\ CF_z \\ CF_x \\ CF_y \\ CF_z \end{bmatrix} = \begin{bmatrix} V_{Fx} \\ V_{Fy} \\ V_{Fz} \\ V_{Fx} \\ V_{Fy} \\ V_{Fz} \end{bmatrix}$$

As an example, the output voltage for channel 3 (V_{Fz}) for a set of known input loads (Fx, Fy, Fz, Mx, My, Mz) would be:

Equation 2: $V_{Fz} = (S_{31}*F_x+S_{32}*F_y+S_{33}*F_z+S_{34}*M_x+S_{35}*M_y+S_{36}*M_z)*CF$

CF is a conversion factor that includes the amplifier gain and excitation voltage (discussed below) for channel 3. The units for V_{Fz} are Volts.

In practice, the crosstalk terms are small and can usually be ignored, so equation 1 can be reduced to:

Equation 3: $V_{Fz}= S_{33}*F_z*CF$

Similar equations are used for the other five outputs.

The calibration report provides four matrices. The first two matrices are in SI units (N, N-m) and the last two are in English units (lb, in-lb.) labeled USC units. The first and third matrix on the report are the sensitivity matrices S(i,j). The second and fourth matrices are the calibration matrices B(i,j). The calibration matrix is the inverse of the sensitivity matrix and can be used to calculate the input loads for known output voltages. The full matrix calculation of applied loads is shown in equation 4.

The calculation of a specific load is similar to equation 2 if the crosstalk terms are included in the calculation.

Equation 4: $F_z = (B_{31}*V_{Fx}+B_{32}*V_{Fy}+B_{33}*V_{Fz}+B_{34}*V_{Mx}+B_{35}*V_{My}+B_{36}*V_{Mz})/CF$

If only the main diagonal terms are used, then the input load for a given output voltage can be calculated using either:

Equation 5: $F_z = V_{Fz}/(S_{33}*CF)$ or $F_z=(V_{Fz}*B_{33})/CF$

This is true because the calibration matrices are the inverses of the sensitivity matrices. B_{33} is taken from the appropriate calibration matrix.

The conversion factor, CF, includes the amplifier gain, excitation voltage, and a factor of .000001 to convert from microvolts to volts. The micro-volt to volt conversion factor allows the use of the matrix numbers directly without added exponents.

Example: $CF = V_{excite}*G_{amp}*10^{-6}$

Typically, the excitation voltage is 10 volts and the amplifier gain is 4000 (but these values could be different for each channel). In this example, the value for CF is 0.04.

For an OR6-7-2000, the sensitivity for the Fz channel is approximately 0.08 micro-volt/volt/N, so (using equation 2) the output level for a 1000 N input load is

V_{Fz} = 0.08*1000*0.04

VFz = 3.2 Volts

Using the above equations the saturation load for a gain of 4000 can be calculated by computing the input load, which generates a 10 Volt output signal:

Fz = 10/(.08*.04)

Fz = 3125 N

If the input load exceeds 3125 N, then the amplifier gain should be reduced so that the output voltage remains below the saturation value of 10 volts. If the gain is changed, then the conversion factor, CF, should be recalculated.

NOTE: Due to electrical noise considerations it is best to reduce the gain on a saturated channel rather than the excitation voltage when the choice is available.

Although the three force components of the resultant applied force (Fx, Fy, Fz) are independent of the true XYZ location of the resultant, the moment outputs (Mx, My, Mz) are not. If a force is applied to the top surface at location X, Y (and Z_0, a negative number), the moment outputs are:

$$Mx = Fx*0 - Fy*Z_0 + Fz*Y + Tx$$

$$My = Fx*Z_0 + Fy*0 - Fz*X + Ty$$

$$Mz = - Fx*Y + Fy*X + Fz*0 + Tz$$

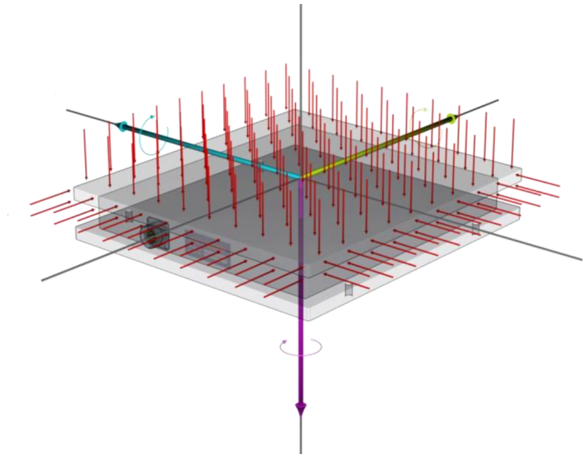
Where Tx, Ty and Tz are the pure moments applied to the top of the plate.

Under normal conditions there is no physical way to apply Tx or Ty, so Tx=Ty=0. Then, knowing Z_0 (from the calibration procedure) and the three outputs (Mx, My, Mz), we can determine X, Y, and Tz (the location of the resultant force vector and the moment applied about the Z-axis). In many applications the horizontal loads are small and the equations for Mx and My can be replaced by a good approximate set:

Mx = Fz*Y thus:	Y = Mx/Fz
My = - Fz*X	X = My/Fz
Mz = - Fx*Y + Fy*X + Tz	

Appendix D: Optima Force Platform Calibration

The calibration of an Optima system is an exacting process involving up to 4000 measurements taken along a 1-inch-grid pattern.



Multiple loads are applied at up to 400 locations using a precision machine capable of maintaining absolute positioning accuracy of 0.005 mm (certified by The Association For Manufacturing Technology).

Live loads from 50 pounds to Full Scale Capacity (FSC) are applied across the top and sides of the force plate.

Dead weights of 50, 100, and 200 pounds (accurate to 0.01%) are used to verify the system's performance in the physiological testing range.

Secondary characteristics, such as linearity and hysteresis are measured at eight locations using a ten-point-up, ten-point-down calibration protocol.

This exhaustive calibration and verification process ensures that each Optima system offers the best possible quality, accuracy, and performance available.

In your Optima Precision Calibration report, you will find three plots that characterize the accuracy of your Optima-HPS platform at 200.00 lb. (890 N) applied Fz load. Each intersection of the grids represents a physical location at which performance verification data was taken. Any measurement deviation is reflected by the contours of the plots that extend above and below the zero plane.

Appendix E: AMTI Biomechanics Force Platform Mounting Surface Specification Detail

Force platforms behave like accelerometers and can produce data outputs from floor vibrations, so the mounting surface must be as flat and rigid as possible. Criteria for acceptable floor vibration can be found in Generic Criteria for Vibration-Sensitive Equipment by Colin G. Gordon. Refer to Proceedings of International Society for Optical Engineering (SPIE), Vol. 1619, San Jose, CA, November 4-6, 1991, pp. 71-85. Vibration levels should be less than the limit appropriate for Operating Theaters.

"Rigidity" and "strength" may be related but are not the same. There are many possible mounting methods that are strong enough but not sufficiently rigid. Metal plates and structural steel weldments that seem rigid can flex and bend the force platform.

"Rigid" itself is a relative term. For the highest quality data from the AMTI Force Platform, the base structure should have higher rigidity than the sensors and top plate. You can minimize vibration-induced errors by firmly bolting the entire platform, including the base structure, to a rigid mounting surface. (The platform base itself is only moderately rigid; it is stiffened by the bolted connection to the mounting surface.)

Vibrations may be more or less difficult to control at your particular installation site. Mounting the platform on a ground floor is preferable, but if you must mount the platform on an upper floor level, locate it over support beams, near support columns, or near walls whenever possible.

Acceleration-caused outputs are related to the mass of the top plate; you can minimize them by going to a composite-top platform, which will have higher resonant frequencies. (AMTI Models OR6-6, BP400600HF, and all larger size force platforms).

The mounting surface should be not only rigid, but flat (i.e., flat and level over the area of the force platform to better than .05 mm (.002")). Bolting the force platform directly to any non-flat surface will cause the platform to bend or twist the sensing elements and can add extraneous forces and moments to the force plate. For some uses, it may be sufficient to make sure that the platform does not visibly rock when placed on the mounting surface.

Metal or other types of non-compressible shims can be used to eliminate rocking if necessary, but the initial mounting installation should be made as flat as possible. The force platform base should contact a flat, machined surface; un-machined cold-rolled or hot-rolled steel or aluminum surfaces are almost never flat enough to be used as a mounting surface. AMTI manufactures mounting fixtures using commercially available precision machined cast aluminum plate. Alcoa manufactures this material under the trade name MIC6.

Building vibrations tend to be of lower frequencies, and may be in the range relevant to the user. In that case the vibration signal cannot be removed from data by filtering. The bottom line is that the force platform should be mounted in a manner appropriate for the type of testing to be performed and the data quality desired. There is considerable latitude in the design of an installation, including several mounting methods and a broad choice of mounting configurations.