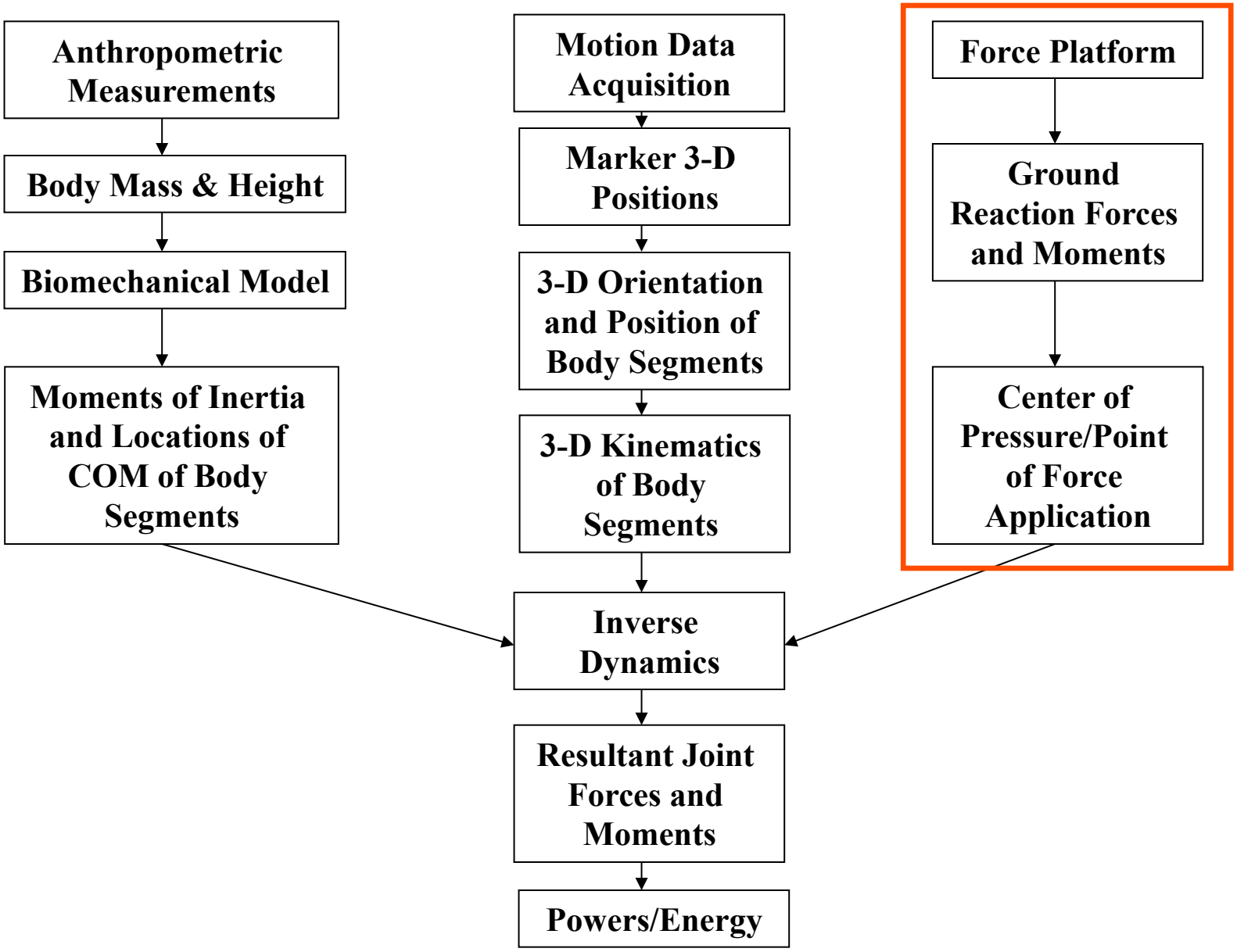
Three-Dimensional Biomechanical Analysis of Human Movement

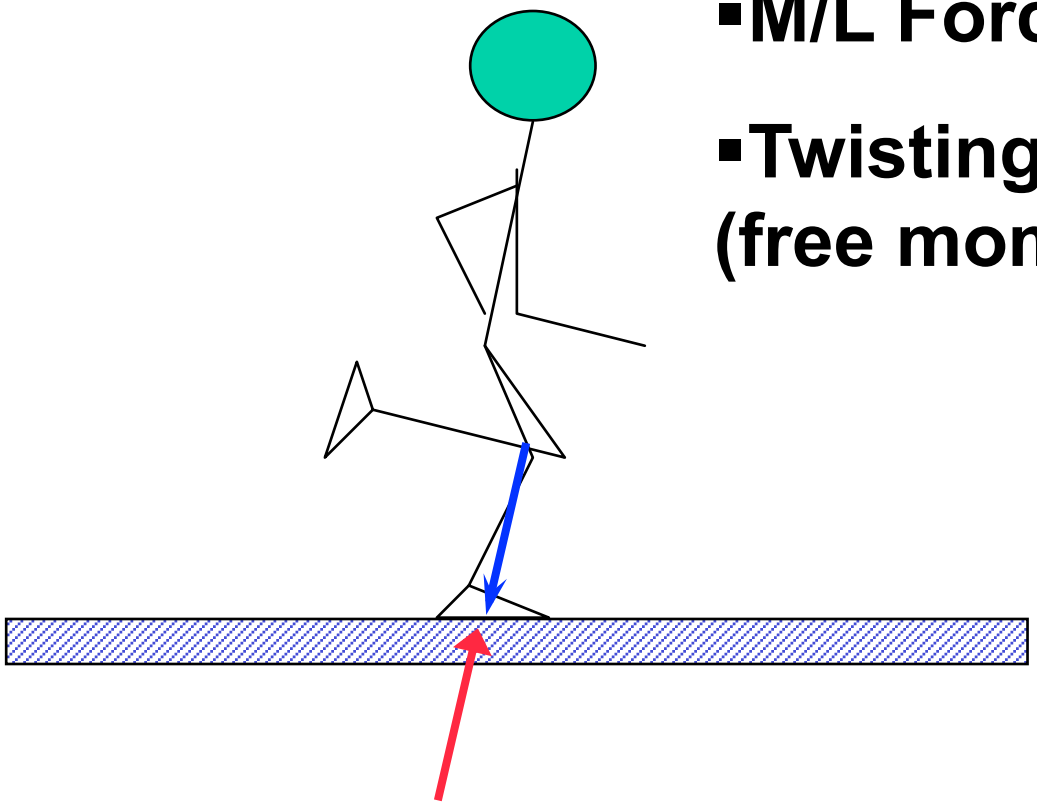


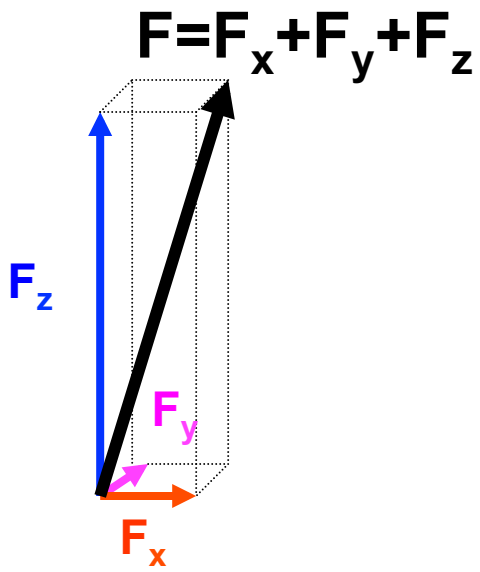
Ground Reaction Forces

- Vertical Force
- A/P Force
- M/L Force

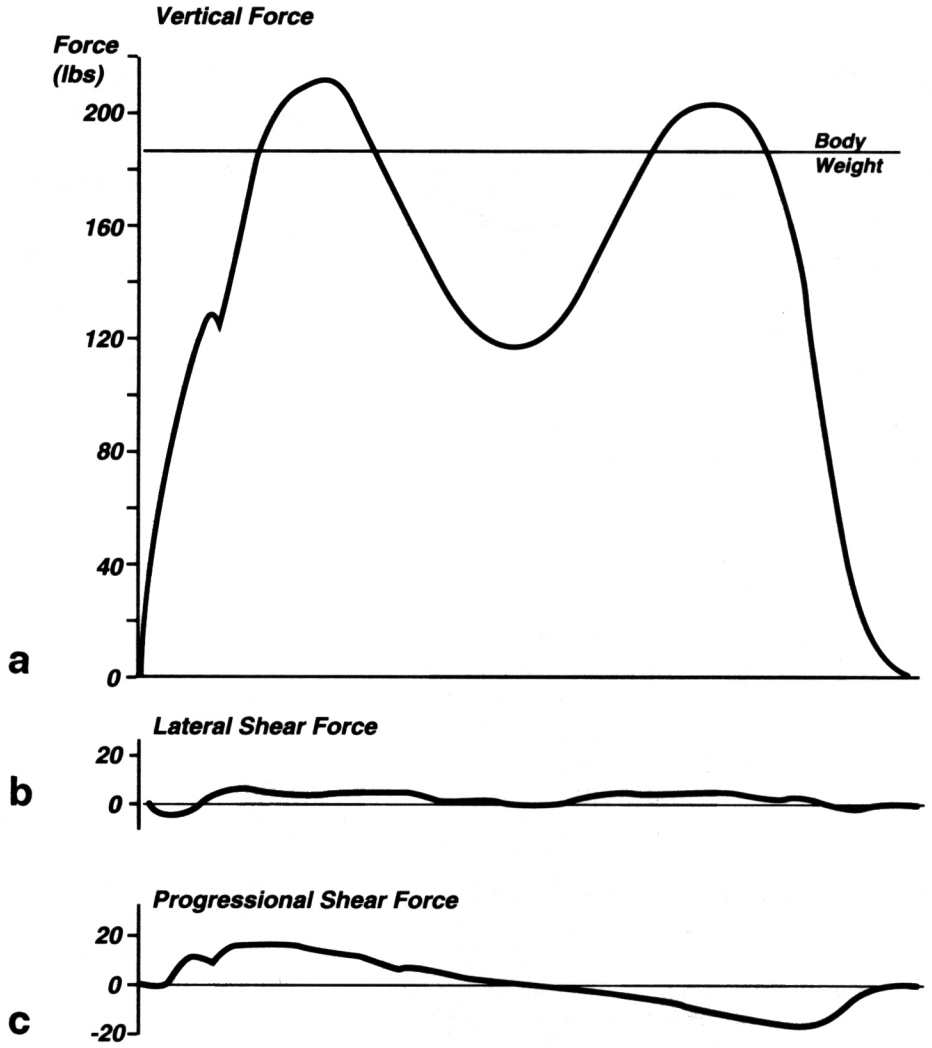
} Horizontal Shear

- Twisting Torque (free moment)





Ground Reaction Forces



Force Platforms

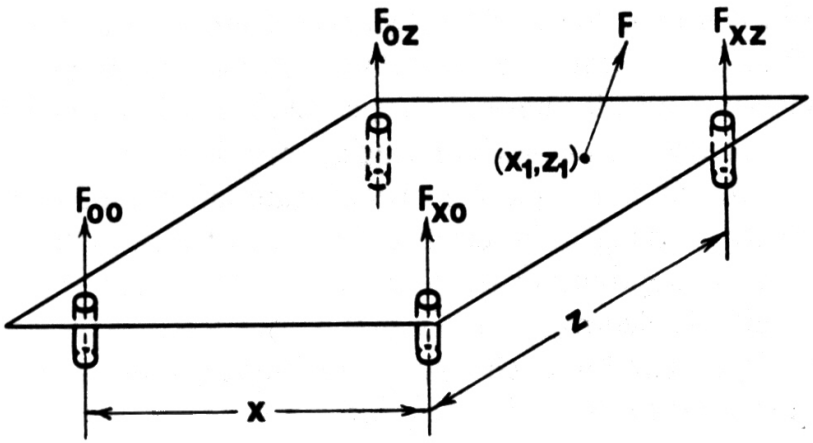
Piezoelectric type

A piezoelectric material, quartz crystal, will generate an electric charge when subject to mechanical strain. Quartz crystals are cut into disks that respond to mechanical strain in a single direction.

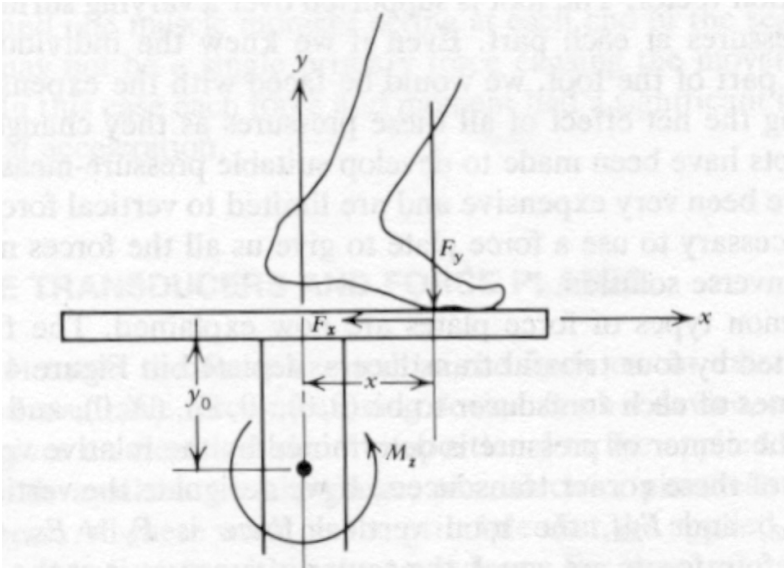
Strain Gauge type

Use strain gauge to measure stress in machined aluminum transducers (load cells). Deformation of the material causes a change in the resistance and thus a change in the voltage (Ohms Law: $V = I * R$).

Two Common Types of Force Plates

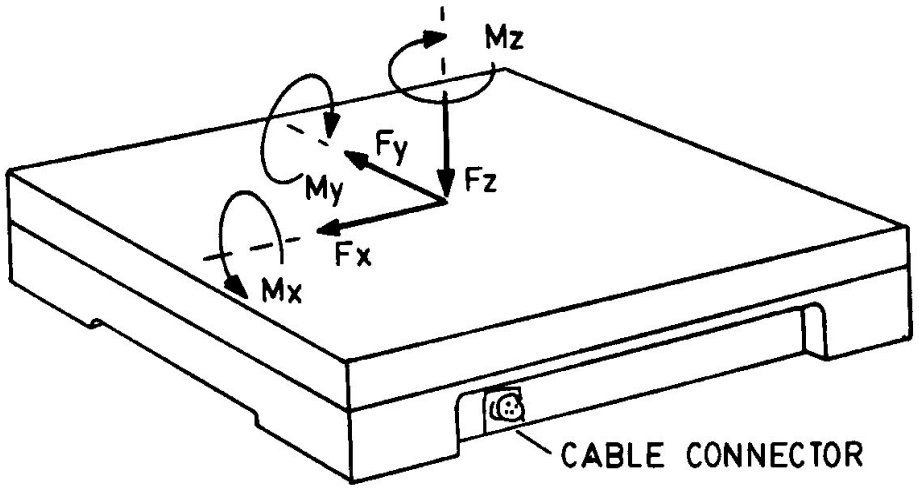


A flat plate supported by four triaxial transducers



A flat plate supported by one centrally instrumented pillar

AMTI (Strain Gauge) Force Platform



Output signals from the platform:

F_x: the anterior/posterior force

F_y: the medial/lateral force

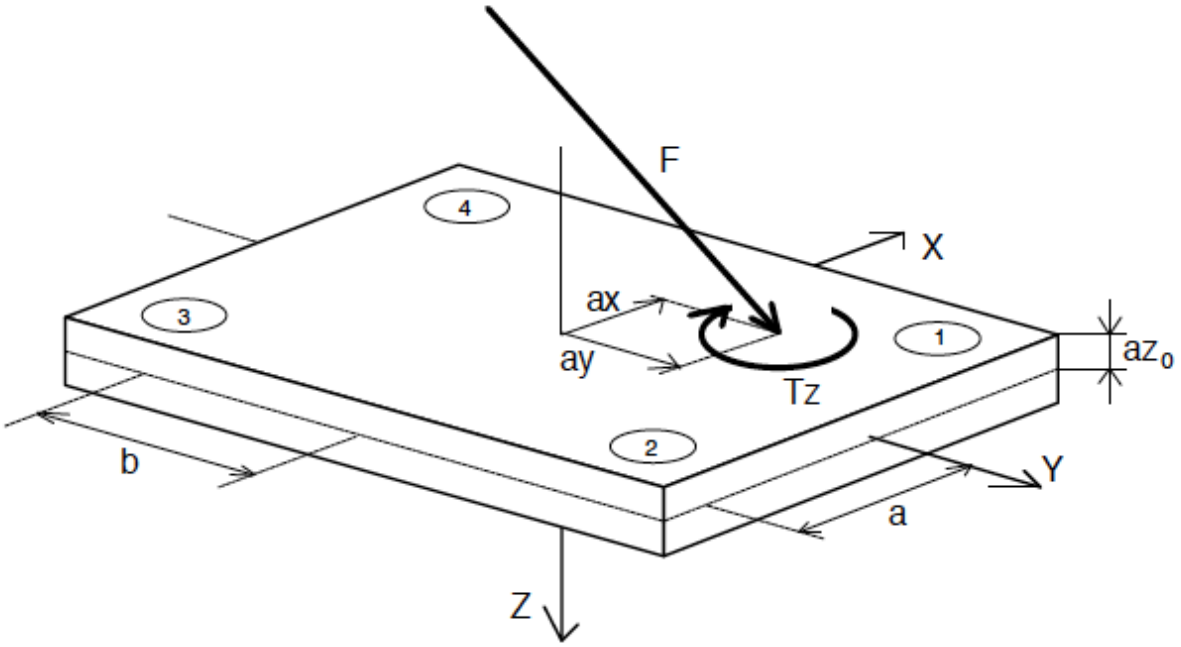
F_z: the vertical force

M_x: the moment about the anterior/posterior axis

M_y: the moment about the medial/lateral axis

M_z: the moment about the vertical axis

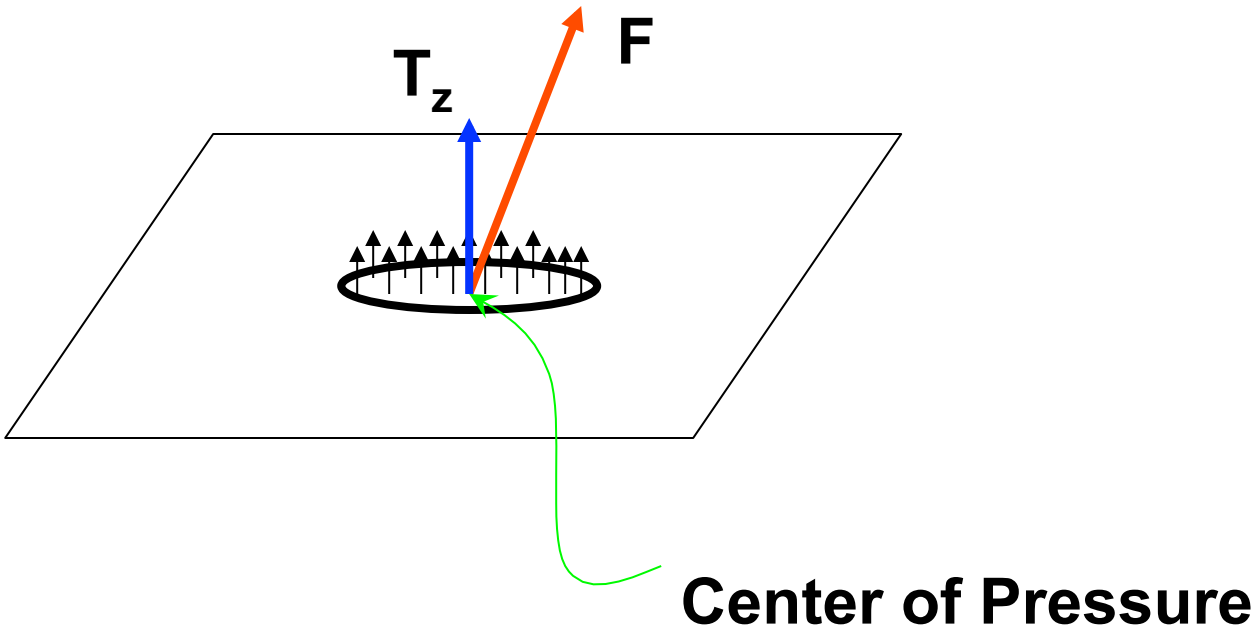
Kistler (Strain Gauge) Force Platform



Force plate output signals

Output signal	Channel	Description
fx12	1	Force in X-direction measured by sensor 1 + sensor 2
fx34	2	Force in X-direction measured by sensor 3 + sensor 4
fy14	3	Force in Y-direction measured by sensor 1 + sensor 4
fy23	4	Force in Y-direction measured by sensor 2 + sensor 3
fz1 ... fz4	5 ... 8	Force in Z direction measured by sensor 1 ... 4

Center of Pressure (COP)

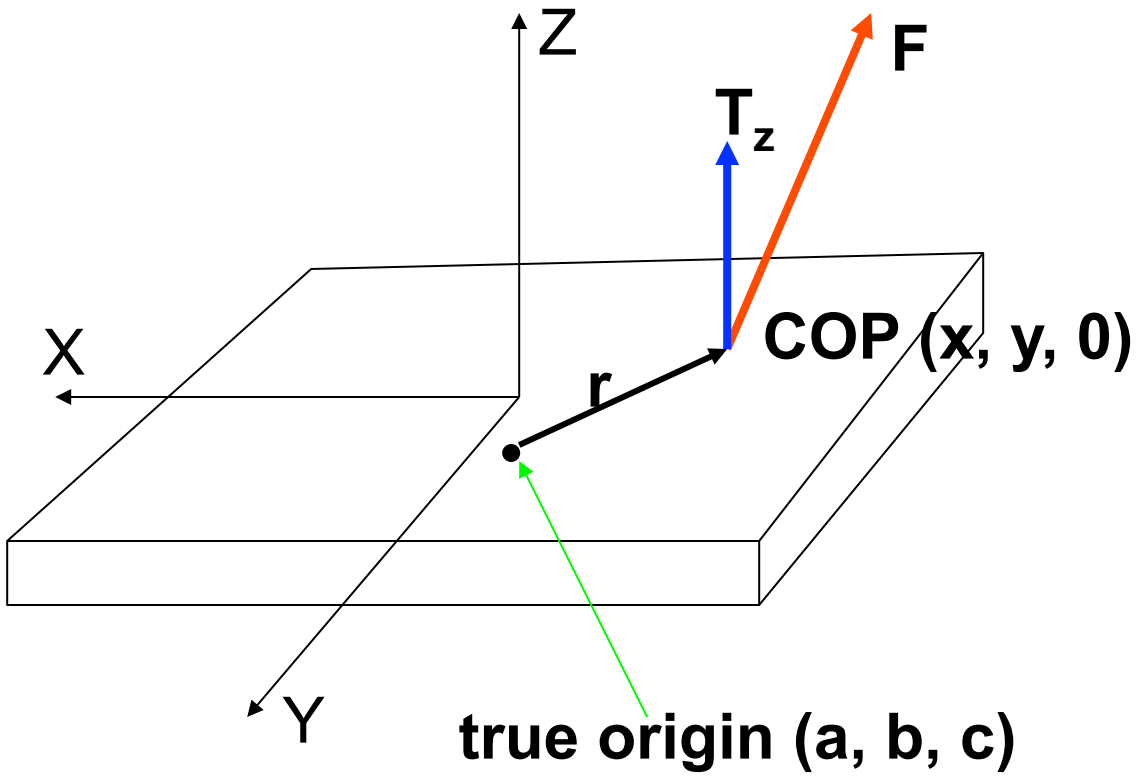


All the forces acting between the foot and the ground can be summed and yield a single reaction force vector (F) and a twisting torque vector (T_z about the vertical axis). Under normal condition there is no physical way to apply T_x and T_y.

The point of application of the ground reaction force on the plate is the center of pressure (COP).

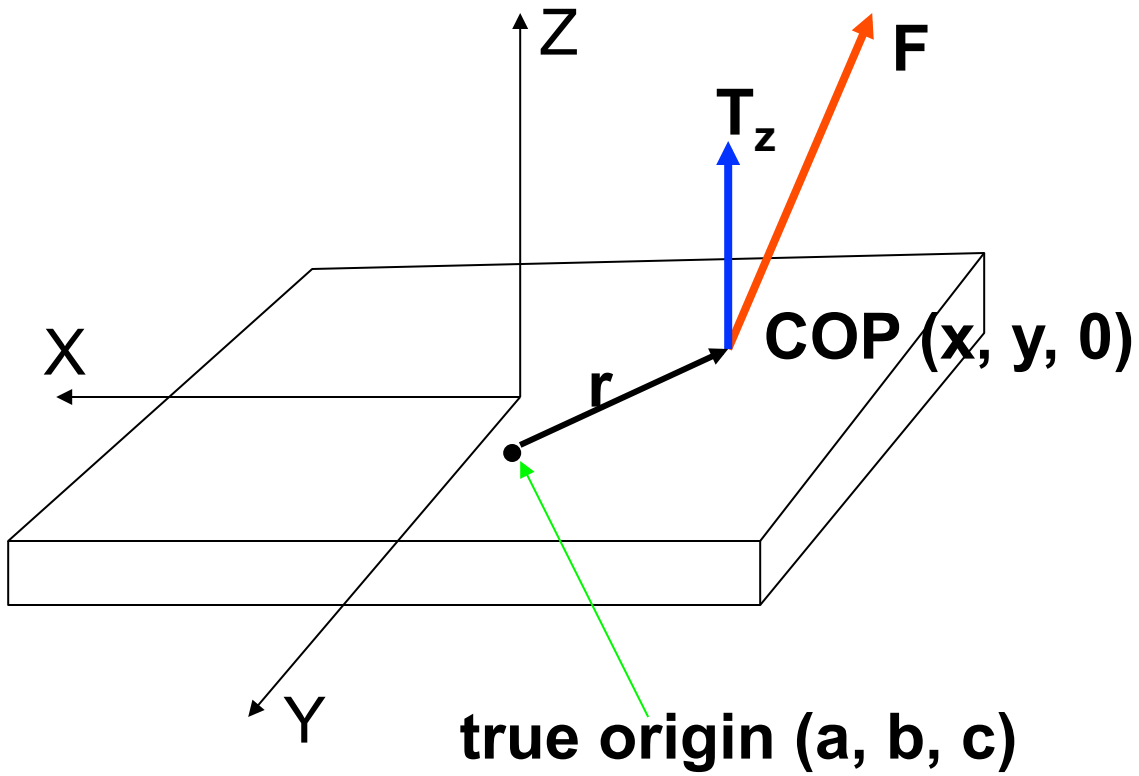
Computation of the COP

Generally, the true origin of the plate is not at the geometric center of the plate surface. The manufacturer usually provides the offset data.



The moment measured from the plate is equal to the moment caused by **F** about the true origin plus T_z.

Computation of the COP

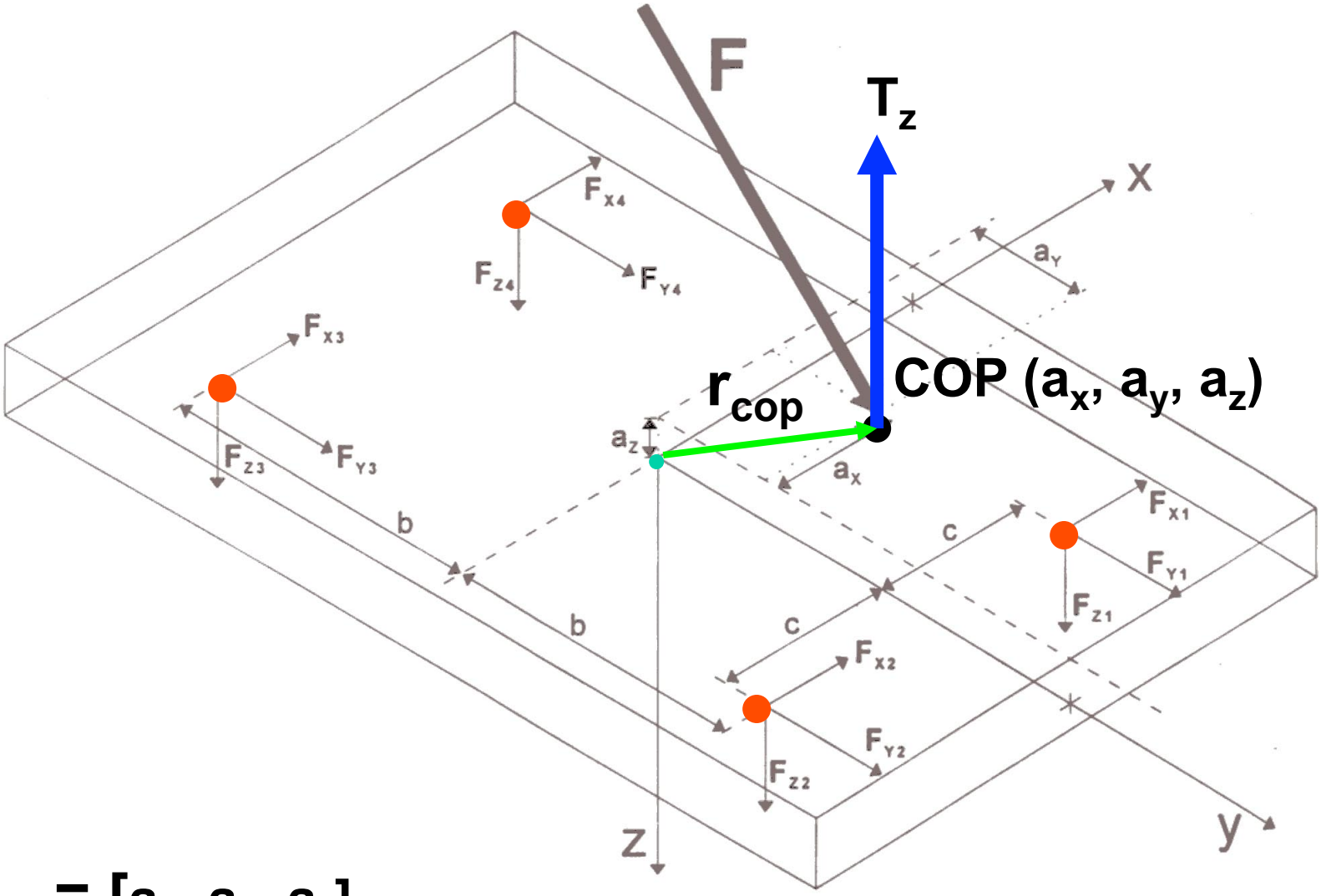


$$M = r \times F + T_z$$

Computation of the COP

$$M = r \times F + T_z$$

$r = (x-a, y-b, -c)$	known: a, b, c; unknown: x, y
$F = (F_x, F_y, F_z)$	force values from plate outputs
$T_z = (0, 0, T_z)$	unknown: T_z
$M = (M_x, M_y, M_z)$	torque values from plate outputs



$r_{cop} = [a_x, a_y, a_z]$

$M_{GRF} = r_{cop} \times F + T_z$

Computation of the COP

$$M_x = (y-b)\,F_z + c\,F_y$$

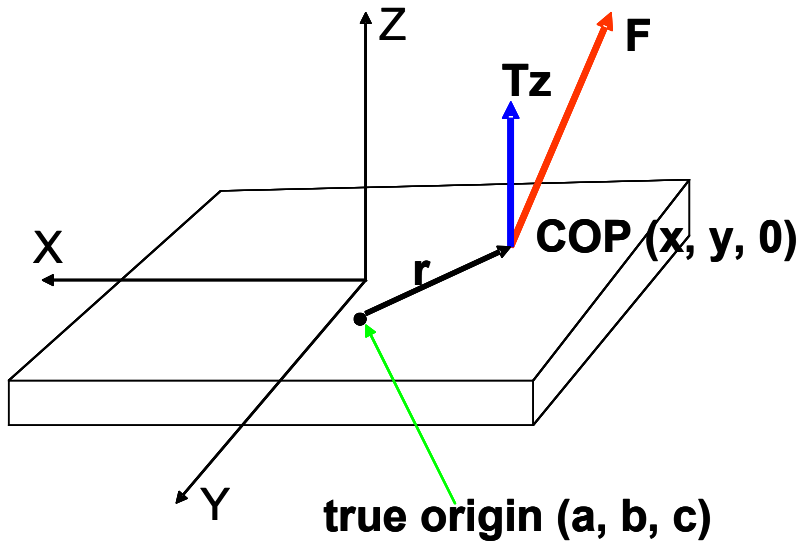
$$M_y = -c\,F_x - (x-a)\,F_z$$

$$M_z = (x-a)\,F_y - (y-b)\,F_x + T_z$$

$$x = -(M_y + cF_x)/F_z + a$$

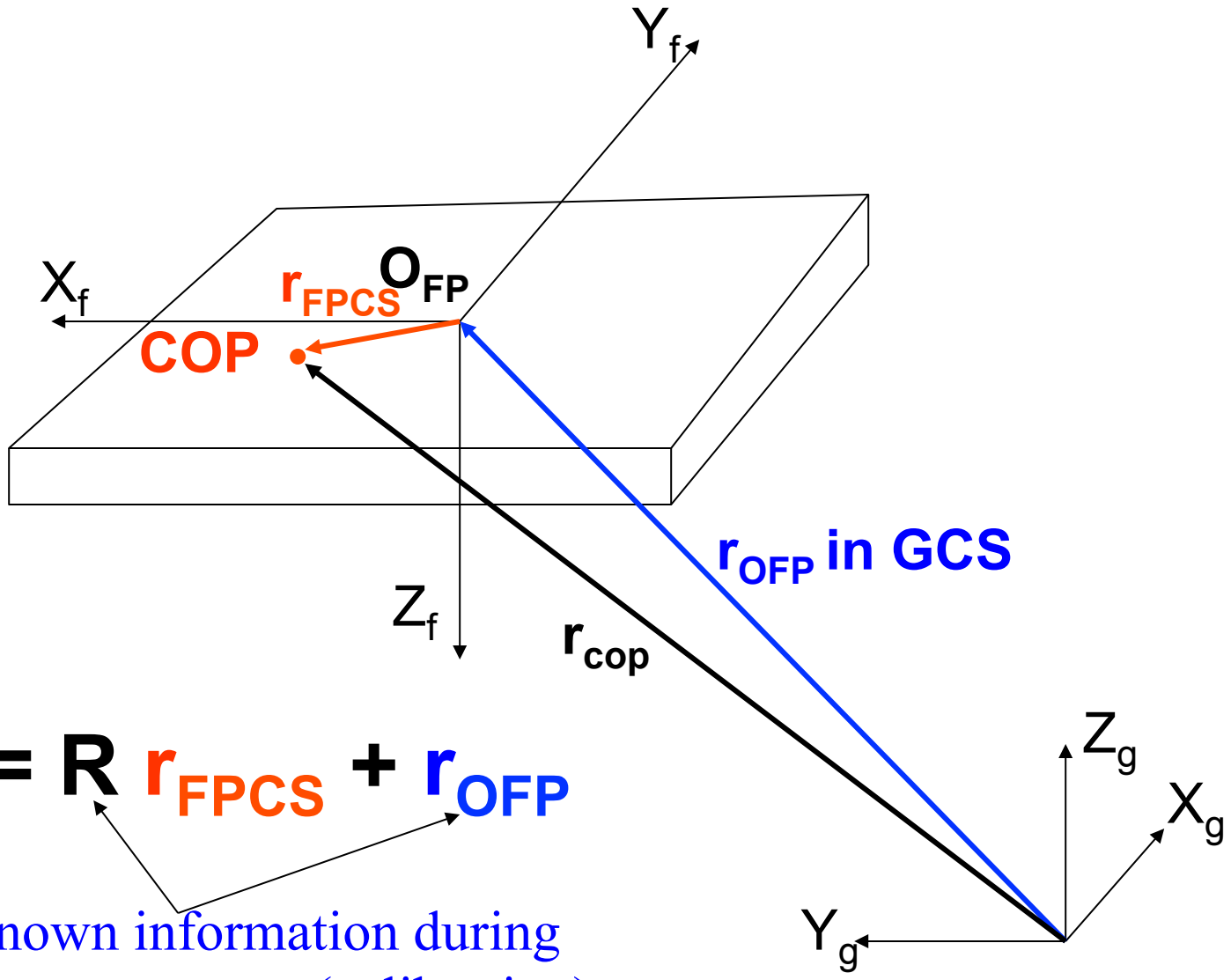
$$y = (M_x - cF_y)/F_z + b$$

$$T_z = M_z - (x-a)F_y + (y-b)F_x$$



$$M = r \times F + Tz$$

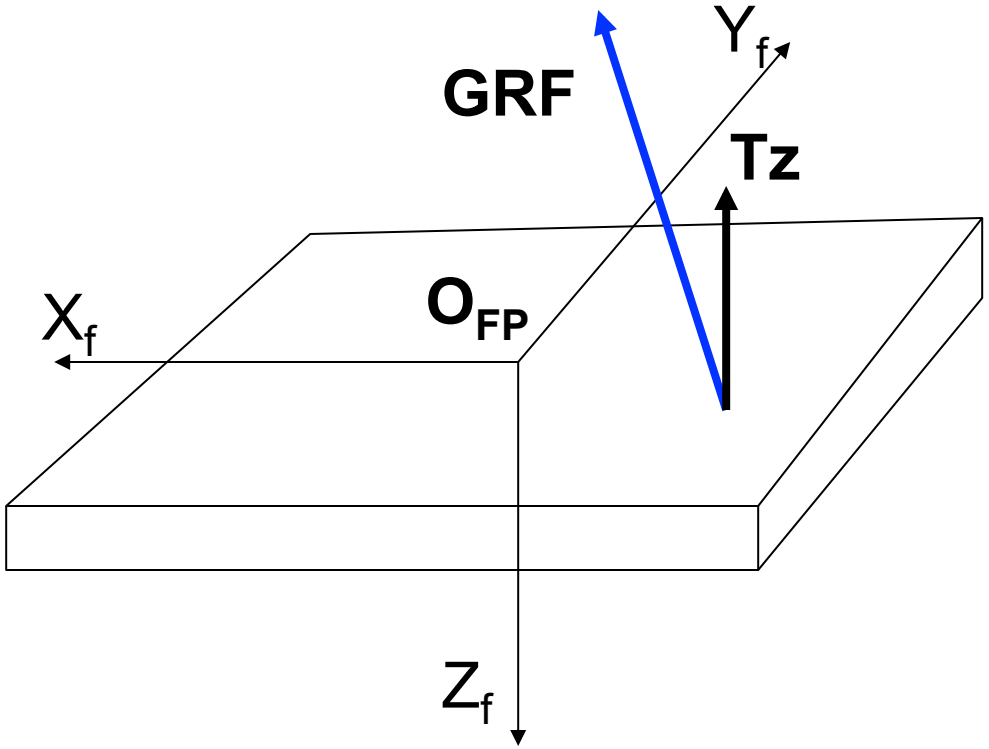
Force Plate Coordinate System



$$r_{cop} = R\, r_{FPCS} + r_{OFP}$$

known information during laboratory setup (calibration)

GRF in Global Coordinate System



$$GRF_{GCS} = R\ GRF_{FPCS}$$

$$Tz_{GCS} = R\ Tz_{FPCS}$$