## **State Class: 6-DOF Load State**

The kinetic state required by the simVITRO software is the 6-DOF load in the appropriate anatomical reference frame. In its generic form, this state can be defined as the 6-DOF load acting on a rigid body given a 6-DOF load cell sensor output and a 6-DOF Position state. The 6-DOF Position, describes the position of that rigid body with respect to the position of the load cell. In some scenarios, the load cell may be moving relative to the gravity field (attached to the end of a robot). Therefore, the mass of an object attached to the load cell can introduce gravitational cross-talk that is not representative of the external loads applied to the rigid body. Computational correction for this is referred to as gravity compensation. This state is designed to transform the loads from the sensor to the rigid body coordinate system either with or without gravity compensation.

The gravity compensation algorithm requires knowledge of the gravity vector relative to the current load cell orientation. The load cell offsets are subtracted from the output of the sensor. Then, the forces and moments are transformed to the world reference frame where the mass, at a known center of mass from the load cell (also transformed), can be multiplied by the gravity vector and subtracted from the sensor output. Next, the forces and moments can be transformed back to the load cell reference frame where the resulting loads are gravity compensated. The last step transforms the gravity compensated loads to the rigid body. Each step in this process requires transformations of the forces and moments (Eq. 1, 2) from one reference frame (REF1) to another (REF2).

Force transformation: 
$$\mathbf{F}^{REF2} = \mathbf{R}_{REF2, REF1} \cdot \mathbf{F}^{REF1}$$
 (1)

Moment transformation:  $\mathbf{M}^{REF2} = \mathbf{R}_{REF2, REF1} \cdot \mathbf{M}^{REF1} + \mathbf{t}_{REF2, REF1} \times \mathbf{F}^{REF2}$  (2)

Where:

- F = 3D force vector from load cell
- M = 3D moment vector from load cell
- R = Rotation portion of the transformation matrix
- t = translation portion of the transformation matrix