**Three-Dimensional Dynamics**

**Must use centroidal coordinate frames**

 for 

 for  

 

 















**Equations of motion (EOM)**





 or 



nb = number of moving bodies

nk = number of kinematic constraints

nd = number of driver constraints

nc = total number of constraints (nc = nk + nd)

**Inverse dynamics – kinematically driven**

solve kinematics 

 must have full rank nc = 6nb

compute constraint forces 



**Statics**

 and  and 



**Inverse dynamics – simultaneous EOM matrix**







**Lagrange multipliers for specific constraints**









local joint definition frame at P







**Spherical**











**Double spherical**











**Dot-1**

****









**Dot-2**











**Forward dynamics - dynamically driven**

nc < 6nb

 does not have full row rank

given 

compute 



must use forward time integration of  to get  at next time step



**EOM using Euler parameters**





**Euler parameter**











