



Using Abaqus to Enable Accurate Stress Predictions of a Multi-Body System with Sliding Contact



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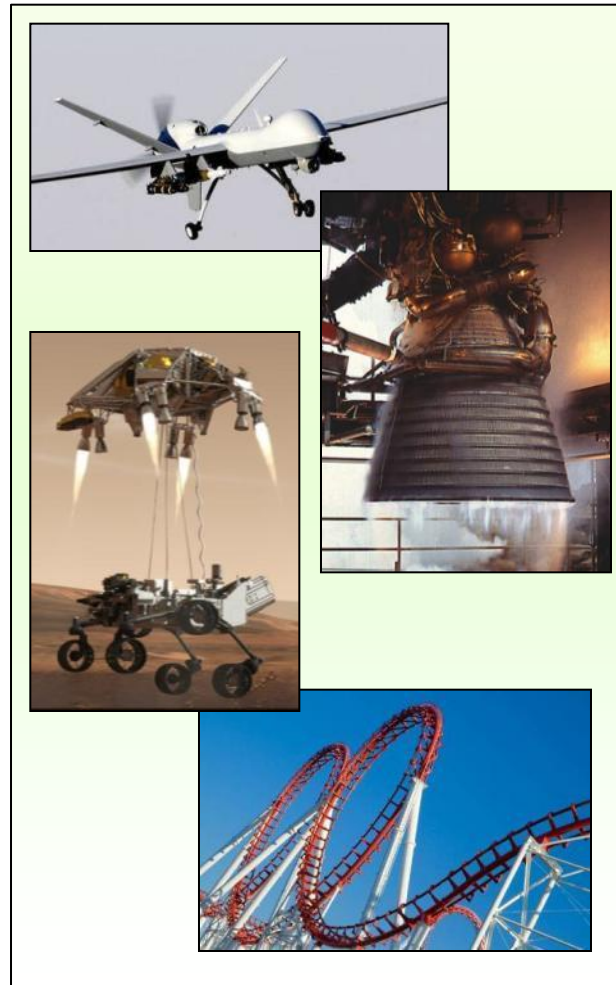
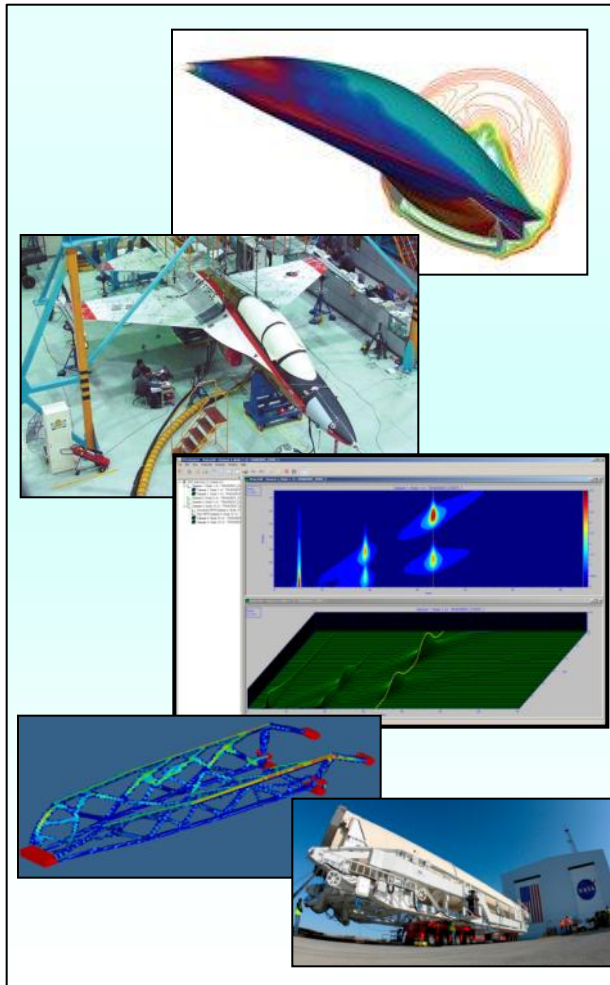
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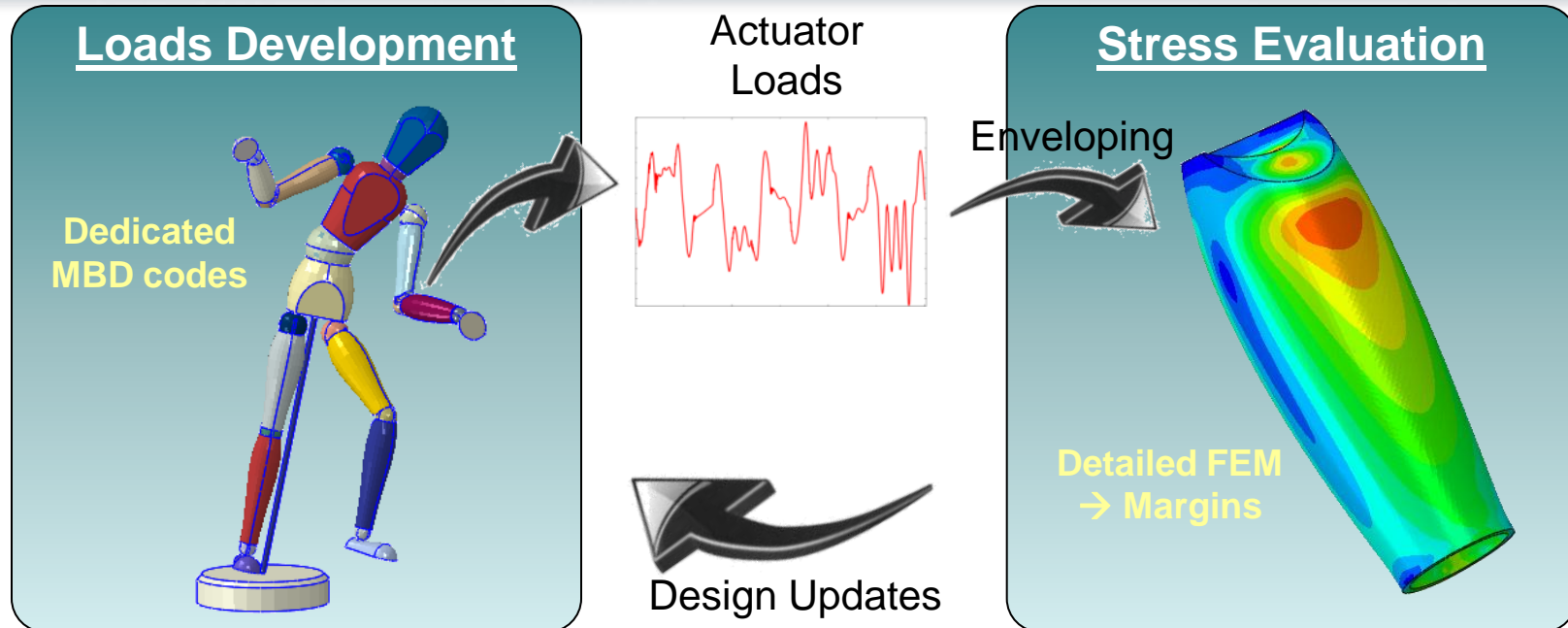
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ATA Engineering, Inc.

The right people. The right skills. The right experience.



The standard loads/margins two-step for complex mechanisms



Challenges

Enveloping loads often causes conservatism/design inefficiency

Maintaining version control can be difficult:

- Loads/stress often separate groups

- Loads/stress models use different modeling platforms

Objective to explore/demonstrate all-FEM approach



1. Use Abaqus to simulate kinematic operation of flexible MBD model that ...
 - uses a single model/simulation for loads and stress
 - includes sliding contact with flexible component, enabling accurate local stress predictions
 - accounts for coupling of flexible components with actuated motions
2. Examine modeling strategies to facilitate fast model updates in highly dynamic design environment

Dedicated MBD codes have their uses and limitations



Dedicated MBD codes ...	But ...
Enable rapid model development, fast runtime	Fewer DOF means less resolution/accuracy
Use rigid components	Neglects coupling of flexible components, may overpredicts loads
Can include modal flexibility	Accounts for coupling, not always appropriate for stress
Can include sliding contact	Can't recover local stress, detailed FEM still required
	Cannot include component nonlinearities (mtrl or geometric)
	Rudimentary contact enforcement

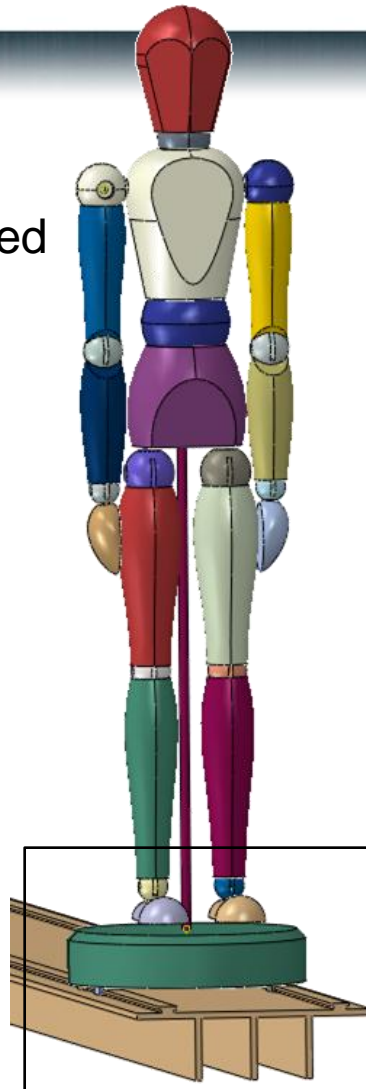
Requirements of demonstration model derived through customer discussions

Requirements:

- Articulating joints with enforced motion
- Include flexible components
- Accurate sliding contact on flexible component
- Must enable rapid design updates

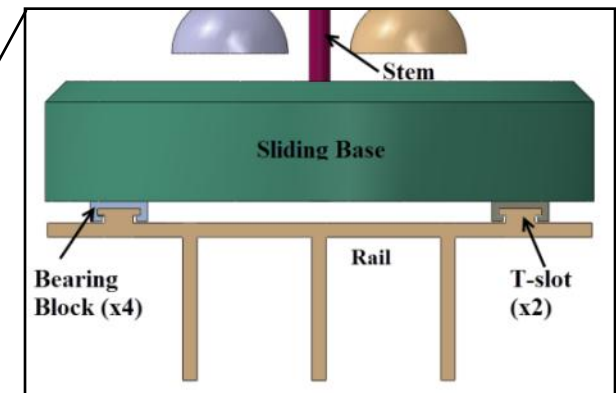
Goal:

- Size joint actuators
- Verify design of rail



Model Overview*:

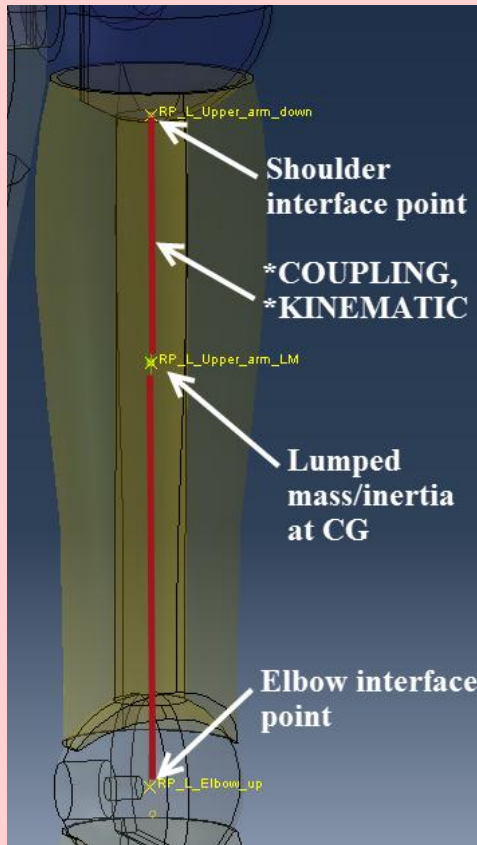
- 31 rigid parts
- 25 articulating joints (connectors)
- 1 flexible rail (S4, C3D8)
- 4 contact domains (bearing block/T-slot)



*Mannequin CAD from user
"Tony" on grabcad.com

Examined two ways to model rigid components

*MASS, *COUPLING *KINEMATIC, *DISPLAY BODY



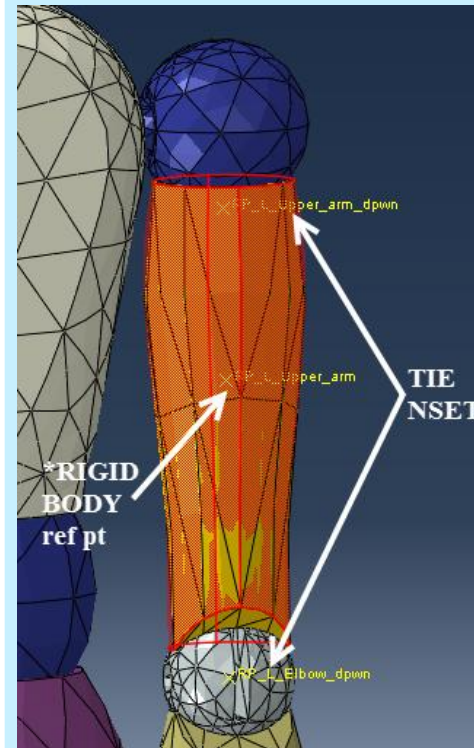
Pros

- Easy mass props updates
- Computationally efficient

Con

- Setup is user-intensive

MESH + *RIGID BODY



Pros

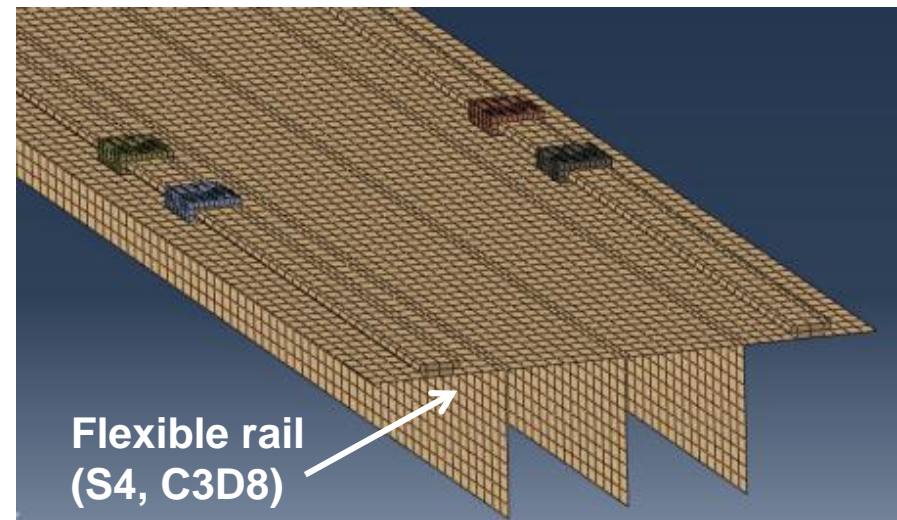
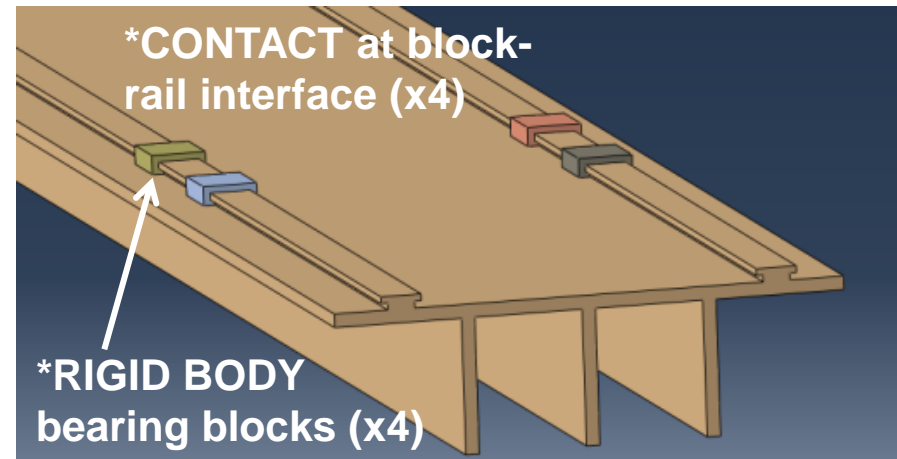
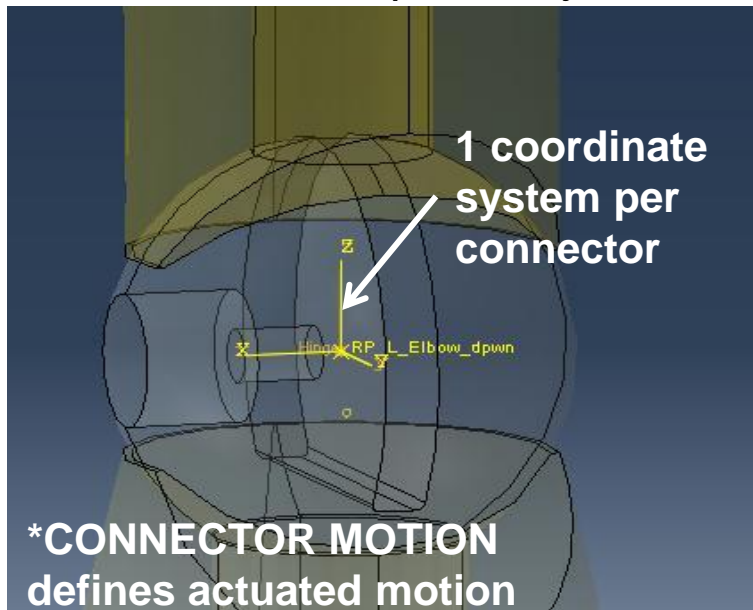
- Easy component setup
- Mass props from mesh
- Easy to change from rigid/ flexible
- Can be used for contact/clearance checks

Con

- Computationally expensive

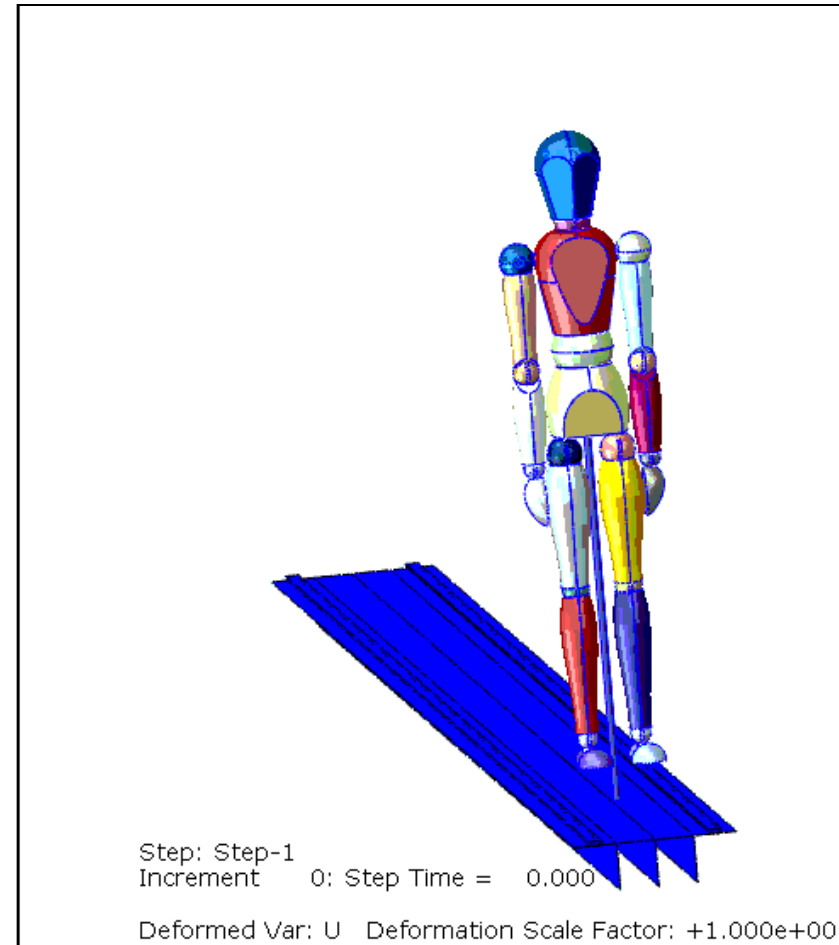
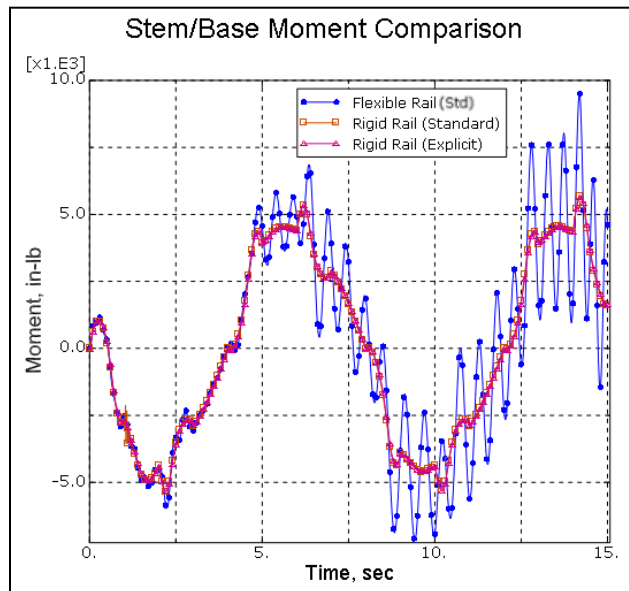
Joint and rail modeling

Coincident ref points and connector elements represent joints



Simulation recovers local stress, includes flexible component coupling

- Flexible rail case best suited to /Standard
 - Dominant low-frequency, stress-fidelity mesh
- Rigid rail case well suited to either solver
 - Excluded rail since 4 connection points are statically indeterminate → No contact definition



Solution type and modeling choices dramatically affect runtime



- Rigid component modeling method strongly affects runtime
- Including flexible rail also strongly affects runtime
 - Flex rail model 200k DOF vs. rigid rail model 6k DOF
- Despite higher runtime of flex rail case:
 - Includes coupling effects on actuators → More accurate
 - Provides stress results directly → No load enveloping required
 - Loads/stress from single model → Easier version control

		Runtime, min ¹	
		*MASS + *COUPLING	MESH + *RIGID BODY
Rail	Solver		
Flexible	Standard	144	170
Rigid ²	Standard	5	22
Rigid ²	Explicit	3	9

6k DOF

200k DOF

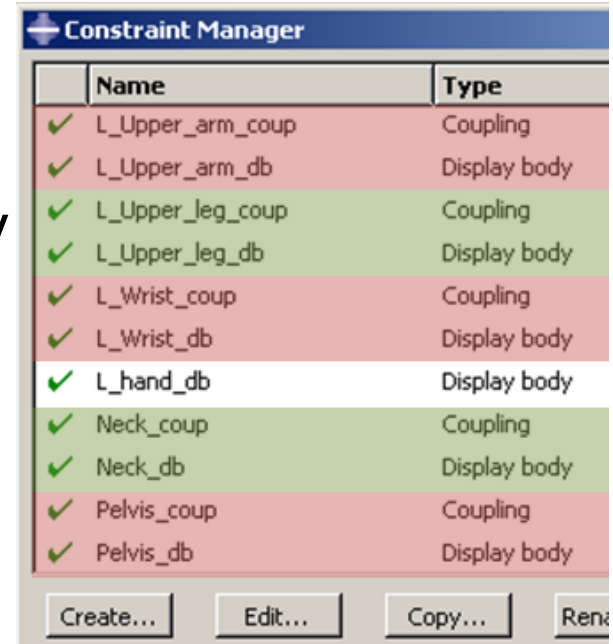
¹10 CPUs, high-end desktop, max time step = 0.02 sec

² No rail or contact included in simulation

Modeling recommendations for a dynamic design environment, 1/3

1. Use intuitive naming for all modeling features

- No graphics-based selection for connectors/constraints/loads/boundary conditions, must select from list
- All connectors require coincident reference points, coordinate systems
- Keep in mind alpha-numeric sorting to group related entities



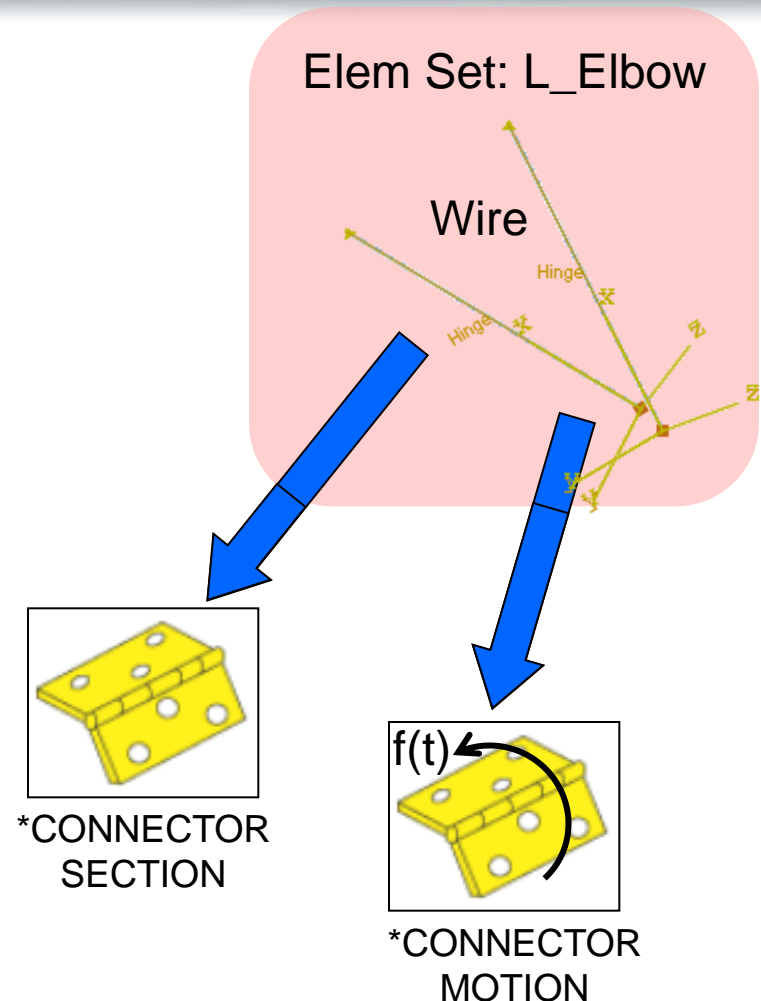
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✓	L_Upper_arm_db	Display body
✓	L_Upper_leg_coup	Coupling
✓	L_Upper_leg_db	Display body
✓	L_Wrist_coup	Coupling
✓	L_Wrist_db	Display body
✓	L_hand_db	Display body
✓	Neck_coup	Coupling
✓	Neck_db	Display body
✓	Pelvis_coup	Coupling
✓	Pelvis_db	Display body

Create... Edit... Copy... Ren

Modeling recommendations for a dynamic design environment, 2/3

2. Avoid graphically selecting immature design features for assignments

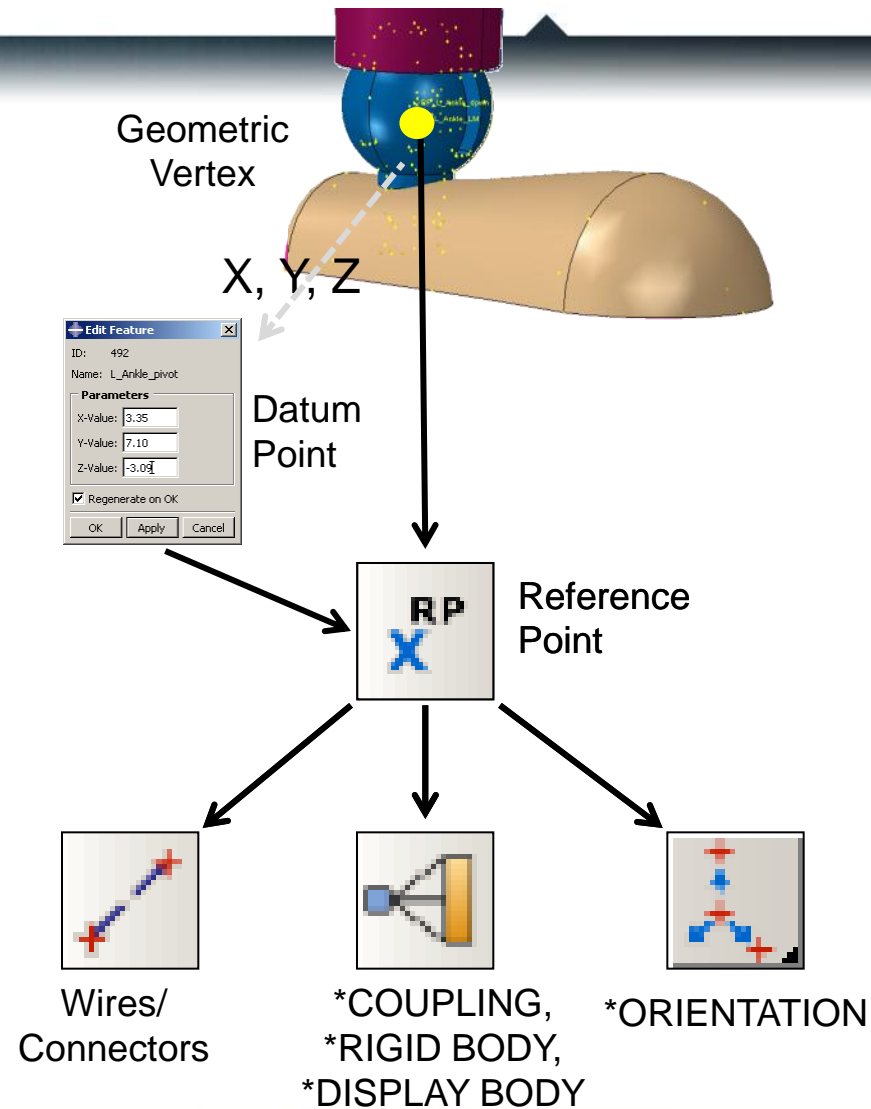
- Recreating wire will invalidate all graphically selected features
- Using named sets (*ELSET) will minimize rework
 - Valid for wires, surfaces, edges, etc.



Modeling recommendations for a dynamic design environment, 3/3

3. Avoid directly selecting geometric vertices for ref point creation

- When replacing instances, ref points and all dependent items become invalid
- Instead manually specify coordinates of ref points or datum points



Summary



- Can use all-Abaqus simulation for loads and accurate stress recovery
 - Can includes local contact stress
 - Correctly accounts for sliding contact
 - Runtime sensitive to rigid component modeling strategy
- To enable rapid model updates
 - Use intuitive naming for modeling features
 - Use named sets
 - Keep reference points independent of geometric vertices



Questions?