Artisan's ASYLUM

Designing Simple Hydraulic Joints

Gui Cavalcanti

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Overview

- Designing a joint made from a pivot and a hydraulic piston from scratch can be confusing, given the near-infinite design options
- Characterizing such a joint for range of motion, torque, and flow while having infinite design options can be even more confusing
- In this presentation, my goal is to convey a simple, quantitative method to design single-pivot hydraulic joints

Example Joint

Let's take the elbow joint of an earthmover and use it to generate common terminology.

Example Joint

Example Joint

Example Joint

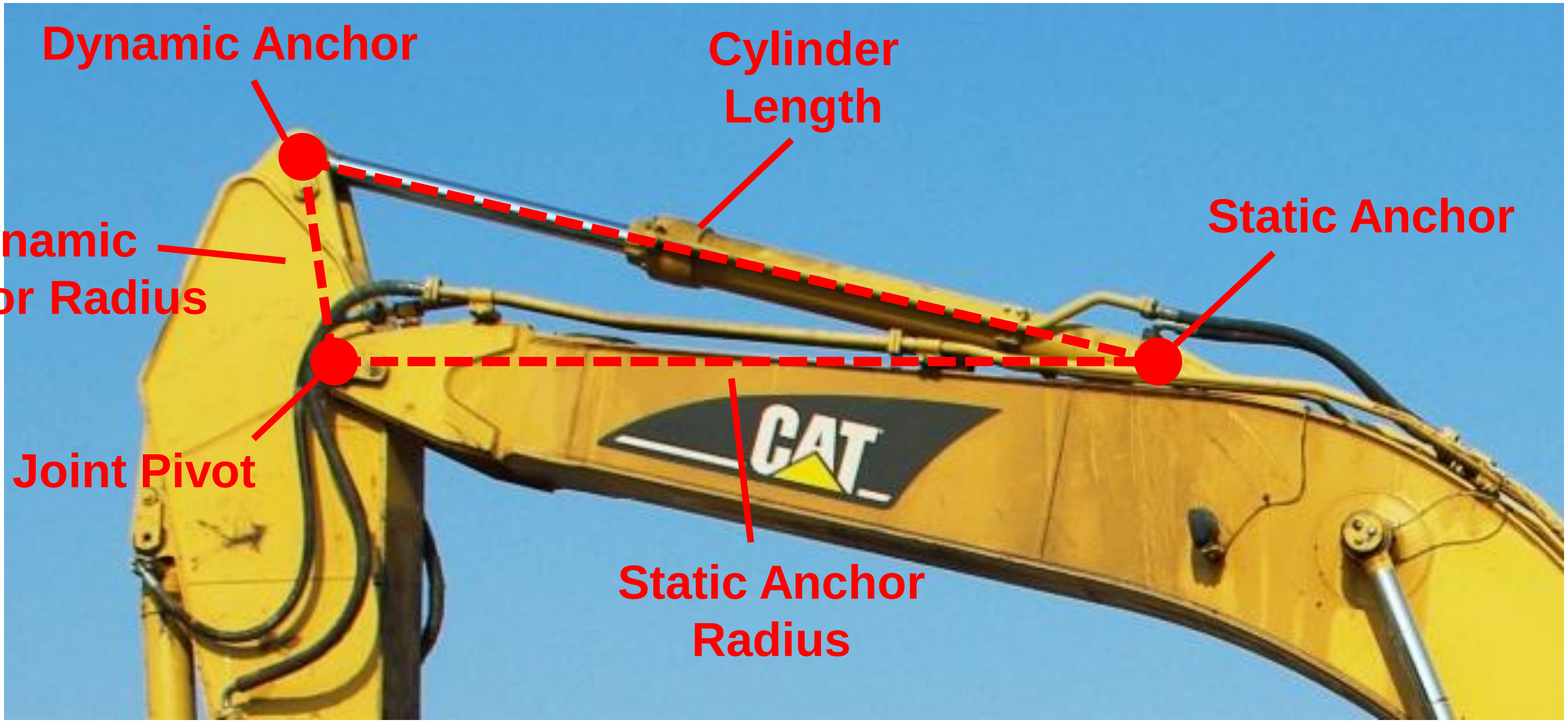
For the moment, let's only care about the cylinder, the joint it's driving, and where it's mounted relative to the joint it's driving.

Example Joint

Example Joint

Now, let's define some terminology.

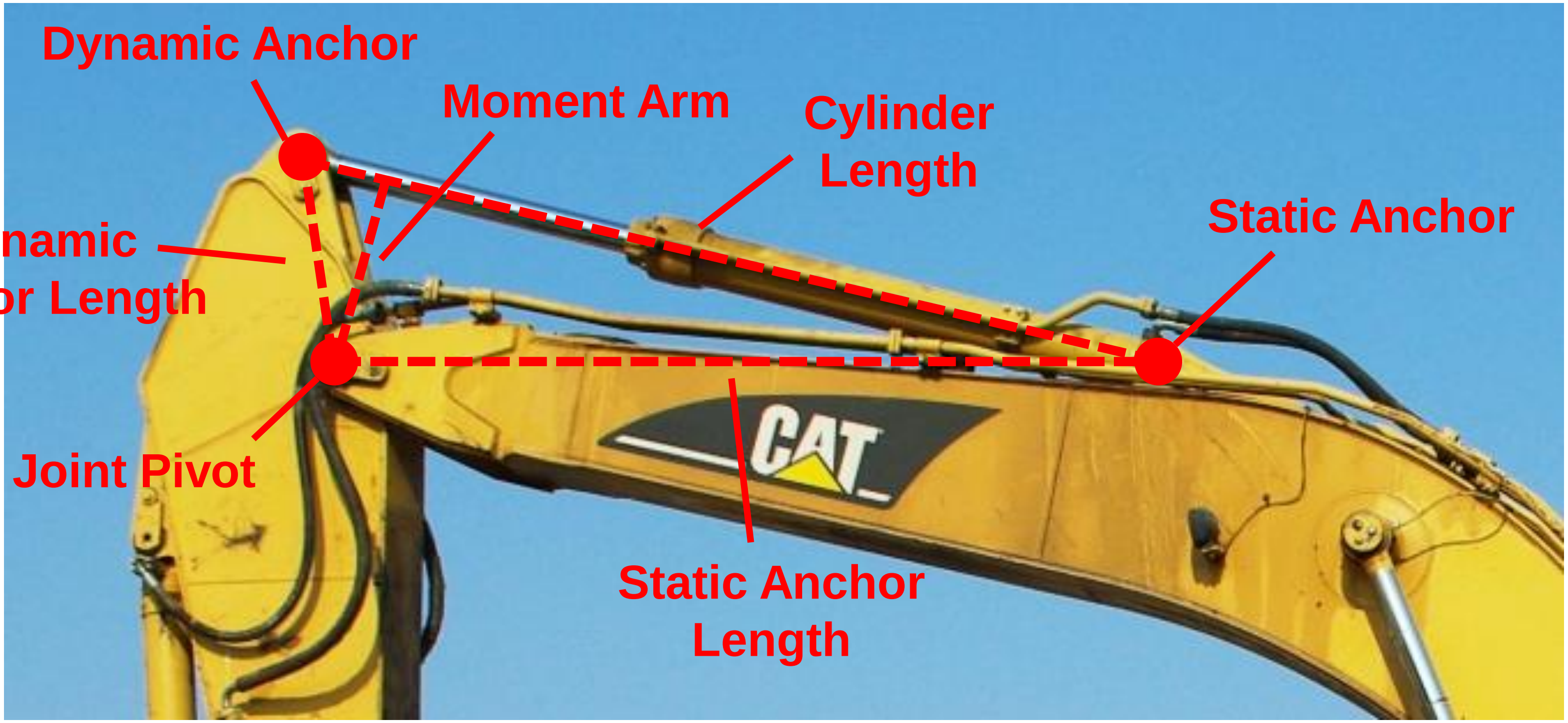
Example Joint



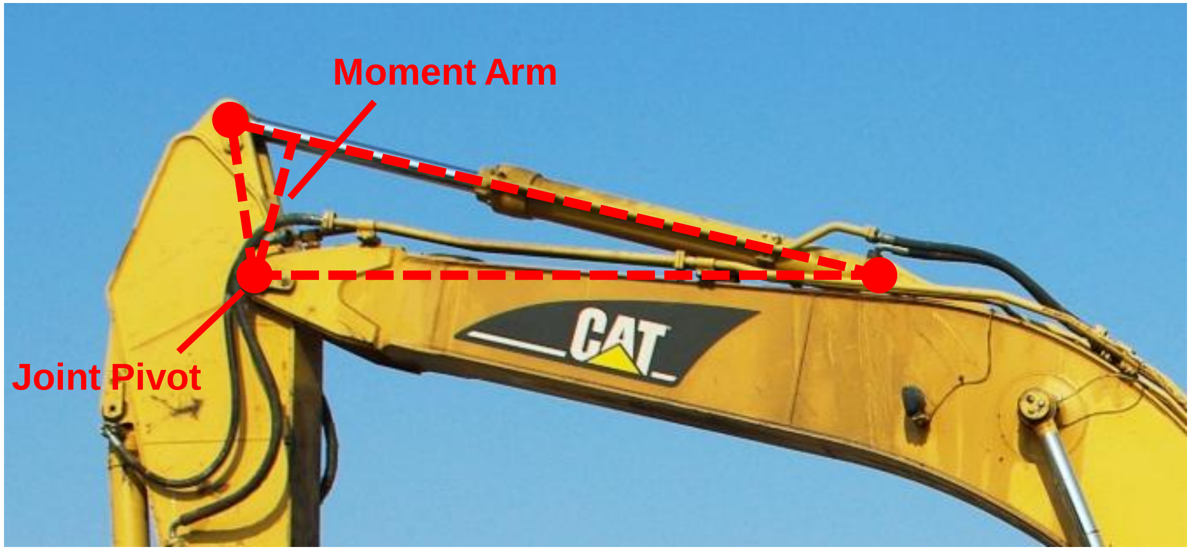
Example Joint

Let's add one more dimension, whose purpose may not be immediately obvious.

Example Joint



Example Joint



Linear Piston Force * Moment Arm = Torque @ Joint

Example Joint

Now that we have terminology, let's start designing.

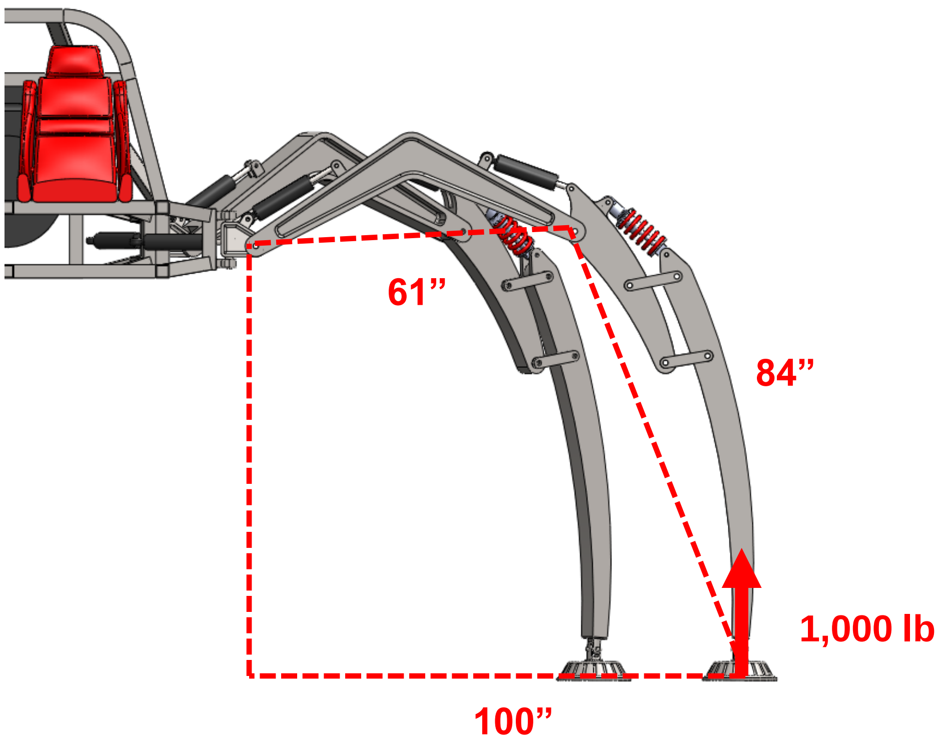
Joint Design

1. Determine joint range of motion (ROM), minimum desired torques, and directions of torque
2. Determine if there are any constraints on where the dynamic and static anchor must be placed due to the rest of your design
3. Select an appropriate piston bore, rod size, and moment arm based on requirements
4. Choose an initial piston length to evaluate
5. Create constraining sketches
6. Iterate on hydraulic cylinder length until moment arm relationships are satisfied; iterate bore if necessary

1. Joint Characterization

1. How large of a sweep (less than ~120 degrees) do you want?
2. What maximum/minimum torque is required at the joint, at which position?
3. What direction is that torque in?

Joint Characterization Example: Extended Stompy Leg



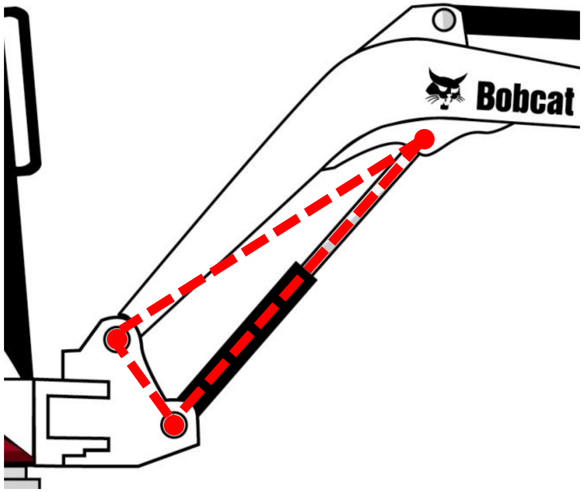
Maximum hip pitch torque required for Stompy:

100” * 1,000 lb (1/3 of tripod gait) = 100,000 in*lb

100,000 in*lb * 1.2 Factor of Safety = 120,000 in*lb

2. Determine Position Constraints

1. **Will the dynamic anchor or the static anchor be closer to the joint?**
   - **Static anchor closer: traditional pitch joint placement on excavators**
   - **Dynamic anchor closer: traditional elbow joint placement on excavators**



Position Constraint Example: Extended Stompy Leg

Since we're creating miniature excavator legs, let's **keep the static anchor closer** to the driven joint

3. Select Appropriate Actuator Size

1. Divide required torque by a reasonable moment arm length for your system
2. Search for stock piston bores (1.5”+, in ½” increments) that produce forces that are equivalent to what you need at your operating pressure
3. Fine tune your moment arm to match available bores/forces

Appropriate Actuator Example: Extended Stompy Leg

1. 6” seems like a reasonable moment arm; 120,000 in*lb / 6 in = 20,000 lb

2. 3” bore @ 2500 psi = 17,670 lb

3. 120,000 in*lb / 17,670 lb = 6.8” moment arm

4. Choose An Example Piston

1. Choose a moderate length piston to experiment with in a sketching or 3D modeling program

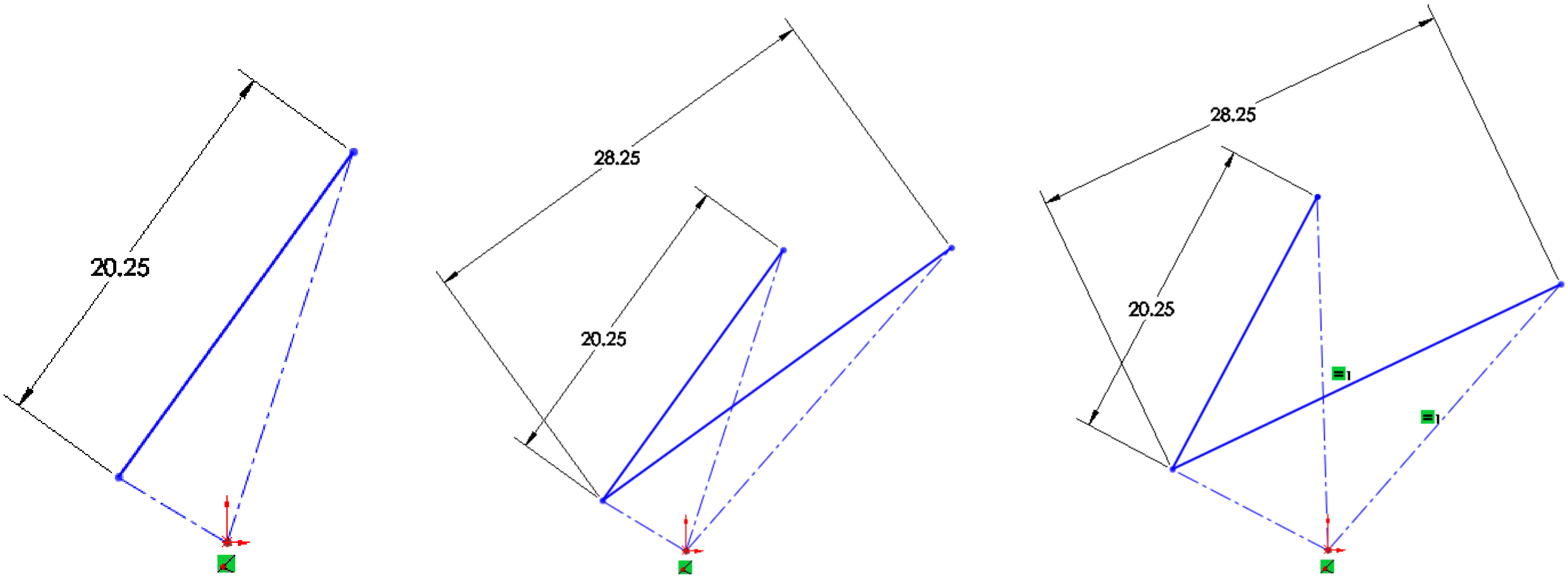
Choose An Example Piston: Extended Stompy Leg

1. **Choose an 8" length, 3" bore piston:**
   - **Prince A300080ABAA07B**
   - **3" bore, 8" stroke, 1.375" rod**
   - **Retracted length: 20.25"**
   - **Extended Length: 28.25"**

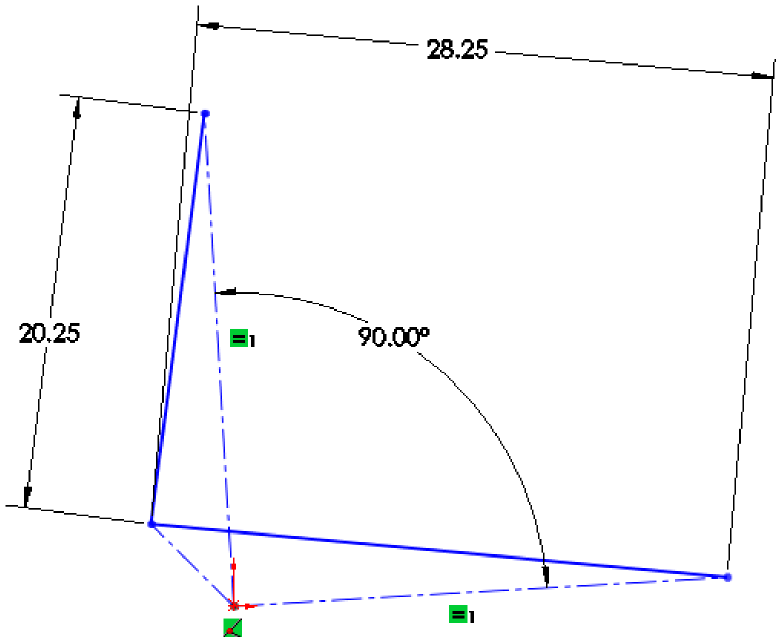
5. Create Constraining Sketches

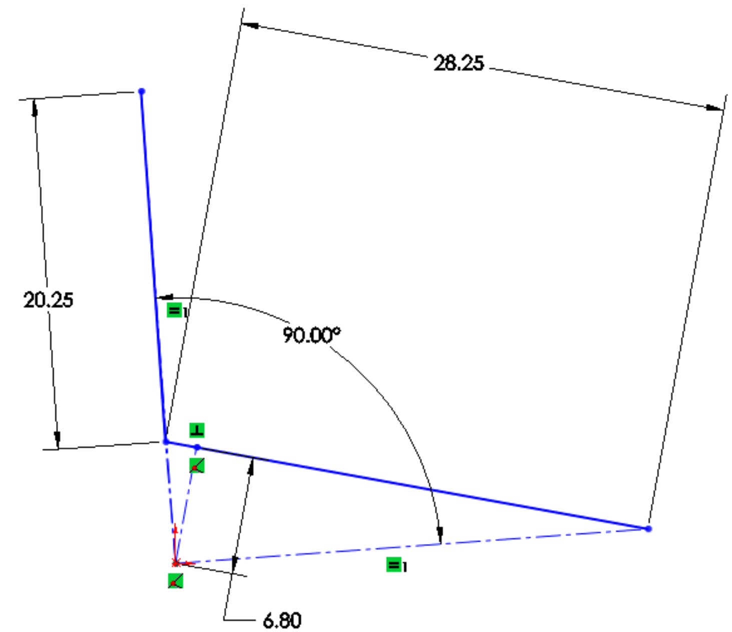
1. Draw an initial triangle between the driven joint, the static anchor, and the dynamic anchor, using the retracted length
2. From the same joint position and static anchor position, draw a new triangle to a second dynamic anchor, using the extended length
3. Equate the two dynamic anchor radii to themselves
4. Constrain the two dynamic anchor radii with the desired range of motion
5. Draw in the moment arm on the appropriate triangle to fully constrain the sketch

Create Constraining Sketches: Extended Stompy Leg



Create Constraining Sketches: Extended Stompy Leg





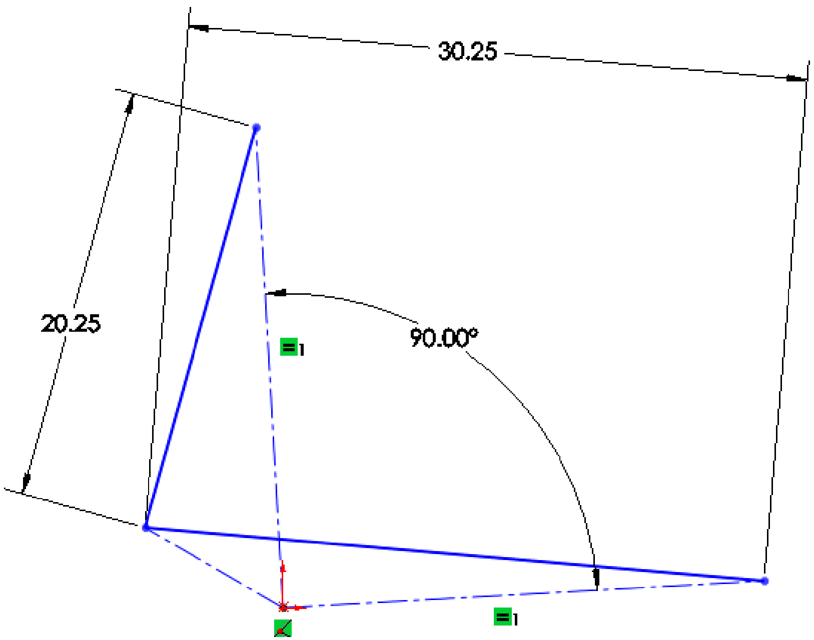
Create Constraining Sketches: Extended Stompy Leg

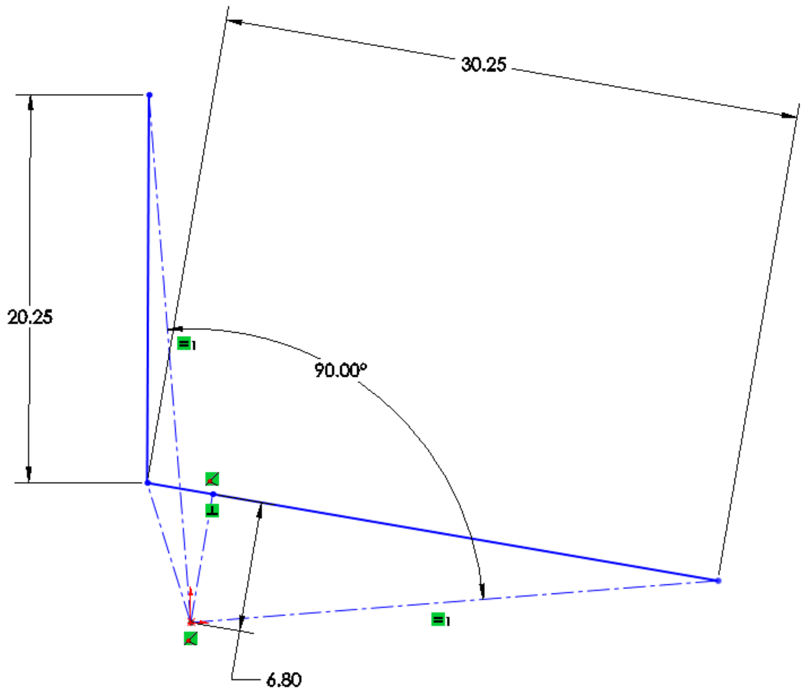
Note that by enforcing a 6.8” moment arm at one end of the stroke, there is almost no moment arm (i.e., we’re at a singularity) at the other end of the stroke. Thus, we need a longer piston, or we’ll get trapped in that position.

Choose An Example Piston: Extended Stompy Leg

1. Choose a 10” length, 3” bore piston:
   - Prince B300100ABAAA07B
   - 3” bore, 10” stroke, 1.375” rod
   - Retracted length: 20.25”
   - Extended Length: 30.25”

Create Constraining Sketches: Extended Stompy Leg





Create Constraining Sketches: Extended Stompy Leg

Since the upper portion of the motion is just to retract Stompy's legs into transport position, no significant moment arm is needed; thus, this solution is good enough

Final Steps

1. **Make sure stroke length and piston diameter are reasonable (i.e. not too skinny and long, not too short a travel)**

2. **Rotate positioning triangles around joint as needed into reasonable positions relative to their attached links**

3. **Integrate point positions into mechanical design**

4. **If iteration is needed on point positions, go back to triangles and rotate all positions as a group – <u>don't change them arbitrarily</u>**