

Spring Validation Tests:

- **Sensing and Perception Test**
 - **Requirements:**
 - i. **M.P.1.1, M.P.1.2.1, M.P.1.2.2** The system shall localize the robot arm in real-time with respect to the pelvis before and during surgery with a latency ≤ 500 ms.
 - ii. **M.P.4.1-3** The system shall compute error and interpret the movement of the pelvis during reaming with a latency ≤ 500 ms, and detect changes with a position error of ≤ 3 mm and orientation error ≤ 3 degrees.
 - **Procedure:**
 - i. Clamp test model to Vention table.
 - ii. Place a fiducial marker on the robot's end-effector.
 - iii. Record the end-effector marker's pose from the camera.
 - iv. Record time to get end-effector pose.
 - v. Place a marker in the initial slot on the test model. Record its pose.
 - vi. Move the marker to the planar slot. Record its pose.
 - vii. Move the marker to the slanted slot. Record its pose.
 - viii. Record computed translation and orientation error for the new marker positions.
 - **Validation**
 - i. End-effector pose must be displayed with a latency ≤ 500 ms.
 - ii. Position error on test model must be ≤ 3 mm
 - iii. Orientation error on the test model must be ≤ 3 degrees.
 - iv. The robot must record new marker poses with a latency ≤ 500 ms.
 - v. The robot must compute errors for each new marker position.
- **Motion Planning and Controls Test**
 - **Requirements:**
 - i. **M.P.2.** The system shall plan the trajectory of the robot arm based on the given surgical plan with a latency ≤ 500 ms.
 - ii. **M.P.3.1, M.P.3.2.** The system shall execute a surgical plan by reaming along the generated trajectory with a position error of ≤ 3 mm and orientation error ≤ 3 degrees.
 - iii. **M.P.5.** The system shall adapt and compensate for movement by generating a new trajectory with a latency ≤ 500 ms.
 - **Procedure:**
 - i. Command the robot to go to an endpoint.
 - ii. Record the time taken for the robot to generate trajectory.
 - iii. Run the Quantitative Trajectory Evaluator and examine the results folder to determine if the results are acceptable according to our performance requirements.
 - The Quantitative Trajectory Evaluator examines the difference between the ground truth, which is what MoveIt plans, and the actual trajectory (as determined by the camera and joint encoders).
 - iv. Measure the force output over the trajectory and ensure that it does not go above the maximum force threshold.
 - **Validation:**
 - The robot end-effector must generate a new trajectory within 500ms.
 - The robot end-effector reaches the end point within a threshold without moving through singularities.
 - The maximum error at any point during the trajectory must be within a certain error threshold (specified in requirements).
 - The maximum force at any point during the trajectory must be less than the maximum force threshold (20N).