Industrial Calibration

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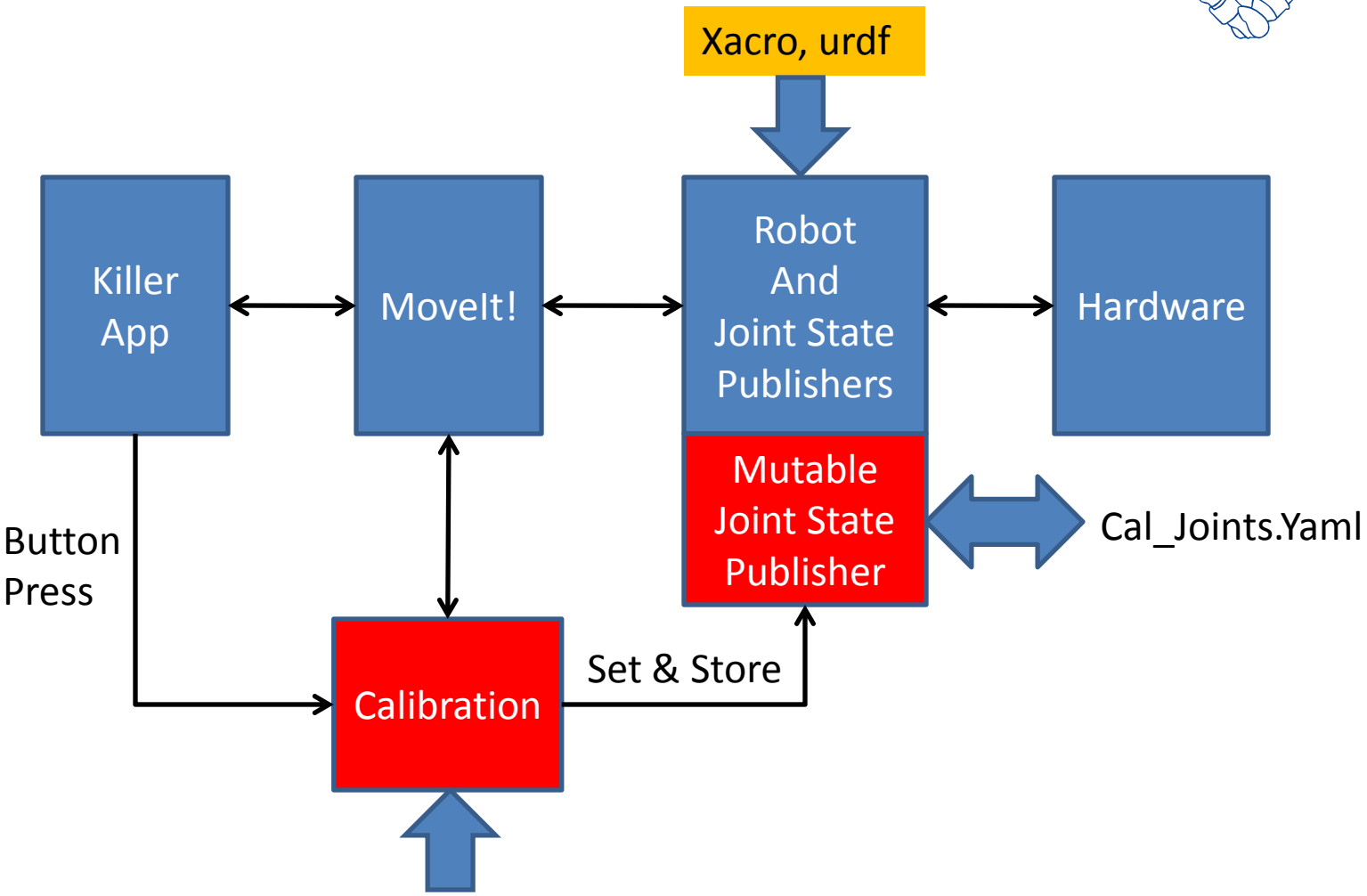
Motivation

- Push button intrinsic and extrinsic calibration with predictable accuracy.
- Unified Framework for a wide variety of calibration tasks
- Automate motion, data collection, and solving
- Package Includes
  - Extensive set of cost functions
  - Examples
  - Tutorial

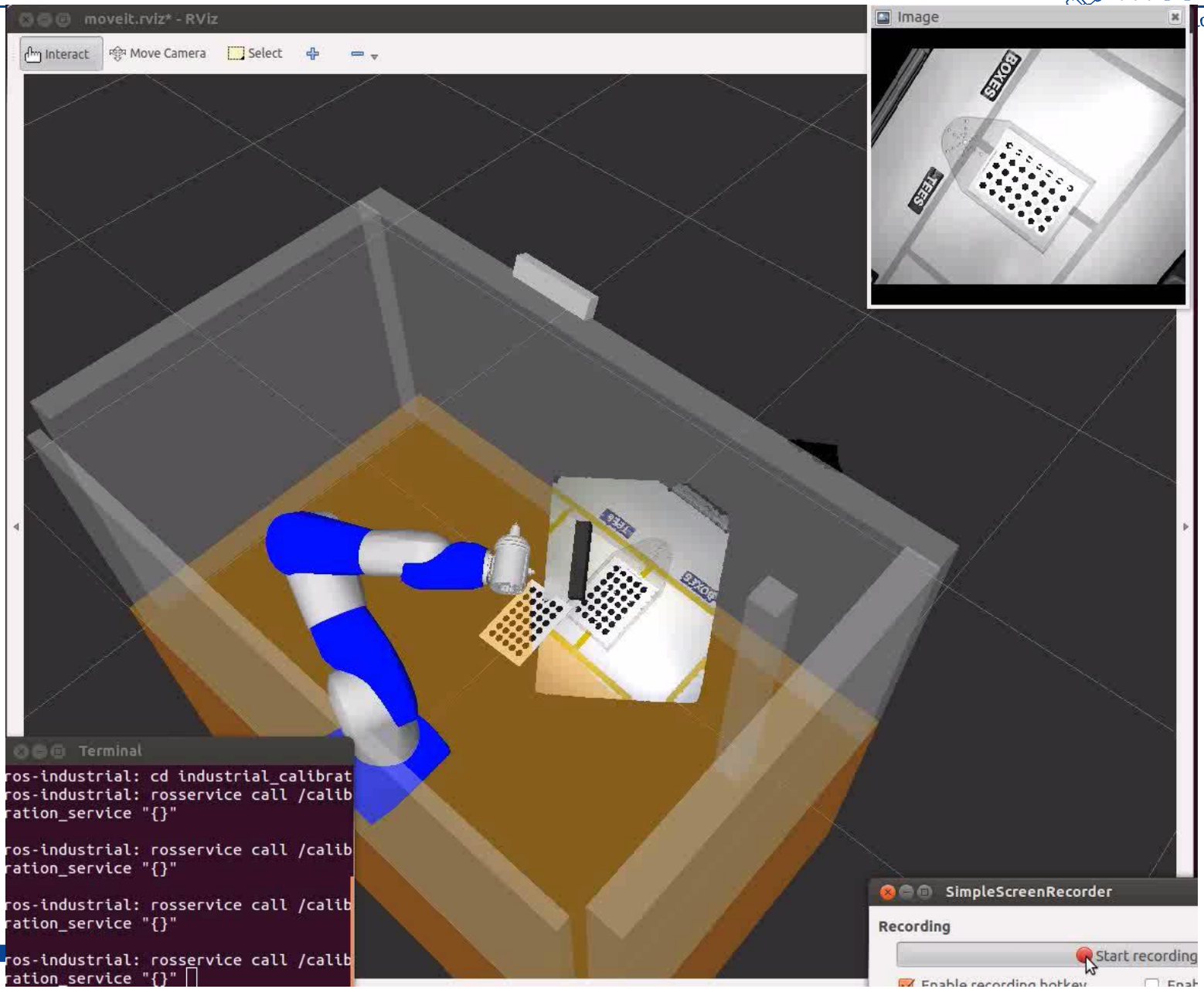
Calibration Tasks

- Extrinsic calibration of an array of cameras using an array of targets
- Calibration of robots and cameras
  - Cameras observing the work cell
  - Cameras mounted on and moving with the robot
- Soon to come
  - Intrinsic Calibration
  - Stereo Calibration
- Potential Extensions: Kinematic parameters

Node Architecture



Tool Mounted Camera



Key Aspects

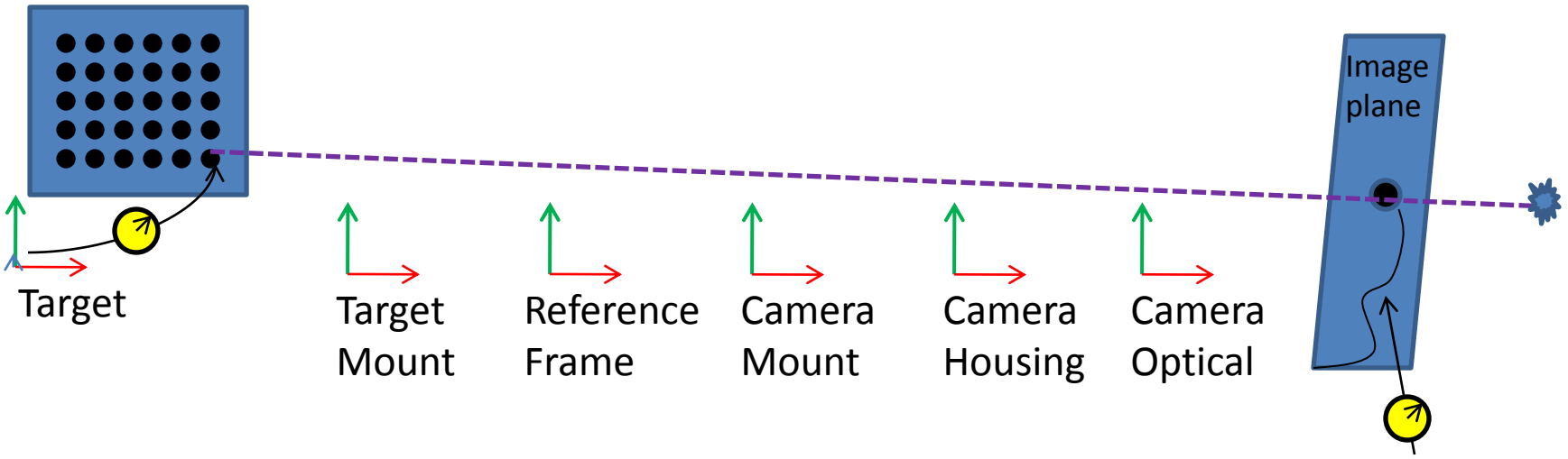
- Interfaces with MoveIt! to plan and execute collision free paths between scenes.
- Collect Sufficient Statistics and Geometry
- Interfaces with TF to capture kinematics
- Results immediate and persists with re-launch
- Computes:
  - 6Dof transform between tool and camera
  - 6Dof transform between robot base and target
- Results: Consistent 3D data regardless of robot pose

Calibration Primer

- Maximize the consistency of a collection of observations with the physical model of those observations by minimizing SSE (re-projection error).
- Compute the Cost of Each Observed Point
  - Project points defined in target's frame into camera coordinates
  - Project camera points into image
  - Compare to observation

Projection

Constants and Parameters



- Cost functions differ by what is known and what varies
  - Extrinsic parameters
  - Intrinsic parameters
    a. Target 3Dof(Printing accuracy)
    b. Camera, typically 9Dof
- A robot might hold and move the camera or the target.
- One may want to refine the location of the device doing the holding.
- Cost functions may be written to cover any situation.

Focal Length
Optical Center
Distortion
Model

Calibration Process

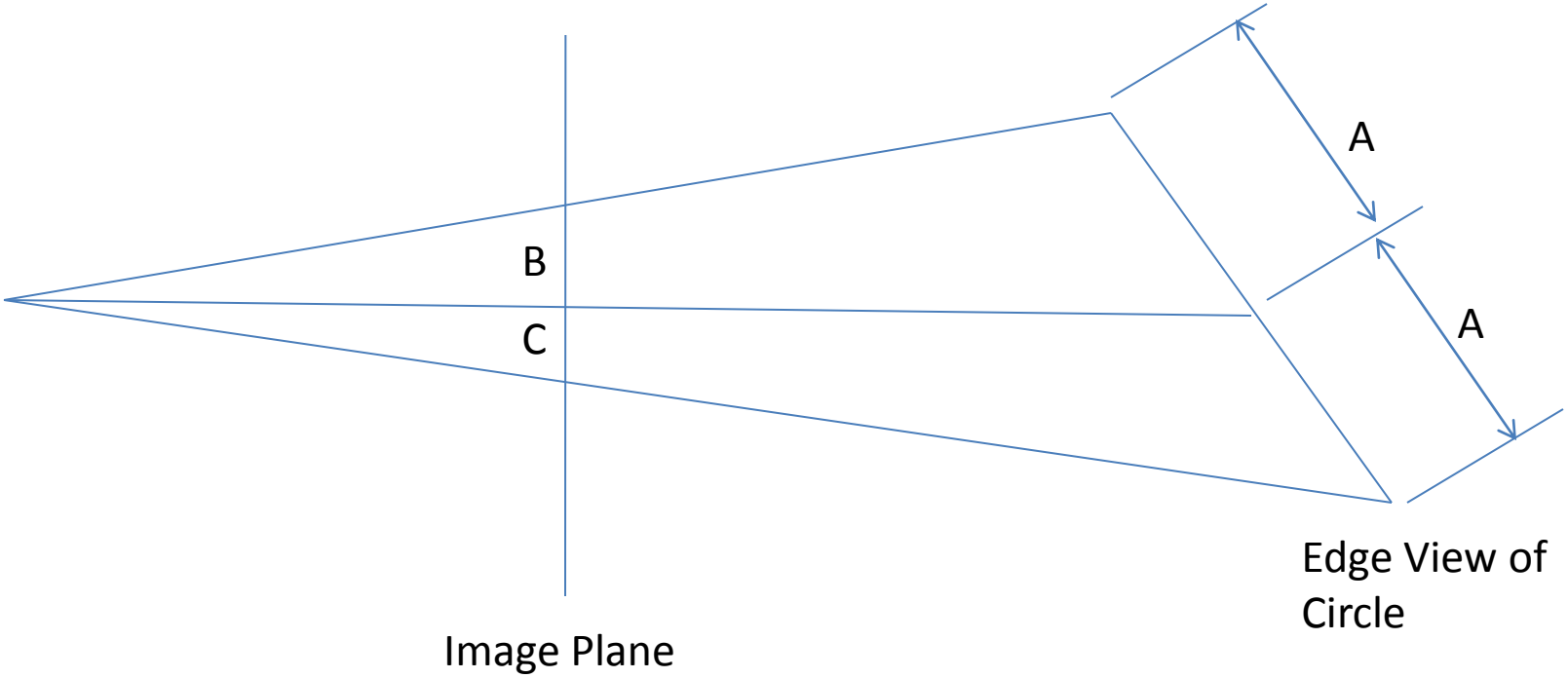
- Collect Observations
  - For each static scene
    - Wait for scene trigger
    - Collect Transform Information
    - For each camera in scene
      - For each target
        - » Look for target in ROI
        - » Add observations to list
- Add each cost to a Ceres problem
- Problem.solve()
- Output Results
  - Set and store on the mutable joint state publisher
  - Write new static transform publishers

What's Special?

- Ceres
  - Best Optimization Package Ever
  - Computes analytic Jacobians from templated cost functions
- Scene Triggers
  - MoveIt!
    - Joint Value Move
    - Cartesian Move
- Camera Observers
  - Circlegrids
  - Checkerboards
  - AR Tags
- Transform Interfaces
  - TF
  - Mutable Joint State Publisher
    - Calibration Results are immediate and persist with subsequent launches
- Library of Ceres Compatible Projection Cost Functions93

Geometry of Viewing Circles

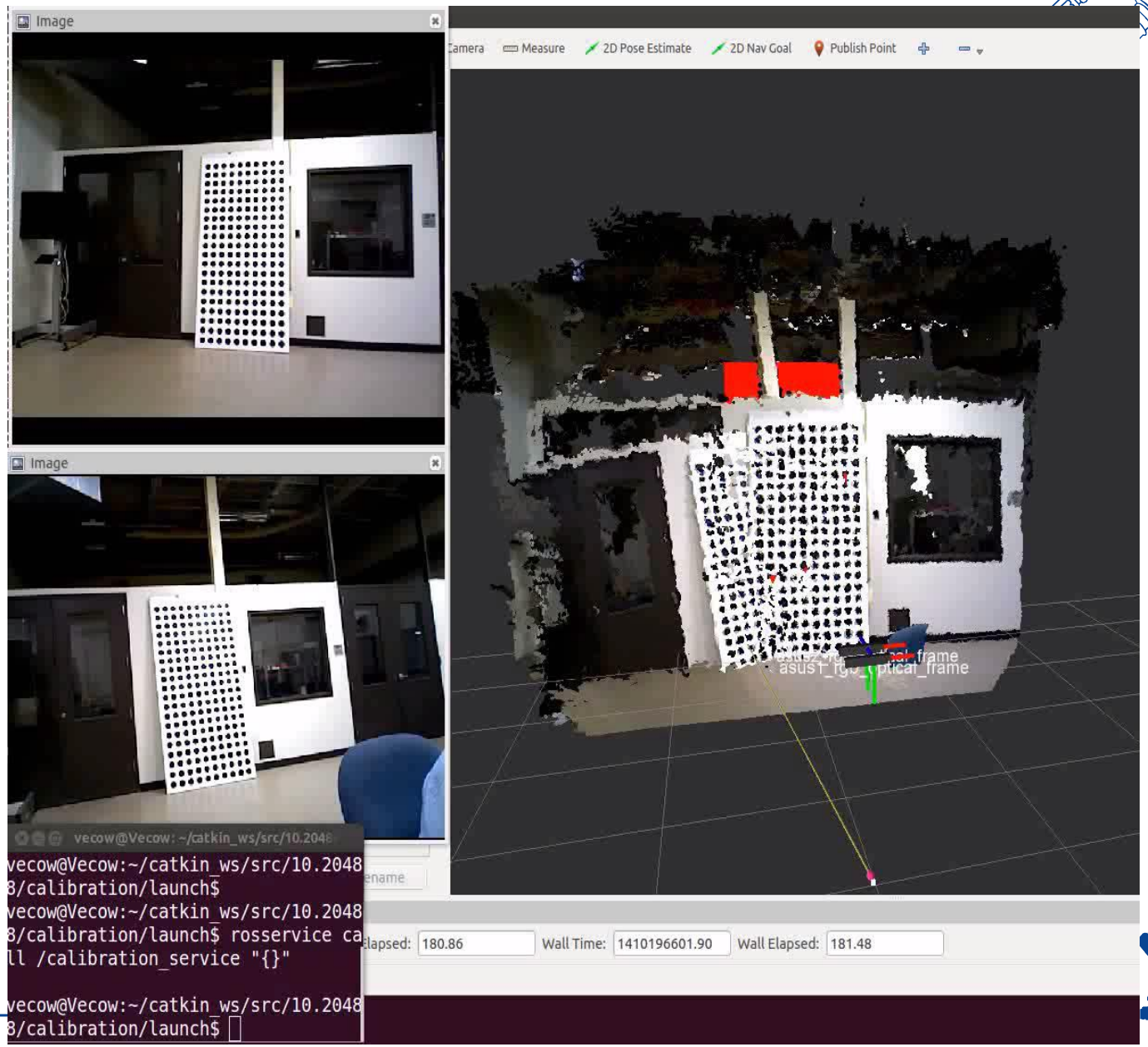
- The center of an observed ellipse is NOT the projected center of the circular disc. B>C



Best Practices

- Take a Statistically Significant Set of Static Images.
  - No Motion Blur
  - Image Noise
- Cover Region of Interest
  - all the way to the edge, extrapolation is much worse than interpolation
  - Move robot to kinematic extents
- Don’t Tilt Your Targets, or Use a Cost Function that Accounts for the Offset
- Don’t Count on Residual Error Alone as an Indication of Accuracy
  - High residual error is bad
  - Low does not guarantee accuracy
- Use high quality targets
  - NIST Traceable if Possible
  - Calibrate target if possible
  - Lay as flat as possible

Two Asus Sensors Single Shot



Try Some Examples

- https://github.com/ros-industrial/industrial_calibration_tutorials.git
- calibrate_from_images.launch
  - Images Included
  - 8 Asus Cameras 4 on tower on either side of target
- camera_scene_cal.launch
  - 2 live Asus, as shown in previous video
  - Add your own cameras,
  - Swap in your own target

Where Are We?

- A few working examples
- Rough tutorials
- Lots of code not covered by gtest
- Experimental
- Needs
  - Hybrid Target Detection
    - Orientation Aware
    - Target ID Aware
  - GUI for creating yaml files