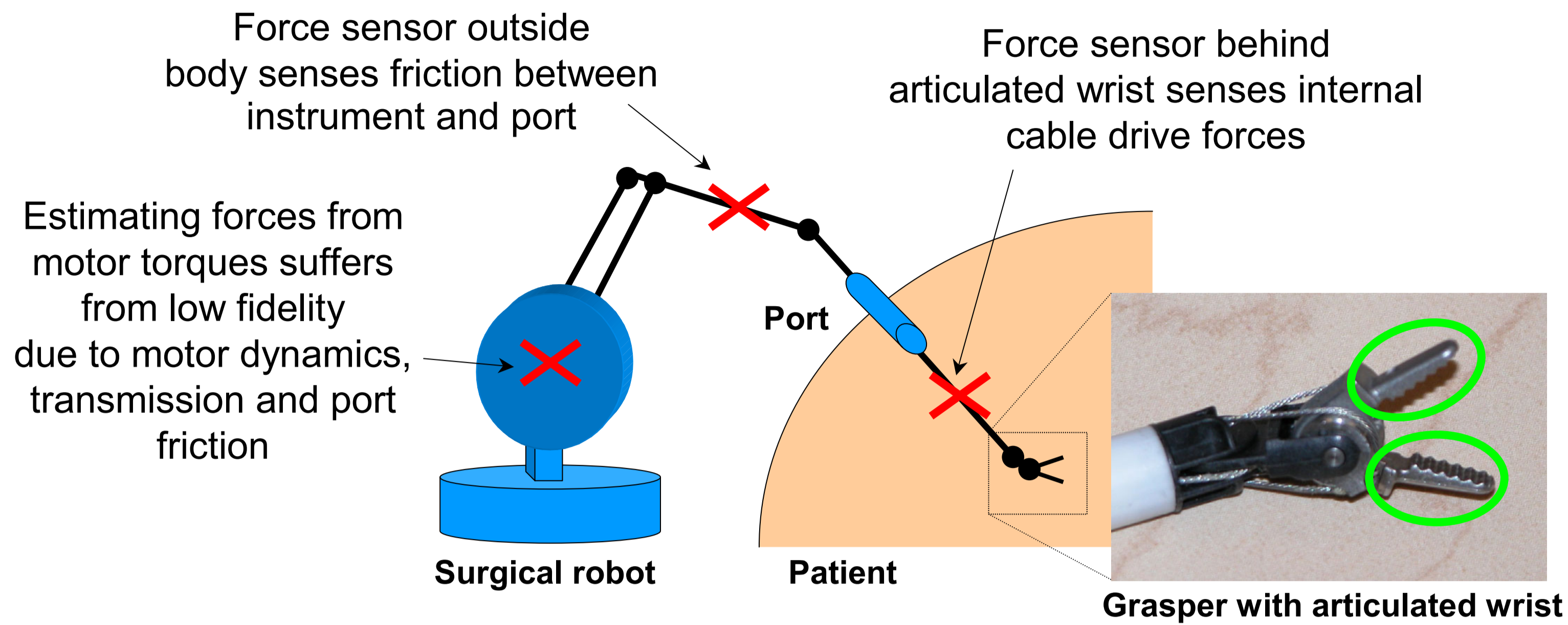


Embedded Strain Gage Force Sensor For Robotic Surgery

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- Force feedback can decrease applied force magnitudes and errors in robotic surgery [1]
- Commercial robotic surgical systems lack force feedback
 - Masters have actuators
 - Instrument tip force sensing is missing [2]
- Force sensor must accurately sense grip and interaction forces between instrument and tissue

Where can we put the force sensor on a surgical robot?



Place force sensors on grasper jaws

- Port forces don't interfere
- Transmission forces don't interfere
- Can sense interaction forces as well as grasp forces
- Must fit through port

Sensor Design and Construction:

- Use six silicon strain gages for high force resolution and sensitivity in 3 axes
- Embed strain gages in a pourable epoxy (Resin 105 Fast Cure, West System) to avoid complicated bonding procedure
- Single pour construction process easily adapted for mass production – **Disposable force sensors**
- Benefits of design
 - All wires exit at same spot with intrinsic strain relief
 - Two sensors can fit through 12 mm port

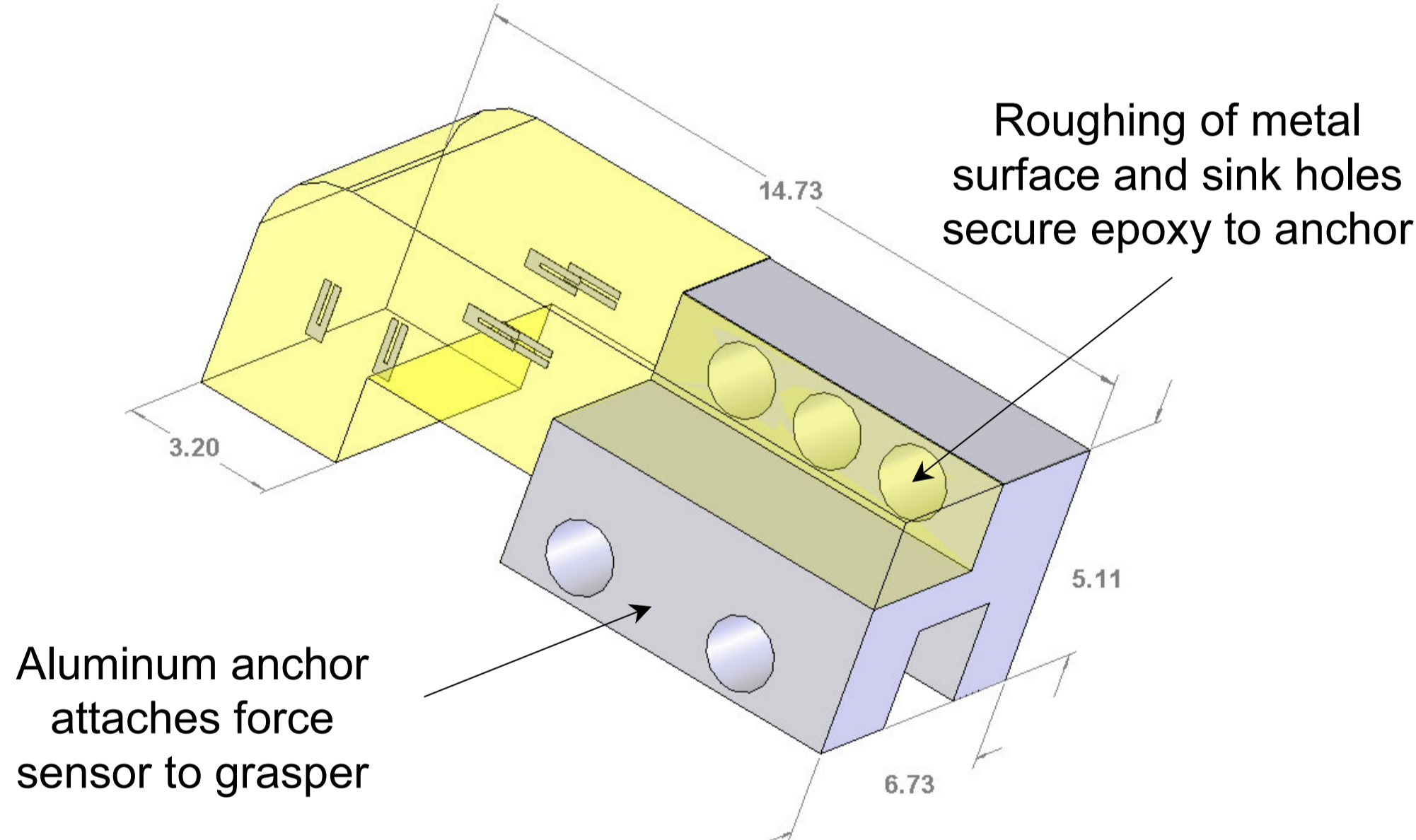
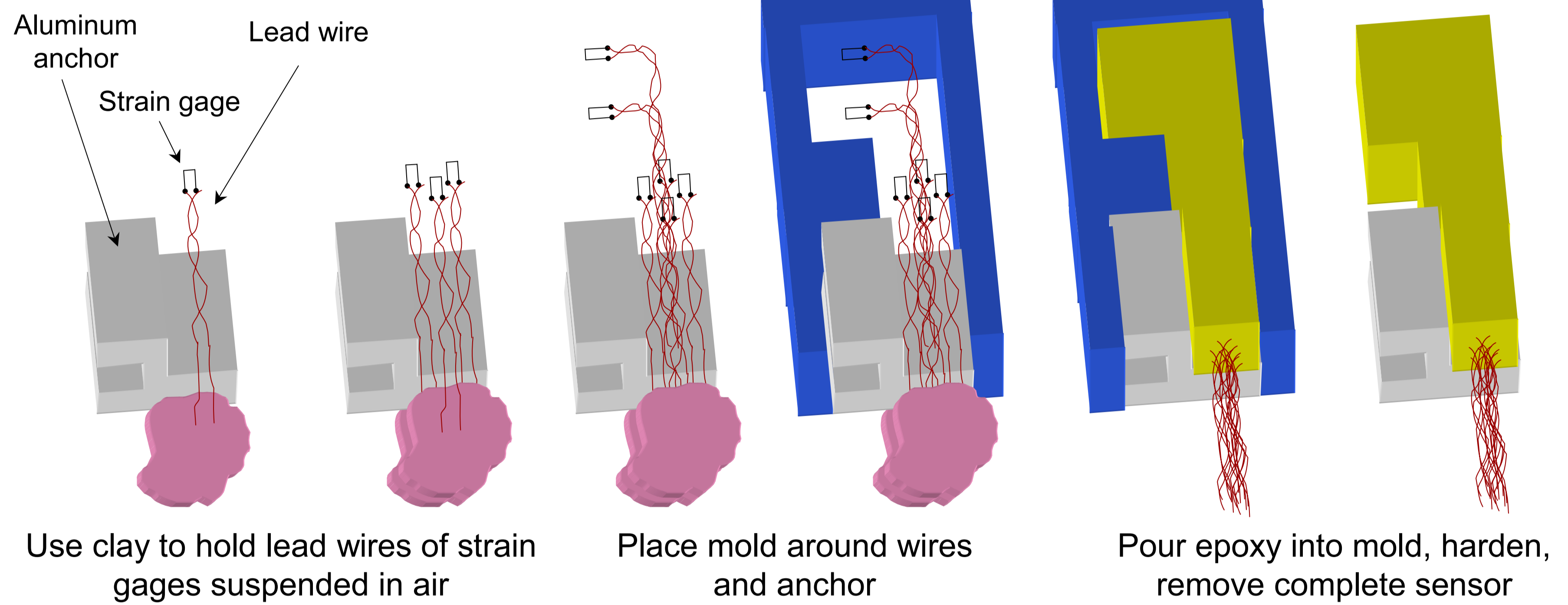
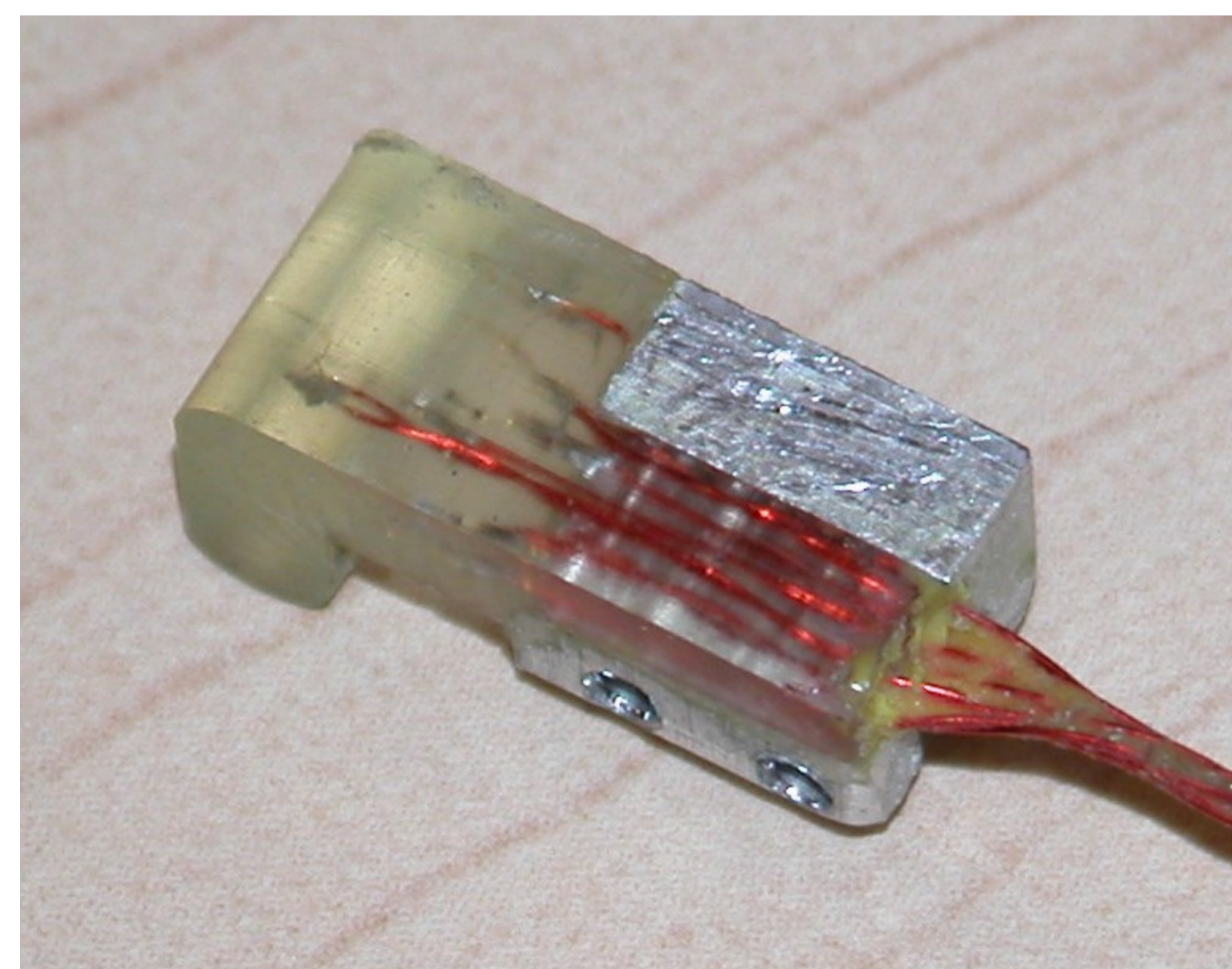
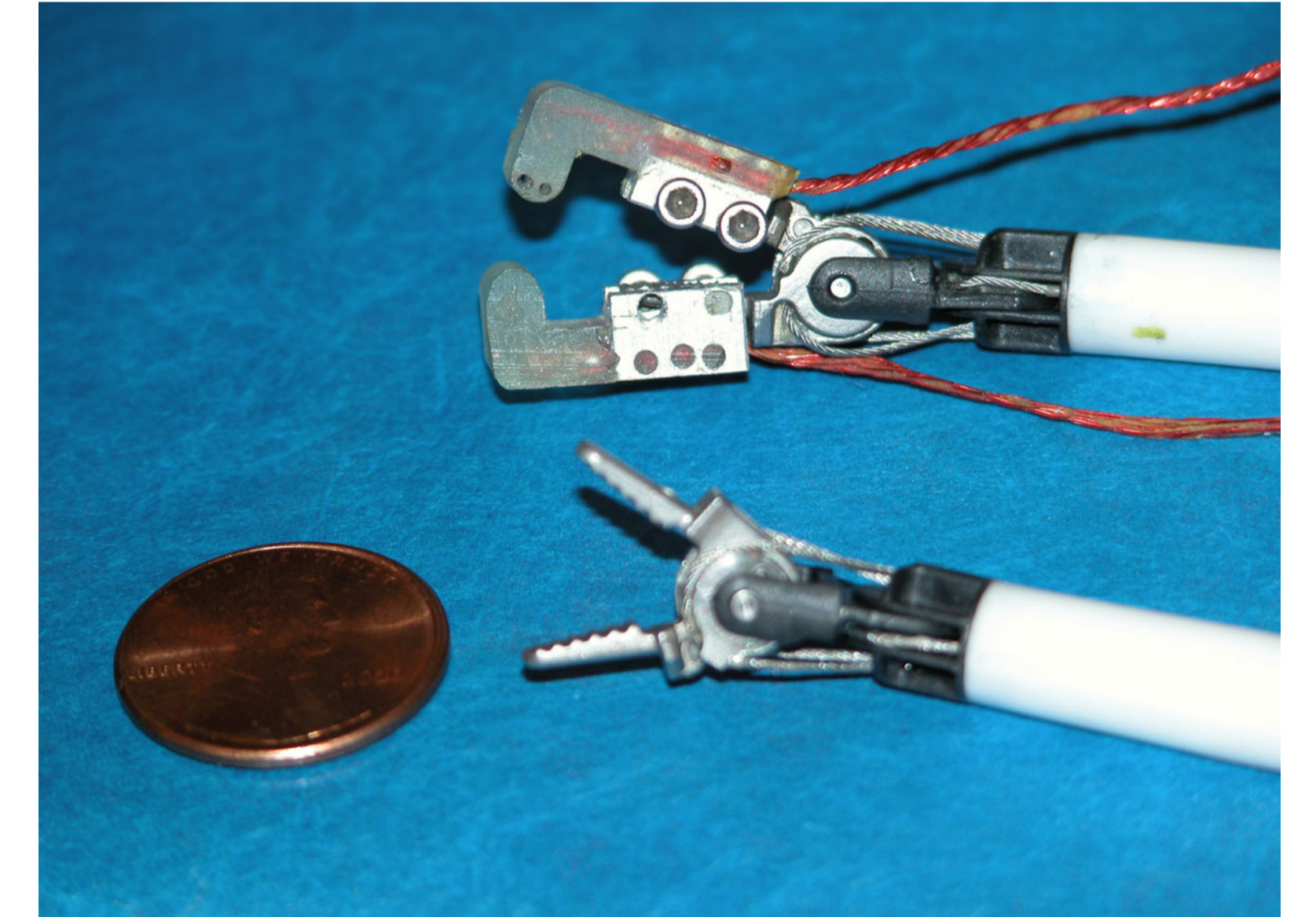


Diagram of force sensor design. Dimensions in millimeters.

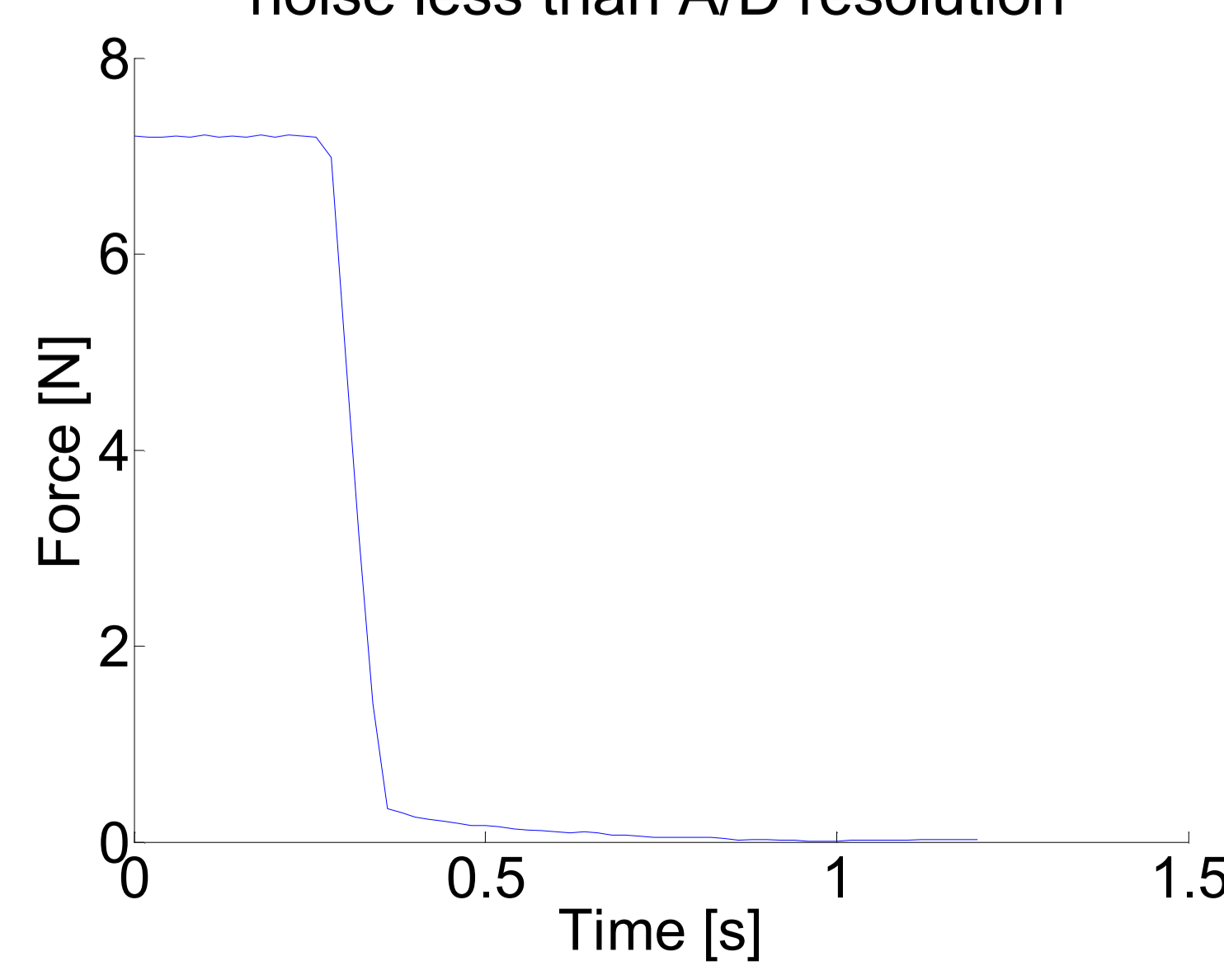
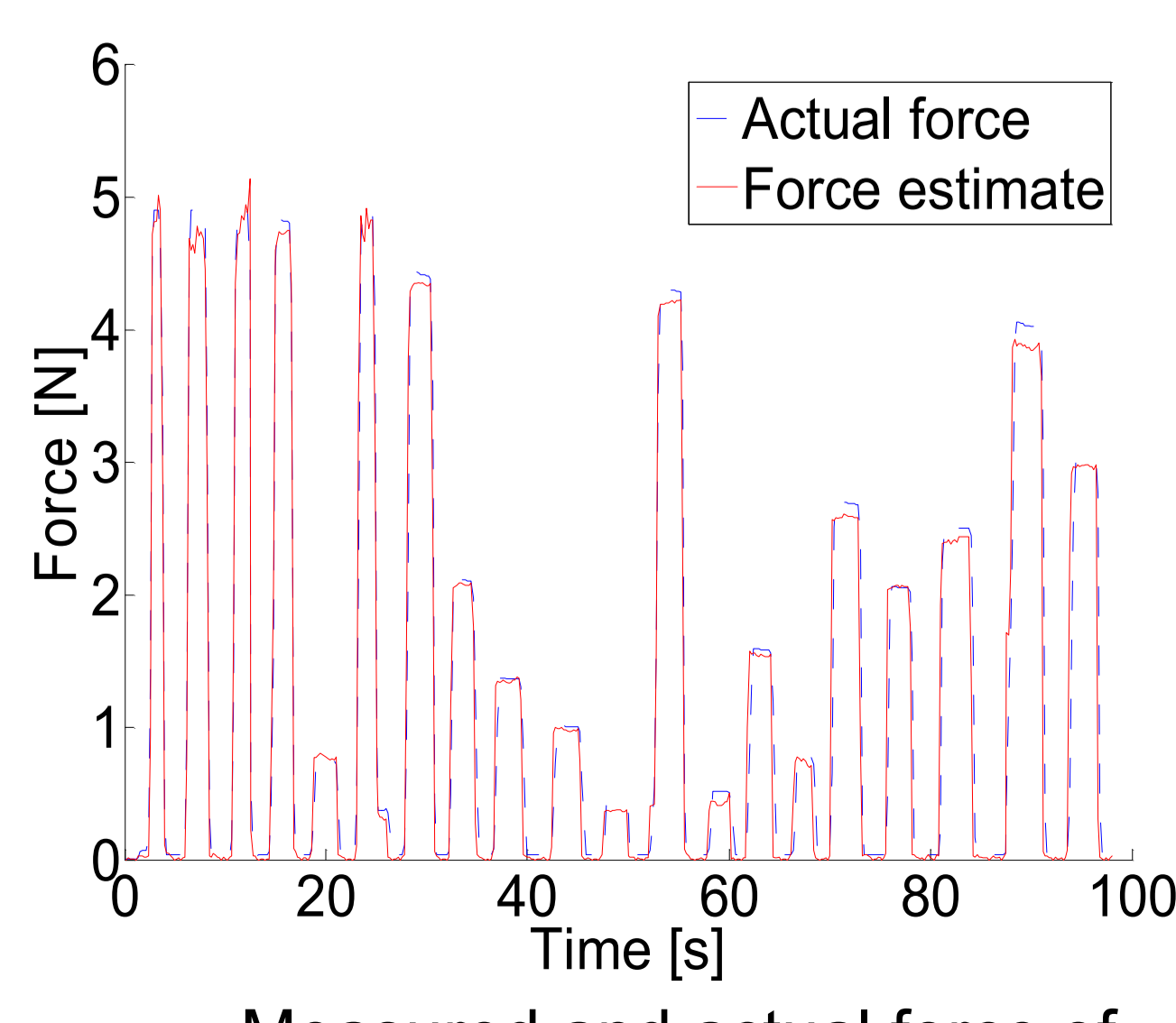
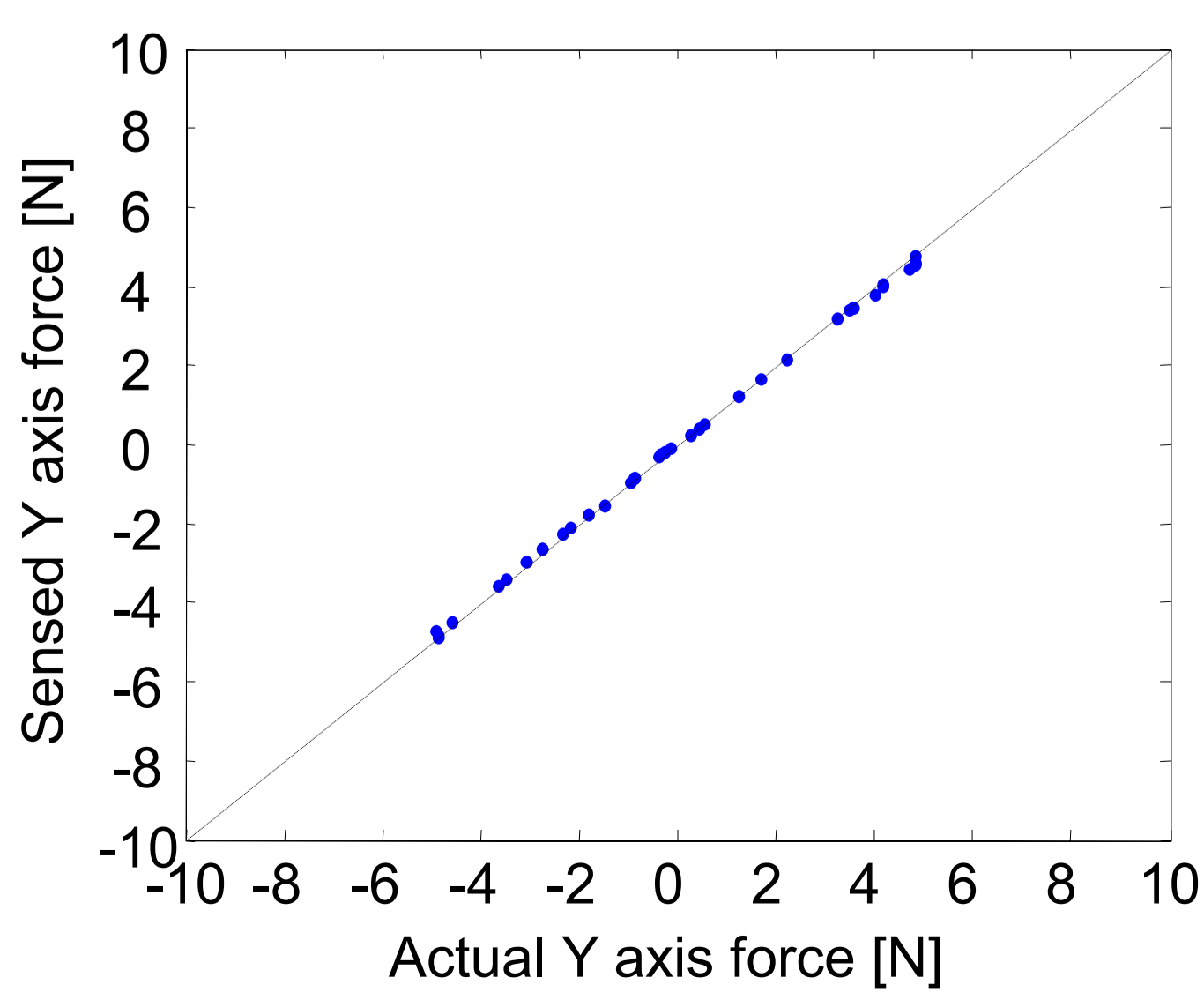
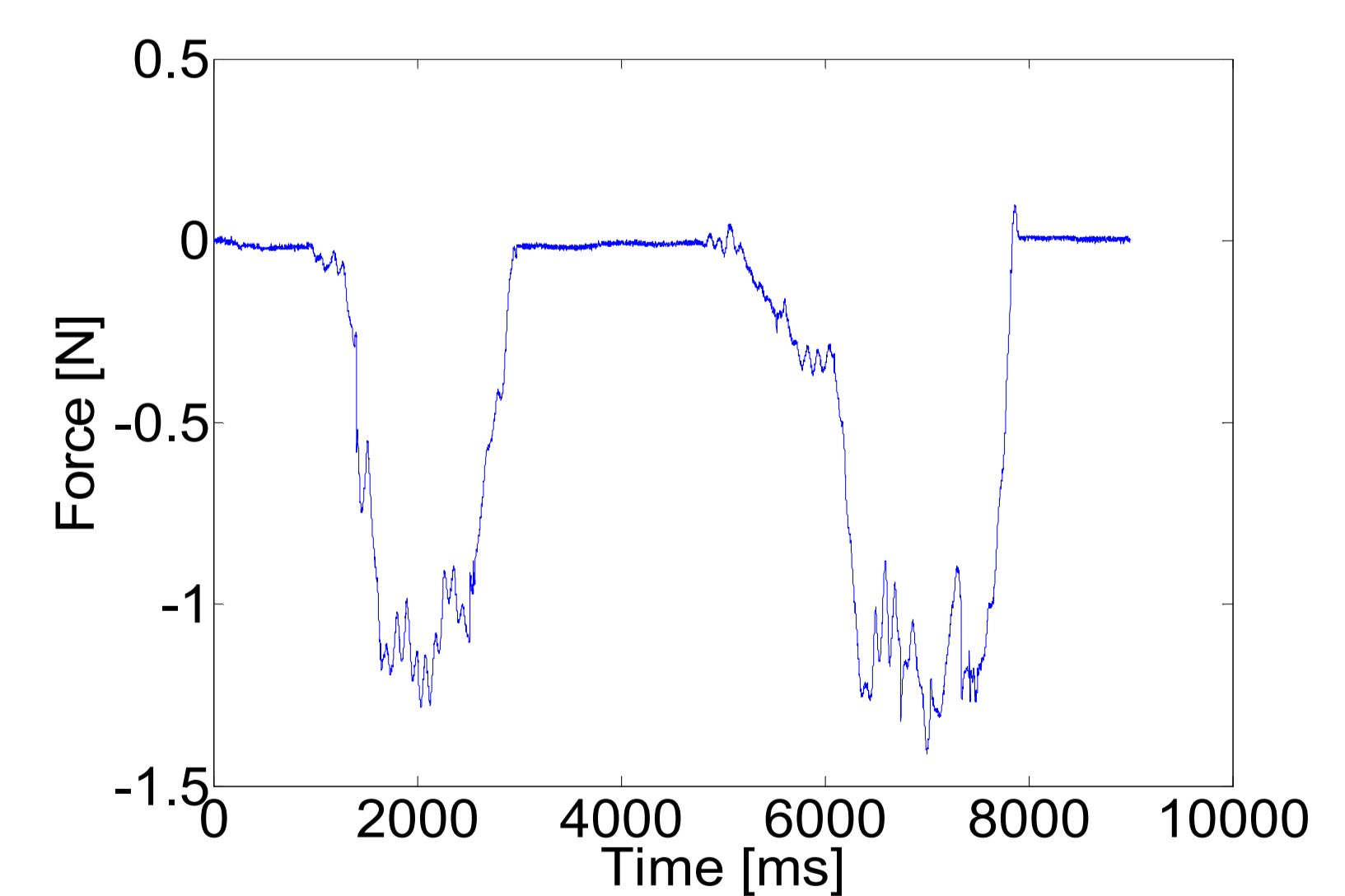
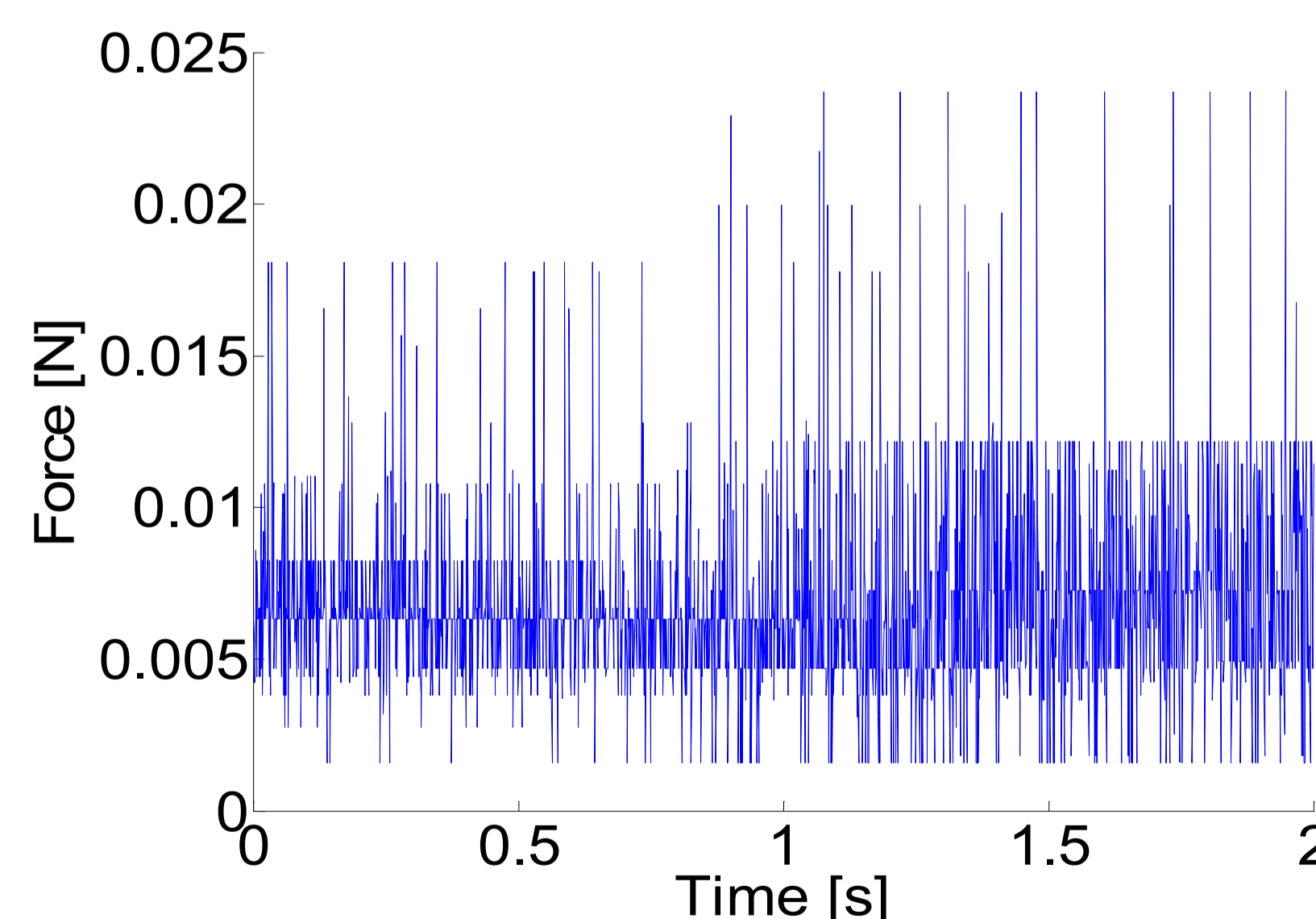
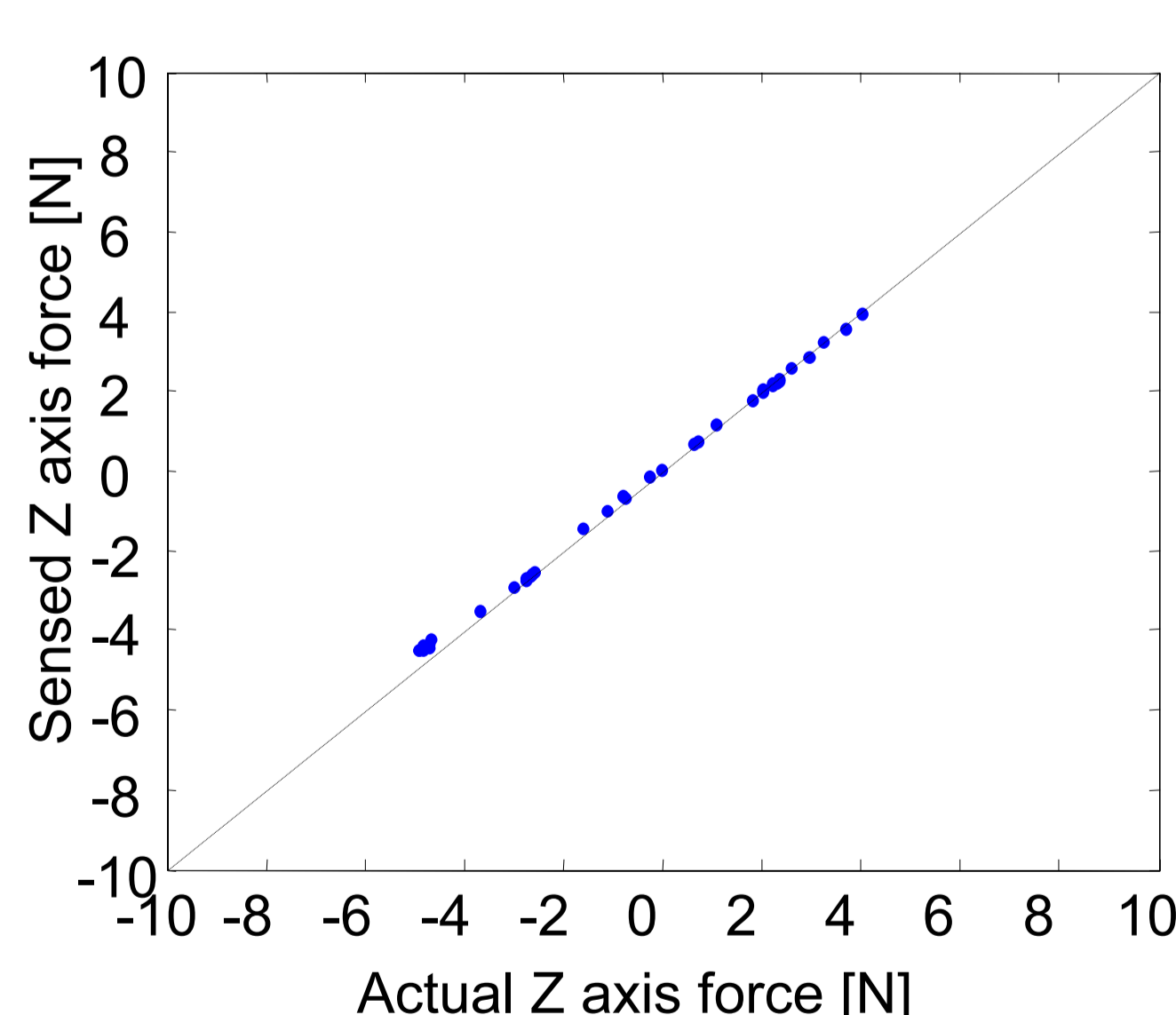
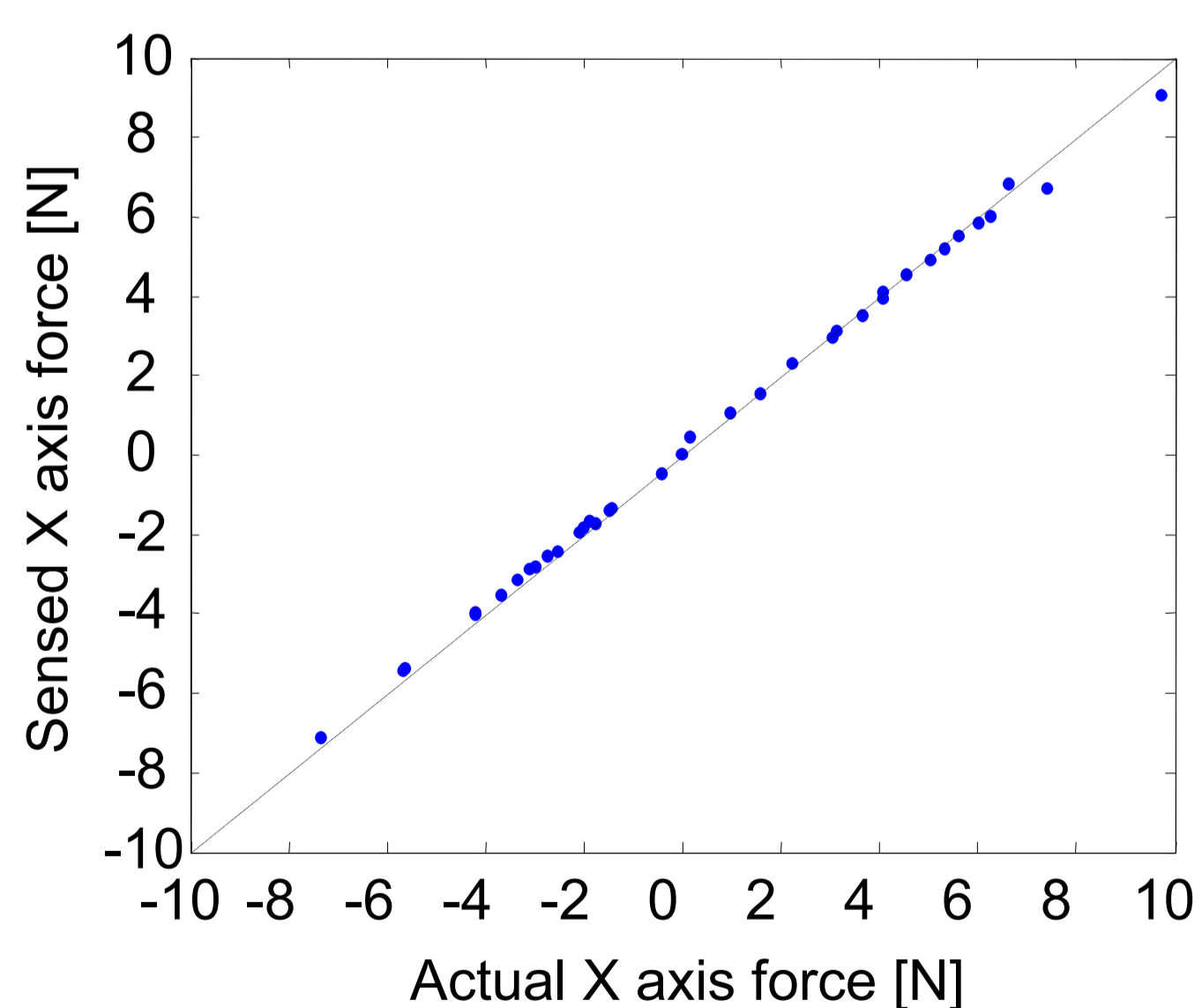


Three axis force sensor. Note distribution of strain gages throughout epoxy.



Articulated wrist surgical graspers with and without force sensors attached

Sensor Characterization:



Future Work:

- Reduce temperature effects
- Analyze effects of moments
- Embed metal grasping surface (for needle gripping)
- Reduce sensor size for 10 mm port

References:

- [1] Wagner, C.R., Stylopoulos, N., Howe, R.D., The Role of Force Feedback in Surgery: Analysis of Blunt Dissection, Haptics Symposium, Orlando, March 24-25, 2002
- [2] P.J. Berkelman, L.L. Whitcomb, R.H. Taylor, P. Jensen, A miniature microsurgical instrument tip force sensor for enhanced force feedback during robot-assisted manipulation, IEEE Transactions on Robotics and Automation, Vol 19, Iss. 5, 2003