COMPLEX PATH FOLLOWING AND FORCE CONTROL

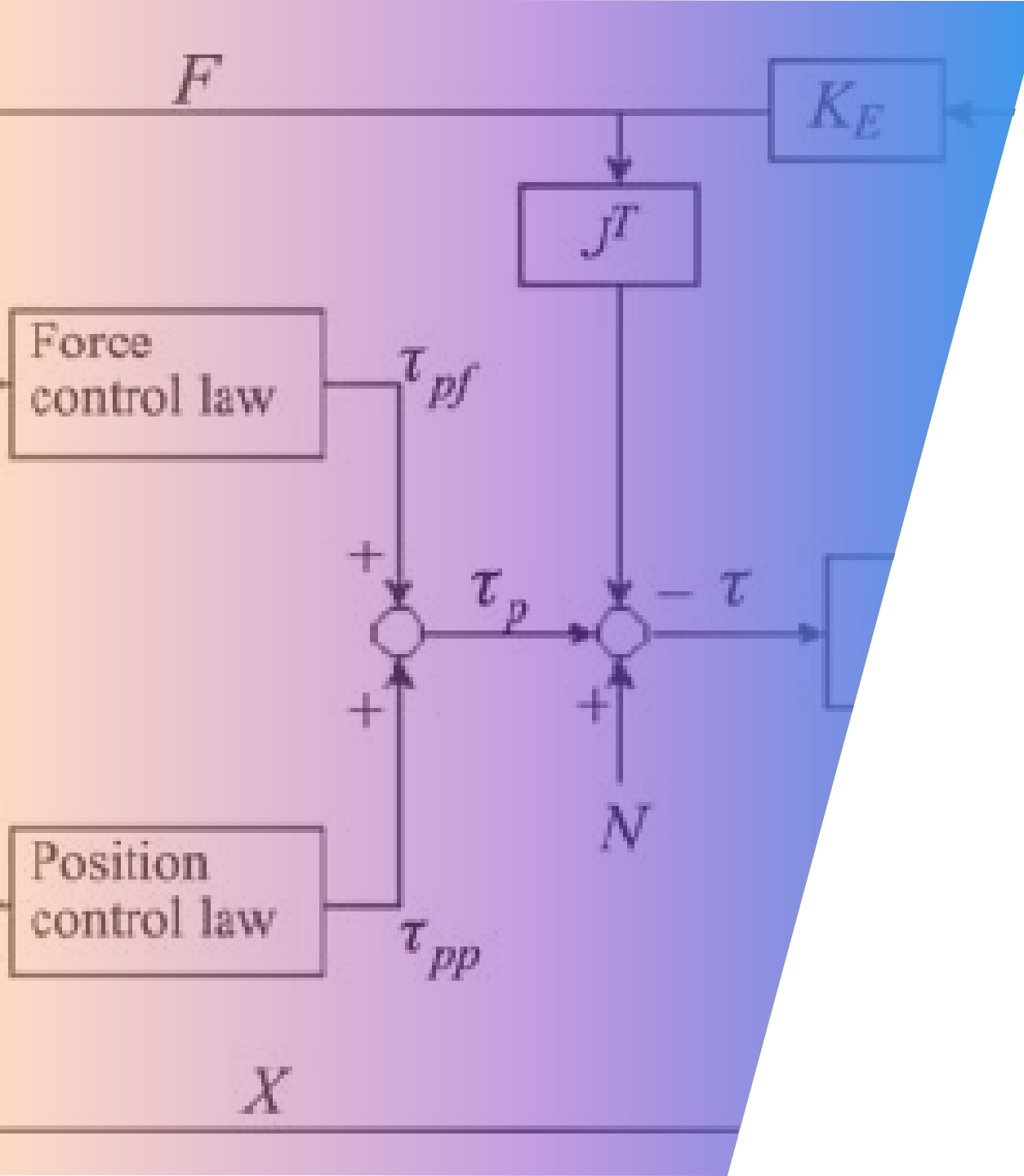
and how to do it with a robot

October 9, 2018

www.crossrobotics.com

AGENDA

- Force Control Overview
- Path Following Overview
- Force Control + Path Following
- Considerations when using a Robot
- Application Examples
- Key takeaways



FORCE CONTROL

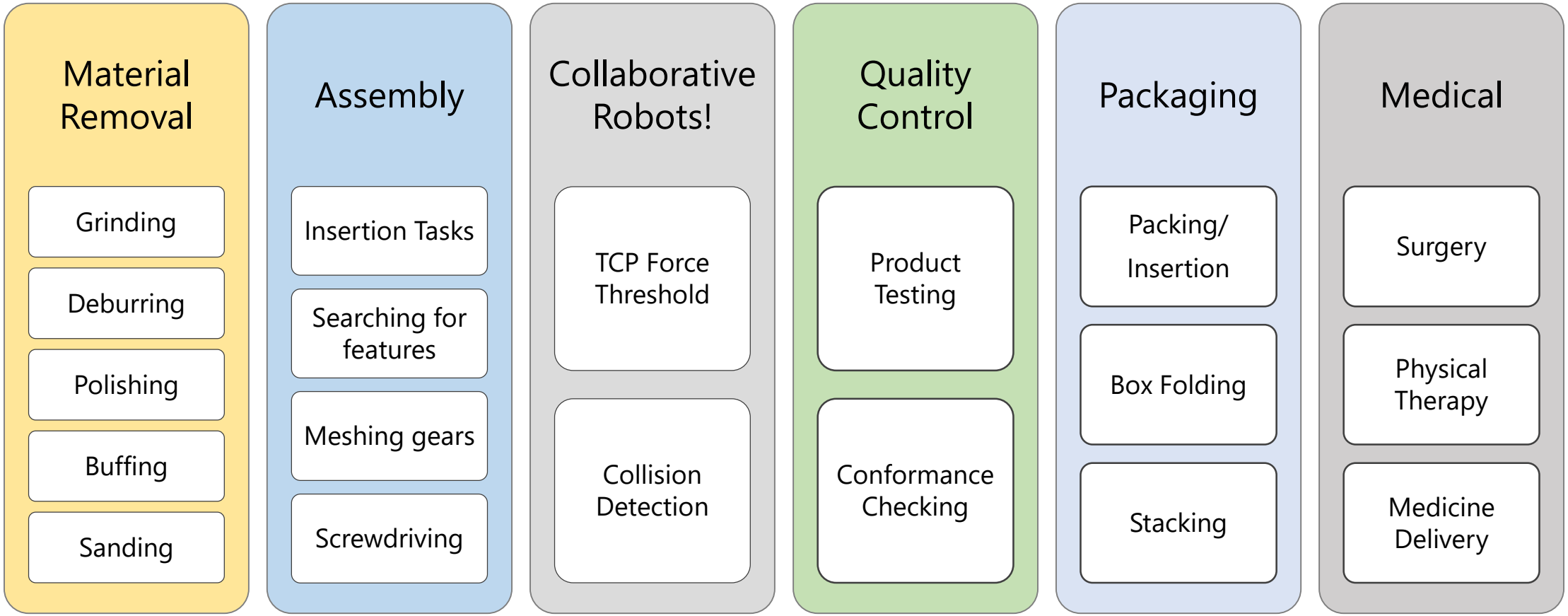
More Than Just Sounding Cool

Force/Torque Control?

- **Detect** changes in **magnitude** of forces
- **Apply, monitor,** and **maintain** a constant force in one or more degrees of freedom
- Other examples?

What Applications use Force Control?

Answer: A lot of them.



Key Concepts in Force Control

Resolution (N)

- Smallest increment picked up by the sensor

Noise (N)

- Caused by electrical interactions
- Digital sensors are immune to external noise.
- Should be a very small fraction of the nominal resolution

Drift (N)

- When the sensor reads a changing force that isn't there
- Can be affected by temp/humidity
- Frequent calibration reduces drift

Output Rate (Hz)

- **100Hz** is suitable for most robot applications
- Finer precision (eg. surgery) needs higher output rates
- **If Control system BW >> Sensor BW… Poor accuracy**

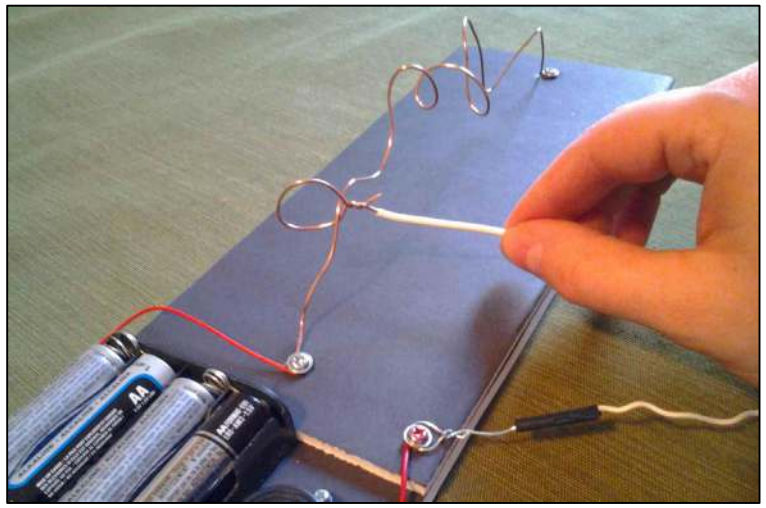
Unless your application requires very fine forces or sophisticated control systems, it's generally not worth going beyond the resolution spec.

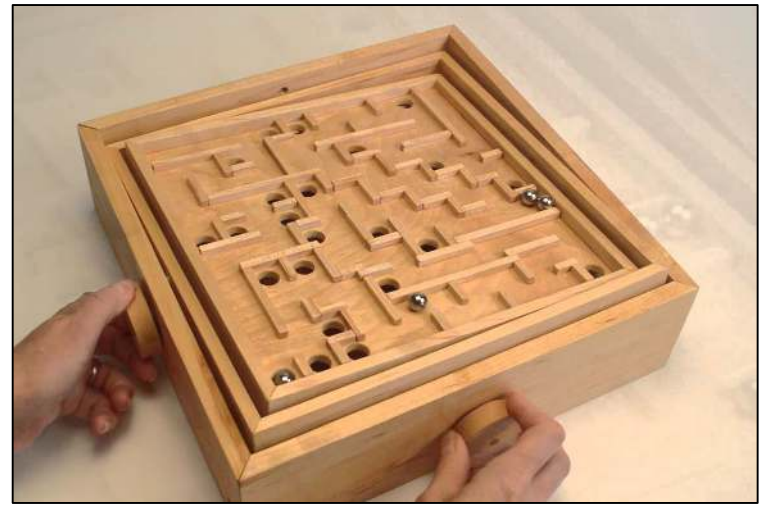
PATH FOLLOWING

Staying on Track

Path Following?

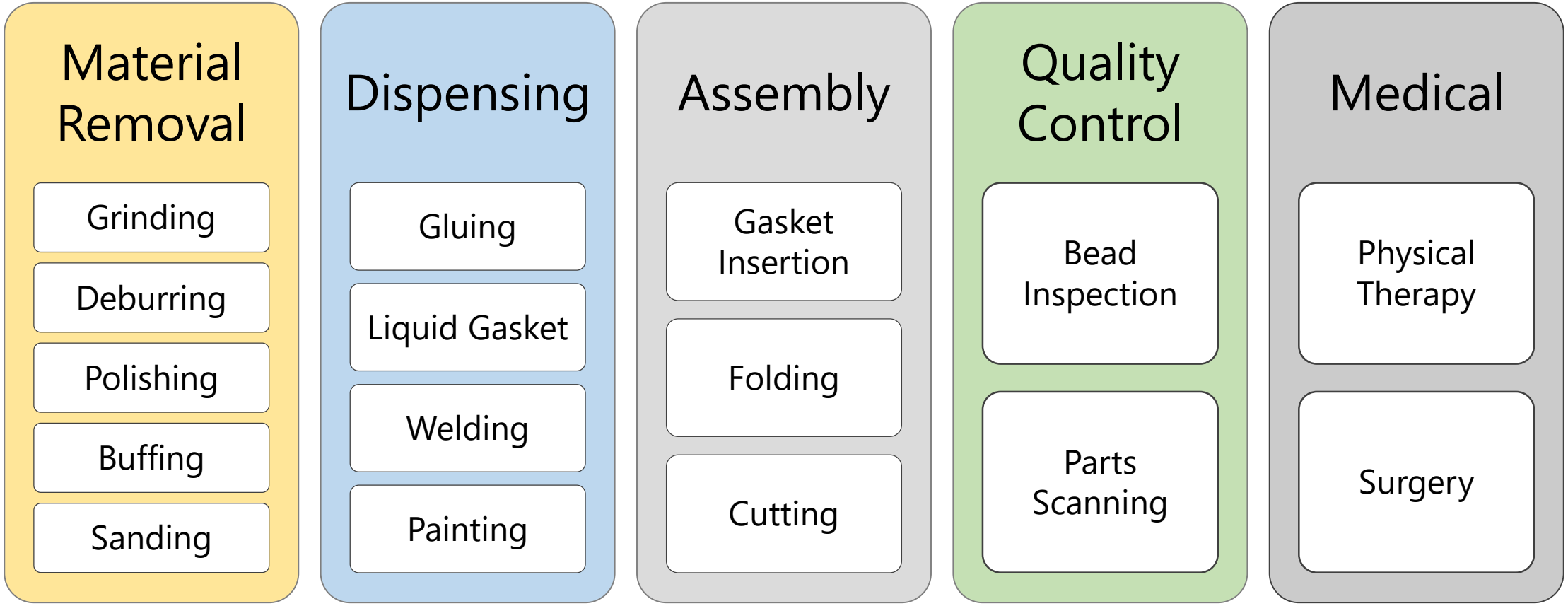
- Exactly what it sounds like
- More than just Point A to Point B
- Requires constant adjustment of position during movement





What Applications use Path Following?

Answer: Many types.



Key Concepts in Path Following

Hand-Guiding

- User guiding the robot TCP by hand
- Force sensor assists by commanding robot to move in the direction of detected movement

Path

- The trajectory followed by the robot TCP
- Usually made up of thousands of waypoints
- Can be created by hand guiding or with software

Control Force

- Constant force applied in a specified direction while following a path

Process Move

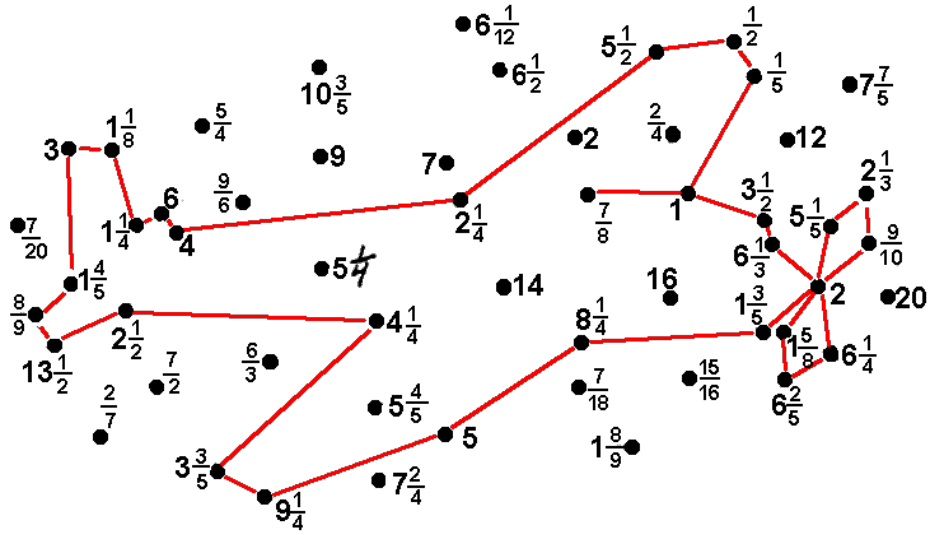
- Following a path with a certain speed profile
- Can be constant speed (Dispense, inspection, etc.)

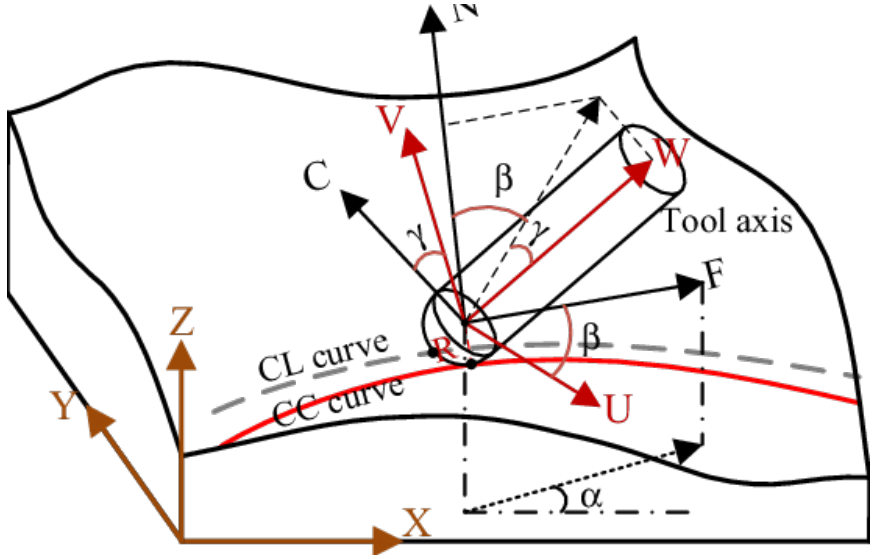
Complex Path Following with Force Control

Putting them together

Challenges

- Programming from pendant is generally done with discrete waypoints
  - Tough for complex, variable-radius curves





Control forces and tool tip kept at specific angles

- Humans are intuitively pretty good at this (e.g. writing, drawing)
- **BUT** – this skill doesn't necessarily translate to programming a robot

Potential Solutions

Program all your waypoints manually

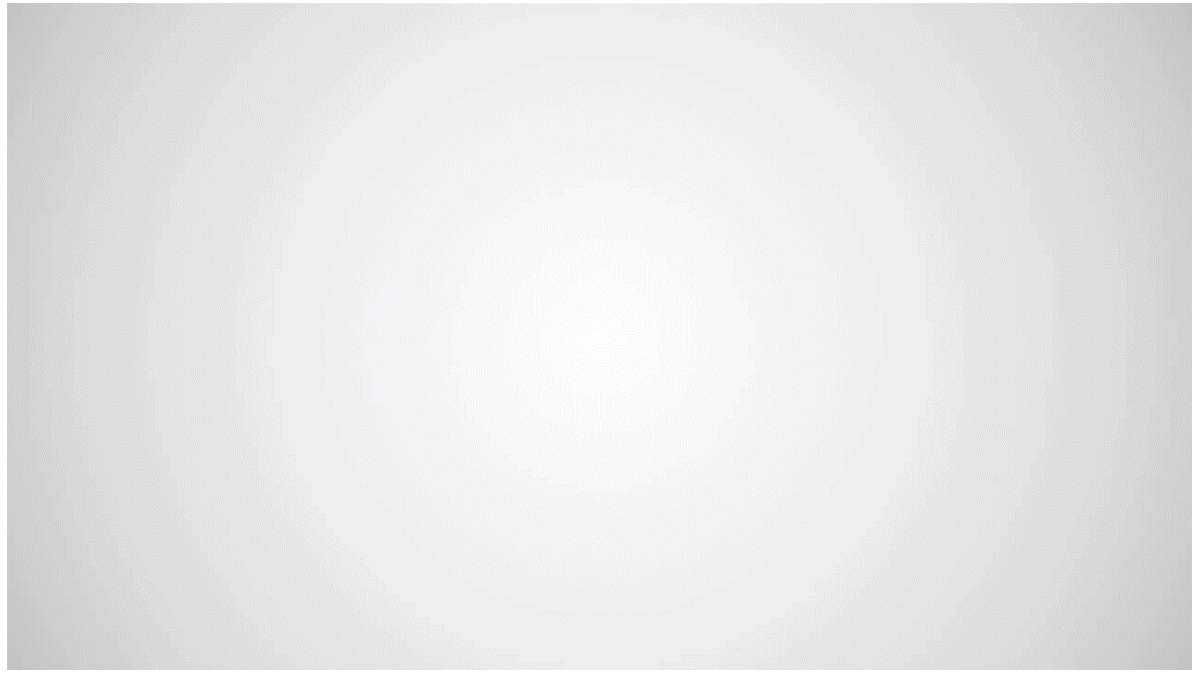
- **PROS**
  - No additional equipment required
- **CONS**
  - You will regret every single thing about doing this

Potential Solutions

Path Recording with a Force/Torque Sensor

- Hand-guiding the TCP to record a path

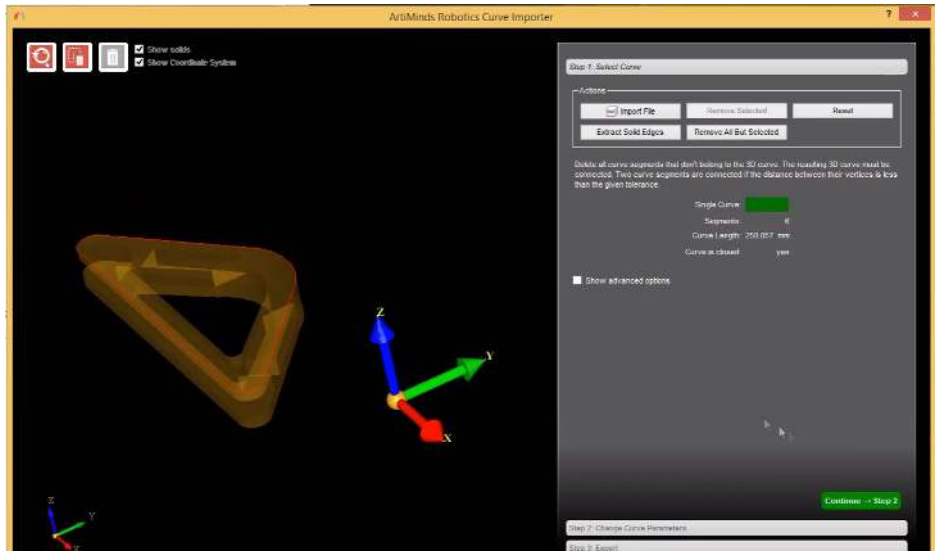
- Can execute:
  - At recorded speed
  - At constant Speed
  - Relative to an offset



Potential Solutions

Generate paths from software with imported CAD

- ARTIMINDS can convert CAD models and sketches to robot paths
- Convert edges to path segments
- Project a path onto a surface
- Generates code in robot's native language



Application Considerations

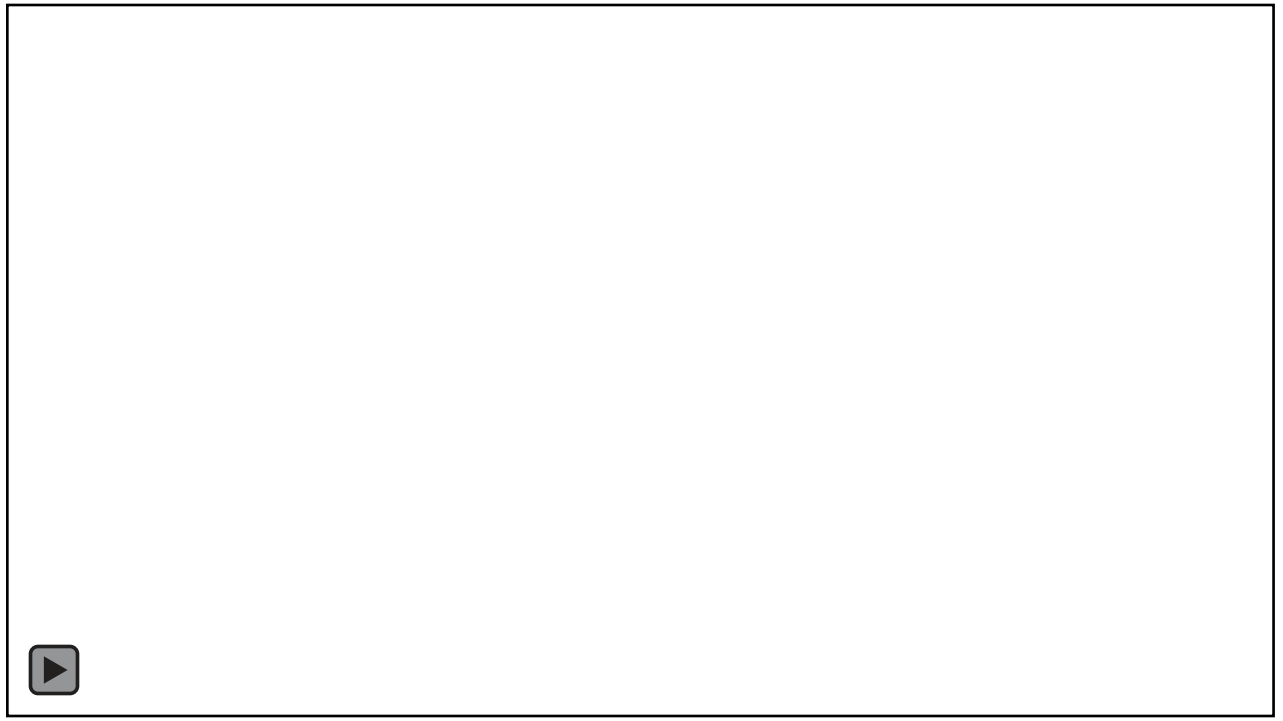
Things to Consider

Force Sensors ≠ Safety-Rated Devices!

Specialized robots for surgery etc. have been thoroughly evaluated as a whole system

Repeatably Placing Part

- Jigs/fixtures are generally most reliable, but not always feasible or the most efficient
- Can also use 2D camera or force sensor to locate part and apply offset to a path



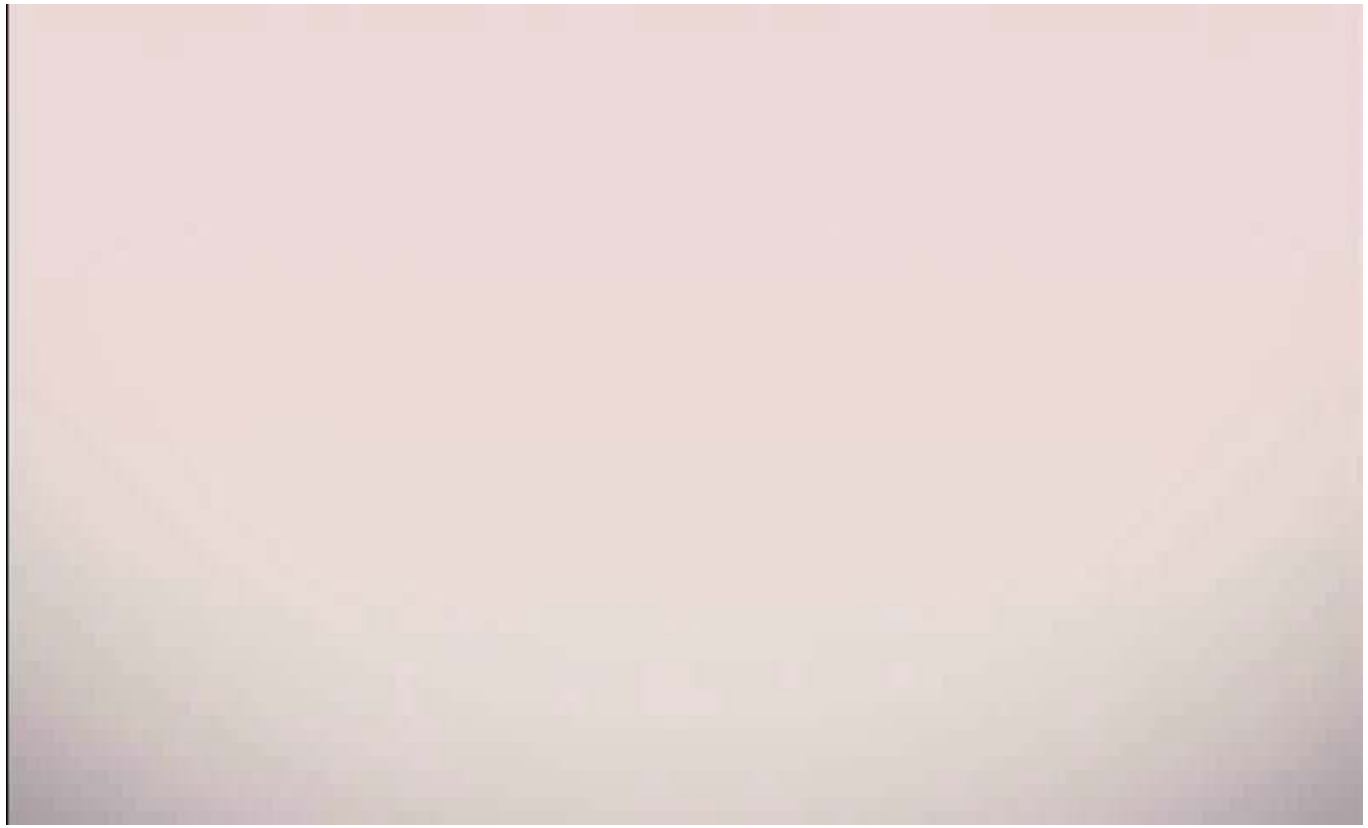
Reach/Pose Required of Robot

- Especially with offsets applied – executing paths could lead to singularities

- Speed control suffers greatly when passing through singular positions

Complexity of Surfaces/Edges

- More complex edges = more time spent perfecting path
- Having CAD model + simulation software can greatly help
- Control forces can also help with unknown or complex surfaces

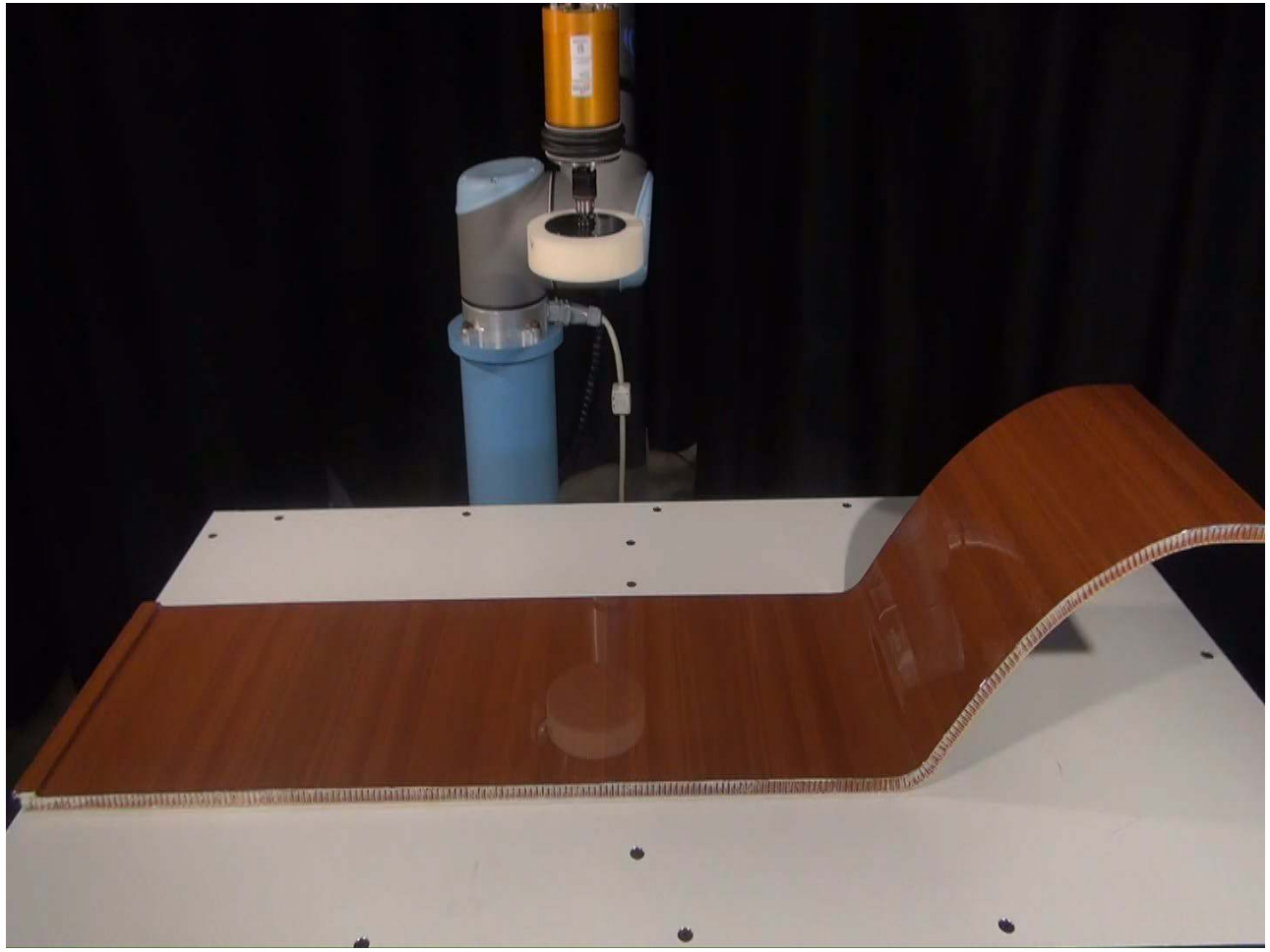


End of Arm Tooling Factors

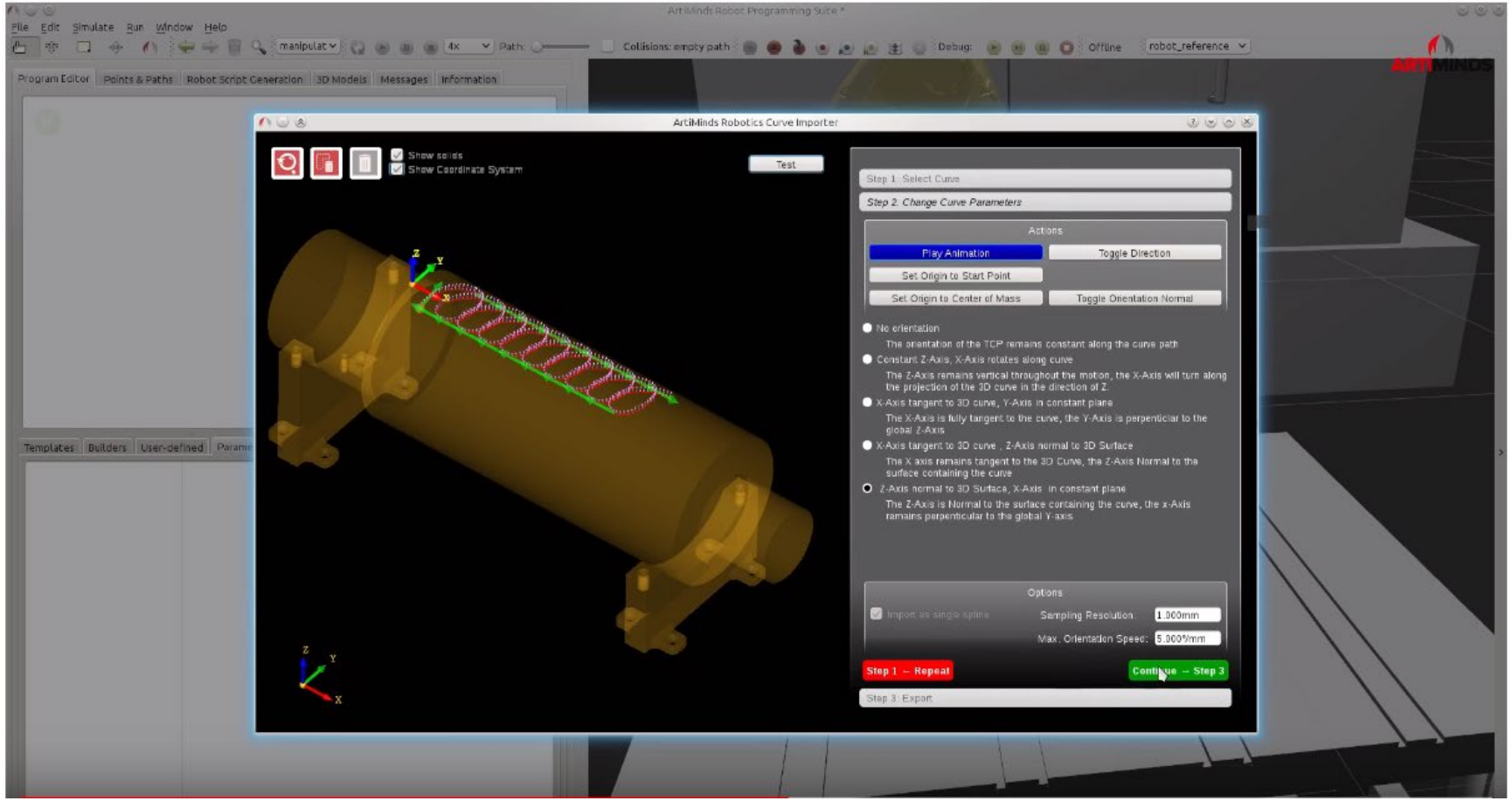
- Force Sensor Make and Model
- Dispenser
- Cutting/abrasive Media
- Material dispensed & dispense rate
- Part material & desired finish
- Etc.

APPLICATION EXAMPLES

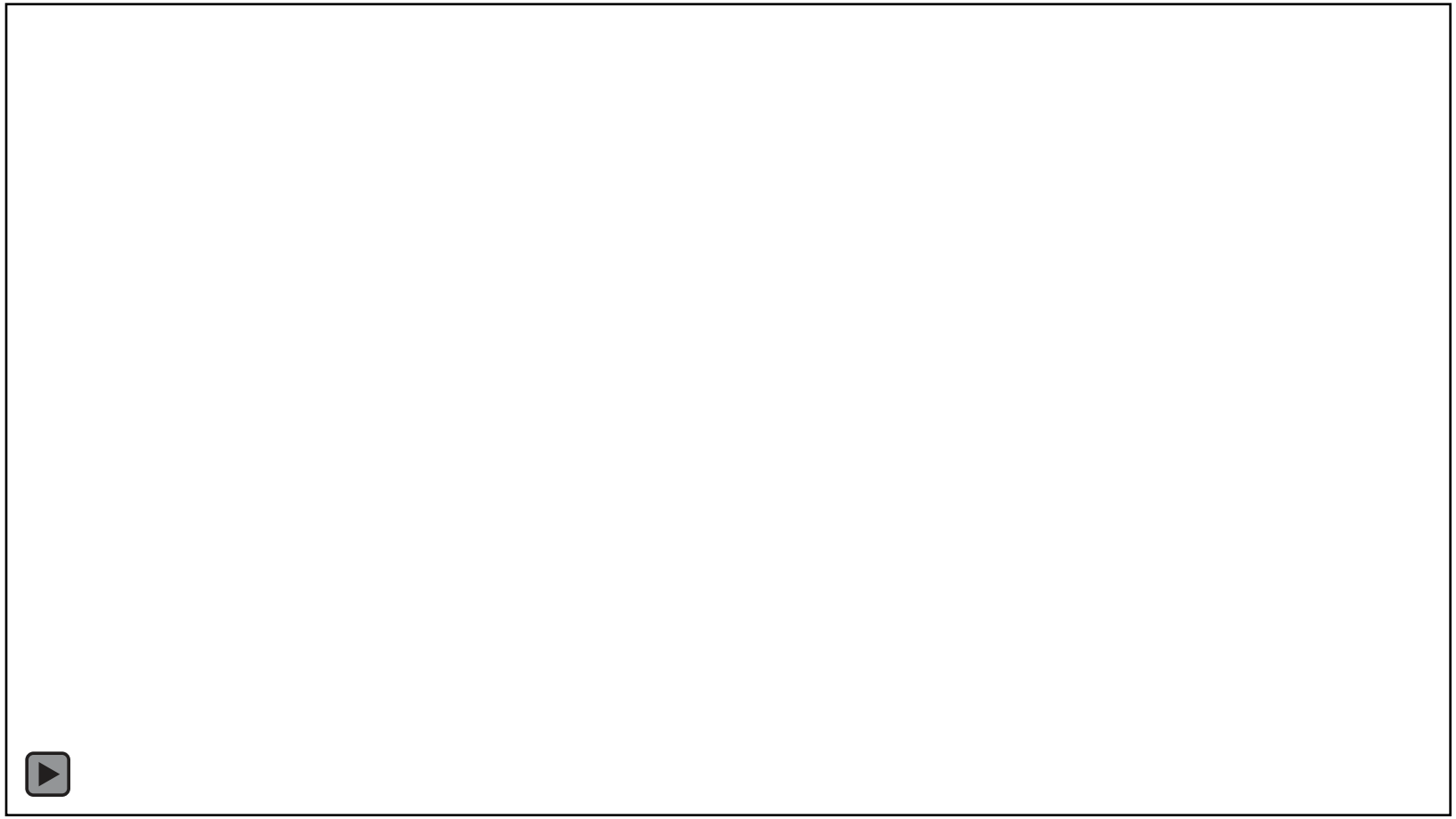
Buffing of High-Gloss Veneer



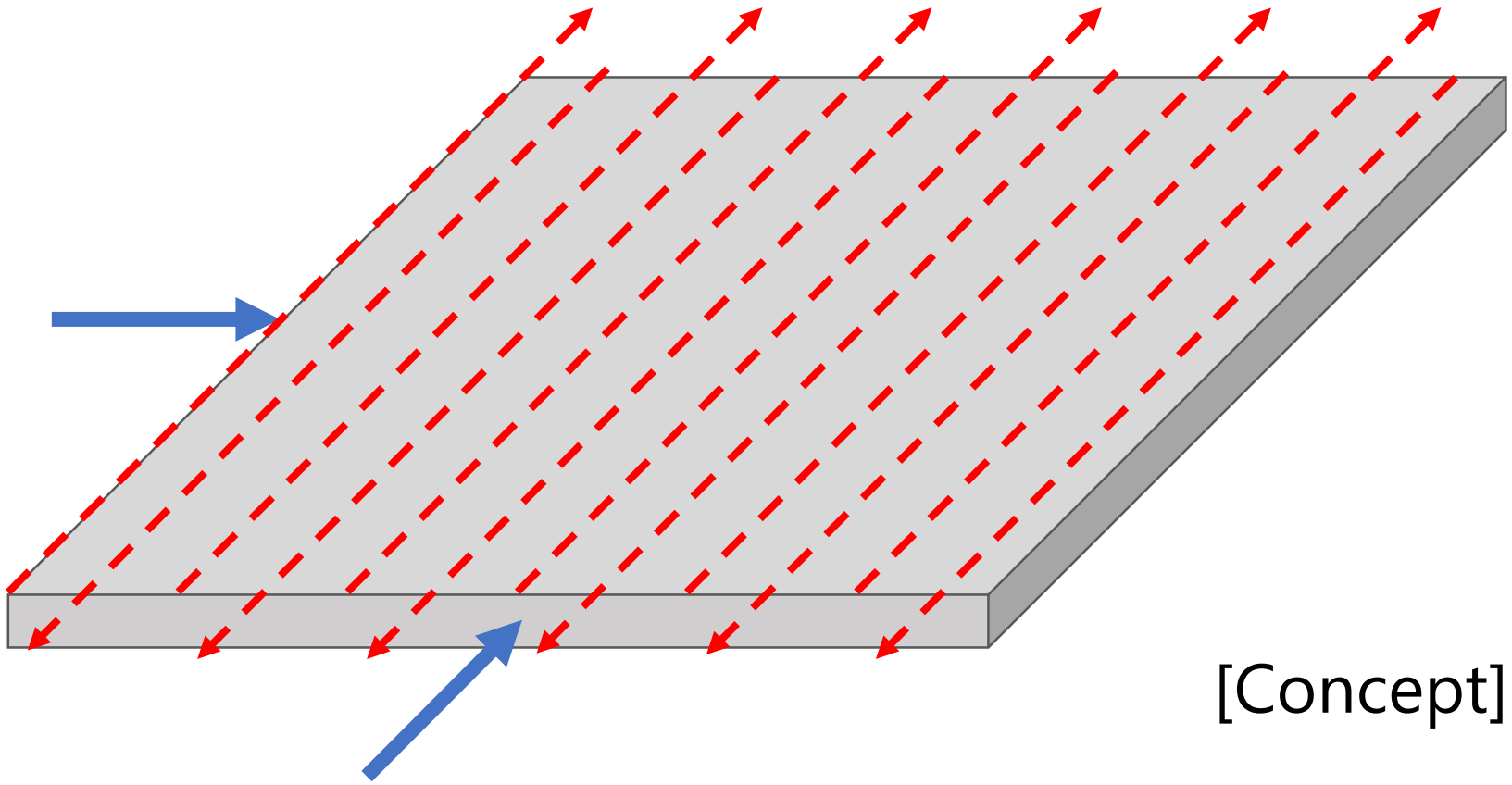
Polishing a Muffler



Ultrasonic Inspection



Griding w/ Part Location by Touch



[Concept]

WRAPPING UP

Key takeaways

Key Takeaways

- Sensitive force control tasks (insertion, assembly, etc.) may require a Force/Torque Sensor

- Force/Torque Sensors allow control over not only force-sensitive tasks, but a lot of flexibility on path-based tasks as well

- **Software such as Artiminds** makes complex multi-DOF path generation considerably easier and quicker to implement

THANK YOU

WWW.CROSSROBOTICS.COM

MANAN BANERJEE

(704) 723-2036

manan.banerjee@crossco.com