Competitive U.S. Composite Manufacturing Through Automation

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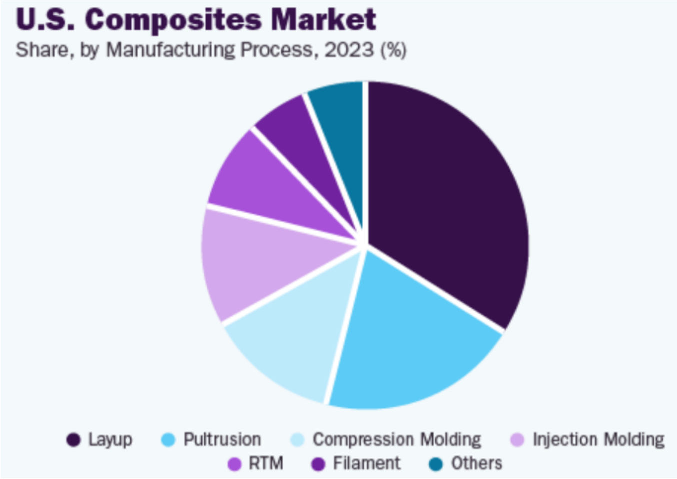
Presentation Overview

1. Project Motivation
2. Previous Tool Design and Toolpath Generation
3. Recent Progress in Real-Time Control
4. Project Goals

Composite manufacturing in the U.S.

- The U.S composites market was $15.58 billion in 2023 and expected to grow annually by 5.3% (Grand View Research, 2023).



Graph from Grand View Research (2023)

Composite manufacturing in the U.S.

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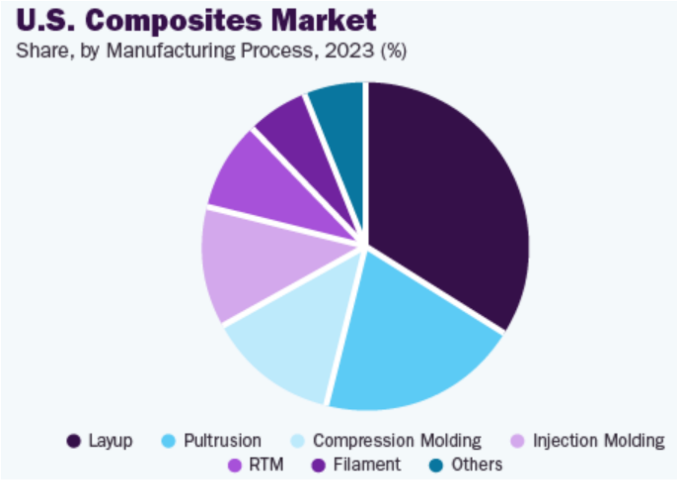
- Largest manufacturing process is layup, with growth expected in automotive, energy, infrastructure, architecture, aerospace, and marine applications.



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The goal of this research is to encourage investment in U.S. composite manufacturing

- Automated finishing can encourage investment through
  - Increasing quality
  - Reducing cycle time
  - Increasing throughput.

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  - Increasing quality
  - Reducing cycle time
  - Increasing throughput.
- However, to make automated composite finishing economically viable:
  - Keep capital costs low
  - Be able to adapt to new parts
  - Dramatically reduce cycle time.
- The combination of these objectives will lead to onshoring of composites manufacturing, leading to:
  - More U.S. manufacturing facilities
  - Increased U.S. jobs.

Why automate composite finishing?

- A National Association of Manufacturers survey found (Bloom, 2025) that almost half (47.46%) of U.S. manufacturers identified hiring and retaining labor as a big challenge
  - Improving worker safety and well-being is a priority for strengthening the workforce.

Photo by Casey Nichols, NREL

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- Significantly reduce manufacturing cycle time.
- Consistent part quality.

Photo by Casey Nichols, NREL

Automating composite finishing is a unique challenge

- Composites are often used for manufacturing large, lightweight structural components.

Photo By Hunter Huth, NREL

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Automating composite finishing is a unique challenge

- Composites are used for manufacturing large lightweight components.
- Large, flexible parts are difficult to fixture and lack the necessary consistency for pre-planned toolpaths.
- Our automated system produces toolpaths from high-precision vison systems to enable automation for these composite structures.

Photo By Hunter Huth, NREL

Previous Work

Photo by Hunter Huth, NREL

Automation tool design and toolpath generation

- Designed and selected tools to optimize for composite finishing:
  - Bandsaw for flashing removal
  - Drum sander for surface preparation.

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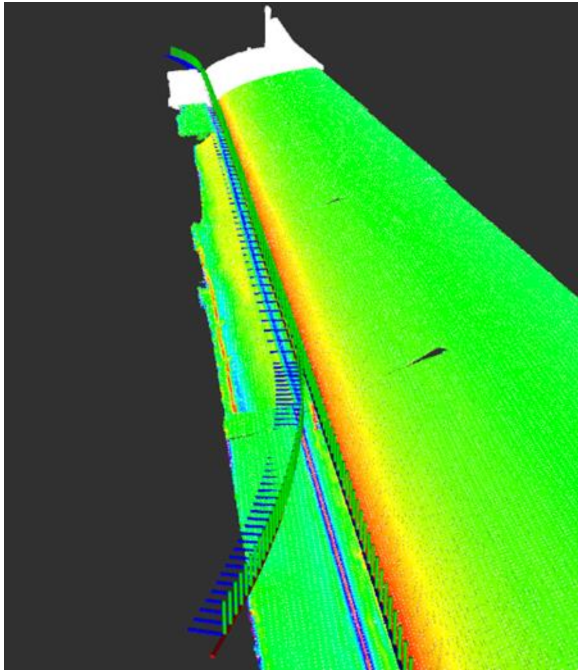
Automation tool design and toolpath generation

- Designed and selected tools to optimize for composite finishing:
  - Bandsaw for flashing removal
  - Drum sander for surface preparation.
- Toolpath generation from high-precision scans
  - Can adapt to variations in the produced part
  - Account for inconsistent fixturing.



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Demonstrations

Trimming – 4x speed

Surface Preparation - 4x speed

Videos by Hunter Huth, NREL

Despite successful trials, further development needed to improve the speed and quality

- Previous phase focused on how to use captured blade geometry to plan toolpaths.

Collect 3D data of blade geometry

↓

Process data to plan a toolpath

↓

Execute toolpath

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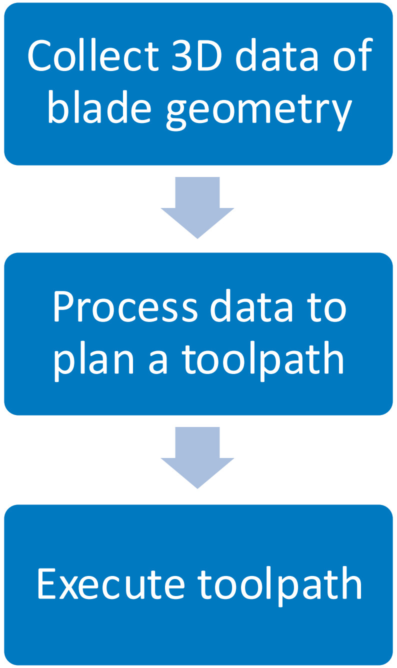
- Sequentially captured data, planned a toolpath, and executed the toolpath
  - Inefficient in terms of cycle time.



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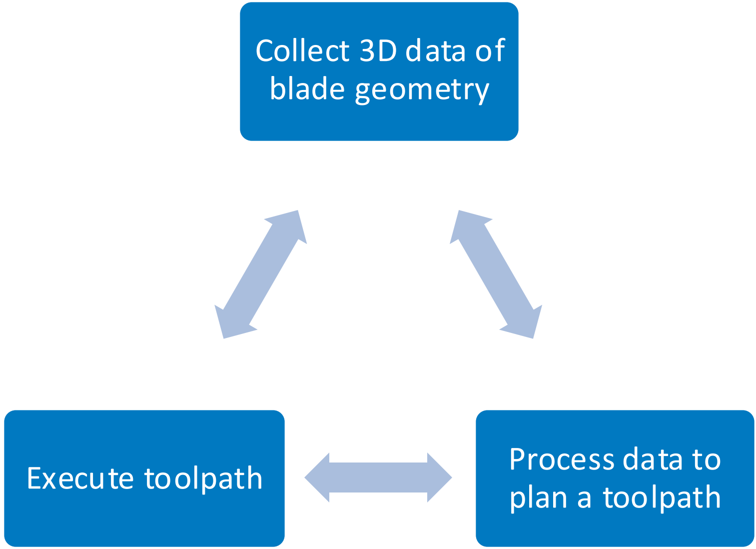
- Previous phase focused on how to use captured blade geometry to plan toolpaths.
- Sequentially captured data, planned a toolpath, and executed the toolpath
  - Inefficient in terms of cycle time.
- Current phase will scan, plan, and execute in parallel
  - Substantial reduction in cycle time
  - Limited by tool operation speed
  - Real-time feedback to improve finish quality.
  - Aligns with AMMTO smart manufacturing objectives



Current Work

- Real-Time Control Interface
- Simulation
- Flashing Detection
- Surface Construction
- Bandsaw Design

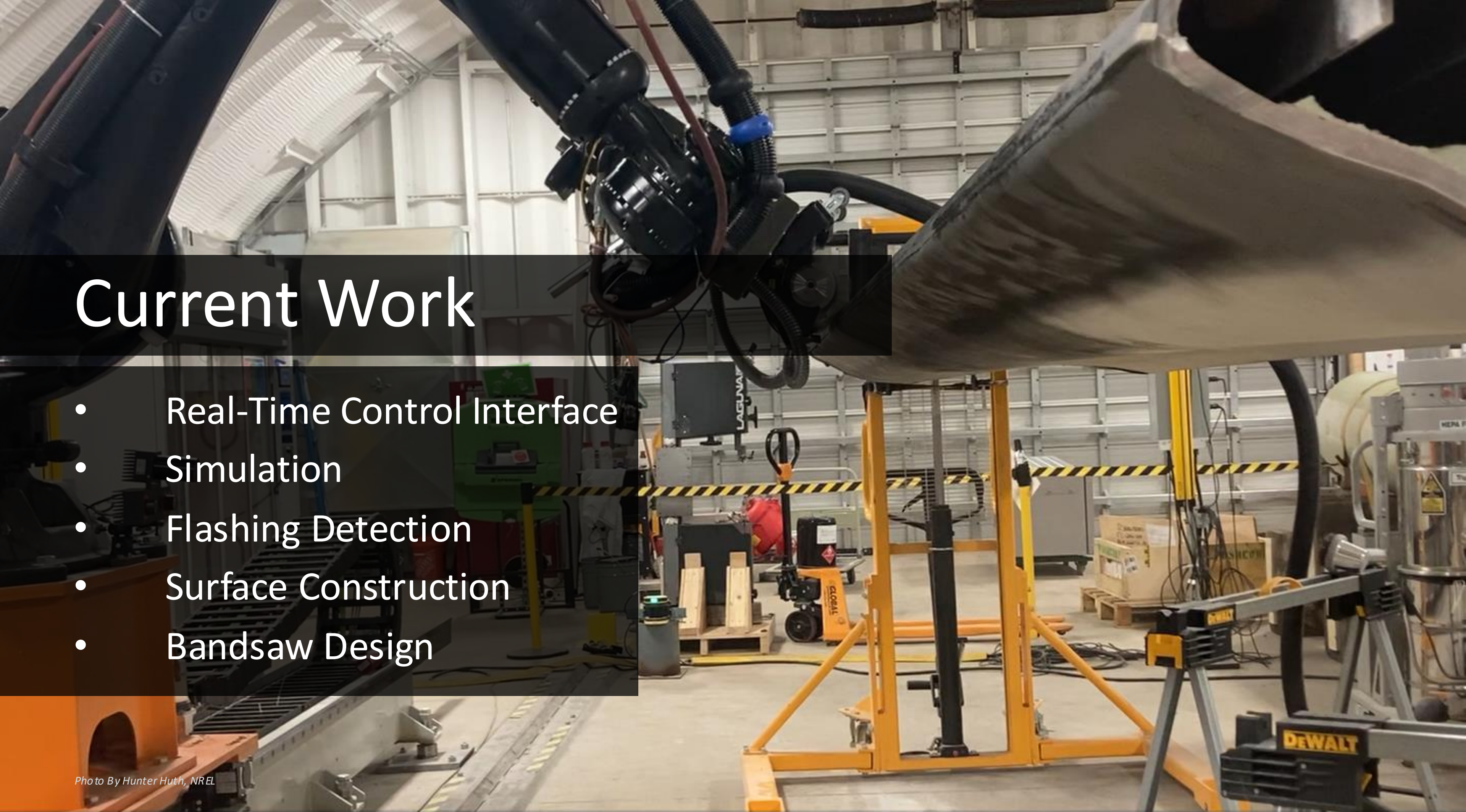
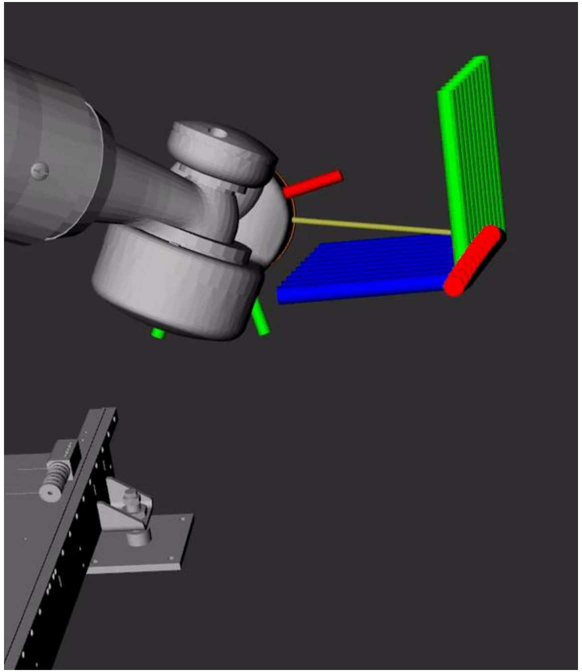


Photo By Hunter Huth, NREL

Real-time control interface

- Controlling real-time motion of an industrial robot is not typical operation
- Developed a ROS2 (2022) interface to controlling the motion in real time
- Stream joint commands to the robot at 250 Hz
- Continuously update trajectory from sensor measurements
- Ensure final trajectory is smooth for precise execution.



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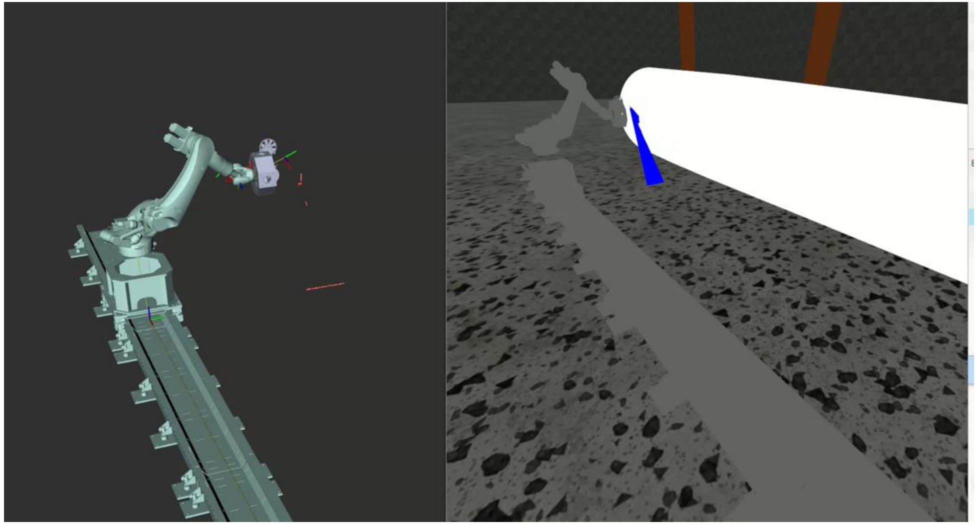
Large-scale composite finishing simulation

- Developed in Gazebo to test on simulated parts
- Inform robot configuration of tools, sensors, and mobility
- Rapid development of real-time toolpath generation algorithms.



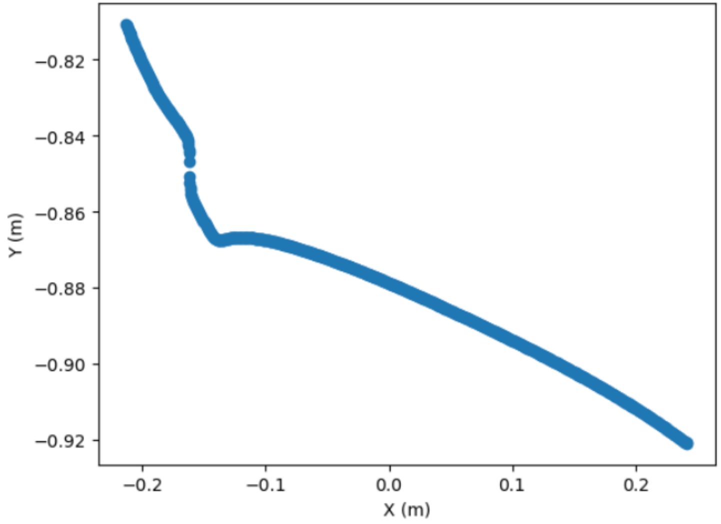
Robot Visualized in Rviz

Gazebo Simulation

Video by Hunter Huth, NREL

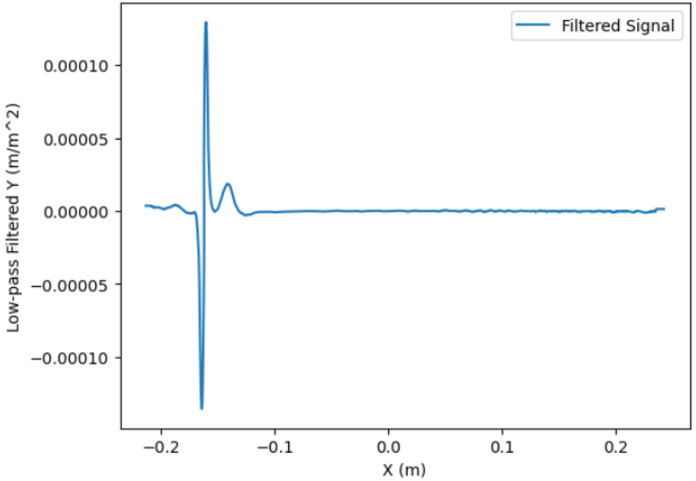
Flashing detection algorithm

- Starting with a raw 2D surface profile measurement



Flashing detection algorithm

- Starting with a raw 2D surface profile measurement
- Apply a Savitzky-Golay (1964) digital filter
  - Low-pass filter to find large changes to data trend
  - Create peaks at the mold line



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- Apply a Savitzky-Golay (1964) digital filter
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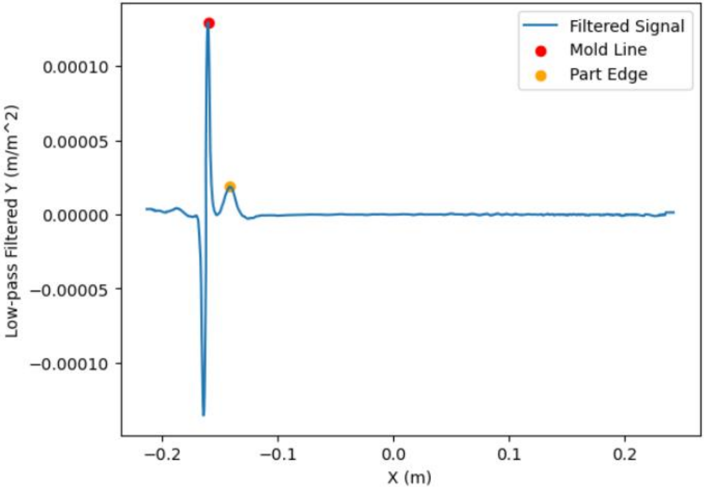
- Digital signal thresholding and peak detection
  - Adaptive thresholding based on the estimated signal-to-noise ratio.



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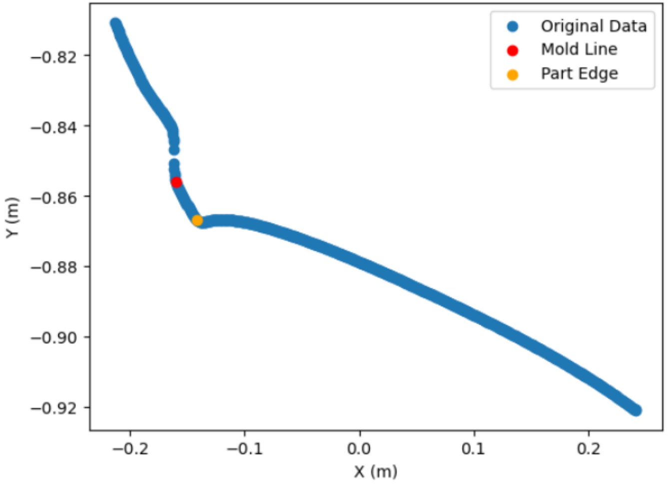
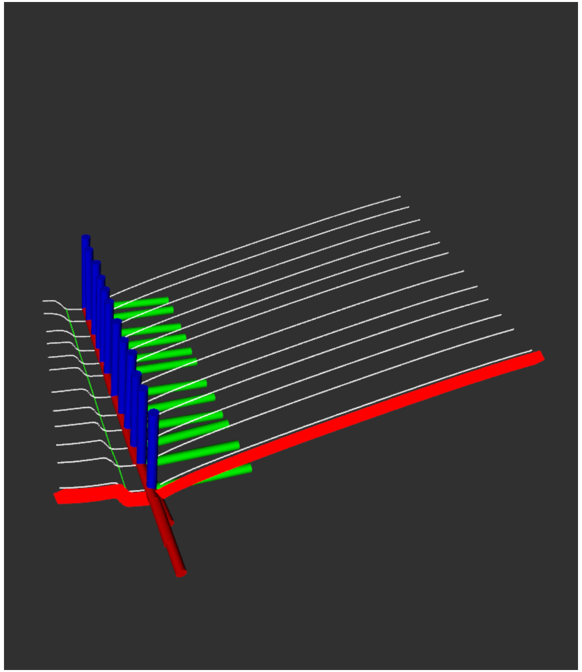
- Digital signal thresholding and peak detection
  - Adaptive thresholding based on the estimated signal-to-noise ratio.
- Extract these peaks from the original data
  - Obtain part boundaries in 3D space.



Next step: build a 3D surface from 2D measurements

- Data are captured at a high rate of ~100 Hz



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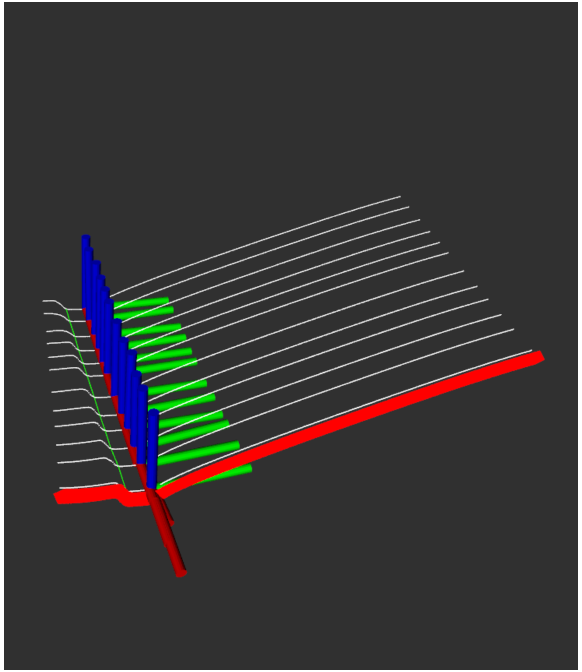
Next step: build a 3D surface from 2D measurements

- Data are captured at a high rate of ~100 Hz
- Identify flashing on every scan



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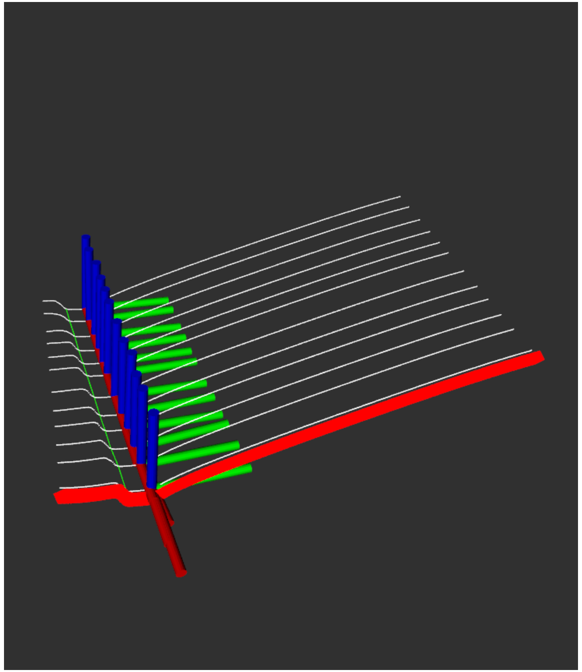

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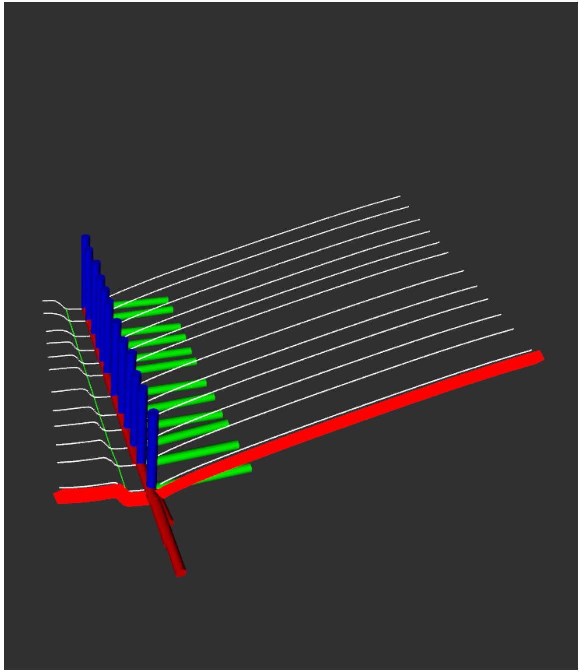
Next step: build a 3D surface from 2D measurements

- Data are captured at a high rate of ~100 Hz
- Identify flashing on every scan
- Separate scans by ~1 cm in the scanning direction
- Drop scans that produce discontinuities in the mold line or part edge
  - Secondary check on flashing detection algorithm.



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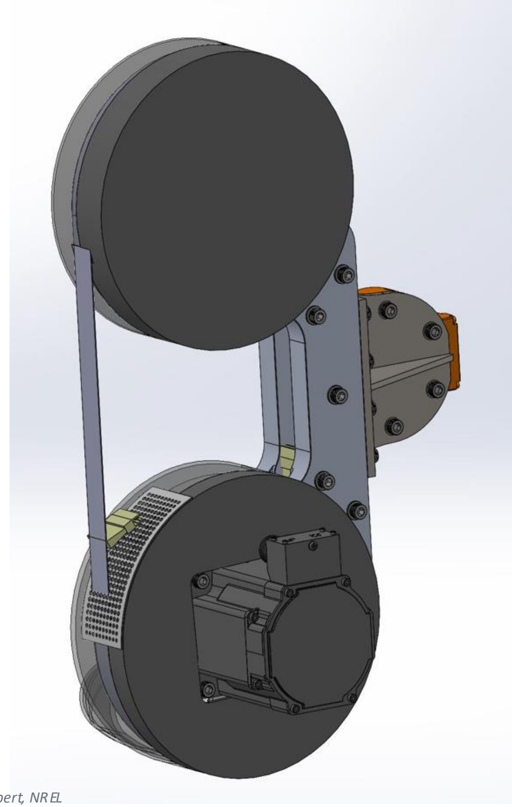
Bandsaw end effector

- Previous research adapted a standard bandsaw for automated trimming



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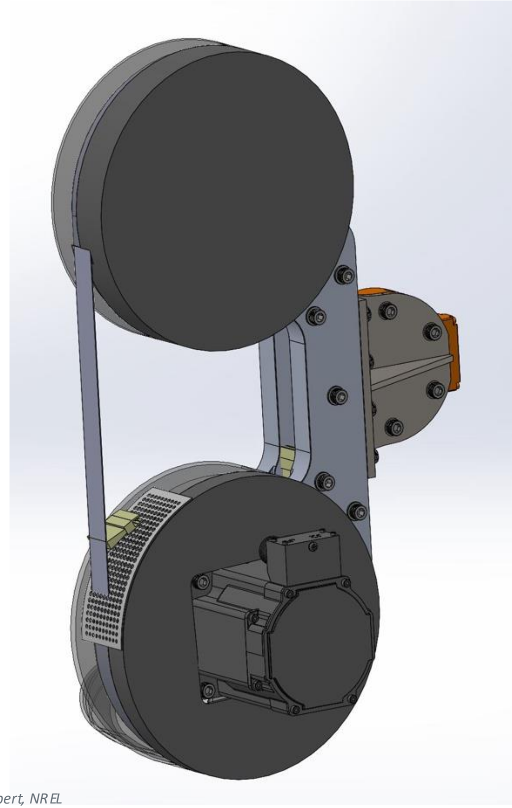
- This phase is designing a custom bandsaw optimized for the operation



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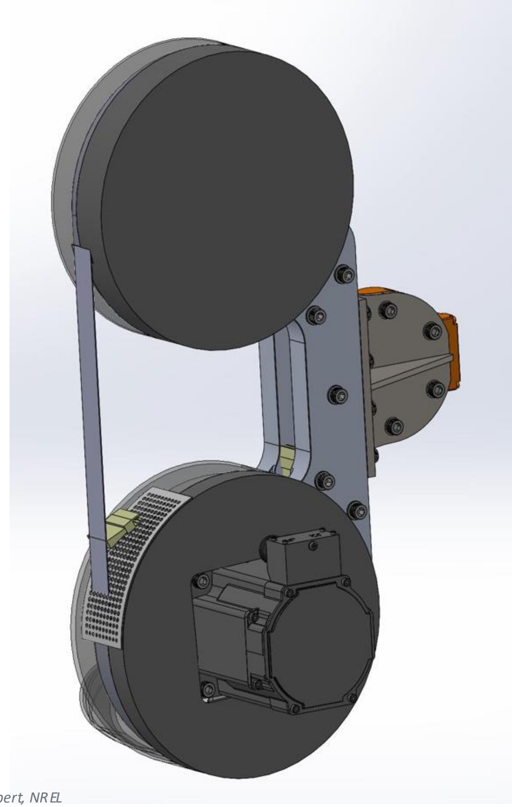

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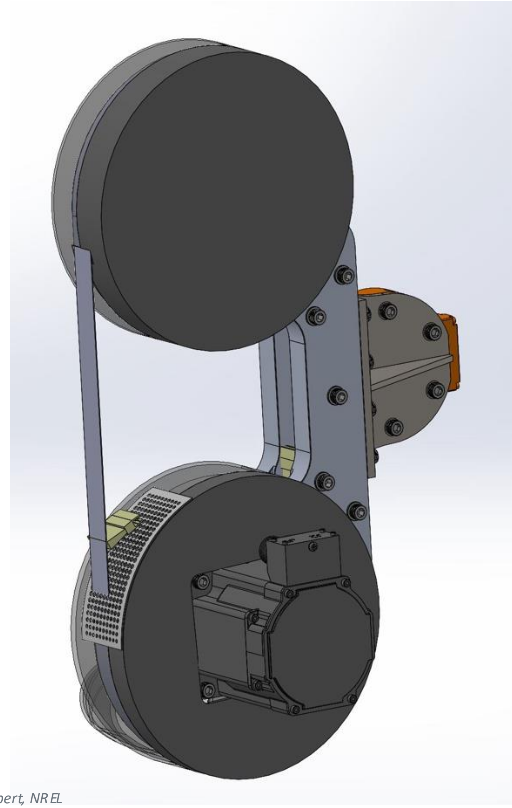

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Bandsaw end effector

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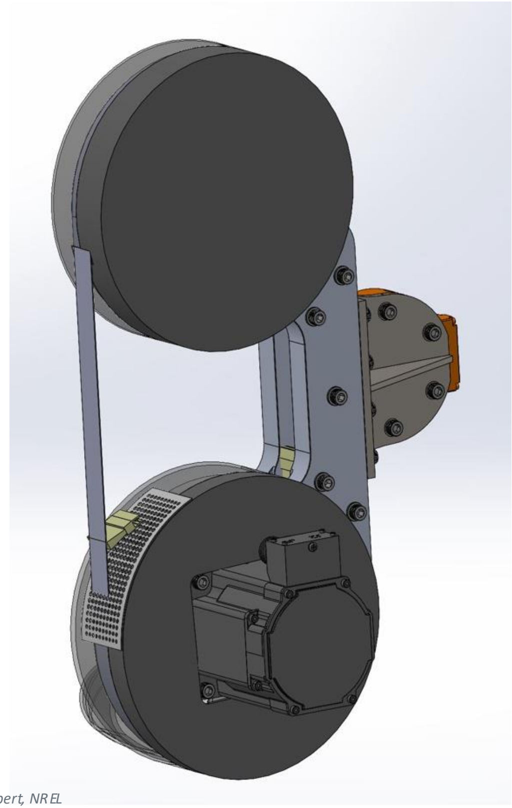
- This phase is designing a custom bandsaw optimized for the operation
- Reduced footprint to avoid collisions
- Powerful motor for increased operations speed
- Higher blade tension to improve accuracy



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Bandsaw end effector

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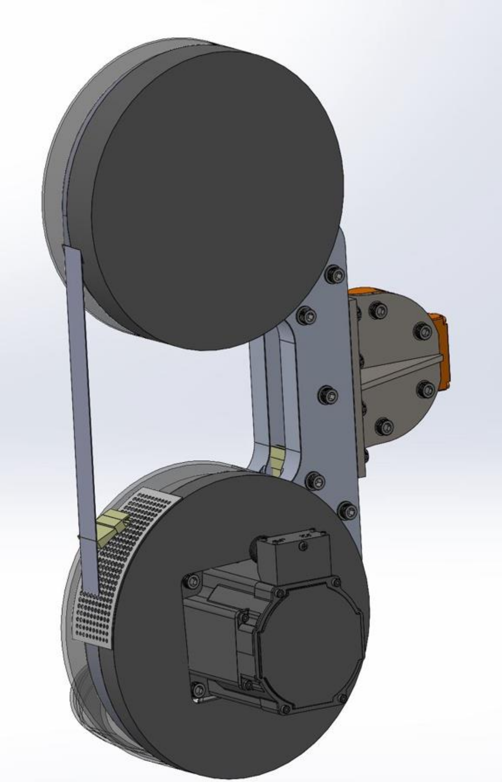
- Reduced footprint to avoid collisions
- Powerful motor for increased operations speed
- Higher tension to improve accuracy
- Supercharged dust collection system.



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The future of this research

Year 1 Automated Trimming

- Automation system for removing the bulk of flashing material
- Develops the core enabling technology
  - Real-time control
  - Real-time toolpath generation

Year 2 Automated Grinding and Surface Preparation

- Adapts the core algorithms previously developed to grind the surface to meet shape tolerances
- Prepare for bonding protective material to the surface

Year 3 Full-Scale Demonstration

- Work with our industry partner, GE Vernova, to install this system in a U.S. manufacturing facility
- Enable follow-on projects to further improve automation in composites manufacturing (inspection, repair, etc.)

Acknowledgments

- IACMI, The Institute for Advanced Composites Manufacturing Innovation
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Photos from IACMI.org, oedit.Colorado.gov, energy.gov, and gevernova.com

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