

Project Title: Stem Clipping for Automated Harvest

Report Type: Final Project Report

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Cooperators: N/A

Project Duration: 2-Year

Total Project Request for Year 1 Funding: \$125,000

Total Project Request for Year 2 Funding: \$125,000

Total Project Request for Year 3 Funding: N/A

Other related/associated funding sources: None

WTFRC Collaborative Costs: N/A

Budget 1

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Item	2025	2026	
Salaries	\$115,000.00	\$115,000.00	
Benefits			
Wages			
Benefits			
RCA Room Rental			
Shipping			
Supplies	\$5,000.00	\$5,000.00	
Travel	\$5,000.00	\$5,000.00	
Plot Fees			
Miscellaneous			
Total	\$125,000.00	\$125,000.00	

Justification

With support from industry partners and the WTFRC, advanced.farm started developing an automated apple harvester in 2021. After basic field studies in 2021, our robots picked their first apple in the 2022 season, and have since picked hundreds of thousands of apples in Washington. For the first time ever, robotic apple harvest now seems within reach. With this in mind, we now look to the next frontier of technical challenges that will enhance robot performance, improve fruit quality and lower cost.

Up to this point, we have focused on de-risking tech around gently picking and conveying an apple. However, when our robots pick apples of varieties that require stem clipping, this task is performed by a human standing on the machine. This is not a sustainable approach long term as we aim to reduce cost and scale operations. We also do not believe that growers will accept no stem clipping given the increased damage it will cause in the final packout.

After studying precedents, few, if any, tools exist to automate stem clipping. The task is mostly performed with basic scissors in the field as part of manual harvest. To that end, we propose a new R&D project supported by the Commission to develop a stem clipping mechanism that would enable automated harvesting in line with the timelines we expect for commercial release of the robotic harvester overall. Benefits and goals of this project would include:

- The ability for a robotic harvester to pick more varieties of apples without the need of an operator on a machine. Robots are now picking so fast that a single person cannot keep up with the workflow of one machine. Unit economics studies show that we (and others) will actually need to remove the person entirely from a machine to scale operations cost effectively.
- Improving the quality and value of the packout, both directly and indirectly: by removing stems, we will directly reduce the puncture and bruising damage in a bin. Automated stem removal will also open up new opportunities for in-field cull sorting, especially if the stem removal is coupled with a vision system (which may itself be a part of the mechanism).

At the end of the 2024 season, we collected data to facilitate the design direction of this project. For example, in a test informed by grower partners, we looked at puncture damage on three samples of 100 Pink Lady apples, picked fresh from the orchard. The goal was to understand if a “flush cut” stem would produce more or less damage than an apple with a stem clipped below the bowl of the apple (i.e. traditional stem clipping). Results are below.

% Puncture damage on sample of 100 apples

Apples with no clipped stem	Apples with clipped stem (flush cut)	Apples with clipped stem (traditional stem clippers)
6%	2%	3%

We believe a “flush cut” concept will be significantly easier to mechanize and automate. Given that these preliminary test results are promising, we will move forward to develop this solution.

We expect a prototype to be available in the 2025 season following detailed studies, with a second generation version integrated onto our robotic harvester by 2026. We are requesting funding to cover 1 full-time engineer plus materials.

Objectives

This project directly supports the primary stated objective of the 2025 WTFRC technology RFP, the automation of apple harvest.

Methods

We will perform R&D in three distinct phases:

First, we will do concept “sprints” wherein we test several ideas to understand the problems associated with automated stem clipping, and explore potential implementations. This will happen in Q1 2025.

Second, we will down-select a concept that we wish to bring to field trials. In field trials, we will test an advanced version of the chosen concept on un-clipped apples taken from a packhouse (i.e. Gala). This will happen in Q2 2025.

Third, we will take lessons from the field testing to develop a concept that can be integrated with a full harvester in time for the 2025 apple season. This will happen in Q3-Q4 2025.

Finally, we will repeat this cycle in 2026 using the learnings from the first year of the project to continue to move towards a commercial solution. The second year of the project will most likely involve making the solution more robust and reliable.

Literature review

We have reviewed the study by Ines Hanrahan titled *WA 38 Stem Punctures & Semi-commercial Packout in the 2017-18 Storage Season* to understand the financial impact of stem clipping. Given the expected 3% incremental damage saved by stem clipping, we consider this project worth pursuing.

Wood Removal Sprint

System Design Requirements

We recognized early on in the development of the automated apple harvester that sometimes when picking an apple, some amount of fruiting wood is pulled along with the apple. We developed better gripping and removal techniques, but still between 2-5% of apples came with fruiting wood. We needed a method to reliably remove this wood before the apples entered any sort of conveyance system. If an apple entered conveyance without attached wood removed, there was a high likelihood that the wood would be lodged into the conveyance system and damage adjacent or subsequent apples.

Due to these system requirements, we landed on a concept of wood removal that took apples directly after being picked, removed long wood/stems, and progressed the apple to the next step of conveyance. This system would need to support roughly one apple per second. We then sprinted on a few different systems that could achieve this goal:

Passive Scraper



Video: <https://photos.app.goo.gl/XF6eCVACCrmAojg26>

The passive scraper was the very first concept tested on removing fruiting wood from apples. This was a crude mock up that ultimately did not show consistency and was not pursued further.

Micro-roller + Belt picture and testing



Micro-roller + Belt Prototype Build

This system was designed to use multiple small rollers spinning in opposite directions to suck the fruiting wood through and off of the apple, while the large orange belt would progress the apple down the length of the system. While showing some promise, the apples did not consistently rotate, and would often “orbit” a standard axis, which proved problematic when trying to randomize the rolling to allow fruiting wood to be removed.

Auger Concept



Multiple Auger Prototypes

Video: <https://photos.app.goo.gl/spgzur2Q9eGpJg1B6>

The Auger concept went through many iterations, testing multiple shapes, profiles, pitches, and screw materials. Many solutions showed promise, but the smooth, ~3” pitch screws showed the most promise and moved into material choice selection and lifetime testing

Auger Lifetime Testing



Lifetime Testing Setup and Results

Video: <https://photos.app.goo.gl/cLDXrqPGZLOYbbe89>

Before making a full-scale Auger (7ft long in our system design), we co-molded multiple types of silicone material onto 3D printed cores to test the durability of various durometer materials. We set up a system designed to recirculate apple-like objects and test the durability of the system across many apples. In the first picture above, you can see the results of multiple sections of overmold wearing off and failing, giving valuable insights into that design's durability. Other sections on the roller still intact had $\sim 1/4$ " of overmold material, proving much more robust.

Auger Alpha Design



Full Build of Alpha Design

Video: <https://photos.app.goo.gl/m3UwL3sc1SWEDbQi9>

The Alpha Auger design that we landed on showed over 98% reliability in removing all fruiting wood from apples placed on the augers through testing on fresh apples in Washington and simulation apples in the lab. The design met the requirements for both conveying apples and removing fruiting wood reliably.

Stem Clipping Sprint

System Design Requirements

Stem clipping was the primary purpose of this research. Fully burdened, our apple harvester system design showed we could achieve pick rates of 9000 apples per hour across 12 robots. Humans can only reliably pick ~2000 apples per hour, so our harvester was going to quickly outpace the rate humans can clip on board the harvester.

We decided to divide the 12 robots into 6 separate apple conveyors, in an effort to keep apples in defined lanes and safer from potential damage. 6 lanes means that each lane needs to clip stems at a rate of ~1500 apples per hour, or one every ~2 seconds, in order to keep up with steady-state anticipated pick rates.

Buzz Chop Concept Picture, Testing and Video



Buzz Chop Clipping Prototype Build

Video: <https://photos.app.goo.gl/1Zzfkjwc67H1a3Jh6>

The buzz chop system was designed to have a cutting surface directly beneath a “grate” of sorts that kept the apple away from the blade. The attempt here was to create a simple mechanical system that the apple could roll across and trim its stem, without any additional features or automation. Ultimately, the stem clipping was unreliable, apples were damaged by the grate, and the stems were not clipped sufficiently to reduce damage in the bin.

Nose Clipper Concept



Nose Clipper Concept Build

The Nose Clipper concept relied on a spinning cutting bit, nestled within a curved guard, to reach into the stem well of the apple and clip the stem below the top of the stem well. While this worked decently well, indexing the apple into the correct location to clip the stem, without damaging the apple, proved difficult.

Counter Rotating Concept



Various Counter-Rotating Concept Parts

The concept sprint of the Stem Clipping project focused on refining the apple orientation and stem removal mechanisms for integration into the 2025 Alpha Harvester. The sprint explored multiple physical prototypes and test setups aimed at automating apple alignment and clipping with minimal damage. Early experiments centered on a vertical drop system using linear rails to test how apples centered when dropped onto whiskers and flat plates. These trials revealed that flat-plate balancing was more effective for achieving perpendicular orientation, capable of correcting up to 25° of apple tilt.



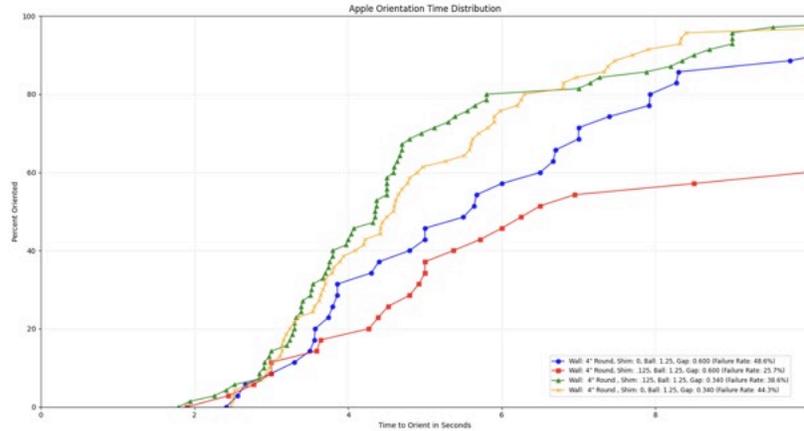
Early Iteration of Counter Rotating Concept, with Separately Driven Right/Left Rollers

Subsequent iterations combined the clipping and orienting processes into a unified module inspired “spinning apple clip” concept. Tests using dual drill-driven wheels simulated differential spinning to position stems between clippers for cutting. Adjustments included widening the stem gap (~ 0.3 ”), enlarging the inner ring to reduce catching, and experimenting with ring-based “lazy susan” rotation versus dual-wheel spin. However, interference from ring surfaces and inconsistent rotation prompted further exploration. Later designs incorporated TPU halves and O-ring friction surfaces, revealing that conical rollers outperformed flat ones in guiding apples smoothly without snagging stems.



Subsequent Iteration with Cutting Blades for Stem Clipping

The team conducted extensive A/B testing across variables such as wall slope (40° – 90°), wheel diameter (≈ 1.25 ”), and inter-wheel gap (0.320 – 0.438 ”). Steeper and more vertical wall geometries improved both orientation reliability and “turntable” rotation effects, while smaller wheel gaps yielded more stable centering and spin performance. The optimal configuration featured a 4” round topper, 0.125” shim, 1.25” wheel, and 0.320” gap. Quantitative testing (≈ 50 runs per setup) confirmed higher orientation rates, though some apples became locked off-center. Damage assessments using Honeycrisp apples showed consistent bruising and scrape marks, emphasizing the need for softer wheel coatings (e.g., Dragon Skin silicone) and refined wheel geometry.

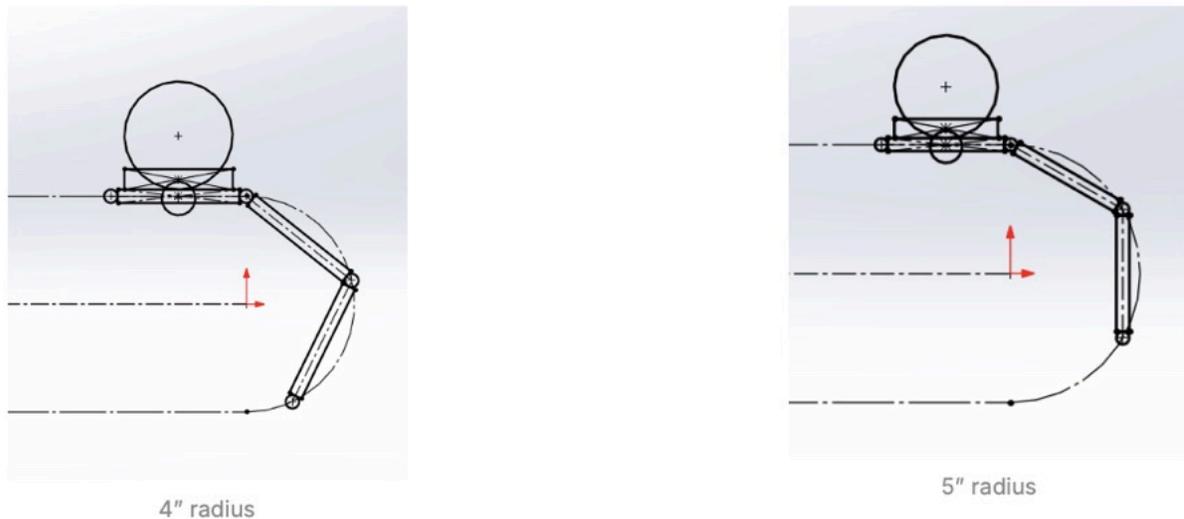


Test Results for Time to Apple Orientation for Various Pocket Geometries

Overall, the concept sprint produced valuable insights into mechanical parameters governing apple alignment, stem accessibility, and damage reduction. The team established a clear experimental foundation for merging the orientation and clipping systems in the next design phase.

Counter Rotating Alpha Design

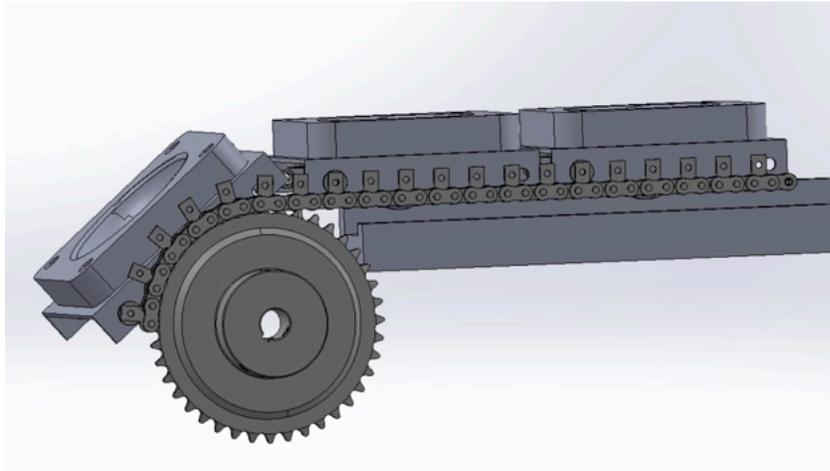
The Stem Clipper Benchtop Test Unit sprint marked a major step toward validating a functional single-lane prototype for automated apple stem clipping, forming part of the 2025 Alpha Harvester program. The project focused on designing and assembling a scalable test platform to evaluate mechanical clipping forces, chain-driven transport geometry, and cutter manufacturability. Early sketches modeled 4–5-inch conveyor radii, balancing mechanical clearance with under-deck volume, and explored configurations for integrating bowl walls above or within sheet metal assemblies.



Layout Sketches for Various Alpha System Chain Pockets

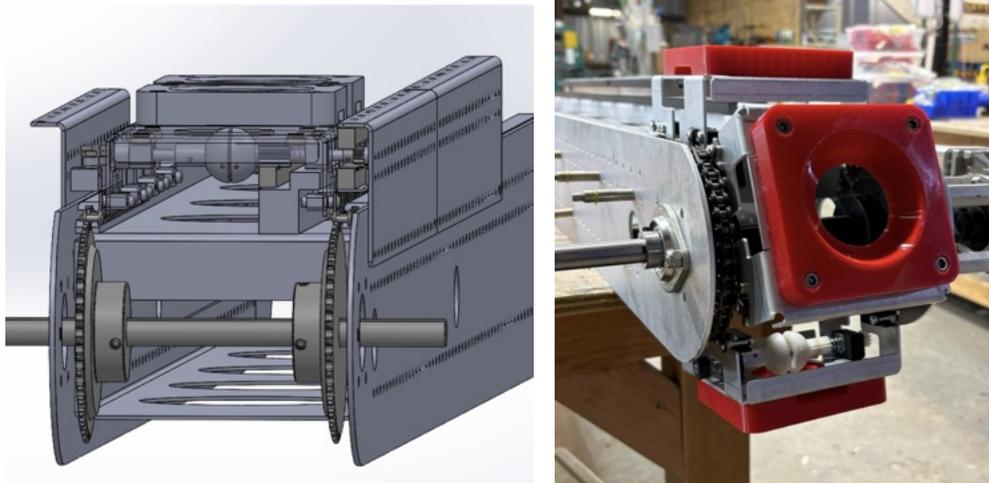
The team iterated through multiple drive chain configurations (#35 and #40 ANSI) to optimize chain pitch, sprocket size, and pocket spacing for apple conveyance. A 40-tooth sprocket on a 60-inch span proved optimal for maintaining 26–30 slats with even chain length distribution. The #40 chain was ultimately favored for its higher working load and superior tolerance to misalignment compared to smaller chains. Plastic chain guides and pin-slot attachments were evaluated for smoother motion and easier assembly. Spring-assisted retract mechanisms and linear actuators were incorporated to automate the clipping motion, while mounting features and a benchtop superstructure were finalized

in CAD for manufacturability.

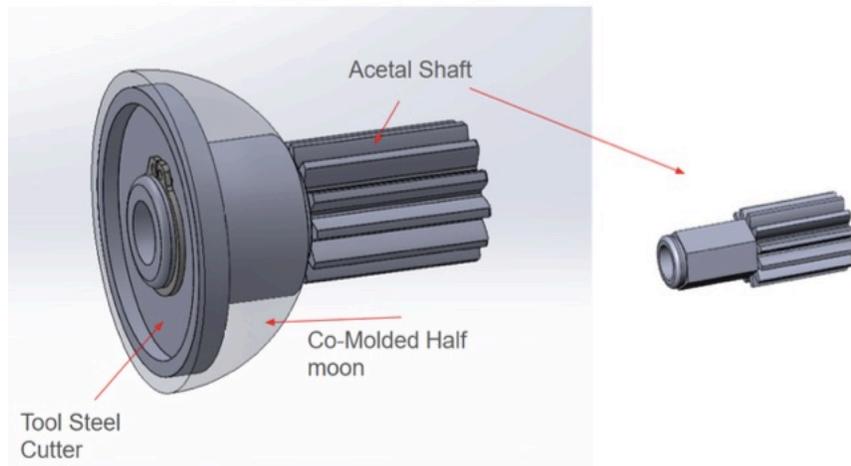


Early Design for Alpha Conveyance System

The clipper assembly was physically constructed and powered, revealing minor meshing issues in the rack drive but demonstrating full kinematic motion. Attention turned to the cutting subsystem, exploring cutter fabrication via involute gear cutters and testing cam-based and bearing-actuated clipping mechanisms. Formal testing measured cutting forces across different cutter geometries, using dial indicators to derive a spring constant. Measured stem-cutting forces averaged ~ 22 lbf, closely matching manual field clippers and confirming feasibility for automation. Shear-style cutters offered minimal additional benefit but validated force consistency across designs.



Clipper System CAD and Build Side by Side



Detail View of Clipper Roller, with Soft Co-Molded Rubber



Test Setup for Clipping Force Measurement

The completed benchtop system serves as a representative single-lane test platform for downstream automation and durability studies. It demonstrates integrated feeding, clipping, and stem disposal with wash-down capability while remaining scalable to multi-lane deployment.

Video: <https://photos.app.goo.gl/qAPHKPCSPkubSft8>

Conclusions

The Wood Removal prototypes established a robust method for detaching fruiting wood from apples immediately after picking to prevent damage in downstream conveyance. Early trials with a passive scraper and micro-roller belt showed limited success, leading to the development of an auger-based system that reliably removed attached wood while moving apples along the line. Through extensive testing of auger shapes, materials, and wear resistance, the team identified a smooth, 3-inch pitch silicone-coated design as the most durable and effective, achieving over 98% wood removal efficiency in both lab and field tests.

The Stem Clipping Sprints focused on automating stem removal to keep pace with robotic harvesting rates far exceeding human capability. After testing several mechanical approaches, the counter-rotating and benchtop clipper systems emerged as viable solutions, integrating apple orientation and stem clipping at rates of one apple every two seconds. Iterative testing refined roller geometry, chain-driven transport, and clipping force mechanics, ultimately producing a prototype

capable of clean, repeatable cuts using about 22 lbf of force, comparable to manual tools. Together, these systems form the foundation for fully automated apple preparation ahead of binning in the 2025 Alpha Harvester.