Vacuum Assisted Harvest for PA Orchard Conditions and Systems

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PENNSTATE

Presentation

Bridging the harvest automation gap

The issues

Background on project

Prototype development

Results

Other project activities

"Harvest assist"

Bridging the gap between fully manual and fully automated harvest…

What is driving the push for new technologies?

Labor

Efficiency

Dwindling land

Competition from foreign sources

The Issues

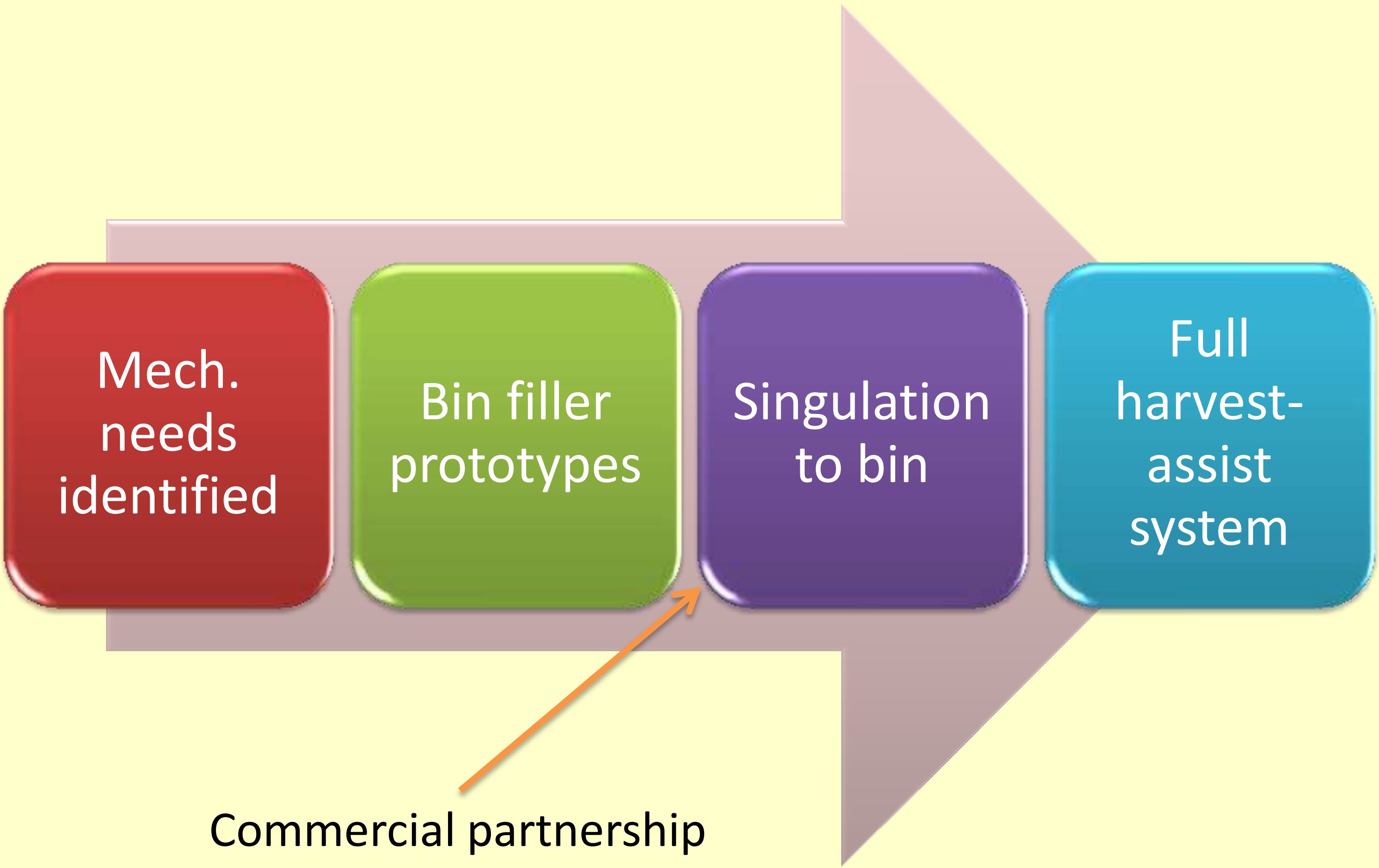
Harvest 1900

Harvest 2000

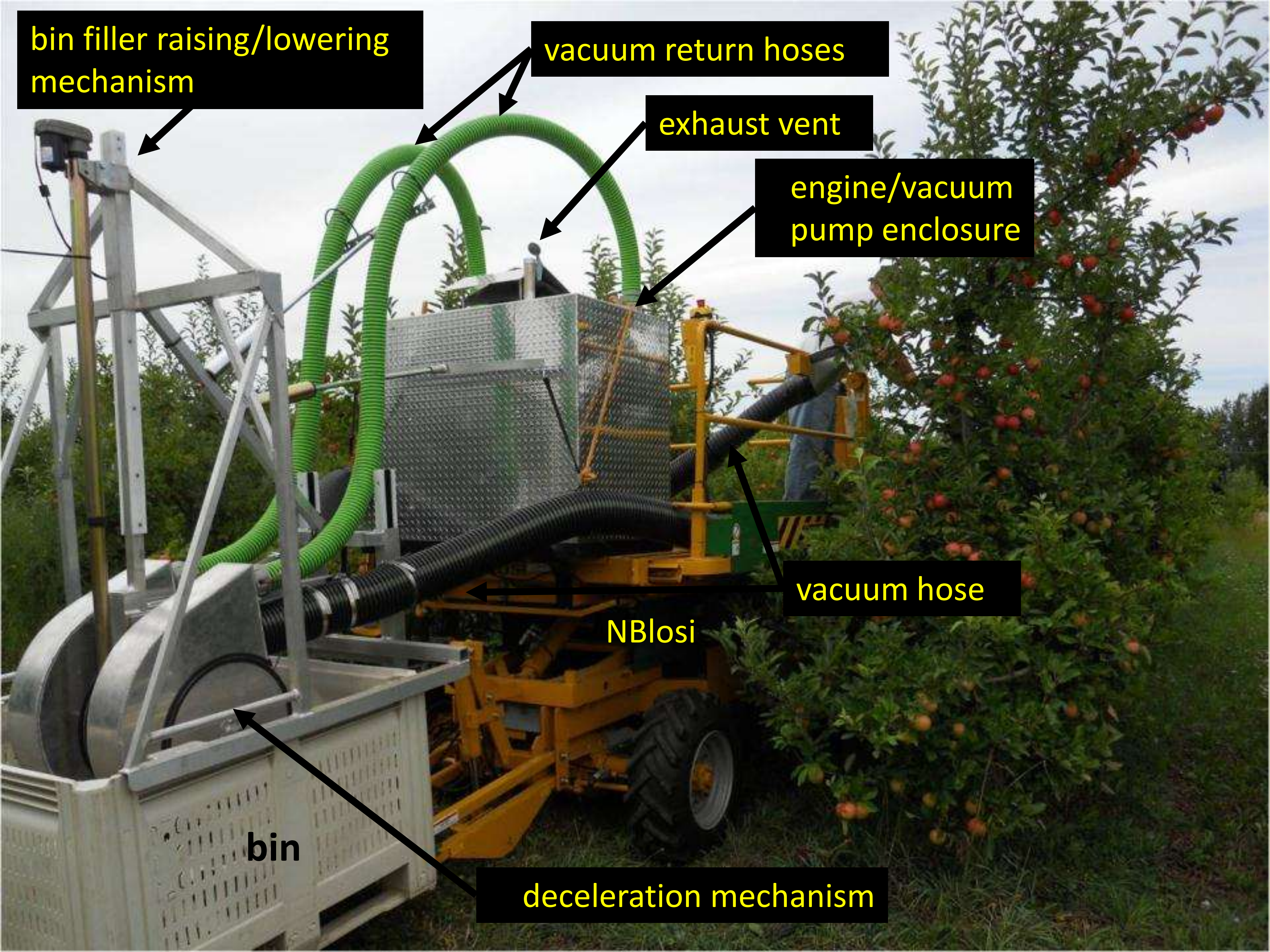
Harvest 2015?

Harvest 2025?

Project development history



Prototype development – 2010



bin filler raising/lowering mechanism
vacuum return hoses
exhaust vent
engine/vacuum pump enclosure
vacuum hose
NBlosi
bin
deceleration mechanism

Vacuum-driven unit

Loaded bin transfer

Vacuum-driven unit

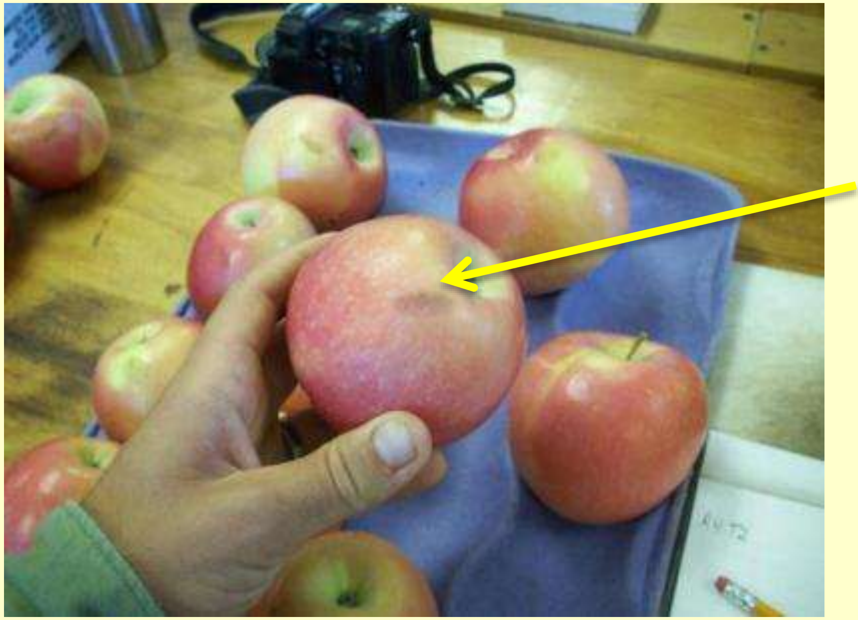
vacuum return tubes

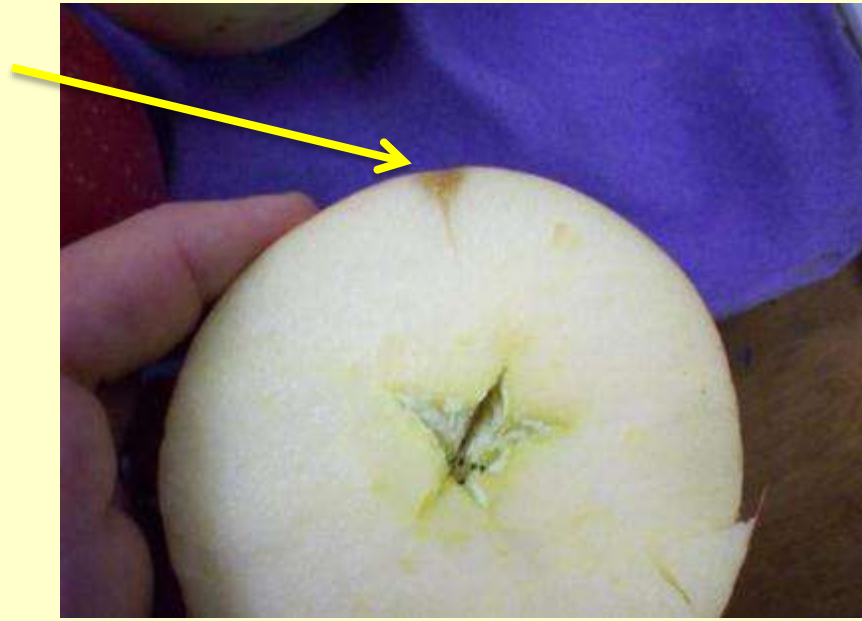
Prototype development -2010

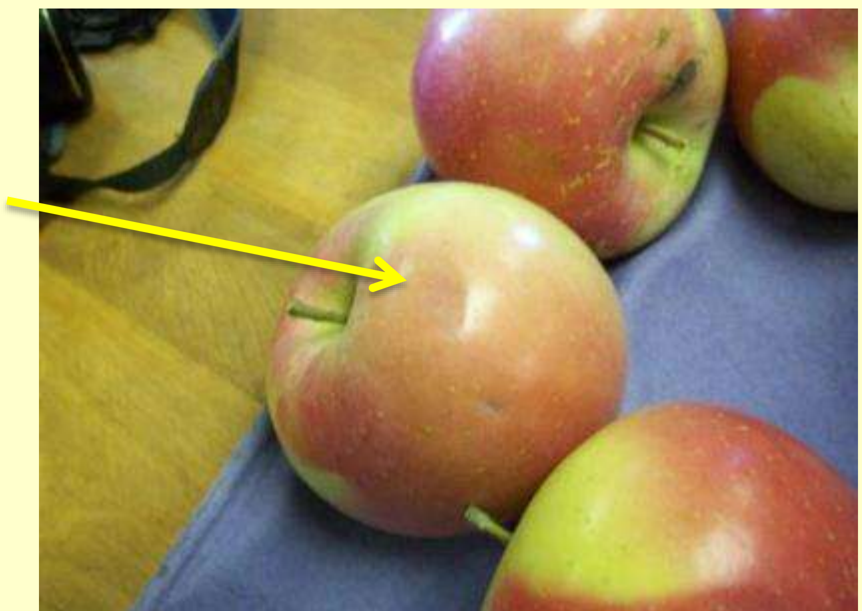
First tests are run in high heat. Some issues arise with adhesives letting go in high heat, etc.

Some bruising is occurring, and while often not bad, it is sometimes above the threshold for incidence.

Original “elephant ear” distributor







Prototype development -2010

Troubleshooting with instrumented sphere identifies some problems with apples hanging up in decelerator, and occasional impacts with elephant ears.

Revised "elephant ear" distributor

New decelerator pads and elephant ears are developed by DBR and installed by Mike Rasch and Jim Schupp in September 2010

Revised “elephant ear” distributor

Subsequent testing confirms bruising greatly alleviated.

PA Trials, 2010

DBR Harvester with Two Vacuum Tubes Mounted on NBlosi Platform

Cultivar	Location of Sample	Bruise width (mm)	Bruise volume (mm^3)	Cuts or punctures (%)
Honeycrisp	Before vacuum tube (control)	0.40 b	2.01 b	0.0 a
	After vacuum and decelerator	1.14 ab	12.81 ab	1.3 a
	After elephant ears	1.61 a	20.31 a	0.0 a
	From bin	0.92 ab	8.34 ab	1.3 a
Daybreak Fuji	Before vacuum tube (control)	0.00 b	0.00 b	0.0 b
	After vacuum and decelerator	0.63 b	13.52 b	0.0 b
	After elephant ears	0.66 b	14.72 ab	0.0 b
	From bin	2.29 a	34.58 a	4.0 a
Golden Delicious**	Before vacuum tube (control)	0.21 a	2.50 a	0.0 a
	After vacuum and decelerator	0.71 a	7.94 a	0.0 a
	After elephant ears	0.83 a	10.41 a	0.0 a
	From bin	1.32 a	17.10 a	0.0 a

** harvested after modifications to tubes and elephant ear distributor

Bottom line:

With only two tubes, bruise level was minimized so that it was less than or equal to hand harvest.

Prototype development -2011

- 2011: DBR builds a new prototype, based on input and outcomes of 2010 work
- new prototype is quieter, faster, narrower, and has a lower center of gravity. Some more efficiency tests run with 2010 prototype in PA, but research focus shifts to latest prototype in WA.

Prototype development -2011

Prototype development -2011

Prototype development - 2012

- Modify 2011 version to suit Eastern and Midwest (Michigan) orchard architecture
- Evaluate fluid power characteristics of the vacuum-driven prototype fruit conveyance components, modify as needed.
- Field test in research and commercial orchards.

2012 design – Phil Brown

Efficiency in apple orchard plots harvested with harvest assist system and platform compared to hand harvest and ladders.

PA Trials, 2012

Cultivar	Harvest System	Harvest time/bin (min/1 person)[z]	Harvest time/acre (hrs/4 workers)	(% change)
Golden Delicious	Vacuum assist	45.6 c[y]	8.3	33
York	Vacuum assist	45.5 c	5.8	33
Cameo	Vacuum assist	58.0 b	11.6	15
	Hand	68.0 a	13.6	--

[z] 23 bushel plastic bin.

[y] Completely randomized design with 4 replicates. Mean separation by Fisher's protected least significant difference at $P \leq 0.05$.

Quality of apples harvested with vacuum assist system and platform compared to hand harvest and ladders.

Cultivar	Harvest System	Extra Fancy[z] (%)	Fancy (%)	Downgraded (%)
Golden Delicious	Vacuum assist	85.0 a[y]	7.1 a	7.9 a
	Hand	85.4 a	7.5 a	7.1 a
York	Vacuum assist	85.0 b	7.1 a	7.9 a
	Hand	96.1 a	2.1 a	1.8 b
Cameo	Vacuum assist	93.7 b	3.8 a	2.5 a
	Hand	99.2 a	0.8 b	0.0 b

[z] Bruise evaluations conducted on 60 fruit per treatment from each of four replicates. Percentage of fruit in each market grade based on bruise allowances in USDA fresh market grade table.

[y] Mean separation within columns and cultivars by Fisher's protected least significant difference at P≤0.05.

Classifications of bruise damage based on USDA Fresh Market Grades.

Class	USDA Fresh Market Standard	Bruise specifications
1	"Extra Fancy"	No bruising
2	"Extra Fancy"	Bruise diameter $\leq$ 3.2 mm (1/8 in.)
3	"Extra Fancy"	Bruise diameter 3.2 to 6.4 mm (1/ 8 to 1/4 in.)
4	"Extra Fancy"	Bruise diameter 6.4mm (1/4 in.) to 12.7 mm (1/2 in.) or area of several bruises $\leq$ 127 mm^2
5	"Fancy"	Bruise diameter 12.7 to 19 mm (1/2 to 3/4 in.)
6	Downgraded	Bruises larger than the tolerances in "Fancy"
7	Downgraded	Cuts or punctures of any size

Detailed breakdown of Extra Fancy apples following harvest assist system handling.

Cultivar	Class 2 (%)	Class 3 (%)	Class 4 single bruise (%)	Class 4 multiple bruises (%)
Golden Delicious	0.0	12.1	8.3	6.3
York	0.0	5.0	3.3	0.8
Cameo	0.4	6.3	5.4	0.4

Grade classes described in USDA fresh market grade table.

Differences between 2010 and 2012 results

2010: 2-tube system, lower level of bruising

2012: 4-tube system, much higher efficiency but there was an increase in bruising

This is being further addressed in 2013

In a trial conducted on Golden Delicious harvested at 3 levels of maturity:

Bruising in the vacuum harvest system increased on apples that were harvested when over-mature

Bruise width and incidence measured following harvest with the vacuum system was not related to:

- Firmness
- Starch index
- Fruit Size

Growers' Perspectives on Adopting New Technologies

Shannon Caplan, Brian Tilt, Clark Seavert, OSU; Tara Baugher, PSU, Karen Lewis, WSU

- Case study interviews with fruit producers to assess factors that influence the adoption of new technologies or practices, drawing upon a field called "diffusion of innovations."
- 18 producers total, 6 each from small, medium or large operations
- Technologies – assisted harvest, automated insect traps, automated tree caliper

Benefits of Assisted Harvest Adoption Identified by PA and WA Growers

- Reduced human error and fatigue during harvest
- Lower labor costs
- Eliminating some risk associated with current labor pool
- Possible increase in fruit quality and harvest management efficiency

Barriers to Assisted Harvest Adoption Identified by PA and WA Growers

- Possible large financial burden
- Geographic concerns – hilly terrain; multiple small parcels to move harvester to
- Potential for equipment breakdowns
- Managing harvest employees

Some additional work:

Detailed engineering assessment of the apple decelerator and distributor of the vacuum harvest assist system

What has been studied

- Effect of gravity on apple travel speed and distance
- Observation of apple motion on the machine with a transparent tube
- Multiple-apple behavior during transport inside the vacuum tube
- Effect of presence of one vacuum tube on the other
- Effect of apple size, aspect ratio, and tube diameter and length on apple travel speed and distance

Gravity Test

- Performed with small, medium, and large apples.
- Using rigid clear tube
- Tube lengths: 2 ft, 4 ft, 6ft
- Padded and Non-padded

Velocity Observation

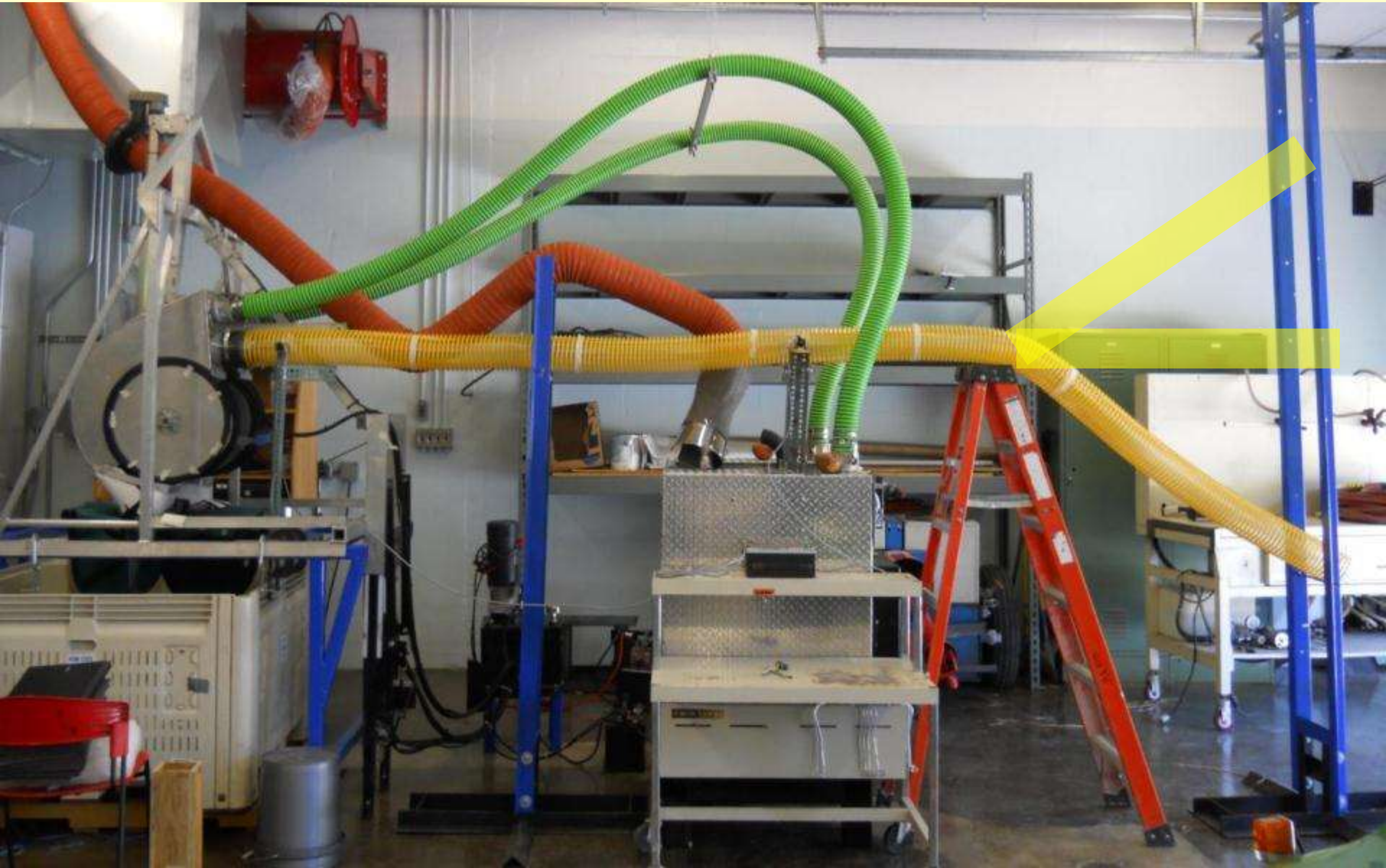
Gravity Test

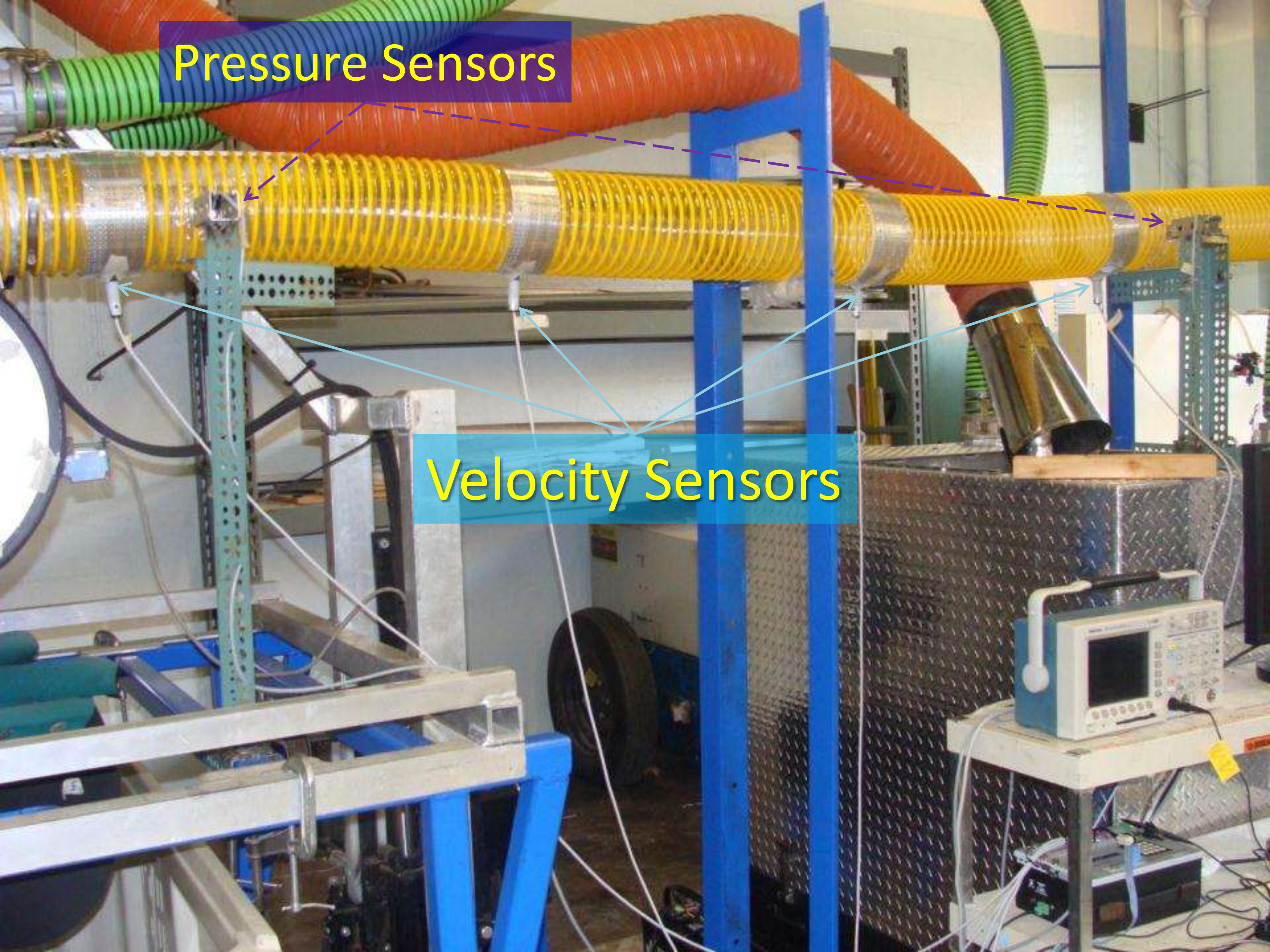
- Performed with small, medium, and large apples with different aspect ratios.
- Using flexible clear tube
- Tube lengths: 15-ft
- Tube inside diameters:
  5-in, 6-in
- Non-padded

Vacuum System Testing

- High Throttle, Low Throttle, Medium Throttle

Different Tube Configurations




Pressure Sensors
Velocity Sensors

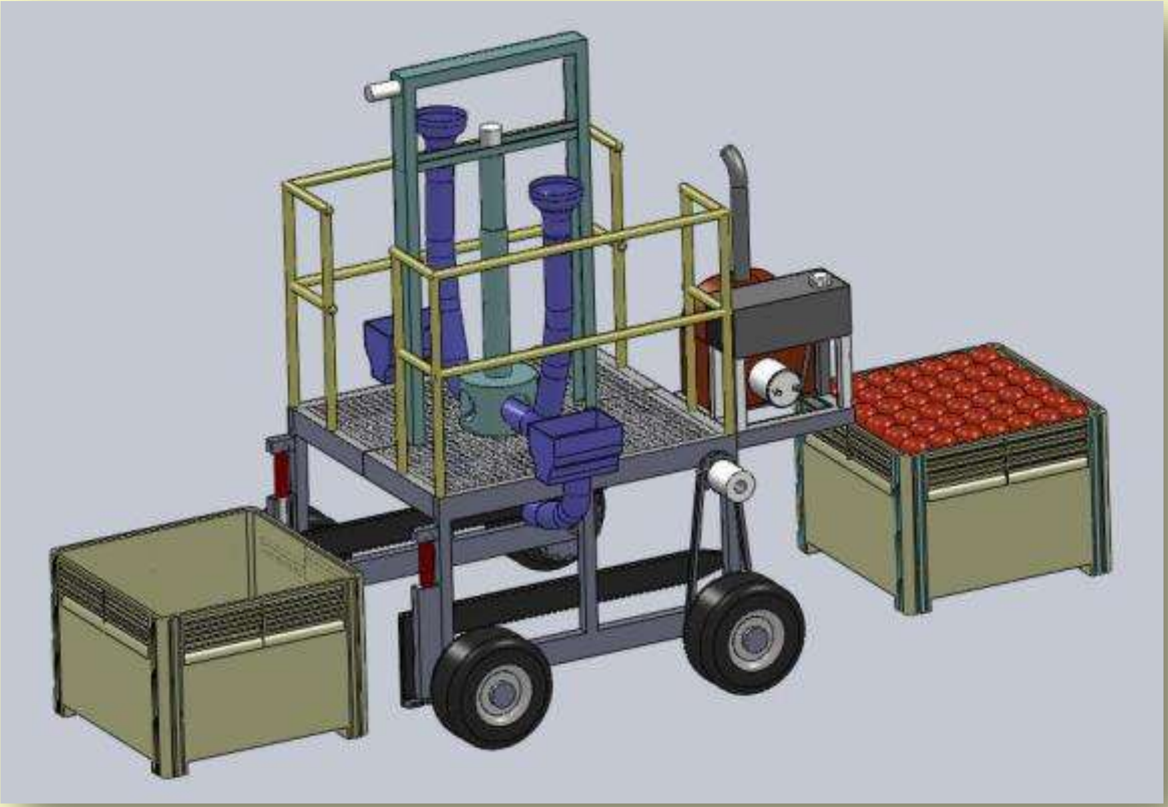
Findings

- Apple speed is sensitive to apple size and vacuum tube size.
- Larger apples can catch up with small apples.
- Decelerator and elephant ear rotating speeds should be individually-adjustable. The relationship between these two speeds needs to be investigated.
- Two vacuum pumps should be able to “engage” or “disengage” separately.
- Gravitational force can be utilized to “assist” transporting apples from the upper part of the tree to the bin.
- Tube diameter has an important impact on apple motion under gravity driven and when applying vacuum air flow.

Other designs

- Low-cost gravity based
- Vacuum assist
- Vacuum driven

Low-cost devices for small operations



Transport of fruit primarily by gravity or vacuum-assist

Other proposed activities

- Ergonomics
- Socio-economic

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