CITRUS MECHANICAL HARVESTING: MACHINE ENHANCEMENT AND IMPROVEMENT

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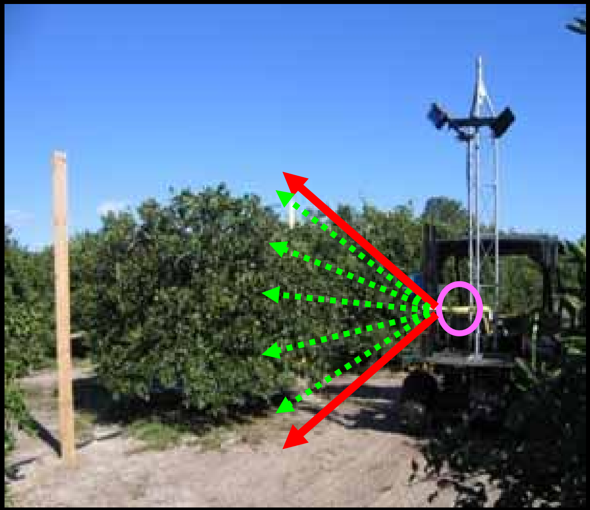
Machine Enhancement and Improvement

- Yield monitoring
  - Developing a rugged fruit mass flow sensor
- Reducing tree injuries through improved canopy shaking mechanisms
  - Study the parameters that effect fruit removal or causes tree injuries

- Variable rate shaking
  - Measuring canopy size and volume
  - Developing a control system to adjust the optimal shaking parameters

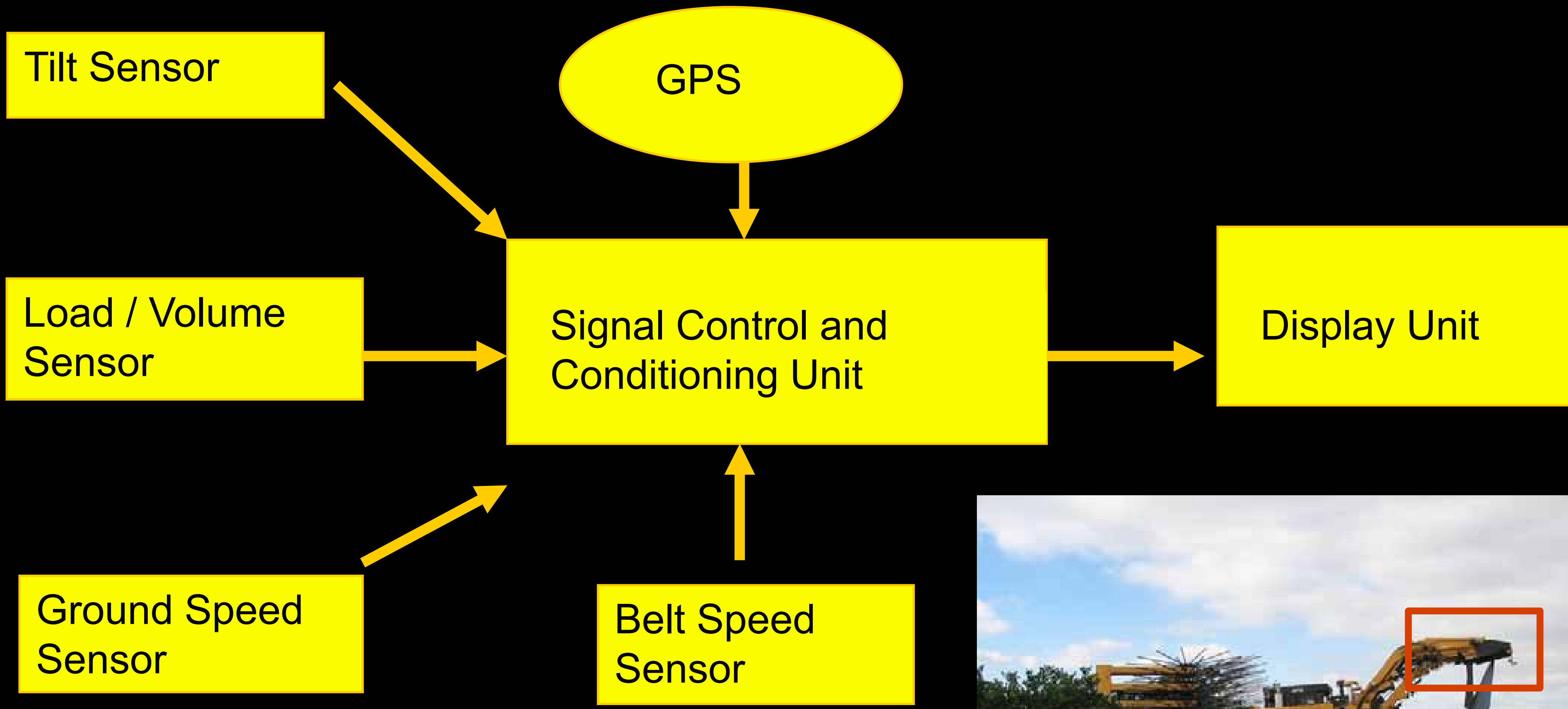


Yield Monitoring System for Citrus Mechanical Harvesting Machines

- Yield monitor can be used to:
  - Quantify the yield variability within or between a citrus orchard block
  - Prevent overloading or under-loading of citrus transportation truck

- Yield monitoring system for citrus mechanical harvesting machines
  - Simple
    - Easy to install and operate
    - Easy to maintain and calibrate
  - Rugged and durable
  - Cost-effective

Components of a Yield Monitor for Citrus Mechanical Harvester



Mass Flow Sensor

SYSTEM COMPONENT/s

-Two photo interruption layers

- 20 laser beams per layer

- PIC microcontroller

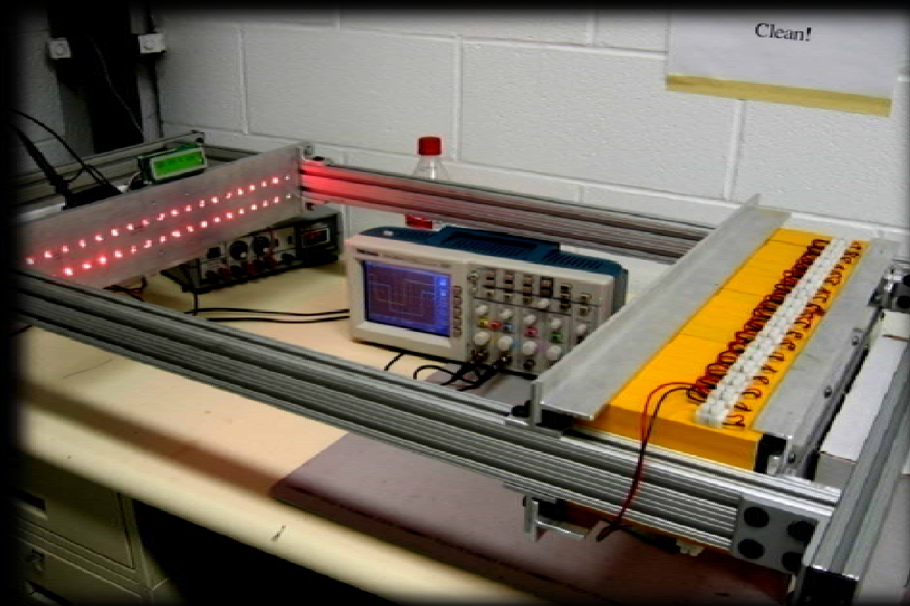
ADVANTAGE

-Absence of defocus problem

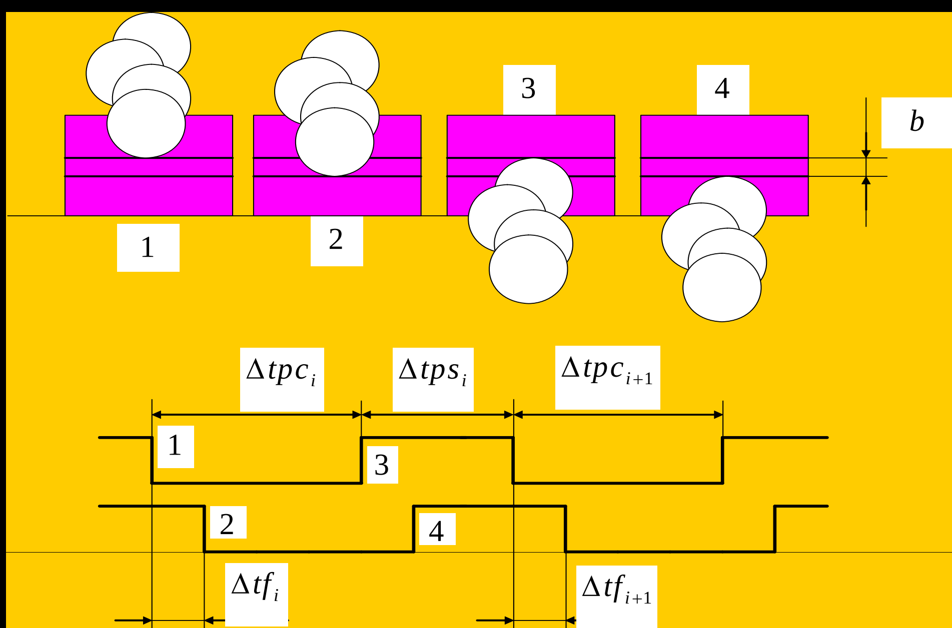
-Long life calibration

DISADVANTAGE

- erroneous signals due to vibrations.



Mass flow sensor with 40 laser beams



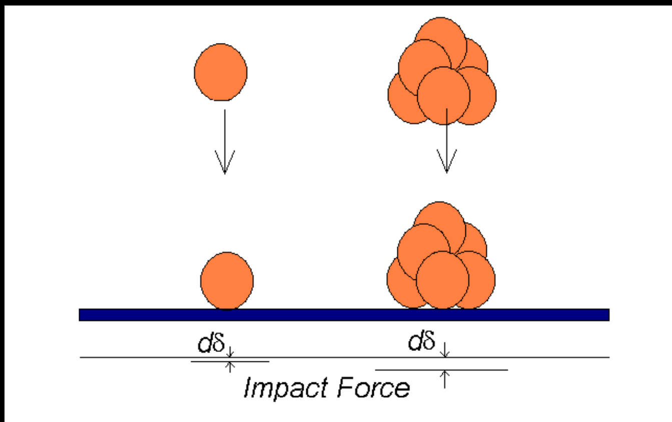
Dual interruption timing mechanism

$$\hat{N} = N_T\left(\frac{\sum_{i=1}^{N_T} v_i \sum_{i=1}^{N_T} \Delta tpc_i}{\sum_{i=1}^{N_T} v_i \sum_{i=1}^{N_T} \Delta tps_i} + 1\right) = N_T\left(\frac{\sum_{i=1}^{N_T} \Delta tpc_i}{\sum_{i=1}^{N_T} \Delta tps_i} + 1\right) = N_T\left(\frac{\overline{\Delta tpc_i}}{\overline{\Delta tps_i}} + 1\right)$$

CONSTRAINT

Poisson Flow

Impact Plate



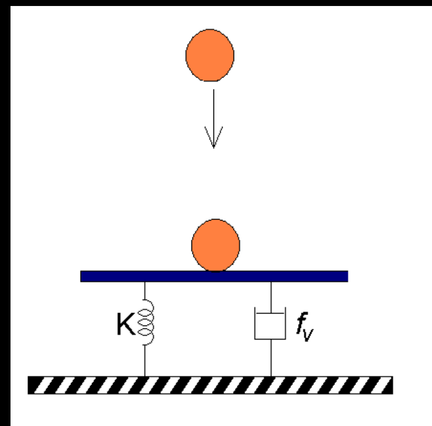


Plate displacement

SYSTEM COMPONENT/s

- *Four (4) Load Cells*
- *Tern Controller, GPS*

ADVANTAGE

-*Rugged and easy to handle*

-*Easy to install and maintain*

IMPACT FORCE

$$\frac{1}{2}Mv^2 = \int_0^{\delta_{\max}} F d\delta + \int_0^{\alpha_{\max}} F d\alpha$$

PLATE DISPLACEMENT

$$\Phi(f) = \frac{|S(f)|^2}{|S(f)|^2 + |N(f)|^2}$$

FILTER

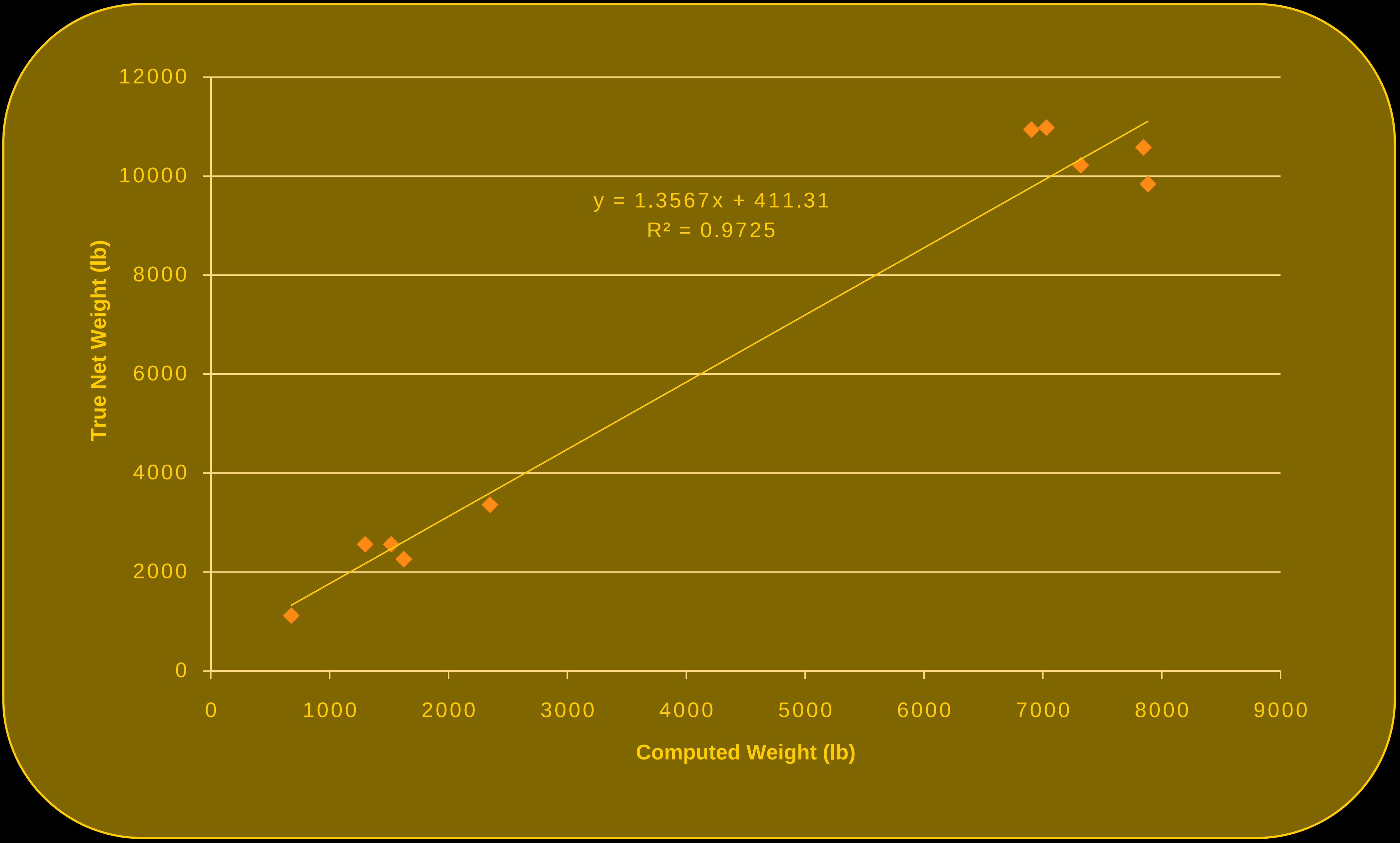
$$\text{Clumps} = \begin{cases} \beta(x\text{-}T) & \text{for } (x-T) > \alpha, \\ (x-T) & \text{otherwise.} \end{cases}$$

$$\text{Pr. Weight} = \begin{cases} \text{Clumps} & \text{for } x > T, \\ 0 & \text{otherwise.} \end{cases}$$

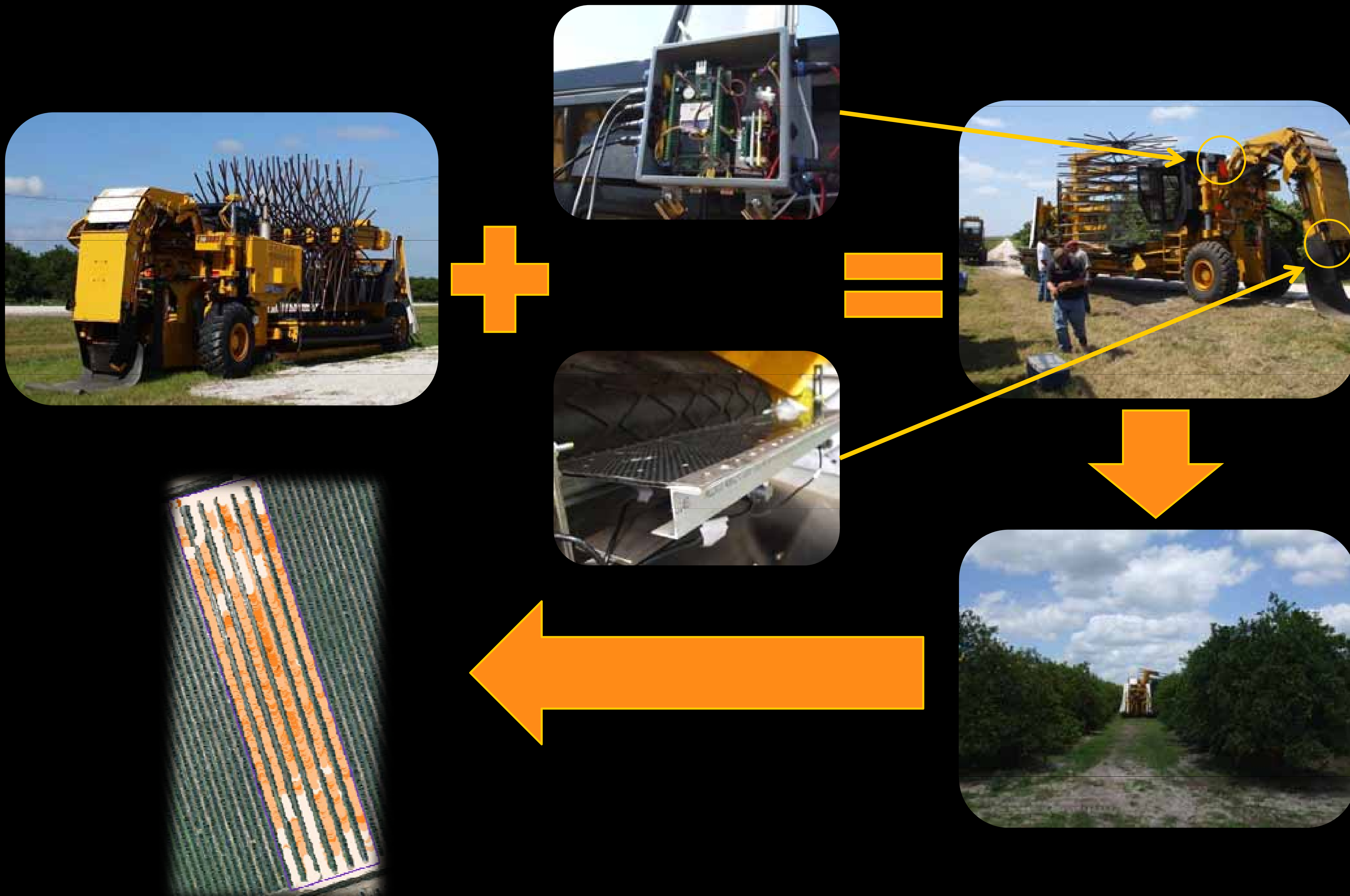
WEIGHT

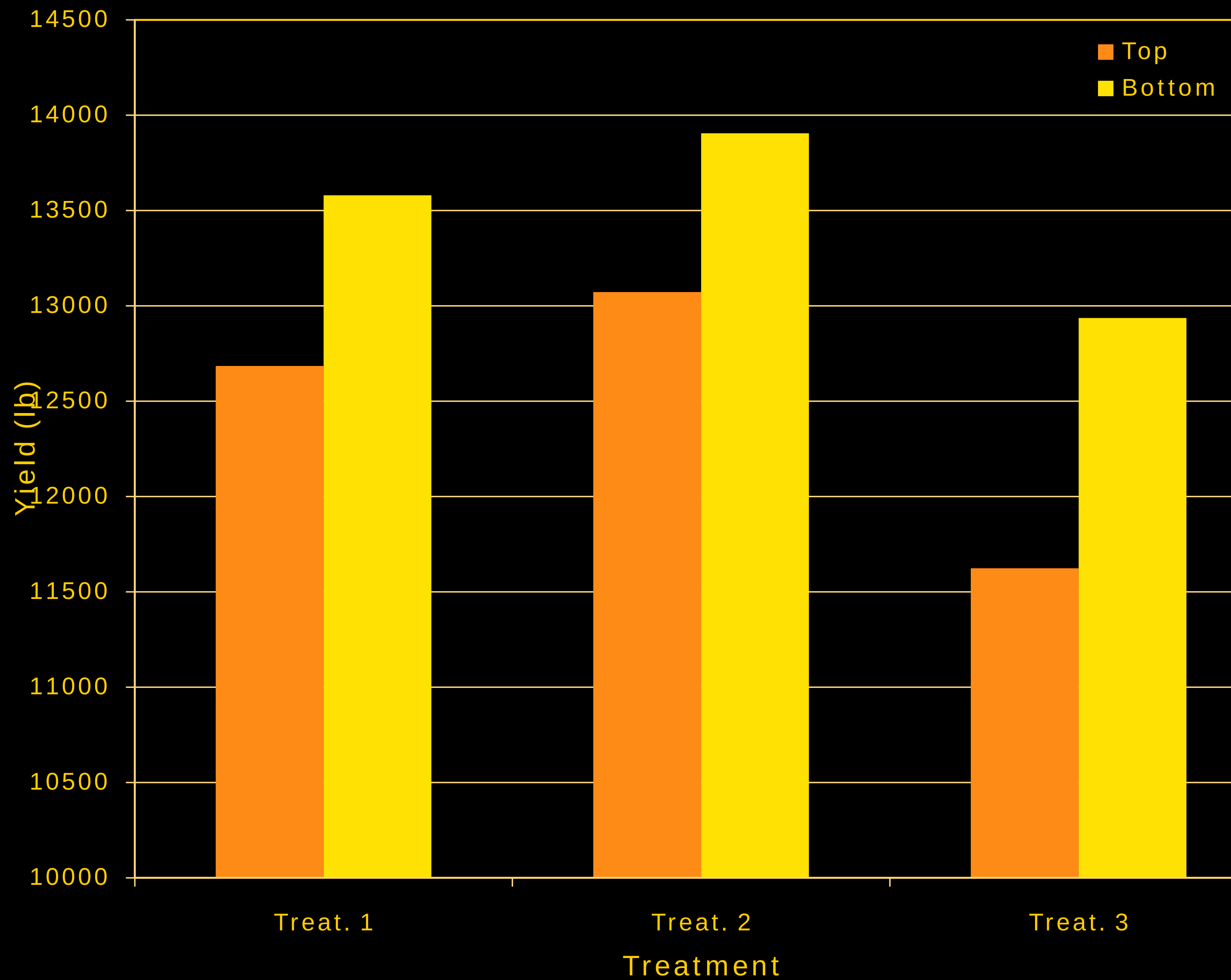
LABORATORY & FIELD TEST

Field Calibration



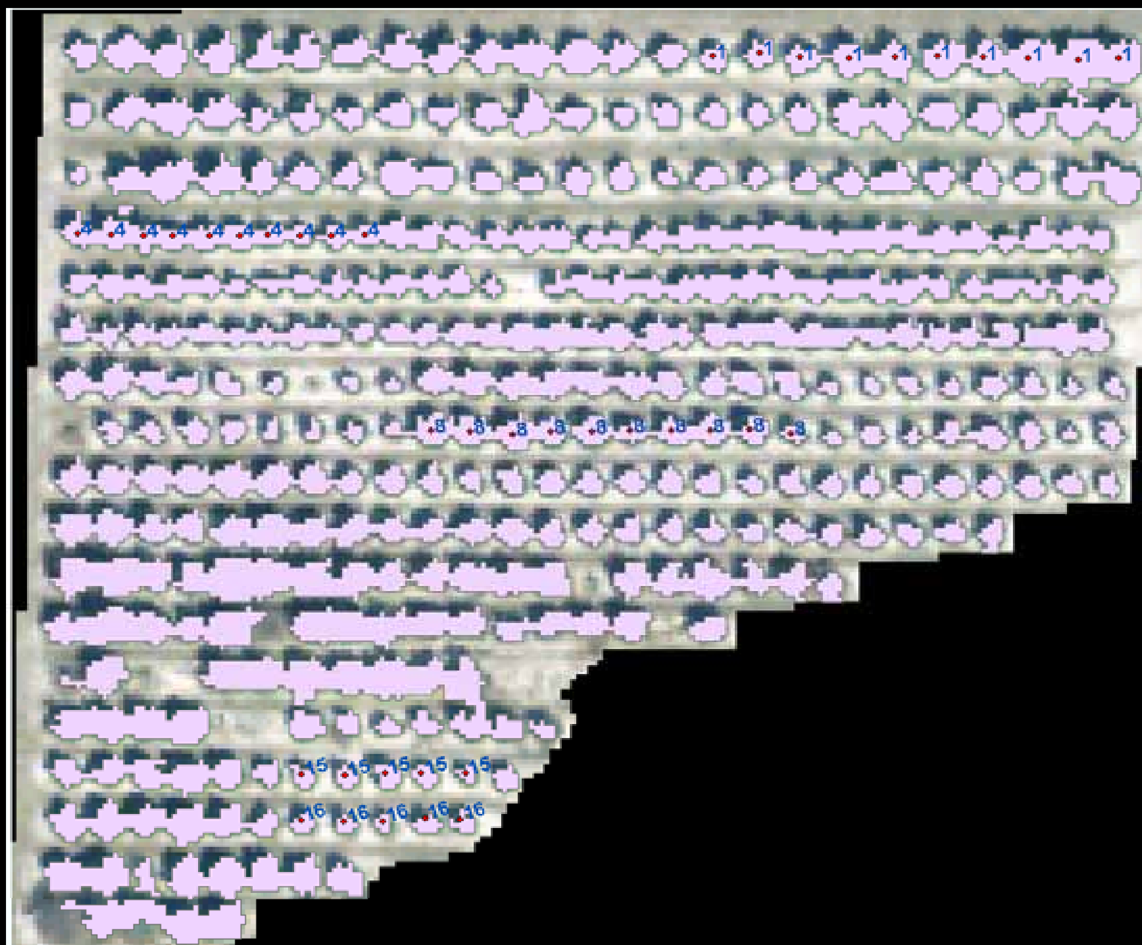
Yield Monitoring System in Action



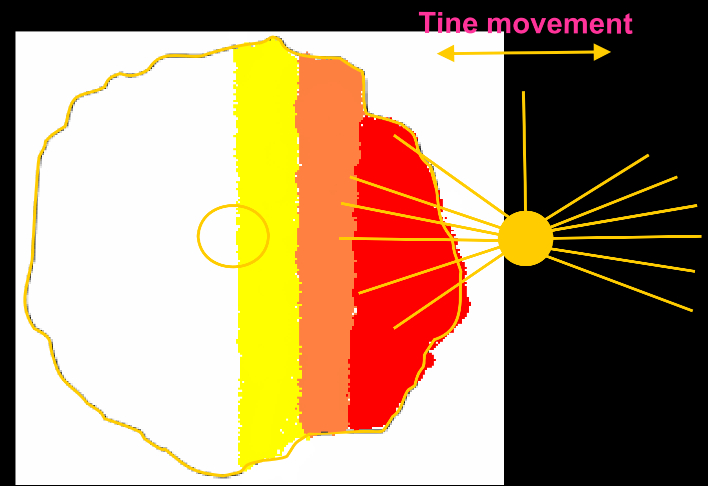


Top
Bottom
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
Yield (lb)
Treat. 1
Treat. 2
Treat. 3
Treatment

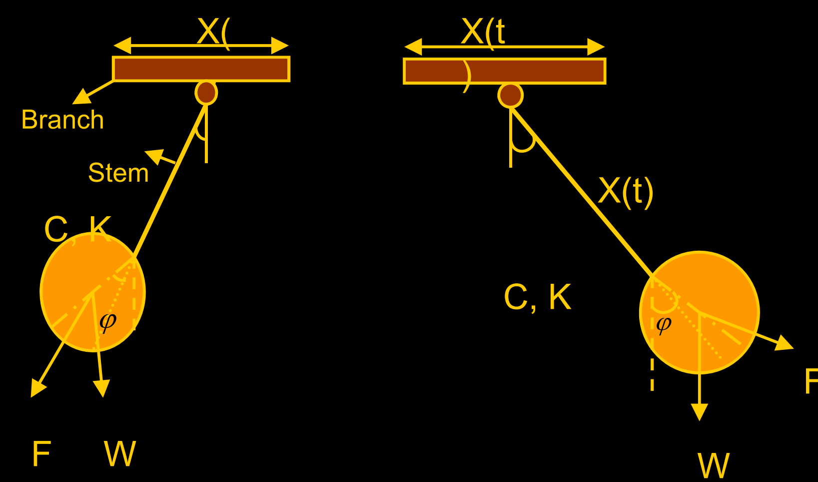
Reducing Tree Injuries & Improving Fruit Removal



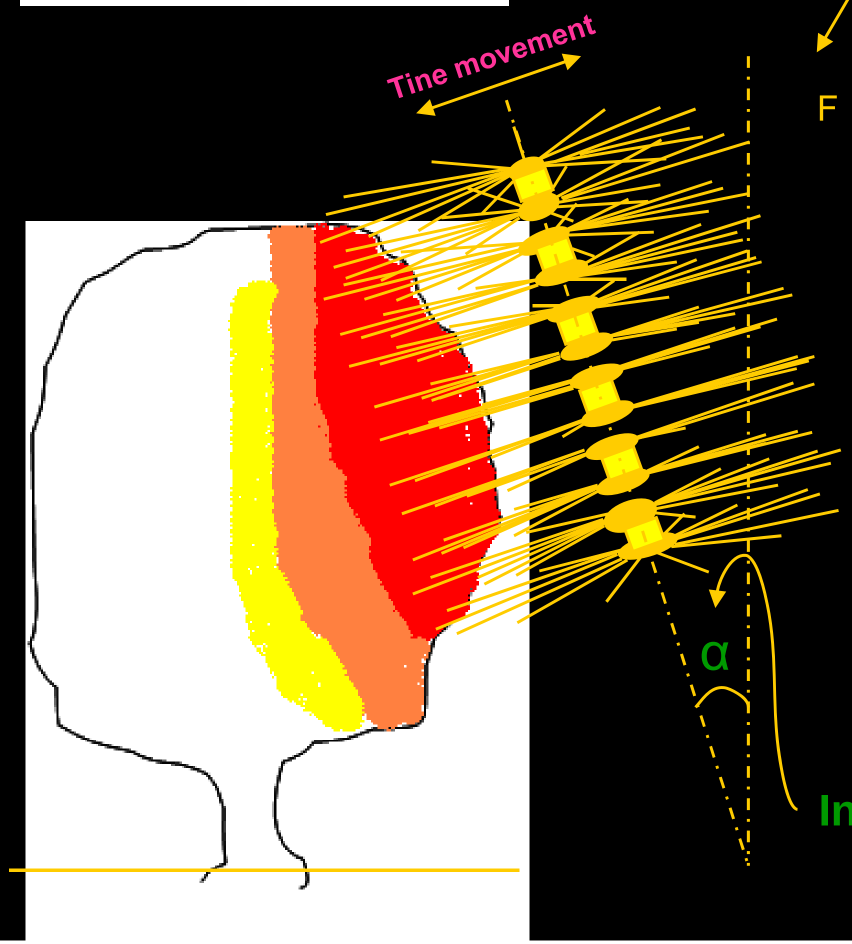
Force Distribution in the Tree Canopy during Mechanical Harvesting



Tine design variables



Forward Speed
Amplitude
Frequency
Inclination (α)



Shaking force

- High
- Medium
- Low

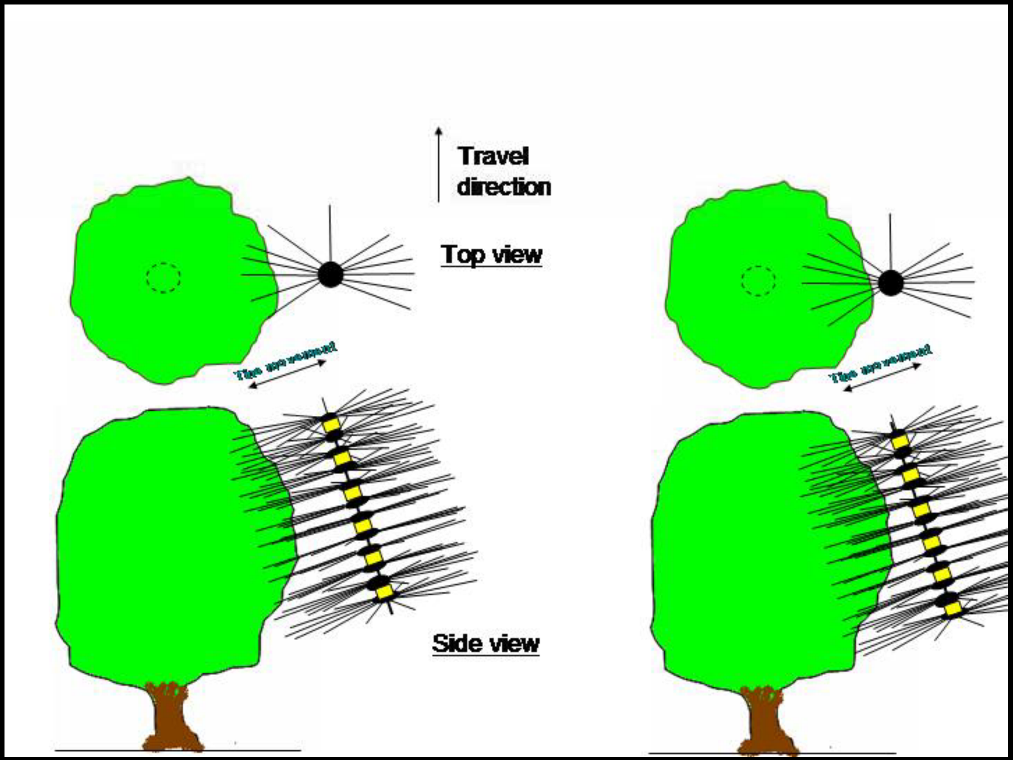
Reducing Tree Injuries & Improving Fruit Removal

- Study the force distribution in a canopy of citrus trees and determine the best shaking parameters for each type and size of tree
  - Study the force distribution in an individual branch in the tree when harvested by a canopy shaker
  - Study the effects of frequency of shaker, angle of tines and tree size on the force distribution
- Variable rate shaking
  - Measuring canopy size and volume
  - Developing a control system to adjust the optimal shaking parameters

Independent Variables

- Tree size
- Angle of tines
- Frequency of the canopy shaker

	Independent Variable	Levels	Values
1	Tree Size (2 Levels)	1	Large
		2	Medium
2	Angle of Tines (3 Levels)	1	5°
		2	20°
		3	35°
3	Frequency of canopy shaker (3 Levels)	1	200 cpm
		2	250 cpm
		3	300 cpm



Methodology

Instrumenting the branch:

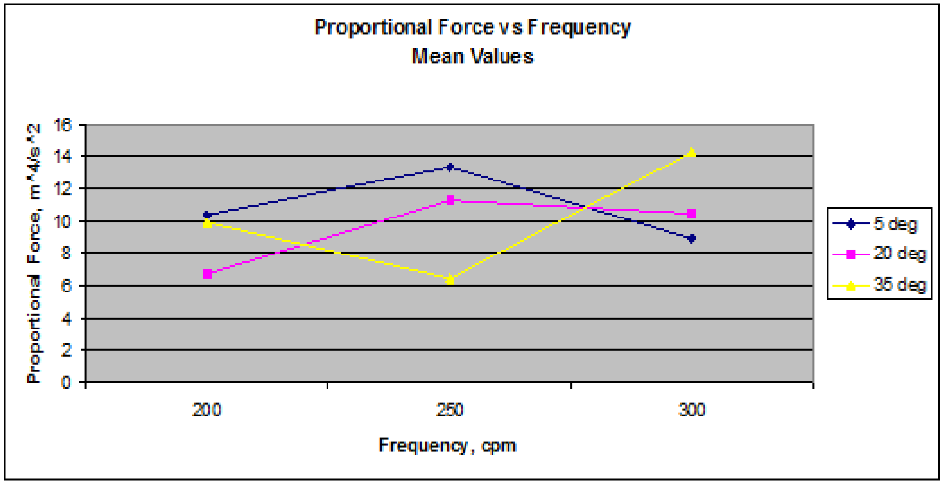
- Instrumenting the selected branch starts from the base of the branch where it is joined with the main trunk.
- A sensor is placed at the base.
- From the base of the branch, the sensors are placed at distances of multiples of 50 cm.
- The last sensor is placed such that the diameter of the branch at that location is about 15 cm.

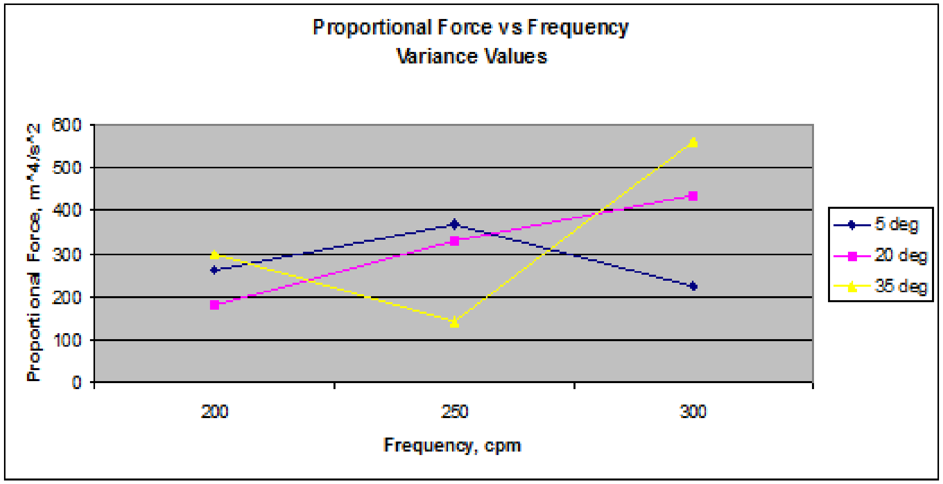
Images of a Tested Tree

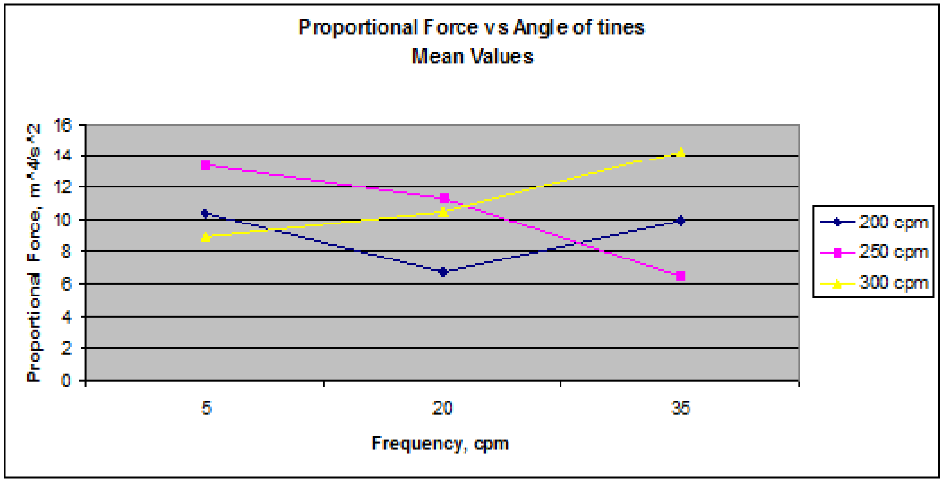
Videos of Experiment

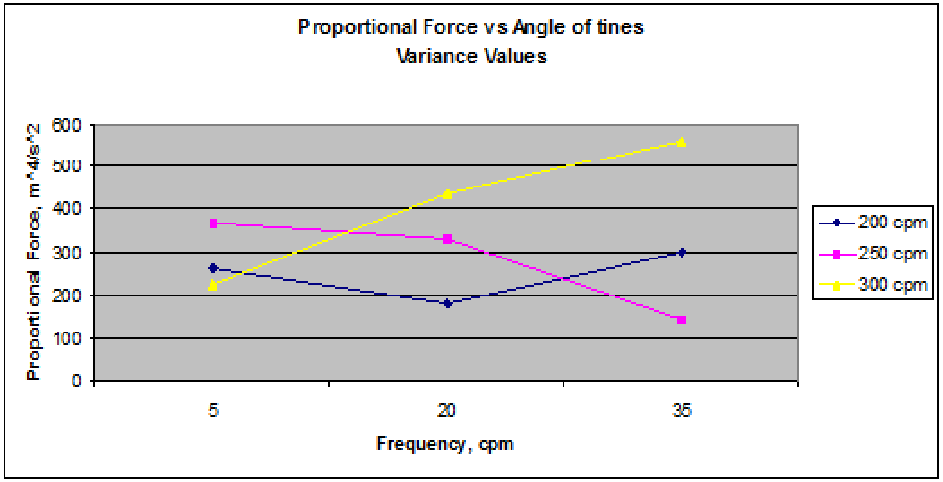
PRELIMINARY RESULTS

Large Tree



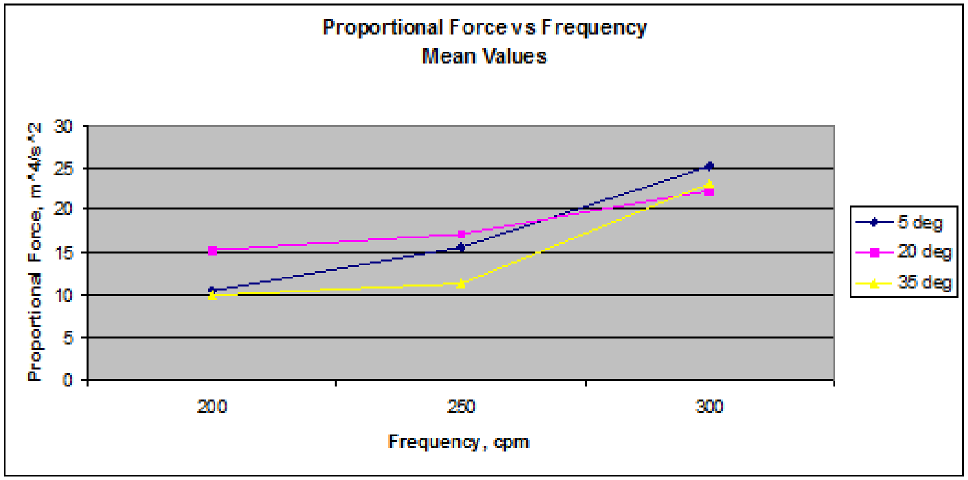


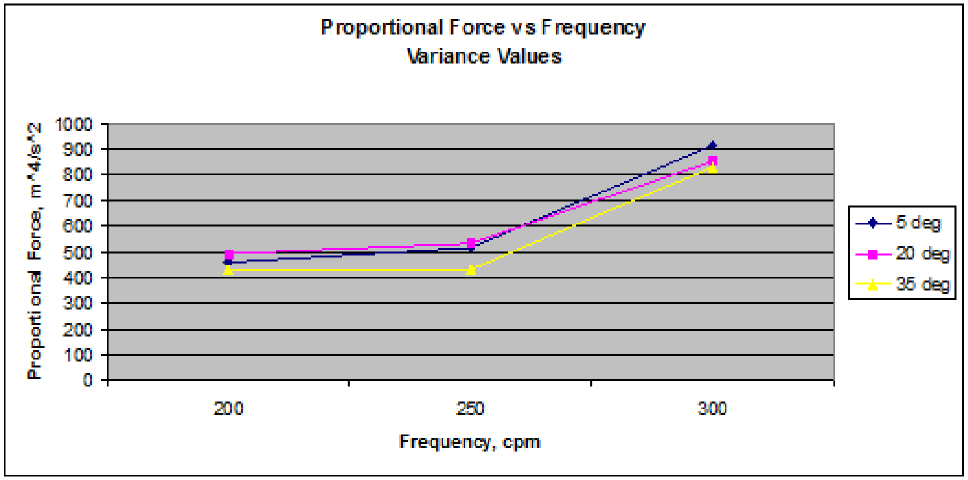


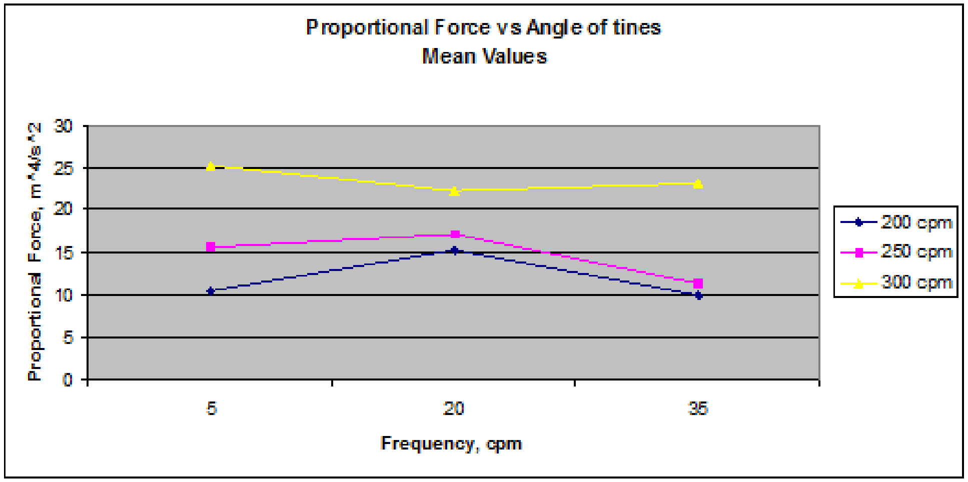


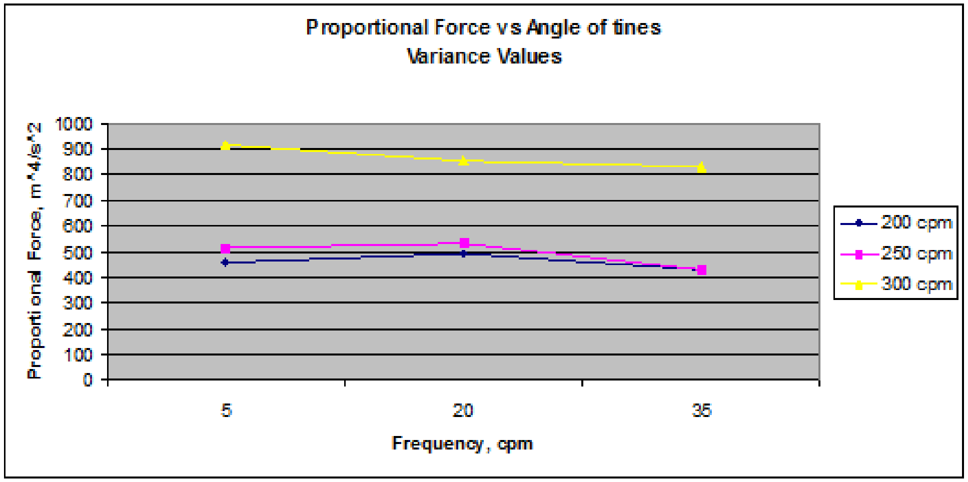
Preliminary Results

Medium Tree

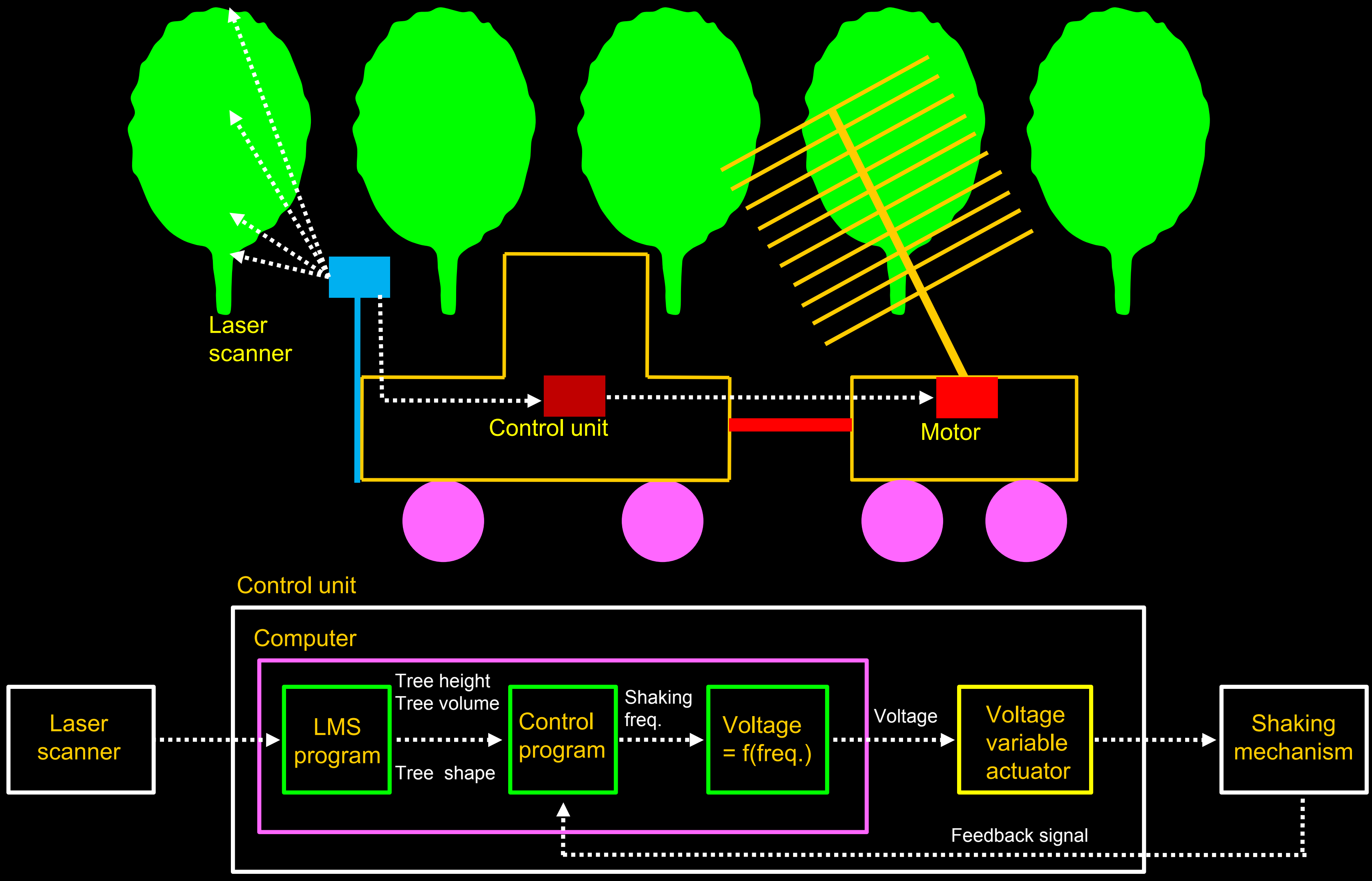




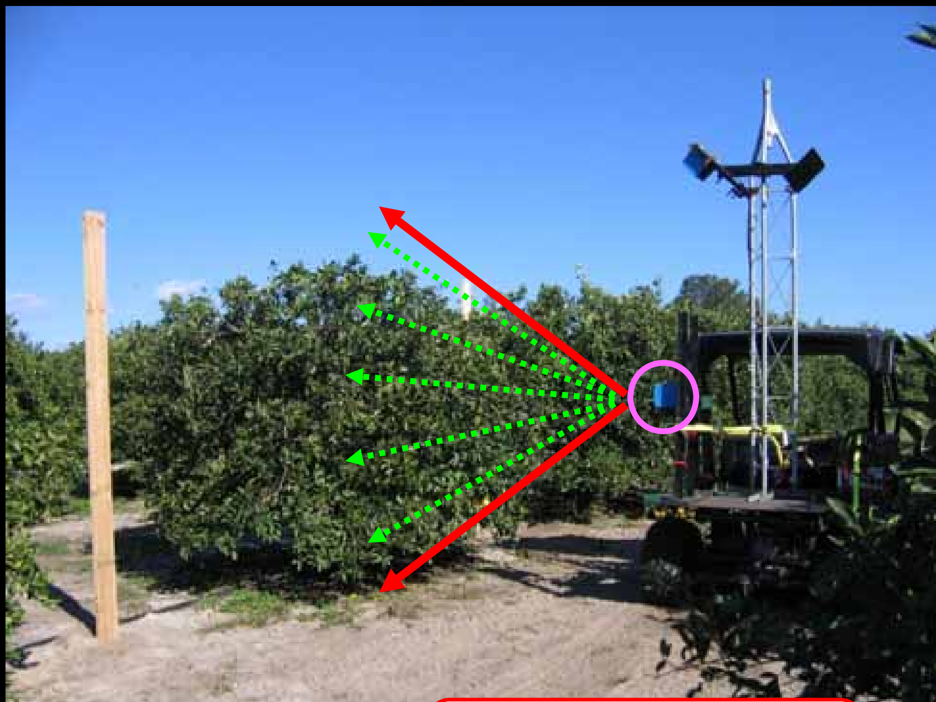


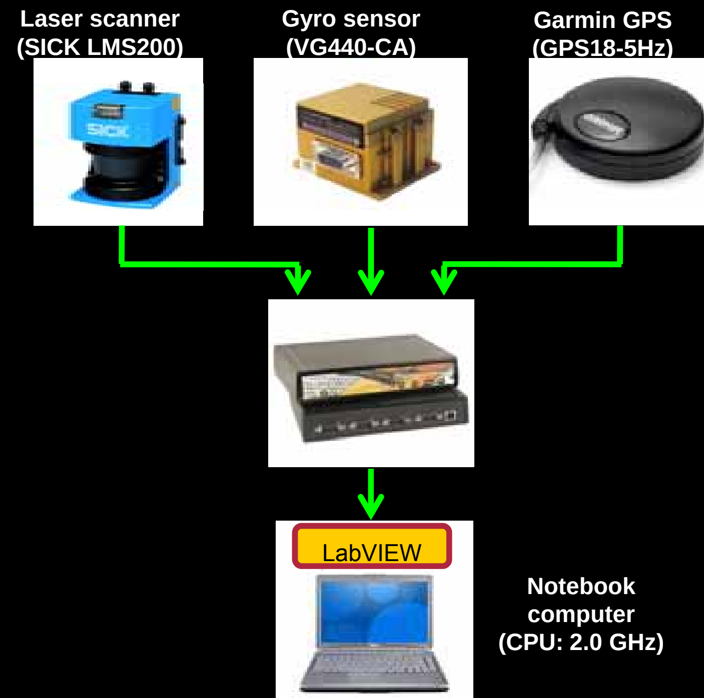


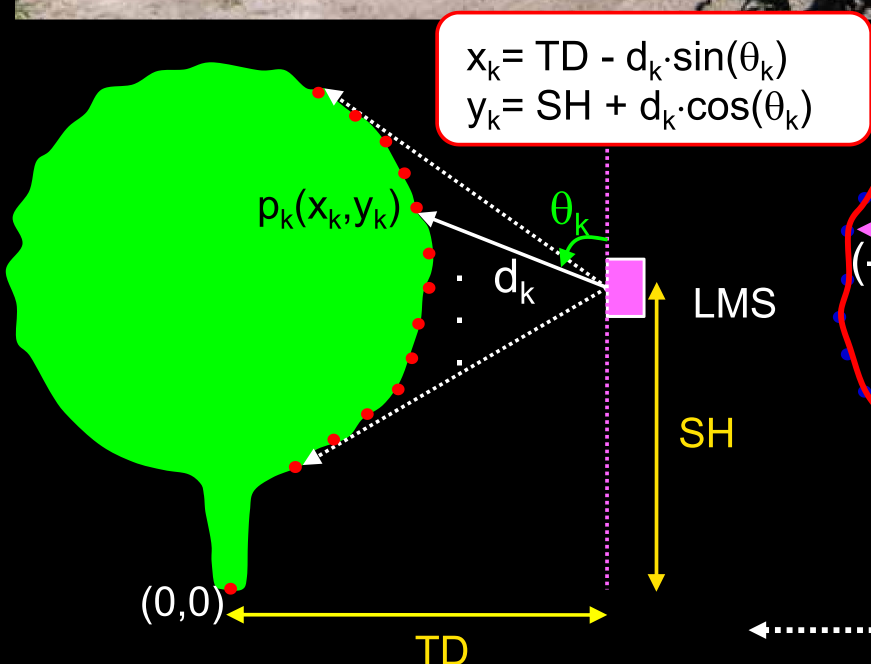
Variable Rate Shaking of Trees According to Size by Canopy Shakers

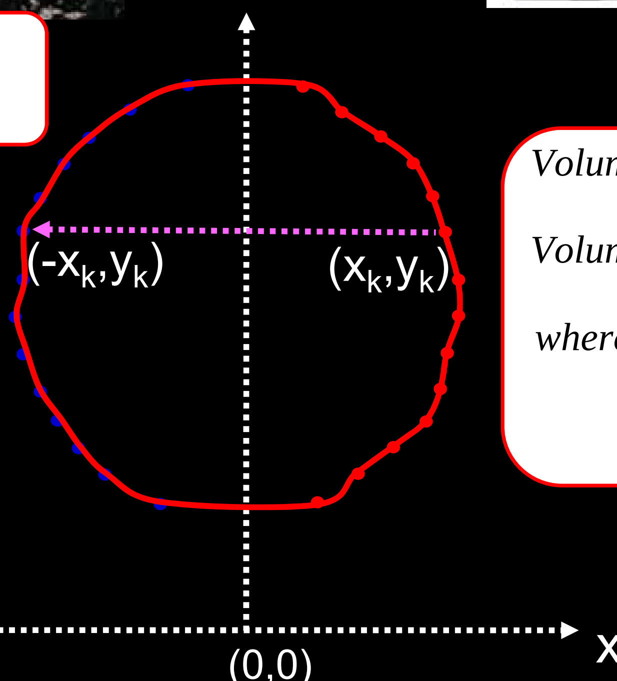


Tree Canopy Volume Measurement









$$Volume \;\; of \;\; slice \; (V_i) \; = \; A_i \cdot \Delta t \cdot S$$

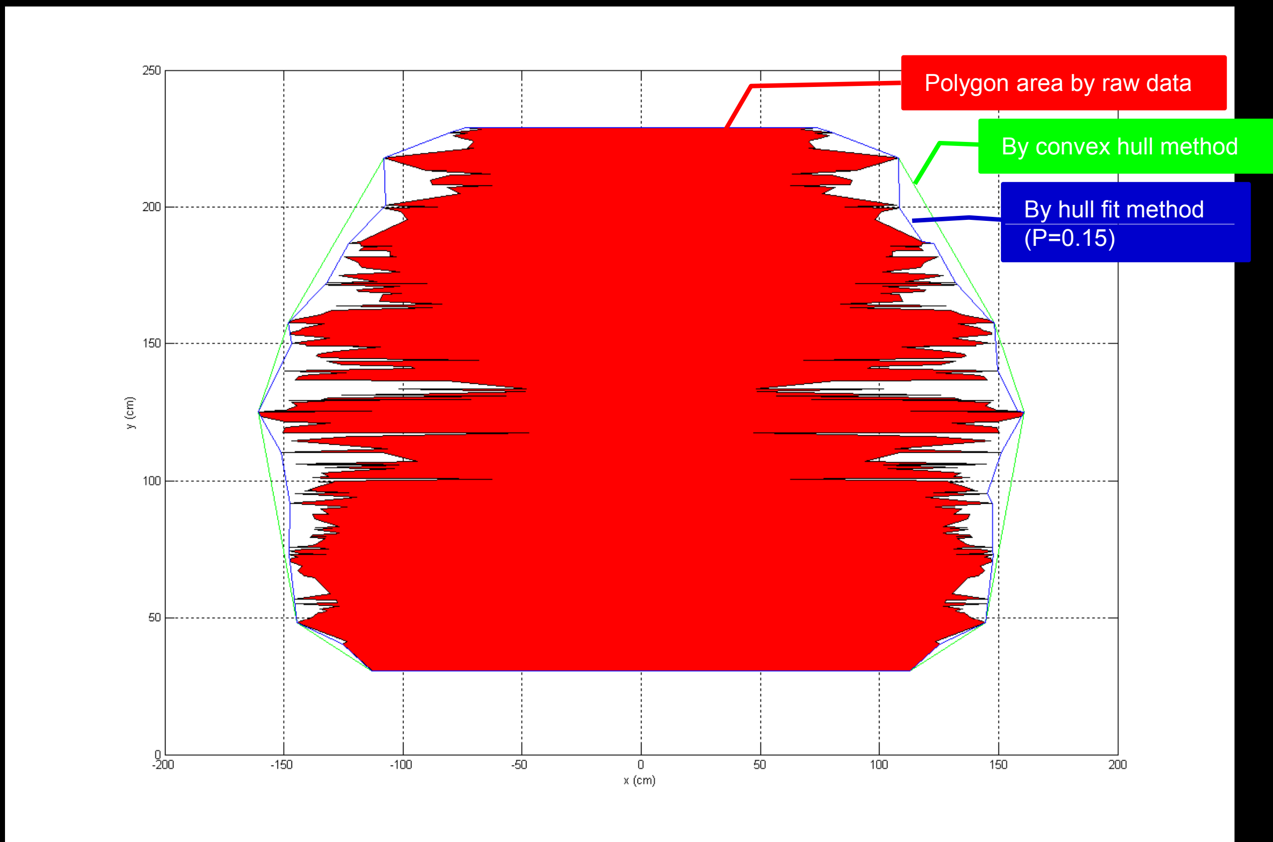
$$Volume \;\; of \;\; tree \; (V) \; = \; \sum_{i=1}^{n} V_i$$

$$where, \; \Delta t \; = \; scanning \;\; time \;\; per \;\; cycle$$

$$S \; = \; vehicle \;\; speed$$

$$A_i = area \; of \;\; polygon$$

Tree Canopy Volume Measurement



* Roll angle correction
(roll angle = 8.8°)

Tree geometric characteristics			Travel speed of the vehicle = 1.0 (m/sec)	
			Meas-True	Error (%)
Height (cm) (True=240)			-0.991	-0.41
Volume (m^3) (True=11.286)	Raw data		-1.580	-13.99
	Convex hull		0.665	5.89
	Hull fit	P=0.15	0.010	0.09
		P=0.30	0.409	3.62
		P=0.60	0.585	5.18

Tree Height / Volume		Raw data / Roll angle Correction	Travel speed of the vehicle = 1.0 (m/sec)	
			Meas-True	Error (%)
Height (cm) (True=240)		Raw data	-43.510	-18.13
		Roll angle correction	-6.770	-2.82
Volume (m^3) (True=11.286)	Hull fit (P=0.15)	Raw data	-0.610	-5.40
		Roll angle correction	-0.060	-0.53

Thank You

Any Questions?