Autonomous Orchard Efforts

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Moog Inc.

Working Partnership Between:

MOOG

- Multinational Aerospace / Defense / Industrial Automation Company
- Specializing in precision motion control
- Headquartered in Buffalo NY
- $2.7 Billon in Sales / 13,000 employees

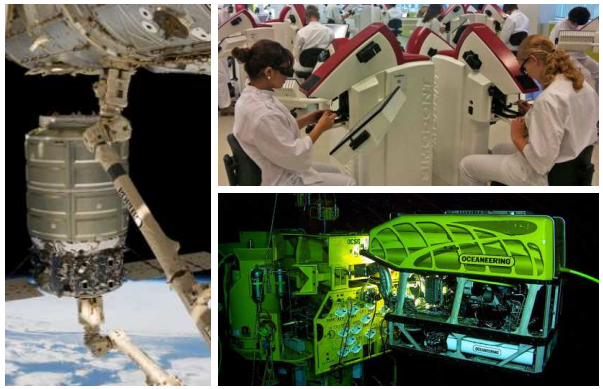
When Performance Really Matters™

World Leader in Customized, High Performance Control Systems and Products

Safety Critical

High Performance

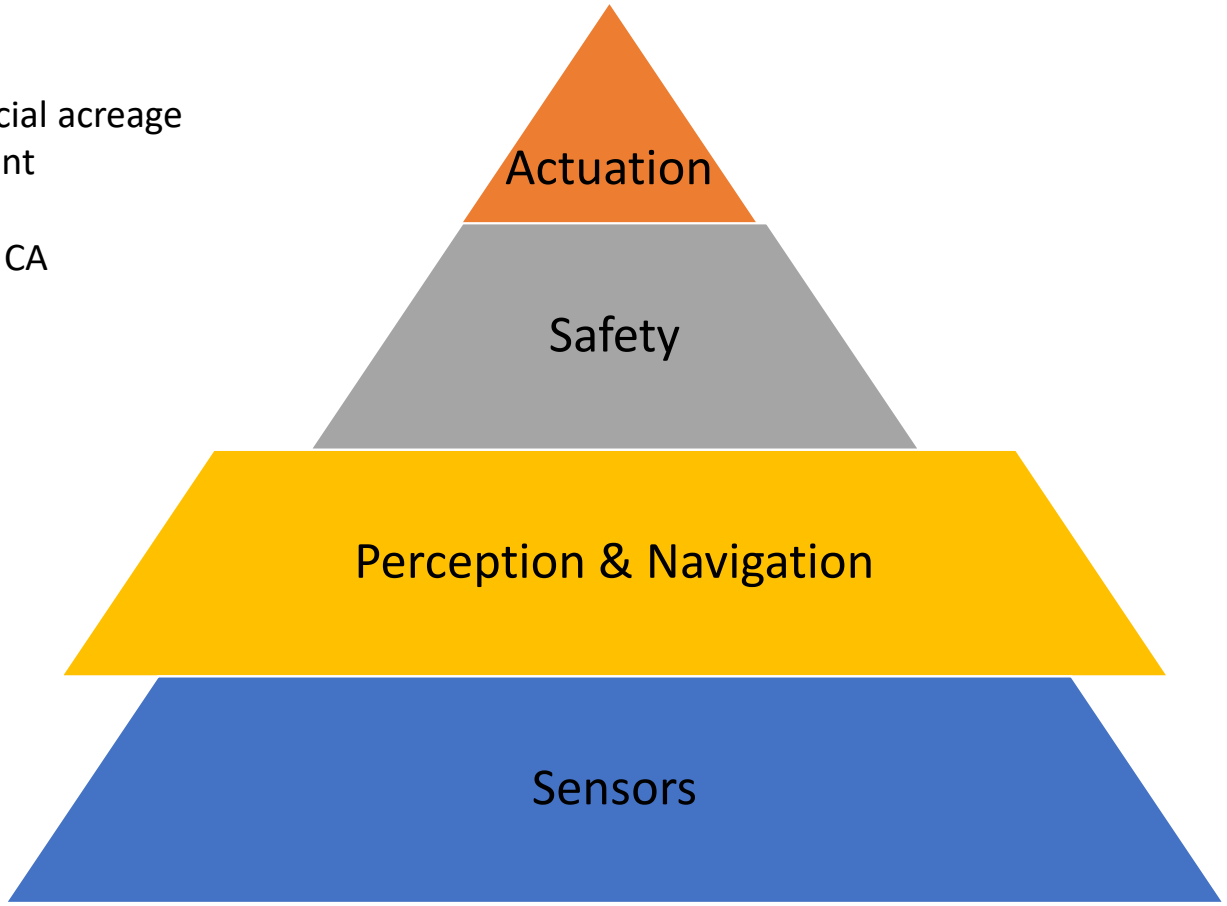
High Reliability



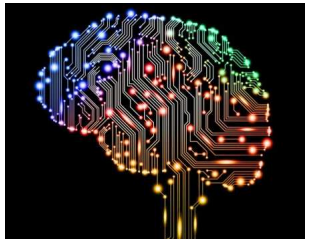
Demanding Environments

VERDANT ROBOTICS

- Agricultural Services Company
- Experienced with large commercial acreage
- Specialized software development
- AI / machine learning expertise
- Headquartered in San Francisco CA
- 10 employees



Autonomous Ecosystem



Artificial Intelligence

Autonomous Driving

Data Highway

VERDANT ROBOTICS

MOOG

Mechatronics

Data Analytics

System Safety

Perception Systems

So Why Apple Orchards?

1939

2014

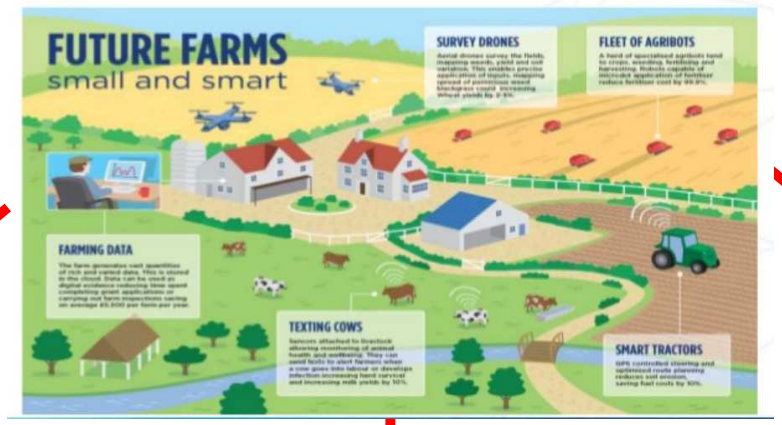
75 years of innovation

20+ Billion Times

1 apple/ 2 seconds

Agricultural are the "Gateway" to many autonomous applications

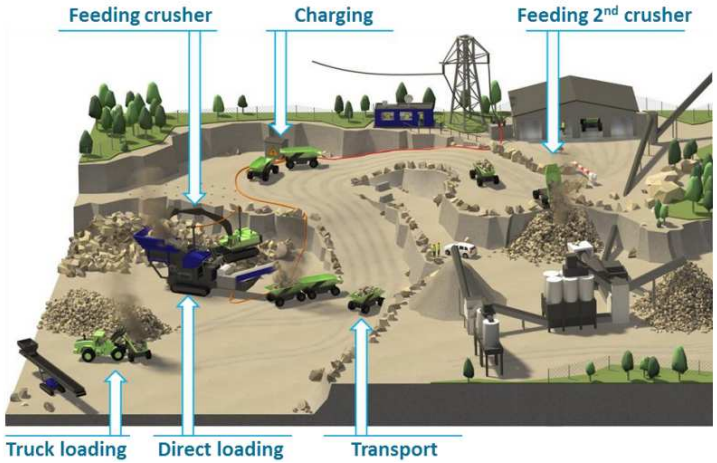
- Dull, Dirty & Dangerous
- Operation in and around humans
- GPS denied environments



Why Orchards?

- Structured environment
- Complex manipulation req'd
- Requires high speed
- Needs to be highly reliable
- Large amounts of data to be processed
- Lots of repetitive actions

Military & Defense

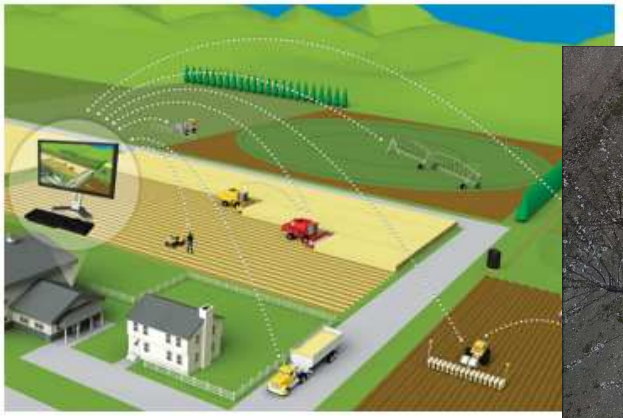


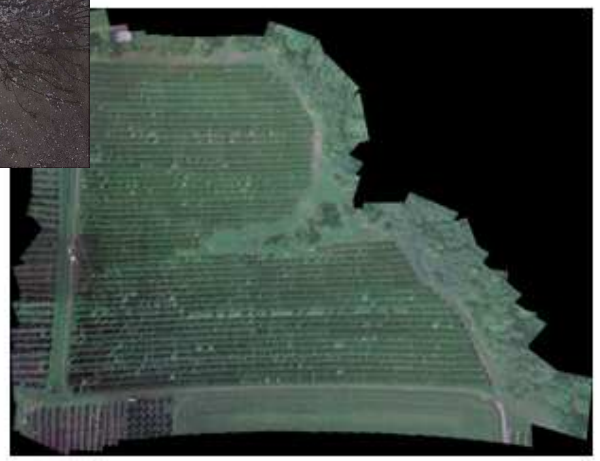
Construction & Mining

Forestry & Nuclear

Initial Efforts Focused on Navigation

(Almond Industry)





Autonomous Apple Orchard

All phases look similar with respect to autonomous

- Perceiving (Counting)
- Tracking
- Identification
- Action
- Verification






Where to start:

- Biggest effect on crop quality?
- Significant labor reduction?
- What can't be done today?
- What adds the most value?

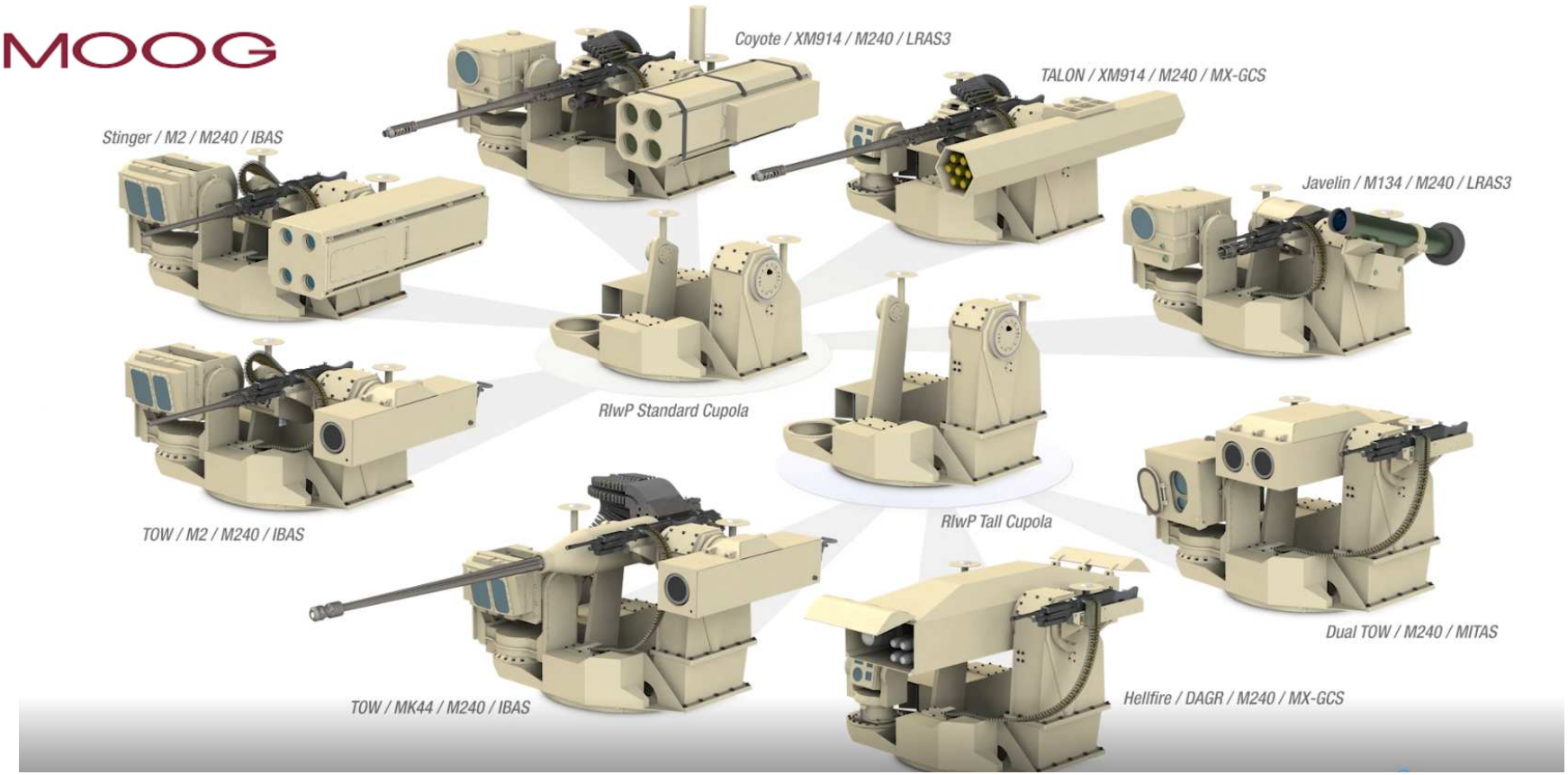
Difficulty

Time

Cluster Thinning During the Pink Phase ?

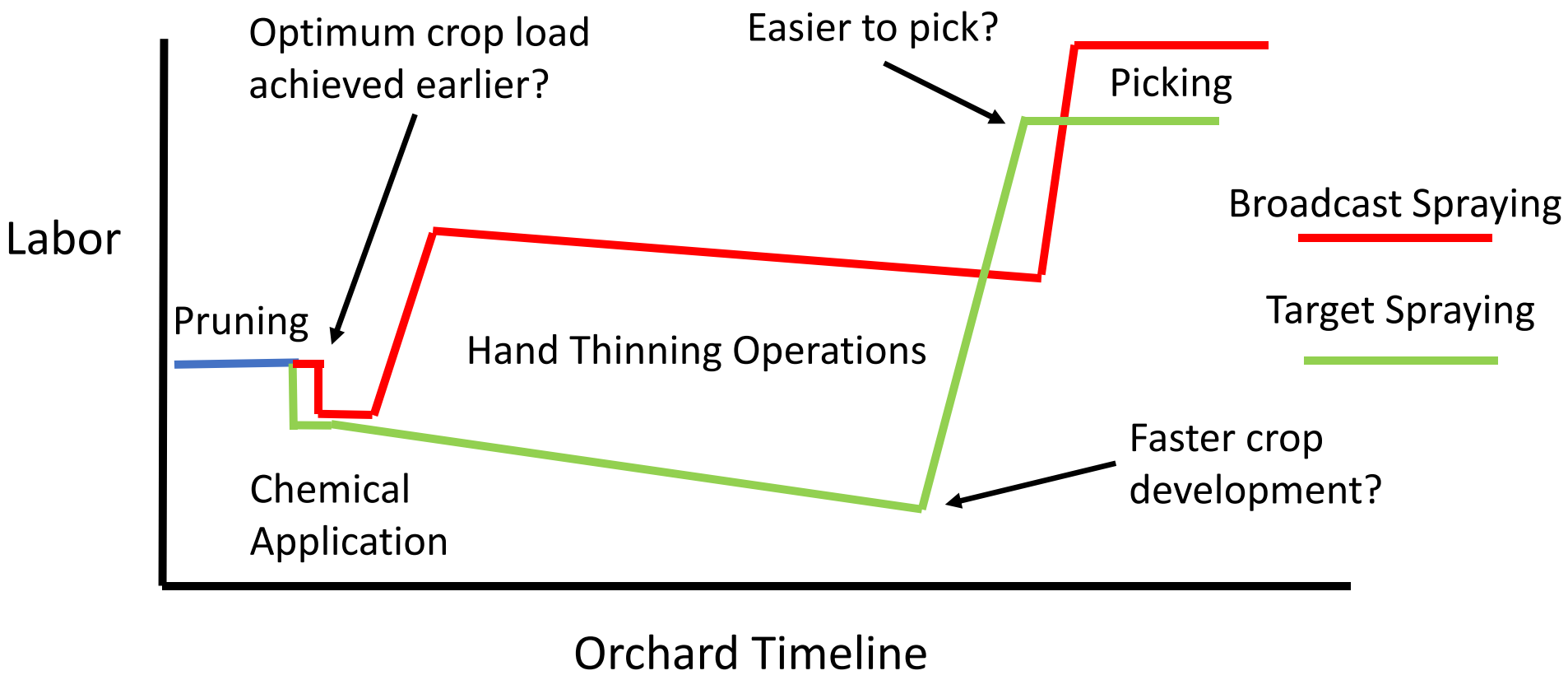
- Get it before it blossoms
- Mabey even earlier at fruit bud break?

Where “Fire” Control Meets the Orchard

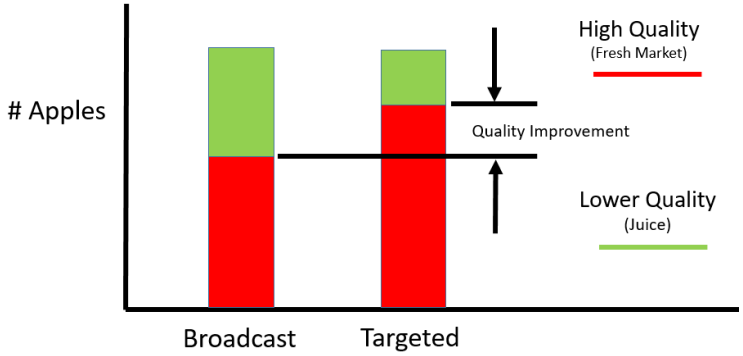


Technology required for the Cluster reduction is similar!

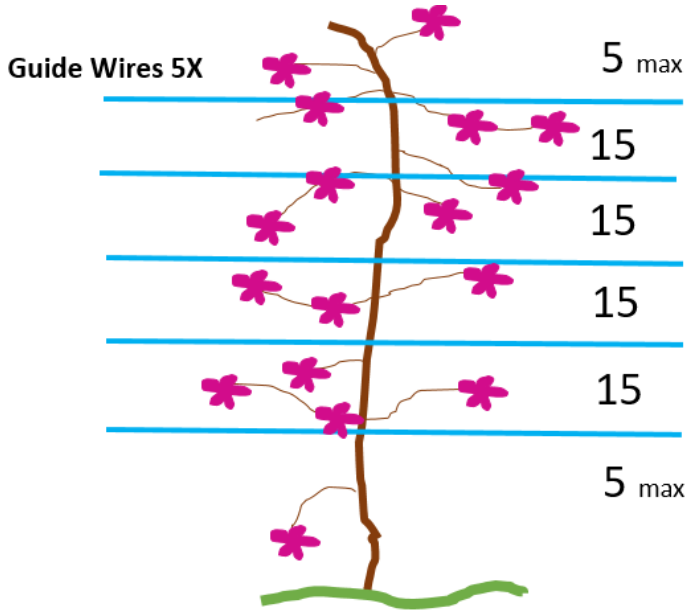
Target vs. Broadcast Spraying Potential



Cluster (Pink) Thinning



- Opportunities
  - Improved apple quality
    - Better crop load management
  - Reduces the down stream thinning labor
    - Subsequent jobs get easier
  - Reduces the risk of uncertainties associated with broadcast spraying
    - Controlled fruit distribution across the tree
    - Hit what you want to hit
    - Thinning rules can be tightly controlled



Cluster (Pink) Thinning

- Lots of challenges to overcome (to name a few)
  - Grower acceptance?
  - Time fence
  - Lighting
  - Minimizing leaf damage
  - What to spray?
  - Pruning practices
  - Ground dynamics
  - Speed
  - Processing time
  - Affordability

Buffalo Test Orchards

“Winter Orchard”

Where Are We Today?

- Successfully autonomously navigated a real apple orchard
- We have been able to simulate functionality in a warehouse
  - Blossom counting and identification
    - Closed the loop around vision
  - Target spraying of 1mm targets
- Collecting imagines on a variety of orchards
  - Working East and West cost orchards
  - Working both northern and southern hemispheres

What's next?

- Headed to the orchard in April to count, track and target "pink"
  - Mark clusters with die
  - Verify system accuracy
- Investigating alternate cluster elimination techniques
  - Chemical (Traditional & Non Traditional techniques)
  - Mechanical thinning (Laser, water jet, air knife, liquid nitrogen,etc.)
- Collecting more tree data
  - Working individual tree prescription
- Exploring combined air and ground domain effectiveness

Were Can You Help?

- Does this make sense?

- Interested lead users
  - Help define operational requirements
  - Provide thinning rule options
  - Provide test acreage for ground truthing
  - Feedback on understanding the financial models