



Lessons Learned Building and Deploying a Weed-Killing Robot

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agriculture



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Jetty



=



1x robot

40x crew

Jetty replaces hand-weeding and herbicides on vegetable farms with thermal micro-jetting technology

Robotics-as-a-Service pricing

→ \$50/acre + \$0.005 per weed

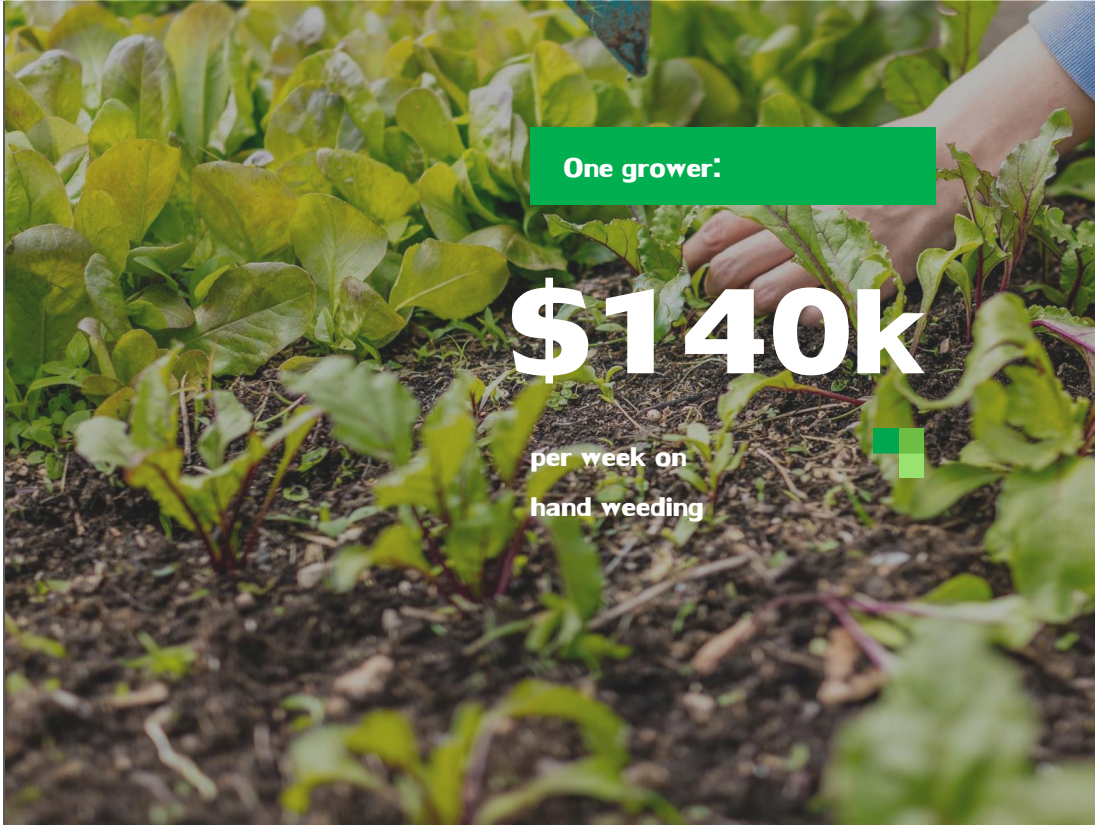
→ \$1.2M ARR potential per robot

Stage:

→ Paid trials with largest US

organic produce grower







US
market
size

4.3M

acres of vegetables
grown in the US

\$2.9B

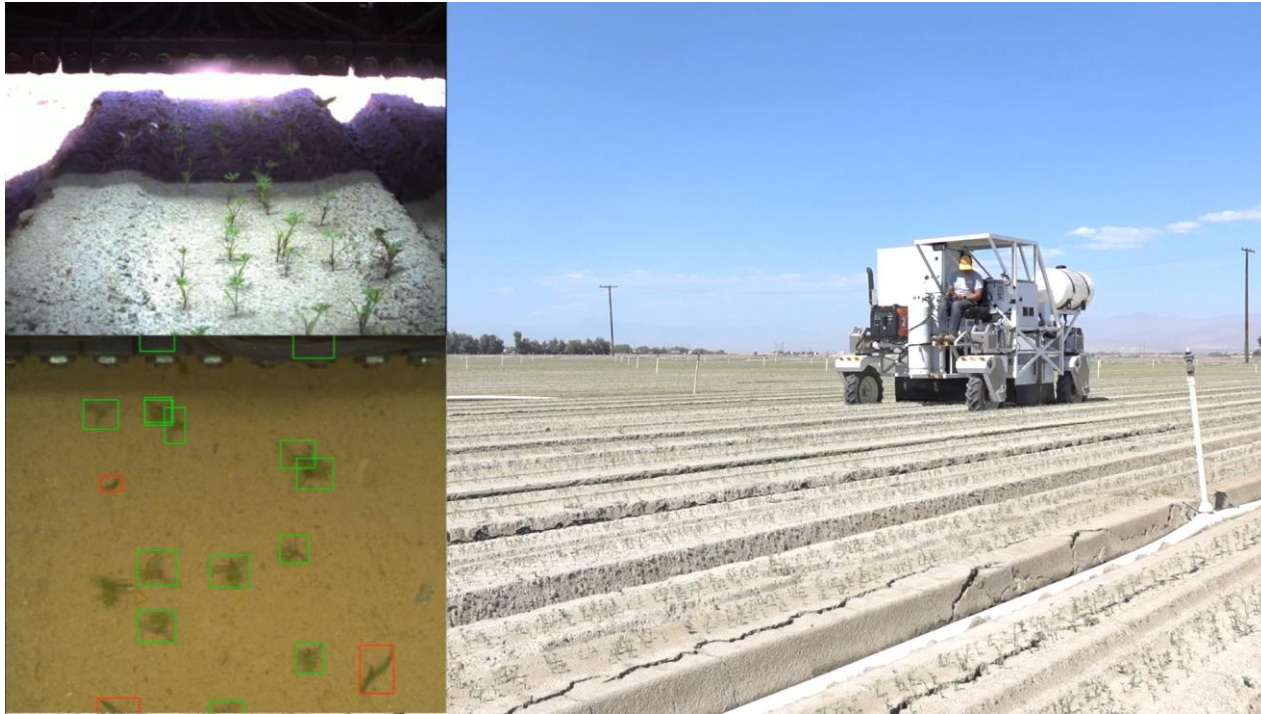
weed control & thinning
in vegetable row crops

\$440M

robot revenue opportunity
– top 14 vegetable crops

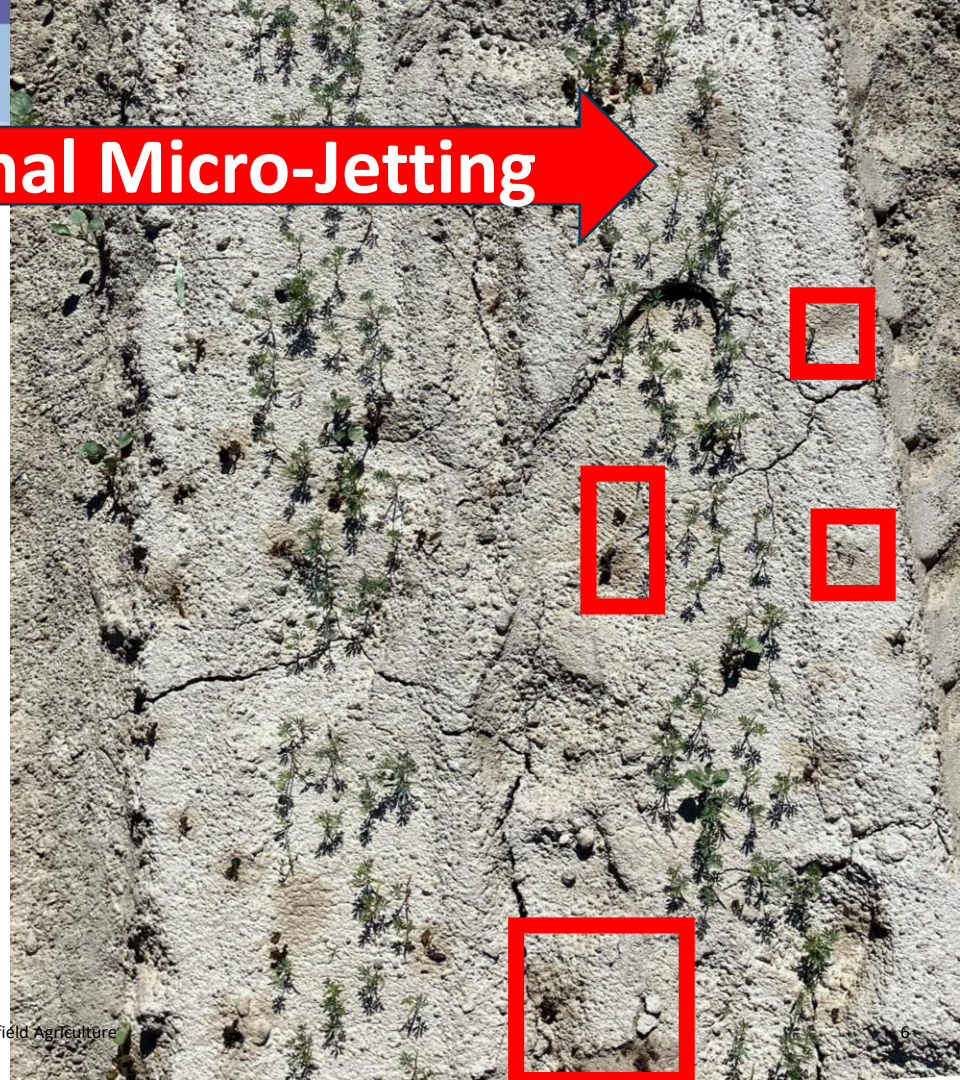
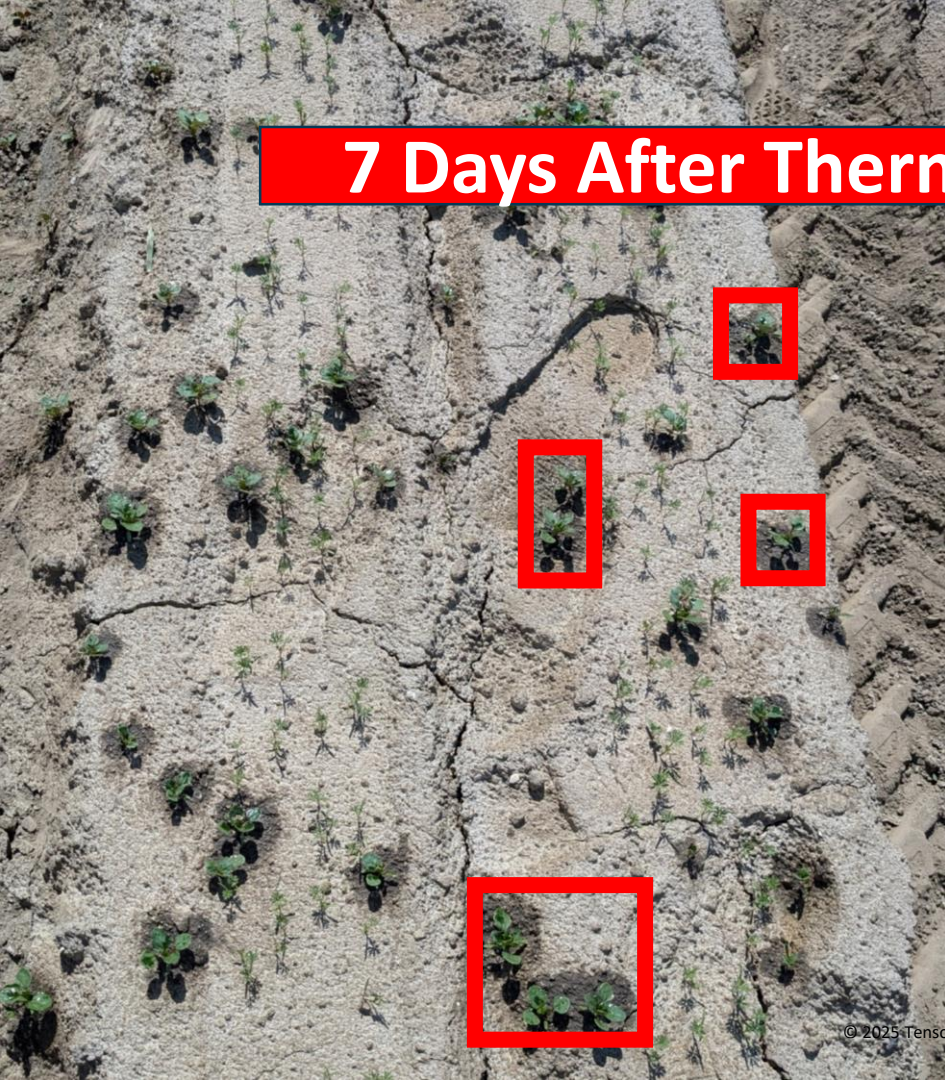


How It Works



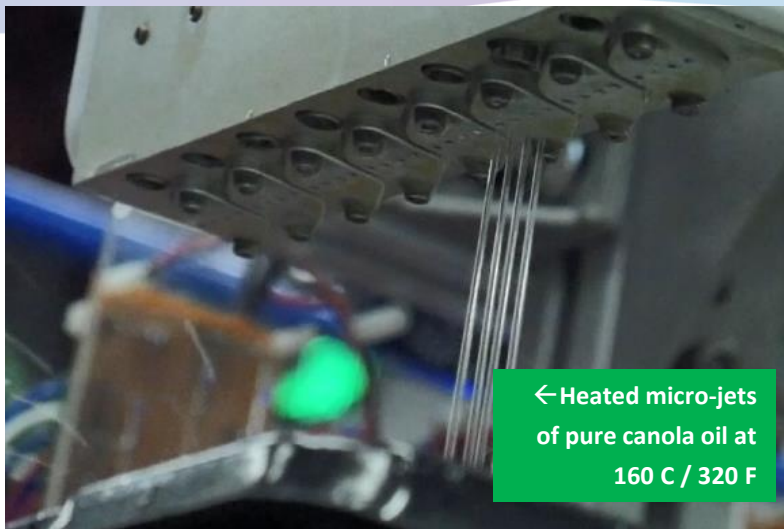
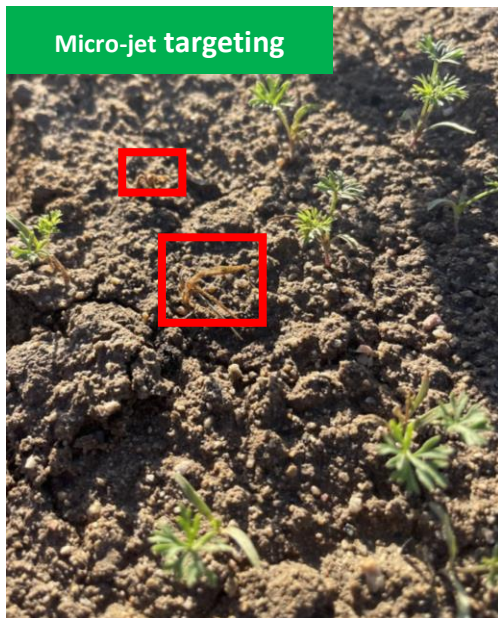
https://www.youtube.com/watch?v=tFqt_va8FLE

7 Days After Thermal Micro-Jetting



Thermal Micro-Jetting

Micro-jet targeting



← Heated micro-jets
of pure canola oil at
160 C / 320 F

Before treatment



After treatment



UC Davis

Original thermal micro-jetting research paper - [link](#)

University of Bonn

Weed control with hot oils from renewable raw materials - [link](#)

University of Helsinki

Impact on soil health paper - [link](#)



Precision Micro-Jetting

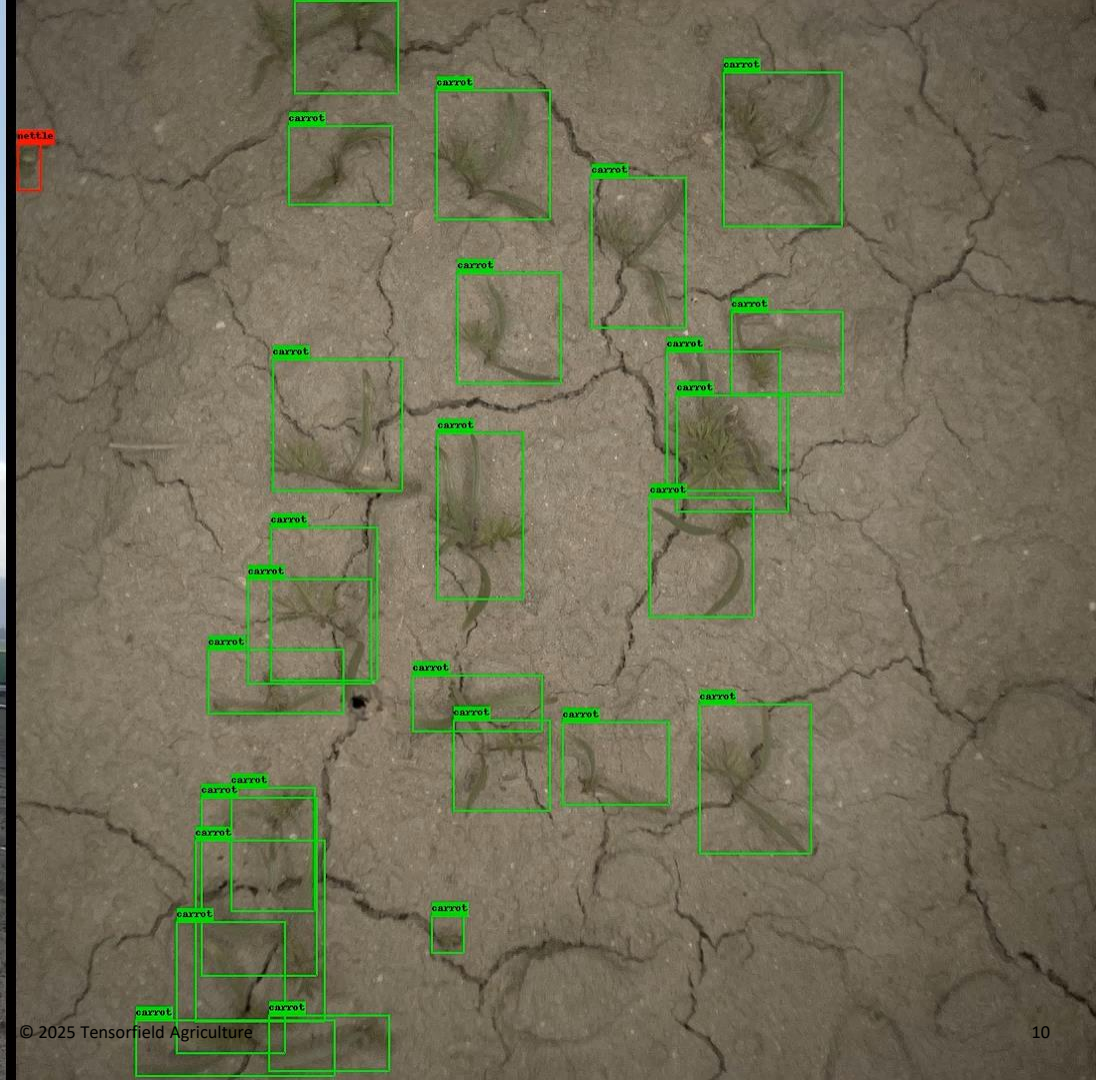


Precision Micro-Jetting





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Tensorfield prioritizes 3 competitive pillars:

1. Convenience

→solution must be fast and adaptable

2. Cost

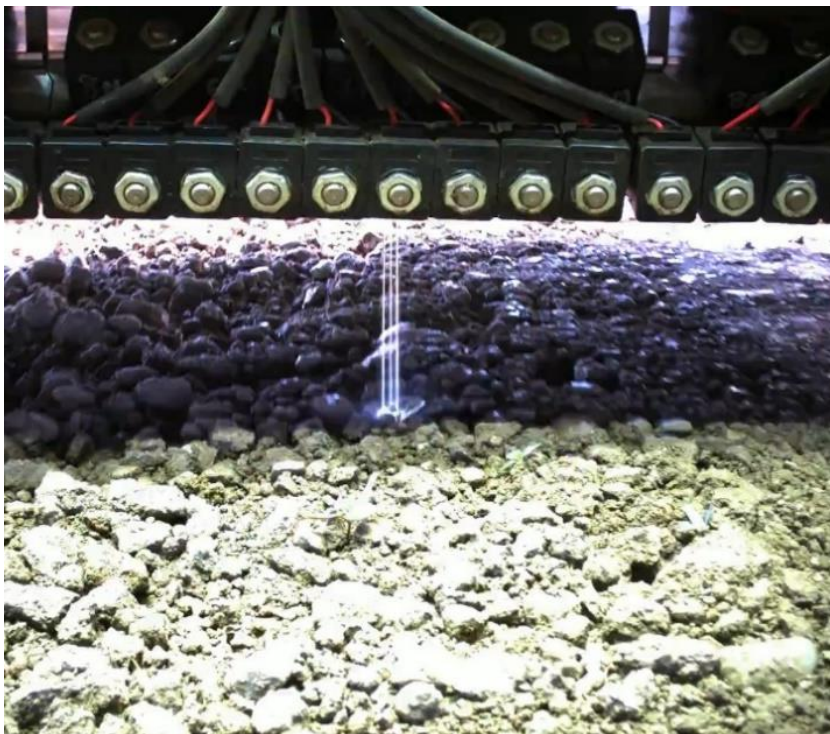
→solution must be affordable to deploy

3. Reliability

→solution must deliver on the day of callout



1. Convenience: Why Tensorfield?

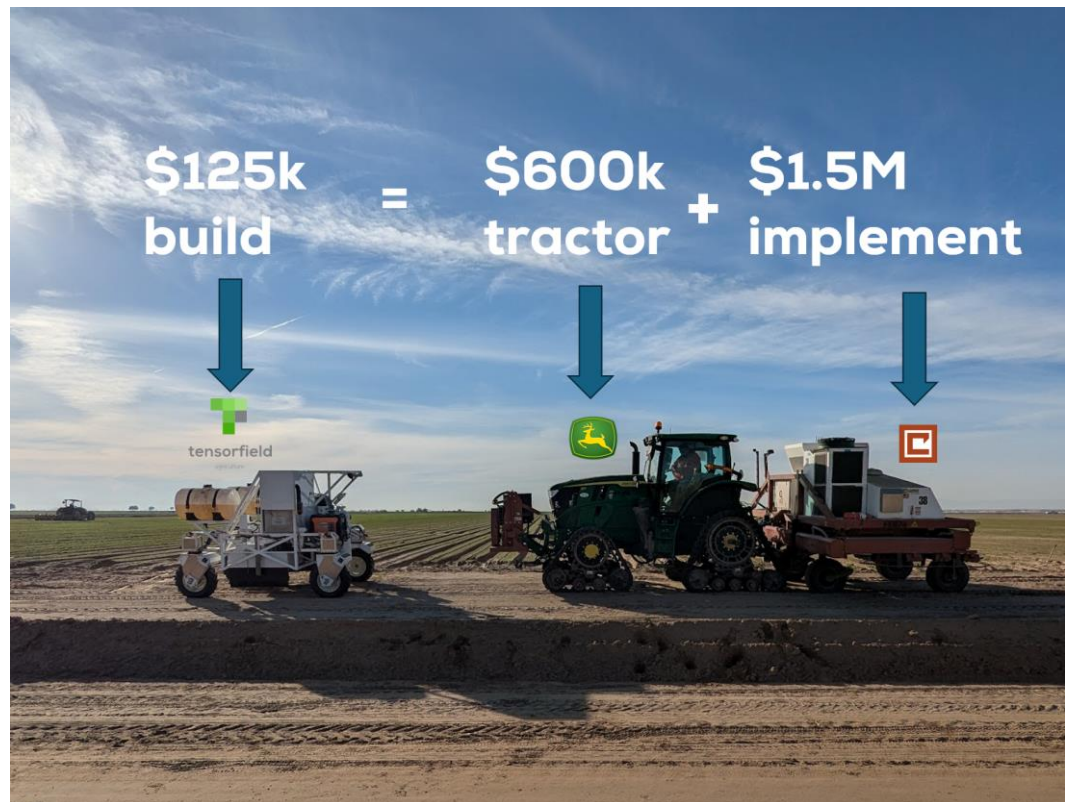


- **Universal Hardware:** one design covers all 4.3M acres of U.S. vegetable crops
- **Chemical-Free:** Thermal method approved for all conventional & organic fields
- **Access & Throughput:** 4X faster at $\frac{1}{4}$ the weight vs. competitor – damp fields OK!



2. Cost: Why Tensorfield?

- **Cost Advantage:** 10X productivity per dollar of CapEx
- **Lean Build:** Commoditized parts
- **Speed Wins:** 4X faster coverage reduces per-acre CapEx & labor costs

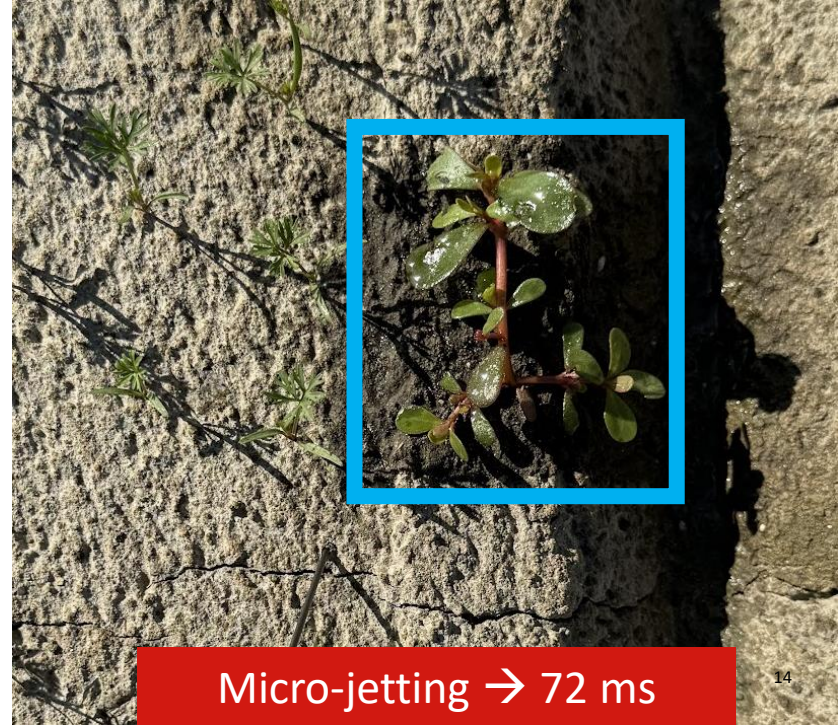
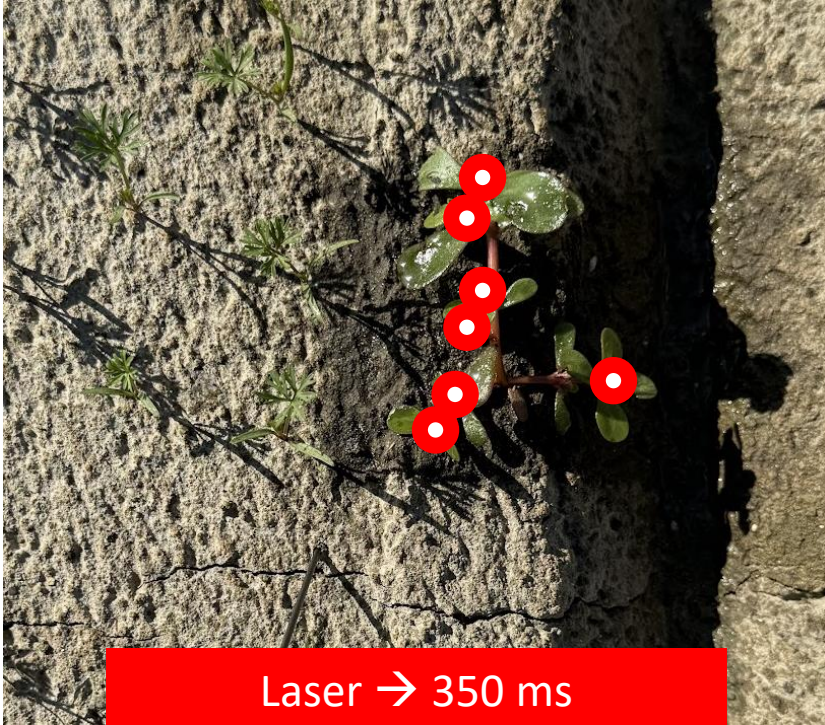


Laser vs. Micro-Jet

Q: Why is micro-jetting travel speed 2-6X faster than laser weeders?

A: No dwell time and 5X more efficient heating mechanism

Example: Purslane weed with 7 meristem target regions







3. Reliability: Why Tensorfield?



- **High speed and low CapEx**
→ system redundancy
- **Service model (HaaS)**
→ responsive to outages
- **Customer experience**
→ redundancy as backstop



Tensorfield Development Timeline

2020 – Snappy: Computer vision proof of concept



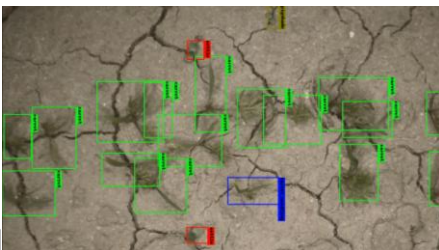
2022 – V2: Engineering validation



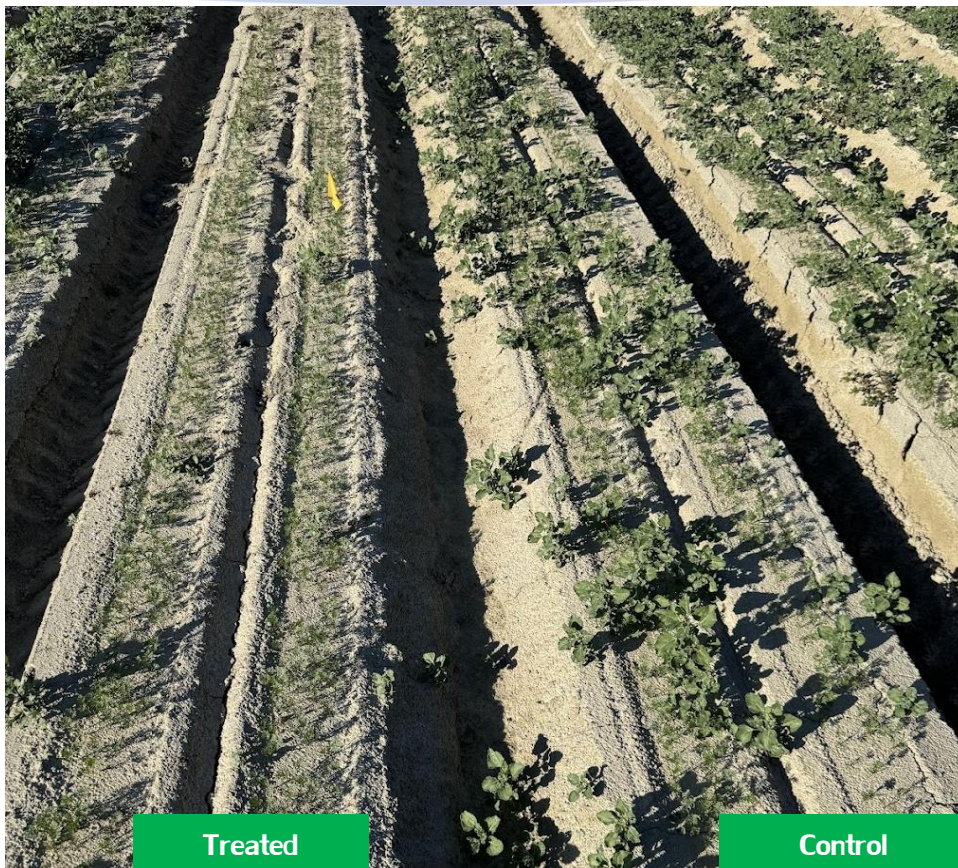
2024 – V3: Jetty - Commercial alpha



2025 Q1 - Going to market

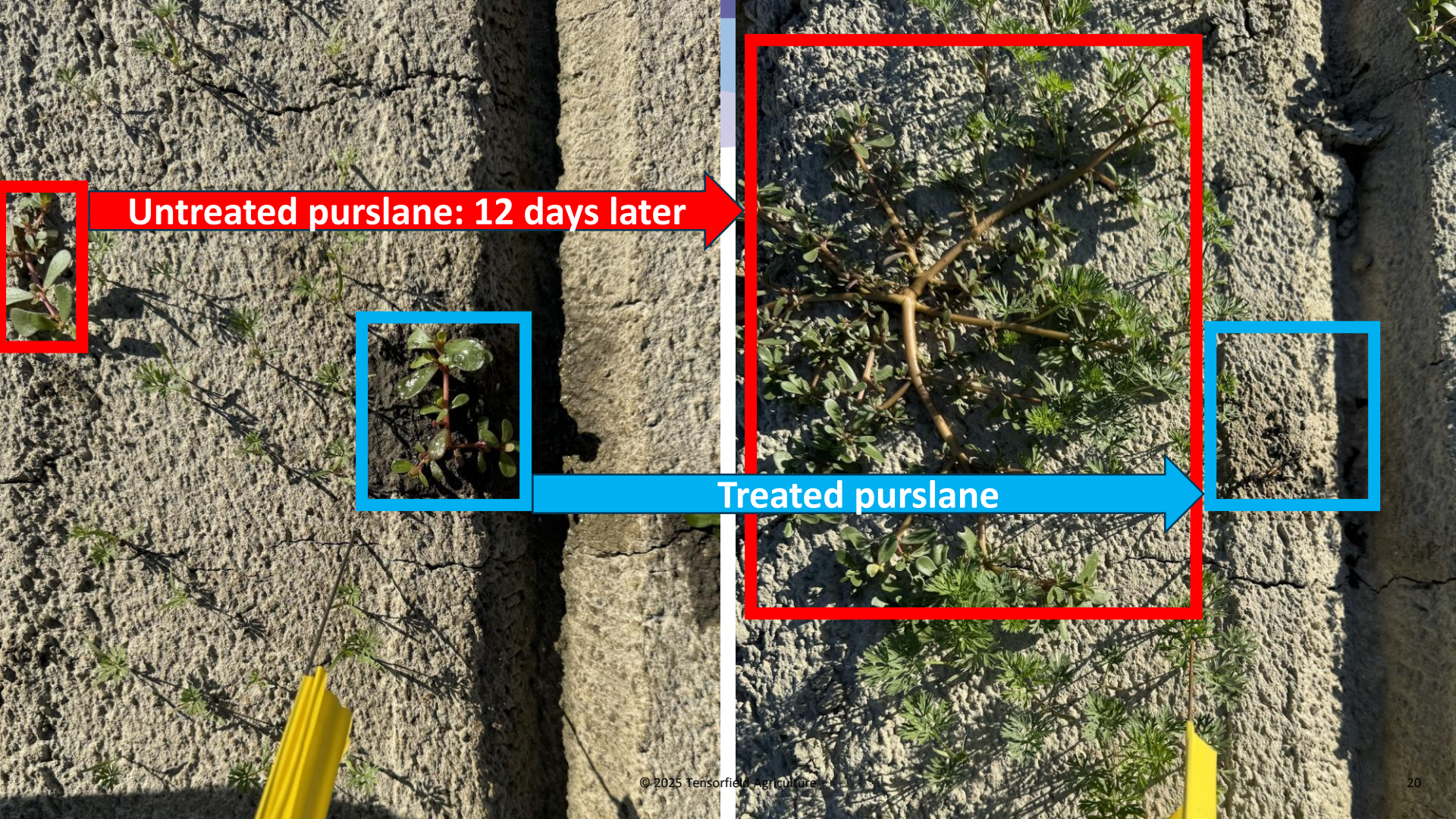


Commercial Testing



**“Performed very well
in broadleaves... No
detectable carrot loss”**

- Head of automated
equipment for major US
grower



Untreated purslane: 12 days later

Treated purslane

Pricing model



\$50
per acre

+

0.5
cents
per weed



Pilot study



\$3M

savings ~40%

3

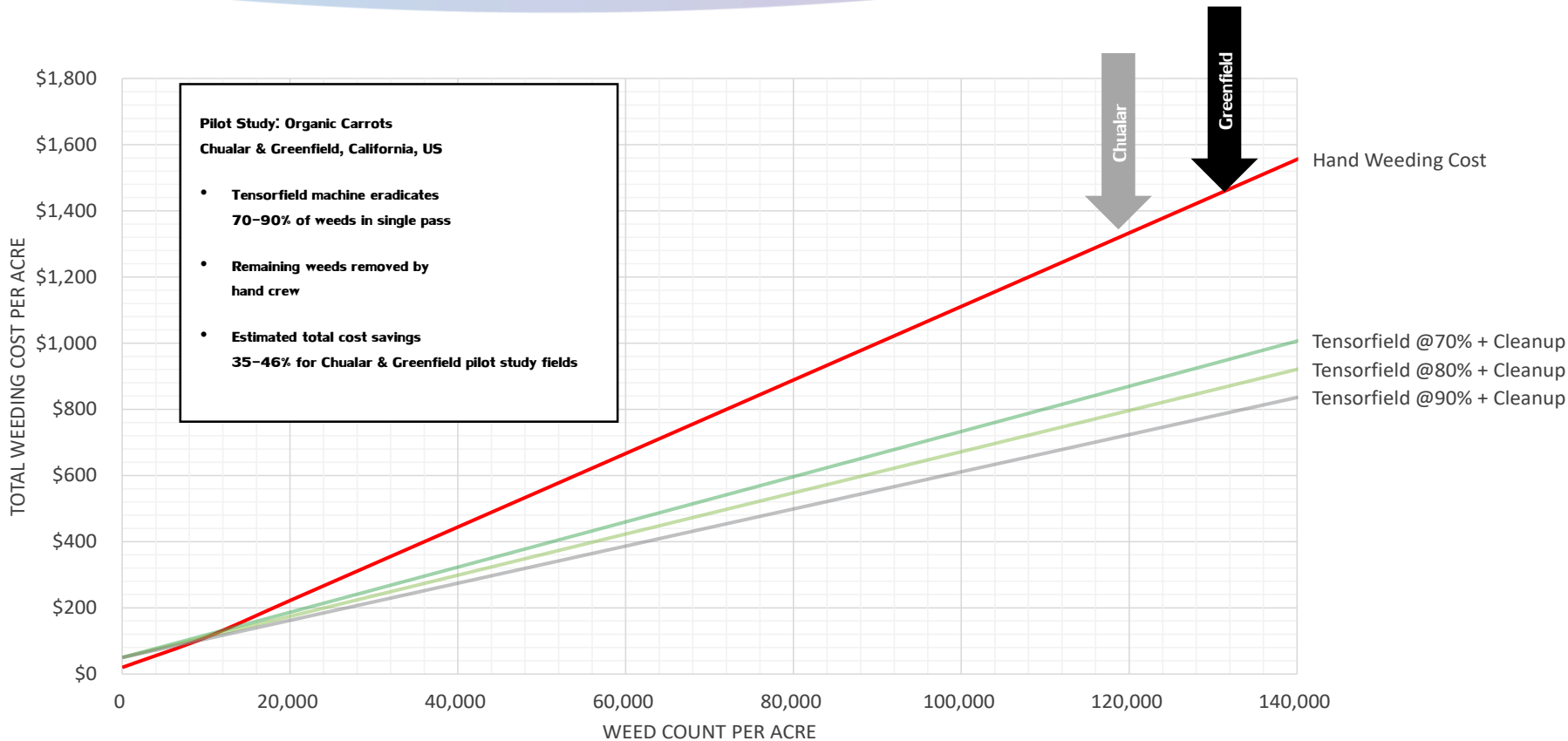
robots
(estimate)

\$2.7M

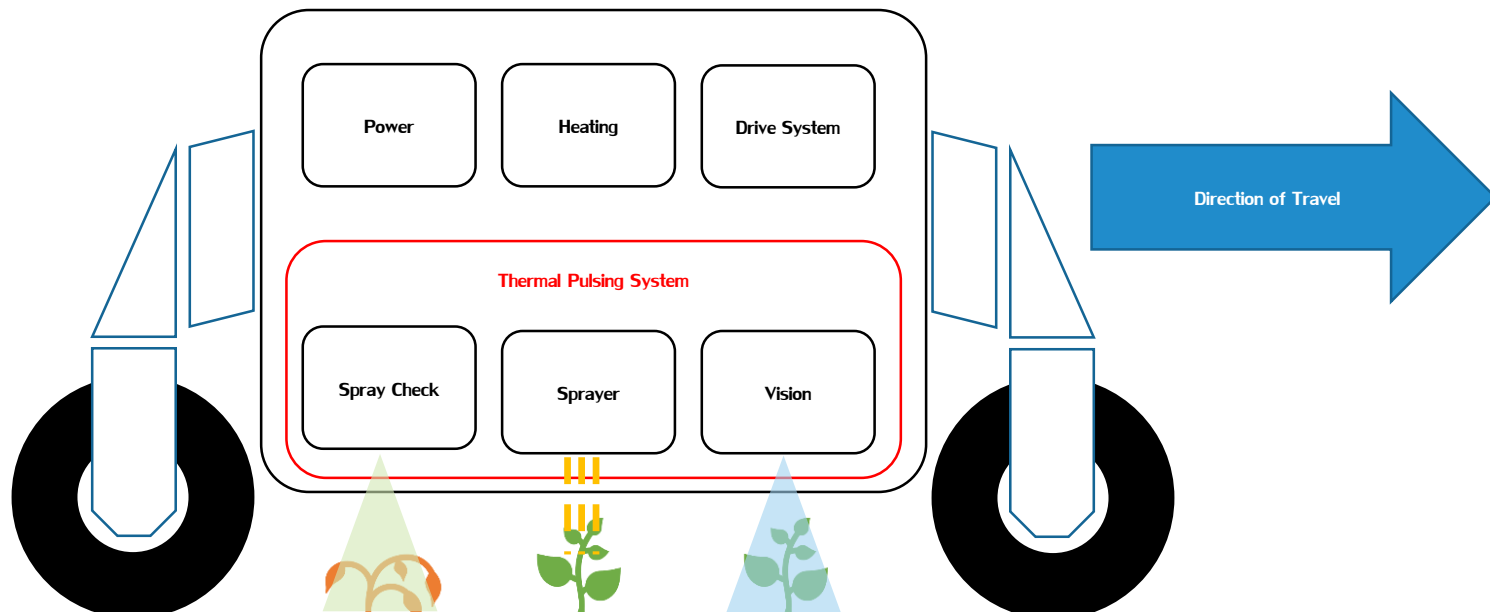
ARR from customer



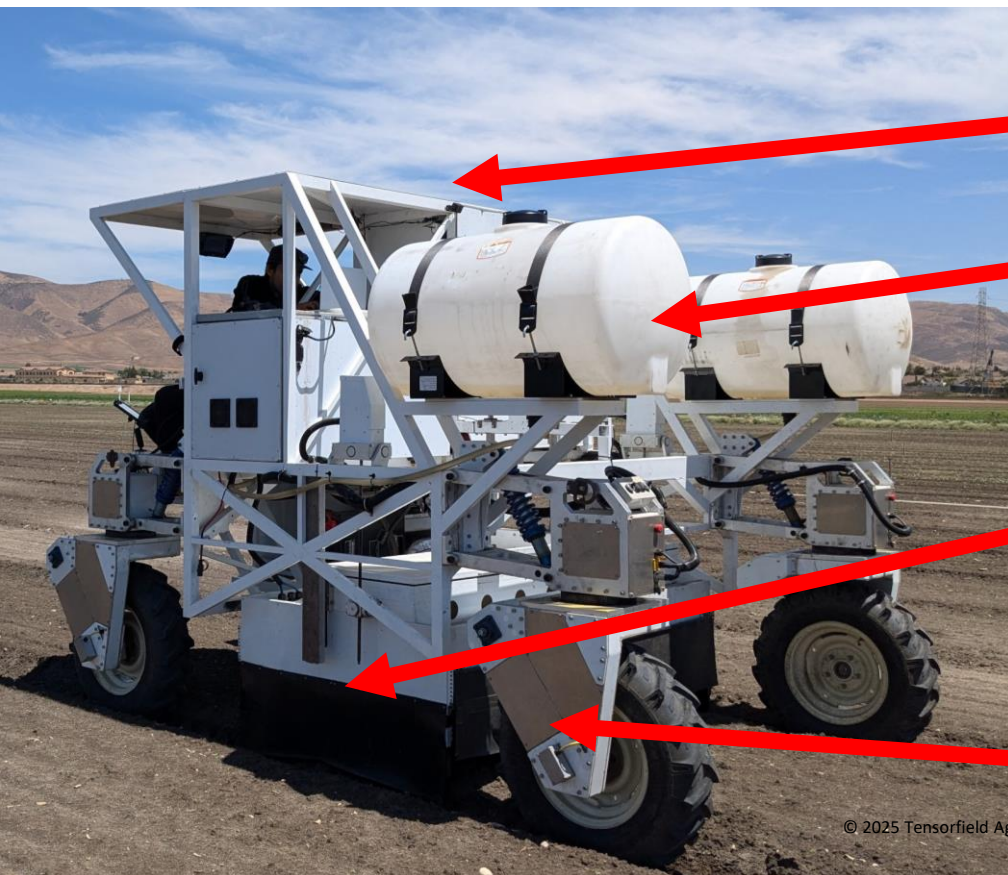
Weeding Costs vs Weed Pressure



System Overview 1/2



System Overview 2/2



Generator, LiFePo4 Battery & Heating Unit

Applicant (canola oil) storage

Thermal Pulsing System

Cameras & Lighting

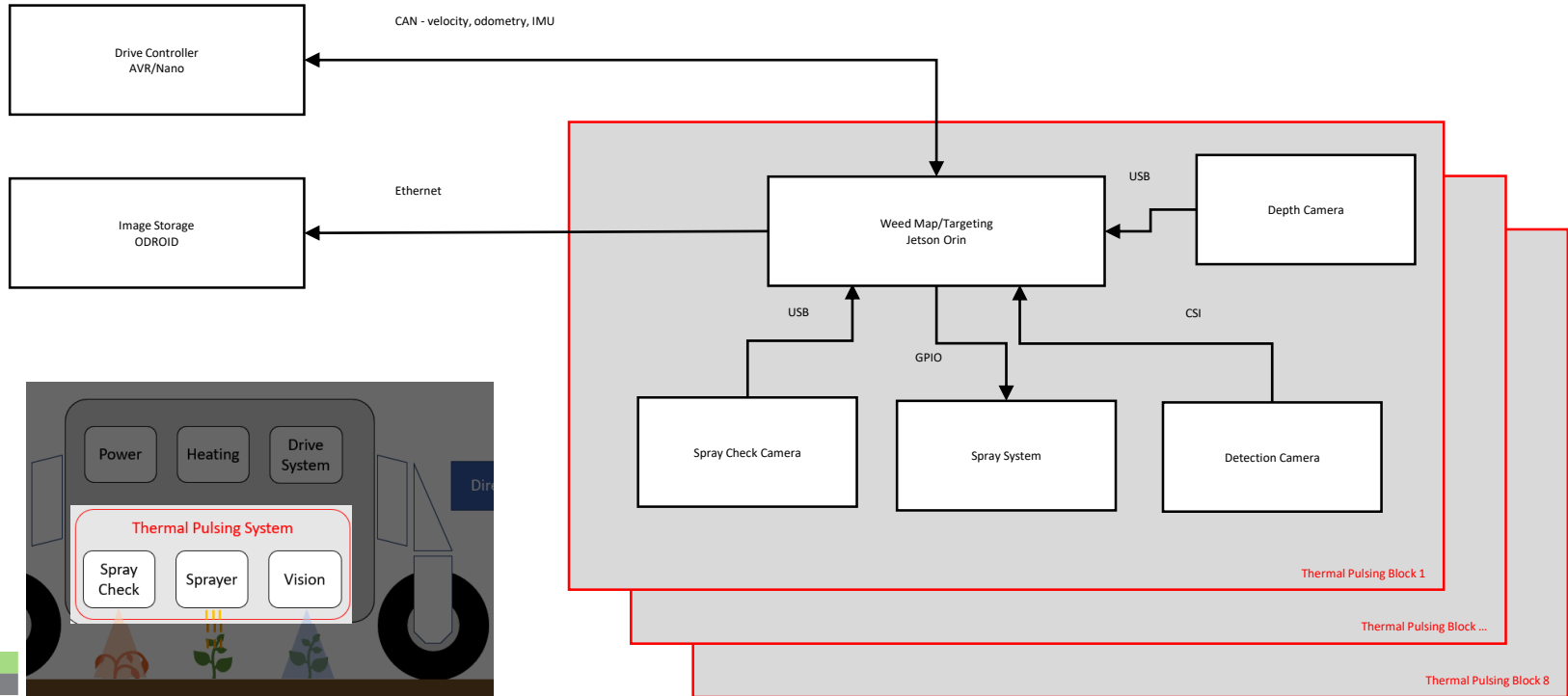
Vision Processing

Heated Sprayer Array

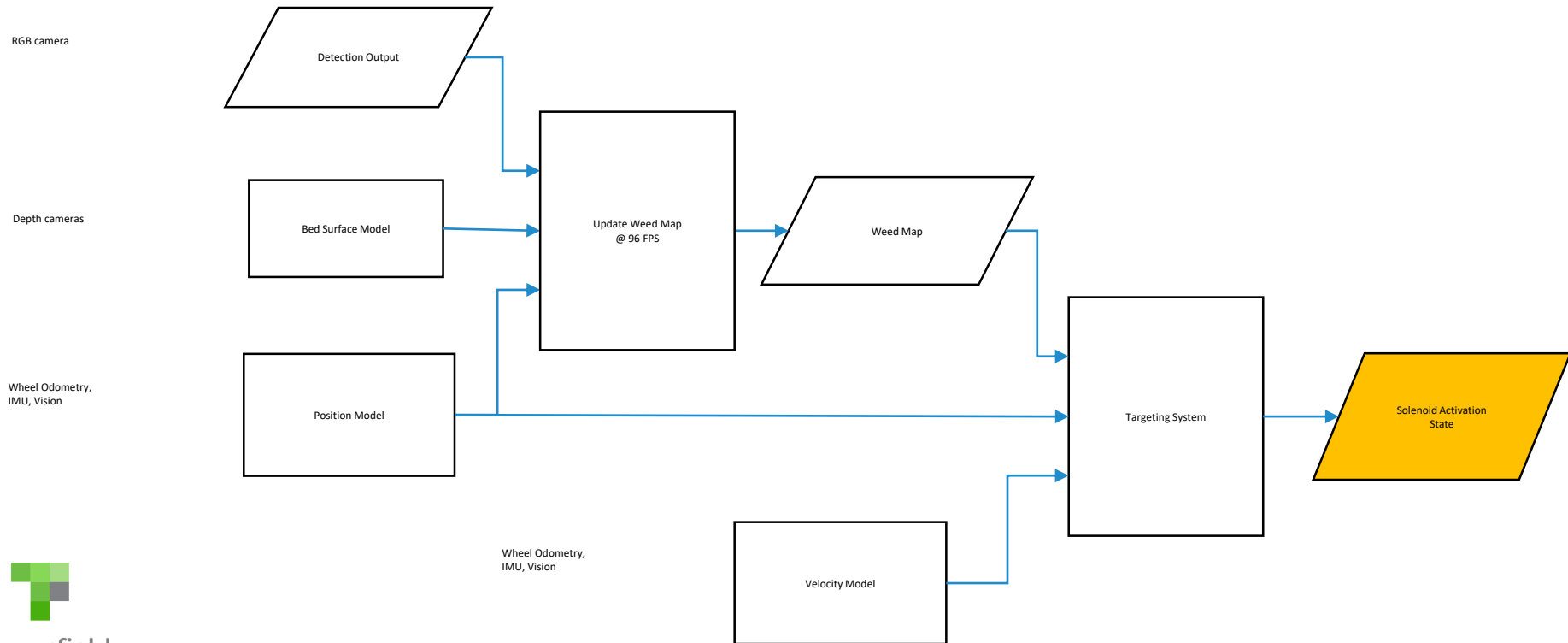
Spray Check Cameras

4x independent drive/steer suspension modules

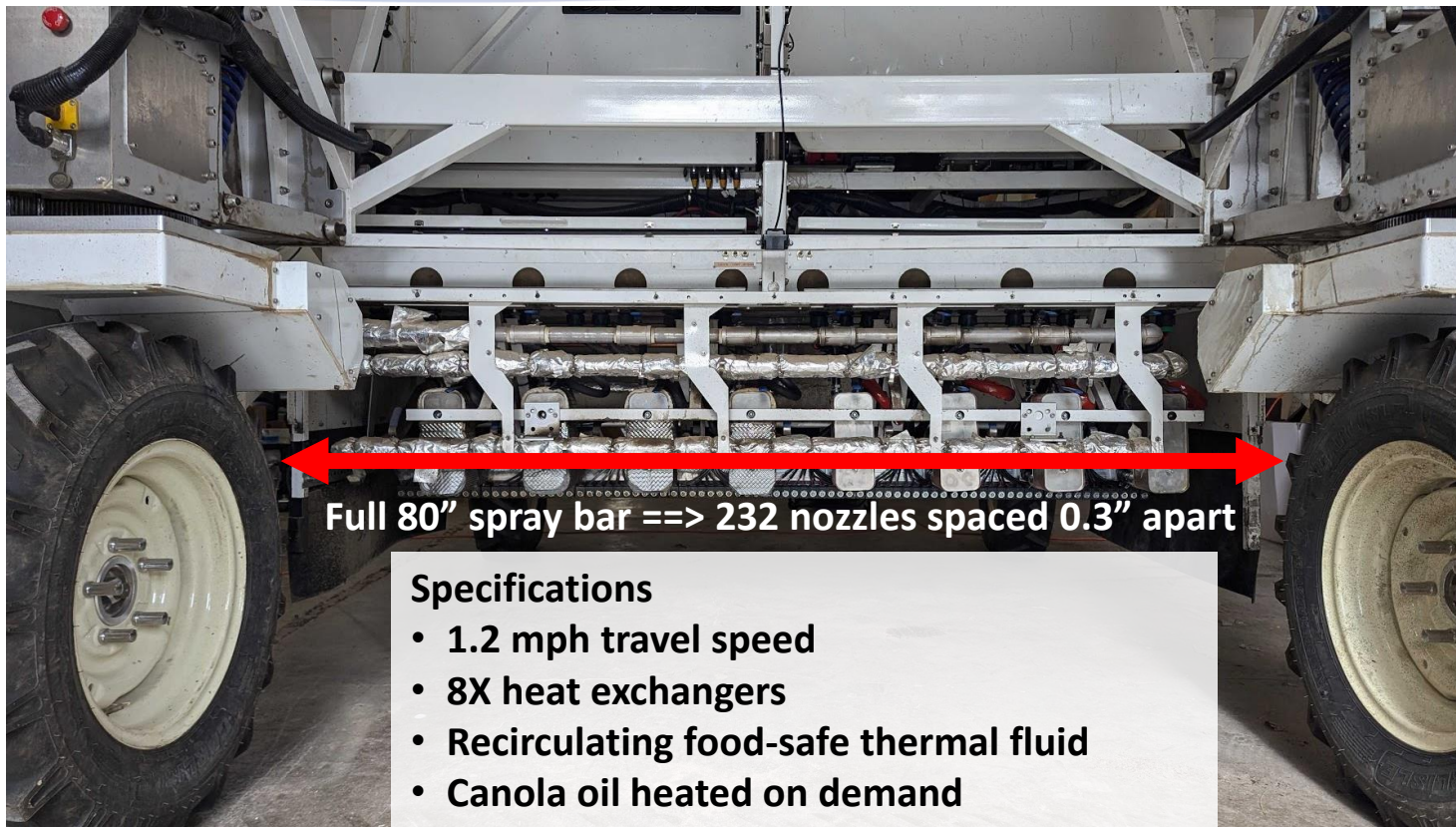
Thermal Pulsing System



Targeting Pipeline



Under the Hood 1/2

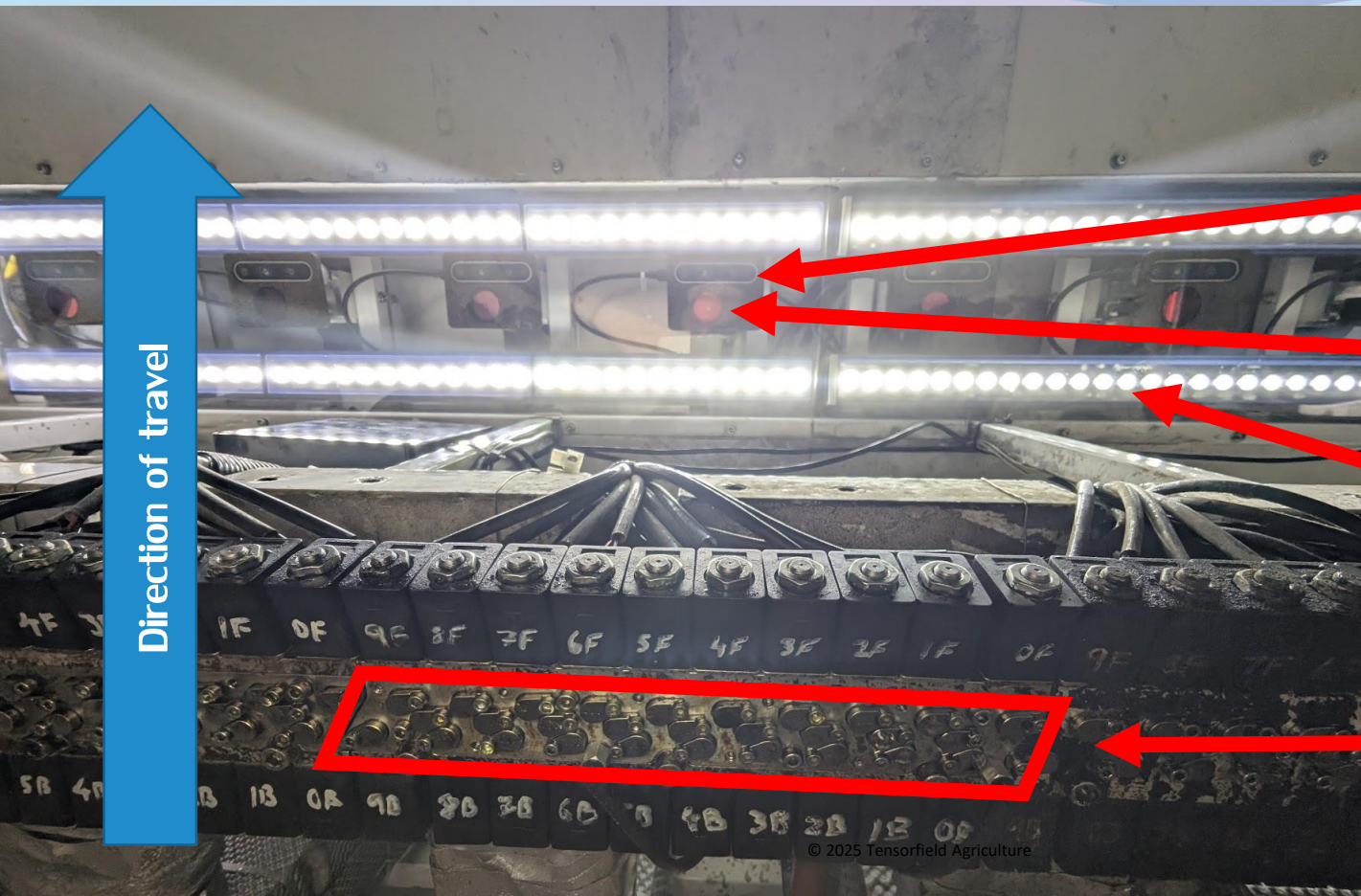


Full 80" spray bar ==> 232 nozzles spaced 0.3" apart

Specifications

- 1.2 mph travel speed
- 8X heat exchangers
- Recirculating food-safe thermal fluid
- Canola oil heated on demand

Under the Hood 2/2



Direction of travel

8X depth cameras

8X detection cameras

Strobe lights

Heated nozzle bank

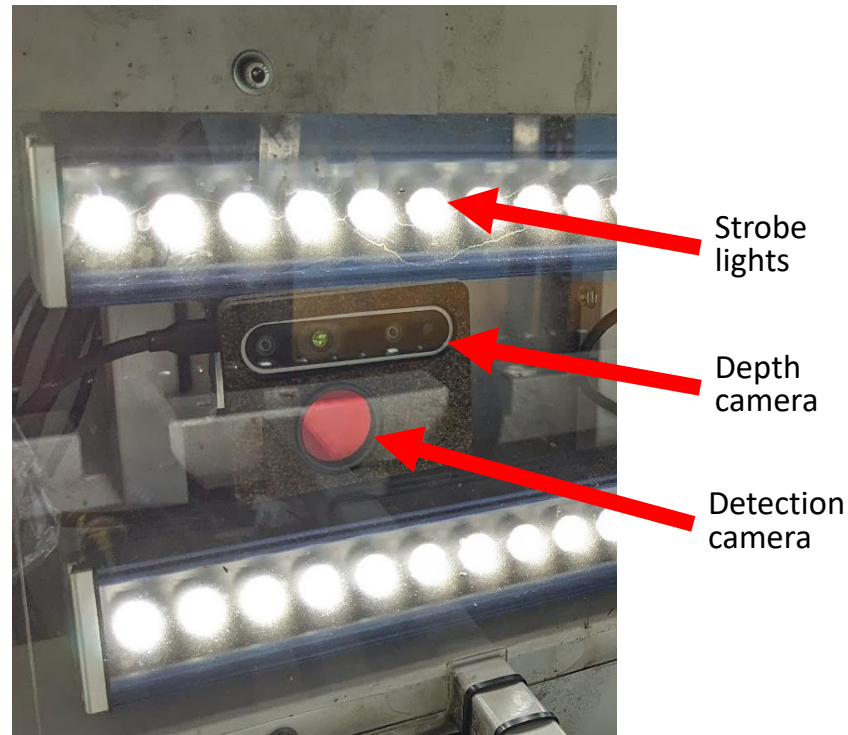
Recent Challenges

Our experience of being a small resource-constrained company attempting to bring embedded vision solutions to market



Eight cameras + strobes

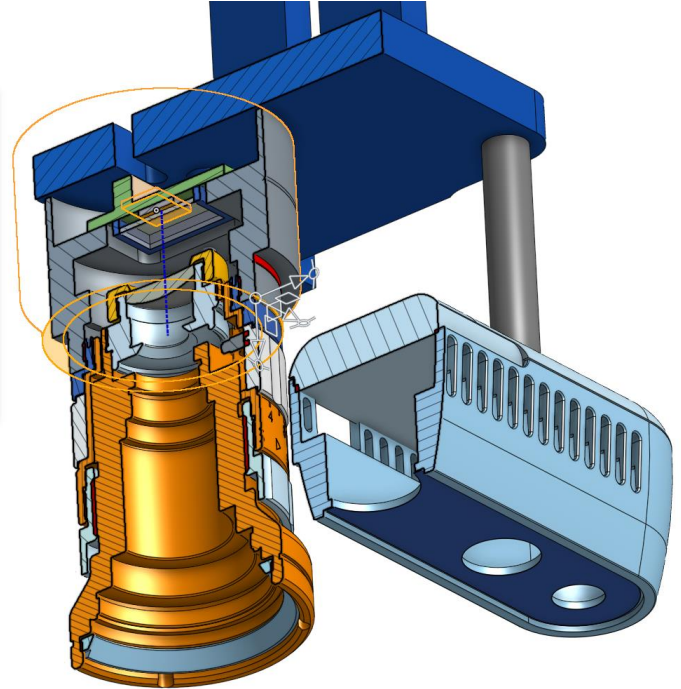
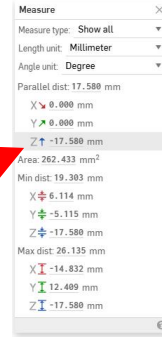
- Real-time detection:
 - MIPI-CSI2 bus
 - Global shutter ~ 60 fps
 - Jetson Xavier/Orin
- **Selected Vendor 1:**
 - External trigger / flash
 - **CSI-2 Output: 2 / 4 lanes (claimed)**



Vendor 1 Challenges: Lens Mounts

IMX568C Dev Kit Order

- Incorrect part numbers manually added to order
- Flange focal distance off; discovered in testing
- Quoted \$274 for single 1 mm C-mount spacer (vs. \$7 Amazon)



Vendor 1 Challenges: 0.5X speed CSI


Testing → only ½ speed CSI

- No Orin support
- Vendor 1 confirms **2-lane CSI max** for Orin dev kit

custom project QTY >100?

→ **switch to Vendor 2 → 4-lane support but no trigger support**

Thread # engineering



Xiong Chang Aug 14th, 2023 at 10:39 AM
I think one of those cables is a 15-22 and one is a 22-22 as sold by [redacted] That setup was able to take photos - I guess there's a chance that the cables were swapped or something since then but I'm not sure how that would have happened

cheehan Aug 14th, 2023 at 10:39 AM
You can 'take photos' but that won't be using all 4 lanes.

Xiong Chang Aug 14th, 2023 at 10:39 AM
Do you think they sent us the wrong part number then?

cheehan Aug 14th, 2023 at 10:39 AM
It'll be at half the throughput.



Vendor 2 Challenges: Lens Mounts (again)

Silent order change: CS-mount → M12

Rationale:

CS lenses “can’t focus without a spacer”

→ pushed for alternate, spec-mismatched sensor

Reality:

CS-mount kit focused perfectly w/o spacer

4 additional lens mounts inexplicably added to order



Vendor 2 Challenges: Lead Time & Compatibility

Dev kit order confirmation:

16-week(!) lead time on dev kit adapter boards

- Same P/N diff. rev available from Mouser
- Vendor 2 unable to confirm compatibility of Mouser version



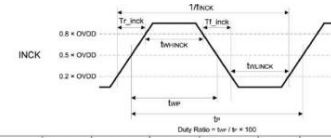
Vendor 2 Challenges: Trigger Implementation

External Trigger Implementation:

Vendor source code sent over email

Low-level interaction with sensor required:

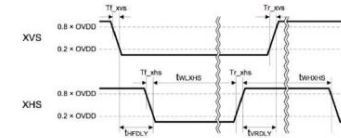
- **Detailed knowledge** of sensor spec
- **Custom pogo PCB** to vendor test points
- **Custom microcontroller PCB** to generate MHz signals to drive sensor XVS/XHS/XTRIG



Item	Symbol	Min.	Typ.	Max.	Unit	Remarks
INCK clock frequency	f_{inck}	$f_{inck} * 0.96$	f_{inck}	$f_{inck} * 1.02$	MHz	$f_{inck} = 37.125$ MHz, 74.25 MHz
INCK Low level pulse width	t_{wlnck}	4	—	—	ns	$f_{inck} = 37.125$ MHz, 74.25 MHz
INCK High level pulse width	t_{whnck}	4	—	—	ns	$f_{inck} = 37.125$ MHz, 74.25 MHz
INCK clock duty	—	45.0	50.0	55.0	%	Define with $0.5 * OV_{DD}$
INCK Rise time	T_{r_inck}	—	—	5	ns	20 % to 80 %
INCK Fall time	T_{f_inck}	—	—	5	ns	80 % to 20 %

*The INCK fluctuation affects the frame rate.

XHS, XVS Input Characteristics In Slave Mode (XMASTER pin = High)



Item	Symbol	Min.	Typ.	Max.	Unit	Remarks
XHS Low level pulse width	t_{wloxhs}	$4 / f_{inck}$	—	—	ns	
XHS High level pulse width	$t_{whloxhs}$	$4 / f_{inck}$	—	—	ns	
XVS - XHS fall width	t_{fbdly}	$1 / f_{inck}$	—	—	ns	
XHS - XVS rise width	t_{rbdly}	$1 / f_{inck}$	—	—	ns	
XVS Rise time	T_{r_xvs}	—	—	5	ns	20 % to 80 %
XVS Fall time	T_{f_xvs}	—	—	5	ns	80 % to 20 %
XHS Rise time	T_{r_xhs}	—	—	5	ns	20 % to 80 %
XHS Fall time	T_{f_xhs}	—	—	5	ns	80 % to 20 %

Detection Cameras with External Triggering:



Dev Timeline Summary

- **Late vendor swap** due to CSI bus issue
- **Sales team confusion** around part compatibility
- **Duplicate parts** added to orders
- **Custom hardware** required for external trigger support

Challenges across vendor ecosystems
→ **delay to customer rollout**



Recent Challenges – Sourcing Jetson Orin

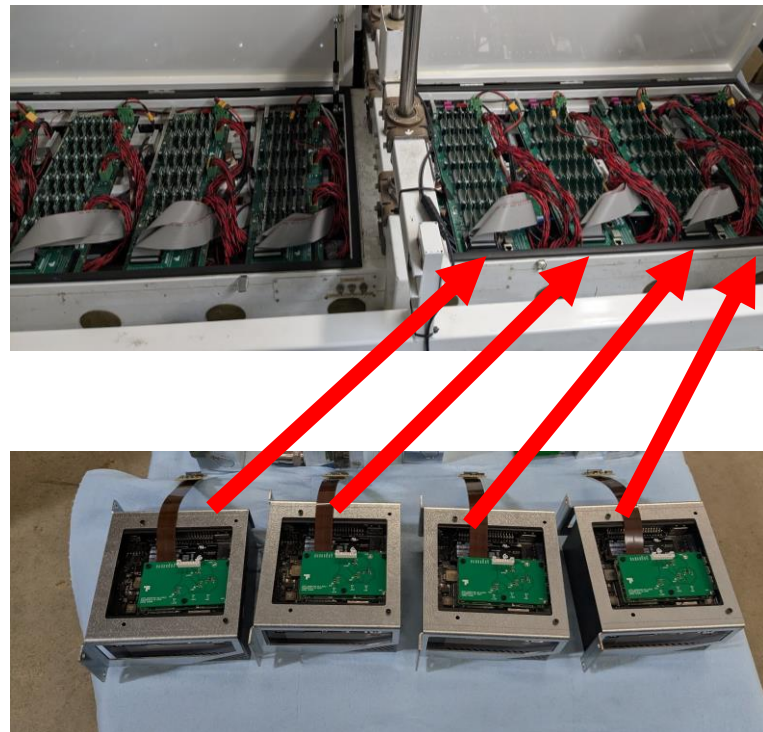
Inception Program:

“In stock” → 24 weeks lead time

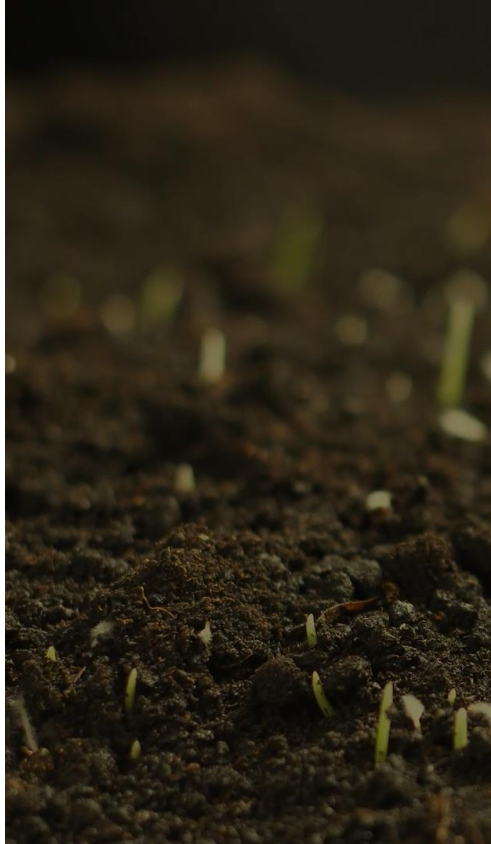
Migrating from Orin dev kit to production

- Cooling, data & mechanical interface changes
- Development effort hard to justify
→ dev kits already work!

Would love a production-approved carrier solution which mirrors dev kit



Embedded Vision Ecosystem Asks



- Better **documentation**
- Better **ecosystem “Legos”**
- Better **knowledge from Sales** teams
- **Reliable lead times** communicated
- **Minimal changes** in dev kit → PDN



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