

Aerial Spraying with UAV's For Wildland Weed Control

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Biological & Agricultural
Engineering**

**Cal-IPC Symposium
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Overview:

-UAV development and deployment in the United States

Vehicles

- from the hobbyist industry
- rapid growth in commercial design and market

Operation

- remote control
- autonomous



Hobbyist:

Line of sight

< 55 lbs

< 400 ft AGL

➤ 5 nm airport

➤ Registration

(Nov 2015)



Federal Aviation
Administration

Guidance for Model Aircraft Operators

What Can Hobby/Recr

Having fun means fly
FAA authorization.

Avoid doing anything

"Dos"

- Do fly a model a
- Do take lessons
- Do contact the i
- Do fly a model a

"Don'ts"

- Don't fly near m
- Don't fly beyond
- Don't fly an airc
- Don't fly contrar
- Don't fly model

Model Aircraft

According to the FAA
accordance with a cc
is limited to not more
administered by a cc
aircraft; (5) when flow
prior notice of the op

- [More information](#)

This page was published at: <http://www.faa.gov>

Hobby / Recreational Flying

What Can I Do With My Model Aircraft?

Having fun means flying safely! Hobby or recreational flying doesn't require FAA approval but you must follow safety guidelines. Any other use requires FAA authorization.

AVOID DOING ANYTHING HAZARDOUS TO OTHER AIRPLANES OR PEOPLE AND PROPERTY ON THE GROUND.

- ✓ **DO** fly a model aircraft/UAS at the local model aircraft club
- ✗ **DON'T** fly near manned aircraft
- ✓ **DO** take lessons and learn to fly safely
- ✗ **DON'T** fly beyond line of sight of the operator
- ✓ **DO** contact the airport or control tower when flying within 5 miles of the airport
- ✗ **DON'T** fly an aircraft weighing more than 55 lbs unless it's certified by an aeromodelling community-based organization
- ✓ **DO** fly a model aircraft for personal enjoyment
- ✗ **DON'T** fly contrary to your aeromodelling community-based safety guidelines
- ✗ **DON'T** fly model aircraft for payment or commercial purposes



MODEL AIRCRAFT OPERATIONS LIMITS

According to the FAA Modernization and Reform Act of 2012 as (1) the aircraft is flown strictly for hobby or recreational use; (2) the aircraft is

flight test, and operational safety program administered by a community-based organization; (4) the aircraft is operated in a manner that does not

Overview of current status:

-Regulatory process

Commercial use allowed under Section 333 Exemptions.

Public agencies can deploy UAV's via the COA (Certificate of Authorization) process.

Self certify airworthiness.

Limited operations, areas, aircraft.



Overview of current status:

-Regulatory process

Significant uncertainty and
misinformation in the market

A number of UAV companies are
petitioning for and receiving
“333” Exemptions
(primarily airworthiness)

R&D can be conducted with
approvals after “Safety Case”
analysis.



**ADULT
SUPERVISION
REQUIRED**





Hazards of ground-based application:



Photo courtesy of CAL FIRE / Napa County Fire Department

The remains of a tractor that rolled down a hill Thursday morning. The driver was extracted from under the tractor by first responders and taken to an area hospital.

Tractor driver suffers life-threatening injuries

May 07, 2015 6:06 pm • Register Staff

A man suffered life-threatening injuries Thursday morning when his tractor overturned on Langtry Road west of St. Helena, according to CalFire/Napa County Fire. The crash was reported at 10:33 a.m.

First-responders found the man pinned under the tractor, said CalFire/Napa County Fire Capt. Joe Fletcher. First responders treated and extricated the driver from under the tractor.

An ambulance transported the man from the heavily wooded area to a landing zone at Robert Louis Stevenson School in St. Helena, Fletcher said. He was then placed in a REACH helicopter and airlifted to Queen of the Valley Medical Center in Napa, according to CalFire and REACH.

The crash remains under investigation, Fletcher said.



Overview of current work:

- Regulatory process
- Commercial availability
- Suitability for herbicide delivery
- Testing protocol and results
- Further payload developments



Overview of current projects:

-Regulatory process (COA)

Must have pilot and observer with both passed FAA knowledge test for Private Pilot and Class 2 Medical Certificates.

Must file NOTAM 48-72 hrs prior to flight and notify Air Traffic Control.

Typical line of sight operation, daylight hours, VFR, > 5 nm from airport.



Overview of initial UCD UAV project:

-Regulatory process

“Dropping of objects” prohibited.

Pending a Safety Analysis

?



Overview of initial UCD UAV project:

-Regulatory process

“Dropping of objects” prohibited.

Conducted a safety analysis of spraying water and was approved.

Two operational areas in CA:

Napa grape growing area

Central Valley nut growing area



Overview of current UCD UAV project:

Issued COA for pesticide application.

Conducted a safety analysis and certified to comply with FAR Part 137 (agricultural applications).

Have three operational areas in CA:

Napa grape growing area

San Joaquin Valley nut growing area

Sacramento Valley nut / field crops



Commercial Product:

RMAX™ –

Yamaha Motor Company.

- 200 lbs
- 2-stroke, liquid-cooled, 250 cc, 18 hp engine
- 10 ft rotor diameter
- 4.2 gal liquid capacity
- 3 nozzles (1 or 2 active)
(Fine / Med-Fine cat.)
- 1200 ft line of sight ops
- 1000 hr life
- Remote control with visual, not autonomous operation



Commercial Product:

RMAX™ –

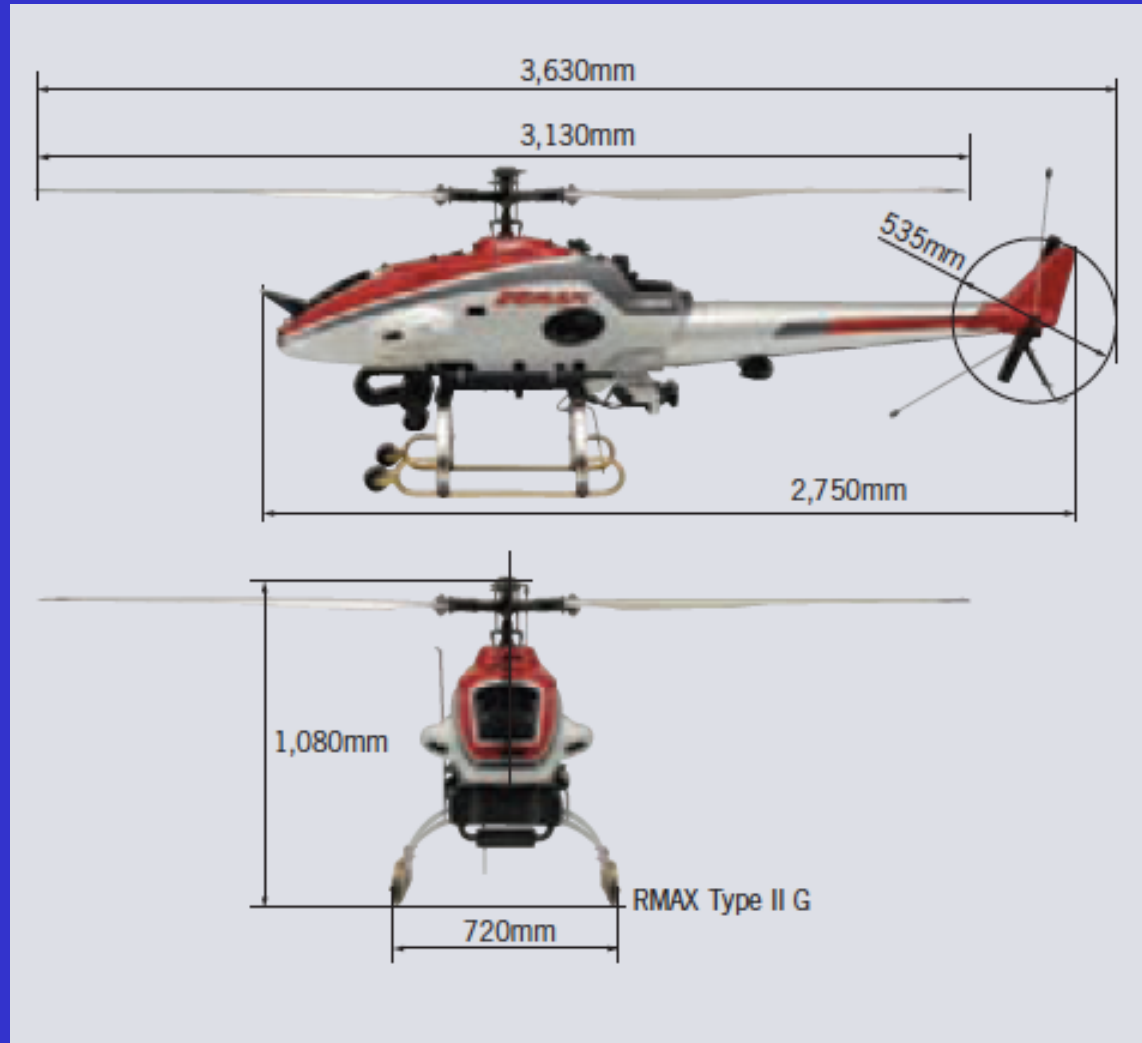
Yamaha Motor Company.

4.2 gal tank mix capacity
@ 1.06 gpm =

4 minute endurance

1.5 gal fuel capacity
@ ~ 1.5 gph =

1 hr endurance



Challenging spray conditions:

Small, complex fields
(45° slope)

Limited access during
certain phases of season

Permanent plantings

High value



Specialty Crops:



Spray deposition:

COA allowed only water to be sprayed:

Water sensitive paper for sample medium

13 sample locations
within canopy and
on ground

Analyzed using
Drop Vision AG

(Leading Edge Assoc.)

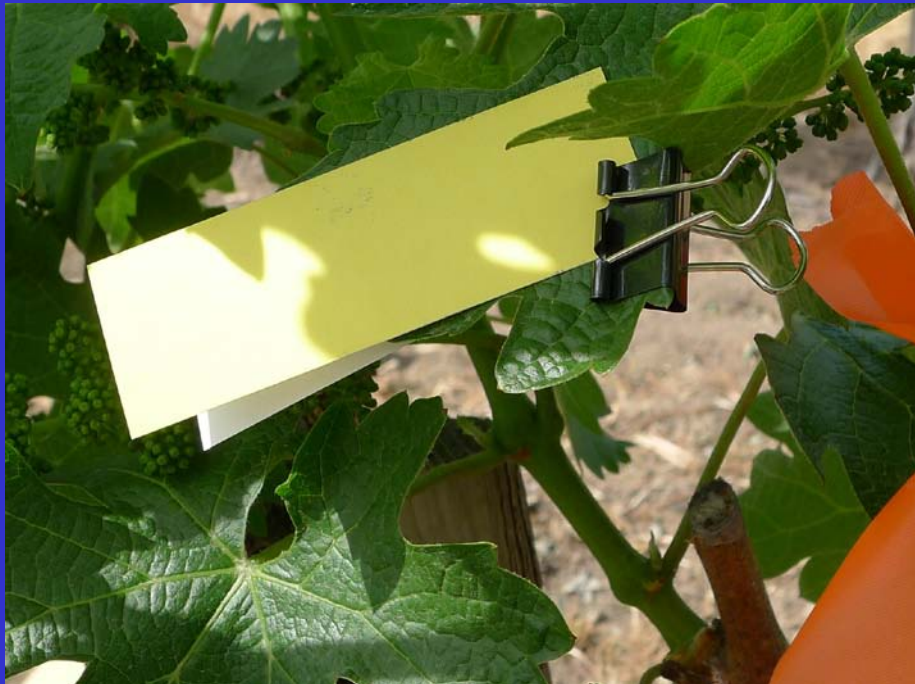


Spray deposition:



Test Results:

Field deposition



Application rates & productivity:

Productivity and application rate testing in a Cabernet Sauvignon block at the Oakville Field Station (UC) in Napa Valley, CA

Forward & downward video cameras on aircraft

Direct measurement of area and spray volume discharged

Spray, ferry, refill times observed.

Local meteorology recorded



Test Design:

Due to payload and spray pump constraints on aircraft, only method to adjust application rate was by swath width and number of passes.



Test Results:

Field productivity

1.32 acres test block

200 ft length

1 -2 tank loads



2 row swath x 2 passes = 3.06 acres/hr

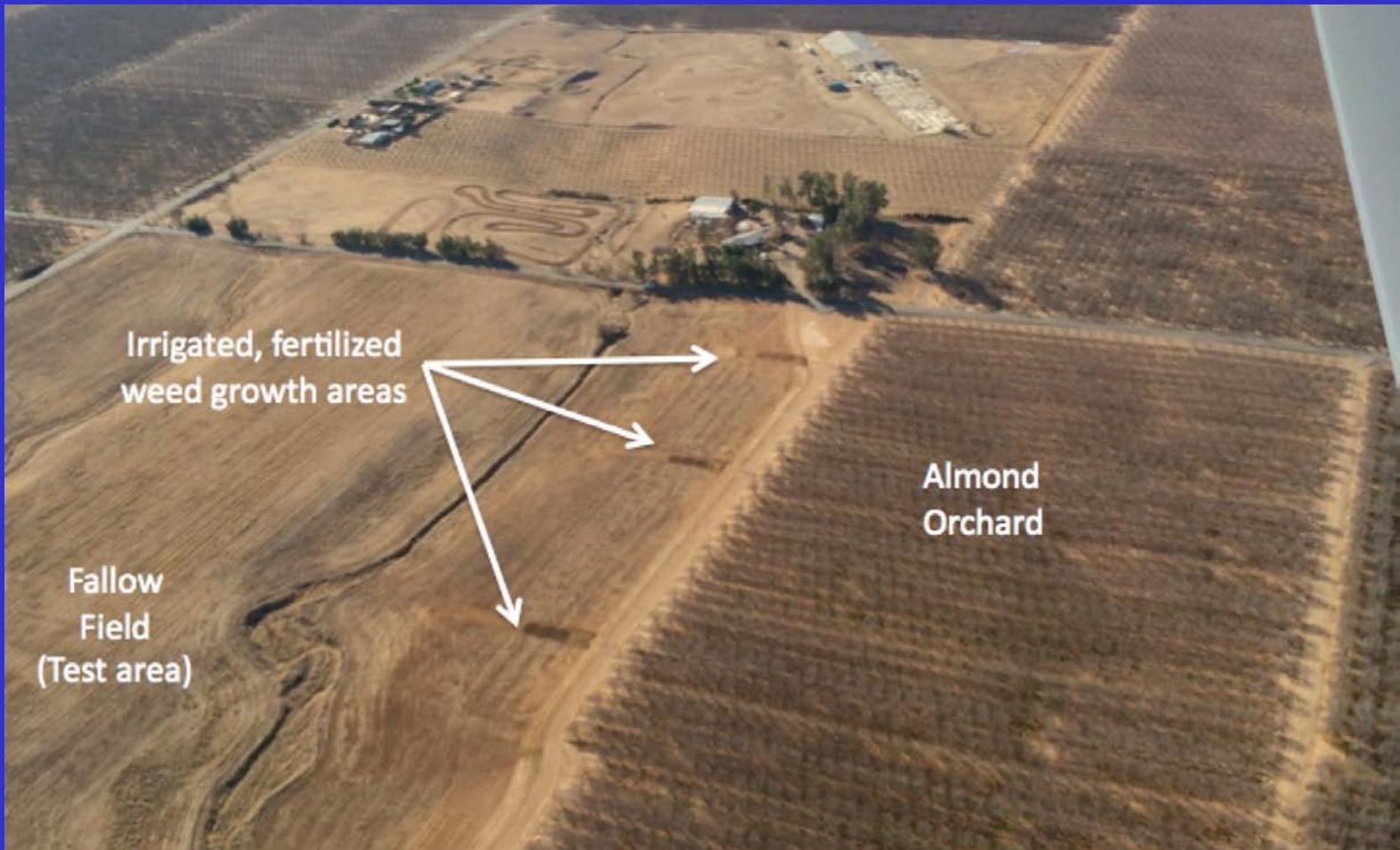
2 row swath x 1 pass = 6.12 acres/ha

3 row swath x 2 passes = 5.13 acres/hr

3 row swath x 1 pass = 7.35 acres/hr

Active ingredient (2014):

Efficacy from low volume UAS application of herbicide.



Active ingredient (2014):

Turf strips installed in fallow field and irrigated.



Active ingredient (2014):

Glyphosate (22 oz) + 1 lb AMS in 1.0 gal/acre.

← 12 mph
Single pass



Active ingredient (2014):

Treated compared to control @ 14 DAT.



Active ingredient (2014):

7 ft center to edge swath

Sharp edge

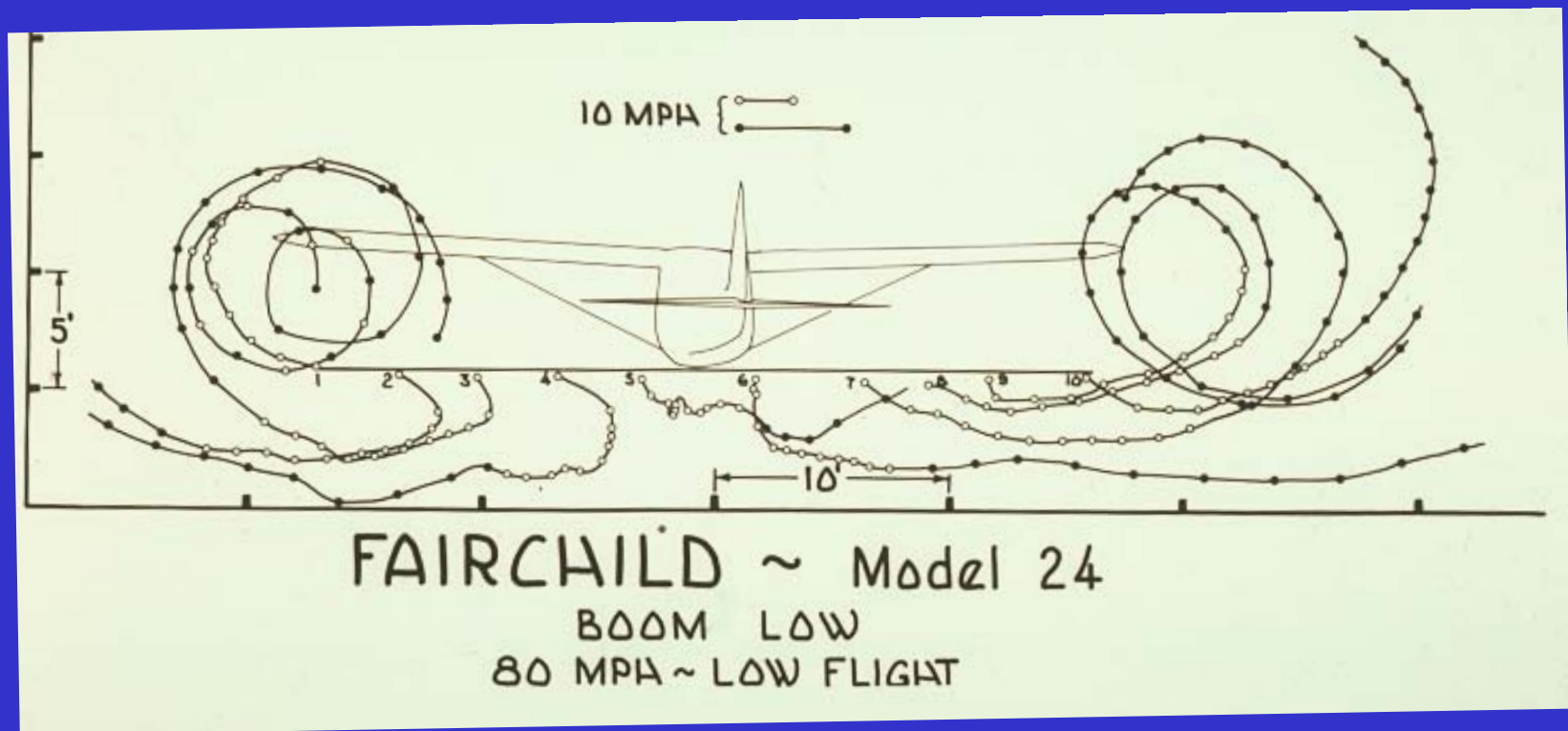


Where do we go from here?



Major regulatory issues:

- Aviation
- Pesticides



Model in AGDISP

$AgDisp = AgDrift$

The regulatory model used to predict spray drift from aerial spraying and approval of application methods for pesticides.

Used by USEPA and California EPA (Dept. of Pesticide Regulation).

Developed for manned aircraft and with a library of typical aircraft.

Model in AGDISP

Many key parameters outside of model limits

Rotor Diameter

Boom Vertical Disp.

Forward Speed

RPM

Weight



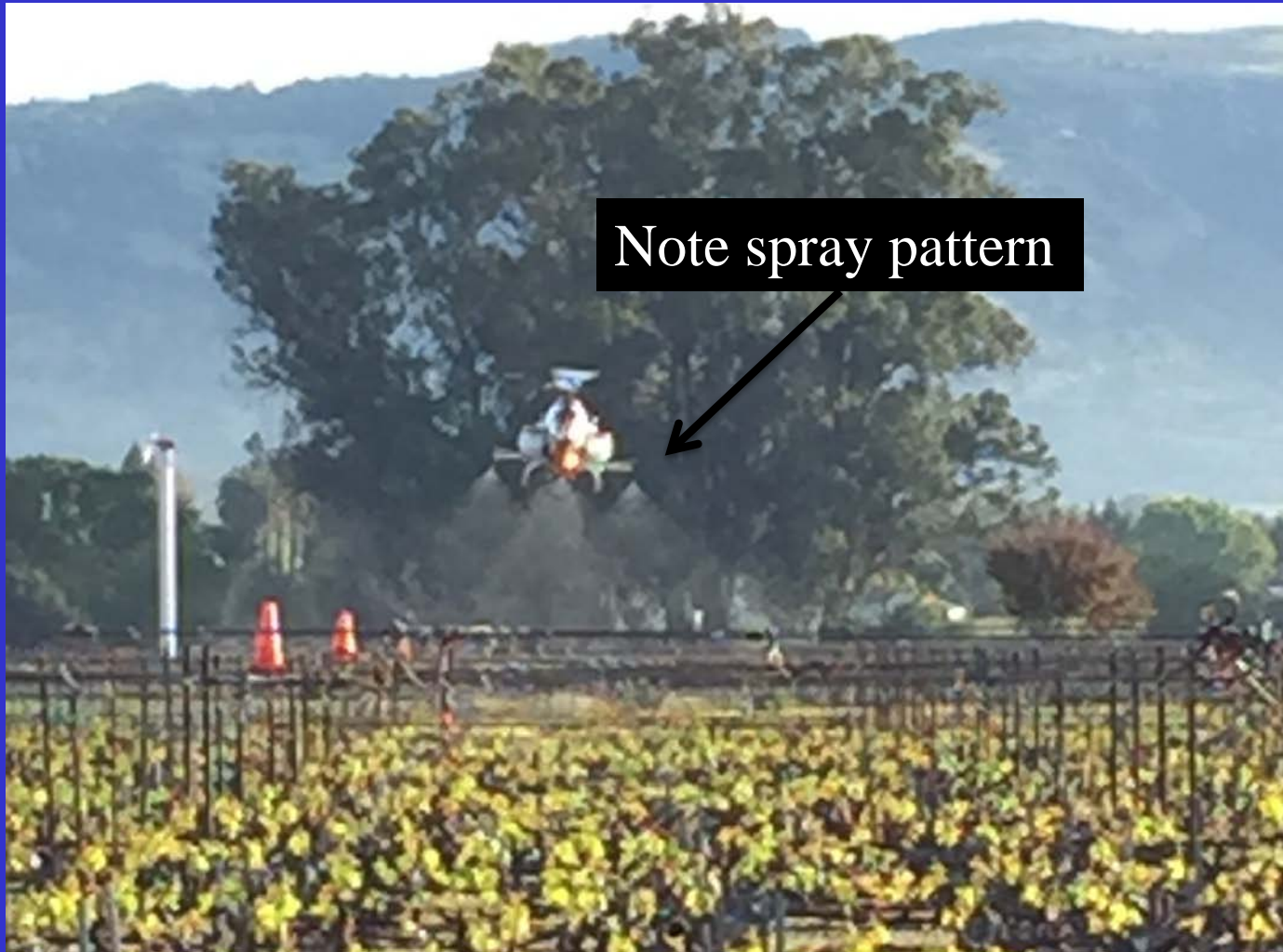
Flying outbound

(Yamaha RMAX 10 April 2015 Oakville CA)



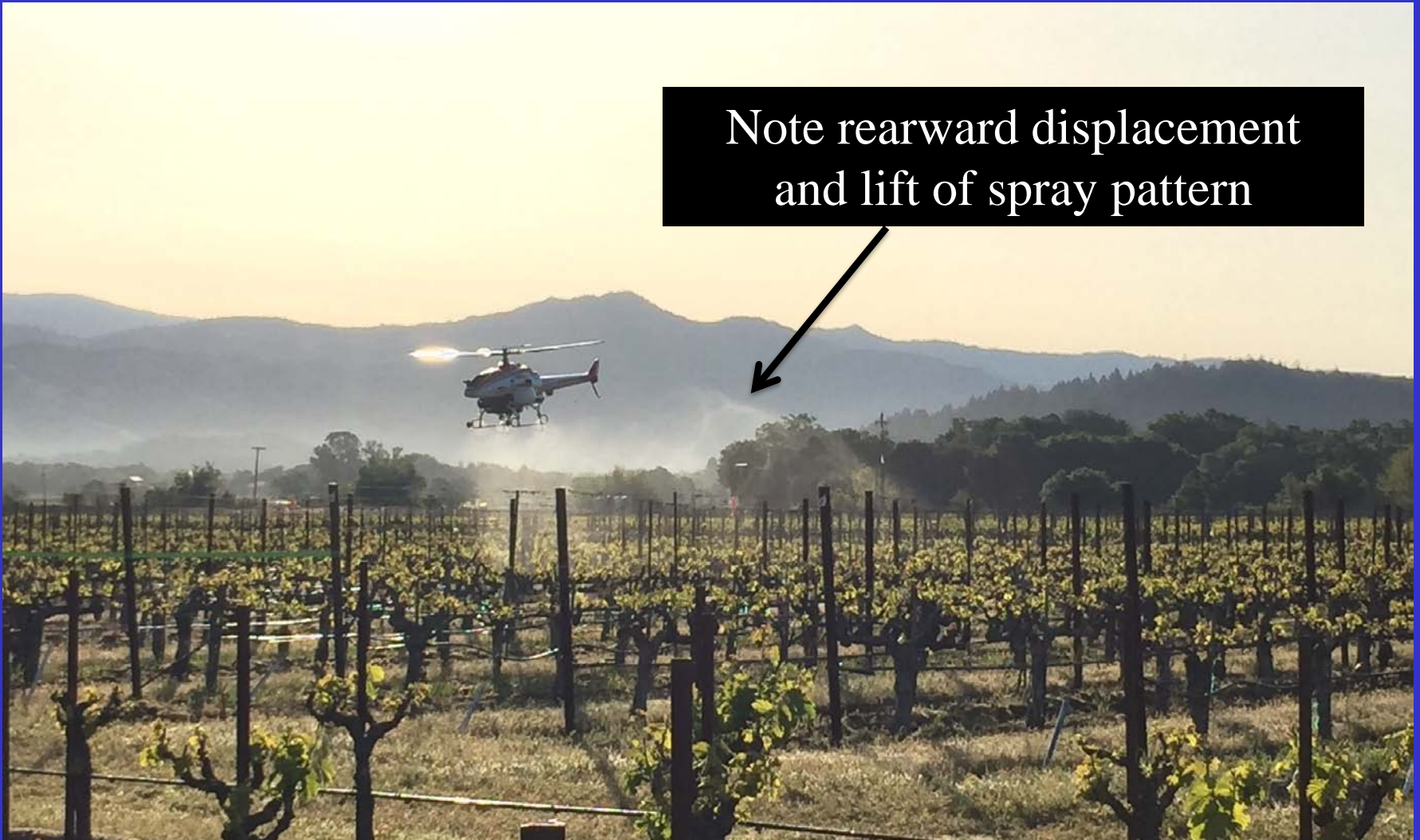
Flying return to operator

(Yamaha RMAX 10 April 2015 Oakville CA)



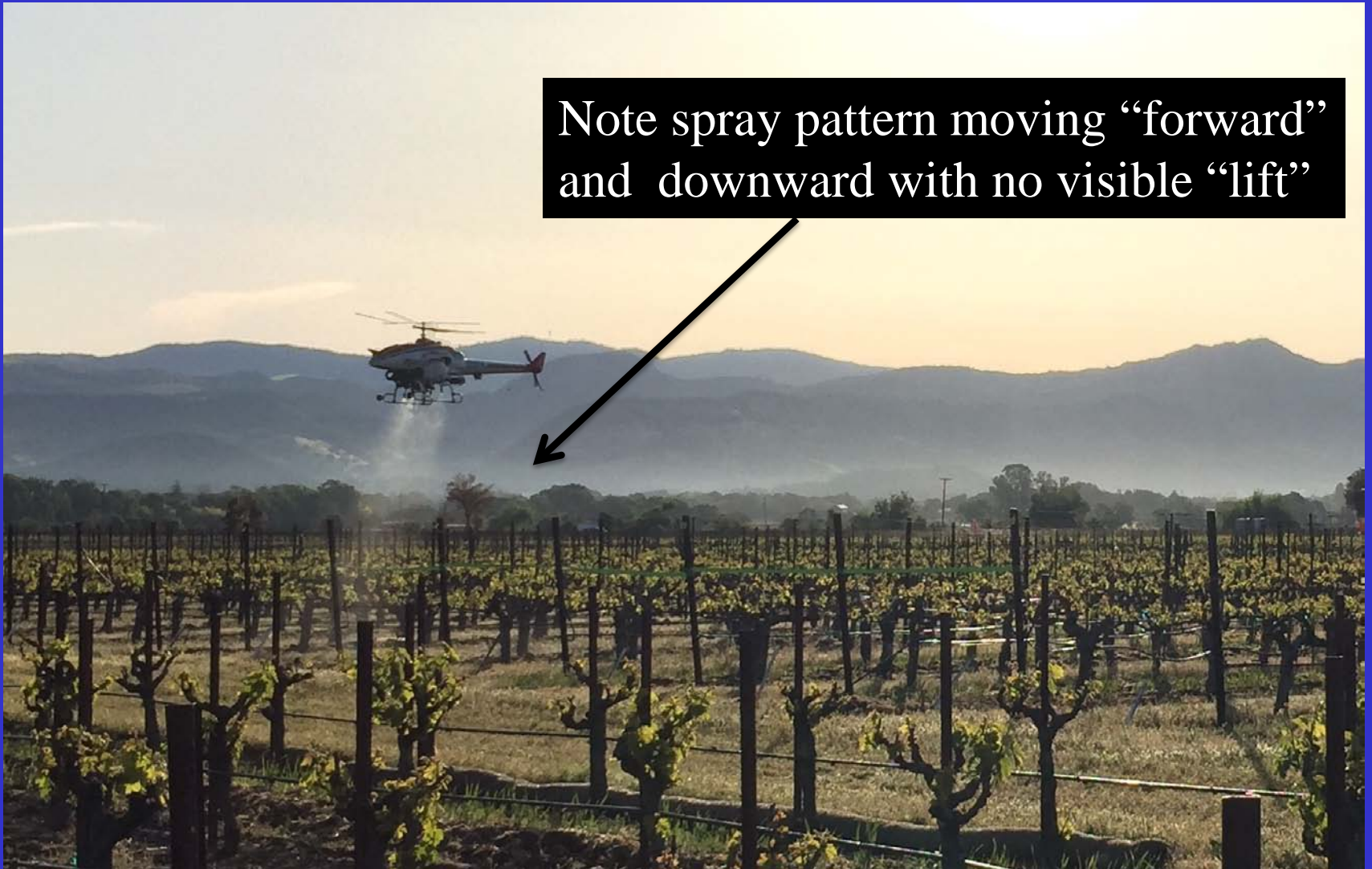
Flying forward (right to left)
(Yamaha RMAX 10 April 2015 Oakville CA)

Note rearward displacement
and lift of spray pattern



Flying rearward (left to right)
(Yamaha RMAX 10 April 2015 Oakville CA)

Note spray pattern moving “forward”
and downward with no visible “lift”



Measuring vortex decay for adapting AgDisp



Measuring vortex decay for adapting AgDisp



Topics with UAV spraying:

Low payload capacity.

Conflicts (airspace & other):

Aerial application industry:

airspace and conflicts
commercial concerns

Chemical registrants

Regulatory concerns – licensing, certification, drift

Labels – ground application or aerial label?

Labeling for UAV spraying:

Aerial Application

Apply in a minimum of 5 gallons of water per acre unless otherwise directed. Avoid application under conditions when uniform coverage cannot be obtained or when excessive spray drift may occur. Disease control may be reduced if uniform coverage is not obtained.

Chemigation Application

Rally 40WSP must be applied on a regular protectant fungicide schedule, not an irrigation schedule. If irrigation cycles are less frequent than the application intervals for Rally 40WSP, ground or aerial applications must supplement chemigation applications to achieve adequate disease control.

Directions for Sprinkler Chemigation: Apply this product only through center pivot, lateral move, end tow, side (wheel) roll, traveler, solid set, or hand move irrigation systems. Do not apply this product through any other type of irrigation system.

Chemigation Equipment Preparation: The following use directions are to be followed when this product is applied through irrigation systems. Thoroughly clean the chemigation system and tank of any fertilizer or chemical residues, and dispose of the residues according to state and federal laws. Flush the injection system with soap or a cleaning agent and water. Determine the amount of Rally 40WSP needed to cover the desired

Chemigation Equipment Requirements

- The system must contain an automatic check valve (e.g., a backflow prevention device, a functional check valve, or a low-pressure backflow prevention device), and low-pressure backflow prevention device on the irrigation pipeline to prevent back flow. Refer to the American Society of Professional Engineers Engineering Practice 409 for more regulations.
- The pesticide injection pipeline must contain a quick-closing check valve to prevent backflow to the injection pump.
- The pesticide injection pipeline must contain a closed, solenoid-operated valve before the injection pump and connected to the pump to prevent it from being withdrawn from the system. This valve must be either automatically or manually operated.
- The system must contain a device that will automatically shut off the pump if the pump motor stops.
- Systems must use a metering device on the injection pump (e.g., diaphragm pump) constructed of materials that are compatible with the pesticide.

Labeling for UAV spraying:

Aerial Application

Apply in a minimum of 5 gallons of water per acre unless otherwise directed. Avoid application under conditions when uniform coverage cannot be obtained or when excessive spray drift may occur. Disease control may be reduced if uniform coverage is not obtained.

Do not apply by unmanned aircraft.

Directions for Sprinkler Chemigation: Apply this product only through center pivot, lateral move, end tow, side (wheel) roll, traveler, solid set, or hand move irrigation systems. Do not apply this product through any other type of irrigation system.

Chemigation Equipment Preparation: The following use directions are to be followed when this product is applied through irrigation systems. Thoroughly clean the chemigation system and tank of any fertilizer or chemical residues, and dispose of the residues according to state and federal laws. Flush the injection system with soap or a cleaning agent and water. Determine the amount of Rally 40WSP needed to cover the desired

Chemigation Equipment Req

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UAV spray system:

CO₂ cartridge liquid
pressure

Fat Shark™ remote
camera

Xbee radio control /
Arduino μ processor/
latching solenoid
valve

Straight stream nozzle



UAV spray system:

Spray operator
“the applicator?”

Fat Shark™ remote
camera and goggles
for targeting

Manual trigger
Xbee radio control
up to 26 miles away



UAV spray system:

Tested on ground vehicle

Traffic cone targets







Direct applications in weed control



Improved safety and efficiency



UAV Spray Operations:



UC DAVIS

University of California, Davis

