Aerial Spraying with UAV’s
For Wildland Weed Control

Ken Giles
UC-Davis
Biological & Agricultural Engineering

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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)
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:

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
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)

Note vortices
Flying return to operator
(Yamaha RMAX 10 April 2015 Oakville CA)

Note spray pattern
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 injection valve, a functional check valve, and low-pressure protection system to prevent back flow. Refer to the American Society of Agricultural Engineers Practice 409 for regulations.
- The pesticide injection pipeline must include a quick-closing check valve to maintain the injection pump.
- The pesticide injection pipeline must be closed, solenoid-operated, and equipped with a shut-off valve, and connected from being withdrawn from the tank while the pump is either automatically or manually shut off.
- Systems must use a metering device to accurately inject the chemical.
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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.**

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UAV spray system:

CO$_2$ cartridge liquid pressure

Fat Shark™ remote camera

Xbee radio control / Arduino µprocessor/ 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: