Introduction to the Yamaha RMax Remotely Piloted Helicopter and Review of U.S. Activities

Steve Markofski – Unmanned Systems Division
History & Milestones

1955
- Founding of Yamaha Motor Corporation
  - Production of first motorcycle (YA-1, 125cc)

1960
- Begins business operations in the United States (Los Angeles, CA)

1987
- Development completed for Yamaha’s first commercial-use unmanned helicopter “R-50”
Yamaha Global Products

- **Land** (Motorcycle, ATV, SxS, Snowmobiles, Electric & Electro-Hybrid Vehicles)

- **Water** (Boats, Marine Engines, Water Vehicles)

- **Power Products** (Golf Carts, Generators, Snow Throwers)

- **Commercial & Industrial Products** (Aeronautical Products, Engines, & Other)

Key Attributes: Innovation, High Quality Products, Customer Satisfaction
General Product Background

- Load into Vehicles
- Sprayer Tanks
- Sprayer System
- Control System
**RMax Basic Specifications**

**ENGINE**
- **TYPE**: 2-stroke, horizontally opposed 2-cylinder
- **CYLINDER DISPLACEMENT**: 246 cc
- **MAXIMUM OUTPUT**: 21 hp
- **STARTING SYSTEM**: Electric starter
- **FUEL**: Regular unleaded mixed with 2-stroke engine oil
- **SOUND DATA**: 72dB (at 50 meters)

**DIMENSIONS**
- **MAIN ROTOR DIAMETER**: 10 ft. 3 in.
- **TAIL ROTOR DIAMETER**: 1 ft. 9 in.
- **OVERALL LENGTH**: 9 ft. (Overall length with rotor 11 ft. 10.91 in.)
- **OVERALL WIDTH**: 2 ft. 4 in.
- **OVERALL HEIGHT**: 3 ft. 7 in.
- **DRY WEIGHT**: 141 lbs.
RMax Performance Specifications

**PERFORMANCE**

**LOAD CAPACITY***
- 61 lbs. 12 oz.

**CONTROL SYSTEM**
- Yamaha Attitude Control System (YACS) with GPS

**TRANSMITTER**
- 72 MHz / 6 Frequency

*The performance may vary depending on environmental conditions, such as the temperature, humidity, and altitude.*
RMax Sprayer Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIQUID SPRAYER</td>
<td></td>
</tr>
<tr>
<td>CASSETTE TANK CAPACITY</td>
<td>2 gal. 1 pt. x 2 tanks</td>
</tr>
<tr>
<td>DISCHARGE METHOD</td>
<td>Double-acting piston with flat nozzle</td>
</tr>
<tr>
<td>DISCHARGE RATE</td>
<td>.32 to .53 gal/minute (speed-linked method)</td>
</tr>
<tr>
<td>NOZZLE PITCH</td>
<td>4 ft. 4.75 in.</td>
</tr>
<tr>
<td>SPRAYER WEIGHT</td>
<td>16 lbs. 5 oz.</td>
</tr>
</tbody>
</table>
Spray Application Height

• 10 ft above the target

Basic Spray Operation, Pattern & Speed

• Nose Away Attitude from Pilot in Command
• 9 – 12 mph Maximum Speed
• 65 ft distance-off required for all participating crew
Standard RMAX Flight Pattern

Napa Valley – June 2013

Spotter (Radio communication)

RMax

Pilot (Radio communication)
Safety Systems Overview

- Self-Monitor Function (Diagnostic before takeoff)
- YACS - Yamaha Attitude Control System (Attitude control)
- GPS flight control system (Speed & altitude control)
- Radio interference / Loss of radio communication (Loss link hover)
- YACS warning Light / GPS indicator light (Visual indicators during flight)
- Speed indicator light (Visual indicator during flight)
- Rotor brake
Development History

20+ Years of Safe & Reliable Commercial Operations

1980’s
1983: Development begins with request from Japanese Government
1987: Yamaha completes development of R-50

1990’s
1991: Yamaha begins marketing R-50 Type II in Japan
1995: Yamaha Attitude Control System (YACS) introduced on R-50
1997: RMax released offering greater payload & greater ease of use

2000’s
2002: 1 million acres per year sprayed by remotely piloted helicopters
2003: RMax Type II released, updates include GPS for greater control
2012: 2,400 RMax helicopters in service in Japan
Yamaha has Manufactured over 4,500 Helicopters
RMax Use in Japan

Agriculture Applications

- Rice Paddies
- Wheat
- Soy Beans
- Pine Trees
- Vegetables
- Fertilizer
Remotely Piloted Helicopters are Recognized Solutions to Several Key Problems Confronting Agriculture Today

• Aging farming population
• Restrictions on manned crop dusting due to spread of urbanization (less drift)
• The depressed cost of agricultural products

Success of Remotely Piloted Helicopters in Japan

• Increased safety
• Coverage efficiency and accuracy
• Significantly lower costs

Success of RMax

• Yamaha’s advance flight control system
• Reliability
• Training
Overseas Expansion
South Korea / Australia / USA
UC Davis Project

UC Davis Experimental Vineyard

Harlan Estates

Paramount Farms

Demonstration Flights
Project Background and Goal:

In 2012, UC Davis and Yamaha Motor Company initialied a project investigating the use of the RMax, unmanned helicopter for agricultural spraying. 2015 project is a continuation and expansion of the cooperative work.

Project Objectives:

1. Conduct an analysis of typical pesticide label suitability for use with the RMax spray system and identify pesticide labels consistent with RMax application;

2. Apply registered pesticides with RMax to manage portion of Oakville test vineyard from bud break to harvest in order to determine efficacy and deposition;

3. Adapt the AgDisp model to the RMax characteristics and field verify the performance of the model as compared to observed spray swath; and,

4. Demonstrate the vehicle operation to agricultural industry, media and regulatory representatives and educate them on the technology and concepts of UAV use in agricultural spraying.
Identified Advantages

- Safer than manned ground application
- Improved operational efficiency
- No soil compaction
- No crop damage
- Quality spray deposition

Tractor driver suffers life-threatening injuries

Photo courtesy of CAL FIRE/Shasta County Fire Department

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

### 2015 Residue Spray Test Results

<table>
<thead>
<tr>
<th></th>
<th>Pre sample</th>
<th>0.18 ppm</th>
<th>150 leaves</th>
<th># grams in sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 leaves per sprayed sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Ground ppm boscalid</th>
<th>g sample</th>
<th>UAV ppm boscalid</th>
<th>g sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom Block 1</td>
<td>12.80</td>
<td>185.69</td>
<td>19.50</td>
<td>209.00</td>
</tr>
<tr>
<td>Bottom Block 2</td>
<td>15.70</td>
<td>204.69</td>
<td>13.90</td>
<td>219.75</td>
</tr>
<tr>
<td>Bottom Block 3</td>
<td>17.20</td>
<td>189.59</td>
<td>10.40</td>
<td>239.41</td>
</tr>
<tr>
<td><strong>Bottom Ave</strong></td>
<td><strong>15.23</strong></td>
<td><strong>193.32</strong></td>
<td><strong>14.60</strong></td>
<td><strong>222.72</strong></td>
</tr>
<tr>
<td>Bottom Std Dev</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.24</td>
<td>10.04</td>
<td>4.59</td>
<td>15.42</td>
</tr>
<tr>
<td>Middle Block 1</td>
<td>15.40</td>
<td>257.02</td>
<td>12.00</td>
<td>241.71</td>
</tr>
<tr>
<td>Middle Block 2</td>
<td>12.00</td>
<td>225.59</td>
<td>26.90</td>
<td>244.13</td>
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<tr>
<td>Middle Block 3</td>
<td>18.10</td>
<td>210.53</td>
<td>18.80</td>
<td>245.67</td>
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<tr>
<td><strong>Middle Ave</strong></td>
<td><strong>15.17</strong></td>
<td><strong>231.05</strong></td>
<td><strong>19.23</strong></td>
<td><strong>243.84</strong></td>
</tr>
<tr>
<td>Middle Std Dev</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.06</td>
<td>23.72</td>
<td>7.46</td>
<td>2.00</td>
</tr>
<tr>
<td>Top Block 1</td>
<td>9.51</td>
<td>199.55</td>
<td>43.40</td>
<td>182.49</td>
</tr>
<tr>
<td>Top Block 2</td>
<td>23.50</td>
<td>192.50</td>
<td>34.30</td>
<td>189.95</td>
</tr>
<tr>
<td>Top Block 3</td>
<td>22.20</td>
<td>201.95</td>
<td>14.20</td>
<td>197.17</td>
</tr>
<tr>
<td><strong>Top Ave</strong></td>
<td><strong>18.40</strong></td>
<td><strong>198.00</strong></td>
<td><strong>30.63</strong></td>
<td><strong>189.87</strong></td>
</tr>
<tr>
<td>Top Std Dev</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.73</td>
<td>4.91</td>
<td>14.94</td>
<td>7.34</td>
</tr>
</tbody>
</table>

#### Summary of means and standard deviations

<table>
<thead>
<tr>
<th>Foliage location</th>
<th>Ground spray ppm</th>
<th>UAV spray ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td>18.40 (7.73)</td>
<td>30.63 (14.94)</td>
</tr>
<tr>
<td>Middle</td>
<td>15.17 (3.06)</td>
<td>19.23 (7.46)</td>
</tr>
<tr>
<td>Bottom</td>
<td>15.23 (2.24)</td>
<td>14.60 (4.59)</td>
</tr>
<tr>
<td>Overall</td>
<td>16.27 (4.59)</td>
<td>21.49 (11.23)</td>
</tr>
</tbody>
</table>
Section 333 of The FAA Modernization and Reform Act of 2012

Section 333 gives the FAA the authority to grant case-by-case authorization for certain UAS to perform commercial operations in the NAS prior to the finalization of UAS rules.

Section 333 Exemption process provides a path for operators who wish to pursue safe and legal entry into the NAS.

Yamaha Received Grant of Exemption for the RMAX on May 1, 2015

Grant of Exemption allows Yamaha Motor Corp., USA to operate the RMAX for agriculture related operations in the US.

Summary of conditions & limitations:

- VLOS
- Pilot in Command (PIC) must hold a Sport Pilot Certificate
- PIC must hold a current US Driver’s License
- PIC + Visual Observer (VO) must complete Yamaha RMAX Certification Training for roles
- Daylight Hours / Good Weather
- Operations over uninhabited areas (e.g. vineyards, fields, groves & orchards)
- Operations defined as “agricultural aircraft operation” will be in accordance with 14 CFR part 137
Yamaha’s COA for the RMAX is effective from May 4, 2015 to May 31, 2017

**COA** allows Yamaha Motor Corp., USA to operate the RMAX in the US under the following provisions:

- Below 200 feet AGL
- Distant (D) NOTAM must be filed no more than 72 hours, but not less than 24 hours prior to ops
- PIC to remain clear & give way to all manned aviation ops & activities at all times
- PIC & VO maintain instantaneous communications at all times
- 5 nautical miles (NM) from airports with operational control tower
- 3 NM from airports with published instrument flight procedures, but no tower
- 2 NM from airports with no published instrument flight procedures or tower
- 2NM from heliport, gliderport or seaport
UAV Regulatory Issues
Ken Everett
Areas that UAV’s Could be Used

- Sloping Terrain
- Vector Control
- Future sites?
DPR is looking at:

- Licensing
- Labeling
- Worker Protection
- Drift/Buffer Zones
Licensing Requirements

Commercial Pilots License
FAA Medical
Journeyman Certificate
Apprentice Certificate
Exam Questions regarding UAV’s
Aerial Labels
- Required To Follow Aerial Instructions
- Could See Specialized UAV labeling
- Reduced Water Volumes
Exposure/Drift studies

Environmental Monitoring
- Working on a Drift Study
- Modeling

Worker Health and Safety
- Exposure Study Protocols being prepared
- Pilot exposure
- Observer/Mix Loader Exposure
- Equipment Movement Exposure
- PPE Requirements
Questions?