FY18 RWDC National Unmanned Aerial System Challenge: Practical Solutions to Precision Agriculture

Background

By 2050, there will be an estimated additional two billion people on Earth, which will significantly impact the availability of food. It has been estimated that there will be a need to produce 70% more food to address such a population growth. Throughout history, advances in technology have allowed farmers to produce more food. One piece of current technology that has the potential to greatly help the modern farmer is the unmanned aircraft system (UAS). By using a UAS, the farmer can more precisely monitor a field of crops and be able to apply water, fertilizer, or pesticides in a manner that saves time, saves money, saves resources, and increases crop yield.

The FY18 RWDC National challenge will continue the focus on unmanned systems and precision agriculture through the design and implementation of a UAS to support precision agriculture in the production of corn. The teams will use concepts from Engineering Technology (i.e., application of science and engineering to support product improvement, industrial processes, and operational functions) to identify, compare, analyze, demonstrate, and defend the most appropriate component combinations, system/subsystem design, operational methods, and business case to support the challenge scenario. Through use of an inquiry-based learning approach with mentoring and coaching, the students will have an opportunity to learn the skills and general principles associated with the challenge in a highly interactive and experiential setting. For example, the students will need to consider and understand the various unmanned system elemental (subsystem) interactions, dependencies, and limitations (e.g., power available, duration, range of communications, functional achievement) as they relate to the operation, maintenance, and development to best support their proposed business case.

To support the inquiry based learning approach, each team will perform and document the following:

1) ***Task Analysis*** - analyze the mission/task to be performed
2) ***Strategy and Design*** - determine engineering design process, roles, theory of operation, design requirements, system design, crew resources, integration testing, and design updates
3) ***Costs*** - calculate costs and anticipated capabilities associated with design and operation, including modification of the design to further support a competitive and viable business case

You will need to work together as a team with coaches and mentors to identify what you need to learn while pursuing the completion of this challenge. By connecting your own experience and interest, you will have an opportunity to gain further insight into the application of design concepts, better understand application of unmanned system technology, and work collaboratively towards completion of a common goal.

Challenge

This year's challenge is to design unmanned aircraft systems, create a theory of operation, and develop a business plan for the commercial operations of the system based on the following scenario.

Scenario: *Based on your group's work using the company's test field, your company has decided to further study the case of whether Part 107 regulations are restricting precision agriculture. Based on company research of prospective users of your system, a typical field layout has been created (see Fig. 1). The layout includes four 1 mile by 1 mile (640 acres) fields of corn that are surrounded by gravel access roads. To represent the possibility of heavily traveled public roads, no fly zones for certain altitudes are included in the layout. Your group must design unmanned aircraft that perform better than the DJI Agras MG-1 at spraying and perform better than the eBee SQ at surveying.*

The final UAS must use unmanned aircraft to survey and spray the fields. Your group may design two different unmanned aircraft to perform the tasks (i.e. one aircraft to survey and a different aircraft to spray), or your group may design a single unmanned aircraft that can perform both tasks. You may use unmanned ground vehicles or other robotic systems if desired. In addition, multiple aircraft may be used at the same time. You will be comparing the performance of your system to the benchmark performance scenario using the eBee SQ (surveying) and the DJI Agras MG-1 (spraying) found in the detailed background.

The system your group is designing will provide the surveying and spraying as a service to the farmer. You may NOT say your business case is to sell the aircraft (i.e. you are not selling the aircraft to the farmer).

Field: *As mentioned earlier, the layout your group is using contains four corn fields that are 1 mile by 1 mile (640 acres) creating a total of 2560 acres. Gravel access roads surround each field. The width of each gravel access road is 14.7 ft with an additional 3.3 ft on either side for drainage. Therefore, the total width of the gravel access roads are 21.3 ft. Aircraft must be able to takeoff and land from the gravel access roads, so the maximum wingspan is 14 ft. Aircraft may fly over the gravel access roads, but access over the no fly regions is restricted. Aircraft that fly at an altitude of 400 ft above ground level or lower may not fly in the no fly zone. If the aircraft can fly at an altitude greater than 400 ft above ground level, it may cross the no fly zone. The width of the no fly zone is 100 ft (30.5 m). Design your system using the layout provided in Fig. 1. Note that the figure is not to scale.*

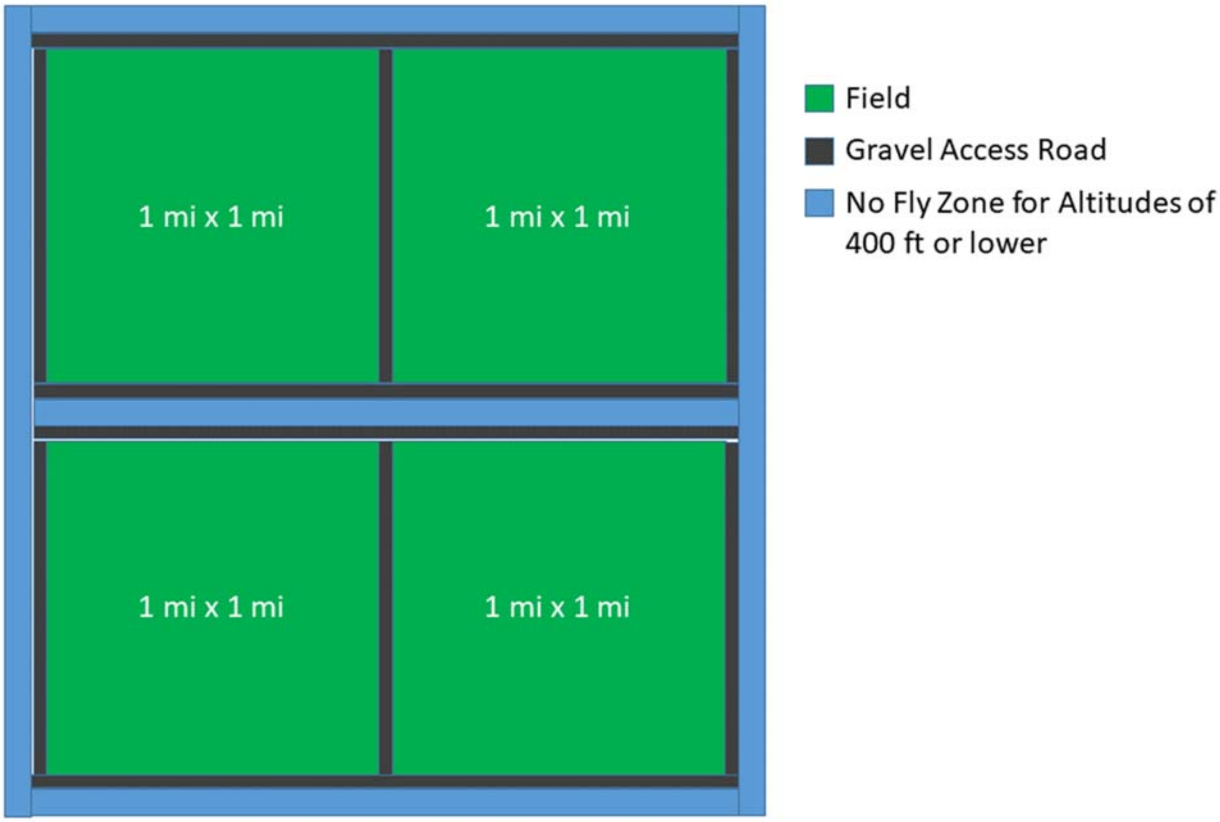

Figure 1: Field layout for FY18 National challenge (not to scale).

Safety: *For each area that your team decides to go outside of Part 107 with your UAS, you should include ways of addressing any possible safety issues that might arise. Besides any safety concerns from being outside of Part 107, your aircraft should also, at a minimum, have the following safety features:*

- *Procedures for loss of signal from the pilot and GPS*
- *Procedures for obstacle detection and avoidance*

Specific Part 107 regulations can be found at

http://realworlddesignchallenge.org/resources/021515_sUAS_Summary-1.pdf

Business case: *Your team should operate from the perspective of being part of a larger company. Your company will provide the final funding for your design. Your team will need to determine the cost of the system and a reasonable return on investment plan. Teams will be looking to see if they can make a case that their designs outside of Part 107 regulations will lead to an increased opportunity for profit. The increased profit should be made from a reduction of costs or an improvement in revenue (through increased crop yield). Teams should NOT just raise the price of their system to improve its profitability. Any increase in price should be within a reasonable price for a farmer to spend and still make money from an increase in crop yield. Your team is designing a system that will provide a service to farmers; you are NOT selling the aircraft to farmers.*

Comparison: *The outcome from your team will be an unmanned system capable of surveying a field and spraying pesticides. You will be comparing the performance of your system with the ones given to you in the detailed background. You will determine if going outside of the Part 107 regulations will provide the opportunity to significantly improve the profitability of your system.*

Objectives

Unlike previous challenges, there will not be an objective function. Instead, your designs will be judged on how well they satisfy the objectives. You should note that maximizing one objective might be at the detriment of another objective. It will be up to your team to decide the importance of each objective and provide sound engineering arguments to justify your design decisions.

- Maximize crop yield
- Minimize resources used (man-hours, cost, energy, etc.)
- Maximize profit for the farmer and your company

Constraints

- Antennas on-board the vehicle(s) are separated by a minimum of 18 inches to avoid destructive interference
- Your choice of system control hardware, sensor selection, remote vehicle element(s), C3, support equipment, and other subsystem components is not solely limited to cataloged items; substitutions are permissible and encouraged with justification and analysis provided in the design decisions in the Engineering Notebook.
- Your design complies with any other FAA guidelines and regulations
- Aircraft has safety protocols and procedures to account for loss of signal and obstacle detection
- Aircraft can safety operate outside of Part 107 regulations if needed
- Aircraft can takeoff and land using the gravel access roads

Assumptions

- You may assume that your company has received permission to disperse pesticides using your UAV.
- Communications must be maintained with ALL remote vehicle elements (redundant secondary system required)
- The control system:
    - Include global positioning system (GPS) navigation and telemetry for operating the vehicle and payload.
    - Include ability to relay mission payload commands (release dispersant, change pressure, etc.) from control station, and ability to implement repetitive mission payload command routines (e.g., release dispersant over specific targeted areas logged in GPS).

- *NOTE:* *Autonomous controls can include capabilities to follow a pre-programmed path (waypoint following) as well as the ability for the "operator" to update movement (flight or driving) patterns in real-time during the mission*

- A human operator will be required to take control of an unmanned system in an emergency (i.e., redundant secondary control)
- U.S. Standard Atmosphere and Standard Day conditions at sea level are assumed, with no winds aloft

Other Resources

- RWDC State Unmanned Challenge: Detailed Background
- Challenge statements and Detailed Backgrounds from previous RWDC Precision Agriculture years
- Winning Engineering Design Notebooks from previous years
- RWDC Content Webinars (schedule to be determined)
  - Overview of Unmanned Systems
  - Systems Engineering and Vehicle Performance Factors
  - Precision Agriculture and Application of Unmanned Systems
  - Business Case and Cost Considerations
- The RWDC Support Site with FAQs, tutorials, material allowables, library of available propulsion systems and fuselages, and other supporting materials: Getting Started section of the RWDC website (http://www.realworlddesignchallenge.org).
- The following represent the recommended baseline remote air vehicle element (i.e., UAV) platforms for this challenge:
  - Fixed-wing (tractor propeller) UAS Design
  - Fixed-wing (pusher propeller) UAS Design
  - Hybrid Design (fixed-wing/quadrotor)
  - Rotary-wing Design
  - Multirotor Design
- Baseline CAD models for each baseline remote vehicle element to be provided
- Mentors from the aerospace and defense industry, government agencies, and higher education

Tools

- PTC Creo
- Excel cost worksheet

Team Submissions

The Engineering Design Notebook submission including the business plan and appendices must be 80 pages or less. Detailed information regarding what must be documented can be found in the RWDC FY18 National Challenge Scoring Rubric. Teams must submit the following:

1. Engineering Design Notebook (refer to RWDC FY18 National Challenge Scoring Rubric)
2. CAD drawings (refer to RWDC FY18 National Challenge Scoring Rubric)

Scoring

- Teams' submissions will be evaluated based on criteria outlined in the RWDC FY18 National Challenge Scoring Rubric and in reference to the example mission scenario
- Technical scoring will be based on deliverables to be incorporated in the Engineering Design Notebook
- Engineering Design Notebooks must follow the paragraph order of the RWDC FY18 National Challenge Scoring Rubric
- Judges will be looking for the ability to express comprehension and linkage between the design solutions with what students have learned. Specific recognition will be given for design viability, manufacturability, innovation, business plan development, and additional application beyond precision agriculture

Merit Awards

Special RWDC Merit Awards will be given at the National Challenge Championship in Washington, DC. Merit awards will be granted at judges' discretion to teams that do not place in the top three, but are top performers overall. Only one merit award will be granted per team. Awards will be based on the team presentation and Engineering Design Notebooks.

- Innovation
- Design Viability
- Team Work and Collaboration
- Effective Mentor Collaboration
- STEM Interest Impact
- Most Creative
- Against All Odds
- Best Business Case
- Best First Year Team

Contacts

Dr. Ralph K. Coppola
Founder & Executive Director, Real World Design Challenge
Phone: 703-298-6630
Email: rkcoppola@yahoo.com

Authors

Dr. Robert Deters
Assistant Professor, Embry-Riddle Aeronautical University-Worldwide

Jeff Coppola, MBA
Program Manager, Real World Design Challenge