FY14 RWDC State Unmanned Aircraft System Challenge: 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. An increase in food production can be realized through implementation of higher yield farming, using precision agriculture.

In 2012, President Obama signed the *Federal Aviation Administration (FAA) Modernization and Reform Act 2012* to integrate unmanned aircraft systems (UAS) into the national airspace system (NAS) by 2015. Existing FAA regulations do not currently provide provisions for commercial UAS support of precision agriculture. This year's challenge represents a means of identifying potential policy or regulatory changes necessary to support such future operations.

Unmanned aircraft systems (UAS) represent remotely controlled airborne assets used to perform tasks requiring persistence in situations or environments that carry a high degree of risk or are beyond the capability of manned platforms. There are a multiple private companies, researchers, and governments developing UAS to perform a variety of missions, including precision agriculture, conservation, wildlife monitoring, damage assessment, infrastructure inspection, and research. One common focus of such development is the integration of a diverse mix of components and capabilities into a single, unified framework. While the uses, designs, and operations of the systems vary, they all rely on a common organizational composition based on payload, air vehicle, command, control, and communication (C3), support equipment, and crew.

This year's challenge will be focused on the design and implementation of a UAS to support precision agriculture, specifically the monitoring and assessment of crop conditions to achieve increased yield. The teams will employ a systems engineering design and integration approach to identify, compare, analyze, demonstrate, and defend the most appropriate component combinations, subsystem designs, operational methods, and business case to support the challenge scenario. Through use of an inquiry-based learning approach with mentoring and coaching, the student's 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 UAS subsystem interactions, dependencies, and limitations (e.g., power available, duration, range of communications, maintenance of visual contact) as they relate to the operation, maintenance, and development to best support their proposed business case.

To support the inquiry based learning approach, the students will be provided with a basic framework associated with the following focus areas:

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 business case
4) ***Alternative Uses*** - identify alternative uses of system to improve marketability and use cases

As the student's progress through the challenge, they will incrementally be presented with background relating to the composition and operation of UAS designs, basic aeronautical and engineering design principles, UAS application to precision agriculture, and business management and development tools. They will work together as a team with their coaches and mentors to identify what they need to learn as they move towards the completion of this challenge. By connecting their own experience and interest, students will have an opportunity to gain further insight into the application of design concepts, better understand application of UAS technology, and build those priceless experiences that will guide them on their own path to success.

Challenge

The State Challenge is to design a UAS, which may have a fixed-wing, rotorcraft, or hybrid design, and to develop a business plan for the commercial operations of the system based on the following mission scenario.

Mission Scenario: *The negative economic impact of invasive species is a major concern in all areas of the country. This is no less true in Iowa where farmers must contend with a variety of plants, animals, insects, fish, and fungi to ensure their crops remain healthy, achieve high yields, and remain profitable. For this challenge, the European Corn Borer has been identified as the target pest. Teams should research the insect to determine how it affects corn, identify sensors that effectively identify the insect or its effects, refine a vehicle design based on those provided as part of the challenge or produce their own design, develop a search pattern of the area of interest, identify the optimal altitude for the collections based on sensor and platform performance, and the associated ground control system, analysis, and crew requirements. The goals for the design include early and accurate identification of infestations, a plan to remain within a prescribed development and operational budget, and a business case outlining and justifying the selections made.*

Figure 1. Late-stage larvae tunneled into the earshank of an ear of corn (Iowa State University)

The predation of crops is a major concern for global agricultural production. It is estimated that in the United States the economic losses due to invasive species are $137 billion annually. One reason invasive species in any region can be so damaging is that they often have no natural predators as they would in their homeland. This means they can reproduce rapidly while causing extreme damage to the ecosystem in which they live.

Although there are many crop types that could be explored for a precision agriculture application of UAS, this challenge focuses on corn because it is grown throughout American, and national output represents 32% of the total corn production globally. The Midwest, specifically Iowa, was chosen for the challenge because it is a large corn producing state. As such, there is ready availability of resources and research related to predation of crops by invasive species in this region, and substantial benefit would be achieved through the application of UAS in precision agricultural applications including identification and monitoring of invasive species.

Yield loss from the European Core Borer may occur due to five major factors during one or more generations of the European Corn Borer through the growing season. Not only can damage result in diverted plant resources to maintenance and repair rather than ear and kernel, entire ears may be lost in the harvest because they have fallen from the stalk or the stalk itself has broken. Infestation can also result in disease, likely from two primary fungi species, Fusarium moniliforme and Gibberella zeae.

Crop type: Corn (US national output represents 32% of total corn production globally)

Invasive pest: European Corn Borer

Location: Midwestern, US (central Iowa)

Area of Interest Corner Points			
Northeastern	Northwestern	Southeastern	Southwestern
Latitude: 42.5009	Latitude: 42.5009	Latitude: 42.4863	Latidude: 42.4863
Longitude: -93.9514	Longitude: -93.9714	Longitude: -93.9513	Longitude: -93.9715
Area of Interest Size			
1.657458 km wide = 1.0299 miles		1.609533 km tall = 1.00012 miles	
Approximately 1 square mile or 640 acres			

Altitude: Ground level is assumed to be 1,500 ft MSL for the challenge.

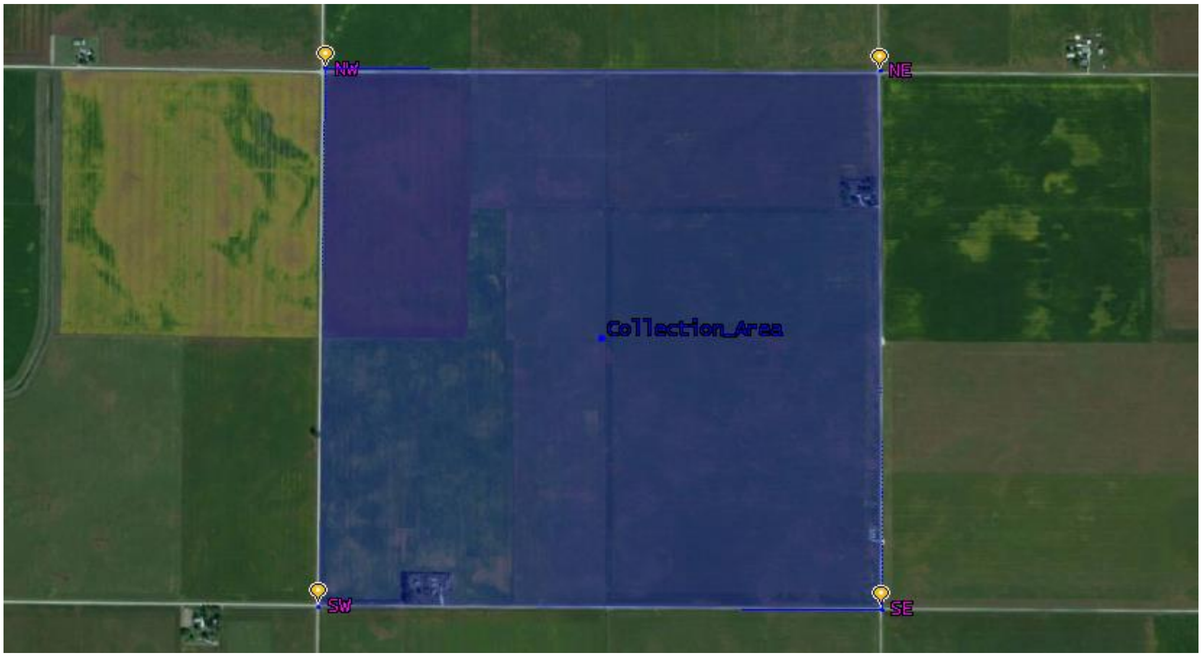

Figure 2. Area of Interest – Shaded with Corner Points Shown

Objective Function

Each team is to operate from the perspective of a small company seeking funding for the demonstration of a prototype system. The challenge proposal should utilize the PACE model of product development (as advocated by the Product Development Management Association; www.pdma.org) such that the engineering development costs are minimized but also include information about the acquisition cost and operations and support cost of the system to show that the product can be competitive in the market place. The following steps are recommended in pursuit of a response to the challenge scenario:

1. Develop a prototype/conceptual design
2. Fund concept (i.e., identify funding source and approach to obtain)
3. Prove the prototype design (i.e., identify process/plan to validate and verify conceptual operation)
4. Obtain further funding to productize concept (i.e., identify funding source and approach to obtain)

Since this is the first phase of the project, the development cost will receive the highest scrutiny and should have more precise and detailed information available as compared to the other costs. The successful proposal should also include an estimate of the timeline to recover the initial investment and any potential future year profits.

The successful team should strive to maximize the ratio of the increase in annual crop yield to the life cycle cost (*LCC*) of the system. This can be expressed as:

$$maximize\left(\frac{Increase\ in\ Crop\ Yield}{Life\ Cycle\ Cost}\right)$$

If this number is too low this could indicate that either the crop yield is not very substantial or the *LCC* is too high. The *LCC* includes the initial cost to the costumer (acquisition cost) plus the operational and support cost (*O&S*) over a period of team defined number of missions (minimum number of at least 50; e.g., 50 missions could equate to 10 clients with five missions per client or any such combinations):

$$LCC = Acq + O\&S$$

Where:

- *Acq* is the acquisition cost and includes the number of air vehicles required to conduct the mission, in addition to the cost of the ground control station and associated support equipment. Careful consideration should be given to the cost to design, build and test a prototype system.
- *O&S* is the operational and support cost and it includes the fuel burn cost per mission, required manpower per mission, number of missions in a year, and any maintenance cost, such as part replacement, that the team identifies.

Design Variables

- Air vehicle design parameters (i.e., wing, tail, fuselage, construction material) and all aeronautical based subsystems such as propulsion, power systems, etc. NOTE: Careful consideration should be given the concept for launch and recovery (i.e., catapult, grass field, etc.) since this will affect the requirement, design, and selection of the landing gear (if necessary)
- Sensor payload and telemetry selection
- UAV crop search pattern and the number of UAVs to achieve the mission
- Mission control equipment selection and post processing equipment
- Manpower tradeoff between design and analysis and testing

Aircraft Constraints

- UAV will comply with FAA technical readiness guidelines.
- Routine maintenance should be able to be completed by customer/user.
- Post-processing should be able to be completed by customer/user with minimal training.
- Antennas on-board the UAV must be separated by a minimum of 18 inches to avoid destructive interference.
- Your choice of flight control hardware, sensor selection, air vehicle element, command, control, and communication (C3), support equipment, and other subsystem components is not solely limited to cataloged items; substitutions are permissible with justification in design decisions.

Assumptions

- If the vehicle remains within the designated crop search area, visual line-of-sight (VLOS) contact is maintained.
- The flight control system:
  - Include GPS navigation and telemetry for operating the vehicle and payload.
  - Include ability to relay mission payload commands (pan, tilt, zoom) from ground control station, and ability to implement repetitive mission payload command routines (e.g. sweeping pan back and forth).
  - NOTE: Autonomous flight controls can include capabilities to fly a pre-programmed fight path (waypoint following) as well as the ability for the 'operational pilot' to update aircraft flight patterns in real-time during the mission.
- A human pilot will be required to take control of a UAV in an emergency (i.e., redundant secondary control).
- The payload sensor shall use a separate link to download video data to operator to be processed or it shall be locally stored (onboard vehicle) and post-processed after flight.
- U.S. Standard Atmosphere and Standard Day conditions are assumed, with no winds aloft.
- Plan for the system to be used to support at least 50 missions (this number will be defined by student teams, with a minimum of 50; e.g., 10 clients with five missions per client or any such combinations that equates to final number)
- Subject operating area is as follows:
  - Ground level is 1,500 feet Mean Sea Level (MSL).
  - Width = 1.02990 miles, Length = 1.00012 miles (approx. 1 square mile or 640 acres).

Other Resources

- RWDC State Aviation Challenge: Detailed Background
- Student Aviation Content Webinars (schedule to be determined)
  - Overview of Unmanned Aerial Systems
  - Systems Engineering and Aeronautical Performance Focus
  - Precision Agriculture and Application of UAS
  - Business Case and Cost Considerations
- The RWDC Support Site with FAQs, tutorials, Mathcad modules, material allowables, library of available propulsion systems and fuselages, and other supporting materials: www.ptc.com/go/rwdcgettingstarted
- The following represent the recommended baseline air vehicle element (i.e., UAV) platforms for this challenge:
  - Fixed-wing Pusher Propeller Design
  - Fixed-wing Tractor Propeller Design
  - Rotary-wing Design
  - Multirotor Design
  - Hybrid (Fixed-wing/Quadrotor) Design

- Mentors from the aerospace and defense industry, government agencies and higher education
- Baseline CAD models for each baseline air vehicle element to be provided

PTC Tools

- PTC Creo, Mathcad Prime 2.0, and the Windchill collaboration and data management site provided by PTC
- Mathcad and Excel sizing, performance, and cost worksheets

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 Work Flow document and the Scoring Rubric. Teams must submit the following:

1. Design Notebook (refer to scoring rubric)
2. Creo CAD files (refer to scoring rubric)
3. Completed MathCad/Excel worksheets and other supporting analytical work (refer to Work Flow document for specific tools)

Scoring

- Teams' submissions will be evaluated based on criteria outlined in the RWDC FY14 Aviation 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 should follow the paragraph order of the Scoring Rubric.
- Judges will be looking for 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 Use of Mentors
- Impact on STEM

- Best Presentation
- Against All Odds
- Best Business Plan
- Best First Year Team

Contact

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