Real World Design Challenge (RWDC) – An Overview

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Abstract. In this paper, the Real World Design Challenge (RWDC) competition is discussed in detail. This paper highlights the need, history, and approach taken for the design of the challenge. The authors discuss how this challenge promotes Science, Technology, Engineering and Mathematics (STEM) education and provides opportunities for high school students to acquire knowledge and experience beyond their traditional curriculum. The challenge is based around a real world problem. Students are asked to work in teams to find feasible solutions for the identified problem. The process for developing the challenge, student engagement, learning opportunities, student evaluations, publicity and recruitment efforts, design objective and timeline, and assessment metrics are some of the topics discussed. In this paper, the lessons learned from developing and running the challenge are also addressed.

Introduction

The RWDC is an initiative to improve interest and involvement of high school students in the Sciences, Technology, Engineering, and Mathematics (STEM). The motivation of this public-private partnership is to attempt to boost the ability of the United States to compete in an increasingly competitive global economy and to reverse the "brain drain" that has been occurring in STEM fields over the past 50 years. Partners have invested $263 million dollars in resources to support the RWDC concept. Partners include the Federal Aviation Administration, the Department of Transportation, the National Governor's Association, NASA, SpaceX, the AIAA Foundation, as well as numerous other industry and academic supporters. Investment includes approximately $1 million in engineering software that is provided to each participating teacher. Further, participating teachers are given access to training and curriculum materials as well as being provided access to industry or academic mentors to assist in the process. Lastly, teachers are given a $1,000 stipend to the teacher who best integrates the RWDC into their classroom.

Teams of 3-7 high school students are given a real-world aerospace engineering problem that they must address within the confines of the scenario presented in the RWDC. These groups first compete in a state-wide competition, the Governor's Cup. Currently, 34 states are participating in addition to 7 territories and districts. Winners of this step are then given an all-expense paid trip to Washington, DC to compete in the final stage of the competition. Winners are awarded $50,000 scholarships to pursue STEM education at Embry-Riddle Aeronautical University. This is aimed to improve participation in STEM education and hopefully the pursuit of careers in these fields. In future years, it is hoped that the RWDC will extend beyond the aerospace-centric focus and provide more comprehensive STEM topics (RWDC, 2013) [1, 18].

Purpose of the Competition

The Real World Design Challenge (RWDC) was created to build the American Science, Technology, Engineering, and Math (STEM) workforce sustainably and on a national scale. STEM jobs are an increasingly important piece of the world economy. And the pool of qualified STEM graduates is no longer suitable to meet the demand. In jobs involving US National Security and Defense, employees must be Security Clearable US citizens. This pool of talent is even more limited, and is not sufficient to meet the needs of workforce.

The RWDC is set up to build the workforce by infusing STEM learning across the United States. The US educational system varies widely at a local level. Many of the educational decisions are made at a state or local level. There is no top-down mechanism to mandate changes, but the workforce needs grow every day. The RWDC has taken an approach to open STEM learning opportunities to as many students as possible. The program can be done in school or in an after school setting. The program is free so that cost is never a factor. Companies donate real professional tools to schools, and to allow scaling, agreements are in place to provide donations to any student who wants the tools.

The RWDC also partners with governors and lt. governors across America to tap into the state-level education infrastructure. The RWDC is also partnered with numerous agencies at the federal-level including the US Department of Education. The ultimate goal of the RWDC is to prepare students for the 21st Century STEM workforce.

Brief History

The first students competed in the RWDC in 2008 and the first national finals were held in 2009 in Washington, DC. But the impetus for the competition grew from the experiences of a variety of stakeholders over the preceding decade.

At the time, industry was beginning to become concerned over the decreasing availability of US STEM graduates. The Third International Mathematics and Science Study (TIMSS) had shown that in Math, the United States ranked 12th out of 26 countries at grade 4; 28th out of 41 countries at grade 8; and 19th out of 41 countries at grade 12. In science, the US ranked 3rd at the 4th grade level out of 26 countries; 17th out of 26 countries at the at the 8th grade level out of 26 countries; and 16th out of 26 countries at the 12 grade level [2].

Some research on the inclusion of design and engineering in schools in other countries had yielded some promising results. In the UK, the “CAD/CAM In Schools Programme” was in 83% of the secondary schools [3]. And Loughborough University in the U.K discovered that 70.4 % of students who had used 3D design software in secondary school to produce their A level D&T projects experienced significant benefits when they began studying industrial design at university [4]. But in the US, top-down programs like the UK’s CAD/CAM program are near-impossible to orchestrate.

A group of businesses, universities, and non-profits called the PTC-MIT Consortium came together to discuss the issue. The business leaders explained that not only did they need a more STEM graduates, but the employees who were really valuable to them were people with 7-10 years of real world experience. The RWDC grew out of the ideas presented at this meeting. The competition we designed to work within the confines of the US educational system using both a grass roots and top down approach. And the Challenge was designed to infuse the real world experience that the business community was looking for into the classroom.

Thus in the 2008, ten states had their governors sign on, and two hundred teams began participating in the first Real World Design Challenge. Tremendous support from aerospace companies and entities helped make this a reality. The Department of Energy, Cessna, Boeing, PTC and Flomerics, and the FAA all played a crucial role in implementing the RWDC in its first year. Focus was given to the event at one of the largest air shows in the world - AirVenture. Discussion between Cessna’s CEO and the head of Build-A-Plane provided the impetus to take the RWDC from concept to reality [5].

Since then, many more governors have signed on, and thousands of teams have participated from states all across the country and six US territories. Over 70 partners support the RWDC with expertise, financial support, and other resources. And today, the RWDC is one of the largest and fastest growing high school STEM competitions in the world.

2014 Real World Design Challenge

By 2050 there will be an estimated additional two billion people on Earth, which is expected to significantly impact the availability of food [6]. It has been reasoned that there will be a need to produce 70 percent (70%) more food to address such a population growth [7]. Recent research has indicated that higher yield farming can be achieved using precision agriculture and UAS [8]. Based on this perceived need, potential for UAS application, and recommendations of the 2013 RWDC Blue Ribbon Judges Panel, the challenge design team chose to focus the challenge scenario on the student team development and recommended implementation (i.e., operation) of a full unmanned aircraft system (UAS) design to support a precision agriculture task.

Engineering Approach

Because this challenge represents an opportunity for the students to apply knowledge in a real world setting, the selection of an engineering approach to establish contextual application was deemed essential. After a review of past engineering approaches applied to the RWDC, RWDC scenarios, and U.S. demand for engineering disciplines, the challenge design team elected to place the engineering focus on a discipline with an exhibited need [9] that also has practical use in meeting the challenge scenario (e.g., requirements management, system design, system analysis, validation and verification, logistics and operations, integration, customer interfacing, technical management, information management, process management, coordination, and computer applications; [10]). Application of a systems engineering approach, a growing discipline anticipated to provide an opportunity for exposure to a wider variety of engineering concepts [9, 20, 21], was chosen for the teams to analyze, evaluate, demonstrate, and defend a proposed design, operational method, and business case.

It was recognized early in the challenge development process that a successful team would need to focus on teamwork, communication, and leadership; fundamental skills necessary for success in today's competitive and collaborative working environment [11]. The challenge team internalized a motivating philosophy during the course of challenge development; that experiences students gain in pursuit of a solution would serve them well later in life for the selection of a collegiate focus (e.g., selection of major, minor, type of degree) and the development of their professional careers. Understanding the importance of such skills and the implications for the students, influenced the construction and presentation of challenge materials (e.g., development of supporting documentation, production of webinar videos, and identification of recommended roles and evaluation criteria).

Learning Framework

The majority of the challenge development team are employed as faculty and staff and Embry-Riddle Aeronautical University-Worldwide (ERAU-Worldwide). As such, the experiences and knowledge gained as professors, instructors, and course developers at this university influenced and guided the selection of a learning framework for the challenge. ERAU-Worldwide embraces and encourages the use of inquiry-based learning [12, 17, 19], an instructional method designed to engage and motivate students based on their own interest and the pursuit of a solution to a challenge [13]. When ERAU-Worldwide was asked to develop this year's challenge, the assembled challenge development team brought with them the skills and expertise associated with implementation of inquiry-based learning.

Through the employment of an inquiry based learning approach, with mentoring and coaching, the students were provided with an opportunity to learn the skills and general principles associated with the challenge in a highly interactive and experiential setting. Emphasis was placed to on ensuring students would learn how to find and apply knowledge rather than directing towards what the designers, webinar instructors, coaches, and mentors know (e.g., memorization and response of presented material; [14]). The intent was to provide a learning framework that would provide an introduction to background material and concepts (e.g., overview of UAS, UAS application for precision agriculture, basic aeronautical performance factors, and business case development and management), while supporting collaborative student work in team settings to research potential solutions (e.g., explore the knowledge space) and provide peer review of project work. The learning framework would also support providing access to tools the students would need to succeed, including relevant reference materials, resources, and the mechanisms to locate information through their own research [14].

Scenario and Design Method

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, they achieve high yields, and they can remain profitable. For orientation, students were provided with the exact coordinates for the search area, roughly a square mile in central Iowa, and several maps showing the area of interest at varying levels of detail. Figure 1 presents the area of interest and the surrounding area provided for student reference.

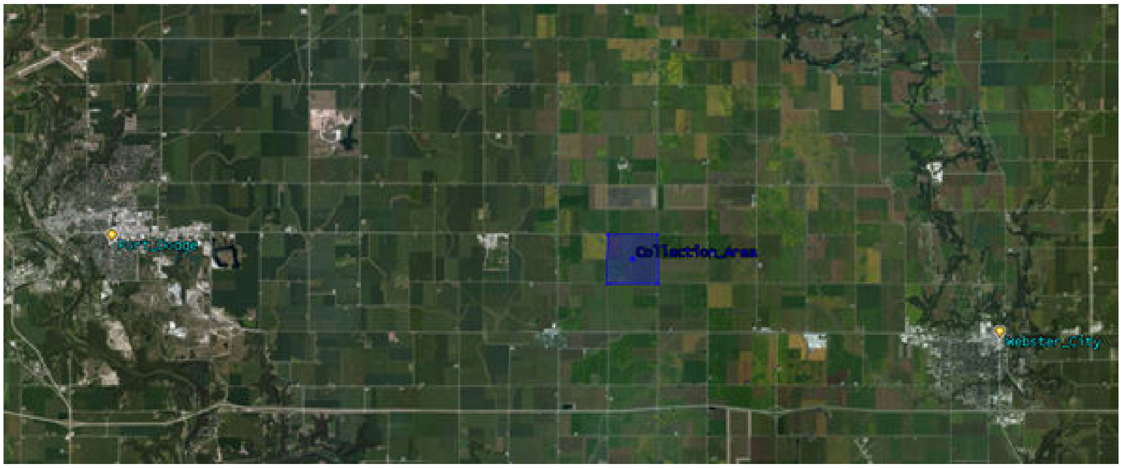

Figure 1: Area of interest – Surrounding area

For this challenge, the European corn borer was identified as the target pest. Teams must 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. Additionally, teams must carefully consider the business case for their approach including the projected costs for their solution and the resulting potential increases in revenue for the farmer. 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.

The challenge was design so that as the students' progressed, they would incrementally be presented with background relating to challenge through review of content webinars and videos, readings, and design tools. To achieve success, the teams would need to work together as a team, with their coaches and mentors, to identify what they needed to focus on (i.e., learn), while applying knowledge and concepts towards the completion of the challenge. As designed, the student teams would need to consider and understand the various subsystem interactions, dependencies, and limitations associated with their UAS design. Although they were provided instructions regarding what UAS are and how they operate, it was left up to the teams to perform the detailed research to determine why a specific airframe and payload sensor configuration would be best suited for the precision agriculture task of this challenge. Figure 2 shows how a UAS may be integrated into precision agriculture application as a remote sensing platform.

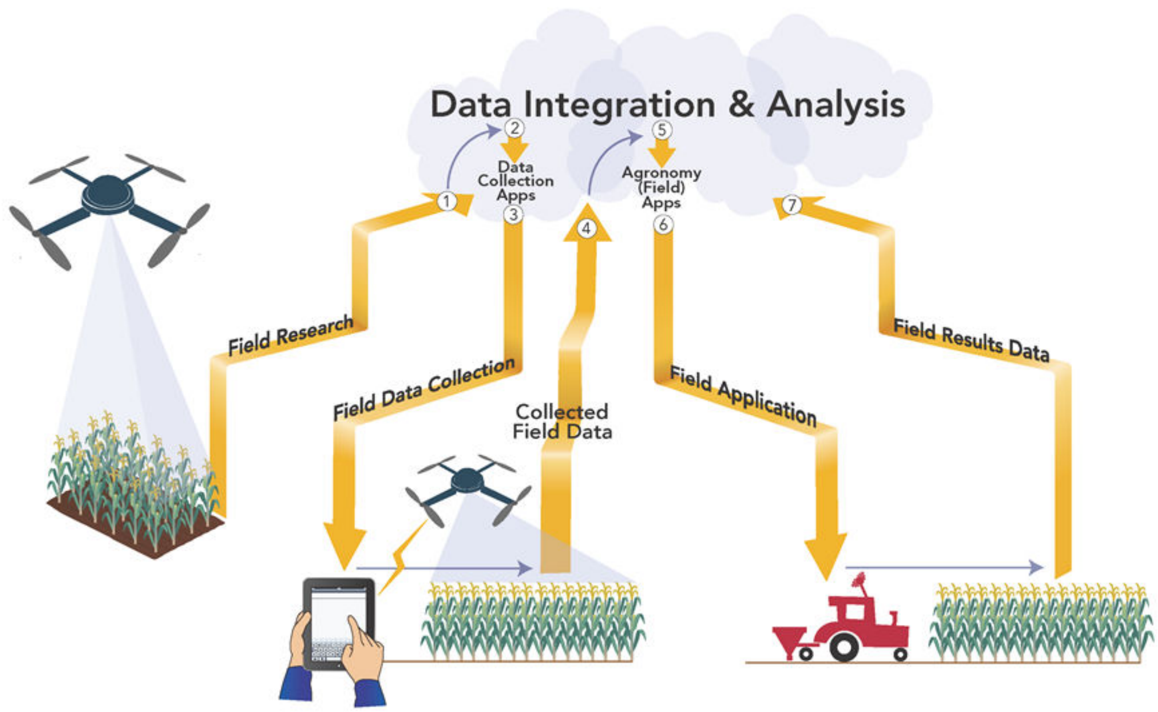

Figure 2: UAS integration into precision agriculture

UAS can support research to learn about the best methods for a given application. After initial research, UAS can collect data for analysis to provide information for decision-making and implementation of a selected course of action. Data may also be collected during the normal farming process that can inform future decisions. For this challenge, students were asked to research and leverage past research and existing knowledge related to the application of UAS in precision agriculture and to focus on the field data collection and analysis phase during the design of their solution.

The Process

For this year's challenge, each team was required to operate from the perspective of a small company seeking funding for the demonstration of a prototype system, followed by the development of the business case for a second round of funding for full commercialization. They were to utilize the PACE model of product development. The PACE model requires that the team submit for review the proven prototype and the accompanying business case and assumptions for funding the development and market launch of the prototype [15]. This approach focuses the team on minimizing the engineering development costs so that a case may be made for profitable commercialization. The business case also includes information identifying the acquisition, operations, and support costs of the system to show the system would be competitive in the market.

The challenge development team business case subject matter expert (SME) recommended the student teams plan their challenge solution pursuit in accordance with the following series of steps:

1) Develop a prototype or conceptual design; create an initial design of the UAS to meet the challenge scenario

2) Fund the concept; identify applicable funding sources and the approach to obtain funding

3) Prove the prototype design, identify the process or plan to validate and verify the conceptual operation

4) Obtain further funding necessary to productize the concept by making the case for further funding using rigorous guidelines for assessing the success potential for the full commercial product.

Because this was the first phase of the student project, the development cost was anticipated to receive the highest scrutiny with the inclusion of more precise and detailed information, compared to the other costs. The student teams were informed that a successful proposal should also include an estimate of the timeline to recover the initial investment and any potential future year profits. In addition of the investment recovery timeline, students were asked to identify the most appropriate application of the product in the marketplace, the competitive landscape and market situation, and finally, the risks associated with the overall development and launch.

The results of a team submission would be based around demonstrating the optimization of an objective function. For this challenge, the teams were instructed to maximize the ratio of the increase in annual crop yield to the life cycle cost (LCC) of the system. If the objective function result was too low, it would indicate that either the crop yield was not very substantial or the LCC was too high. The LCC included the initial cost to the consumer or acquisition cost, plus the operational and support cost over a period of missions over the course of a year.

The recommended process for the design of a UAS submission was based around the identification, selection, and integration of five major elements (i.e., subsystems) and their constituent components as shown in Figure 3.

Figure 3: Suggested UAS design approach

First, the payload sensors that would be used to capture data are shown. Second, the Air Vehicle Element (i.e., UAV) platform used to carry the payload and fly over the subject area are listed. Third, the command, control, and communication or C3 element used to pilot and interact with the Air Vehicle Element are displayed. Fourth, the support equipment necessary for operation are shown. And fifth, the operational and support personnel necessary for safe and efficient application of the system are included. A description and series of generic base catalog options for each of these elements was provided in the RWDC FY14 State Unmanned Aircraft System Challenge: Precision Agriculture Detailed Background Document [16, 20]. While the teams were provided with baseline options (i.e., generic base catalog options) for each element, they were strongly encouraged to locate alternatives through their own research efforts with the stipulation that they provide supporting rationale and the same level of detail as the catalog options.

The teams were also provided the recommendation to construct and update a theory of operation throughout their design process. It was envisioned that it this theory of operation would be used to identify how they plan to operate the system, including the identification of any legislation or regulatory constraints that may impede or prevent optimal operation. The teams were presented with the recommendation to consider what changes or additional guidance may be necessary to further facilitate the growth of UAS for precision agriculture. The result of this consideration would be the identification of why such flight should be permissible as a case submission to the FAA.

Learning Opportunities for Students

To enhance the learning opportunities, the students were provided a suite of tools for the design and analysis of their system designs. This enabled them to make modifications to selected system components and quickly explore the design space and compare to the requirements. Providing the students with this detailed tool suite enabled them to modify the system based on their own ideas, but yet reduced the variability of how the solutions were reported. Thus, providing common metrics to evaluate the solutions each team presented.

The suite contained: spreadsheets, Computer Aided Design (CAD) models, and aerodynamic performance computations. Table 1 shows a sample of the potential inputs the students were able to select to explore the system design space from a cost perspective. The spreadsheets included information related to systems acquisition and life cycle cost (LCC) which feed directly in the objective function computation. The LCC included costs for mission operation. Within the spreadsheets students were able to compare and contrast solutions for components such as sensors and propulsion systems.

Table 1: System Costs

PAYLOAD (SENSOR)		
Payload (Sensor) Subtotal Cost		**ENTER PAYLOAD DATA**
Air Vehicle Element (UAV) Designs		
Air Vehicle Element (UAV) Design-1		
Airframe Configuration Design	$	-
Additional Flight Control Options	$	-
Alternate Powerplant (Propulsion) Options	$	-
Onboard Sensor Options	$	-
Additional Options	$	-
Air Vehicle Element (UAV) Design-2		
Airframe Configuration Design	$	-
Additional Flight Control Options	$	-
Alternate Powerplant (Propulsion) Options	$	-
Onboard Sensor Options	$	-
Additional Options	$	-
Air Vehicle Element (UAV) Design-3		
Airframe Configuration Design	$	-
Additional Flight Control Options	$	-
Alternate Powerplant (Propulsion) Options	$	-
Onboard Sensor Options	$	-
Additional Options	$	-
Air Vehicle Element (UAV) Design-4		
Airframe Configuration Design	$	-
Additional Flight Control Options	$	-
Alternate Powerplant (Propulsion) Options	$	-
Onboard Sensor Options	$	-
Additional Options	$	-
Air Vehicle Element (UAV) Design-5		
Airframe Configuration Design	$	-
Additional Flight Control Options	$	-
Alternate Powerplant (Propulsion) Options	$	-
Onboard Sensor Options	$	-
Additional Options	$	-
Air Vehicle Element (UAV) Designs Subtotal Cost		**ENTER AIR VEHICLE DATA**
Command, Control, and Communication (C3) Equipment		
Control/Data Processing and Display Options	$	-
Communications Equipment Options	$	-
Additional C3 Options	$	-
C3 Subtotal Cost		**ENTER C3 DATA**
Support Equipment		
Support Equipment Subtotal Cost		**ENTER SUPPORT EQUIP DATA**
Engineering/Construction Labor		
Engineering/Construction Labor Subtotal Cost		**ENTER ENG LABOR DATA**
TOTAL UAS COST (System Initial Cost)		**ENTER DESIGN DATA**

As part of this competition, students are expected to create 3-dimensional (3D) CAD models. PTC CREO(r) modeling software is used for this purpose. Students are provided with the baseline CAD models. They have the option of either modifying the baseline models based on their analyses or design a new model from scratch. This exercise not only exposes students to an engineering design tool but also encourages creativity and innovation. The baseline models include fixed wing pusher configuration, tractor configuration, pure rotary wing configuration, multi-rotor and hybrid configurations. Pictures of the baseline CAD models are shown in Figure 4.

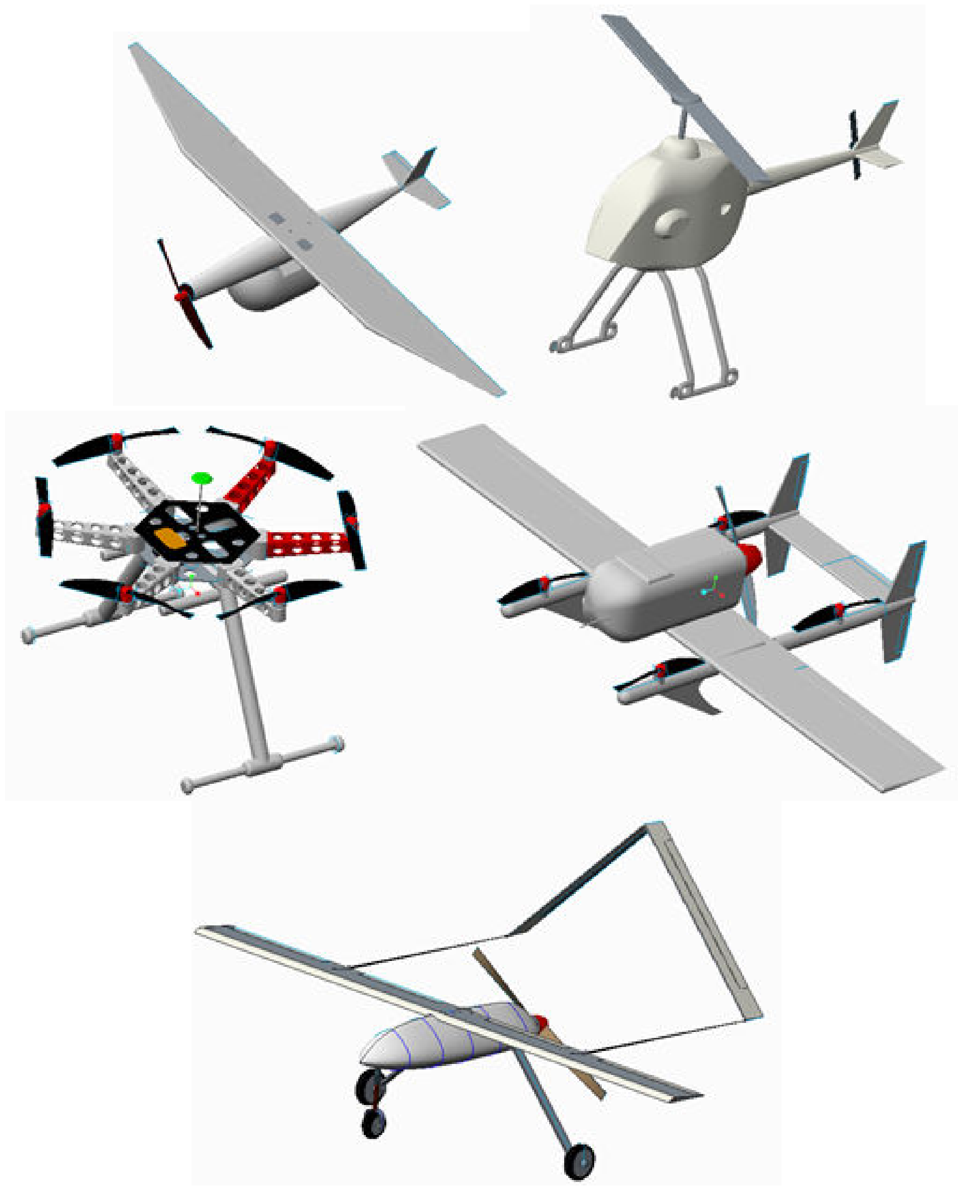

Figure 4: Baseline CAD Models provided to students

More detailed engineering analysis on the air vehicle performance, both fixed-wing and rotorcraft solutions, and the computation of the objective function were enabled through the use of PTC Mathcad ®. Mathcad is an interactive programming tool that allows users to easily modify and visualize the computations. Figure 5 shows an example of a computation found in the Mathcad worksheets made available to the students. This illustrates the readability provided by Mathcad. It provides a visual forum and enables the students easily understand what computations are being performed. It is an interpretive tool so the new solutions are immediately available to the students once changes to the input variables are made. Other computations available within the Mathcad worksheet included aerodynamic performance of the selected wing design, vehicle performance such as best velocity to achieve maximum range, and power calculations for the rotorcraft designs.

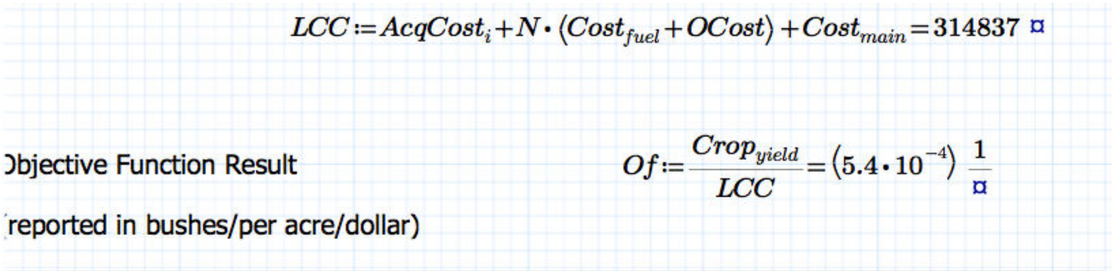

Figure 5: Excerpt from Mathcad Worksheet

Competition Timeline

A timeline is established. Important dates are summarized in Table 2.

Table 2: Competition Timeline

Event	Date
State Challenge Issued	October 10, 2013
Team Registration Deadline	December 20, 2013
Solution Submission Deadline	March 31, 2014
State Challenge Digital Submission Scored by Judges	April 1-10, 2014
State Winners Announced	April 10-20, 2014
National Challenge Issued	April 21, 2014
Solution Submission Deadline	November 3, 2014
National Challenge Digital Submissions Scored by Judges	November 3-14, 2014
National Challenge Event	November 14-16, 2014

Scoring Rubric

A rubric, for use by the competition judges to score and evaluate each student team entry, was developed by the challenge development team for the FY14 challenge. The design of the FY14 rubric was based on a baseline format used in previous years, with updates aligned with categorical coverage of the competition focus areas, including team engagement, system design, mission plan, and business case. The team engagement represents 12.3 percent (12.3%; 45/365 points) of the total scoring and is further subdivided, including assessment areas for team formation and project operation, acquisition and engagement of mentors, project goal identification, tools setup and use, and impact on STEM. System design represents 37 percent (37.0%; 135/365 points) of the total scoring and is subdivided to include design, component selection, considerations, weight and balance, analyses, CAD modeling, and identification of flight vehicle dimensions. Mission plan represents 19.2 percent (19.2%; 70/365 points) of the total scoring and is subdivided to include precision agriculture crop sensing pattern, system detection and identification, example mission, and mission time and resource requirements. Business case represents 19.2 percent (19.2%; 70/365 points) of the total scoring and is subdivided to include identification of targeted commercial applications, system costs, market assessment, and cost/benefit analysis and justification. The assignment of value for each focus area (i.e., scores out of 365) was determined based on identified importance of the tasks to the final design, as determined by the challenge development team. Each team member was provided an opportunity to propose changes or modifications, which were incorporated into the final design after internal deliberation.

Training Material

In addition to the baseline models, students are also provided with the webinars. These webinars contain videos describing the challenge in detail. Students are introduced to the key engineering concepts. The webinar are also useful for learning the various design tools.

Webinars

Module 1 - Overview of UAS, a series of videos covering an introduction and overview of UAS, including definition, missions, how they work (i.e., operate), associated regulation, certification, and licensure, subsystems/elements, and example system designs.

Module 2: Precision Agriculture and UAS, three-part series of videos covering an introduction to precision agriculture applications, operational considerations related to the implementation of UAS in precision agriculture (i.e. platform performance, electromagnetic spectrum, spectral signatures, sensor types, resolution), and an overview of the design challenge scenario and considerations.

Module 3 - Engineering Design and Aeronautical Performance Factors, a series of videos covering an overview of the engineering design process, description of process models, associated design diagramming, overview of systems engineering, and aeronautical performance factors for fixed-wing and rotary-wing aircraft.

Module 4 - Business Case, video covering business principles and concepts that could be used to develop the business case and manage the engineering development effort.

Module 5 - Use of RWDC Design Tool, a series of videos describing how to use several of the essential design tools, including the PTC Creo application for 3D CAD, MathCAD, weight and balance calculator spreadsheet, camera footprint calculator spreadsheet, and cost calculator spreadsheet.

Mentor Webinar, a video covering the roles and responsibilities of the team mentors, the background of the challenge scenario, and a discussion of important considerations.

Conclusion

In this paper, an overview of the Real World Design Challenge (RWDC) is provided. The purpose of the competition is to promote STEM education. A brief history of the challenge is provided. High school students are introduced to the engineering approach used to solve real world problems. An inquiry based approach is used to encourage engaged learning. The challenge is based on designing and using Unmanned Aircraft Systems (UAS) to identify the presence of corn-borer as a target pest. Students are tasked with designing and identifying the various components including the aerial vehicle, sensors, tools, and communication devices needed to make the system work. The authors of this paper and the designers believe that participation in a design challenge like RWDC broadens the minds of students, encourages active participation, prepares them for a STEM career and most importantly sets them on a path of lifelong learning.

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References

[1] Ralph Coppola, Real World Design Challenge [RWDC] (2013, October 15) Retrieved from http://www.realworlddesignchallenge.org/

[2] Pascal D. Forgione, Jr., (2013, October 15), International Test Scores http://4brevard.com/choice/international-test-scores.htm

[3] Todd, R. & P. Hutchinson (2000), "The Transfer of Design and Technology (D&T) to the United States: A Case Study", The College of New Jersey, Ewing, NJ

[4] Hodgson, T. & C. Allsop (2002), "Beyond Pro/DESKTOP Computer Aided Design (CAD): the transfer of CAD-based design modelling skills from schools to Higher Education", Department of Design and Technology, Loughborough University, UK, P. 7.

[5] Scheer, M. (2008). DOE to sponsor 'Real World Design Challenge' for high school students. Retrieved from http://www.realworlddesignchallenge.org/pdf/News.pdf

[6] The 9 billion-people question. (2011, February 24). *The Economist.* Retrieved from http://www.economist.com/node/18200618

[7] Food and Agriculture Organization of the United Nations. (2009, September 23). 2050: A third more mouths to feed. Retrieved from http://www.fao.org/news/story/en/item/35571/

[8] Perry, E.M., Brand, J., Kant, S., & Fitzgerald, G.J. (2012). Field-based rapid phenotyping with unmanned aerial vehicles (UAV). *Proceedings of 16th Australian Agronomy Conference 2012.* Retrieved from http://www.regional.org.au/au/asa/2012/precision-agriculture/7933_perrym.htm

[9] Platt, J.R., (2011). Career focus: Systems engineering. *IEEE Today's Engineer.* Retrieved from http://www.todaysengineer.org/2011/nov/career-focus.asp

[10] Sheard, S.A. (1996). Twelve systems engineering roles. *Proceedings of the INCOSE Sixth Annual International Symposium*. Retrieved from http://incose.org/educationcareers/PDF/12-roles.pdf

[11] Hevers, T.E., Daehler, E.S., & Peck, M.A. (2013). Applying University Small Satellite Program lessons to a career in the aerospace industry. *27th Annual AIAA/USU Conference on Small Satellites.*

[12] Embry-Riddle Aeronautical University-STEM Academy. (2013, October 15). About the STEM initiative. Retrieved from http://stemacademy.erau.edu/about-us/index.html

[13] Burke da Silva, K. Auburn, Z., Hunter, N., & Young, J. (2008). Engaging students and improving learning outcomes with inquiry based biology practical classes. *Proceedings of the Visualisation for Concept Development Symposium,* 24-29. Retrieved from http://ojs-prod.library.usyd.edu.au/index.php/IISME/article/view/6237/6885

[14] Annenberg Learner. (2013, October 15). Learning science through inquiry: Frequently asked questions. Retrieved from http://www.learner.org/workshops/inquiry/resources/faq.html

[15] McGrath, M. (2011). *Setting the pace in product development* . (revised ed.). New York, NY: Routledge.

[16] Terwilliger, B., Shepherd, A., Sanders, B., Khalid, A., Marion, J., Lange, P., & Bourdeau, D. (2013). *FY14 state unmanned aircraft system challenge: Precision agriculture, detailed background document.* Washington, DC: Real World Design Challenge

[17] Educational Broadcasting Corporation. (2004). *Workshop: Inquiry-based learning*. Retrieved from http://www.thirteen.org/edonline/concept2class/inquiry/

[18] Rajala, S.A. (2012). Beyond 2020: preparing engineers for the future. *Proceedings of the IEEE, 100*, 1376-1383.

[19] Stephenson, N.L. (2013, October 14). *Introduction to inquiry based learning.* Retrieved from http://teachinquiry.com/index/Introduction.html

[20] Toscano, M. (2013). *Connecting the unmanned system community across the globe.* Presented at the AIAA Policy Symposium: Civilian Applications of UAVs – A California Perspective, Westlake Village, CA. Retrieved from http://www.aiaa.org/uploadedFiles/About-AIAA/Press-Room/Key_Speeches-Reports-and-Presentations/2013_Key_Speeches/CA_Aerospace_Week_2013/Toscano-CAUAV2013.pdf

[21] University of Arkansas at Little Rock, Department of Systems Engineering. (2013, October 15). Outreach. Retrieved from Author website: http://ualr.edu/systemsengineering/about/outreach/

[22] Wilson, D., Kisenwether, E., Capuro, R., Bilen, S. & Nemes, J. (2011). *A capstone exposure to the systems engineering process: Student's experience with the DoD's Pre-positioned Expeditionary Assistance Kits (PEAK) system*. University park, PA: The Pennsylvania State University, Systems Research Center. Retrieved from http://www.ndia.org/Divisions/Divisions/ScienceAndEngineeringTechnology/Documents/Capstone%20Exposure%20to%20the%20Sytems%20Engineering%20Process.pdf