# FY21 RWDC National Unmanned Aircraft System Challenge: Urban Package Delivery and Flight Coordination

## Background

Small Unmanned Aircraft Systems (sUAS) have near-term potential for numerous civil and commercial applications. The FY21 RWDC State challenge will continue the focus on Unmanned Aircraft Systems and implementation of a UAS. This year’s mission is to support package delivery in an urban environment. 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 (and apply) 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 Aircraft 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 in an engineering design notebook:

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

As you progress through the challenge, your team will incrementally be presented with background relating to the composition and operation of Unmanned Aircraft System designs, engineering design principles, business management, and development tools. 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 Aircraft System technology, and work collaboratively towards completion of a common goal.

## Challenge

This year’s challenge is to design Unmanned Aircraft Systems (UAS), 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 the results of your initial proposal, the city has asked your Company to continue to the next round. A few changes have been made to clarify requirements in regards to the UAS and business plan.*

*A city in the USA has announced that it will be allowing package deliveries using UAS, and your Company is pursuing this opportunity. Different levels of the city, state, and federal governments have worked together to develop a set of criteria that interested companies must meet in order to use UAS to deliver packages within the city limits. The purpose of these criteria is to ensure public safety and to establish performance requirements for UAS. Only companies that meet all criteria will receive a license to conduct UAS package deliveries with the city limits.*

***UAS Airfield:*** *The city has developed a UAS Airfield from which all companies will operate. Each company will be provided (via a lease) a warehouse/hanger and additional land for UAS staging. All package deliveries will be within a 5-km radius of the UAS Airfield.*

* *Assumptions*
  + *The airfield is at standard sea level with no winds at ground level or aloft.*
  + *The warehouse/hanger is of sufficient size to store one-half day of packages and all aircraft*
  + *The layout of the warehouse/hanger includes an area for UAS control (equipment provided by the company) and UAS maintenance (equipment provided by the company)*
  + *Packages to be delivered by UAS will arrive by truck to the warehouse/hanger throughout the day*
* *Requirements*
  + *All takeoff/landing (vertical only), loading of packages, refueling/recharging, and any additional aircraft checks will take place in one of three 10 m X 10 m staging areas in front of the warehouse/hanger*
  + *Only 1 aircraft may be in a single staging area at a time.*
  + *The 3 staging areas are side-by-side with a 3 m space between them*
  + *The 3 staging areas are 15 m away from the warehouse/hanger*
  + *Equipment may be moved into and out of each staging area as needed*

***Flight Corridors:*** *Flight corridors throughout the city have been created and UAS must stay within these flight corridors when flying from the UAS Airfield to the delivery sites. The City UAS Traffic Control (CUTC) will set speeds and flight altitudes within the flight corridors based on UAS traffic.*

* *Assumptions*
  + *Atmospheric conditions are based on the standard atmosphere at altitude.*
  + *No winds aloft.*
* *Requirements*
  + *Minimum flight speed is 35 kt; maximum flight speed is 55 kt*
  + *Minimum altitude is 150 m; maximum altitude is 250 m*
  + *After takeoff from the UAS Airfield, aircraft must reach Flight Corridor altitude and airspeed while staying in a 150-m radius of the airfield.*
  + *For landings at the UAS Airfield, aircraft must descend from Flight Corridor altitude while staying in a 150-m radius of the airfield.*
  + *Above the UAS Airfield and at each delivery zone there will a holding area at 150-m altitude in case there is a wait for clearance to land.*
  + *Before an aircraft can takeoff or land at the airfield, clearance must be given by the CUTC control tower at the UAS airfield.*

***UAS Command, Control, and Communication:***

* *Assumptions*
  + *Additional communication towers have been set up by the city along the flight corridors*
* *Requirements*
  + *Only 20 aircraft from a single company may be in the air at a single time*
  + *Redundant systems in case of failure*
  + *Aircraft must have a transponder that identifies itself to CUTC and provides current speed, heading, and altitude*
  + *Aircraft must be continuously monitored by command personnel at the UAS Airfield*
  + *Aircraft must be able to receive new commands while in flight and be able to modify its flight pattern accordingly*
  + *A human pilot must be able to take manual control if necessary.*

***Package Delivery:*** *Deliveries will only be made to designated spots within the city. These designated delivery areas will be on top of buildings.*

* *Assumptions*
  + *Delivery zones will be set up by the managers of the buildings.*
  + *Building managers will be responsible for the required personnel to monitor deliver zones and remove packages.*
  + *There will be a holding area above the building at 150 m*
* *Requirements*
  + *A building will only have one delivery zone*
  + *A delivery zone will measure 3 m by 3 m*
  + *Aircraft must land within the delivery zone to deliver the package. Packages* ***cannot*** *be lowered to the delivery zone nor dropped.*
  + *Only vertical takeoffs and landings are allowed for the delivery zone*
  + *An automatic system must be used to leave the package at the delivery zone. No person will be available to remove the package from the aircraft.*
  + *Aircraft will takeoff immediately after delivering the package.*
  + *Aircraft must descend and ascend to Flight Corridor altitude within a 100-m radius of the delivery zone.*
  + *Aircraft cannot descend to deliver its package until it has received a signal that it is safe to do so.*
  + *Aircraft can only carry one package, which weighs 5 kg and has the dimensions of 0.5 m by 0.5 m by 0.25 m.*

***Flight Performance:***

* *An example flight profile has been provided. By being able to complete this flight profile, the UAS demonstrates that it satisfies the performance requirements needed to delivery packages within the city.*
  + *Takeoff with a package from a staging area at the UAS Airfield and ascend to 250 m within the 150-m radius around the UAS Airfield.*
  + *Fly for 5 km at an altitude of 250 m. The flight speed must be the most inefficient (i.e. uses the most fuel or battery charge) between 35 kt and 55 kt. The aircraft has reached the delivery area.*
  + *Descend to 150 m and loiter for 10 min (must stay within the 100-m radius of the delivery zone). The flight pattern during the loiter is up to your company. Rotorcraft may hover in place while fixed-wing aircraft may fly a pattern as long as it is within the 100-m radius of the delivery zone.*
  + *Descend and land in the delivery zone, which is located at an altitude of 60 m.*
  + *Delivery the package.*
  + *Ascend to 250 m staying within the 100-m radius of the delivery zone.*
  + *Fly for 5 km at an altitude of 250 m. The flight speed must be the most inefficient (i.e. uses the most fuel or battery charge) between 35 kt and 55 kt. The aircraft has reached the UAS Airfield.*
  + *Descend to 150 m and loiter for 10 min (must stay within the 150-m radius of the UAS Airfield). The flight pattern during the loiter is up to your company. Rotorcraft may hover in place while fixed-wing aircraft may fly a pattern as long as it is within the 150-m radius of the UAS Airfield.*
  + *Descend and land at a staging area.*
* *The performance of the aircraft completing the above flight profile is assumed for a standard delivery flight.*
* *In addition to the flight profile, the city wants to know the descending and ascending performance of the aircraft. This information will be used by CUTC in case the aircraft needs to change altitude within a flight coordinator*
  + *Calculate the descending speed and horizontal distance traveled for the aircraft to change from 250 m to 150 m at flight corridor speed while carrying the package.*
  + *Calculate the ascending speed and horizontal distance traveled for the aircraft to change from 150 m to 250 m at flight corridor speed while carrying the package.*
  + *Calculate the descending speed and horizontal distance traveled for the aircraft to change from 250 m to 150 m at flight corridor speed while empty (no package).*
  + *Calculate the ascending speed and horizontal distance traveled for the aircraft to change from 150 m to 250 m at flight corridor speed while empty (no package).*

***Safety:*** *Ensuring public safety is paramount. UAS must adhere to at least the following safety measures in order to be qualified for package deliveries.*

* ***Guidance without GPS (or any other global navigation satellite systems):*** *Even though the city is adding communication towers along Flight Corridors, aircraft cannot solely rely on GPS for navigation. Aircraft must be able to accurately navigate the city when GPS signal is lost or if there is signal interference.*
* ***Lost communications:*** *Protocols must be in place if communication is lost with the aircraft.*
* ***Obstacle avoidance:*** *The aircraft must be able to avoid all stationary and moving obstacles. Geofencing should be used for known fixed objects such as buildings. The aircraft must be able to detect and avoid moving objects or any other stationary objects not included in the geofencing. The aircraft must be able to stay at least 1 m from any obstacles.*
* ***Beyond line of sight:*** *The aircraft must be able to operate beyond line of sight. The aircraft must be monitored during the entire flight, and the aircraft must have a system for a pilot to take control of the aircraft when needed.*
* ***One engine out condition:*** *The aircraft must be able to continue safe and controllable flight if an engine fails. Protocols during an engine out condition will depend on aircraft configuration. For multi-engine aircraft*
  + *If engine fails between takeoff and halfway to delivery zone, the aircraft must safely return and land at UAS Airfield.*
  + *If engine fails past the halfway point to the delivery zone, the aircraft must complete the delivery. Aircraft will then stay at delivery location.*
  + *If engine fails before the halfway point on the way back from a package delivery, the aircraft must safely return and land at the delivery location.*
  + *If engine fails after the halfway point on the way back from the package delivery, the aircraft must complete its flight to the UAS Airfield and land.*
* ***Emergency landings:*** *The aircraft must have a procedure to make an emergency landing in case of a failure on the aircraft or it encounters a scenario in which it does not know how to respond. The aircraft must try to find a location to land that minimizes damage to property and injury to people. The aircraft must provide visual and auditory cues to warn people during the landing. To protect property and people, propellers on fixed-wing aircraft must be foldable and not be spinning during landing. Rotors on multirotor aircraft must be enclosed so that the blade tip cannot strike any object.*

***Business case:*** *The goal of the business will be to maximize the profitability of the business. Deliveries may only be made for a 12-hour window each day. Successful companies will be able to both account for and minimize all of their costs while maximizing the number of deliveries they are able to conduct given the restraints.*

* ***Account for all costs****: Teams will need to account for all of the costs of operating the aircraft*
  + ***Fixed costs****: Calculate what the fixed costs are. These include the cost of all of the equipment needed to fly such as the UAS, Command Communication equipment (command center, communication arrays, etc.), the rental of the warehouse (will cost $25,000 per week), support equipment (any other things you might need to operate), etc.*
  + ***Variable costs****: You will need to calculate the cost to fly. How much is spent on fuel, charging batteries, and personnel. You need to determine how much these will cost per flight and per day based on the personnel and fuel requirements for your aircraft.*
  + ***Justification of cost****: Your team will need to explain why the cost of all of the equipment is justified especially components of the UAV. The cost of components must be justified to explain what value they give to the system. Successful teams will not only justify the use of components but explain how components fit into the teams overall strategy.*
* ***Maximizing profit****: Your team will charge $150 per package they deliver. You will be maximizing profits by minimizing expenses and by completing more flights. Teams will need to demonstrate how they plan to become profitable over time.*

## Objectives

Your designs will be judged on how well they satisfy the objectives while meeting the requirements above. You are also allowed to use more than one design in your system as long as you can justify how the additional UAVs will improve your profitability. It will be up to your team to decide the number of deliveries you will make and provide sound engineering arguments to justify your design decisions.

* Minimize your costs
* Maximize profit for your company
* Maximize the number of packages delivered in a day

## Other Resources

* RWDC National Unmanned Aircraft System Challenge: Detailed Background
* RWDC National Engineering Design Notebook Template
* RWDC National Challenge Scoring Rubric
* Your choice of system control hardware, sensor selection, remote vehicle element(s), Command Control Communications (C3), support equipment, and other subsystem components is not solely limited to cataloged items provided in the Detailed Background; substitutions are permissible and **highly** **encouraged** with justification and analysis provided in the design decisions in the Engineering Design Notebook.
* Challenge Statements and Detailed Backgrounds from previous RWDC competitions
* Winning Engineering Design Notebooks from previous years
* RWDC Content Webinars (schedule to be determined)
  + Overview of Unmanned Aircraft Systems (UAS)
  + Systems Engineering and Vehicle Performance Factors
  + 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 Computer Aided Design (CAD) software for 3D geometry design (if you have other CAD tools you may use them)
* 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 RWDC FY21 National Challenge Scoring Rubric. Teams must submit the following:

1. Engineering Design Notebook (refer to RWDC FY21 National Challenge Scoring Rubric)
2. CAD drawings in Engineering Design Notebook (refer to RWDC FY21 National Challenge Scoring Rubric)

## Scoring

* Teams’ submissions will be evaluated based on criteria outlined in the RWDC FY21 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 FY21 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 the package delivery mission

## Merit Awards

Special RWDC Merit Awards will be given at the National/International 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
* Judges Award

## Contacts

Dr. Ralph K. Coppola

Founder & Executive Director, Real World Design Challenge

Phone: 703-298-6630

Email: [rkcoppola@yahoo.com](mailto:rkcoppola@yahoo.com)

## Authors

Dr. Robert Deters

Associate Professor, Embry-Riddle Aeronautical University-Worldwide

Jeff Coppola, MBA

Program Manager, Real World Design Challenge