# FY22 RWDC State Unmanned Aircraft System Challenge: Airspace Integration of UAS Package Delivery

## Background

Small Unmanned Aircraft Systems (sUAS) have near-term potential for numerous civil and commercial applications. The FY22 RWDC State challenge will continue the focus on Unmanned Aircraft Systems and implementation of a UAS. This year’s mission is to support UAS package delivery and its integration into the airspace. 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:*** *A city in the USA has announced that it will be part of a pilot program to study how UAS can be safely integrated in the National Airspace System (NAS). As part of this program, the city is seeking companies to develop a UAS to safely deliver packages in the vicinity of the city. In order for a company to be considered to participate in this pilot program, a set of criteria have been developed that proposed designs must meet. Successful design proposals may be invited to the next round.*

***Overall UAS Design Criteria:***

* *The UAS shall deliver a package to a location 15 km away from the designated UAS Airfield.*
* *Packages weigh 5 kg and have the dimensions of 0.5 m by 0.5 m by 0.25 m.*
* *Only one package at a time will be carried by the UAS.*
* *Packages shall be removed by hand from the UAS at the delivery location.*
* *The UAS shall have a sufficient C3 (command, control, and communication) system to provide safe beyond visual line of sight (BVOLS) flight.*
* *The UAS shall have a sufficient detect and avoid (DAA) system.*
* *The UAS shall have a well-defined Lost Link protocol.*

***UAS Airfield:*** *The city has redeveloped a General Aviation (GA) airport into a UAS Airfield from which all companies will operate. Only UAS will operate at this airfield. Each company will be provided (via a lease) a warehouse/hanger and additional land for UAS staging. All package deliveries will be within a 15-km radius of the UAS Airfield.*

* *Assumptions*
  + *The airfield is at standard sea level with no winds at ground level or aloft.*
  + *The airfield has a single paved runway with a length of 3,000 ft (914 m) and a width of 60 ft (18 m).*
  + *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*
  + *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 10 m away from the warehouse/hanger.*
  + *Equipment may be moved into and out of each staging area as needed.*
  + *Aircraft may takeoff/land vertically or use the runway (horizontal)*
  + *Vertical* 
    - *Takeoff/landing must occur in a single designated 3 m X 3 m zone.*
    - *Takeoff/landing zone is located 10 m away from the staging areas.*
    - *Only one aircraft may use the designated takeoff/landing zone at a time.*
    - *All personnel must be clear of the takeoff/landing zone (back near staging areas) before any takeoff or landing.*
  + *Runway*
    - *For takeoff, assume that it takes 10 min for aircraft to leave the staging area and start its takeoff roll. This time will account for taxiing and waiting for clearance to takeoff.*
    - *For landing, assume that it takes 5 min for the aircraft to taxi to the staging area after landing.*
  + *Before an aircraft can takeoff or land at the airfield, clearance must be given by the control tower at the UAS airfield*

***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.*
  + *Flight corridors are clear of permanent obstructions (e.g., buildings, towers) starting at minimum altitude (see below).*
* *Requirements*
  + *Minimum flight speed is 35 kt; maximum flight speed is 87 kt*
  + *Minimum altitude is 200 ft (61 m) above ground level (AGL); maximum altitude is 400 ft (122 m) AGL*
  + *After takeoff from the UAS Airfield, aircraft must reach Flight Corridor altitude and airspeed within a maximum distance (horizontal) of 150 m.*
  + *For landings at the UAS Airfield, aircraft must descend from Flight Corridor altitude to landing location within 500 m (horizontal).*
  + *Adjacent to the UAS Airfield and above each delivery zone there will a holding area at 200-ft (61 m) altitude in case there is a wait for clearance to land. The holding areas have a radius of 500 m.*

***Package Delivery:*** *Deliveries will only be made to designated spots within the city. These designated delivery areas may be at ground level or on top of buildings. For performance calculations, only ground level deliveries will be considered.*

* *Assumptions*
  + *Delivery zones will be staffed.*
  + *A person will be available to remove the package from the UAS.*
  + *Delivery site managers will be responsible for the required personnel to monitor deliver zones and remove packages. The personnel at these locations are outside of your company.*
* *Requirements*
  + *A delivery area will only have one delivery zone*
  + *A delivery zone will measure 3 m by 3 m*
  + *Only vertical takeoffs and landings are allowed for the delivery zone*
  + *Aircraft must land within the delivery zone to deliver the package.*
  + *All propellers/rotors must be stopped after landing.*
  + *Aircraft will not have a delivery system. Packages must be removed by a person at the delivery area.*
  + *Aircraft must wait for an all clear signal after delivery before taking off.*
  + *Aircraft must descend and ascend to Flight Corridor altitude within a 100-m horizontal distance of the delivery zone.*
  + *Aircraft cannot descend to deliver its package until it has received a signal that it is safe to do so.*

***UAS Command, Control, and Communication (C3):*** *(see Detailed Background for more information)*

* *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.*
  + *Aircraft must be able to safely fly BVLOS.*
  + *Aircraft cannot solely rely on global navigation satellite systems (e.g., GPS). Aircraft must be able to accurately navigate when satellite navigation signal is lost or if there is signal interference.*

***Detect and Avoid (DAA) System:*** *(see Detailed Background for more information)*

* *Requirements*
  + *Aircraft must detect static and dynamic obstacles.*
  + *Aircraft must avoid conflicts.*
  + *DAA system architecture must fit C3 capabilities.*

***Lost Link Protocol:*** *(see Detailed Background for more information)*

* *Requirements*
  + *Aircraft must have protocols in case of partial loss of communications*
  + *In case of total loss of communication, aircraft must be capable of safely returning to the UAS Airfield.*

***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 the UAS Airfield and ascend to 400 ft (122 m). If using the runway, take into account required taxiing time/energy.*
* *Fly for 15 km at an altitude of 400 ft (122m). The aircraft has reached the delivery area.*
* *Descend to 200 ft (61 m) and loiter for 10 min. 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 holding area radius.*
* *Descend and land in the delivery zone, which is located at ground level.*
* *Shut down all propellers/rotors so package may be removed from the aircraft.*
* *Restart propellers/rotors, takeoff, and ascend to 400 ft (122 m).*
* *Fly for 15 km at an altitude of 400 ft (122 m). The aircraft has reached the UAS Airfield.*
* *Descend to 200 ft (61 m) and loiter for 10 min. 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 holding area radius.*
* *Descend and land at the UAS Airfield. If using the runway, take into account required taxiing time/energy.*

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

* ***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. Emergency landings are a last resort. 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. Power must be discontinued to helicopter rotors at least 3 m above the ground.*

***Business case:*** *The goal of the business will be to maximize the profitability of the business. For this scenario teams will determine how much to charge a customer to deliver a package. Teams will not only calculate how much it will cost to fly each mission but will also decide the amount of profit they would like to make on each flight to determine the final cost to customers. Teams will need to be able to calculate their fixed costs and variable costs, and be able to amortize the costs (Additional information on making these calculations available in the Detailed Background document) to determine how much to charge customers. Teams will be using the following assumptions when making their calculations:*

* *Deliveries may only be made for a 12-hour window each day.*
* *Calculations for amortization and profitability will be done over a year (a year is determined assuming 365 days 12 hours a day in the same weather every day)*
* *Teams will assume there is an unlimited number of customers each day.*
* ***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.), 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.*
  + ***Amortization of costs****: This is a method of accounting for your fixed costs in your price. Teams will calculate the cost for each flight by determining how much they need to account for Fixed costs and how much will be used for Variable costs (additional information on making these calculations available in the Detailed Background document). Calculating how much to account for your fixed and variable costs will be determined by both expenses for fixed and variable costs (as listed in definitions above) and the amount of flights you are able to do in a day.*
* ***Profit****: Your team will determine how much profit you would like to make on each flight. Teams can decide how much profit to charge but should make sure that the total cost to the customers remains reasonable.*
* ***Price for the Customer and Justification:*** *Price for the customer is the price that people will pay to have a package delivered by your company. It is calculated by adding your amortized costs to your profit. Teams will need to not only determine the final amount that they are charging customers but also explain why the price is reasonable. The Justification should compare how the price could compete with other delivery services (both other UAV delivery services and conventional).*

## 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 State Unmanned Aircraft System Challenge: Detailed Background
* RWDC State Engineering Design Notebook Template
* RWDC State 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 FY22 State Challenge Scoring Rubric. Teams must submit the following:

1. Engineering Design Notebook (refer to RWDC FY22 State Challenge Scoring Rubric)
2. CAD drawings in Engineering Design Notebook (refer to RWDC FY22 State Challenge Scoring Rubric)

## Scoring

* Teams’ submissions will be evaluated based on criteria outlined in the RWDC FY22 State 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 FY22 State 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

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