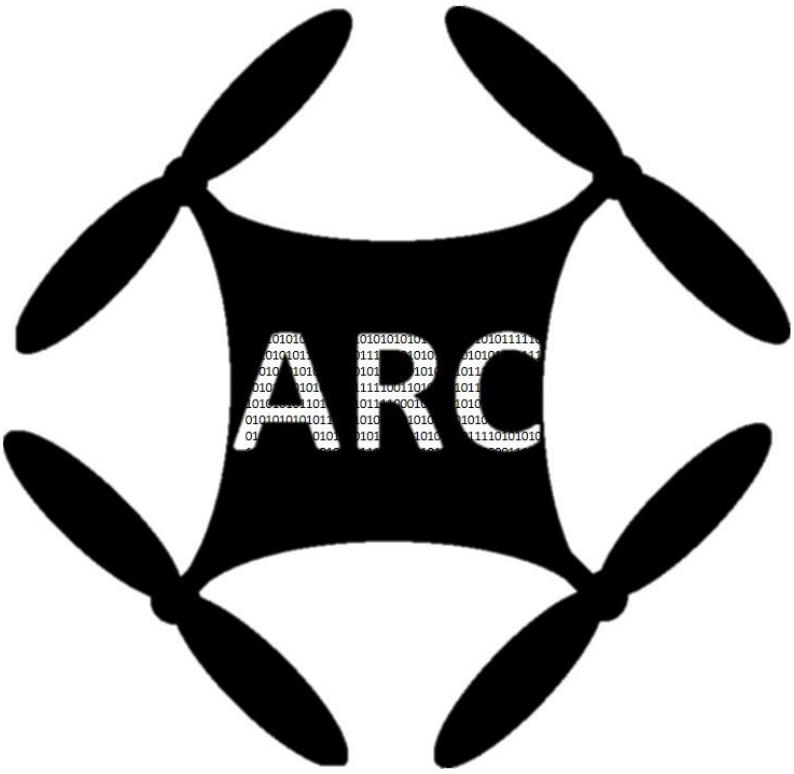

Aerospace Robotics Competition

Rule Book

2019/2020

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Competition Overview

The Aerospace Robotics Competition (ARC) seeks to ignite the passion in aerospace-related STEM work in high schools around the nation. The competition is built upon three pillars:

- Hands-on flying of unmanned aerial vehicles (UAVs)
- Developing knowledge of unmanned and autonomous systems
- Learning about aerospace engineering principles

By definition, autonomy is acting independently, and ARC allows high school students to create UAVs that do just that. Students will program a UAV to act independently of any human pilot. Aspects of the mission will change each year to encompass new challenges, yet still follow the three pillars of the competition. The UAV for this competition will be a quadcopter, which uses four electric motors with propellers to generate lift. The three pillars of the competition are applied via the following sections, each with a corresponding scoring criterion:

1. Autonomous: The UAV will be required to complete an autonomous task, the exact mission of which may change from year to year.
2. Semi-Autonomous: A student pilot will be required to fly the UAV in the completion of a task; the exact mission may change from year to year.
3. Presentation: Teams will demonstrate their understanding of the UAV using core aerospace engineering principles. Creativity is encouraged in their design of the UAV and plan for completing the flight missions; this is where teams can showcase their work.

I. Awards

Prizes will be awarded to the top three teams. The top prizes will be awarded based on total score as aggregated from each of the three parts of the competition. Teams must successfully fly at the competition (take off and sustain flight for over 30 seconds) in order to be eligible for prize money.

1st place:	$1,000
2nd place:	$500
3rd place:	$250

If only 3 teams attend the competition, only the first place prize will be awarded.; if only 4 teams attend competition, only first and second place prize will be awarded. All three prizes will be awarded if the team count in attendance is more than 4.

In addition to monetary prizes, three certificates will be awarded. The winners of these certificates will be chosen by the judges at the competition.

- Sportsmanship prize
- Best Semi-Autonomous Mechanism Design
- Best Autonomous Mission Execution

II. Team Requirements

All members of the team must be full-time high school students. One adult advisor is required and must be listed on the team's application. The advisor may be a teacher, parent, coach, or other adult community member. The advisor is required to attend the competition, but if the advisor cannot attend the competition, notification one month in advance of the event is required in order to register a substitute.

The pilot for the team must be a student member of the team. Each team must also have a student captain, who will be identified by the team after application results are published. While there is no limit on size, it is recommended that the team size should be no larger than 5 students to ensure all team members have an active role. There is no student participant age limitation, as long as they are full-time high school students. Homeschooled students are eligible to either join a local high school team or create their own team if they are full-time high school students; please contact the ARC Working Group in Section XIII with questions.

III. General UAV Requirements

Teams will have the option of purchasing a UAV kit from ARC or using their own UAV components. If teams are using their own components, all vehicles must meet the following requirements. Teams purchasing a kit from ARC may find they need to purchase spare parts, they must ensure the spares meet the following requirements as well. **Teams must operate their vehicles safely; safety requirements are listed in Appendix D.**

A. UAV

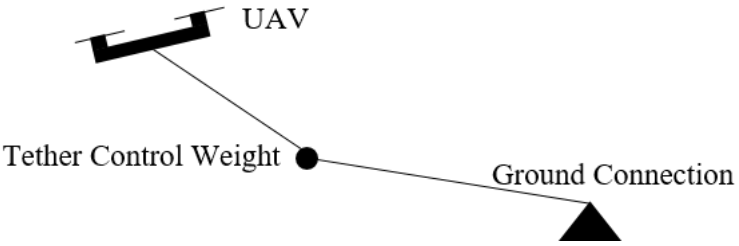
a. The UAV must have 4 motors with 1 propeller each.
b. The UAV may not have any lifting surfaces other than the 4 propellers.
c. The UAV must be registered by the FAA, and the registration number must be visible.
d. Teams must use a Ardupilot-based autopilot system. The MRobotics Pixhawk is highly recommended.

   Note: There are many new systems based off of the Pixhawk from many different companies. Although teams will not be penalized for using a Pixhawk/Pixracer/APM 2.6/Hobbyking Pixhawk/Pixhawk 2, **we highly recommend teams use the Pixhawk from MRobotics as it has been tested by the ARC Working Group.**

e. The UAV must have a telemetry radio that allows it to transmit data to a computer. Having the

transmitter receive telemetry is not sufficient and will not satisfy this requirement.

f. Dimensional limits:
    i. Propellers may not exceed 12 inches in diameter.
    ii. The entire system (quadrotor + mechanism + any associated systems) must fit in a 36-inch by 36-inch by 36-inch box.
g. Battery requirements:
    i. Teams must use a lithium polymer battery.
    ii. Battery cannot have more than 4 cells.
    iii. Teams must use commercially available batteries; homemade batteries are not allowed.
    iv. Teams must use proper battery usage/storage techniques as outlined in Appendix D.
h. To ensure the safety of all students and spectators, each vehicle must have a secure location where a tether can be attached by a carabiner.
    i. The competition tether will be 55 ft of polypropylene twine with a weight tied in the length to prevent it from interfering with the propellers.



    ii. The twine will be secured to the ground on one side and a carabiner on the other side.
    iii. Teams should use a tether for all flights regardless if they are at competition or not.
    iv. NOTE: A tether system will be provided at competition; there is no need to bring a set.

B. Ground Station

Teams must use a ground station to monitor the vehicle during flight. The ground station will be used for the teams and judges to monitor flight characteristics. ARC will not be providing ground stations for the teams even if teams are purchasing a kit from ARC. The requirements of the ground station are as follows.

a. Functions:
    i. Return home function
    ii. Mechanism trigger
    iii. Start mission
    iv. Note: The ground station CANNOT be used to command the UAV to do any other functions during flight (such as modifying the flight plan in flight, manually commanding [through clicking or any sort of human action] the UAV to fly to a waypoint, etc.)
b. Required Vehicle Parameters to be displayed on Ground Station
    i. UAV GPS coordinates
    ii. Altitude

iii. Velocity in the X, Y, and Z directions
iv. Battery level (an additional/separate battery sensor onboard is also acceptable)

c. The ground station must maintain connection to the UAV within 120 ft. This will be tested during Technical Inspection (see Appendix E)
d. Teams may use any open source software that fulfills the requirements stated in the above sections.

C. Sensors
   a. Teams MUST use a GPS sensor that is mounted securely onto the UAV.
   b. Teams may use as many other sensors mounted securely on the UAV as deemed necessary by the team.

These requirements will be verified by a technical inspection, which must be passed to be eligible to compete (requirements listed in Appendix E).

IV. Presentation

A. Presentation will be judged based on content and presentation style of speakers.
   a. Each team will submit their presentation as a PDF document for review 7 calendar days before the competition day. Teams will be contacted after they've been selected to compete with instructions for submitting the presentations.
   b. Presentation content will be graded prior to competition day.
   c. Presentation style will be graded when presentations are given on competition day.
   d. If a team does not submit their presentation 7 calendar days prior to the competition date, the team will receive 0 points for the presentation content.
   e. Only presentations that are submitted by the deadline can be used on competition day, meaning that teams cannot update their presentation after the deadline and ask to present the updated version on competition date. Teams may re-submit presentations if it is outside of the 7-calendar-day deadline.

B. Each team will present for 15 minutes (10-min presentation, 5-min Q&A) covering the required details discussed in the scoring section of Appendix B.

C. Presentation Process
   a. The timekeeper will give a 1-minute warning prior to the 10-minute limit by silently raising his/her hand.
   b. Teams will receive a 5-point penalty if the presentation extends past the 10-minute limit.
   c. Presentations will be stopped at the 11-minute mark.
   d. If a team exceeds 10 minutes, that time will be deducted from the 5 minutes to answer questions; similarly, if a team's presentation is less than 10 minutes, they will have extra time for questions.
   e. Time structure for presentation:

Time	Description
3 minutes	Set up presentation and visual aide (if applicable)
10 minutes	Presentation
5 minutes	Questions
2 minutes	Clean up presentation

V. Competition Schedule

The schedule for the 2019/2020 competition year will be published on the ARC webpage: http://www.aeroroboticscomp.com/

Within 7 days of competition day, a detailed schedule will be sent to teams. This will include times for each team's presentation and technical inspection as well as the flight order for all flight rounds. During the day of the competition, teams must be prepared for the announced schedule of events. Teams that are not prepared when it is their turn for a given event will not be permitted to participate in that event to avoid causing delay of the competition.

VI. Flight Order

The flight competition will begin with the autonomous portion of the competition. After the autonomous portion is complete, teams will compete in the semi-autonomous portion. The flight order for each flight round will be randomized and will be published within one week of the competition. Teams must be prepared to compete per the flight order; teams not ready to fly when it is their turn will forfeit the opportunity to compete in that flight round/portion.

The flight order and number of flight rounds may be subject to change on the day of competition at the discretion of the flight manager due to circumstances such as, but not limited to:

1. Vehicle damage preventing a team from competing
2. Inclement weather delaying the competition schedule
3. A team's vehicle design not complying with technical requirements and therefore not permitted to compete

If the flight manager updates the schedule of flight rounds or the flight order on competition day, this update will be announced prior to each flight round. If the flight order is changed such that teams must be prepared to fly sooner than initially scheduled, there will be a 10-minute preparation period prior to the flight round to ensure teams do not suffer from the change of flight order.

Teams may be given the opportunity for a re-run of a specific flight round due to interference. Participation in a re-run is at the discretion of the flight manager. This re-run is available if a team's flight score was adversely affected by interference. If the flight manager does not think that the interference affected the final results, he/she will not give the team the opportunity for a re-run. Examples of interference include but are not limited to:

1. A team's vehicle crashes during semi-autonomous due to another vehicle intentionally colliding with it.
2. A team is unable to complete the autonomous portion because a different team's radio was on, causing radio interference.

VII. Contest Site

Details of the sites for the competition will be sent to registered teams via email. For contest preparation, teams may obtain historical weather conditions for the competition locations at www.weatherbase.com or www.weatherunderground.com.

VIII. Financial Requirements

Teams selected to participate in ARC will be required to submit a completed Financial Agreement form as linked on the ARC webpage. The requirements will be sent to all selected teams once the team selection is complete. Teams will have the option to purchase a vehicle kit from ARC or to use their own supplies. The payment plan, if electing to purchase a kit from ARC, is outlined in the Financial Agreement Plan.

IX. Competition Application

Teams wishing to participate in the 2019/2020 ARC competition must apply on the ARC website. The dates for the application window will be published on the ARC website. Teams will be notified by the ARC Working Group if they are chosen to compete. Reference Appendix C for the Application Requirements.

X. Scoring

The score sheets and rubrics for technical inspection, the flight rounds, and the presentation will be sent out to teams within one month of the competition date. The scoring method and weight given for each portion of the competition is detailed in Appendix B. Overall, the scoring will break down as follows:

A. Autonomous Mission: up to 300 points
B. Semi-Autonomous Mission: up to 150 points
C. Presentation: up to 150 points

All the points for each team will be combined before making the determination of team rankings.

XI. Judging

A. Autonomous Judging: 3 referees

a. There will be 1 referee monitoring the entire playing field and the ground station
b. There will be 2 referees monitoring the vehicles loiter waypoints. They will judge that the vehicle remains within 2.5 ft of the waypoint in both directions when hovering.

B. Semi-autonomous Judging: 2 referees
   a. There will be 1 referee monitoring the entire playing field and the flight time.
   b. There will be 1 referee monitoring successful ball drops.

C. Judges will be using an Excel document provided by the ARC Working Group to calculate the results of each team.

D. Presentation content will be judged prior to competition day by three judges. During the presentations on competition day, teams' presentation style will be judged by a panel of three judges.

XII. Protest Procedure

All questions and protests on the day of competition should be directed to the Flight Manager.

XIII. Communications

There will be a panel of technical mentors to support the teams throughout the school year. These mentors will have varying areas of specialty so teams will contact different mentors depending on which portion of the competition they need support. Mentors will be introduced to teams after the teams are selected to participate in ARC. Teams are highly encouraged to contact mentors as frequently as needed. There will also be professional mentors who are "industry experts"; these mentors will be an extra layer of support for the teams. Teams should contact these mentors if the technical mentors are unable to support with a specific issue. Teams may also use the industry experts as an opportunity to learn more about commercial applications of UAVs or to develop a professional network for the students.

Any questions for the ARC Staff should be directed to: aero.robotics.comp@gmail.com. The staff can support teams technically, though the technical and industry mentors should be the first point of contact. The staff should be the primary point of contact concerning competition logistics and rule book clarifications.

Questions received by the technical mentors, professional mentors, and the ARC Staff may be posted to the FAQ page on the ARC website if the staff feels the question may be applicable to more than one team.

Each team is required to have a student captain. The student captain will be included in all communication from the ARC Staff and the technical mentors. Teachers are responsible for ensuring that the school has any required parental consent forms in order for students to be able to communicate with the ARC Staff and mentors.

The ARC Staff will setup a forum for teams to communicate with each other during the school year as they build and program their vehicles. Additional details will be communicated via email once teams are admitted to the competition.

Appendix A: Team Supply List for Kit

Should teams choose to use their previously procured supplied instead of purchasing a kit from ARC, the list below is an example of what may be needed for the competition. The following tables include information for the ARC's previously tested competition. This list is intended to serve as an example of what equipment may be needed for completing the competition. Note: A computer/laptop is not included in this list, but is needed for the ground station component.

A. Example of UAV Supply List

Item
Frame
Motors
ESC
Propellers
Propeller Guards
RC 6 Channel Minimum Transmitter & Receiver
PPM Encoder (if RC Transmitter is PWM output)
Pixhawk + GPS (mrobotics) + Telemetry Radio (900 MHz)
LiPo 4 cell battery
Servo
Lipo Battery Bag
Battery Charger

Appendix B: 2019/2020 Mission Details

ARC is a team competition with multiple parts. Before being eligible to fly, each team will have to pass the technical inspection. The scoring strategy is different for each flight portion. The autonomous flight portion has up to 300 points possible. The percentage of the full points received for autonomous flight is based on the number of waypoints successfully completed and the time in which the team completes the flight. The semi-autonomous flight portion has up to 150 points available. The presentation also has a maximum available score of 150 points. The total score for the flight portions is calculated by averaging the score of each flight round of the flight portions.

There will be 2 hours dedicated to semi-autonomous and 4 hours for autonomous. The exact number of flight rounds within the time dedicated to each flight portion may vary, but all teams will be given equal opportunities for competing. Success in each flight round is independent of other flight rounds, i.e., if a team does not receive a score in one flight round, the team may still compete in the other flight rounds.

A. Autonomous Mission
    a. Tasks:
        i. The vehicle must travel to all waypoints in the least amount of time.
        ii. At each waypoint the vehicle will have to complete one of two tasks: hover for 10 seconds or deliver a single payload of a golf ball. The task assigned to each waypoint will be defined in a file given to each team prior to flight.
    b. Rules:
        i. A successful flight is defined by:
            1. Vehicle taking off autonomously.
            2. Vehicle landing autonomously at the same location (within a 8-ft. radius) as where it took off.
            3. Completing at least one waypoint.
        ii. Teams must have their flight radios off during flight to ensure they do not cause interference with the team competing at that time. Teams will be penalized if they fail to do so — see the scoring section for details.
        iii. Teams must complete the mission in a total of 10 minutes in order for the flight to be scored.
            1. The timer starts when teams are given the waypoint file. The timer runs continuously until 10 minutes have expired.
        iv. If teams do not achieve successful autonomous flight or if their UAV crashes or flips, teams may re-attempt the flight so long as time remains on the 10 minute flight timer.
        v. The flight manager will signal the start of the stopwatch for each team to begin the autonomous portion; this will occur when teams are given the waypoint file. There is an overall time limit of 10 minutes; this includes time to calculate the flight route as well as execute the flight.
            1. The timing stops when the time limit is reached or when the vehicle has landed at the home waypoint, signaling their flight is complete.
            2. If a team runs their route determination program before the flight manager gives the signal, 30 seconds will be added to the team's final flight time. The team would now only have 9 minutes and 30 seconds to complete the autonomous flight round.
            3. If a team has not landed by the 10-minute mark, the flight manager will order the team to return their quadrotor to the home waypoint. The team will have 15 seconds to do so.

Note: The team's overall score will decrease as they will not have completed mission for all waypoints and will have a flight time of 10 minutes and 15 seconds.

4. If a team does not land within 10 minutes and 15 seconds as ordered by the flight manager, they will receive an immediate score of 0 for the autonomous flight round regardless of performance.
5. The 10-minute limit is intended to allow teams 5 minutes for route calculation and 5 minutes for flight; however, to maximize the score received, teams should strive to complete the entirety of the autonomous portion (route calculation and flight) as quickly as possible.

vi. Teams will be given a list of waypoints in a CSV file to which they must travel. The number of waypoints will be the same for all teams.

1. The list of waypoints will only have 1 delivery waypoint.
2. Each waypoint will have a specific label in the CSV file as well as on the competition flight arena identifying whether the vehicle should deliver an item or hover for 10 seconds.
    a. CSV file with latitude, longitude, altitude, waypoint type in that specific order. An example is shown here: https://github.com/aeroroboticscomp/ARC-example

vii. The route **MUST** be determined through an output of a computer program that was written by the team. They must be able to demonstrate this at the technical inspection by running a mock waypoint file.

viii. Teams can use any programming language of their choice. Example code will be given in Python. Reuse of example code is allowed. See the example code for more details.

1. Example code can be found here: https://github.com/aeroroboticscomp/ARC-example

ix. A "successful waypoint" is defined as a waypoint where the vehicle was able to fully accomplish a task. The description of the tasks are as follows:

1. Delivery task: The vehicle will need to deliver a golf ball to within 2.5 ft. of the waypoint as measured from the item's final stopping point.
    a. The drop can be automatically triggered or manually triggered.
    b. The vehicle may also land at the waypoint to deliver the item
    c. The flight arena will be marked with the diameter of 5 ft. to mark the delivery zone for judging successful delivery. If the object is delivered outside the 5 ft. target, the delivery waypoint is not considered to be successful.
2. Loiter task: The vehicle will need to stay within 5 ft. of the

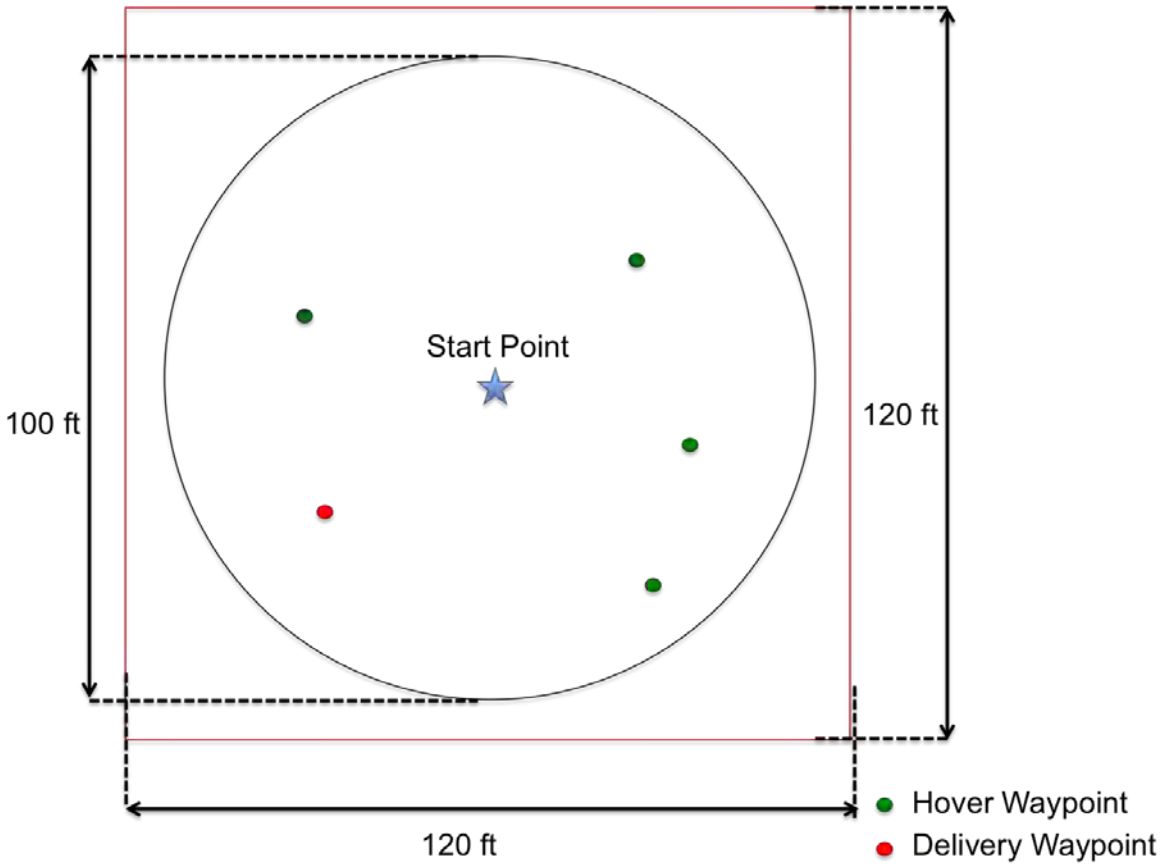
waypoint for 10 seconds in both the horizontal directions and within 5 ft. of the waypoint-specified altitude. This will be confirmed by the flight logs produced by the team as well as visual inspection.

3. Teams must distinctly complete the tasks at each waypoint, i.e., if 2 waypoints are near each other, teams cannot complete the missions of both at 1 location between the 2 waypoints.

x. Route Determination

1. Teams will receive the file with the waypoints directly prior to their flight. Once the file is received there are two ways the teams can determine the route as outlined below.
    a. The team determines the route on a platform independent of the vehicle. Once the route is calculated, the team transfers the route to the vehicle. Once loaded and commanded, the vehicle flies the route.
        i. Note: The vehicle's time determining the route counts against the 10-minute limit.

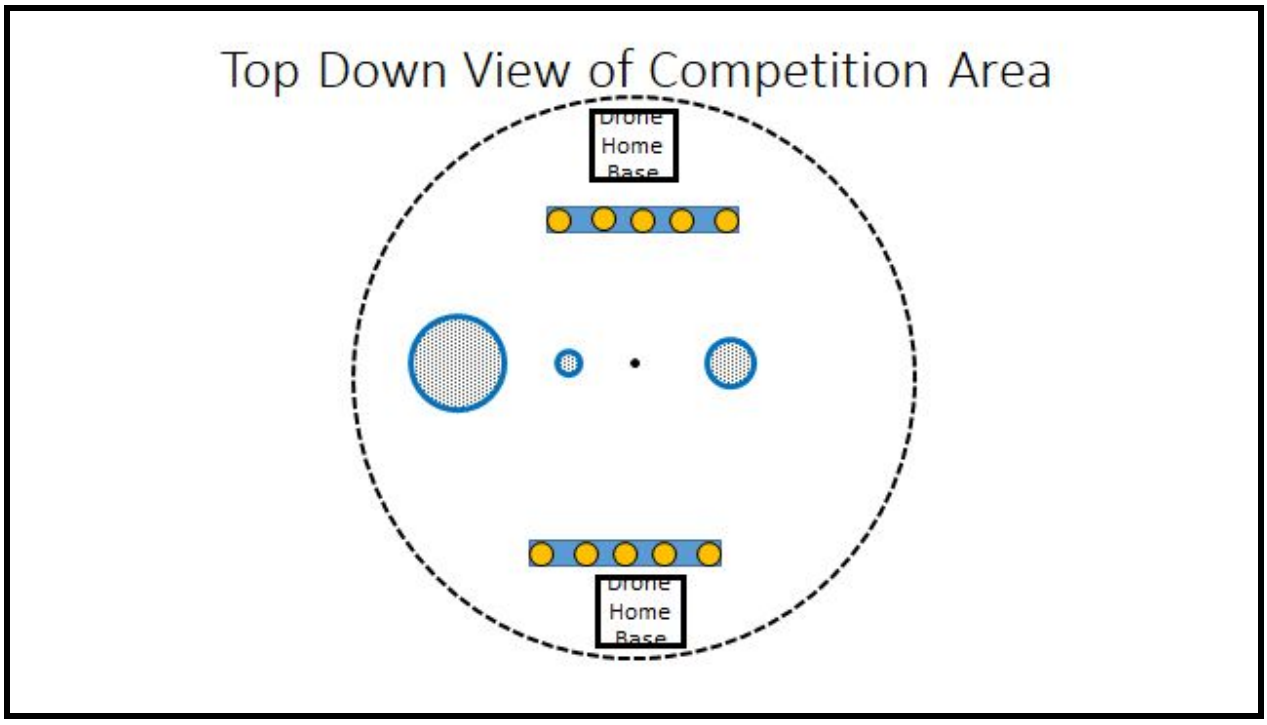
c. Flight Arena

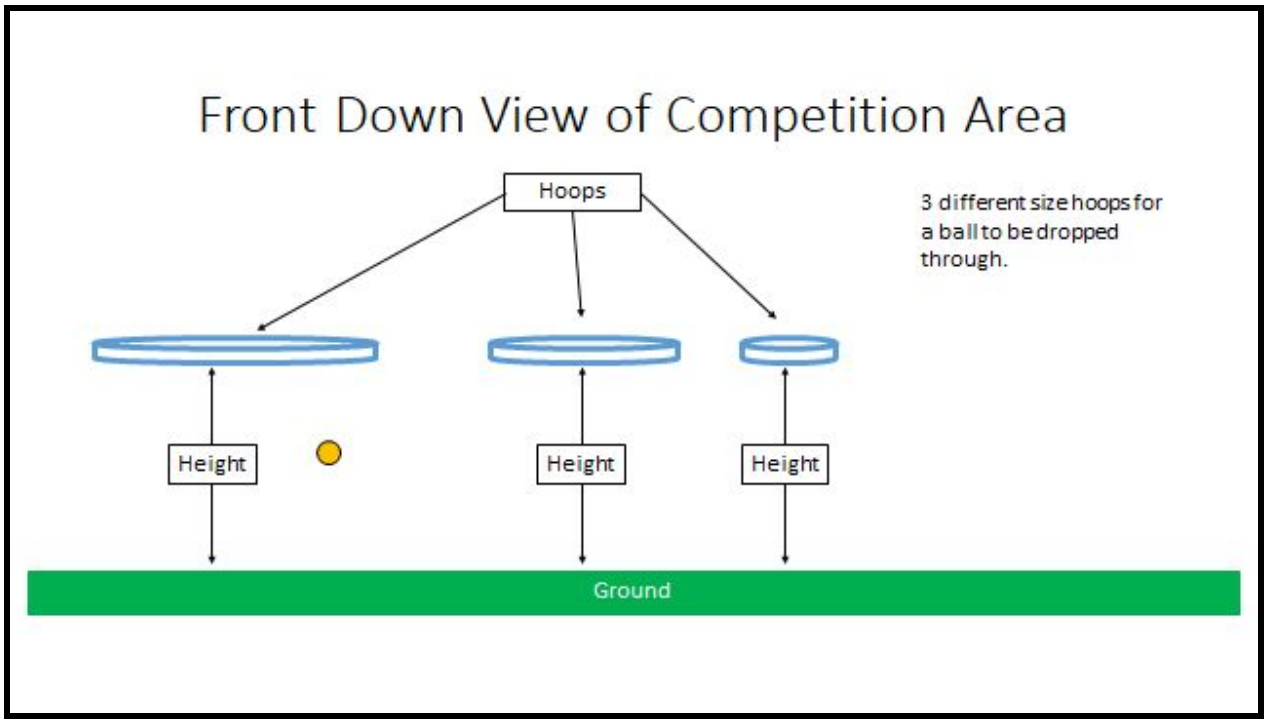


Each waypoint will have a specific marking on the ground indicating the boundary of the acceptable

region. The black line indicates the flyable area of the quadrotor. The red line defines the buffer area where no spectators are allowed; team members within the red zone will be required to wear safety glasses and hard hats. Note: The waypoint locations shown in the flight course are intended to be an example of the distribution of waypoints; exact locations will be defined before the flight rounds.

B. Semi-Autonomous Mission
    a. Primary Tasks
        i. Pilots will fly their vehicles to retrieve tennis balls from a queue area in the flight arena. The tennis balls will start on the ground.
        ii. Pilots release the tennis balls to drop them through hoops.
        iii. Tennis balls must retrieve and drop tennis balls one at a time
        iv. Each team will have the ability to collect and drop up to 5 tennis balls in a 5 minute period.
        v. There will be multiple sizes of hoops in the flying arena. Each hoop will have an associated point value (the smaller diameter hoop, the more points earned).
    b. Rules
        i. Two teams will collect and drop objects simultaneously.
        ii. A vehicle may only carry and drop one tennis ball at a time.
        iii. Each team will have 5 tennis balls each to pick up and deliver to the hoops.
        iv. After a team drops their 5th tennis ball or the 5 minutes are up, the referee will instruct the pilot to land the vehicle. Pilots must land their vehicle, at any location in the flight arena, within 15 seconds of the referee order to do so.
            1. Flight time starts when the referee instructs teams to arm their drones. Flight time is continuous from that point until 5 minutes is up.
        v. The entire vehicle does not need to be above the hoop as long as the entire tennis ball is dropped through to score points.
        vi. If a team's vehicle crashes or flips during the competition, teams are **not** allowed to re-enter the flight arena to restart. Their drone must stay grounded until flight time is up.
        vii. During flight, intentional collisions/interference are prohibited. **Teams causing a collision will be disqualified.**
    c. Flight Arena





As with the autonomous flight arena, team members near the flying arena must be wearing hard hats and safety glasses. Each drone will be tethered to the center point of the course.

C. Scoring Overview
    a. Autonomous:
        i. Teams are scored on both the completeness of the execution (completing all waypoints) and the speed of the execution. All scoring is based on the fastest time and the total number of waypoints that exist.
        ii. Teams will receive a higher score if they complete all available waypoints.
        iii. Teams will receive a higher score if they have the fastest time of all teams.
        iv. Teams will be penalized if a portion of their mechanism falls off during flight or if they cause interference during other teams' flight(s) by leaving their radio on while not flying.
        v. Teams should focus on successfully executing all the tasks at all waypoints before attempting to decrease time.
    b. Semi-Autonomous:
        i. Each tennis ball will be scored individually based on the hoop that the tennis ball was dropped through.
        ii. If a team dropped all 5 tennis balls and lands their vehicle in under 120 seconds they will receive a multiplicative score bonus.
        iii. Team flight time (in seconds) will be calculated as the time when the drone leaves the ground to the time when the drone touches down.
            1. Note: This is only calculated when a team drops all 5 tennis balls through hoops. It defaults to 120 seconds should a team not drop 5 tennis balls through hoops.
        iv. Teams also will receive a higher score if they perform best out of all teams in that flight round.
        v. Teams will be disqualified from the flight round if they cause a collision.
        vi. Teams should focus on consistently dropping all tennis balls through the smallest hoop in the least amount of time.

D. Detailed Scoring Calculations
    a. Autonomous (300 max points / round)
        i. The total score of the autonomous portion is as follows:

$$S = avg(F)$$

        ii. Round score is calculated by:

$$F = 300 * \frac{t}{t_f} * \frac{w_s}{w_t} - P$$

        iii. Legend for autonomous calculations:
            1. t_f =fastest time of all teams of the flight round (seconds)
            2. t =time for completing the round (seconds)
            3. w_s =number of successful waypoints
            4. w_t =number of total waypoints
            5. P=penalty deductions
                a. Teams will lose 50% of their round score if a portion of the mechanism falls off during flight

b. Teams will lose 50% of their total score if they leave their radio on during another team's flight

iv. Competition Time Requirements

1. If teams does not complete the flight within 10 minutes, the team will be required to land within 15 seconds of the 10 minutes expiring; failure to do so automatically results in a score of 0 for the flight round.

b. Semi-Autonomous (150 max points / round)

i. Total score for semi-autonomous flight:

1. $S = avg(F)$

ii. Round for semi-autonomous:

1. $F = 150 * \frac{Round\ Score}{Best\ Score\ of\ Round\ (of\ all\ teams)}$
2. $Round\ Score = (B_1 + B_2 + B_3 + B_4 + B_5) * (\frac{Round\ flight\ time\ (120\ sec)}{Team\ flight\ time\ (sec)})$

iii. Legend for semi-autonomous calculations:

1. B_x : score of tennis ball number x
   a. Largest Hoop, $B_x = 20$
   b. Middle Hoop, $B_x = 35$
   c. Smallest Hoop, $B_x = 50$

iv. Penalty:

1. Score is 0 if the team causes a collision during flight.
2. Score is reduced by 50% if the team's mechanism falls off during flight.

c. Presentation (max score of 150 points)

i. Content

1. Team organization (max 2.5 points)
2. Team schedule (max 5 points)
3. Financial Strategy / Budget (max 10 points)
4. Design/programming methodology and process (max 15 points)
5. Design details: Vehicle Design, Software, Sensors(max 15 points)
6. Vehicle analysis (max 15 points)
7. Mechanism(s) design (max 10 points)
8. Testing (max 20 points)
9. View of entire system (front, top, side) with primary dimensions (height, width, and length) (max 5 points)
   a. Please label important dimensions in the picture
10. List of parts/materials used (max 2.5 points)

ii. Presentation Style

1. Slides are legible (max 10 points)
2. Presenter speaks clearly (max 10 points)
3. Minimal "Uh", "You know" mannerisms (max 10 points)
4. Photos/Models/Videos Present (max 10 points)
5. Presenter speaks to the room, not to their slides (max 10 points)

iii. More details for the presentation will be sent out separately. Please follow those guidelines as the presentations will be judged based on those guidelines.

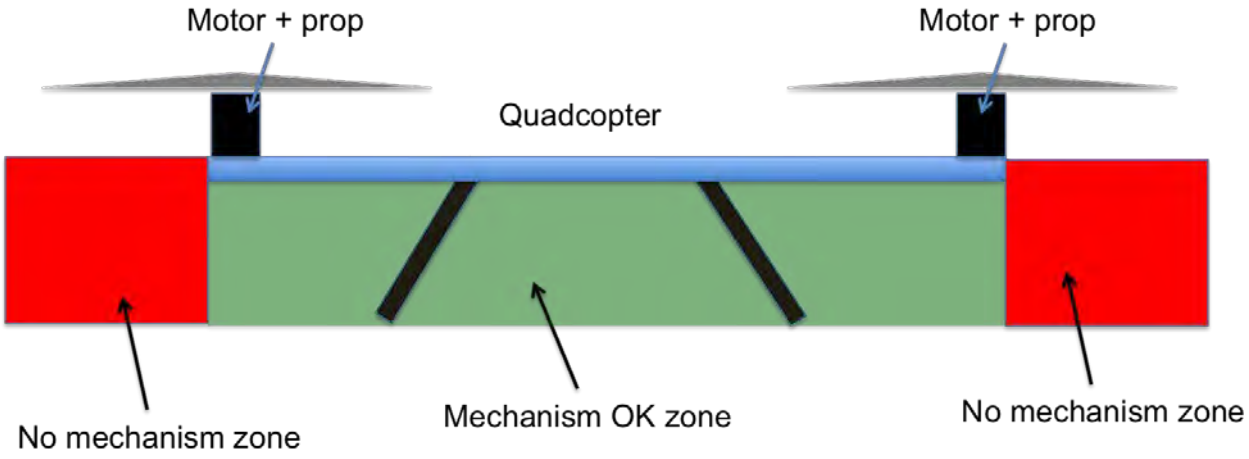
E. 2019/2020 Mission Specific Vehicle Requirements

a. Mechanisms Design

i. Teams will need to design and build their own mechanisms to fulfill both the semi-autonomous and autonomous portion of the competition.

ii. Teams may use the same mechanism for both portions; however, **teams are allowed to build separate mechanisms for both portions and swap them.**

iii. The mechanism(s) must be attached to the UAV and must fit within the area of the UAV arms and beneath the arms when on the ground. If teams are using different mechanisms for each flight portion, teams must demonstrate that both mechanism designs meet this criteria during Technical Inspection. See image below for clarification:



iv. The mechanisms must NOT go above the motor arms of the UAV at any time during flight.

v. No part of the mechanisms should be designed to fall off of the UAV during any part of the competition.

1. If this does occur, regardless if it was or was not intentional, 50% of the score from that portion (autonomous or semi-autonomous) of the competition will be deducted.

vi. All parts attached to the UAV must remain within 4 ft. of the UAV at all times during operation.

b. Route Planning Program

i. Teams must use internally written code to determine the route. Neither Excel nor any GUI-based computer program is allowed.

Appendix C: Application

Note: Each team must submit an application **via the online application site (no paper applications will be accepted)** consisting of their team members and one faculty advisor (required). It is suggested that team size be no more than 5 students.

High School Name:
High School Address:

Faculty Advisor:
Email:
Phone Number:

Team Name:
Number of students:

1) Team Concept (answer the following questions with at least one paragraph response)
    a) Why do you want to compete in this competition?
    b) What is your team's timeline for vehicle assembly (i.e., according to your timeline, when will your vehicle be ready for flight)?
    c) How much experience does your team have with robotics, vehicle design, and programming?
    d) How much experience does your faculty adviser have with robotics, vehicle design, and programming?
    e) This competition is challenging but achievable. Are team-members prepared to motivate themselves to persevere in spite of being challenged?

Appendix D: UAV Safety Requirements

A. General Safety
    a. All UAVs must use all of the required safety materials.
    b. UAVs must only be used in netted areas or when tethered. Any indoor UAV use must be approved by your faculty advisor.
    c. We highly recommend the use of the following for testing only:
        i. Safety nets and/or tethers of at least 30-lb-rated wire/rope
        ii. Enclosed room, empty of any people, with a window from the outside for view
B. Certification
    a. Each UAV must be registered with the FAA and must display FAA number while flying (written in black marker on the UAV or on masking tape on the vehicle and must be visible)
C. Lithium Polymer (LiPo) Safety
    a. Charging
        i. Charging must be done under competition supervision in designated location
        ii. Proper LiPo battery balance charger must be used to ensure safety
        iii. Battery must not be charged over 4.2 V per cell
        iv. Charging battery is not to be left unattended
    b. Care/Usage
        i. Puffy batteries
            1. This is hydrogen released from cell
            2. Excess buildup/puffiness is a fire hazard
            3. Follow disposal process
        ii. Battery cells should not be discharged below 3V
            1. If they are, dispose of the battery following the appropriate process - reference (viii) below
        iii. Do not drop or puncture (impact will cause damage)
        iv. Charging damaged batteries (puffy or punctured) may result in fire
        v. Batteries must be stored in a consistent room temperature (50–80 degrees F) environment
        vi. Batteries must be stored in a proper container (i.e., provided LiPo battery bag)
        vii. Teams are advised to take precautions during travel to competition location, especially with the LiPo batteries; LiPo batteries must always be stored in the provided LiPo battery bag.
        viii. Disposal
            1. Batteries must be discharged prior to disposal.
                - Note: Batteries SHOULD NOT be discharged below 3V per cell unless they are being disposed of
            2. To dispose, take the battery to either the local battery site or to a local

hobby shop.

ix. Fire

1. See this guide for fire safety guidelines in case of battery fire: https://www.riversideca.gov/fire/pdf/forms/2012/H-12-001.pdf

D. UAV Safety Operations
   a. Referees will have full authority over LiPo batteries
   b. Testing by teams onsite:
      i. Teams need to ask referees for permission and go to a referee-specified testing area.
      ii. The team needs to brief the referee on the type of testing they want to perform (run up, telemetry check, etc.) including procedures. The referee can reject any attempts to do any testing deemed unsafe.
   c. The pilot needs to call out to the surrounding area that they are turning on the UAV and ensure that no one is within 5 ft. of the UAV, other than the teammate plugging in the battery.
   d. Referees need to make sure only one teammate is near the UAV and has everything (electronics, ESC, motors, power distribution board, sensors, and receivers) plugged in correctly before giving the LiPo batteries to the teammate.
   e. The referee also needs to make sure one teammate has the tether in hand in case of "fly- aways"; the pilot is paying attention to the UAV and is ready to respond in case the motors suddenly turn on; and all teammates involved in the testing are wearing proper gear (safety goggles and hard hat, hard gloves for the one plugging in the battery).
   f. The teammate is then allowed to plug in the batteries and perform whatever tests are needed, all under the supervision of the referee.
   g. After the team has finished testing, one teammate can approach the UAV to unplug the battery and hand it to the referee for inspection and holding/charging.

E. Competition Flying Safety
   a. Only one teammate is allowed to go into the flying area to plug and unplug the battery.
   b. The referee and the teammate need to make sure that no one is near the UAV except for the teammate plugging in the battery.
   c. The referee also needs to make sure that there is one teammate on the manual override transmitter outside the flying area, and that all teammates involved in flying are wearing proper gear (safety goggles and hard hat). Hat must be a construction-style hard hat; if teams are unsure as to what a construction hard hat is, please contact the ARC Working Group.
   d. Once the referee gives the approval, the teammate may plug the battery into the UAV electronics and secure the battery to the UAV.
   e. The teammate holding the transmitter may not arm the UAV until the other teammate is out of the flying area AND the referee gives approval.

f. Team needs to follow rules during flight dependent on the phase of competition.
g. Once flying is done, the referee needs to give approval before a teammate enters flying area. The referee can give approval when it sees the UAV on the ground, receives notification from the team that they are done, and makes sure that the transmitter is on and throttle is held at 0%.
h. The teammate shall immediately unplug the battery from the UAV electronics.
i. Once the battery has been unplugged, the other team members enter the flying area to help retrieve the UAV.

Appendix E: Technical Inspection Requirements

The following checklist will be used during Technical Inspection.

Technical Inspection Checklist 2019/2020

CAUTION: Vehicle is to be presented with battery and propellers removed

	PASS	FAIL
Battery and propellers removed	_____	_____
Aircraft Identification		
UAV displays FAA number while flying	_____	_____
Battery Safety		
Team use LiPo with no more than 4 cells (4s)	_____	_____
Battery not over charged over 4.2V per cell	_____	_____
Battery not discharged below 3V per cell	_____	_____
Team stores battery in proper container	_____	_____
Battery not puffy or showing visual signs of damage	_____	_____
Safety Equipment		
All team members have safety goggles and hard hats	_____	_____
Vehicle Body Assembly		
Legs safely and securely attached	_____	_____
Motor arms safely and securely attached	_____	_____
Propellers no larger than 12 inches diameter	_____	_____
System stays within the size limitations	_____	_____
Vehicle has no more than 4 propellers and 4 motors	_____	_____
Frame supports all components	_____	_____
Vehicle size matches team's technical plans	_____	_____

Vehicle Electronic Components

Electronics / wires securely attached (no dangling wires) _____ _____

GPS sensor mounted securely to vehicle _____ _____

Receiver matches transmitter choice _____ _____

Autopilot is either 3DRobotics Ardupilot

(Pixhawk, APM 2.6 etc.) or the DJI NAZA _____ _____

Motor cut-off is programmed in transmitter

and demonstrated through a switch on transmitter _____ _____

Ground Station (GS)

Onboard computer connects with ground station _____ _____

Ground station displays necessary vehicle information:

Quadrotor GPS coordinates _____ _____

Altitude _____ _____

Velocity X, Y, Z _____ _____

Battery level _____ _____

Mechanism Design

Note: if the team has multiple mechanisms, each must be inspected

Self designed and built _____ _____

Fits within area of the vehicle and beneath arms _____ _____

Mechanism does not fall off (complete tug test) _____ _____

Mechanism remains within 4 ft of vehicle during operation _____ _____

Vehicle Demonstrations

GS and vehicle communicate within 120 feet:

Physical test by walking vehicle away from GS _____ _____

Teams provide technical spec of radio _____ _____

GS can command vehicle to return home _____ _____

GS cannot control vehicle otherwise _____ _____

Pilot can switch between manual flying mode

and autopilot mode (and vice versa) within a few seconds _____ _____

Autonomous flight mode can be overridden by pilot
(checked via ground test) _____ _____

Mechanism does not fall off during flight _____ _____

Autonomous route determined through computer output
(mock waypoint file demonstration) _____ _____