Aerospace Robotics Competition

Rule Book

2018/2019

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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.

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.

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

I. 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.

Each school may only submit one team entry. The pilot for the team must be a student member of the team. Each team must also have a student captain, which 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 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 aged 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 aged students.

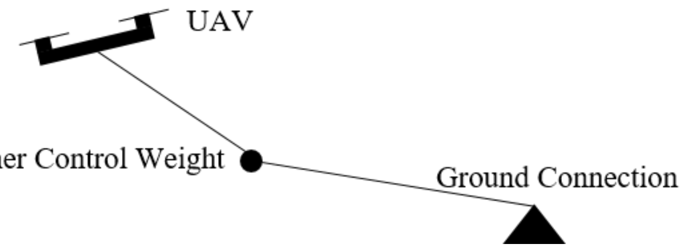
II. General UAV Requirements

Summary: Teams will select their own hardware with the exception of the flight computer. The flight computer/autopilot MUST be chosen from the approved set of flight computers listed below. **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 may choose a flight computer from the following list:
      i. MRobotics Pixhawk

         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 Working Group.**
      ii. DJI NAZA
   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, no need to bring a set.

B. Ground Station

Teams must use a ground station to monitor the vehicle during flight. The ground will be used for the teams and judges to monitor flight characteristics. As is the case with *ALL* UAV components, ARC will not be providing ground stations for the teams. 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 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)

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.

D. Spares
a. Spare parts must be accounted for in the budget.

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

III. 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

IV. Competition Schedule

The schedule for the 2018/2019 competition year will be published on the ARC webpage: http://www.aeroroboticscomp.com/current.html

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 competition day, 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.

V. 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.

VI. 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.

VII. Competition Application

Teams wishing to participate in the 2018/2019 ARC competition must apply on the ARC website. The dates for the application window will be published on the ARC website. The application will include teams' timeline for building their vehicle. Teams also must include their 2018/2019 budget, which must comply with the budget max of $1,200. Teams will be notified by the ARC Working Group if they are chosen to compete. Reference Appendix C for the Application Requirements.

VIII. 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.

IX. Judging

A. Autonomous Judging: 3 total 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: 1 referee
    a. There will be 1 referee monitoring the entire playing field.
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.

X. Protest Procedure

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

XI. Communications

Each team will be assigned a mentor from a university to support the team. This mentor should be the team's first contact for technical questions/difficulties. There will also be a panel of professional mentors who are "industry experts"; these mentors will be an extra layer of support for the teams. The university mentors will facilitate conversations with the professional mentors when teams' questions are outside of the university mentors' level of expertise.

Any questions for the Working Group should be directed to: aero.robotics.comp@gmail.com. The Working Group can support teams technically, though the university mentor should be the first point of contact, and can also answer questions about competition logistics.

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

Each team is required to have a student captain. Once teams are chosen for the competition, the ARC Working Group will send each team a parental consent form for the Working Group and other ARC affiliates to communicate with the student captain.

Appendix A: Example of Team Supply List

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 Cost

Category	Item	Quantity	Individual Cost	Total Cost
Frame	Frame	1	$21.99	$21.99
Propulsion	Motors	4	$29.16	$116.64
	ESC	1	$27.98	$27.98
	Propellers	2 sets of 4	$9.77	19.54
	Propeller Guards	4	$4.34	$17.36
Electronics	RC transmitter & receiver	1	$54.49	$54.49
	PPM Encoder	1	$9.83	$9.83
Autopilot	Pixhawk + GPS (mrobotics)	1	$249.90	$249.90
Sensors	Infrared distance sensor	2	$14.95	$29.90
	Sonar Sensor	1	$24.95	$24.95
	LiPo 4 cell battery	2	$17.85	$35.70
	Raspberry Pi B	1	$29.95	$29.95
	Raspberry PI Battery Pack	1	$9.99	$9.99
	USB to TTL Signal cable	1	$7.74	$7.74
	8GB SD Card Raspbian Wheezy (OS of RPi)	1	$11.95	$11.95
	half-size breadboard	1	$4.98	$4.98
	USB Wifi	1	$12.95	$12.95

	RPi Wall Wart Power Supply	1	$7.95	$7.95
Mechanism	Servo	1	$8.29	$8.29
Misc.	Practice Quad	1	$27.75	$27.75
	Lipo Battery Bag	1	$3.04	$3.04
	Battery Charger	1	$17.97	$17.94
Tools	Soldering Iron	1	$39.97	$39.97
	Lead Solder	1	$7.40	$7.40
	Long Arm hex key set	1	$9.97	$9.97
	Wire strippers	1	$17.97	$17.97
	Screw driver set	1	$6.97	$6.97
Total:				**$833.09**

B. 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)
Infrared Distance Sensor
Sonar Sensor
LiPo 4 cell battery
Raspberry Pi 3B (with onboard wifi)
Raspberry PI Battery Pack
USB to TTL Signal cable
8GB SD Card Raspbian (OS of RPi)
Half-Size Breadboard
RPi Wall Wart Power Supply
Servo
Practice Quad (Small Toy Quadcopter)
Lipo Battery Bag
Battery Charger
Soldering Iron
Lead Solder
Long arm Hex Key Set
Wire Strippers
Screw Driver Set

Appendix B: 2018/2019 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 if continuous route determination is used; if separate route determination, only 75 points are 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 percentage of the maximum score received is based on the number of cubes retrieved and the team's tower height. 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. Note: Teams may have a "successful" autonomous flight while still receiving a score of 0 if there are no successful waypoints.
        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 and are discovered — 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. Within the 10 minutes, teams have 5 minutes for flight calculation and 5 minutes for flying.
            2. Teams will be given an additional 15 seconds to land beyond the 5-minute mark, but their score will suffer as detailed below.
            3. If a team does not achieve successful autonomous flight, the team

may attempt again so long as time remains within the 10 minute limit.

iv. The flight manager will signal the start of the stopwatch for each team to begin the autonomous portion. 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.

v. 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/ARC18-19

vi. 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.

vii. 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/ARC18-19

viii. 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 3 ft. of the waypoint-specified altitude. This will be confirmed by the flight logs produced by the team.
   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.

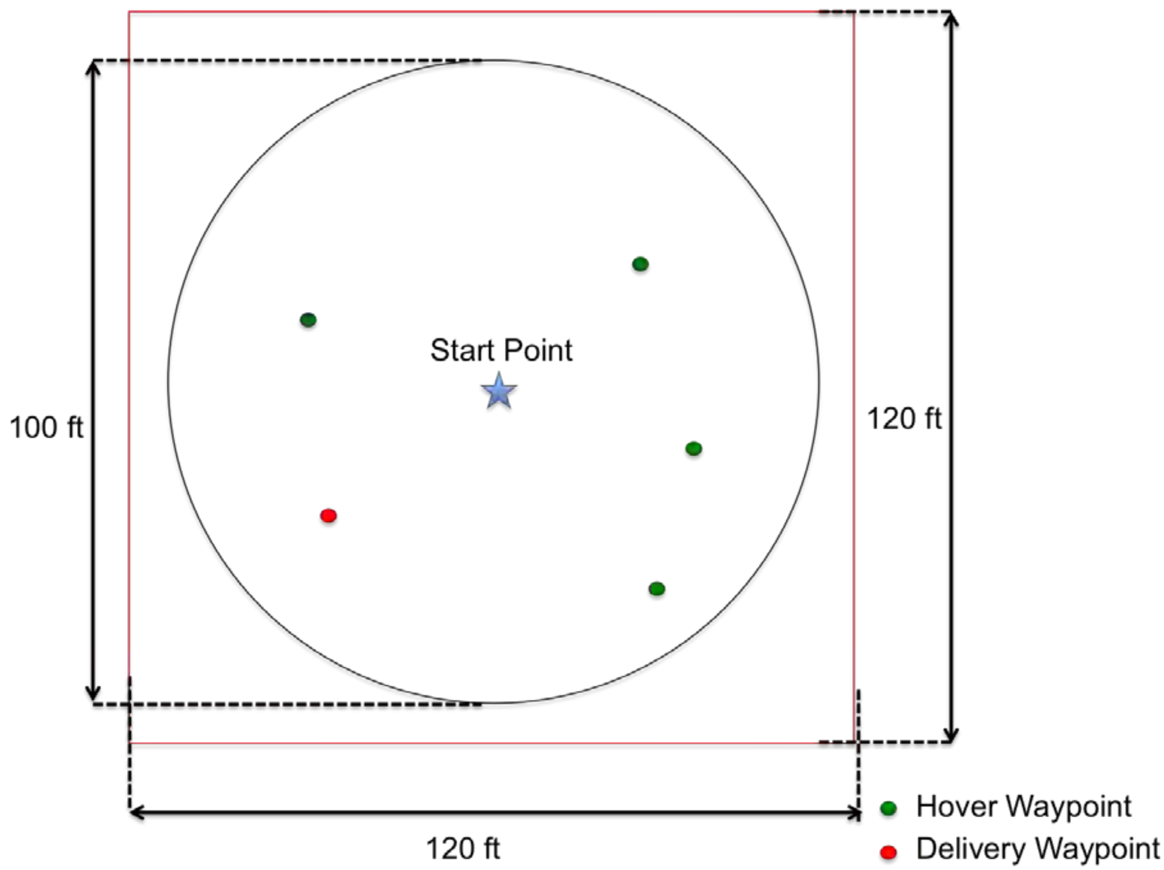
ix. Route Determination
   1. Teams will receive the file with the waypoints directly prior to their flight. Once the file is received there are two ways the teams can determine the route as outlined below. Teams are **highly encouraged** to place emphasis on getting continuous determination working as the scoring for each route determination differs significantly as outlined in the scoring section.
      a. Separate determination: The team determines the route on a platform independent of the vehicle. Once the route is calculated, the team transfers the program to the vehicle either via manual entry (ground station) or uploading route file. Once loaded and commanded, the vehicle flies the route.
         i. Note: The vehicle's time determining the route counts against the 10-minute limit.
      b. Continuous determination: The team uploads the waypoint list to the vehicle directly. The vehicle onboard computer runs the team's route planning program, which determines the route and executes when commanded.
         i. Note: The vehicle's time determining the route counts against the 10-minute limit.
   2. Teams that complete the flight via continuous determination receive a higher score than teams that use separate determination, as outlined in the scoring section.
   3. The flight will be considered as having been "separate determination"

scoring if any human/ground station/outside intervention is required to complete the flight. These include but are not limited to:

a. Manual drop triggering at delivery waypoints
b. Reprogramming route mid-flight
c. Manual takeover for vehicle veering off course

Judges reserve the right to deem any action as “outside intervention.” If a team has any questions about anything that may be deemed as “outside intervention” or want to request a clarification, please email aero.robotics.comp@gmail.com

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. <u>Note</u>: 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. The team pilot will have two minutes to fly the vehicle, using the designed mechanism, to retrieve and deliver k'nex cubes to the team's designated delivery zone.

ii. After 2 minutes, the pilot will land the vehicle, and team members will have 2 minutes to use the retrieved cubes to build a tower.

b. Rules

i. Two teams will collect objects simultaneously.

ii. There will be 13 k'nex cubes randomly arranged in the flight arena

1. 3 7.5-inch rod cubes
2. 5 5.125-inch rod cubes
3. 5 3.4375-inch rod cubes

iii. The UAV will begin in the team's designated take-off zone; pilot must not start the vehicle motors until instructed to do so by the flight round referee.

iv. Each team must have one pilot and one cube retriever; all other team members may assist in tower assembly outside of the flight zone. Only the pilot and cube retriever are allowed inside the flying area.

v. The pilot must use their designed mechanism to pick up cube(s) and drop them in the 5-ft. x 5-ft. delivery zone.

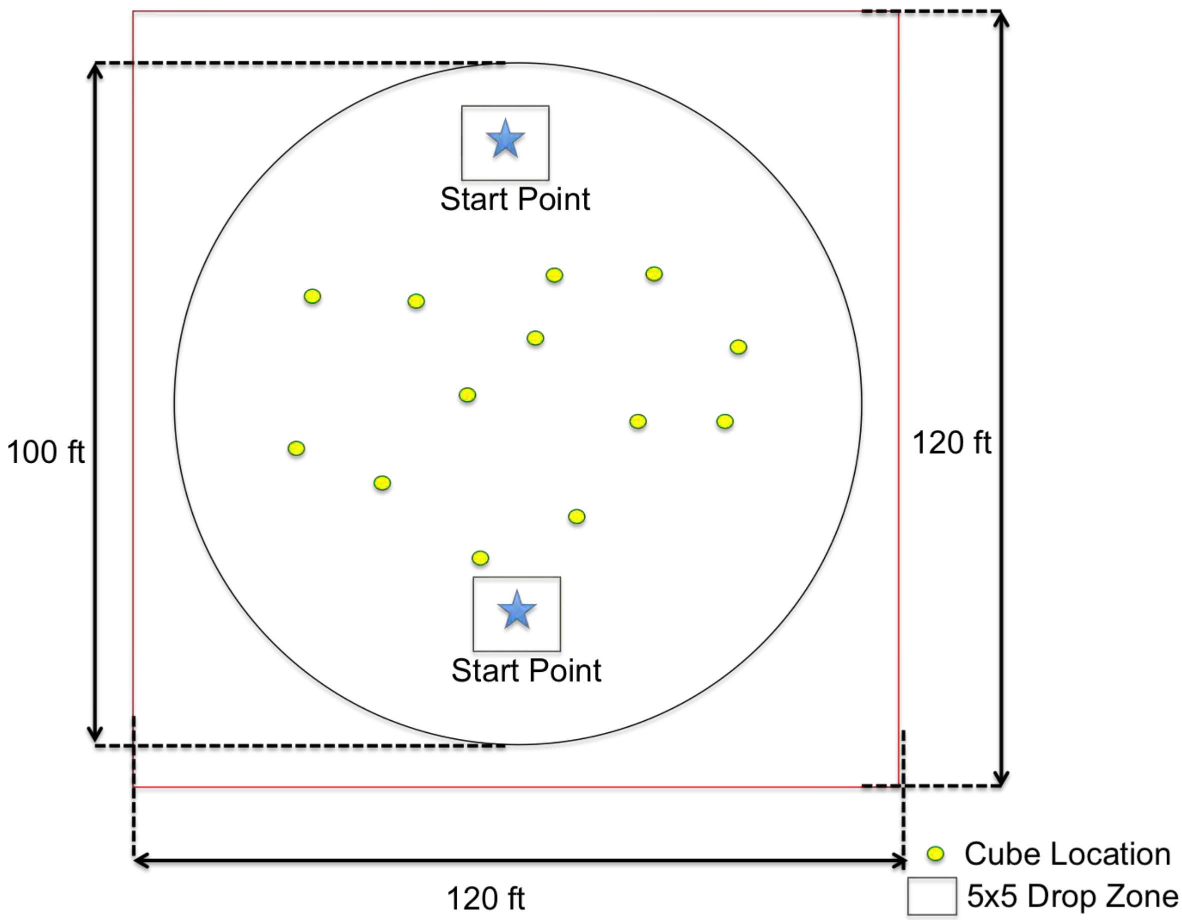
vi. After 2 minutes, the referee will instruct pilots to land the vehicles. Pilots must land their vehicle at any location in the flight arena within 15 seconds of the referee order to do so. Once the vehicles are disarmed, cube retrievers will then enter the arena to take cubes to the tower building area. If teams do not land their vehicle when instructed, they will receive an immediate score of 0 for the flight round.

vii. Team members will have 2 minutes to build their tower. The tower must stand until a judge measures its height.

viii. Teams may disassemble the cubes to build their tower.

ix. During flight, collisions are prohibited. **Teams causing a collision will be disqualified.**

c. Flight Arena



As with the autonomous flight arena, the zone indicated by the red line is for teammemers and judges only not spectators. Team members within this zone must be wearing hard hats and safety glasses. Note: The cube locations shown in the flight course are intended to be an example of the distribution; cubes will be randomly distributed before each flight round. 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 that use continuous determination for the route will receive a higher multiplier than those that use separate determination.

1. There are up to 300 points available for each autonomous flight round if continuous determination is used
2. There are up to 75 points available for each autonomous flight round if separate determination is used

iii. Teams will receive a higher score if they complete all available waypoints.

iv. Teams will receive a higher score if they have the fastest time of all teams.

v. 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.

vi. Teams should focus on successfully executing all the tasks at all waypoints before attempting to decrease time.

b. Semi-Autonomous:

i. Teams are scored based on the number of cubes collected during flight and the height of the tower built from these cubes.

ii. There are up to 150 points available for each semi-autonomous flight round.

iii. The more cubes retrieved during flight and the higher the tower will result in a higher semi-autonomous flight score.

iv. Teams also will receive a higher score if they perform best out of all teams in that flight round.

v. Teams will be penalized if their mechanism falls off during flight or if they cause a collision.

vi. Teams should focus on being able to consistently build a tall tower.

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. If continuous determination, each round score is calculated by:

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

iii. If separate determination, round score is calculated by:

$$F = 75 * \frac{t}{t_f} * \frac{w_s}{w_t} - P$$

iv. 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

v. 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.

vi. The scoring will automatically go to the "separate determination" scoring if any human/ground station/outside intervention is required to complete the flight.

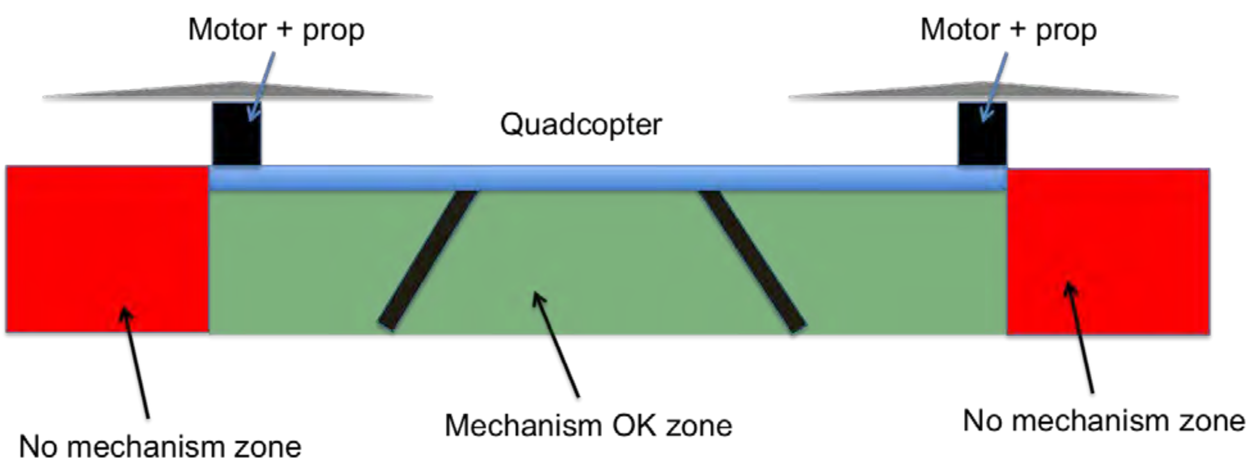
See the Route Determination section above for details.

b. Semi-Autonomous (150 max points / round)
   i. Total score for semi-autonomous flight:
      1. $S = avg(F)$
   ii. Flight round score for semi-autonomous:
      1. $F = 150 * \frac{2c}{c_t} * \frac{h}{h_b} - P$
   iii. Legend for semi-autonomous calculations:
      1. c =number of cubes retrieved by the team
      2. c_t =total number of cubes in the flight arena
      3. h =height of tower
      4. h_b =best tower height of flight round
      5. P =Penalties
         a. Teams will be penalized 50% of their total score (for that flight round) if a portion of their mechanism fall off their UAV.
         b. Teams will be disqualified from the flight round if they cause a collision during flight.
            i. If it is unclear who initiated contact, no team will be penalized.

c. Presentation (max score of 150 points)
   i. Content
      1. Team organization (max 2.5 points)
      2. Team schedule (max 5 points)
      3. Budget (max 10 points)
      4. Design methodology/process (max 15 points)
      5. Design details: Vehicle Design, Software, Sensors, Mechanism Design (max 15 points)
      6. Process and criteria for propeller selection (research, studies, testing) (max 15 points)
      7. Analysis (max 10 points)
      8. Plan for tower construction (max 10 points)
      9. Testing (max 10 points)
      10. View of entire system (front, top, side) with primary dimensions (height, width, and length) (max 5 points)
      11. 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)

E. 2018/2019 Mission Specific Vehicle Requirements

a. Companion Computer
    i. The teams may use an additional small-sized computer systems of their choosing onboard their vehicle to determine the waypoint route for continuous determination. Examples include Raspberry Pi, Beaglebone, and the ODroid.
    ii. Teams can connect any additional sensors of their choosing to their computer system if necessary.
    iii. The companion computer may not impede the flight of the UAV. It must be secured tightly to the UAV and may not fall off at any time. Teams should consider the placement of the computer onboard their vehicle so that it does not change the flying qualities of the UAV.
b. 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 mechanisms must be attached to the UAV and must fit within the area of the UAV arms and beneath the arms when on the ground. 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.
c. Route Planning Program
    i. The code can be hosted on either an onboard computer or off board computer,

not necessary to be the ground station.

ii. 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 interested:

Attach the following items:

1) Team 2018/2019 Budget
2) Team Concept Document (one page or less answering the following questions)
    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?

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, follow appropriate disposal process
      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 precaution 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.
         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 2018/2019

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 meets the Washabaugh Rule	____________	____________
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

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 ____________ ____________

Mechanism(s) can carry both the golf ball and the lightest
object for semi-autonomous portion ____________ ____________

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) ____________ ____________