Beginning in 2009...
Celebrating 19 years of moving the state-of-the-art in aerial robotics forward, the AUVSI International Aerial Robotics Competition is proud to introduce its 5th Mission:

RULES FOR THE INTERNATIONAL AERIAL ROBOTICS COMPETITION 5th MISSION

The official World Wide Web pages for the competition are your source for all information concerning rules, interpretations, and information updates regarding the competition. In anticipation of the Competition, the official rules and application form will be obtained from the official World Wide Web pages and will not be mailed to potential competitors. If you have received these rules as a hard copy from some other source, be advised that the official source of information can be found at:

http://iarc.angel-strike.com/

Prize Money and some logistics funding for the International Aerial Robotics Competition (IARC) is provided by the Association for Unmanned Vehicle Systems International (AUVSI). Logistics funding is also supplied by the DoD Joint Robotics Program under the auspices of the OUSD(A&T)/S&TS/LW office for Joint Architecture for Unmanned Systems (JAUS).

Other sponsoring organizations and the host organization are listed at the Official IARC web site shown above.

IARC 5th Mission: *"Inside the Box"*

Abstract

The 5th mission for the International Aerial Robotics Competition (IARC) will move the challenge to yet a higher level of autonomous aerial robotic behavior. The past two decades have seen a revolution in navigation technologies for operations in the open, but there is still much to be done in the area of indoor navigation. The goal is to create a small aerial robot capable of fully autonomous flight through a confined environment. In performing this task, the state-of-the-art in indoor navigation, vehicle design and integration, and flight control will be pushed to a higher level.

The 4th Mission of the IARC required collegiate teams to create fully autonomous flying robots capable of negotiating urban situations from a significant stand-off distance of 3km. Each aerial robot had to independently find and enter a designated building in order to locate and relay specific target information back to its launch point. The new 5th Mission picks up where the 4th Mission left off by demonstrating the fully autonomous aerial robotic behaviors necessary to rapidly negotiate the confined internal spaces of a structure once it has been penetrated by an air vehicle.

Notional Mission

April 26, 1:23:44 hours Greenwich mean time. Let there be light: and there was light. A great fire ball illuminates the night followed seconds later by the sound of a thunderous explosion. A catastrophe of unknown origin and extent has occurred in Unit #4 of the Ukrainistan nuclear reactor complex. All that is seen now is the dull red glow of burning graphite from the KMBR-1000 reactor.

There are no survivors within the facility. Radioactive elements of Iodine-131, Cesium-137, and Strontium-90 are present in lethal levels. A safe distance for human investigative teams has been determined to be no closer than three kilometers. Units #1 and #3 have apparently shut down automatically, but Unit #2 is still operating, possibly due to a fault in the control system that makes the emergency shutdown unable to function. Long distance aerial photography indicates that the overpressure from the explosion has blown out all windows in the facility.

An autonomous aerial robot (mother ship) carrying sensors and a miniature autonomous flying sub vehicle has been launched from a safe location (three kilometers distant from the complex) in an effort to enter the control room of Unit #2 which is identifiable by two great lights illuminating the Ukrainistani national seal over the main entrance (see http://iarc.angel-strike.com/oldauvs/01IARC/IARC_Cross_Symbol.jpg). The mother ship has successfully located Unit #2 and has identified an opening in the building into which its aerial robotic sub vehicle can be launched. This small, fully autonomous aerial robot must now find and enter the control room to provide a picture of the main control panel gauges and switch positions so experts can see why Unit #2 has not shut down and assess the potential for a meltdown of this unit. The reconnaissance mission must be completed within 10 minutes from insertion into the building due to expected radiation-induced failures within the aerial robot's systems. The aerial robotic sub vehicle must transmit its picture(s) through the concrete walls of Unit #2 to the mother ship waiting outside whereupon the pictures will be relayed back to the human investigative teams outside the safety perimeter three kilometers away.

Mission Critical Elements

The objective will be for a team to construct a fully autonomous aerial robot capable of self controlled flight within a confined environment such as a nuclear power generating plant. The vehicle will first be required to enter the building through a one (1) square meter (or larger) opening from a designated launch area 3m away. The vehicle will have to search for a target area while avoiding unbriefed obstacles such as walls, columns, and furniture.

Upon locating the control panel which will be identified by various blinking lights and an audible warning tone, at least one clear picture of a specific target gauge (monochrome or color, still or video, real time or stored rebroadcast) must be relayed by means of a radio frequency (RF) signal with sufficient power to be received at a distance of 100 meters with a loss of 6 dB (to account for attenuation by the structure) into an antenna with aperture no greater than 1 meter (see http://iarc.angel-strike.com/5th_Mission_Link_Margin.pdf). For a team to be successful, the Judges must be able to read the value of the specific gauge (>64 cm in cross sectional area) on the transmitted picture of the panel. Success in acquiring the target gauge will be evidenced by either a specific still picture autonomously designated from among multiple still images that may be transmitted, or an autonomously designated video segment including the correct target gauge lasting no less than 5 seconds. The target gauge of interest will be the only one with a non-blinking blue LED directly below it.

In addition to the vehicle behavior thus described, the system must be able to provide vehicle navigational and status information to a remote JAUS-compliant terminal via the JAUS protocol (the launch point is to be considered as the origin of the navigation frame with gravity providing the vertical reference).

The Judges will use an industry standard IARC-supplied JAUS-compliant terminal to assess vehicle behavior as well as JAUS compliance. Using those protocols correctly and supplying an appropriate interface to translate from the team's system to the JAUS-compliant terminal will assure that the Judges can see and interpret the aerial robot's navigational and status information. Upon becoming an "Officially Registered IARC Team," JAUS compliant protocols as well as the physical interface requirements for the Judge's JAUS-compliant terminal will be supplied.

General Rules Governing Entries

1. Vehicles must be unmanned and autonomous. They must compete based on their ability to sense the semi-structured environment of the Competition Arena. They may be intelligent or preprogrammed, but they must not be flown by a remote human operator. Any number of air vehicles may be deployed so long as the gross aggregate weight of each air vehicle does not exceed 1.50 kg.

2. Computational power need not be carried by the air vehicle. Computers operating from standard commercial power may be set up outside the Competition arena boundary and uni- or bi-directional data may be transmitted to/from the vehicles in the arena however there shall be no human intervention with any ground-based systems necessary for autonomous operation (computers, navigation equipment, links, antennas, etc.).

3. Data links will be by means of radio frequencies in any legal band for the location of the arena (see http://iarc.angel-strike.com/5th_Mission_Link_Margin.pdf).

4. The air vehicle(s) must be free-flying, autonomous, and have no entangling encumbrances such as tethers. The air vehicle(s) can be of any type. During flight, the maximum dimension of the air vehicle can not exceed one (1) meter. The maximum takeoff weight of the vehicle cannot exceed 1.50 kg. The vehicle must be powered by means of an electric motor using a battery, capacitor, or fuel cell as a source of energy. The vehicle must be equipped with a method of manually-activated remote override of the primary propulsion system.

5. A maximum of two (2) non-line-of-sight (NLOS) navigation aids may be used external to the designated flight area. These must be capable of penetrating simulated walls having 6 dB loss across all frequency bands. It will be assumed that these navigation aids were positioned by a mother ship around the building (but not on top) prior to sub vehicle launch. The navigation aids must be portable, and must be removed once the team leaves the competition area. GPS is not allowed as a navigation aid.

6. The aerial robotic system is required to be able to send vehicle status and navigation solutions to the Judge's remote JAUS-compliant data terminal via the JAUS protocol. This will be done according to the JAUS Standard Set which will be provided to all official teams. Imagery may be delivered to a separate team-supplied terminal using JAUS protocols but other signal formats will also be acceptable. Similarly, kill switch transmissions may use JAUS protocols, but can be achieved by other means without penalty. If more than one aerial robot is deployed simultaneously, intercommunication between the aerial robots may be by any means and any protocol desired.

7. Upon entering the arena under autonomous control, aerial robots must remain within the bounds of the arena or the attempt will end. Vehicles leaving the arena or in the Judges' opinion, are about the leave the arena, will have their flight terminated by a Judge. Flight termination actuation will be controlled by a Judge, not the team. Each team will supply the designated Judge with its manually-actuated kill device as they enter the arena prior to their attempt(s), and must demonstrate that the kill switch is functional for the Judge. Either separate kill switches can be provided for each vehicle in multiple vehicle swarms, or a single kill switch that disables all vehicles in the swarm simultaneously is deemed acceptable.

8. The ground station equipment other than the optional navigation aids, manual kill switch mechanisms, and Judges' JAUS-compliant terminal interface must be portable such that it can be setup and removed from the arena quickly. A suggestion would be to setup the equipment on a roll-cart similar to that shown in Figure 1.

Figure 1. Roll-Cart.

Operations

Teams will be given four (4) flight attempts. The team with the highest static judging score will be given one (1) additional attempt. Each team will be given 15 minutes to setup their system and adjust parameters. The attempt begins when the first vehicle is launched and ends when either manual override is asserted and/or the final functional vehicle is in the opinion of the Judges, no longer able to operate in a meaningful manner. If the team is unable to launch an aerial robot within the 15 minute window, the attempt is forfeited. Each team is granted one (1) pass. Once the attempt is completed the team will be required to leave the arena. No hardware may be left in place.

During the static display of the vehicle(s), the vehicle(s) will be measured to verify the 1 meter maximum dimension constraint. The vehicle(s), in takeoff configuration will be weighed to verify the 1.50 kg maximum weight restriction. The vehicle(s) will also be examined to assure that all kill switch functions are fully operational prior to flight.

Competition Area

The competition flight area (arena) will be constructed within an area that is approximately 30 m long by 15 m wide, and 2.5 m high. This area will be divided into a number of rooms and corridors with various obstacles of various heights. All that is known regarding a priori location is that the target control panel will be on the wall of a room and not in a corridor. The launch location will be fixed at a distance of 3m and oriented toward a 1 x 1 meter (minimum) opening into a corridor. The mission is successful if the desired information is transmitted back to the launch point within the allotted time. The vehicle is expendable and must not return because it will be contaminated. Navigation aids, if used, may be located anywhere in a 3 meter perimeter bounding the outside of the arena (see Figure 2). A list of typical materials and construction notes (which may be updated from time to time) is provided at http://iarc.angel-strike.com/IARC_Arena_Construction.pdf so that teams can construct similar practice arenas for use in refining their aerial robotic systems prior to arrival on the Competition day.

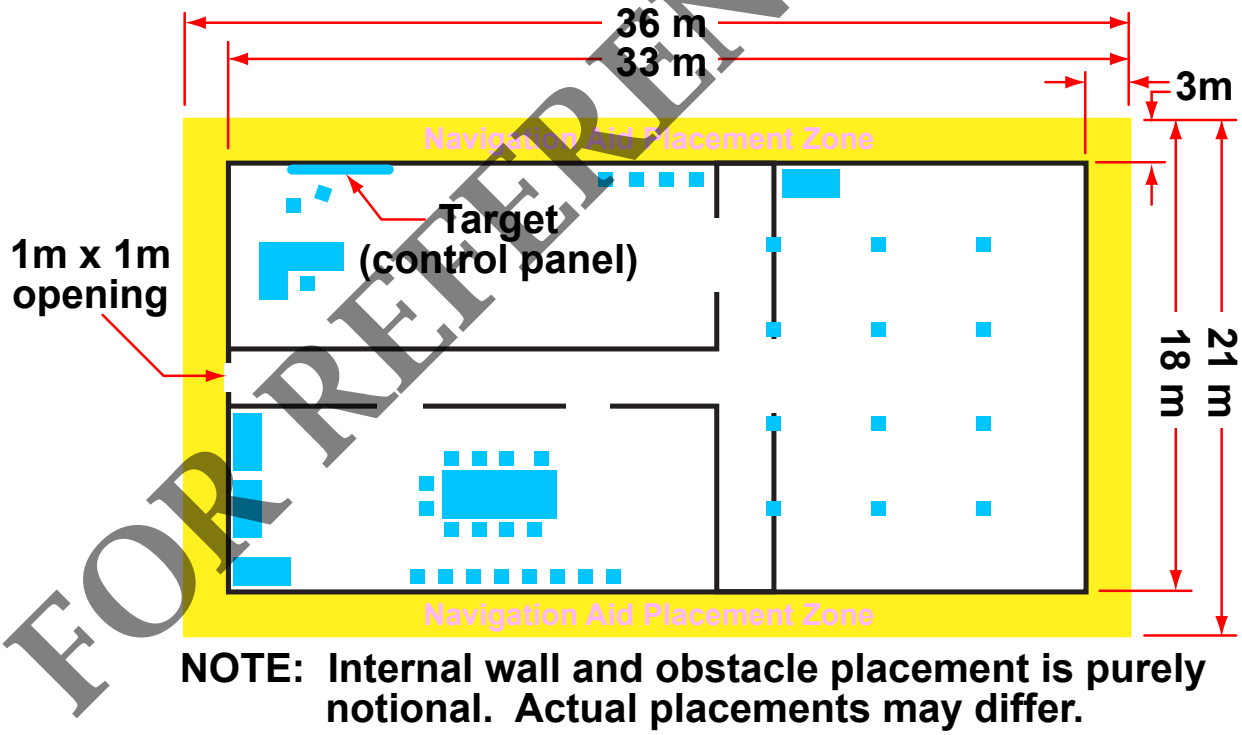

Figure 2. Arena dimensions and notional internal layout.

Making Application to Enter

So your entry form will be anticipated, and so you can be notified that it has not arrived were it to get lost in the mail, an *Intention to Compete* should be received no later than the date shown in the schedule at the bottom of these rules. To avoid unnecessary delay due to the mail (particularly for international entries), a letter of *Intention to Compete* can be transmitted by E-MAIL to Robert C. Michelson, Competition organizer, at millennialvision.llc@gmail.com. Submission of a letter of *Intention to Compete* is not a requirement, however entries received after the deadline which are not clearly postmarked may be rejected as late unless prior intention to compete has been expressed.

The official World Wide Web pages for the competition are your source for all information concerning rules, interpretations, and information updates regarding the competition. In anticipation of the upcoming event, the official rules and application form will be obtained from the official world wide web pages and will *not* be mailed to potential competitors. If you have received these rules as a hard copy from some other source, be advised that the official source of information can be found at:

http://iarc.angel-strike.com/

The application form is available electronically at:
http://iarc.angel-strike.com/entryform.php

All submissions must be in English. The completed application form is not considered an official entry until a check or money order for 1000 U.S. Dollars is received by mail on or before May 1, of the current year for which a team officially enters the Competition (this is a one-time application fee). The application fee should be sent to the attention of the Competition organizer, Robert Michelson, P.O. Box 4261, Canton, Georgia 30114, U.S.A. This application fee covers all of the events for the 5th Mission until it is achieved. Teams entering for the first time subsequent to 2009 are still liable for the application fee. (This fee has been instituted to discourage teams from applying that are not serious competitors). As an incentive, part of this application fee will be returned to those teams performing to a specified level during each event (see the Scoring section for details on fee rebate).

The application fee (in the form of a check or money order) should be made out as follows: AUVSI – IARC. Checks or money orders made out to any name other than "AUVSI – IARC" will be returned. Upon receipt of the one-time application fee, your team will become "official" and will get listed on the official web site (this helps you to gain sponsorship grants), and co-sponsors offering special promotions will be notified that your team is eligible these offers (see offer details as they become available at: http://iarc.angel-strike.com/).

A brief concept outline describing the air vehicle must be submitted for safety review by the Judges (the application form provides space for this). The Judges will either confirm that the submitting team design concept is acceptable, or will suggest safety improvements that must be made in order to participate.

A web page showing a picture of your primary air vehicle flying either autonomously or under remote human pilot control must be posted/updated by June 1 of each year to continue to be considered as a serious entry. The web page should also include sections describing the major components of your system, a description of your entry's features, the responsibilities of each of your team members, and recognition for your sponsors. At least one picture of your vehicle flying is required, though additional photographs of the other components comprising the system are desirable. People accessing your page should be able to learn something about your system from the pages. Web pages that are deemed adequate will be listed with a link from the official Competition web site.

A research paper describing your entry will be due by the date shown at the bottom of these pages. The paper should be submitted electronically in .pdf format via E-MAIL to millennialvision.llc@gmail.com (no hard copy is required).

Teams may be comprised of a combination of students, faculty, industrial partners, or government partners. Students may be undergraduate and/or graduate students. Inter-disciplinary teams are encouraged (EE, AE, ME, etc.). Members from industry, government agencies (or universities, in the case of faculty) may participate, however full-time students must be associated with each team. The student members of a joint team must make significant contributions to the development of their entry. Only the student component of each team will be eligible for the cash awards.

Since this 5th Mission of the International Aerial Robotics Competition was announced in AD2008 and will run until the mission is completed, anyone who is enrolled in a college or university as a full-time student (as defined by their university) any time during or after the calendar year that the team first made application, is qualified to be a team member.

Logistics

Each team will be given four attempts during the total time allotted for performance judging. Within these four attempts the team shall demonstrate as much as it can. The team scoring the most points during the Static Judging will be awarded one additional attempt. However, due to the fact that the competition is not schedule driven, no team will be able to choose what time of day it will be making its attempt– only its place in the sequence. After an attempt has been made, the team can choose to continue and make an additional attempt (within 10 minutes) or leave the arena and reenter the performance sequence. If a team is not ready to make an attempt when in sequence, it is allowed one "free pass" but must be prepared the next time or the lose one attempt. Each team will be allotted 15 minutes to start an attempt. The team captain will declare to the Judges the start of an attempt. The attempt is not concluded until the vehicle is removed from autonomous flight. If in the opinion of the Judges an attempt fails due to a situation beyond the team's control, it will not count against the team's remaining allotment of attempts.

All transmitters will be impounded the night before the day of the competition. They will be issued before taking the arena and must be returned upon completion of the attempts. If a team requires a transmitter on a potentially conflicting frequency between attempts, the team in the arena has priority.

Points will be used to determine team rankings and any progress awards apart from the grand prize.

Teams will be allotted four attempts to accrue points. Each team will be assigned a specific starting time slot at which it must set up and begin its performance. Judges will score each valid attempt, with the highest score being used to determine the final ranking score.

Teams may have no more than one entry, though that entry may be comprised of any number of vehicles. Only one team may be affiliated with any particular university (though different universities may band together to form a single team). If several teams wish to enter from a single university, a decision must be made by the university (not the IARC) as to which team will represent the school. This may be done as a result of an engineering analysis of each team's design and progress, or it may be as a result of an actual demonstration of hardware. The determination should be by a panel of impartial evaluators not directly affiliated with either team. Notification (prior to the journal paper submission) of which university entry is the "official" one must be provided in writing by someone equivalent to the "Dean of Engineering" since various departments or campus may be vying for the honor of representing the university.

It is hoped that teams will join together to offer their best ideas for the benefit of a single unified team, while being willing to compromise and defer to team members with specific training and skills. The most successful teams are interdisciplinary groups of dedicated engineers and scientists with backing from their university administration and industrial partners. Having a strong, involved Faculty Advisor has proven beneficial to all winners in the past.

To discourage multiple entries from a university, each team vying to represent the university must submit its individual applications in accordance with the schedule shown at the bottom of these pages, along with a nonrefundable (see rebate policy) 1000 U.S. Dollar application fee. No application will be considered valid without the accompanying fee being received. It is therefore in the interest of all potential competitors from a single university to form their team without the need for arbitration prior to submission of an application.

Scoring

Scoring will be based on performance of particular autonomous behaviors. Only those completing the 5th Mission goal as defined above are eligible to receive the grand prize cash award. In addition to the demonstrated behaviors described below, the journal quality paper describing the team's entry (defined below) must be submitted by the designated date.

Rebate Incentive: Teams which have vehicles that are able to autonomously complete the entire 5th Mission in their first attendance at the IARC will receive their entire application fee refunded in full (in addition to prize money award). If in their first attendance at their IARC their vehicle does not complete the mission, but is able to enter the room containing the Control Panel (target) under fully autonomous control, $500 of their application fee will be refunded.

The first team to execute the full mission will win the AUVSI prize money and be declared the winner of the entire competition if no other teams are able to perform equally in a given year. During a particular year, if more than one team is able to achieve mission success, then the team that is able to execute the full mission in the least amount of time will be declared the winner. In the unlikely event that multiple teams execute the full mission in the same amount of time (±1 minute), the judges shall use the scoring formula to determine the winner.

A tie-breaking score will be based on a number of factors as follows:

Effectiveness Measures:
Points will be gained for the following:

1. Entry into the 1m x 1m (minimum) opening **(A)** (200 points).
2. Avoiding all obstacles without collision **(B)** (500 points)
3. Arriving within the room containing the Control Panel target **(C)** (200 points).
4. Except for launch and emergency recovery, fully autonomous operation **(z)** is required (+1), else (0).
5. Except for video data transmission, full JAUS compliance **(j)** is required (+1), else (0).

Subjective Measures:

1. Elegance of design and craftsmanship **(D)** (up to 75 points).
1.1 Component integration (0 - 25).
1.2 Craftsmanship (0 - 25).
1.3 Durability (0 - 25).

2. Innovation in air vehicle/subvehicle design **(E)** (up to 150 points).
2.1 Primary propulsion mechanisms (0 - 30).
2.2 Attitude/heading adjustment schemes (0 - 30).
2.3 Navigation techniques (0 - 30).
2.4 Target identification techniques (0 - 30).
2.5 Threat avoidance schemes (0 - 30).

3. Safety of design to bystanders **(F)** (up to 200 points).
3.1 Isolation/shielding of propulsors (0 - 75).
3.2 Energy source stability/safety (0 - 25).
3.3 Crashworthiness (0 - 25).
3.4 Emergency termination mechanisms (0 - 75).

4. ***Journal Paper.*** Each team is required to submit a journal-quality paper (written in English) documenting its project. This paper **(G)** is worth between -100 and 100 points depending on technical quality (0 points minimum for submitting a credible paper, and -100 points for those not submitting a paper by the deadline). Papers are limited to 12 pages (including figures and references, if any). The format shall be single-sided with text occupying a space no greater than 9 inches tall by 6.5 inches wide centered on each page. Font size shall be 12 point (serif font) with 14 point leading. The example format is provided as an addendum to the rules (see http://iarc.angel-strike.com/paperformat.pdf). Topics to be covered are detailed in a printable document found at http://iarc.angel-strike.com/papercontent.pdf. A file in .pdf format of your paper is due via E-MAIL to millennialvision.llc@gmail.com by June 1 of each qualifier year. All papers may become part of the AUVSI Symposium proceedings for that year and will therefore serve as a publication reference on team member resumés.

5. ***Best team Tee Shirt*** **(H)** (10 points to the best, 5 points to others having team Tee Shirts, and 0 points to those not having team Tee Shirts).

In addition to the points scored during the Static Judging (Subjective Measures), the teams will be rank-ordered by the judges based on score.

Scores for a given round will be totaled according to the following formula:

$$\text{SCORE} = z\,(A + B + C + D + E + F + G + H)\,j$$

The highest score accumulated by a given entry after all runs have been completed in any event year will be considered that team's current ranking for that year.

"Air Vehicle" Definition and Attributes

1. "Air Vehicles" are considered to be those capable of sustained flight out of ground effect while requiring the earth's atmosphere as a medium of interaction to achieve lift (as such, pogo sticks and similar momentary ground-contact vehicles are not considered to be flying air vehicles). The scoring formula and arena have been carefully designed to normalize advantages inherent to a given class of air vehicles such that all may compete fairly to perform the same tasks. Prospective teams must decide how best to allocate resources to maximize their potential score in light of the constraints imposed by the arena, the task, and the scoring algorithm.

2. Air vehicles may land and takeoff autonomously within the arena if desired. Vehicles crossing no-fly boundaries, or which seem to be going away from a logical path leading to the target zone, will be brought back under safety pilot control or terminated by the Judges.

3. Each air vehicle must be equipped with an independently-powered, independently-controlled, non-pyrotechnic termination mechanism that can render the vehicle ballistic upon command of the Judges (e.g., if using R/C radio equipment, a separate battery, transmitter, and receiver must serve as the independent relay for the onboard termination signal). This termination mechanism must be demonstrated to the Judges prior to each round of each event. Air vehicles may land under manual control of a safety pilot in the event of an emergency, but credit for that run will be forfeited unless manual control is exercised AFTER the mission has been completed in full. Both autonomous and manually-assisted landings must occur within the boundaries of the Competition arena.

Judging

A team of three judges will determine compliance with all rules. Official times and measures will be determined by the Judges. Subjective measures (1-5) will be Static Judged in accordance with a schedule to be announced a week prior to the competition. Team papers will be ranked and scores assigned to them at this time, though they will have been reviewed by the Judges in advance of this Static Judging.

Prize Awards

The following benefits accrue to the teams participating in, and winning the International Aerial Robotics Competition:

1. Ten thousand dollars will be added to the prize each year. In the unlikely event that the full mission is achieved in the first event year (2009), a US$10,000 prize would be awarded. If for example, the full mission were not achieved after the fourth event year (2012), a US$40,000 cash prize would be awarded to the winner of the Competition.
2. Any other awards prior to the completion of the full mission, shall be distributed at the discretion of the judges.
3. International recognition for the winning students' university.
4. International recognition through AUVSI for the winning industrial/government/faculty organization.
5. Free full-page advertisement for the winning company, governmental agency, or university faculty department in Unmanned Systems magazine.

Schedule

REMEMBER THESE IMPORTANT DATES:

Notification of intention to compete ..... ASAP
Attendee List due ..... May 15, 2009
Current Team web page on line ..... June 1, 2009
Journal quality paper (all teams) ..... June 1, 2009
***Having flown the 5th Mission at home twice ..... June 1, 2009**
(*Recommended strongly)
Teams can arrive on site (earliest 10 AM) ..... July 20, 2009
Team Registration (10 AM - Noon) ..... July 20, 2009
Static Judging (by appointment announced at Registration) ..... July 20, 2009
Performance Judging (visitors welcome) ..... July 22, 2009
Awards Banquet (6-9 PM at the Faro Convention Center) ..... July 23, 2009
Arena take-down ..... July 24, 2009