

THE MILLENNIAL EVENT RULES FOR THE AD2000 INTERNATIONAL AERIAL ROBOTICS COMPETITION

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.
2. Computational power need not be carried by the air vehicle or subvehicle(s). 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.
3. Data links will be by radio, infrared, acoustic, or other means so long as *no* tethers are employed.
4. The air vehicles must be free-flying, autonomous, and have no entangling encumbrances such as tethers.
5. Subsequent to 1998, subvehicles may be deployed within the arena to search for, and/or acquire information or objects. Subvehicle(s), must be fully autonomous, and must coordinate their actions and sensory inputs with all other components operating in the arena. Subvehicles may not act so independently that they could be considered separate, distinct entries to the competition. An autonomous air vehicle is mandatory whereas any number of cooperating autonomous subvehicles is optional. Subvehicles may be deployed from the primary vehicle or may be launched separately from the [landing zone](#). Subvehicles may be ground-based or airborne. All vehicles must remain within the boundaries of the arena.
6. A Note About Ground-Based Subvehicles-- *Ground vehicles must be autonomous and subordinant to the aerial robotic*

component of the system in that it can be directed by the air vehicle or provide cues to direct the air vehicle, but all reporting is from the air vehicle's intelligence. What this means is that the air vehicle is not merely a relay for the ground vehicle transmissions. Rather, intelligent communication needs to be taking place wherein data from the air vehicle is updated and "better informed," based on the experiences of the ground vehicle. Example: The aerial robot detects a potential survivor at coordinates x,y , but due to obscuration of the potential target by smoke or the inability of the air vehicle to safely approach for a better look, the ground robot is instructed to inspect those coordinates while the aerial robot proceeds to search for other targets. Upon arrival to position x,y the ground robot reports that there is a survivor, but there are drums of potentially explosive material nearby at coordinates $x+4, y-1$. This information is uplinked to the aerial robot which is now 100 meters away inspecting another target. The precise information from the ground robot is integrated into the map being compiled by the aerial robot and is transmitted back to the human team as a seamless report.

7. Air vehicles and air-deployed subvehicles may be of any size, but together may weigh no more than 90 kg/198 lbs (including fuel) when operational. Ground-based subvehicles proceeding under their own power from the landing zone have no weight restriction.
8. Any form of propulsion is acceptable if deemed safe in preliminary review by the judges.
9. 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 January 2, 2000**. 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.
10. **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 2000 Millennium Event and third Qualifier, 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: [IARCLaunchPoint.html](#) The application form is available electronically [here](#).** 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 February 1, 2000.** This application fee covers all of the qualifiers. Teams entering in 1998 or 1999 need not submit another application fee. Teams entering for the first time subsequent to 2000 are still liable for the application fee. *(This fee has been instituted to discourage teams from applying that are not serious competitors)*. A brief concept outline describing the air vehicle must be submitted for safety review by AUVSI (the application form provides space for this). AUVSI will either confirm that the submitting team is a qualified competitor, or will suggest safety improvements that must be made in order to qualify. **A web page showing a picture of your primary air vehicle flying either autonomously or under remote human pilot control must be supplied by March 1, 2000** to continue to be considered as a serious entry. This web page will be in lieu of the former requirement for a VHS video tape

of your primary air vehicle. The 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 June 1, 2000** The paper should be submitted electronically in .pdf format via E-MAIL to millennialvision.llc@gmail.com (no hard copy is required). The 2000 International Aerial Robotics Competition (Millennial Event) will be hosted by the U.S. Department of Energy's [Hazardous Materials Management and Emergency Response \(HAMMER\)](#) facility adjacent to the Hanford Nuclear site in Washington State **on June 29, 2000**.

11. 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 the Millennial Event will occur in AD 2000, anyone who is enrolled in a college or university as a full-time student during calendar years 1997, 1998, 1999, or 2000 is qualified to be a team member. "Full-time" is defined as 27 credit hours during any one calendar year (1997, 1998, 1999,

or 2000) while not having graduated prior to May 1998. Graduation after May 1998 will not affect your status as a team member. If your team does not qualify under the above definition, it *may* qualify for the "[High School Open Class Event.](#)" which will be held concurrently with the Collegiate Class Event under different rules.

2000 QUALIFICATION

- The third qualifier in 2000 will involve demonstration of fully autonomous flight over a large area (five acres or more) containing briefed obstacles. Aerial robots must be able to locate enough items that will be encountered in the Millennial event to accrue a qualifying score. This will range from partially-buried, randomly-oriented drums of potentially explosive materials (amid debris and drums of inert materials), the location of fire sources, simulated dead bodies, or simulated injured survivors on the ground that are signalling for help with a "waving arm motion" or other human-like activity. The more items correctly identified, the higher the qualifying score. Details concerning how many target items are present, their location within the boundaries of the arena, and the composition of the target items will be an unknown since this would not likely be a priori knowledge in an actual disaster.
- Expect the following:
 - that some bodies may be partially covered with debris and may be wet (thereby masking infrared signatures).
 - some [drums](#) to be labeled as to their contents.
 - [fires](#) of varying intensity that can disappear after the mission has begun.
 - some [survivors](#) which will remain "alive" for a period that may be shorter than your mission. ("alive" is defined as capable of motion).

[dead bodies](#) at the beginning of the mission, the number of which may increase as the mission progresses. visual obscurants (smoke, aerosols, [water fountains](#) from broken distribution mains).

- Drums scattered about the area will be made of [black plastic](#) or steel of 55-gallon capacity, and containing either harmless substances or hazardous substances. Not all drums will be labeled. Those of interest that *are* labeled will contain either radioactive material, biohazardous material, or picric acid ($C_6H_2(NO_2)_3OH$), a poisonous, explosive crystalline solid. The [drums](#) will appear to be either fully exposed or partially buried (no retrieval of a sample will be required).
- [Radioactive Symbol-- Figure 1a](#), [Biohazard Symbol-- Figure 1b](#), and [Explosives Symbol-- Figure 1c](#) show the three types of identifying labels for drums of interest. The labels are *white* images on a *black* background as depicted in [Figures 1a, 1b, and 1c](#). Label orientation will be random and will conform to the upper surface of the drum in whatever position it is to be found.



- [Figure 2](#) shows a typical drum arrangement (the actual arrangement and number of drums used on the day of the competition will be different).



- "Survivors" will be simulated by animatronic synthetics capable of limited limb motion and sound. All survivors will be incapacitated and unable to move to safety under their own power. These synthetics will be programmed to expire at predetermined intervals unknown to the teams. The number of injured humans and their location relative to the disaster scene will be unknown. Keys to survivor location and will be movement and sound. "Dead bodies" will no longer move or make sound. Survivors and dead bodies may be partially occluded by rubble and debris.
- Fires will range in size from small chemical fires (smoke producers) to large gas fires which will generate less smoke, but significant heat, light, and sound. Fires once ignited will remain burning or can self extinguish anywhere and at any time without warning, but new fires will *not* be ignited once a run has begun.
- Fountains of water from broken pipes will be present. The location, size, and duration of the spray will be unknown to the teams. Streams of water once started will remain flowing or can self extinguish anywhere and at any time without warning, but new fountains will *not* be initiated once a run has begun.
- All entries will be required to qualify in order to progress toward finalist status and admission into the Millennial event in AD 2000.
- An aggregate of 2000 points must be amassed in order to progress to the Millennial Event. For whatever reason, if a team does poorly in the 1998 or 1999 qualifiers, it can still apply again, but must ultimately amass a qualifying score that meets or exceeds the minimum combined score of 2000 points required to progress to the Millennial Event. Teams not attaining at least 2000 points by the conclusion of the qualifiers will be disqualified from the Millennial Event. (Note: because the same judges have scored each team entering the competition since 1998, there has been

consistency in the scoring process. The same slate of judges will be present in AD2000 for the final qualifier and the scoring of the Millennial Event. Since the 2000 point qualifying score was an arbitrary goal set for qualifying in 1998, the judges are empowered to lower the qualifying point goal for the benefit of all teams (scoring “curve”), if it is recognized that the overall scoring for the qualifiers has been too strict.)

- All air vehicles must start from a designated landing zone (LZ) on one edge of the arena. This LZ will be a prepared asphalt surface. Adequate runway will be available for fixed wing aerial robots. At least 100 square meters of the LZ will be level. Take-off must be autonomous. Ground-based sub-vehicles that are not to be deployed from the aerial robot, must deploy from this same LZ. No team member may be within the boundaries of the Competition Arena once a run begins. From lift-off until the end of the round, all team members must remain outside the Competition Arena. A round ends when the aerial robot returns to the LZ and lands autonomously (whether any of the ground-based sub-vehicles have returned or not).
- Teams will be allotted 60 minutes to complete the task. Each team will be assigned a specific 60-minute time slot in which they must set up and perform as many attempts as they wish. Judges will score each valid attempt, with the highest score being used to determine the final qualifying score. Non-flight activities such as set-up, calibration, and take-down will count against the allotted 60 minutes to complete the task. After 60 minutes of arena time for any given team, a new team will be allowed to take control of the arena and the clock for the new team will begin running.
- A run will be declared a valid try if a vehicle leaves the starting area.
- Teams may have no more than one entry, though that entry may be comprised of any number of sub-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 AUVSI) 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 sponsors 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. To discourage multiple entries from a university, each team vying to represent the university must submit its individual applications by February 1, 2000, along with a nonrefundable 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

The score will be based on a number of factors as follows:

Effectiveness Measures:

Points will be gained for the following:

Correctly identifying a survivor (**A**) (300 points) and his location (**B**) (200 points) to within 2 meters of the survivor's actual position. This information must be telemetered back and displayed to the judges during the mission. The value assigned to a survivor will be a function of how long it takes in minutes (**x**) to locate his position and report it back to the judges.

Correctly identifying a dead body (**C**) (200 points) and its location (**D**) (200 points) to within 2 meters of the body's actual position.

Correctly identifying the nature (**E**) and location (**F**) of potential hazards to be encountered by subsequent rescue teams. Hazards consist of large fires, radioactive materials, biohazardous materials, and explosives (100 points each).

Nothing will be accrued for falsely identified hazards (e.g., not really a hazard). Falsely identifying survivors (e.g., really dead) or victims (e.g., really alive) will be worth nothing (**w**) (1 = true ID, 0 = false ID), however correctly identifying the location of the survivor, victim, or hazard will still be worth points. Identifying a survivor that later "dies" before the mission is complete, will not result in deducted points. No points will be accrued for incorrectly specifying the location of a hazard, survivor, or victim (**y**) (1 = true location, 0 = false location). Location error must be less than or equal to two meters from the centroid of the target item as measured by the judges beforehand. In summary for

survivors and victims, finding and correctly identifying a survivor is worth 500 points (total), finding and correctly identifying a victim is worth 400 points (total), misidentifying the life state of either results in only the 200 location points. Obviously if you can't find them, you get no points.

Fully autonomous takeoff and flight (**Z**) is required (+1), else (0).

Fully autonomous landing (**L**) once over LZ after having completed a fully autonomous takeoff and flight (50 points).

Subjective Measures:

Elegance of design and craftsmanship (**G**) (up to 75 points).

Component integration (0 - 25).

Craftsmanship (0 - 25).

Durability (0 - 25).

Innovation in air vehicle/subvehicle design (**H**) (up to 150 points).

Primary propulsion mechanisms (0 - 30).

Attitude/heading adjustment schemes (0 - 30).

Navigation techniques (0 - 30).

Target identification techniques (0 - 30).

Threat avoidance schemes (0 - 30).

Safety of design to bystanders (**I**) (up to 200 points).

Isolation/shielding of propulsors (0 - 75).

Containment of fuel and exhaust by-products (0 - 25).

Crashworthiness (0 - 25).

Emergency termination mechanisms (0 - 75).

Each team is required to submit a journal-quality paper (written in English) documenting its project. This paper

(J) is worth between 50 and 100 points depending on technical quality (50 points minimum for submitting a credible paper, and -100 points for those *not* submitting a paper by the deadline). Papers are limited to 10 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 [example format](#)). Topics to be covered include: competitive strategy, how your system design achieves your strategy, propulsion, stability augmentation schemes, navigation schemes, target identification techniques, risk reduction and threat avoidance schemes. **A file in .pdf format of your paper is due via E-MAIL to robert.michelson@gtri.gatech.edu by June 1, 2000.**

Best team Tee Shirt (K) (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. The starting time slots will be allocated based upon the choice of the teams, with the first choice going to the highest ranked team, the next choice going to the second highest ranked team, and so on until the final time remaining is assigned to the team ranking lowest based on the Subjective Measures during the Static Judging.

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

$$\text{SCORE} = z (\text{SUM} [(\text{A}_N - x)\mathbf{w} + \mathbf{B}_N] \mathbf{y} + (\mathbf{C}_{NW} + \mathbf{D}_N) \mathbf{y} + (\mathbf{E}_{NW} + \mathbf{F}_N) \mathbf{y}]) + \mathbf{G} + \mathbf{H} + \mathbf{I} + \mathbf{J} + \mathbf{K} + \mathbf{L}$$

where N is the individual instance of a particular item.

The number of targets available will be sufficient to achieve in excess of 2000 points when combined with an average static judging score. The highest score accumulated by a given entry after all runs have been completed will be considered that team's current qualifying score.

"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 the no-fly boundaries into populated areas, or which fly too far from the disaster site will be disqualified for that run and must be returned to the LZ. The area over the HAMMER operations buildings and the LZ/spectator areas are considered no-fly zones. There are thousands of acres at HAMMER over which to fly, but if in the judges opinion an air vehicle is reaching a distance that is too far to reliably recall or terminate, it will be recalled and the run terminated.
3. Each air vehicle and subvehicle 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 the first round. Air vehicles may be landed under manual control of a safety pilot in the event of an emergency, but the points that could be awarded for that run will be forfeited. Both autonomous and manually-assisted landings must occur within the boundaries of the Competition Arena (i.e., not in the no-fly zones).

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 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

1. Thirty thousand dollars will be awarded to the winner(s) of the competition.
2. Any other awards resulting from the AD2000 event 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:

1. Notification of intention to competeJanuary 2, 2000
2. Application Deadline February 1, 2000
3. Fee Deadline February 1, 2000
4. Team web page on line March 1, 2000
5. Journal quality paper June 1, 2000
6. Static Judging June 27, 2000
7. Third Qualifier June 28, 2000
8. Performance judging (i.e. "the competition") ... June 29, 2000
9. Rain-day for performance judging June 30, 2000

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