# MAAV System Requirements

MAAV

## 1 Introduction

This document lays out the primary objective of MAAV, the mission constraints of the IARC, and the system requirements to fulfill the primary objective and mission constraints. Requirements may be specified as either **must**, **shall**, or **should**, which are defined below:

| | |
|---|---|
| **shall** | Completion is mandatory |
| **must** | Completion is mandatory |
| **should** | Completion is optional, but recommended |
| **may** | Completion is optional, and neither recommended nor discouraged |

## 2 Primary Objective

The primary objective (PO) of Michigan Autonomous Aerial Vehicles (MAAV) is to compete in the International Aerial Robotics Competition (IARC)[1]:

> To fabricate a vehicle that will herd no fewer than 7 ground robots across a designated goal line, within the specified time, in a scenario that conforms to the rules of the IARC Mission 7a

## 3 Mission Constraints

In order to meet the Primary Objective, Mission Constraints were created from the IARC rules[1].

### 3.1 Autonomy

The system shall be completely autonomous from takeoff to landing, as per the PO.

### 3.2 LiDAR Use

The system shall not use LiDAR-based simultaneous localization and mapping (SLAM) for localization in any way, as per the PO.

### 3.3 Collisions

The system shall not collide with obstacles in the environment at all, as per the PO.

### 3.4 Maximum Flight Dimension

The system shall not have any dimension greater than 1.25m while in flight, as per the PO.

### 3.5 Flight Ceiling

The system shall stay below the flight ceiling of 3m, as per the PO.

### 3.6 Kill Switch

The system shall have a remotely operated kill switch that cuts power from the motors completely. This kill switch shall not require any inputs beside power and ground to operate. Per the PO.

### 3.7 Time Limit

The system shall complete the mission in 10 minutes or less, as per the PO.

### 3.8 Ground Robot Interaction

The system shall interact with ground robots via Hall Effect sensors or physical collisions, as per the PO.

### 3.9 Boundary

The system shall not fly out of the boundary of the arena, except for flying outside the boundary no more than 5 meters for no longer than 3 consecutive seconds, as per the PO.

### 3.10 Ground Robot Loss

The system shall not allow more than 3 ground robots to leave the arena during the mission, except across the goal line, as per the PO.

### 3.11 Power Source

The system shall be powered by a Lithium Polymer battery, as per the PO.

# 4 System Requirements

MAAV has establish system requirements to meet the mission constraints described in Section 3. For each requirement, rationale will be provided. In addition to system requirements, each subsystem has specific requirements.

## 4.1 Ground Robot Detection

The system shall detect ground robots and their positions and velocities in the arena on a "best effort" basis, as per 3.10. The observed position and velocity of a ground robot, relative to the system, shall have less than 10% average error. Accurate ground robot detection is a necessary input to the planning algorithm.

## 4.2 Goal Line Detection

The system shall detect the goal line and out-of-bounds lines on a "best effort" basis, as per 3.10. The observed position of the goal line and out-of-bounds lines, relative to the system, shall have less than 10% average error. As in 4.1, these positions are necessary inputs to the planning algorithm.

## 4.3 Battery Life

The system shall have enough energy to operate for at least 10 minutes, as per 3.10, 3.7.

## 4.4 Ground Robot Bumper

The system shall be able to interact with the ground robot front bumpers, as per 3.8.

## 4.5 Ground Robot Hall Effect Sensor

The system shall be able to interact with the ground robot Hall Effect sensors, as per 3.8.

## 4.6 Kill Switch Delay

The system shall cut power to the motors with 100 ms when the kill switch operator actuates the switch, as per 3.6. Each pulse width modulation (PWM) period is 20 ms, so 5 consecutive low signals are required to kill.

## 4.7 System Safety

The system should be sufficiently protected so that the propellers cannot easily injure a bystander or the competition surroundings.

### 4.8 Ground Robot Interaction Guarantee

The system shall be capable of interacting with any ground robot that is at least TODO meters away from any boundary line, as per 3.10.

### 4.9 Free Fall

The system shall be able to land or impact the ground without damage from a height of 0.5 meters.

### 4.10 Maneuverability

The system shall be able to takeoff, cover the diagonal of the competition arena, and land within 6 seconds, as per 4.8, 3.10, 3.5.

### 4.11 Flight Altitude

The system shall fly shortest path trajectories above a ground effect altitude of 0.5 meters, as per 4.8, 3.10, 3.6.

### 4.12 Hovering

The system shall hover in place on command by the flight controller, as per 4.8, 3.10, 3.7.

## 5 Structural Design Requirements

### 5.1 Thrust/Weight Ratio

The system shall have a thrust to weight ratio of no less than 1.75, as per 4.10.

### 5.2 Maximum Speed

The system shall have a maximum speed of no less than 6 meters per second, as per 4.10.

### 5.3 Mass

The system shall have a mass of no more than 2.2 kilograms, as per 5.1.

### 5.4 Component Shock

The dynamic characteristics of the system must prevent component shocks above 20g for vertical landings up to three meters per second.

### 5.5 Landing Speed

All components of the system must survive vertical landings at a speed at or below 3 meters per second.

## 6 Electrical Design Requirements

### 6.1 Power Distribution

The power distribution subsystem shall allow a maximumpower consumption of 1.16 kW from MT2216 900 KV motors, 30 Watts from Power Conversion board, and 40 mW conusmed by I/O components, a net power consumption of 1.2 kW.

### 6.2 Kill Switch

The power distribution subsystem must stop supplying power to motors if it fails to receive any signal from the kill switch subsystem. 3.6, 4.6.

### 6.3 Connections

The electrical subsystem connectors used to connect PCBs and sensors shall not disconnect during flight-time or any flight-time simulation lasting 10 minutes.

### 6.4 Kill Switch Range

The kill switch subsystem shall have a radio range of at least 30 meters, as per 4.6.

### 6.5 Power Supply

The power supply of the digital subsystem shall not deviate more than 0.1 volts from nominal supply voltage throughout normal operation.

## 7 Navigation Requirements

### 7.1 Game Algorithm

The game algorithm shall acheive a 90% lower confidence bound of mission success in simulation, as per 3.10. In simulation, the game algorithm may have "perfect" knowledge of all ground robot, obstacle, and boundary positions in addition to its own position in order to isolate the algorithm from all environmental problems.

### 7.2 Localization Position Error

The camera-based localization algorithm shall acheive a fixed upper bound on absolute position error of 5 centimeters, given no state error, as per 3.2, 3.9.

## 7.3 Localization Heading Error

The camera-based localization algorithm shall acheive a fixed upper bound on absolute heading error of 20 degrees, given no state error, as per 3.2, 3.9.

## 7.4 Ground Robot Detection

There shall be an algorithm capable of detecting the vehicle-relative position of ground robots. There is no fixed bound on error, but the error must be reported. Per 4.1.

## 7.5 Obstacle Detection

There shall be an algorithm capable of detecting the vehicle-relative position of obstacles with an error no greater than 10%, as per 3.3, 4.7, 7.6.

## 7.6 Obstacle Avoidance

The system shall remain at least 0.2 meters away from detected obstacles, as per 4.7. The maximum in-flight dimension is 1.5 meters, so 0.2 is slightly greater than 10% of maximum in-flight dimension. Due to the low impact of the obstacles on the flight characteristics of the system, no larger distance must be maintained from obstacles.

## 7.7 Controller Communication

The game algorithm shall generate flight paths to be given to the control software, as per 7.1, 3.7. Flight plans shall consist of waypoints. The system shall give the control subsystem one waypoint at a time.

# 8 Controls Requirements

## 8.1 Accuracy

The controller shall achieve a bound on error in the accuracy of converging to a commanded setpoint that is at most 10% of the setpoint value for all controlled degrees of freedom, as per 4.12.

## 8.2 Oscillation

The controller shall acheive an upper bound on oscillations about waypoints of 0.05 meters for position (x, y, z) setpoints and 0.1 radians for yaw setpoints when hovering at commanded waypoints, as per 4.12, 8.1.

## 8.3 State Estimation

The state estimation algorithm shall be capable of filtering raw sensor values and estimating the state of the vehicle with an accuracy rate of +/-10% of the ground truth state, as per 4.10, 4.11, 4.12, 3.5.

## 8.4 State Sensing

The embedded flight controller shall detect the vehicle's attitude, height, and global linear velocities, as per 4.10, 4.11, 3.5.

## 8.5 Plan Execution Time

The controller shall achieve commanded waypoints with a maximum time of 6 seconds, as per 4.10.

## 8.6 Maximum Speed

The vehicle shall achieve a maximum speed of no less than 6 meters per second, as per 4.10, 5.2.

## References

[1] International Aerial Robotics Competition. *Official Rules for the International Aerial Robotics Competition - Mission 7.*