

Questions of Interest

AUVSI SUAS Competition

This document provides teams with a set of questions that should be answered prior to starting a design process. The questions bring up topics that teams may not otherwise discover, and have a substantial impact on competition performance. The goal is to help teams perform better at competition, without giving away answers, and without describing how to approach the problem. Answering the questions is not mandatory and is not a graded element; it is purely for the benefit of the teams.

No further clarification, questions, or answers will be provided. Any communication related to such will be denied. This document is provided as-is without any warranty.

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Mission Components

This section provides questions and hints related to mission components. It focuses on technical details of system design and the per-mission component strategy.

Autonomous Flight

- Sensors
 - What do each of these sensors do: gyroscope, accelerometer, magnetometer, GPS, barometer (static and dynamic pressure), laser altimeter? What are the accuracies, precision, and rate metrics for these sensors and how does it impact autopilot control? Why have both a static and dynamic pressure measurement?
 - How do you calibrate each of those sensors? Why is calibration important? What is the difference in performance of each sensor? Can you improve calibration anyway?
 - What is the accuracy and update rate of GPS? How does this impact auto takeoff and landing? Are there other sensors which could augment this?
 - For a GPS what is cold, warm, and hot start? How does changing location and elapse of time impact this? How can you improve chances of having a warm or hot start? What is an almanac and ephemeris data?
 - What does a ground plane do for a GPS? How does it improve accuracy? Where should the GPS be placed on an aircraft to improve accuracy and chance of lock? How many satellites are needed for a lock? For an accurate position estimate?
- Air Platforms
 - What are the tradeoffs between a fixed wing aircraft, quadrotor, and a helicopter? What parts of the competition are suited to each air platform?
 - For a fixed-wing aircraft, how does a low-wing, mid-wing, and high-wing impact stability and controllability? Does one make flying autonomously easier? Under which situations would stability not be the goal, and does it apply to this competition?
- Autopilots
 - What does a state filter like a Kalman Filter do? What is the difference between a Kalman Filter, Extended Kalman Filter, and Particle Filter?
 - What does a control system like a PID controller do? How are they tuned, and what are their error conditions?
 - At what rate should these components be executed?
- Flight Path
 - What is the minimum turn radius, climb rate, and descend rate that the aircraft and autopilot must perform due to the rules? What is a good factor of safety for

these traits? Based on previous years (example given in rules), was something more difficult required due to practical reasons?

- What is the difference between fly through waypoint and waypoint with pre-turn? When should you use each? Is there a way to improve chances of hitting a waypoint?
- How does wind impact takeoff speed and takeoff distance?
- What is the difference between a tricycle landing gear and a tail-dragger landing gear? Is one easier to control by an autopilot, and why? Does one contain a discontinuity of control?

Search Area

- Imaging
 - What spatial resolution (inches covered per pixel) is needed to image the smallest target detail? What is the smallest target detail? How does image resolution and field of view impact spatial resolution? Does angle of view impact resolution required (e.g. off-axis)? Is the size of a QRC pixel sufficient spatial resolution to resolve a QRC target?
 - How does aperture, shutter speed, ISO sensitivity, white balance, and camera post processing impact image quality? What is aperture-priority and shutter-priority modes? How does each impact exposure, depth of field, and motion blur?
 - There are two general approaches to imaging: high resolution wide-area stare, and low resolution scan and zoom. How do each of these work? When does one perform better than the other? Which competition elements benefit from each? Is there a way to get the best of both (high resolution with scan and zoom)?
 - How does JPEG compression impact display quality? What is JPEG compression quality? What affect does opening a JPEG image and resaving have on image quality? When is PNG better than JPEG and visa-versa? What is a RAW image format, and what is the pros/cons of using it?
- GPS Geotag (Localization)
 - How do you calculate the GPS position of any given point within an image? Does it depend on field of view? Intrinsic parameters like barrel distortion? What are other sources of distortion, and how do you calibrate and correct for them?
 - What is the source of time for imagery, and what is the source of time for autopilot data? Are these synchronized accurately, and what is the impact of poorly synchronized clocks on geotag accuracy? Do these clocks drift?
 - If you have multiple images with the same target, how do you merge individual GPS geotags into a single result?
 - How frequently is autopilot data generated? Can you interpolate between data-points to get a more accurate state for geotag calculation? What is SLERP and how does it impact interpolation? Is there a way to do better than

interpolating between autopilot generated data? Can you do batch-optimization over an entire flight?

- Area Surveillance
 - For a given aircraft turning radius, what field of view and imaging altitude is required to get ground coverage? What capture rate is required? How does this impact required spatial resolution?
 - Is there a benefit to flying at a lower altitude for image capture? At a higher altitude? Should you use both at a competition?
 - How do you know that images achieved good ground coverage?
 - Does the roll or pitch of the aircraft impact imagery (resolvability of targets, geotag error, etc.)? How does wind direction impact the aircraft's ability to fly level?
 - How does the sun impact imaging quality? Is glare ever a problem? Is it dependent on angle of incident? Can the flight plan take this into account?
- Imagery Data Transfer
 - What data rate do you need for a given image resolution and capture rate?
 - What is the data rate provided by a given hardware device? Is this rate full-duplex? Is this rate the aggregate between send and receive?
 - Can you combine multiple radio links to have a higher aggregate bandwidth and reliability? What is link aggregation? How do "communication flows" impact link aggregation hardware? What does this imply in terms of using link aggregation hardware? Can you implement link aggregation in software using network configuration (e.g. subnets)?
 - How far apart do radio links need to be in order to prevent interference? How does this relate to wavelength of the band? Does this apply to bands (2.4 GHz) or just single frequencies (2.412 GHz)?
 - How do conductors impact interference of radio links? What does this imply about hardware on the plane, metal trailers, cars, and other hardware near antennas? Is carbon fiber or fiberglass a conductor? How do these materials impact radio interference? How does the earth impact radio interference? How far off the ground should radio links be placed?
 - How does range impact wireless performance? How does frequency impact wireless performance? Do all frequencies in a band perform the same?
 - How do the ranges and bandwidths differ for 900 MHz, 2.4 GHz, and 5 GHz. What are the wireless G, N, and AC protocols?
 - Where can the antennas for radio links be placed to maximize chance of line-of-sight, and subsequently minimize interference?
- Imagery Review
 - How fast can a single person review an image without impacting false negatives?
 - Given a capture rate and review rate, how many people do you need to review imagery? How can you coordinate the imagery review?
 - Given a set of images with targets identified in each, how do you merge this information into a single submission to the judges?

Automatic Detection, Localization, and Classification (ADLC)

- What is the difference between testing and validation data sets? What is k-fold validation? What is a precision-recall curve? What are the competition's precision and recall requirements?
- How many possible targets could realistically be generated (shapes, alphanumerics, shape colors, alphanumeric colors, shape rotation, alphanumeric rotation, alphanumeric alignment with shape, shape size, alphanumeric size, etc.)? How many examples are needed to have a suitable confidence interval for precision and recall? How practical is it to achieve that many real examples, or at least a single real example for every possible target? How can you generate examples in an accurate way? Can you simulate distortions, noise, motion blur, etc.?
- How can you make it clear that humans are not assisting the automatic algorithm?

Actionable Intelligence

- Which is more difficult, submission of a target while the aircraft is in air, or the accuracy required when submitting only a single target?
- What are the limitations to being able to submit all targets while the aircraft is still in air, and simply selecting the highest confidence target as the actionable one? Can those be overcome?

Off-Axis Target

- What is the incident view angle for the off-axis target? How does aircraft altitude impact incident view angle? What altitude is optimal?
- How far away is the off-axis target from the UAS during imaging (hypotenuse)? How does this increased distance and the incident view angle change the required spatial resolution? How does this impact the choice of field of view or zoom, and imagery resolution?

Emergent Target

- What spatial resolution is needed to resolve the example activities given?
- Does the image angle of incidence impact the ability to understand the scene?

Simulated Remote Information Center (SRIC)

- What is the relative speed to connect via DHCP or static IP address? How much time does it take to connect to the network, and download / upload files, ignoring the time it takes to enter in commands or other human-related activities? How far has the UAS moved in this time, and what does this imply about whether loitering is needed? What does this imply about the benefit of automating SRIC with continuous automatic retries until success?
- What portions of this task must be performed manually, and which can be done autonomously?

Infrared Target

- IR cameras can be very expensive. Are there any cheaper IR cameras and sensors, which out of the box would not be able to perform the task, but with modification could be? Could you change the lenses on cheaper cameras? What about cut-filters?

Air-Drop

- How does wind impact the egg's trajectory? What is the drop distance error that could be caused due to max competition-acceptable winds? How can you estimate the wind direction and magnitude? Can this be corrected for by changing UAS approach trajectory and drop time?
- How long does it take to perform the drop command, or to compute information to determine drop time? How far has the aircraft moved during this time, and can it be compensated for?

Interoperability

- What is a TCP connection handshake, and why does HTTP deal with it? How can you prevent requests from needing multiple handshakes?
- What is the difference between throughput and latency? If you execute requests one at a time, can round-trip latency impact throughput or latency to perform a set of requests?
- If it takes 0.1 seconds to generate UAS telemetry, and 0.1 seconds to send telemetry, can you still send UAS telemetry at a rate of 10 Hz?
- If your interoperability is slow, how do you determine which component is being slow? Is it your software, the time it takes to transfer from client to server, the server, or something else?
- What does the UAS telemetry upload rate imply about the requirements for the autopilot and telemetry radio link?

- If you have to display obstacles on a view which has the same information as the autopilot, would it be easier to download information from the autopilot and display both on a new display, or would it be easier to display obstacles on the autopilot interface? Which one makes manual Sense Detect and Avoid (SDA) practically possible?

Sense, Detect, and Avoid (SDA)

- What are these algorithms and how do they work: potential function, navigation function, discretizing the physical space and then using A*, RRT? What are the benefits of each, and when does each fail? What is a local minimum? Which algorithms can handle simultaneously avoiding an obstacle, and also not going out of bounds or leaving the waypoint path (+/- 100ft)?
- When discretizing the physical space into a graph problem can the UAS heading, altitude, and speed be encoded into the graph? How does this impact computational complexity and does it impact needed code efficiency?
- In which situations does an RRT outperform other avoidance algorithms? What is a side-effect of using an RRT?

System Components

This section provides questions and hints related to system components. It focuses on general engineering topics for each major discipline seen at the competition.

Mechanical/Aerospace Systems

- How many points are given for a custom composite aircraft vs. a balsa Almost-Ready-to-Fly (ARF) aircraft? Why would a custom composite aircraft be beneficial, and is this something your team needs?
- What are sources of noise on servo lines? Does the power supply or length of cord matter? Are there ways to reduce servo noise?

Software Systems

- What is a unit test, integration test, and system test? What is software mocking? What is the difference between a mock, stub, and fake? How could these concepts be used to make testing easier?
- Do power systems fail? Harddrives? Computers? How can you design a system architecture to defend against these failures? What is a fault tolerant system?
- What is an Uninterruptable Power Supply (UPS)? Why would you want to use one?
- Which parts of your systems fail most often? Can you mitigate the impact of those failures? For example, if you lose communication with the aircraft, does it continue to collect imagery?
- Are there manual processes that could be automated to reduce operator workload?

Electrical Systems

- What is voltage regulation? What is the difference between a linear and switching regulator?
- What is optical isolation? How does it protect control circuitry?
- What are the gain, radiation patterns, and polarizations of your antenna? What is the transmit power of your transmitter, and received power of your receiver?