8th Unmanned Systems Canada Student Unmanned Aircraft System (UAS) Competition 2015-2016

Competition CONOPS and Rules
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1 Foreword

This document provides details on a "made in Canada" UAS Student Competition.

The basic mission for the competition is to address problems commonly faced by the **oil and gas, mining and agriculture industries.**

The competition takes place in two phases with the Phase I design report from each team due on **January 15th 2016**, and the Phase II operational demonstration taking place on **April 29th – May 1st 2016** in **Southport, Manitoba**. Teams will be graded on the quality and completeness of their design reports and the results of their flight demonstrations. There will be separate prizes for each phase.

2 Scenario

A local farmer would like to evaluate the state of his cereal crops so that he can plan his fertilization strategy. His crops consist of wheat, oats, barley and rye. These crops are scattered over his land because glacial activity during the last ice age deposited arable soil as discontinuous patches throughout the area. Normally the farmer drives out to each crop area to measure nitrogen content in the plants and to evaluate the extent of top soil erosion, however this year he would like to find a more time and cost effective method to gather the data. He has heard of drone technology that gathers photographic evidence of crop condition[1]. He would like to hire an aerial survey consultant to gather this information for him.

Although the local farmer is aware of the research in aerial crop health determination, he is not fully convinced of its accuracy. To be fully convinced of its usefulness, he would

[1] 2012, Serbin, G., Optical and Thermal Requirements for Agricultural and Environmental Monitoring https://calval.cr.usgs.gov/JACIE_files/JACIE11/Presentations/ThurPM/130_Serbin_JACIE_11.120.pdf

like samples for lab testing to establish ground truth. You, as an innovative consultant, have additional technology to offer the farmer. You have recently acquired government calibrated crop probes that can be dropped into areas of interest to send back real-time soil nitrogen and moisture telemetry.

Your mission is to use your UAS to determine the health of the local farmer's crops. You will be required to identify the crops' location, type and health and to map them with your airborne sensor system. The farmer accepts the validity of using crop probes to measure soil conditions in specific locations to validate the aerial results obtained via the imaging system.

Your team will be rewarded according to the results contained in the surveillance report that you will submit within one hour of your last flight. Points will be attributed according to the Judging Guide given in Annex C.

Your report will be judged on the following results:

1. accuracy of the crop surface area and their geo-location,
2. accuracy of the crop type,
3. accuracy of the crop health, and
4. accuracy of crop probe placement within each designated crop area.

For the purposes of the challenge, the crop areas and types will be assessable with a regular daylight camera. Crop health will require a camera configuration that is able to detect the light from a 940 nm IR illuminator[2].

The competition CONOPS and rules are subject to change.

3 Purpose of the Competition

The purpose of the competition is to promote and develop Canadian expertise and experience in unmanned systems technologies at the university and college levels. Even small scale unmanned vehicles are complex systems requiring a well planned and executed design and rehearsed operational approach. In addition, safety considerations are important factors in this competition as in any other vehicle design project.

4 Eligibility

4.1 General

The competitors shall be teams from a recognized Canadian university or college organized internally at the discretion of their respective members.

[2] 940 nm, 60 LED IR Panel Illuminator
http://pcboard.ca/ir-infra-red-60-led-ir-panel.html?search=ir%20940%20nm%20

4.2 Team Composition

Teams may include graduate and undergraduate students. It is suggested that students from multiple years be encouraged to participate. Joint teams consisting of students from more than one institution are also permitted. For example, a joint university-college team is allowed. All students must be full-time students at a college or university for Fall 2015 or Winter 2016. If a safety pilot is used, only the safety pilot can be a non-student or can be from another team. This competition is not open to commercial entities.

4.3 Team Size

There is no maximum or minimum team size. There is no maximum size for the number of crew in the flight pit during the preparation period. When the team is on the flight deck, the flight crew is limited to 5 people. Note that accommodations and meals may be provided by Southport for the competition and be limited to five people per team. Should more team members choose to attend, a nominal fee per additional person will be assessed to the team to cover meals and/or accommodations.

4.4 Number of Teams

There is no restriction on the number of teams from any given institution. However, no individual student may be on more than one team. Also, the submitted projects must be substantially different. Teams will be accepted at the discretion of the Judges.

5 Competition Format

The UAS Competition is organized in two Phases. Details of the format and structure of each phase will be provided in subsequent sections.

The Phase I Technical Competition consists of a written technical proposal that is submitted by each team. The proposal shall describe the technical details of the proposed competition design. During the Phase II Airborne Competition, teams will use their UAS to complete the assigned mission. Each phase will be judged separately. Prizes will be awarded accordingly for the top teams in each Phase.

All teams must complete the Phase I Technical Competition in order to be eligible to participate in the Phase II Airborne Competition.

At the Phase II competition, teams will be allowed 10 minutes to give a scored oral presentation. This presentation is a sales pitch and not a technical presentation. It is the type of presentation that a contractor would be giving to a client in order to convince him he offers the right solution and conclude a sale. The team's objective for this presentation is to convince the judges that they are the best team to perform the work.

6 Applications and Registration

Teams should send an email showing their interest and a completed registration form to **competition@unmannedsystems.ca**. Once registered, teams will have access to more information. Registration deadline is **October 23th 2015**.

7 Competition Website and Email

All relevant competition documents and information will be located on the competition website (USC Student Competition 2016 DropBox). Check the competition website regularly for updates. Registered teams have access to more information in a file sharing system. All questions should be addressed to: **competition@unmannedsystems.ca**

8 Sponsorship

Student teams are encouraged to seek out any and all available sponsorship opportunities for their project. There is no restriction on the level or type of sponsorship that may be provided to teams. Teams are responsible for covering their own costs including travel for the demonstration phase. Accommodations and meals may be provided for up to 5 members per team.

9 Mission Requirements

9.1 Summary

Teams will design (Phase I), build and demonstrate (Phase II) a small UAS including an Unmanned Aerial Vehicle (UAV), launch and recovery system and a ground control station for an agriculture, mining and oil and gas industry application.

9.2 Design Requirements and Restrictions

9.2.1 Phase 1 Design Paper

The Phase 1 Technical Competition will consist of a written technical proposal submitted by each team that describes the technical details of their proposed competition design. All teams must complete the Phase I Technical Competition in order to be eligible to participate in the Phase II Demonstration Competition. The report should include, but not be limited to:

- Presentation and analysis of the problem
- Analysis of the possible solutions and the one selected
- Presentation of the design
- List of Radio Frequencies used
- Novel features and benefits of the proposed UAS
- Budget
- Safety issues and features
- Schedule and risk management

- UAS performance and safety test plan
- Strategy to resolve proposed mission
- Draft SFOC for the local flight test site near your university.

The design papers will be judged on presentation, technical merit including analytical treatment, technical level, rationale behind design, innovation, safety and project management. The evaluation criteria are provided in Annex B. Each design paper is limited to 10 pages including appendices. Note that the SFOC is not counted in the 10 page limit. The design paper is due on **January 15th 2016. It must be in pdf format and be emailed to competition@unmannedsystems.ca**. The scoring grid will be available to registered teams on www.unmannedsystems.ca.

9.2.2 UAS Design Constraints

Below is a list of the design restriction for the UAS. All UAS must be designed within these restrictions or disqualification will result.

1. Maximum takeoff weight of 10 kg (Probes included). The aircraft will be weighed prior to flight.
2. Only internal combustion engines and electric propulsion (solar cells, batteries or fuel cell) methods are permitted. Micro gas turbines and pulsejets are not permitted. Any other form of propulsion is acceptable if deemed safe in the Phase I Technical Competition by the judges.
3. Vehicles may not memorize or “learn” the course during one flight and then used in subsequent flights. All flight operations will be unrehearsed as would be the case in typical field applications.
4. All teams will designate a “flight crew” consisting of maximum 5 team members. Only the flight crew may be present while the team is on the flight deck (preflight and flight). The entire system must be easily transportable in rough terrain via a typical pick-up truck.
5. Vehicles must have a flight termination system to safely terminate flight as described in the section 9.6.
6. All vehicles must be brightly colored so as to be visible from the ground and to be easily located in the event of a crash. Safety orange day glow paint is recommended. Vehicles must also clearly display the team name.
7. Data links will be by radio, infrared, acoustic, or other means so long as no tethers are employed.
8. It is highly recommended that teams consider including off-the-shelf components where possible into the design of their unmanned aircraft system. For example, teams may consider the use of an “almost ready to fly” radio controlled airplane as the basic airframe with custom avionics or they may choose to use a small-scale commercial autopilot in a custom designed airframe. In any case, the use of off-the-shelf equipment will simplify the design process and greatly improve the likelihood of successfully completing the assigned missions.
9. Multiple aircrafts can be used, if approved by the Transport Canada SFOC for the competition, as long as there is one person who has full control over for each aircraft at all times. In other words, one person cannot be controlling multiple aircrafts at the same time.

9.2.3 Data link Frequency Restrictions

Radio frequency usage in Canada is defined by Industry Canada. Student teams must use the specifically allocated radio controlled aircraft frequencies (72mhz) or unlicensed bands (900MHz, 2.4GHz or 5.8GHz). If a licensed band is used, the license must be obtained and provided to judges before being allowed to fly. Because all transmitters will have to be OFF on the entire airport property during the competition, except for the team flying, it is highly recommended that teams develop an alternate (wired) method to preflight and test their system. The mission simulates a rural operation so fast internet may not be available.

9.2.4 Levels of Autonomy

Different levels of autonomy are allowed for the competition:

Level V0: Manual (direct R/C control)
Level V1: Manual auto-stabilized flight
Level V2: Automated flight (Autopilot following waypoints)

9.3 Flight operations

Weather permitting, the intent is to provide two flight windows for each team. Only one team will fly at a time. A rain day program consisting of a mini-expo day will be implemented in case weather prevents flight activities as per SFOC restrictions (minimum conditions are to be determined locally and are typically: ground visibility of 3 statute miles, clear of clouds and a ceiling of 1500ft AGL.). Teams should note that if there is neither wind limitation nor rain limitation, flight activities will continue if SFOC weather minima are respected.

Figure **1** shows the approximate SFOC approved area, competition flight area and general designated crop area. It should be noted that the team's GCS will be just south of the SFOC boundary by the launch and recovery location and will be outside of the competition flight boundary. Precise SFOC and competition flight boundaries will be given to teams at a later time. Maximum altitude will depend on the SFOC but should be around 1000ft AGL.

Figure 1 - Competition flight area, Southport airport

The time allowed to teams is expected to fall between 30 and 45 minutes for preparation and flight. The actual amount of time allowed to teams for flight will be announced prior to the start of the competition flights. The allocated time is subject to change due to uncontrollable factors.

Time starts when teams are allowed to turn their transmitters ON. Teams must turn their transmitters OFF after their preparation and flight window has elapsed. After their last flight of the competition, teams then have 60 minutes to give their report, in pdf format, to the lead judge. A team may be setting up or flying while another one is preparing their report. Teams are encouraged to have a quick setup time as this has proven to be very successful in the past. It is intended that all teams be given two flight attempts; however, this will depend on weather and other factors.

9.4 Safety

Safety is of primary concern when operating UAS. All UAS should be equipped with a safety flight termination system that can be activated either automatically or remotely (kill switch). For fixed wing, this could consist of using a parachute, or shutting down the engine and performing aerodynamic termination, which corresponds to full aileron, elevator up, full rudder and no motor. Circling down is not accepted. For rotary wing, a quick vertical descent and touchdown should be performed. The following is a list of emergency procedures that each UAS must comply with. These safety features should be mentioned in Phase 1 design report.

During the competition, teams must have visible on their GCS at all times, the SFOC approved area and the competition flight area.

9.4.1 Flight Termination System

The flight termination mechanism must be operational at all times. If the flight termination mechanism is not working, the aircraft must terminate the flight itself automatically and rapidly. The flight termination mechanism will be validated during the Flight Readiness Review check.

Note:

a. Propellers must be removed from the aircraft during FRR checks.
b. If the aircraft leaves the flight boundaries, the operator will be asked to bring it back within the boundary. If the operator is unable to do so, he will be asked to activate the kill mechanism.
c. All anomalies with respect to the GPS, Datalink, RC and flight boundaries must be reported to the Air Program Director.

Teams must comply 100% to be allowed to fly.

9.4.2 General safety rules

1. A video proof of previous successful flight of the aircraft in the configuration planned for the competition must be presented to judges one week prior to the competition to be allowed to fly.
2. Teams will be required to present a valid SFOC to be allowed to fly. Teams should apply for a SFOC for their test site at least **6 months** before the competition and ensure the local inspector is processing it in time.
   a. The competition or the team’s SFOC can give additional limitations than those listed in this CONOPS. A copy of last year’s competition SFOC is available upon request to registered teams.
3. Teams are required to have hands free bilateral communication between GCS operator and safety pilot (if safety pilot is used) for a range of 100+ m. Unaided voice will not be sufficient.
4. Teams must have an electrical or mechanical way of preventing propellers from accidently spinning when aircraft is not in takeoff position and ready for takeoff (i.e. when working on the aircraft).

Annex A - Transport Canada Points of contact for obtaining mandatory Special Flight Operation Certificate (SFOC).

Each team is required to obtain a SFOC. The SFOC application is to cover flight testing their UAS at their test location and flying during the demonstration early May. A separate SFOC will be obtained by the Competition organization for the flight demonstration area. Each team's SFOC should refer to the Competition SFOC. Each team's individual SFOC will be required to be allowed to fly at the competition and will have to be presented to the judges. Transport Canada may require around **6 months** to approve an SFOC. It is consequently highly recommended that teams submit their SFOC application to Transport Canada **early in the fall** and do follow up with their local inspector (refer to Table 1) to ensure they received the application and are processing it.

Transport Canada UAS information website:

http://www.tc.gc.ca/eng/civilaviation/standards/general-recavi-brochures-uav-2270.htm

Table 1 - Transport Canada Regional Contacts

Pacific Region	
800 Burrard Street Suite 620 **Vancouver**, B.C. V6Z 2J8	RECAVSF: (604) 666-5575 Facsimile: (604) 666-4839 john.mrazek@tc.gc.ca
Prairie and Northern Region	
344 Edmonton Street **Winnipeg**, MB R3C 0P6	RECAVSF: (204) 983-4341 Facsimile: (204) 984-2069 PNRspecialflightops@tc.gc.ca
Ontario Region	
4900 Yonge Street Suite 300 **Willowdale**, ON M2N 6A5	Aircraft Registration/SF: (416) 952-0230 Facsimile: (416) 952-0165 caso-saco@tc.gc.ca
Quebec Region	
700 Leigh Capreol Place **Dorval**, QC H4Y 1G7	Inspector: 514-633-3577 Facsimile: (514) 633-3052 csva-vsca@tc.gc.ca
Atlantic Region	
P.O. Box 42 **Moncton**, NB E1C 8K6	Telephone: 1-800-305-2059 Facsimile: 1-855-726-7495 christian.allain@tc.gc.ca

Annex B - USC Student Competition 2016 – Design Paper Evaluation Guide

Table 2 - Design Paper Evaluation Guide

Section or Topic	Topic Scores (all out of 10)	Section Weight
Overal Report Presentation		
Grammar and spelling, page limit adhered to (penalty for papers exceeding page limit)		15
The report is well structured and clearly organized		
Effective use of figures, charts and tables		
References provided for all cited content		
The paper is objective and free from commercialism		
Technical Description of the Unmanned Vehicle System		
Clear and concise summary of the critical design requirements in the students' own words		50
Alternate solutions presented and rationale for chosen solution presented		
Detailed description of the major features of the vehicle segment of the system including propulsion, power, autonomous control (if included), weight and balance (UAV) and mission payload.		
Detailed description of the major systems of the communication segment of the system including radio fequencies and transmitter powers.		
Detailed description of the major systems of the control station segment of the system including vehicle control methods, vehicle health and status monitoring and payload operations.		
Description of the major functions and features of the integrated unmanned vehicle system.		
Description of system level testing completed and/or planned to demonstrate that the UVS meets the stated design requirements.		
Technical Innovation and Novelty		
The described UAV system represents a novel approach to the mission requirements.		10
Adequately emphasizes the novel elements of the proposed system.		
Safety and Risk Management		
Complete description of system level safety issues		15
Identification of potential single point failure modes		
Completed draft SFOC application attached to the technical report as an appendix		
Technical Risk Mitigation plan described (ie what technical problems are possible during the construction and testing phase and how will they be dealt with)		
Project Management		
Clear, concise and complete list of milestones presented		10
Schedule provided for detailed design, construction and testing phases prior to competition.		
Overall project budget provided (including estimate of labour, cash and donations required)		
Total Mark out of 100		

Annex C - USC Student Competition 2016 – Judging Guide

1. Introduction

The competition is set up around a mission scenario. The goal of each team is to achieve as many of the stated mission objectives as possible and be rewarded accordingly. This guide outlines how points are awarded for each mission objective.

2. Mission Elements

There are six mission elements:

a) present the team and its capabilities to convince client that the team is able to do the job,
b) determine geo-location of the crop area centroids,
c) determine size and type of the crop areas,
d) determine health of each crop area,
e) accurately drop crop probes onto designated crop centroids,
f) prepare a report that summarizes the team's findings.

3. Object Characteristics

3.1 Crop areas

Each contaminated field is delineated by a border made from wide colored ribbon (about 1 meter wide) that has good contrast with the underlying terrain. Only the corners of the areas will be highlighted. Typical shapes are shown in Figure 2. Teams are asked to calculate the enclosed surface area of the shape and to geo-locate the centroid of the figure. The X will not be visible in the field. It is provided here for illustration purposes only.

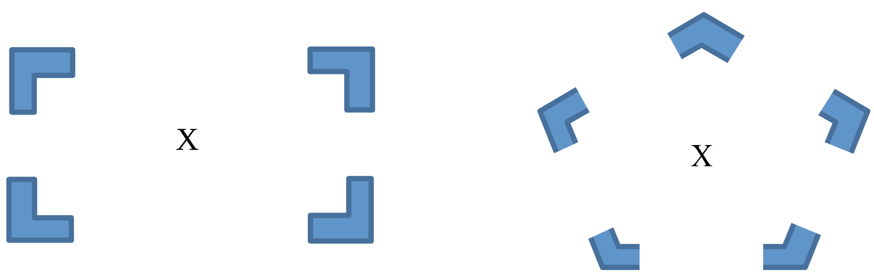

Figure 2 - Typical features of simulated crop areas

3.2 Crop types

The crop type is defined by a QR code where the code measures 2.75 m x 2.75 m with each pixel measuring 12.7 cm x 12.7 cm. The QR code will be placed within the boundaries of the crop area. Dimensions are subject to change.

3.3 Crop health

The state of a crop area is defined by the presence of a 940 nm IR illuminator in the crop area. If an illuminator is present, the crop is healthy.

3.4 Crop probe

The crop probe is a cylinder measuring approximately 12 cm in diameter x 10 cm long with an overall weight not to exceed 90 g (i.e. a standard toilet paper roll).

Each team shall design a mechanism that maintains positive retention of the probe on the aerial platform until a release command is given. The retention and release mechanism shall only be a mechanical device that is activated by a control signal from the RC transmitter, the GCS or a secondary transmitter.

Three probes will be provided to each team. Non-metallic hooks, eyelets or similar devices can be attached to the probes on site at the competition.

Each probe shall be dropped as close to one of the designated crop area centroids as possible. Only one probe may be dropped into each designated area.

The area will be designated with a letter “P” placed in the crop area. (Approx. 5 meters by 3 meters)

See Annex D FAQ Crop Probe for additional information.

4. Documentation Characteristics

4.1 Presentation

Each team will make a ten minute presentation to reassure the fictitious clients that they are able to do the work. The presentation shall ideally contain the following elements:

a) who your team is,
b) what is the expertise of each team member,
c) what equipment you propose to use for the work,
d) how you propose to cover the area of interest,
e) why the clients should put their confidence in your team.

4.2 Reporting

Each team is required to produce a report detailing their findings. The report should be provided to the judges in pdf format on the USB key supplied by the competition committee. The report shall ideally contain the following elements:

a) title page
b) problem statement
c) description of flight plan strategy for data gathering
d) results for crop areas
    a. numerical estimation of each area
    b. geo-location of each area centroid
    c. photo of each area tagged with lat-long coordinates
e) results for crop type
    a. alphanumeric interpretation of QR code
f) results for crop health
    a. presence or absence of IR illuminator
    b. geo-location of IR illuminator
    c. photo of IR illuminator
g) results for crop probes

    a. estimated accuracy of probe drop onto designated crop centroid[3]
    b. photo of probe in the designated crop area
h) summary
    a. tabulated results
    b. map of competition flight area showing positions of geo-located objects
    c. concluding comments

Note that photos may be tagged with lat-long coordinates offline during the production of the report.

An Excel file template will be provided to each team to record results for surface area, geo-location and object identification. This results file shall be provided to the judges along with the team report.

Each team shall submit only one report and one set of results to the judges 60 minutes after the end of their last flight. The report and results set can be based on the data collected during the two allocated flight windows.

5. Scoring

5.1 Presentation

The team presentation will be evaluated according to Table 3.

Table 3 - Presentation evaluation criteria

Criteria	**$Score_{pres}$**
well organized, contains all elements, convincing client opinion – has great confidence in selected team	1.0
adequately organized, has most elements, mostly convincing client opinion – has confidence in selected team	0.7
somewhat disorganized, missing elements, partially convincing client opinion – some doubt in selected team	0.5
unorganized, missing many elements, not convincing client opinion – looking for replacement team	0

[3] Probe locations will be measured by the competition committee.

5.2 Surface area

The numerical value for each crop area will be evaluated for accuracy according to the function shown in Figure 3. The parameter definitions are:

value_i = abs(1 - answer_i/true_i)
answer_i = user estimated area or volume of i-th item (m^2 or m^3)
true_i = true area or volume of i-th item (m^2 or m^3)
score_i = 1 – (value_i – C_tol)/(C_max-C_tol) if C_tol < value_i < C_max
score_i = 1 if value_i < C_tol (--)
score_i_area or vol = score for user estimated area or volume of i-th item (--)

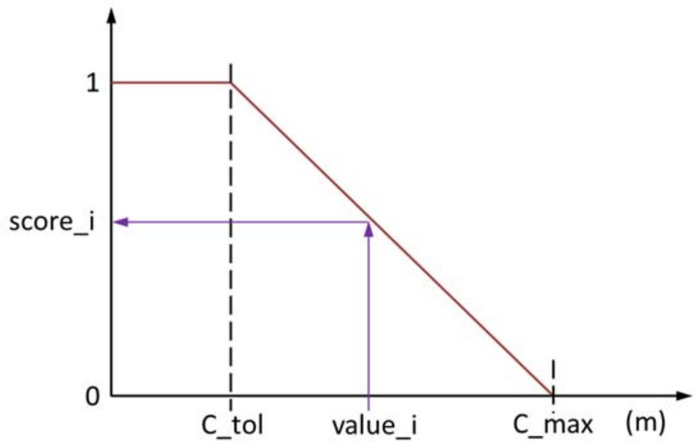

Figure 3 - Scoring function for surface area and volume results

5.3 Geo-location

The lat-long coordinates of crop area centroids will be evaluated for accuracy according to eq. 1 and the function shown in Figure 4. The error distance between the true geo-location and the user estimated geo-location is calculated by

$$d_{err} = 1609.3\sqrt{69.1(LatN_{tru} - LatN_{usr})^2 + 53.0(LonW_{tru} - LonW_{usr})^2} \quad (1)$$

where

d_{err} = error distance between user estimate lat-long and true lat-long (m)
$LatN_{tru}$ = true LatN in dd.dddd format
$LatN_{usr}$ = user estimated LatN in dd.ddddd format
$LonW_{tru}$ = true LonW in dd.dddd format
$LonW_{usr}$ = user estimated LonW in dd.ddddd format

The parameter definitions are:

value_i = d_{err} (m)
C_max = maximum allowed error distance (m)
score_i = 1 – (value_i – C_tol)/(C_max-C_tol) if C_tol < value_i < C_max
score_i = 1 if d_{err} < C_tol (m)
score_i_loc = score for d_{err} of i-th item (--)

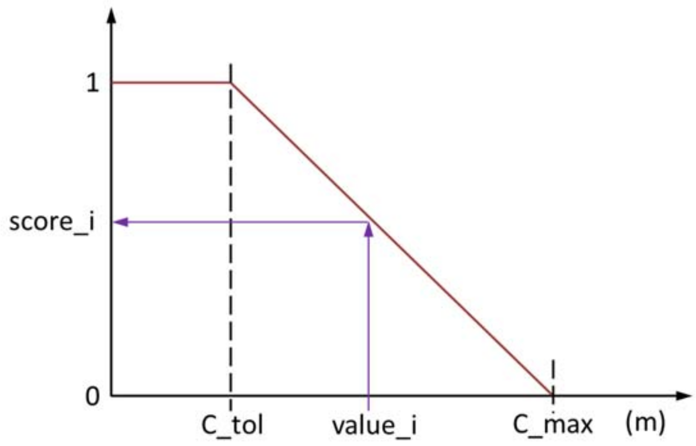

Figure 4 - Scoring function for geo-location results

5.4 Object photo

The photos will be subjectively evaluated according to Table 4.

Table 4 - Photo evaluation criteria

Criteria	$\mathbf{Score_{photo}}$
sharply focused image with balanced contrast and colour	1.0
adequately focused image with acceptable contrast and colour	0.6
poorly focused image with poor contrast and colour	0.3
no photo	0

5.5 Identification

QR code and crop health identification will be evaluated according to Table 5.

Table 5 - Object identification criteria

Criteria	$\mathbf{Score_{obj}}$
Object/condition/value correctly identified	1.0
incorrectly identified	0

5.6 Probe drop accuracy

The drop accuracy will be evaluated according to Table 6.

Table 6 – Drop accuracy criteria

Criteria	**$Score_{obj}$**
Within 5 m of true crop centroid in designated crop area	1.0
Within 10 m of true crop centroid in designated crop area	0.75
Within 20 m of true crop centroid in designated crop area	0.25
Greater than 20 m from true crop centroid in designated crop area	0.0

5.7 Report

The results report will be subjectively evaluated according to Table 7. Note that the report is scored according to how well it is written and how clearly results are presented. No consideration is made here on the accuracy of the results. The accuracy of results is evaluated elsewhere.

Table 7 - Report evaluation criteria

Criteria	**$Score_{rep}$**
well written, contains all required elements, nicely presented client opinion – greatly satisfied, report worthy for sharing with key outside organizations	1.00
well written, contains most required elements, adequate presentation client opinion – satisfied, report worthy for wide distribution within internal organization	0.75
adequately written, contains most required elements, adequate presentation client opinion – moderately satisfied, report will have limited distribution within internal organization	0.50
poorly written, missing many required elements, poorly presented client opinion – not satisfied, use report for internal discussions only	0.25
only results are provided in an arbitrary format client opinion – not satisfied, file document and read when time is available	0

5.8 Score calculation

The team score will be calculated according to Table 8.

Table 1 - Score tabulation

Item	Weight	Calculation	Sub-total
Presentation	W_{pres} = 15	$T_{pres} = \frac{W_{pres}}{M_{pres}} score_{pres}$	T_{pres} (ref. Sec. 5.1)
Area	W_{area} = 10	$T_{area} = \frac{W_{area}}{M_{area}} \sum_{i=1}^{N_{area}} score_{i_{area}}$	T_{area} (ref. Sec. 5.2)
Geo-loc	W_{loc} = 15	$T_{loc} = \frac{W_{loc}}{M_{loc}} \sum_{i=1}^{N_{loc}} score_{i_{loc}}$	T_{loc} (ref. Sec. 5.3)
Photo	W_{photo} = 10	$T_{photo} = \frac{W_{photo}}{M_{photo}} \sum_{i=1}^{N_{photo}} score_{i_{photo}}$	T_{photo} (ref. Sec. 5.4)
Identification	W_{obj} = 15	$T_{ID} = \frac{W_{ID}}{M_{ID}} \sum_{i=1}^{N_{obj}} score_{i_{ID}}$	T_{ID} (ref. Sec. 5.5)
Probe	W_{prb} = 15	$T_{prb} = \frac{W_{prb}}{M_{prb}} \sum_{i=1}^{N_{prb}} score_{i_{ID}}$	T_{prb} (ref. Sec. 5.6)
Report	W_{rep} = 20	$T_{rep} = \frac{W_{rep}}{M_{rep}} score_{rep}$	T_{rep} (ref. Sec. 5.7)
Total (T_{pres}+T_{area}+T_{loc}+T_{photo}+T_{ID}+ T_{prb}+T_{rep})			T_{tot}

Note: M_{pres} is the maximum score for the presentation.
M_{area} is the maximum score for N_{area} areas in the competition flight area.
M_{loc} is the maximum score for N_{loc} geo-located objects in the flight area.
M_{photo} is the maximum score for N_{photo} photos of objects in the flight area.
M_{ID} is the maximum score for N_{ID} objects in the flight area.
M_{prb} is the maximum score for N_{prb} probes in the designated crop area.
M_{rep} is the maximum score for the report.

Annex D - FAQ Crop Probe

Type:
Toilet paper roll

Specifications:
1. Brand – Royale Velour 2 ply (they use white fluffy kittens in their advertising)
2. Weight – 75g as purchased
3. Outside diameter of roll – 115mm
4. Inside diameter of cardboard tube – 40mm
5. Length – 100mm
6. Surface texture – imprinted pattern on 2 ply paper

Q&A

1) Are there any holes, eyelets, etc. on the "probe" already?

Answer: There are no holes, eyelets, etc. already on the toilet paper roll when they are provided to the teams the day before the start of the flight competition.

2) Should we be worried about certain kinds of glues or adhesives reacting with the "probe" material?

Answer: There should not be any problem using adhesives with the toilet paper roll.

3) Will the mass be consistent between probes, or just any mass reasonably < 90 g?

Answer: See specifications for the toilet paper roll. There is a 15g margin for teams to use for their preferred attachment method. The total weight of the probe (toilet paper roll + attachment) must not exceed 90g.

4) What exactly are the attachment options available? Can we glue/affix non-metallic things to the "probe" permanently, or must all attachments be removable?

Answer: There is a 15g allowance given to teams to implement their attachment of choice. The total weight of the probe (toilet paper roll + attachment) must be 90g or less. The metal or plastic attachment can be permanently attached to the toilet paper roll. Toilet paper rolls will be provided to the teams the day before the flight competition starts.

5) Can things like fins or other aerodynamic purpose be attached to the "probe" to aid its descent, or are attachments only allowed to fix the "probe" to the aircraft?

Answer: No modifications to the toilet paper roll aside from fixing the attachment point(s) to the roll may be made.

6) Could the probe be duct-taped to an attachment mechanism including hooks, fins, nose-cone etc.?

Answer: No aerodynamic surfaces or forms may be attached to the toilet paper roll. Adhesives or adhesive tapes may be used to fix the attachment point(s) to the toilet paper roll.

7) Are there any restrictions regarding falling speed or the level of impact force on the "probe" when it falls and hits the ground?

Answer: No, the toilet paper roll is meant to free-fall at the speed dictated by its weight and drag coefficient.

8) Can a parachute be fixed to the "probe"?

Answer: No, the toilet paper roll is meant to free-fall at the speed dictated by its weight and drag coefficient.

9) Are the probes to be carried one at a time (i.e. loaded, sent to deliver, return x3), or must the aircraft delivering the probes carry all three at once but deliver one at a time?

Answer: It is the team's choice.

Annex E - FAQ How to turn in a competitive round in the student UAV competition

Winning a competition is like doing well in an exam; the results reflect the effort that was spent preparing for the event. By the time teams arrive at the competition site, development work should be complete and systems tested and backed up. The actual competition should be an extension of the ongoing proof of their system design. Teams must apply proven project management techniques and procedures that will allow them to manage both time and resources effectively.

There were several crashes at the 2013, 2014 and 2015 competitions. These incidents suggest that teams did not identify and prepare themselves to respond to the many variables that could lead to an on-site system failure. These teams did not manage risks effectively as part of their conceive/design/develop/test/fly process. To succeed, teams must implement a robust risk management process designed to identify potential risk events in order to reduce the impact of realized risks on the team's performance in the competition. Obviously, risk management is only one part of an overall project management approach, but many of the failures observed at the competition could have been avoided had the team used a more disciplined project management approach during their system development process.

To improve their chance of success, teams must do as much as possible to get major issues identified and resolved long before they show up for the competition. For example:

- There is a year before the next competition. Now might be a good time to develop a schedule with clearly identified milestones that will serve as go/no-go points. This will allow the team to change direction before additional time and effort is expended working on a suboptimal solution.
- Use a life cycle approach. The CONOPS details the challenges that the competition will present. Analyze this document with the intent of identifying the most significant challenges and plan your system design and search strategy accordingly.
- Review the schedule and adjust the timelines to reflect the effort required to develop and test potential solutions. The schedule review process is iterative. This will allow the team to assess its progress throughout the design/test process so that the effort will not be concentrated at the end of the academic year when there are greater demands on the students' time.
- Implement a sound risk management process. As a first step, create a risk register that will serve as a basis for the initial risk assessment. Revisit the risk analysis at each team meeting to reassess risk items and to identify new or emerging risks. Assess risks based on probability and impact and decide early whether to accept, avoid, mitigate, or transfer identified risks.
- As the competition date approaches, conduct a risk management process specific to the venue. This is critical because there are certain risks—high winds, for example—that could easily make requirements other than UAV performance the deciding factor in winning the competition. Prepare contingency plans.

- Develop a pre-event test plan based on the competition criteria. There is no substitute for training and experience. By the time the aircraft is flown in competition, it reflects the team's readiness to provide a proven solution to a client's problem. The client wants results; it is up to the team to convince the client that their solution is able to provide quality results. Do not forget that quality can be defined as conformance to specification. Designs that attempt to "gold plate" their system inevitably generate additional risks.
- Prepare the competition search plan by optimizing for the UAV's unique combination of performance characteristics and sensor resolution. This will generate the best opportunity for mission success.
- Environmental conditions can vary greatly over the course of the competition. Be prepared to adjust the search parameters in response to the prevailing conditions.
- This is critical: conduct a post-competition analysis and evaluation that will document and record successes, failures, and lessons learned. Do not forget that lessons learned can also be derived from a competitor's performance/strategy!
- Finally, keep in mind that "Flying is so many parts skill, so many parts planning, so many parts maintenance, and so many parts luck. The trick is to reduce the luck by increasing the others." – David L. Baker
- This competition is all about being able to demonstrate what your system can do without being sidelined by gotchas or mishaps.
- Practice. You need to understand your system and your team mates.
- Reliability is key. Predictability is almost as good.
- Get through your checklist as far as possible before the clock starts.
- External umbilical cables are your friends. Do not start uploading firmware or assembling the aircraft after the clock starts – have it ready to take to the runway!
- Your only pre-clock constraint is radio silence. Think about how far you can prepare before radios come on. Minutes count.
- Checklists are key to a predictable outcome. Ideally checklists after the clock starts are short.
- Team radio calls should be practiced when doing your flights before the competition. Having standard messages will prevent confusing conversations.
- Boring is good. Boring wins. Flashy often stays on the ground.
    - Corollary1: you can win with a well-understood, low-tech approach. You won't likely win with a complex system that you haven't learned to manage.
    - Corollary2: it isn't all about winning. Get your system out and exercise it in the competition environment. That's how you win next year!
- RF and data link technology can be the biggest issue in the system, especially if a system uses more than one frequency.
- Keep it simple.
- Test data links extensively before the competition.
- When testing, understand that ground-to-ground range is short compared with ground-to-air.
    - Corollary 1: get your GCS antennas up on a stick.
    - Corollary 2: don't stand on front of your teams' antenna.
- Frequencies mix. Nearby antennas can conflict even on different frequencies.

- Look up "heterodyne". Think of it as a bad thing. Don't forget your GPS has an antenna too.
- Watch the other teams operate.
- Bring a spare. Keep software backups.
- Be gentle with your wires - on board and in the ground. Harness failures are a leading cause of not being able to fly that day.
- Practice more.
- Read the CONOPS and rules! Understand the scoring system! Deliver the data or data product that is asked for!
- It does not matter how well your system works if you do not deliver the stuff that scores points!
- Evolve your system incrementally year-by-year. If you think you are on the right path, then do not change up everything and start over from scratch. This includes your team roles and training.
- The winning teams are very selective in the changes they make to their system architecture and team architecture.