AUTONOMOUS AERIAL VEHICLE CHALLENGE 2021-2022

In 2021, Kasetsart University was honored to be the host for 2021 Autonomous Aerial Vehicle Challenge (AAVC2021). Unfortunately, the event needed to be postponed due to the incident of COVID-19 pandemic. It is projected that the situation is improving due to the international efforts on the vaccine development progress, which leads to the possibility that the AAVC event could be resume in the year 2022. By considering relevance factors including lead time, number of the "projected" participating teams, and the limitations of the host organization's support infrastructure/event management capability, it is decided that in this upcoming event, The AVVC2021-2022, the "technical screening" process will be introduced an initial selection phase prior to the actual on-site aerial challenge. Each participating team will be expected to submit the report detailing the development (engineering design, construction and testing) of their aerial platform and associated subsystems to the AAVC committee in 2021 for technical evaluation. A number of participant teams will then be selected for the on-site operational challenges in 2022 based on the technical evaluation result.

AAVC2021-12 Task Overview

Each participant team will be tasked to develop their unmanned aircraft systems (UAS) for Surveillance and Reconnaissance (SAR) operation. There is no restriction on platform configuration. The aerial platform configuration could be either fixed-wing, rotary wing (multi-rotor, or other rotorcraft), or hybrid (convertiplane such as tilt-rotors, fixed wing with vertical lift components, tail-sitter, etc). However, the platform must be developed under the following capability requirements:

Operating range and search area coverage: The system shall be able to maintain line-of-sight (LOS) communication with the control station at a minimum at a minimum range of 1000 m for provide continuous feed of both target imaging and flight telemetry data. Also the vehicle shall be able to perform a search covering the area of 1100 x 700 m (fixed wing/hybrid) and 600 x 700 meters (rotary wing). The search operation consists of level-flight patterns and loitering/hovering over target (configuration dependent).

Search and Target Identification: The vehicle shall equipped with a suitable imaging system to capture and transmit the imaging data of the target to the control station. There is no restriction on the type and capability of the system e.g. the system could use either electro-optical, infra-red, or the combination of the two as well as multiple sensors of the same type a part of sensor suite. The use of image processing algorithm is encourages for better search capability. There is no restrictions on the equipment and/or technique used to determine the position (coordinates) of the target except the minimum flight deck (altitude) restriction e.g. additional sensors such as laser range-finder is also allowed.

Payload system: The air vehicle shall have the payload handling system that could accommodate the payload module(s) and release the module to the ground target in mid-flight. The maximum weight of each payload module is at 1kg with the minimum weight of 0.5 kg (see the description in chapter "Payload Specification" for further details on the specified size and dimensions of the payload module).

The air vehicle is allowed to carry multiple payload modules. However, the payload handling system must have the ability to control the release of each payload module independently from each other (it is not allowed to released multiple payloads at the same time).

Flight system: The system shall equipped with autonomous flight system using an open-source flight computer architecture which enables the air vehicle to fly autonomously in the pre-programmed flight paths (waypoints) during operations. The use of advanced algorithm such as machine learning to enhance the autonomy of flight operations (auto target identification and payload release, auto flight search pattern, etc.) is encourages.

To ensure operational safety, the system shall have a suitable level of safety by introducing emergency/fail-safe measures and/or system engineering approach e.g. system redundancy by-design.

Flight and imaging data relay: The control station shall have the ability to relay both flight and imaging data from the UAS main control station to the third-party display unit for operational performance evaluation.

Area of Flight Operation Challenge

The on-site flight operation area is set in the Kasetsart University (Kamphaeng Saen Campus), Nakornpratom province, Thailand. The campus is located north west from Bangkok metropolitan area as shown in figure 1, which is approximately within 90 minutes driving range form Bangkok. The GPS coordinate of the air operation site is at 14°01'09.2"N 99°57'47.3"E (14.019220386460661, 99.96312975833375).

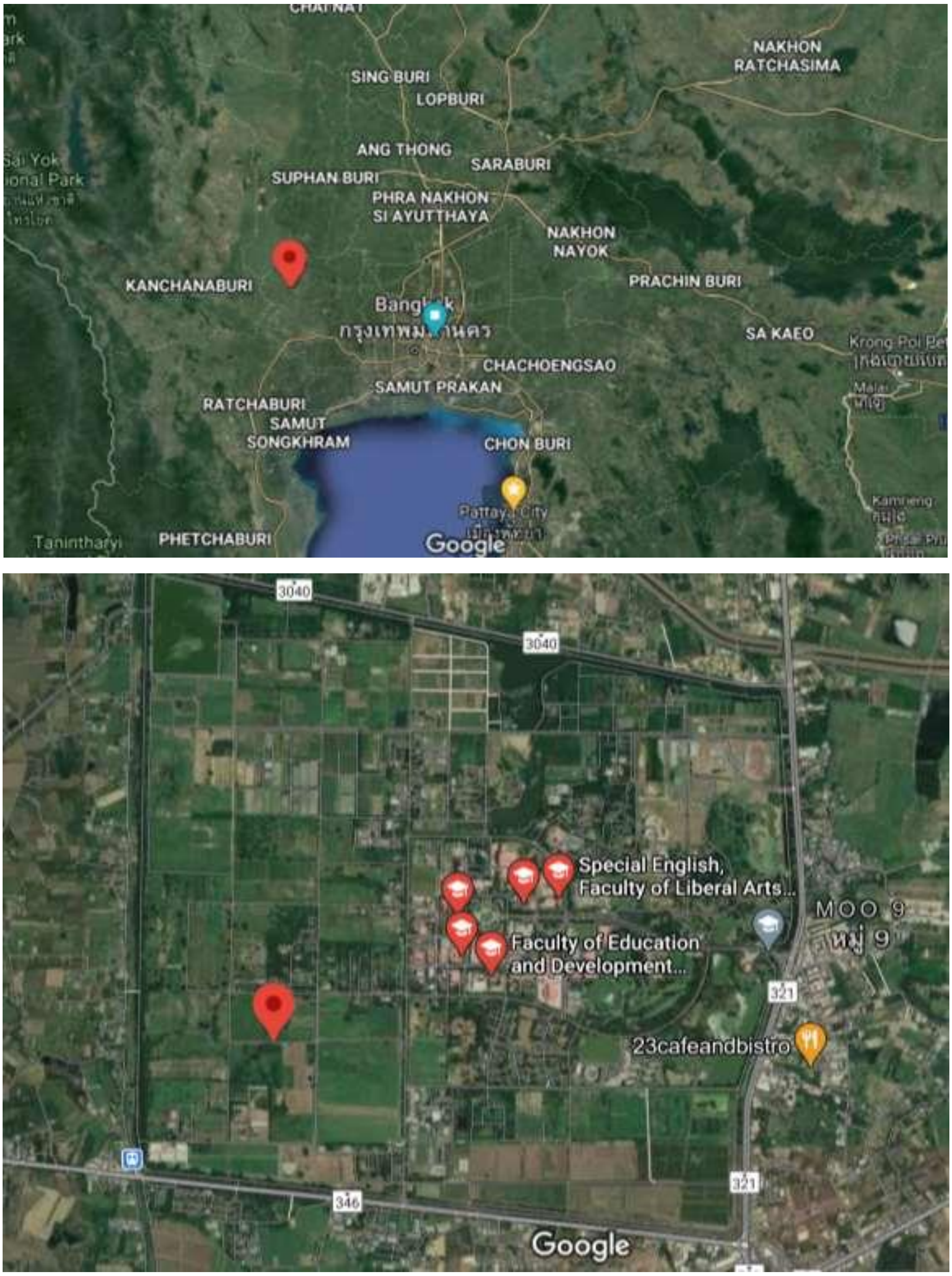


Figure 1. Location of the on-site aerial challenge area.

Operating Scenario Overview

During the development of the vaccines to cope with the pandemic causing by a certain type of lethal virus. Two of the test subjects were escaped from the research facility. A containment perimeter surrounded by a high-voltage fence is set to prevent the test subject from reaching the residential area, which could instantly kill any animals once it make contact with the fence as a last resort. However, it is strongly recommended that the test subject is to be captured alive due to the valuable of the test subject's developed immune system during the experiment, which is invaluable for the vaccine development.

The search and capture team has already been deployed for search and capture operation. However, according to the information provided by the scientists working in the test facility, the escaped test subjects are predator-type species which is highly aggressive and would violently attack the capturing team once they are detected. Moreover, one particular test subject has also developed the ability to detect heat signature from other sources including other mammals at a certain distance as a side-effect from the experiments. Hence, the conventional capturing approach such as tranquilizer dart is deemed to be impractical as their heat-detection range exceeds the effective range of the dart rifle.

Fortunately, there is currently a development of a prototype tranquilizer bomb which could be deployed form an aerial vehicles such as unmanned aircraft to the target located on the ground. It is designed for a rapid release of the strong sedative gas on-impact which is expected to effectively subdue a highly-agitated animal once the payload hit the target directly or hit the ground near an animal within the effective gas range. According to the data regarding to the size and weight of the test subject provided by the test facility, the payload development team was able to produced a number of tranquilizer bombs compatible with the small unmanned aircraft, The overall weight of the tranquilizer, depending on the amount of sedative inside the casing, is varied between 0.5-1.0 kg. However, due to the intensity of the sedative, there is a risk of “fatal” overdosing if more than two tranquilizer bombs are dropped within the effective range to the test subject.

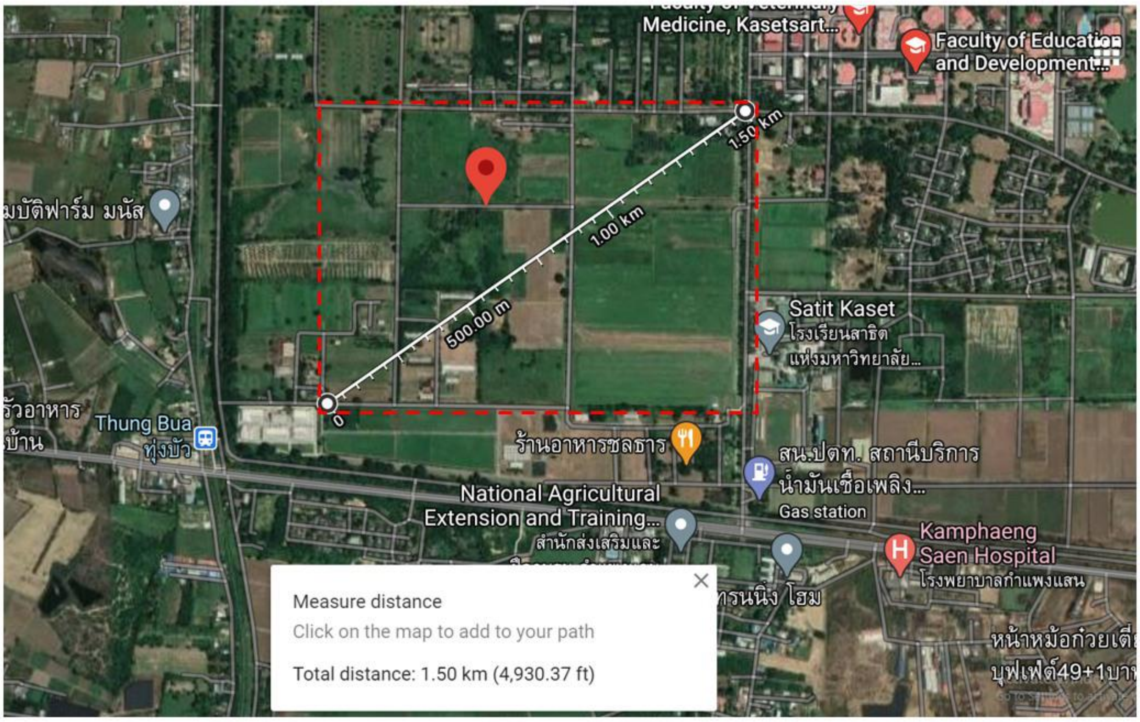


Figure 2. Overview of operation area showing the containment zone (search areas), runway and preparation area.

Figure 3. line-of-sight view from launch and recovery site (runway).

Equipped with the newly developed payload, another capturing team specialized in aerial surveillance operation using UAS is assembled and deployed to the operation area. The team will be tasked to locate all the test subjects inside the containment area and deploy the tranquilizer bomb to one of the test subject within a specified time window. The launch and recovery site consist of a 100m runway, a 5x5 m launching pad, and an aircraft preparation area, is established close to the containment area as shown in figure 3.

Flight Operation Tracks

Three different flight operation profiles (tracks) is established in which it would reflects on the inherit flight characteristics of fixed-wing, rotary wing, and hybrid configuration, respectively. The detail description for each track are described as follows:

Track 1 : Fixed-Wing

For fixed-wing configuration, the air vehicle will perform takeoff from the runway and perform in-flight system check over the preparation zone before entering the search area. Once the in-flight system check is complete is ready, the air vehicle will enter the operating area following the established ingress route set by the committee.

The air vehicle will then conduct a searching flight across the containment area to locate the target (test subject). The team is required to obtain the GPS coordinates of all targets and deploy the payload (tranquilizer bomb) on one of the targets (the identity of the dropping target is provided before the mission).

Once the payload drop operation is completed, the air vehicle will perform loitering flight over the dropping area to provide persistent imaging feed of the target as well as its surroundings for 60 seconds. This will provide situational awareness to the ground capturing team for better planning on recovering the sedated target. Finally, the aircraft will cruise out from the operational area and return to the launch and recovery site for landing.

The team has 15 minutes time window to complete the operation.

Track 2 : Rotary-Wing

For rotary wing configuration, the air vehicle will perform vertical launch from the launchpad and perform in-flight system check while hovering over the launchpad before entering the search area. Once the in-flight system check is complete is ready, the air vehicle will enter the operating area following the established ingress route set by the committee.

The air vehicle will then conduct a searching flight across the searching area to locate the target. The team is required to obtain the GPS coordinates of all targets and deploy the payload (tranquilizer bomb) on one of the targets (the identity of the dropping target is provided before the mission).

Once the payload drop operation is completed, the air vehicle will perform hovering flight over the target (see restriction for minimum allowable hover altitude) to obtain the detailed description of the target and as well as its surroundings. This will provide situational awareness to the ground capturing team for better planning on recovering the sedated target. Finally, the aircraft will cruise out from the operational area and return to the launch and recovery site for landing.

The team has 15 minutes time window to complete the operation.

Track 3 : Hybrid Configuration

For hybrid configuration the air vehicle will perform vertical launch from the launchpad and perform in-flight system check while hovering over the launchpad before entering the search area. Once the in-flight system check is complete is ready, the air vehicle will enter the operating area following the established ingress route set by the committee.

The air vehicle will then conduct a searching flight across the searching area to locate target. The team is required to obtain the GPS coordinates of all targets and deploy the payload (tranquilizer bomb) on one of the targets (the identity of the dropping target is provided before the mission).

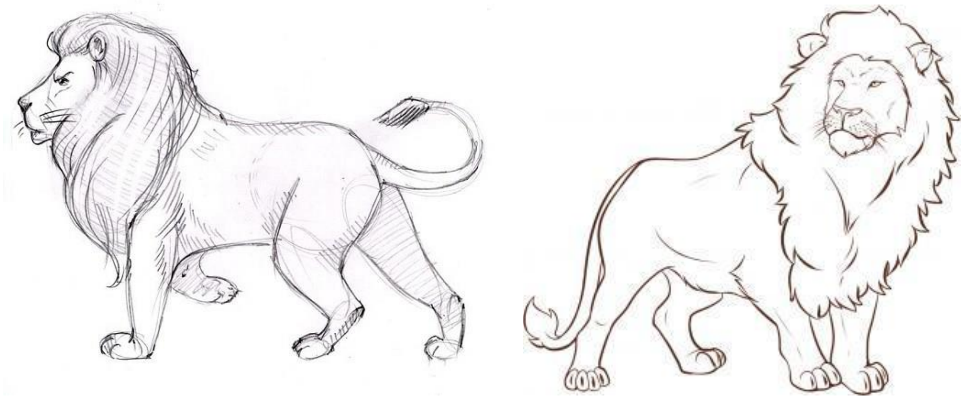
Once the payload drop operation is completed, the air vehicle will perform hovering flight over the target (see restrictions for minimum allowable hover altitude) to obtain the detailed description of the target and as well as its surroundings. This will provide situational awareness to the ground capturing team for better planning on recovering the sedated target. Finally, the aircraft will cruise out from the operational area and return to the launch and recovery site for landing.

It is expected that this configuration would perform all forward flight phases (cruise, loiter) using only the aerodynamic lift generates from the fixed lifting surfaces i.e. wings, horizontal tail, lifting body, etc. instead of using manipulated thrust vectors generated by propulsion unit. However, a combinations between vertical and horizontal thrust is allowed during the transition phase.

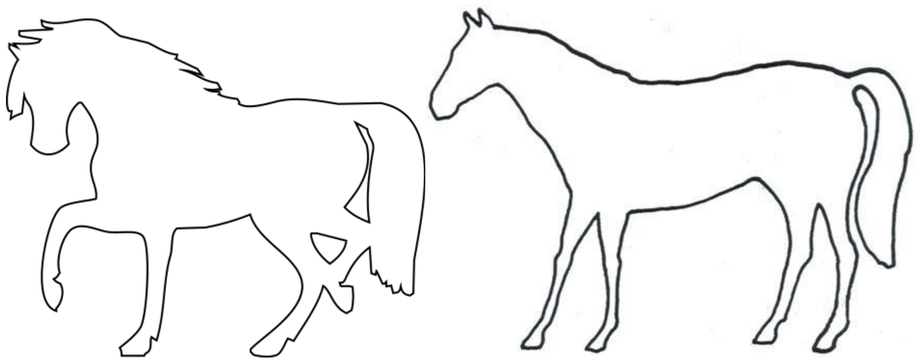
The team has 15 minutes time-window to complete the operation.

Target Placement

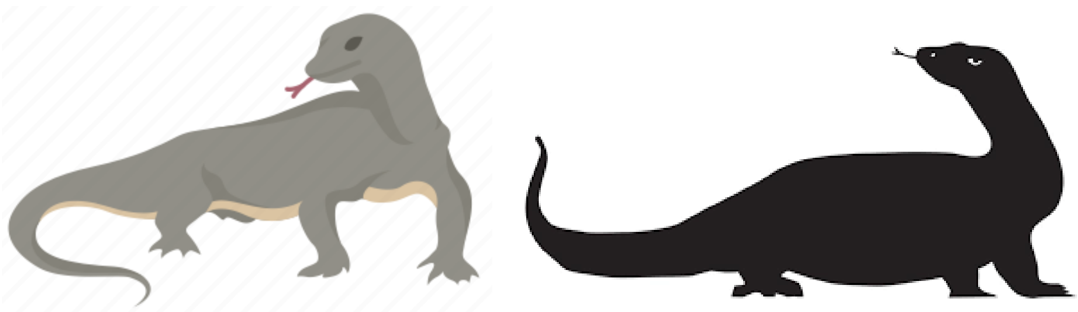
For this AAVC 2021-2022 challenge the targets are presented as the 2-D image of the outline shape of the animal species listed in the test subject's database (There are five animal species of test subjects; Lion, Horse, Sheep, Water Monitor, and Buffalo). During the on-site operation the image will be printed in about 2 x 2 meters vinyl sheets (color and dimension may slightly different according to the type of animals) as shown in Fig.4, which will be placed on the location by the field staff. The example of the target is represent as a 2D drawing in a vinyl sheet as illustrated in figure 5.



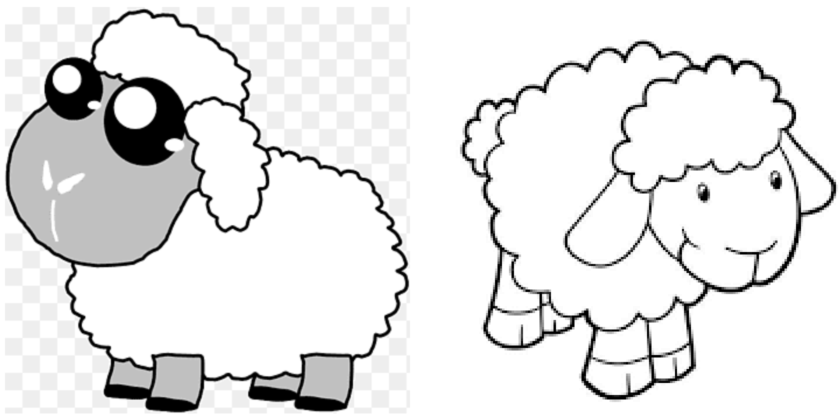
Lion (Yellow - Brown)



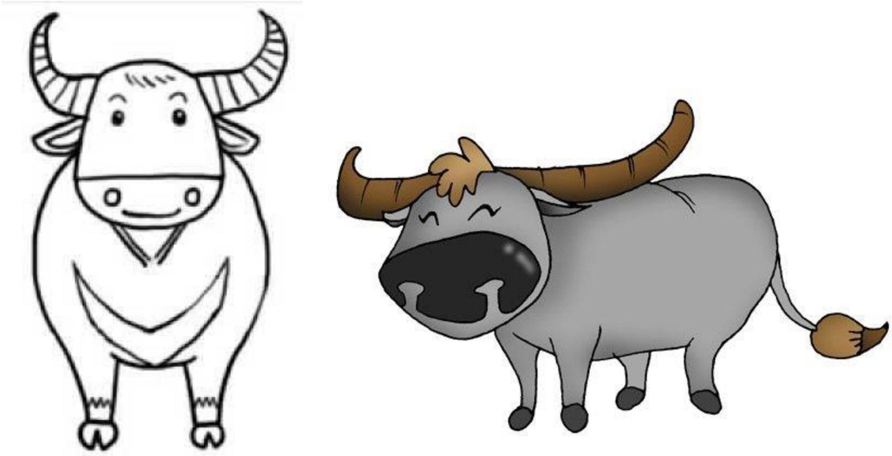
Horse (Brown - Black)



Water Monitor (Grey - Green)



Sheep (Yellow – Light Brown)



Buffalo (Black - Grey)

Figure 4. Example of 2-D outline shape of animal uses as target.

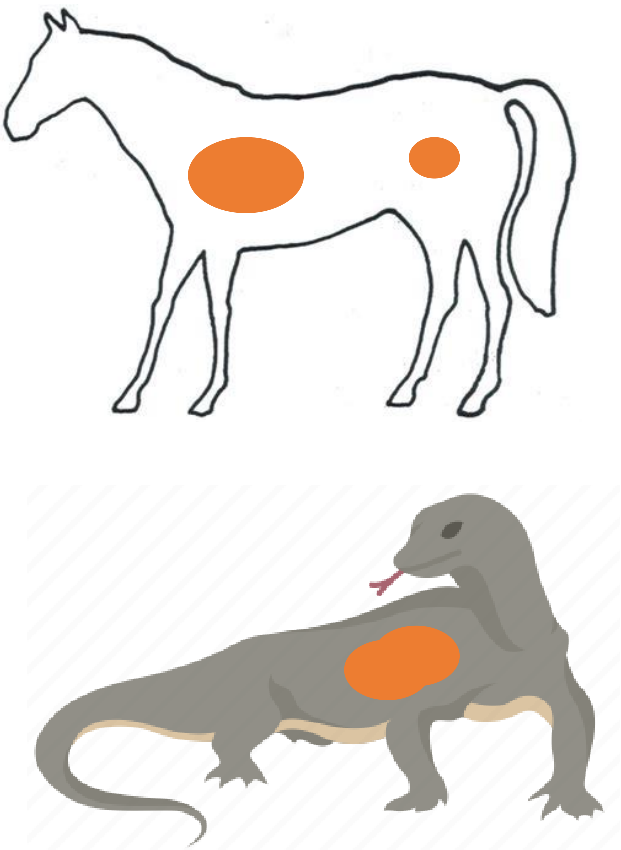


Figure 5. Example of the test subject which need a tranquilizer bomb

Event Schedule and Details

In addition to the on-site operational challenge, this AAVC 2021-2022 event would includes the technical evaluation phase prior to the on-site operational challenge, resulting as a two-phase event. The technical evaluation committee (selected from the member of CASE) will evaluate the reports submitted by all participating teams and rank the teams based on the evaluation scores. The first twelve (12) teams in the ranking list will be qualified for entering the on-site operation challenges directly. However, the team that does not qualified in this phase will be granted for a second opportunity by submitting the VDO footage demonstrating the capability of the system within a specified time-frame after the technical evaluation result is announced. The evaluation committee will then select six (6) teams for participating in the on-site challenge.

Phase 1 : Technical report submission (2020)

The participating teams would submit the report describing the technical detail regarding the development of the air vehicle including engineering design, fabrication and testing. See section *Technical report guidelines* for report structure and technical detail guidelines.

Phase 1 *Submission Deadline :* ***1 July 2021***

Phase 1 *Evaluation Result Announcement* **:** ***31 July 2021***

Submit via an email: ***aerokaset@gmail.com***

Phase 2 : Demonstration Footage Submission (2021)

The participating teams that does not pass the technical evaluation phase shall have an opportunity to enter the second evaluation by submitting a five-minute video footage demonstrating the capability of their UAS. In the submitted footage, the air vehicle must, at minimum, demonstrate basic flight operation profile consists of take-off, climb, cruise, descend, and landing.

Phase 2 *Submission Deadline :* ***30 September 2021***

Phase 2 Evaluation Result Announcement **:** ***10 October 2021***

Phase 3 : On-Site Aerial Challenges (2022)

A total of twenty teams (18 from phase 1 and phase 2 evaluation, plus 2 teams by invitation) will enter the on-site operation challenges set in **January 2022** (Date: TBA and upon the Covid-19 Situation). The participating teams will arrives at the challenges venue at the date specified by the host organization. There will be a suitable time window before the actual challenge begins (at least 24 hrs) for the flight trials/practicing to ensure the team's system and operational readiness as well as enabling the team's familiarization with the operational area.

The final detail including recent update of the situation (operating environment), target data, the operating time-slot for each team would be announced in due time before the date of an actual on-site operation.

During the actual on-site operation challenges the participating teams will perform system set-up and other necessary preparations at the assigned area, waiting for the organizing staff to escort them to the stand-by area near the launch and recovery site. While waiting for the operation time slot the team is allowed to perform the final system preparations, in which all preparation activities must be conducted according to the safety rules and restrictions (see annex for details).

Once team is cleared to move from stand-by area and to the launch and recovering site, the team will have a total of twenty (20) minutes time window to perform the mission where the first five (5) minutes window would be dedicated for setting up the control station at a designated area as well as positioning the air vehicle at the launch position. The team leader will notify the committee when the system is ready for operational. The committee will start timing for the fifteen minutes mission time window, in which the team would perform the aerial challenge operation. If the team is able to ready the system before the 5-minutes time window run out, the committee will start the air operation timer (15 minutes count-down) and discard the remaining preparation time. However, the mission timer will start automatically if the 5-minutes time window is passed and the team is still unable to ready the system, this would results in a reduced operation time-window for the team to complete the operation.

Within the operation time-window, the team will operates the system, manage the team, and make decisions with full autonomy. However, the safety committee will have the authority to terminate (abort) the flight operation in case of any unforeseen scenario that would considered critical to safety.

During the period of air operation challenge the participating teams are required to operates under the restrictions stated by the committee. See regulation section for further details.

Scoring Matrix

During the air operation time window, the operational performance for each team will be evaluated by the field technical committee based on the scoring matrix design for each track.

Please see the next page

Track 1 (Fixed Wing) Scoring matrix

The scoring matrix of track 1 (fixed wing) is described in table 1.

Scoring Criteria	Evaluation Scheme
Take-off	Maximum 10 points for safely take-off operation.
Payload drop accuracy	The accuracy score will be evaluated from $$P_{acc,drp} = (25 - D) + (25/n)$$ where D is the distance (in meters) away from the center of the target (based on the 25 m effective range of the tranquilizer bomb), and n is the number of drop trials. The maximum point is 50. Note: - The minimum allowable payload weight at each drop is 0.5 kg (maximum 1.0 kg) - The accuracy score will be zero if more than two bombs made their impact within 25m from the target, causing overdose to the target.
Loitering time while maintaining the target's field-of-view.	The loitering time points is evaluated from $$P_{loit} = 0.5t$$ where t is the time (in seconds) that the target stays in the sensor's field-of-view (image frame) while performing loiter flight over target area. The maximum point is 30 for maintaining the image of the target in the field of view for a maximum time of 60 seconds. Note: - The field committee will start timing for t once the team leader mark for target image acquisition and the timing is stopped once the image of the target moves away from the frame. - Multiple attempts are allowed within operating time window. The best attempt will be used for score evaluation
Target location acquisition accuracy	The accuracy of the target location acquisition will be evaluated from $$P_{GPS} = 20(f_{acc,GPS})$$ where $f_{acc,GPS}$ is the accuracy factor. The maximum point is 20 for the GPS positioning error within 5 meters error, 0 if the error exceed 50 meters.
Landing location accuracy	The maximum point is 10 if the landing point is within 10 meters from the center line of runway.
Condition after landing.	The maximum point is 20 when the air vehicle return with no damage.
Operation time penalty	The penalty will be represent as a "negative" points, which will be added to the overall score. Once the operation time window is reached, he penalty score will be "-5" for every one minute.

Track 2 (Rotary Wing) Scoring matrix

The scoring matrix of track 2 (rotary wing) is described in table 2.

Scoring Criteria	Evaluation Scheme
Take-off	Maximum 10 points for safely take-off operation.
Payload drop accuracy	The accuracy score will be evaluated from $$P_{acc,drp} = [2(15 - D)] + (20/n)$$ where D is the distance (in meters) away from the center of the target (based on the 15 m effective range of the tranquilizer bomb), and n is the number of drop trials. The maximum point is 50. Note: - The minimum allowable payload weight at each drop is 0.5 kg (maximum 1.0 kg) - The accuracy score will be zero if more than two bombs made their impact within 15m from the target, causing overdose to the target.
Hovering time while maintaining the target's field-of-view.	The loitering time points is evaluated from $$P_{hov} = \frac{t}{1.5}$$ where t is the time (in seconds) that the target stays in the sensor's field-of-view (image frame) while performing hovering flight over the target. The maximum point is 20 for maintaining the image of the target in the field of view for a maximum time of 30 seconds. Note: - The field committee will start timing for t once the team leader mark for target image acquisition and the timing is stopped once the image of the target moves away from the frame. - Multiple attempts are allowed within operating time window. The best attempt will be used for score evaluation
Target Identification accuracy.	The target identification accuracy score will be evaluated from the following aspect : - Overall shape of the target. (Maximum 10 points) - Details on the target. (Maximum 10 points)
Target location acquisition accuracy	The accuracy of the target location acquisition will be evaluated from $$P_{GPS} = 20(f_{acc,GPS})$$ where $f_{acc,GPS}$ is the accuracy factor. The maximum point is 20 for the GPS positioning error within 5 meters error, 0 if the error exceed 50 meters.
Landing location	The maximum point is 10 if the air vehicle is landed within the perimeter of

accuracy	the launchpad.
Condition after landing.	Maximum point is 20 when the air vehicle return with no damage.
Operation time penalty	The penalty will be represent as a "negative" points, which will be added to the overall score. Once the operation time window is reached, he penalty score will be "-5" for every one minute.

Track 3 (Hybrid) Scoring matrix

The scoring matrix of track 3 (Hybrid) is described in table 2.

Scoring Criteria	Evaluation Scheme
Take-off	Maximum 10 points for safely take-off operation.
Payload drop accuracy	The accuracy score will be evaluated from $$P_{acc,drp} = [2(15 - D)] + (20/n)$$ where D is the distance (in meters) away from the center of the target (based on the 15 m effective range of the tranquilizer bomb), and n is the number of drop trials. The maximum point is 50. Note: - The minimum allowable payload weight at each drop is 0.5 kg (maximum 1.0 kg) - The accuracy score will be zero if more than two bombs made their impact within 15m from the target, causing overdose to the target.
Loitering time while maintaining the target's field-of-view.	The loitering time points for each target is evaluated from $$P_{loit} = 0.5t$$ where t is the time (in seconds) that the target stays in the sensor's field-of-view (image frame) while performing loiter flight over target area. The maximum point is 30 (per target) for maintaining the image of the target in the field of view for a maximum time of 60 seconds. This will result in a total of 60 points. Note: - The field committee will start timing for t once the team leader mark for target image acquisition and the timing is stopped once the image of the target moves away from the frame. - Multiple attempts are allowed within operating time window. The best attempt will be used for score evaluation

Scoring Criteria	Evaluation Scheme
Target Identification accuracy.	The target identification accuracy score will be evaluated from the following aspect : - Overall shape of the target. (Maximum 10 points) - Details on the target. (Maximum 10 points)
Target location acquisition accuracy	The accuracy of the target location acquisition will be evaluated from $P_{GPS} = 20(f_{acc,GPS})$ where $f_{acc,GPS}$ is the accuracy factor. The maximum point is 20 for the GPS positioning error within 5 meters error, 0 if the error exceed 50 meters.
Landing location accuracy	The maximum point is 10 if the air vehicle is landed within the perimeter of the launchpad.
Condition after landing.	Maximum point is 20 when the air vehicle return with no damage.
Operation time penalty	The penalty will be represent as a “negative” points, which will be added to the overall score. Once the operation time window is reached, he penalty score will be “-5” for every one minute.

Score Multiplication Factor

In addition to the raw evaluation scheme, the following multiplication factors will be applied to each evaluation scheme.

Autonomy level factor (f_{auto}) : This factor reflects the system’s level of autonomy in each flight segment regarding scoring criteria. The highest factor will be awarded when the operation segment is conducted with full-autonomy (Onboard decision, no human interventions), and lowest when the operation segment is conducted by manual controls.

Level of autonomy	Factor	Description
Low	1	Manual control by the pilot
Medium	1.25	Automatic flight by preprogram before flight, The UAV does not decide by itself.
High	1.5	Onboard decision, no interference by any staff

Note: Clear detail will be announced later and upon decision of committee

Payload capacity factor (f_{pyl}) : This factor reflects the vehicle's weight efficiency. This factor will be evaluated based on the ratio between the payload weight and takeoff weight of the vehicle. The highest factor is awarded for the vehicle having the highest payload weight ratio.

$$RP = \left(\frac{Wpayload}{Wto}\right)$$

$$Fp = \left(\frac{RPi}{RPmax}\right)$$

Where *"Fp"* is the weight fraction of the air vehicle with maximum payload weight ratio in each track and *"RP"* is the payload weight ratio of the team under evaluation.

Mission Score

The overall score is then evaluated by multiplying each scoring component with the autonomy factor. The sum of all "factored" scoring components will then be multiplied with the payload capacity factor.

Flight Retries

The team would have full autonomy to operate the system within the designated airspace under the specified operation time-window. This includes the decision to return back to the launch and recovery site in the middle of the operation should the system malfunction is detected, and re-start the flight operation once the malfunction is sorted. These retries, as long as it stays within the operation time window, could be done in any number of times with no penalties incurred.

Payload Specification

The maximum weight of each payload is 1000g based on the assumption that it is designed to contain sedative at a maximum volume of 450ml, which its density is resemble to pure water. The payload shape is of a cylindrical bottle with approximate dimension of 65mm in diameter and 240mm in length. Instead of fabricating the payload, the participating teams is allowed to use a conventional 450ml water bottle as payload as the dimension of the payload, especially the diameter is similar.

The payload could be modified to be compatible with the vehicle's handling mechanism. Any "fixed" aerodynamic surfaces such as fins could be attached to the payload to improve the payload drop trajectory. However, it cannot be equipped with any "active" secondary delivery aid system such as motorized wheel/articulate joints, propulsive units, or actively controlled aerodynamic surfaces.

The team will submit the payload to the field technical committee for inspection before the flight operation begins. The payload weight will be recorded for evaluation and the overall description of the payload will be recorded to aid the field staff on the drop-point identification.

Technical report guidelines

The technical report submitted to the committee shall contains information according to the guidelines described in table 4.

Report Structures Outline	Detailed Arguments	Means of Evidences
Executive summary (10 points)	The team shall provide an overall summary of the entire report.	
Team organization (10 points)	The team shall provide information regarding the organization of the team and the description on the function each team member e.g. team manager, flight operation supervisor, aerodynamic analysis, structural design analysis, system engineer, software engineer, etc.	The team organization structure could be represent in various forms such as : - Organization chart - Table describing them member's roles and functions. * Picture of team member (grouped or individual) is recommended*
Concept development (30 points)	The team shall describe the process used in the development of the air vehicle design concept and the architecture of the relevant sub-systems.	- Description of the UAS design requirement specifications captured from the operational capability stated in chapter X. - Description of the selected air vehicle configuration and the rational used for configuration selection. - Overview of the design methodology used for conceptual design sizing.

		Discussion regarding the assumption used as well as the validation of the calculation scheme and/or mathematical model is encourages. - A summary of the overall specification of the design concept obtained from the methodology used such as weight, geometries, propulsion thrust (or power) requirements - Overview of the architecture of an air vehicle and its sub-system including its features and capabilities e.g. flight modes, imaging and target acquisition, communications, and payload handling, as well as other relevant safety features such as GEO fencing.
Preliminary and detailed design (40 points)	The team shall describe technical detail regarding engineering analysis method applied to the air vehicle and subsystems in major areas such as aerodynamics, airframe structure, flight performance, and subsystem performance to gives confidence on the performance, safety and reliability of the system.	- Description of the method and assumptions used to analyze/test for the air vehicle's aerodynamic analysis, with the analysis/test result. - Description of the method and assumptions used to analyze/test for the air vehicle's propulsion performance, with the analysis/test result. - Description of the method and assumptions used to analyze/test for the air vehicle's structural integrity, with the analysis/test result. - Description of the method and assumptions used to analyze/test for the air vehicle's subsystem functionality reliability, with the analysis/test result. - Description of the safety feature of the flight system e.g. Geo-Fencing - Description of the method and assumptions used to analyze/test for the air

		vehicle's flight performance, with the analysis/test result.
Manufacturing (10 points)	The team shall describe the prediction on the processes involved with the production planning of an airframe as well as its subsystem. Also the team shall project the cost associated with the development of the UAS. Note: It is not required that the airframe-system must reached the production stage at the time this report is submitted.	- Material selection for airframe structures and other major airframe-system components. - Fabrication method selection. - Manufacturing plan. - Projected cost breakdown data.
Testing (10 points)	The team shall describe technical detail regarding the test planning to evaluate the operational performance of the air vehicle and its relevant subsystems.	- Method used for ground/flight testing - Test plan - Test result (if already achieved)
Appendix (10 points) - Budget	For engineering, not only a performance and an efficiency of the platform are main concern, development team also need to consider also budget and cost as well. Although the budget is not taking into account for the score in this challenge, a team need to provide the cost of all hardware used.	- Equipment - Materials

Restrictions

There are operation restrictions that the participating teams must comply to ensure operational safety and evaluation fairness throughout the challenge. Ignoring or violating the restrictions and other safety rules stated by the event organizer will incurred heavy penalties and may results in disqualification for the team. Key important restrictions are summarized as follows:

Launch and recovery: The air vehicle must perform takeoff and landing at the designated launch and recovery site.

Operating Airspace: Entering the no-fly-zone (all areas outside the operational air-spaces above the containment area are considered as no-fly-zone) is strictly prohibited. This could be achieve by demonstrating GEOfencing as well as other flight path safety protocol.

Operating *Altitude*: All air operations, except take-off and landing at a designated launch and recovery site, must be conducted at a minimum altitude of 20 m AGL and shall not exceed maximum altitude of 45 m AGL.

Radio telemetry operation: Activating the radio control equipment and other telemetry are strictly prohibited while in the stand-by area.

Commercially made hardware: It is allowed to use a commercial-grade "empty airframe" integrates with an open-source flight system architecture in conjunction with other stand-alone imaging and telemetry systems. It is not allowed to use a "complete flight system package" found in the commercial-grade remotely piloted aircraft industries with any airframe. The use of the commercial-grade ready-to-fly UAS is strictly prohibited, even if it is embedded with the custom-made high-level computing algorithm.

Payload modification: Based on its basic configuration, the team is allowed for a minor modification of the payload to be compatible with the air vehicle's payload handling system. The "static" fixed aerodynamic surfaces could also be attached to the basic payload to enhance the stability of the drop trajectory. Attaching the payload with any "active" delivery aid system such as motorized wheel/articulated joints, propulsive units, or actively controlled aerodynamic surfaces are strictly prohibited.