Thailand High-School Agricultural CanSat Model: Applications in Vladimir, Russia

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Agricultural Exploration Assistant Satellite, A.E.A.Sat, is a CanSat (can-sized satellite model) prototype which is created for three special purposes: studying environmental factors that affect the crops growth, exploring the most suitable areas for various types of agricultural actions, and advising agriculturists and farmers. It is originally utilized for Thai economic crops as it was created for participation in Thailand CanSat Competition 2018. The first mission took place in Chai Badan, Thailand, and thereafter the result indicated that sugarcane was the most suitable crop to be planted. The team later got involved in Russia CanSat Competition 2018 as the representative team of national winner. The second prototype was later designed for greater performance, accuracy, precision, size, and weight. Raspberry Pi Zero W was used instead of Arduino Pro Mini as a processor. It recorded quantitative data: temperature, relative humidity, and light intensity, along with Vladimir annual rainfall data. Aerial imageries were taken and used in qualitative analysis. The ground station software: LabView, Google Earth, and MATLAB was also utilized for handling both types of data. The department or, specifically, farmers can access and use the analyzed data via the website which the details were published. In summary, farmers and agriculturists could expect more products quantity with the aid of the data.

I. Nomenclature

3D	:	three-dimensional
A	:	Surface area, meter squared
CSV	:	comma-separated value
c_D	:	Drag coefficient
GIS	:	Geographical Information System
GNSS	:	Global Navigation Satellite System
GPS	:	Global Positioning System
g	:	Acceleration due to gravity, meter per second squared
m	:	Mass, kg
N	:	Number of samples
PCB	:	Printed Circuit Board
R.S.	:	Relative Suitability
SBC	:	Single-Board Computer
t	:	Time, second
v	:	Speed, meter per second
x	:	Distance from start, meter
ρ_{atm}	:	Air density, kilogram per cubic meter

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II. Introduction

THAILAND CanSat Competition 2018 is a national CanSat competition for Thai high-school students to participate and compete. Its purpose was to develop students' abilities based on science, technology, engineering, and mathematics according to guidelines of STEM education Thailand and project-based learning. The champion of the competition would be chosen to be a representative team to join the CanSat competition in Russia in order to test their CanSat ability and performance in different types of environment.

Agriculture in Thailand is quite remarkable. Nevertheless, Thailand is designated as 'the kitchen of the world,' where most of the income of its farmers is significantly lower than that of average Thai people (57,032 Baht to 320,000 Baht per year). Furthermore, 40 percent of the farmers have lower income than the poverty threshold. The team was aware of this major problem of the farmers and came up with ideas and solutions to the problem. Agricultural Exploration Assistant CanSat model which was one of the CanSat models in the competition was aimed to help exploring land area that had the most suitable conditions for planting and growing crops. By using technology and computation method, the human effort and resource usage is lowered. It was also capable of long-term exploration usage. The mission of A.E.A.Sat was to measure quantitative atmospheric conditions: temperature, relative humidity, and light intensity; record the area (in this case, Vladimir) annual rainfall data; and capture aerial image data using CanSat. The quantitative parameters were, subsequently, analyzed to calculate the most suitable crop to be planted in the study area and visualized in a form of suitability map to find the most suitable area for crops to be grown. A.E.A.Sat was first launched in Chai Badan, Lop Buri Province, Thailand, descended from the height of 350 m.

After the competition, A.E.A.Sat Team was concluded as the winner of the competition in 2018. The team was chosen for participation in 8^{th} CanSat Russia Competition later in July 2019. A.E.A.Sat and referencing data were originally utilized for 6 Thai economic crops: rice, sugarcane, cassava, rubber tree, palm, and maize; but Russia (Vladimir) has completely different geography and climate from Thailand. To make A.E.A.Sat compatible with those factors, the mechanical designs were modified for more extreme conditions. The referencing data (types of crops) were changed to Vladimir-locally-grown crops: wheat, barley, beets, and maize.

III. Mechanical Designs

A. Enclosure and internal compartment design

Due to the fragility and vulnerability to shock, vibration, and instantaneous impact force, the configuration of electronic circuits which consists of the processor, the power system, and sensors were 2 PCBs connected by standoffs with top, bottom, and side 3D-printed Polycarbonate enclosure as illustrated in Fig. 1. Polycarbonate plastic in this configuration has very high rigidity and structural integrity so as to absorb such shock force. The shell was designed to increase its aerodynamic properties and reduce turbulence flow which could cause shaking. The aerial imageries were taken by Raspberry Pi Camera V2.1 installed at the bottom lid. The final dimension of A.E.A.Sat has the diameter of 68.0 mm and the height of 190.0 mm.

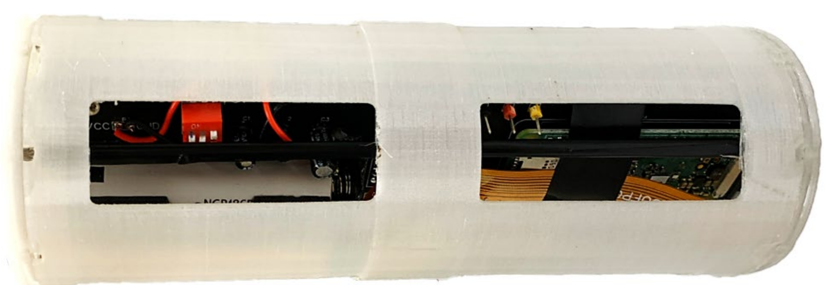

Fig. 1 Mechanical Layout of A.E.A.Sat (Russia-based Prototype)

B. Parachute design

A.E.A.Sat was taken into the atmosphere by drone and descended from it at 350-meter height. The parachute aided in slowing the descent rate as any instantaneous impacts would cause damage to the components. The round-type parachute with air vent in the middle was selected because of its high stability, forward speed, and ease of manufacturing. The area ratio of air vent to body is 2:25. As the overall weight of A.E.A.Sat with the parachute was

310.0 g, the selected terminal descent speed would be approximately 5.0 m.s^{-1} according to Eq. (1) which was safe for landing, recovery, and future reuses.

$$\Delta t = \int_{v_i=0}^{v(t)} \frac{1}{g - \frac{\rho_{atm} c_D A}{2m} v^2} \mathrm{d}v \, , \tag{1}$$

IV. Electronic and Circuitry Design

According to the mission requirements, the components could not be connected by wires; thus, the designs of circuit were chosen over wiring method. The PCB was selected as an option for placement of electrical power subsystem, sensors subsystem, and other electronic components. As mentioned, the double-layer-stacked PCB configuration with modules installed on both sides was preferred and the area of the PCBs were used as much as possible. The two PCBs have communication and power line to connect all systems together. The components are categorized into 4 main parts, allocated by their functions and usages: electrical power subsystem, sensors subsystem, processor unit, and data and communication subsystem as follows.

A. Electrical power subsystem

The electrical power subsystem is one of the essential parts of the systems. Its purpose is to maintain the stability and safety of voltage and current of the system. Two parallel 3.7 V Lithium-ion (Li-ion) batteries configuration with total energy of 25.9 W.h was selected. The 5 V MT3608 voltage step up regulator module and 3.3 V AMS1117 voltage regulator module were utilized for supplying two different subsystem power lines with 3.3 V and 5 V voltage. The safety of the power subsystem was controlled by TP4056 battery management module. It helps prevent overcharging and overcurrent and features with short-circuit protection. The module also has LEDs that indicates the battery status and can be seen from outside of the enclosure.

B. Sensors subsystem

The sensors subsystem consists of the sensor modules according to objectives and data acquisition requirements. The A.E.A.Sat was designed to be as compact and sturdy as possible and thus meet the competition requirements of the mission. The size of individual PCB is 190.0 mm x 60.0 mm which fits tightly in the enclosure to prevent disassembly and damages on impact at touchdown point.

No.	Components	Functions
1.	BME280	Measures atmospheric temperature, relative humidity, and air pressure.
2.	CCS811	Measures Carbon dioxide intensity.
3.	GY-801	Measures gyroscopic orientations: roll, pitch, and yaw angle.
4.	Ublox NEO-M8N	Retrieving GNSS coordinates with GPS in decimal degree format.
5.	GY-9960	Measures red, green, and blue light intensity.

Table 1 Sensors components and their functions.

C. Processor unit

The main purposes of processor unit are to acquire data from sensors, process them, and utilize communication between modules. The selected processor is Raspberry Pi Zero W, an SBC, because of its small size and powerful performance. Raspberry Pi also has significantly better camera interface. The original prototype used two parts of processor units: two Arduino Pro Mini modules for data communication and sensors data acquisition and one Raspberry Pi Zero W for capturing images. The second model had accordingly better efficiency for both power and area usage.

D. Data and communication subsystem

The data and communication subsystem consists of wired and wireless communication. After acquiring measured data parameters from sensors, the data, then, was stored into SD card. The other section was transmitting the data from A.E.A.Sat to the ground station using 433.00 MHz LoRa Ra-02 wireless communication module. The parameters were formatted in CSV format for uncomplicated data sorting, separation, and further usages. The selected SD card model was SanDisk Extreme Pro 32 GB for its sufficient storage memory and high speed which is minimum requirement for Raspberry Pi operating system and data. The telemetry was mainly used for tracking the coordinates of A.E.A.Sat in decimal degree: latitude, longitude, and altitude and for backing up data.

V. Integration Tests

After A.E.A.Sat prototype model was assembled, the final integration test was required and held. The continuity and reliability of the data were tested and verified before the launch day. The communication range and obstruction tests, the power consumption test, and the drop test were also held.

A. Wireless communication range and obstruction test

The major part of using A.E.A.Sat as telemetry is wireless communication (one way in this case). The range is tested by means of a quadcopter drone, taking A.E.A.Sat which was held in place to the altitude. The maximum range of transmission was recorded in ground distance and altitude.

B. Power consumption test

The power consumption was first approximated by calculation. The time interval of power-on state of A.E.A.Sat was measured with a stopwatch/timer for full functionality including data telemetry and wireless communication. Until A.E.A.Sat stopped transmitting data or telemetry data was irregular or fluctuating, the battery would be considered died or non-functional.

C. Drop test

The drone installed with a deployer with A.E.A.Sat in it performed a drop test at the altitude of 300 meters which was an approximation for apogee altitude of the rocket. The consistency of data communication was tested and noted. The drone with the deployer installed which was used is shown in Fig. 2.

Fig. 2 Drone used to perform a communication test and a drop test

VI. Ground Station

The ground station includes a laptop, a Yagi-Uda 410.00-460.00 MHz antenna, and an antenna mounting-tripod which can be demounted on-the-run, hence portable. The software used in the ground station was LabView and Google Earth Pro. LabView acquired all telemetry data in comma-delimited format, plotted all the parameters in graphs, and saved all fields in CSV format for backup and further analyses. Google Earth Pro plotted all coordinates obtained in 3D and in real time. The windows of ground station software are shown in Fig. 3.

Fig. 3 Ground station software: LabView (left) and Google Earth (right)

VII. Data Analysis

A. Quantitative data analysis

Each Vladimir-locally-grown type of crop—wheat, barley, beets, and maize—has different suitable ranges of growth factors: atmospheric temperature, relative humidity, Carbon dioxide intensity, average annual rainfall, and light intensity. A.E.A.Sat was used for telemetry to measure these parameters as growth factors of various plants. These external (environmental) factors directly determine the efficiency of being planted and grown in such condition and period apart from internal factors (plant hormones). The suitability of each crop was stated in Eq. (2) and was calculated with statistical bell curve equation as shown in Table 2 [1, 2].

$$S = \frac{100}{N} \sum_{k=1}^{N} \exp\left\{-\left(\frac{x_{0,k} - x_k}{x_{0,k}}\right)^2\right\}, \qquad \textbf{(2)}$$

where $x_{0,k}$ is the best value of each factor and x_k is the measured value of each factor.

Plants	Temperature (%)	Humidity (%)	CO_2 intensity (%)	Light intensity (%)	Overall (%)
Wheat	84.49	67.49	76.01	73.41	77.05
Barley	62.36	95.88	76.01	73.41	71.47
Beets	87.31	91.09	76.01	73.41	75.39
Maize	48.50	99.47	76.01	73.41	77.48

Table 2 Suitability of growth factors of the four crops in percent which Maize had the most overall suitability.

B. Qualitative data analysis

Aside from the quantitative data, the qualitative data was also analyzed. Certain types of data include aerial photograph. The methods used for this type of analysis were visual interpretation and human logical determination. A.E.A.Sat used Raspberry Pi camera to obtain the individual frame of aerial photographs, and then looked for any obstacles: residences, roads, airfields, and features around the study area.

VIII. Conclusion

In this paper, A.E.A.Sat second prototype model, designs, and development were explained. The missions, objectives, and software were also elaborated. The detailed mechanical and electronic designs: enclosure, parachute, PCBs, sensors, and communication interfaces were included. As a result, A.E.A.Sat is expected to be transformed to be applied as a telemetry probe, hence more flexible and accurate. Because the rocket can be deployed and set up remotely, A.E.A.Sat can be sent to most rural areas for agricultural exploration and use the data to advise agriculturists and farmers. Finally, they could expect more products and use the farming area effectively.

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