



Development of the 1U CubeSat

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Abstract

Mission Objective:

Design and assemble a small, autonomous 1U CubeSat measuring instrument, weighing up to 1,500 grams and measuring 105 mm x 105 mm x 105 mm (L x H x W), capable of conducting atmospheric research, aerial photography, and safe return to Earth.

Mission Objectives:

- Study the composition of air in the lower atmosphere, including measuring temperature, pressure, humidity, gas composition, and the air quality index (AQI);
- Capture aerial photography of the surrounding area for visual analysis, including determining cloud cover and identifying potential pollution;
- Create a web application displaying dynamic graphs in real time;
- Transmit data to a ground station in real time and store it on an SD card.

Mission Significance:

Research into the lower atmosphere plays a key role in air quality analysis, pollution monitoring, and meteorological observations. This problem is particularly pressing for Almaty, as it ranks first on the list of the most polluted cities in the world, with an air quality index of 208 (Ulysmidia.kz, 2025). High levels of air pollution and industrial emissions pose a serious environmental threat, impacting public health and the environment.

This work is both research-based and practical, focusing on monitoring atmospheric conditions and developing an autonomous measuring device.

Construction and System design

To design and optimize the satellite, we analyzed mass, aerodynamics, power consumption, and thermal conditions.

The 1U CubeSat has standard dimensions of 105 x 105 x 105 mm and weighs up to 1500 g. We use PLA-CF plastic for the enclosure due to its exceptional strength and tolerance to all conditions. Our enclosure is open-sided for access to the automation and reduced weight. We used Orca slicer to calculate the enclosure mass. When fully populated, the enclosure weighs approximately 70 grams. With embedded electronics, it weighs approximately 980 grams.

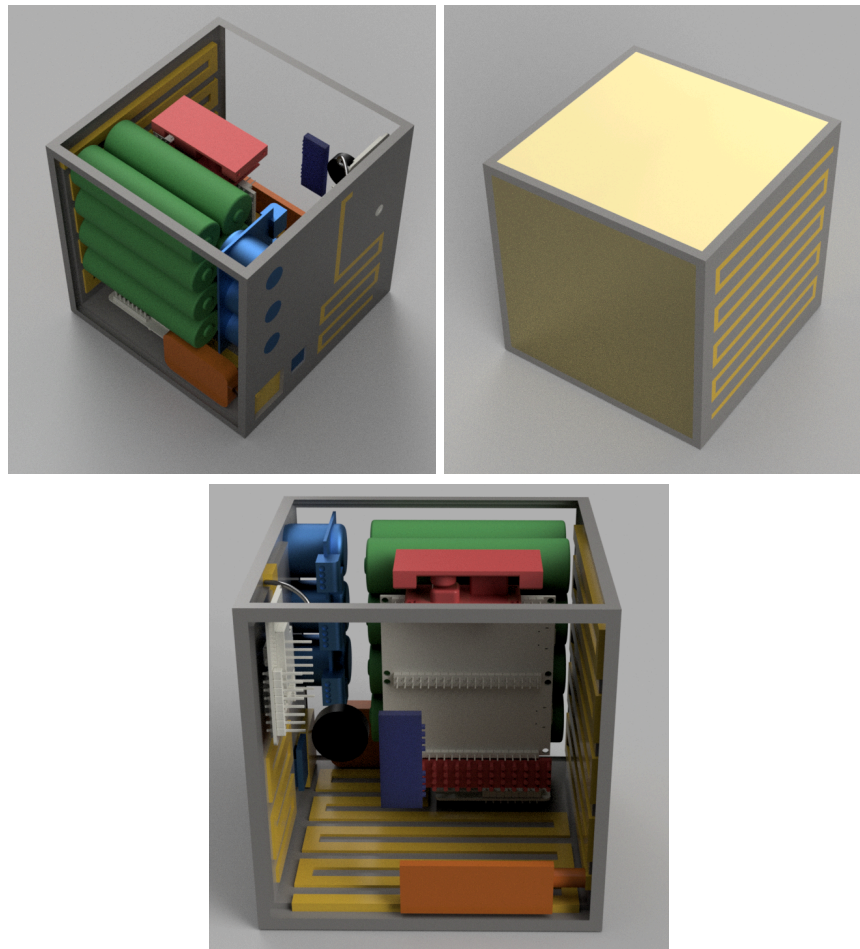


Figure 1. Model of the CubeSat 1U satellite

Electronics and Microcomputers

We chose boards based on the ESP32 WROOM 32 microcontroller due to their outstanding power, variety of interfaces, and attractive price.

Parameter	Arduino Uno	Raspberry Pi Pico	Arduino Mega	ESP8266	ESP32 WROOM 32
Clock frequency	16 MHz	133 MHz	16 MHz	80 MHz	240 MHz
Flash memory	32 KB	2048 KB	256 KB	40 KB	8096 KB
RAM	2 KB	264 KB	8 KB	80 KB	520 KB
Power consumption	50 mA	90 mA	50 mA	200 mA	280 mA
Analog pins	6	3	16	1	32
Digital pins	14	26	54	17	32
I2C interfaces	1	2	1	1	2
SPI interfaces	1	2	1	1	2
UART interfaces	1	2	3	1	1
CPU cores	1	2	1	1	2

Table 1. Microcontroller Comparison

Component	Purpose	Quantity
ESP32 WROOM 32 (38-pin)	Microcontroller	2
Jumper wires (male–male, female–female)	Connecting components together	40
CD Updator	Reading and updating SD card data	1

GY-9110DOF MPU9250 + BMP280	Multifunctional sensor: barometer, magnetometer, temperature	1
DHT11	Humidity and temperature measurement	3
MQ-135	Measurement of carbon dioxide and smoke concentration	1
MQ-4	Measurement of methane concentration	1
MQ-8	Measurement of carbon dioxide concentration	1
GY-NEO6M GPS	GPS module	1
NRF24L01P + PA + LNA	2.4G wireless radio module	1
ESP32 CAM C6	Video camera for satellite video demonstration	2
Antenna	Individual antenna for cameras and radio module in plastic casing, long-range data transmission	3
Buzzer KY-012	Buzzer for sound alerts	1
MT3608	Adjustable step-up voltage converter	1
CN3791	Solar panel power converter for system supply and battery charging	1
Solar panel (100 × 100 mm)	Solar energy harvesting	3
18650 batteries	High-current batteries, 3400 mAh each, for full system power	8
Power distribution board	Board for 5V and GND output from batteries with power management	1

SD card reader	Memory card reading device	1
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Table 2. Satellite components

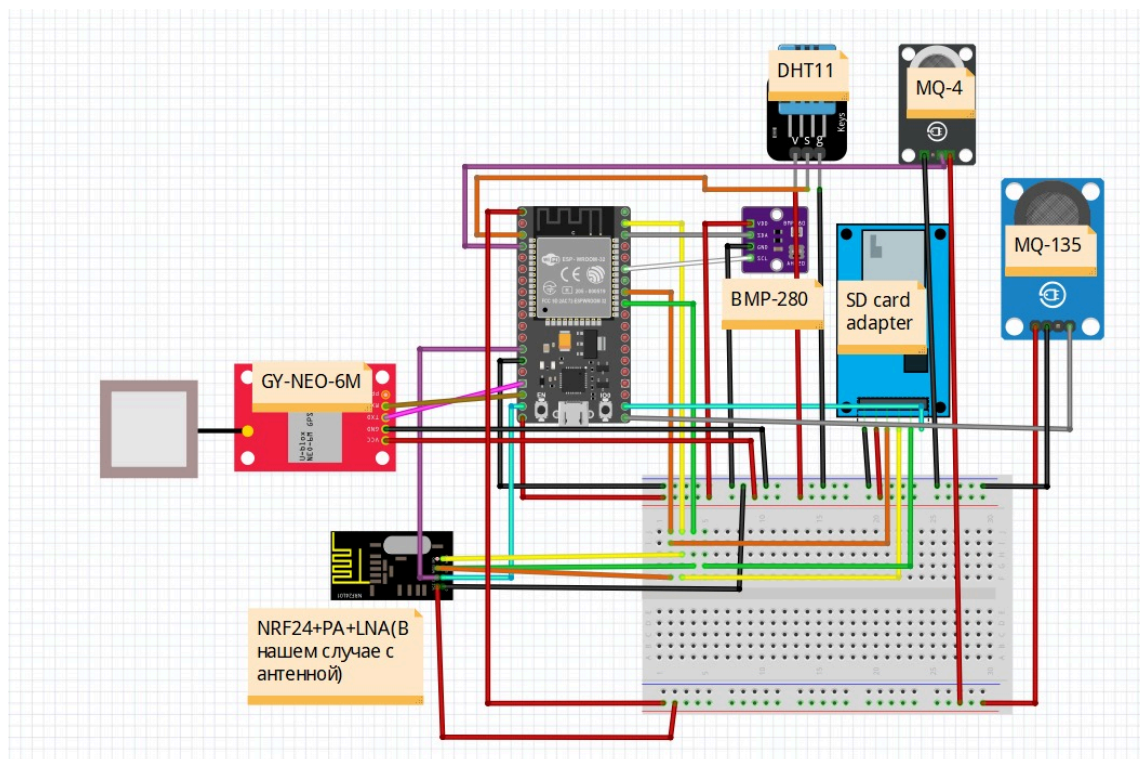


Figure 2. Wiring diagram of the device's electronics

Software part

Telemetry graphs:

The satellite code and graphs are available at
https://github.com/Kirirto-kun/stargate_KSDT

Kirirto-kun Update README.md		7434249 · now	🕒 12 Commits
📄	Graphs_Stargate_Rocketry.mp4	readme update	7 minutes ago
📄	README.md	Update README.md	now
📄	kazrockets_full_code_of_sputnik.ino	code of satellite, dynamic/static graphs	15 minutes ago
📄	server_dynamic_graphs.py	code of satellite, dynamic/static graphs	15 minutes ago
📄	server_static_graphs.py	code of satellite, dynamic/static graphs	15 minutes ago

Figure 3. Satellite code repository

To visualize satellite data, we use the Python programming language and the Matplotlib library. The graphs are dynamic, updating in real time as data arrives via the radio module. Furthermore, all measurements are saved to an SD card installed on the satellite, allowing for data analysis even after the mission is complete.

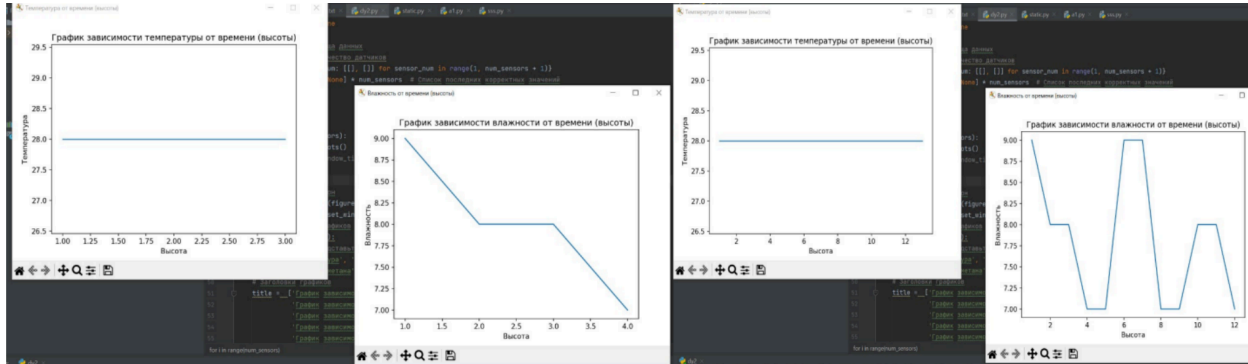


Figure 4. Displaying data graphs in Python

Flight Visualization:

Website code is available at <https://github.com/Bebdyshev/KSDT2025>

Flight visualization includes displaying the satellite's trajectory, altitude parameters, and other data collected during the mission. This allows for real-time tracking of the satellite's behavior and analysis of its flight characteristics.



Figure 5. Website with graphs, a map of movements and flight visualizations

Power Supply

Our satellite's power management system utilizes eight parallel-connected 18650 Li-Ion batteries with a total capacity of approximately 27 Ah. To ensure a stable power supply, a CN3791 MPPT controller is used, configured for 4.2 V for efficient charging from the solar panel (5 V, $\geq 2-4$ A). A step-up converter (MT3608) provides a stable 5 V supply to power the peripheral devices and the ESP32 microcontroller. The batteries are constantly recharged.

When the batteries reach critical charge, all associated electronics (except for the spare antenna and one ESP32 board) are shut down. The batteries fully charge within approximately 24 hours, and the satellite turns on automatically or upon a signal from the ground. Even if completely discharged, the battery charging board continues to function, making the satellite stable and energy-independent.

Component	Typical power consumption (mA)
BMP280	3
DHT11	1.5
MQ-135	150
MQ-4	150
MQ-8	150
GY-NEO6M GPS	20
SD card reader	50
NRF24L01 + PA + LNA	45
ESP32 WROOM	80 (up to 280)
GY-9110DOF MPU9250 + BMP280	3–10
ESP32-CAM C6	200
Buzzer KY-012	15
Total power consumption in active mode	867.5–900 mA

Table 3. Table of power consumption of components.

References

- Vsevolod Kanaev's book: The Key to Start, 1972.
- OpenRocket — rocketry software.
- Fusion 360 — CAD software.
- Radiomart.kz — electronics.
- Ulysmidia.kz. (2025, February 10). Almaty again tops the ranking of cities with the dirtiest air in the world.
<https://ulysmidia.kz/news/46264-almaty-snova-vozglavil-reiting-gorodov-s-samym-griaznym-vozdukhom-v-mire/>