1st Progress Update Reports for the LASC

Team 15 (SIGHT CubeSat) 1st Progress Update for the 2023 LASC

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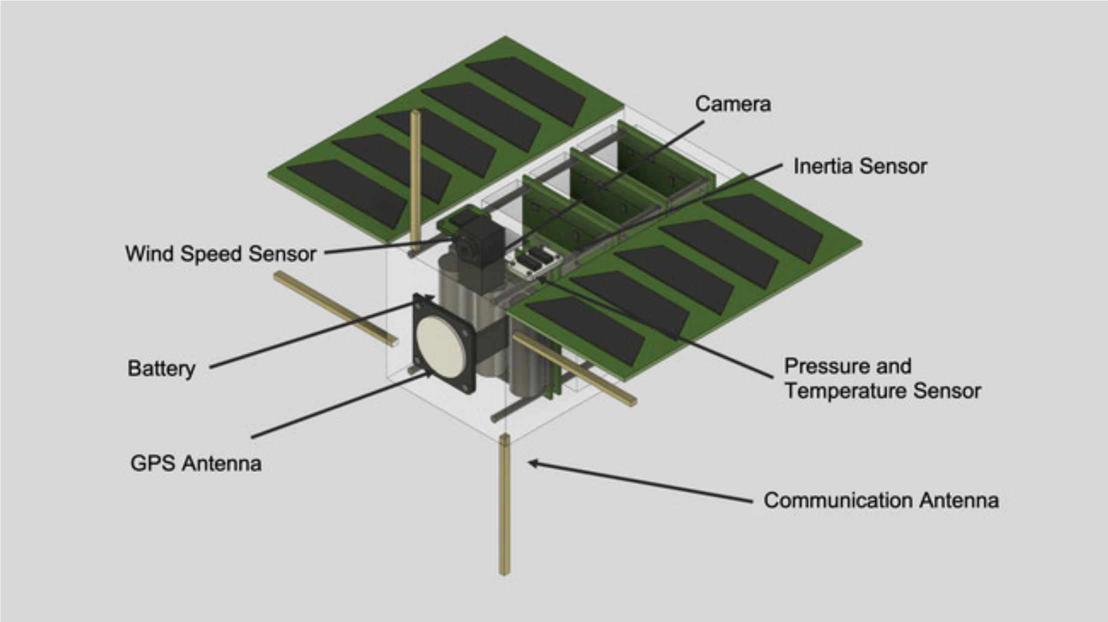
1. **Introduction**
   This is a multifunctional science CubeSat.



2. **Short description**
   This cubesat can take inertia, GPS, humidity, temperature and pressure data. With the camera on cubesat ,it can take aerial photography.
3. **Choose Your Team:** 15 - Dept. of Space Science and Eng. - NCU
4. **Mission ID:** 15
5. **Project Name:** SIGHT CubeSat
6. **Category:** CubeSat
7. **Is there a category change since Acceptance Announcement?** No
8. **Mission Patch:**
   https://drive.google.com/file/d/1BOKwN5HLzBccHhvsnRmeouqTBN0VYnPT/view?usp=share_link
9. **Exterior Dimensions [mm]:** 200 x 100 x 100 (CubeSat 2 U)
10. **Satellite Mission, Goals and ConOps:**

The mission objectives of this CubeSat are:
10.1 To monitor temperature, humidity, GPS data, and atmospheric pressure at various altitudes during descent.
10.2 To capture the CubeSat's flight path using an onboard Pi Camera.
10.3 To test the effectiveness of a parachute system for descent from a height of up to 3 kilometers.
10.4 To verify the practicality and performance of a CubeSat designed and built by students.
10.5 To cultivate students' ability to construct CubeSats as a hobby.

The CubeSat can be broadly divided into six subsystems:
10.6 Electrical Power Subsystem: Responsible for providing power and maintaining the system's survival.
10.7 Communication Subsystem: Responsible for communication and transmitting data and GPS signals.
10.8 On-Board Data Handling Subsystem: Responsible for controlling and processing the entire CubeSat and its data.
10.9 Sensors, Actuators Subsystems: Responsible for scientific observations and data collection.
10.10 Structure Subsystems: Responsible for the structure, mass, and spatial configuration of the CubeSat.
10.11 Descent subsystem: Uses a parachute or airbag to safely land the CubeSat.

The ConOps for this CubeSat mission can be divided into three main parts:
10.12 CubeSat: The CubeSat is responsible for collecting the necessary data and storing it on an SD card or transmitting it to the ground station via the Communication Subsystem.
10.13 Rocket: The rocket is responsible for launching the CubeSat to the designated altitude, with two primary requirements: it must allow the CubeSat to be ejected in the direction of the designated coordinate axis, and it must be able to carry a 2U-sized structure for the CubeSat.
10.14 Ground Station: The Ground Station is responsible for receiving CubeSat data and GPS signals, collecting data, and processing and analyzing the CubeSat's location and data.

11. Electrical Power System

The Electrical Power System of SIGHT CubeSat uses 18650 Li-ion batteries produced by Kinyo company, with a specification of DC 3.7V 1200mAh and a weight of 33g. It is expected to be powered by four batteries connected in series.

For battery charging and voltage regulation, a TP4056 is planned to be connected in the circuit. The batteries will be charged before launch and during the functional testing phase. TP4056 can be charged through a Type C connector, with a charging current up to 1A and input voltage of 5A. Its size is 0.52.61.7CM, and the Type C USB socket and the + - solder pad next to it are the power input terminals, connected to 5V voltage. B+ is connected to the positive pole of the lithium battery, and B- is connected to the negative pole of the lithium battery. OUT+ and OUT- are connected to the load. The red light indicates that it is charging, and the blue light indicates that it is fully charged.

For power output, a self-designed PCB will be used, which contains 4 sets of small transformers that can provide 3.3V, 5V, 7V, and 12V power supply. According to the final design, the voltage divider, current size, and special voltage supply of each circuit will be adjusted.

12. **Communication System**

The Communication System of the SIGHT CubeSat uses the DAC MCP4725 to convert the output signal of the Raspberry Pi from digital to analog. The DAC is responsible for this signal conversion. The signal amplification is achieved by the INA125P, which amplifies the signal up to 5W. The ground antenna has a gain of 6 dBi, enabling the reception of signals up to -62.033 dBm.

The Up-Down Converter (ADL5350) is responsible for frequency up-conversion to 2.2 GHz and transmission to the Antenna (2135230011). The baud rate is calculated to be 1.83 Mbit/sec with a 2.2 GHz/12-bit ratio.

Backup: To obtain complete data, the data should be stored on the Raspberry Pi's SD card using open ("data.csv", "a") command. The data storage process is synchronized with the data download process.

Even if the communication system fails or there is an error in the process, there is still data backup available for analysis.

DAC(MCP4725):

A. 12-Bit Resolution

B. Single-Supply Operation: 2.7V to 5.5V

C. I2CTM Interface:

1. Standard (100 kbps)

2. Fast (400 kbps)

3. High-Speed (3.4 Mbps)

D. Extended Temperature Range: -40°C to +125°C

E. Power Requirements:

1. Supply Current: I¬¬¬D¬¬= 210 µA

2. Power-Down Current: I¬DDP¬¬= 0.06 µA (V¬DD¬=5.5V)

F. Short Circuit Current (Max): 24 mA (VDD=5V, VOUT =Ground)

G. Output Amplifier:

1. Phase Margin: PM= 66 degree(°) (CL=400pF¬)

2. Capacitive Load Stability: CL= 1000 pF (RL = 5 kΩ)

3. Short Circuit Current: ISC=15 mA (VDD = 5V, VOUT = Grounded)

4. Output Voltage Settling Time: Ts=6 µs

H. Digital Interface:

1. Output Low Voltage: VOL= 0.4 V (LOL=3 mA)

2. Input High Voltage (SDA and SCL Pins): VIH= 0.7 VDD (V)¬

3. Input Low Voltage (SDA and SCL Pins): VIL= 0.8 VDD (V)¬

Power Amplifier (INA125P):

A. 16-PIN DIP AND SO-16 SOIC PACKAGES

B. Number of channels

C. Extended Temperature Range: -40°C to +85°C

D. Power Supply:

1. Single Supply: 2.7V to 36V

2. Dual Supply: ±1.35V to ±18V

E. Vs=±5V

1. Input:

a. Initial Offset Voltage(type): ±75 µV (Max): ±500 µV

b. Common-Mode Rejection (VCM = +1.1V to +3.6V)

i. G=4(type): 84 dB (Min):78 dB

ii. G=10(type): 94 dB (Min):86 dB

iii. G=100(type): 114 dB (Min):100 dB

iv. G=500(type): 114 dB (Min):100 dB

2. Gain:

a. Gain Error (VO = +0.3V to +3.8V): G = 4 ±0.01%

3. Output Voltage:

a. Positive(type): (V+)–0.8 V (Min): (V+)–1.2 V

b. Negative(type): (V-)+0.15 V (Min): (V-)+0.3 V

4. Power Supply:

a. Specified Operating Voltage: ±5 V

b. Specified Voltage Range: ±2.7 to ±36 V

c. Quiescent Current: 460 µA (Io = IREF = 0 mA)

Up Down Converter (ADL5350):

A. Conversion loss: 6.8 dB

B. Noise figure: 6.5 dB

C. High input IP3: 25 dBm

D. High input P1dB: 19 dBm

E. 850 MHz Receive Performance:

RF frequency Range (Min, Type, Max):750, 850, 975 MHz

LO frequency Range (Min, Type, Max):500, 780, 945 MHz

Conversation Loss: 6.7dB

SSB Noise Figure: 6.4 dB

F. Supply Voltage: 3 V

G. Supply Current: 16.5 mA

Antenna (2135230011):

A. Component Type: External Antenna

B. Function Signal

C. Length: 171.50mm

D. Width: 19.40mm

E. Mounting Style: N/A

F. Net Weight: 14.143/g

G. Electrical:

1. Band#1 F_End: 960 MHz
2. Band#1 F_Start: 698 MHz
3. Band#2 F_End: 2690 MHz
4. Band#2 F_Start: 1710 MHz

H. Peak Gain:

1. 698 MHz: 2.3 dBi
2. 1710 MHz: 4.8 dBi

I. Return Loss: < -10, < -5 (dB)

J. Total Efficiency:

1. 698 MHz: >55%
2. 1710 MHz: >70%

13. On Board Data Handling System

OBDH picking：Raspberry Pi 3 Model A+

Specification：

1. 40-pin GPIO header
2. CPU : Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
3. camera port for connecting a Raspberry Pi Camera
4. Micro SD port for storing data(512MB LPDDR2)
5. 5V/2.5A DC power input

Considerations & Advantage：

1. Suitable for Raspberry Pi Camera.
2. With full features and abundant resources, suitable for student teams to operate with moderate difficulty.
3. The processor performance meets the task requirements.
4. Has a complete flight heritage.

Pinout diagram：

I/O：Camera popup switch、Kill Switch、DHT22→ Physical Pin7,11,13,15,22,36,37,38,40(9)

PWM：Descent subsyste→ Physical Pin33,35(2)

UART(Rx,Tx)：NEO-6M-0-001→ Physical Pin8,10(2)

I2C：MCP4725、MPU6050、BME280→Physical Pin3,5(3 slave connect on I2C)

(camera)：Raspberry Pi Camera→15-Pin Connector

14. Sensors, Actuators & Additional Systems

1. Inertial measurement unit：

● Component name: MPU6050

● Data provided: 3-Axis Accelerometer & Gyro

● Digital interface: I2C communication protocol (SCL, SDA)

● Gyroscope range: ±250 / 500 / 1000 / 2000°/s

● Accelerometer range: ±2 / ±4 / ±8 / ±16g

● Dimensions : 21.2 x 16.4 x 3.3mm

● Supply current : 3.6 ~ 3.8mA

● Supply voltage : 2.375 V to 3.46 V

Data calculation method:

data output：voltage level

For X-axis Acceleration:

Rx = InvertAxz * (AdcRx * Vref / 1023 – VzeroG) / Sensitivity

Assuming only gravity is present, the satellite attitude angle is obtained through the total acceleration vector.

For YZ-axis Angular velocity:

RateAyz = InvertAyz*(AdcGyroYZ *Vref /1023–VzeroRate)/Sensitivity

calculate xy,xz,yz axis,then satellite rotation angular velocity is obtained.

2. Barometer & Altimeter & temperature / humidity sensor

● Component name : GY-BME280-5V

● Data provided : temperature、humidity、barometric pressure

● Digital interface : I2C communication protocol (SCL,SDA)

● Relative Humidity Range : 0~100 % (±3.0%)

● Temperature range : -40 to 85(±0.5)°C

● Pressure range : 300 – 1100(±1.0) hPa

● Dimensions: 11.5 x 15mm

● Supply Voltage: 5V or 3.3V

● Current Consumption: 0.6 mA

3. temperature / humidity sensor

● Component Name: DHT22

● Data provided: Temperature, Humidity

(data verified with GY-BME280)

● Digital Interface: GPIO

● Relative Humidity Range: 0 to 100% (±2.0% accuracy)

● Temperature Range: -40 to 80°C (±0.5 accuracy)

4. Pi Camera

The Pi Camera is another set of observation payloads on this satellite, with the purpose of recording the visual journey during the satellite's flight. The main specifications are an image quality of 1080p30, with dimensions of 25mm x 24mm x 9mm.

5. GPS (NEO-6M-0-001)

The GPS chip is responsible for receiving the accuracy and latitude of satellites.

A. Power Supply Voltage (type): VCC=3.0 V

B. Supply Voltage USB (type): VDDUSB=3.3 V

C. VCC_RF Voltage: VCC - 0.1 V

D. VCC_RF Output Current: 50 mA

E. Antenna Gain: 50 dB

F. Receiver Chain Noise Figure: 50 dB

G. Operating Temperature: -40 to 85 °C

H. Receiver Type:

1. 50 Channels

2. GPS L1 frequency, C/A Code

3. SBAS: WAAS, EGNOS, MSAS

I. Sensitivity:

1. Tracking & Navigation: -161 dBm

2. Reacquisition: -160 dBm

3. Cold Start (without aiding): -147 dBm

4. Hot Start: -156 dBm

J. Maximum Navigation update rate: 5Hz

K. Horizontal Position Accuracy:

1. GPS: 2.5 m

2. SBAS: 2.0 m

3. SBAS + PPP7: < 1 m (2D, R50)

4. SBAS + PPP7: < 2 m (3D, R50)

L. Configurable Timepulse Frequency Range: 0.25 Hz to 1 kHz

15. Planned Tests & Discussion

1.Electrical Power Subsystem Planned Tests: Three tests are planned for the electrical power subsystem:

(1) A 5-hour operation test of the satellite will be conducted to determine whether it can support the power requirements of all subsystems. This number is calculated

based on the total time required for preparation before launch and satellite acquisition after launch.
(2) After 10 charging cycles, the total capacity of the battery is still sufficient to complete the first test. This number is based on the assumption that a new battery will be installed before launch.
(3) The current heat effect of the satellite after 5 hours of power supply will not exceed the temperature limit that the contacted subsystems can withstand. If it exceeds, the main and passive heat dissipation devices need to be increased. It is determined by the individual components.
2.Structure Subsystems Planned Tests:
(1) The structure can withstand 4G acceleration while remaining stable. It is expected to be analyzed by Solidworks simulation.
(2) The structure can remain intact after landing. It is expected to be analyzed by Solidworks simulation.
3.Descent subsystem Planned Tests:
(1) The parachute can open after the specified acceleration is reached. This value is determined by the parachute design.
4.Camera
(1) The Pi Camera image can remain clear. The test will be conducted by actual filming under different accelerations to ensure that the image is not blurry. The maximum acceleration value is 250m/s, which is the highest speed that a CubeSat can reach during its free-fall after reaching an altitude of 3000 meters.
5. Temperature / Humidity sensor
(1) Verify with a standard temperature and humidity meter and the temperature/humidity sensor on the ground, and test whether the error is within the manufacturer's specified error range.
(2) Connect to the power supply and on-board computer, measure the effect of the heat emitted by the satellite on the temperature/humidity sensor, and adjust the final values based on this data.
6. Barometer sensor
(1) Verify the measured pressure with a standard barometer and test whether the error is within the manufacturer's specified range.
(2) Calculate the altitude using (formula#1) and compare it with the actual altitude.
7. Accelerometer & Gyroscope
(1) Place the IMU separately on three axes on a platform and measure the effect of gravity on the accelerometer.
Expected result: If the +Z axis is facing upwards, the accelerometer on the Z-axis

should receive a reading of -1g due to the effect of gravity, while the readings on the X and Y axes should be 0g.
(2) Place the IMU in any orientation and measure the readings on the X, Y, and Z axes (Rx, Ry, Rz), which should satisfy the equation：SQRT(Rx^2 + Ry^2 + Rz^2)=1g.
(3) Fix the IMU on a platform and use a motor to provide a fixed acceleration. Expected result：The acceleration reading remains the same, and measure the acceleration error to see if it falls within the manufacturer's error range.
(4) Fix the IMU in a cubesat structure and place it on a platform rotating at a constant velocity separately on pitch, yaw, and roll vector.
Expected results:Measure the gyroscopic output voltage using the above equation and determine if the angular velocity error is within the manufacturer's error range

8. COMM
Considering the possibility of rocket deviation and highest rocket distance three kilometers, which may cause an increase in transmission distance, five kilometers is taken as the basis. The antenna is then connected to a computer and adjusted to the same frequency, 2.2 GHz, for signal reception. Finally, the transmitted computer is checked, and the demodulated data is verified for errors. Multiple packets can be sent using ping to calculate the packet transmission loss ratio.

Regarding the Doppler effect, the impact can be considered as zero, as the two vectors - the vector of the satellite's descent speed and the gradient vector of the dipole omnidirectional antenna radiation to the ground receiving station - can be considered at a right angle when the transmission distance is sufficiently long. The problem of continuous changes in antenna directionality can be solved by setting up multiple antennas at the ground station.

9. GPS (NEO-6M-0-001)
The verification method involves using the Central University campus as a verification range, creating a two-dimensional table of latitude and longitude information obtained through GPS, and observing the differences between the table's route and the actual route whether it falls within the range provided by the manufacturer.

10. GPS Tracker
The verification method involves using the Central University campus as a verification range, creating a two-dimensional table of latitude and longitude

information obtained through GPS, and observing the differences between the table's route and the actual route whether it falls within the range provided by the manufacturer.