

# High Altitude Balloon Payload Design for Atmospheric Observations

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**Abstract** – In 2016, Microcontroller Research Group at Dept. of Electrical Engineering Universitas Muhammadiyah Yogyakarta has designed and developed a payload for High Altitude Balloon. This payload has function measuring atmospheric parameter vertically and sending the data to ground station on earth using telemetry. The parameters measured are air pressure, temperature and relative humidity. Besides sending these parameters, payload also have mission monitoring real positions of payload using GPS, real time video transmission, regulary capturing and sending image from payload . This payload is tested on the annual Atmosphere Balloon Payload Competition (KOMBAT) 2016. This paper will describe the design payload, payload software algorithms and the results that have been obtained. **Copyright** © 2017 Universitas Muhammadiyah Yogyakarta- All rights reserved.

**Keywords:** high altitude balloon payload, atmospheric parameter, air pressure, temperature, relative humidity, telemetry.

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## I. Introduction

The atmosphere is a layer of gas mixture that wraps around the surface of the earth and serves as a protector of the life of living things on earth. The weather conditions on this earth are fully influenced by the atmosphere because the atmosphere is able to withstand the heat of the earth coming out and entering the earth. Observation is needed to get the actual condition of atmosphere.

The purpose of observation and recording is to obtain complete and appropriate data on the condition of a particular area. The updated weather information of a region is important. One of the technological advances used to observe and record the atmospheric conditions of the Earth's surface is the atmospheric balloon. This balloon has electronic payload to measure the profile of temperature, humidity, and also the air pressure on the surface of the earth. In addition, the physical surface capturing of the earth based on altitude, latitude, and longitude is also necessary to

determine the condition of atmospheric profiles above the earth's surface.

Annually Indonesian National Institute of Aeronautics and Space (LAPAN) with Ministry of Research, Technology and Higher Education organize an event called Atmosphere Balloon Payload Competitions (KOMBAT). In this competition, selected participants can test the payload in real atmosphere environment using high altitude balloon provided by LAPAN. In 2016, Microcontroller Research Group Team at Dept. of Electrical Engineering Universitas Muhammadiyah Yogyakarta (UMY) has been selected and participated in this event.

In this paper will describe the design payload include hardware design such as sensor unit, data processing section, power supply unit, telemetry radio and video transmission section. Also generally describe payload application algorithms and the results that have been obtained during competition.

## II. Payload Mission

- Payload will conduct the following mission.
- Atmospheric parameter measurement consist of air pressure, temperature and relative humidity.
  - Sea surface and costal area monitoring using camera.
  - Sending atmospheric parameter data, video and image captured by payload wirelessly to ground station.

## III. System Design

Payload is designed and developed by following the KOMBAT 2016 rule. Generally payload divided into subsystem such as sensor, data processing section, power supply unit (PSU), telemetry radio and video transmission section. In the sensor section, the components of the electronic circuit will detect the parameters according to the function of each sensor. After the measurement parameter values obtained then processed on the data processing section. Microcontroller and a single board computer is used to process data in data processing section. Microcontroller will process the data from the entire sensor, while the single board computer will process the image data captured from camera and combine it with sensor data. The results of combining sensor and image data are sent to Ground Station (GS) using 433MHz telemetry radio transmitter on the payload. Payload has a video transmitting section in charge of sending realtime video from payload to GS using transmitter at 5.8GHz. Figure 1 shows the block diagram of payload system.

### III.1. Sensor Unit

Here are the sensors used in the design of the payload:

- HTU21D
- MS5611-01BA03
- Ublox NEO-M8N GPS

HTU21D is a high performance digital relative humidity sensor, low cost and easy to use. This sensor is ideal for environmental sensing, data logging and perfect for weather stations. In addition to relative humidity, these sensors are capable of performing temperature measurements. Each sensor individually has been calibrated and tested by the manufacturer. The output data has been linearized in digital form and can be read directly by microcontroller. The data protocol uses I<sup>2</sup>C which requires only two data line [1]. Considering specification of sensor the operating range of humidity readings and temperature, this sensors is a suitable to be applied to the payload. Here are the HTU21D sensor specifications.

TABLE I  
HTU21D SPECIFICATION

Ratings	Value	Unit
Supply Voltage (Max)	3.6	Volt
Humidity operation range	0 to 100	%RH
Temperature Range	-40 to +125	°C
Current Consumption (Typ)	450	µA

MS5611-01BA03 is high resolution barometric pressure sensor. This sensor optimized for altimeters and variometer. High resolution specification achieved using 24 bit  $\Delta\Sigma$  onboard

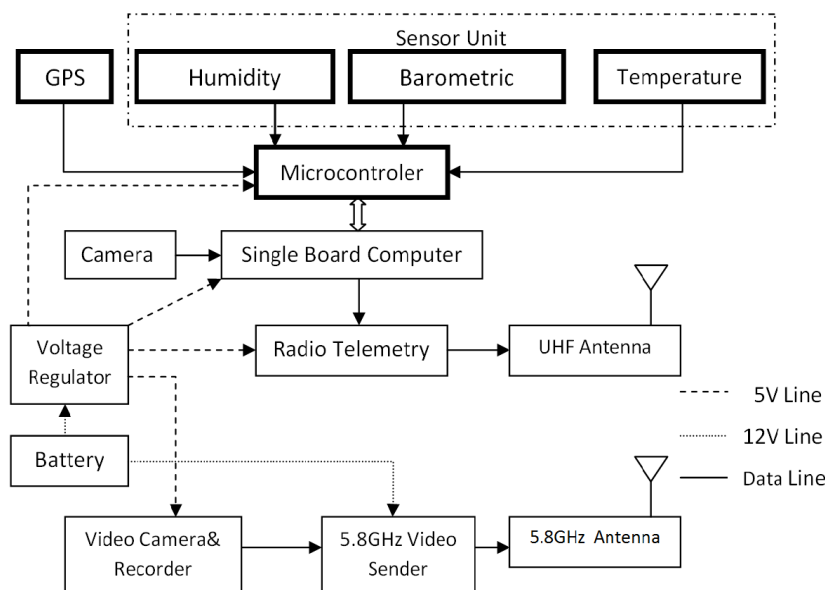


Fig. 1. Payload System Block Diagram

ADC with internal factory calibrated coefficients. Sensor provide a precise 24 bit pressure and temperature value [2]. This value can be accessed using SPI and I<sup>2</sup>C interface. Because both sensor (HTU21D and MS5611-01BA03) can measure temperature so there is no need special temperature sensor on payload. Table 2 shows sensor specification. Figure 2 shows humidity and pressure sensor on this sensor unit.

TABLE 2  
MS5611-01BA03 SPECIFICATION

Ratings	Value	Unit
Supply Voltage (Max)	4	Volt
Pressure range	10 to 1200	mbar
Pressure Resolution(up to)	0.012	mbar
Temperature Range	-40 to +85	°C
Temperature Resolution	<0.01	°C
Current Consumption (Typ)	1.4	mA

Ublox NEO-M8N GPS module is used in payload to provide payload actual position data. This GPS can receive up to 3 GNSS (GPS, Galileo, GLONASS, also BeiDou) 72-channel with position accuracy up to 2.0 meter CEP. Operating voltage 2.7 V to 3.6 V and current consumption 21 mA @ 3V (continuous mode) [3]. Based on specification and altitude operation up to 50,000 m, this GPS module very suitable to use in payload.

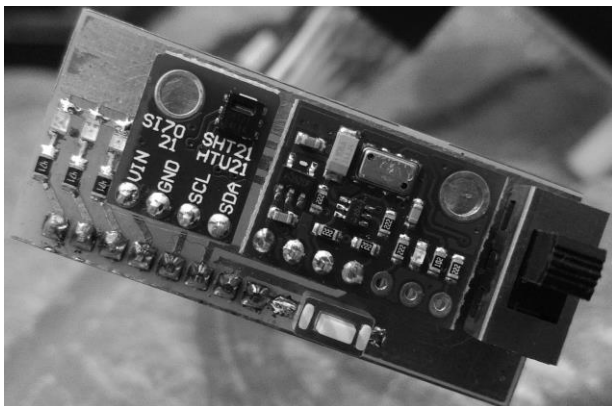


Fig. 2. HTU21D and MS5611-01BA03 in Sensor

### III.2. Data Processing Section

The payload uses a ATmega328 microcontroller to process all sensor data and a Single Board Computer (SBC) to process image data. Single Board Computer used on this payload is Raspberry Pi A+. This SBC powered by 700 MHz ARM processor and Linux Operating System. With

high specification SBC all processing data such as image processing both capturing, conversion, and merging with data sensor can be done quickly. Raspberry Pi Cam is used to capture image. Raspberry Pi Cam is a camera specially designed for Raspberry Pi family SBC. This camera has OmniVision Sensor 5647 with resolution up to 5MP fixed focus lens. Camera size is small only 25 x 24 mm as well as lightweight, very appropriately used on payload. Figure 3 shows SBC connected with power supply unit, sensor board and image camera.

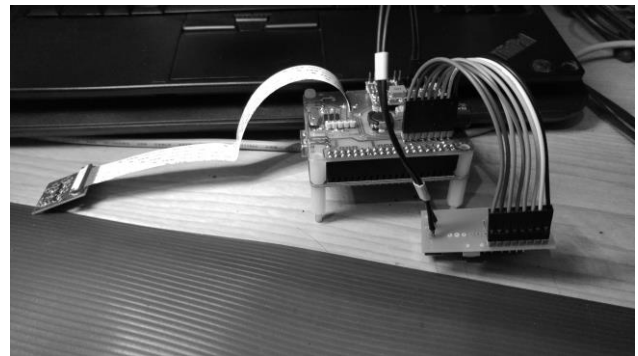


Fig. 3. SBC,PSU, Sensor Board, and Rasp Pi Cam

### III.3. Power Supply Unit

The main power on this payload is 3-cell series Lithium Polymer battery. This battery have specification 11.1 Volt and capacity up to 1000mAh with small dimension, lightweight, and high density power. From battery,the voltage is regulated using MP1584 DC-DC converter to provide power for sensor, data processing unit, and telemetry radio.

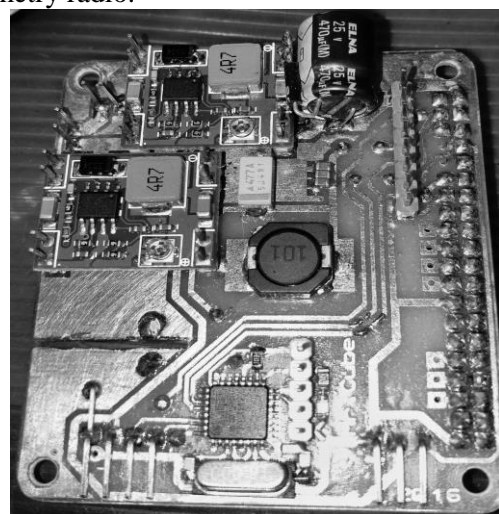


Fig. 4. Power Supply Unit and Microcontroller Data Sensor Processor

### III.4. Telemetry Radio

Wireless communication between payload and GS is provide using telemetry radio based on HM-TRP. This telemetry radio have transmission power 20dBm or 100mW output power and -117 dBm receive sensitivy. Operating frequency used in payload is 433MHz. With build in error correction code can correct up to 25% of data error. This telemetry radio very reliable and give nice performance. With tuned halfwave antenna at payload and high gain 10 element x 2 array yagi in GS can reach 30 km (LOS condition).

### III.5. Video Transmission Section

This section handle realtime video transmission from payload to GS. Camera for video capturing is different from image capturing. Video camera using small CMOS based analog camera. This camera resolution 320 x 240 pixel and feed to 5.8GHz 600mW video TX with Clover Leaf RHCP antenna. All componens in this section directly powered from battery. Figure 5 shows this section.

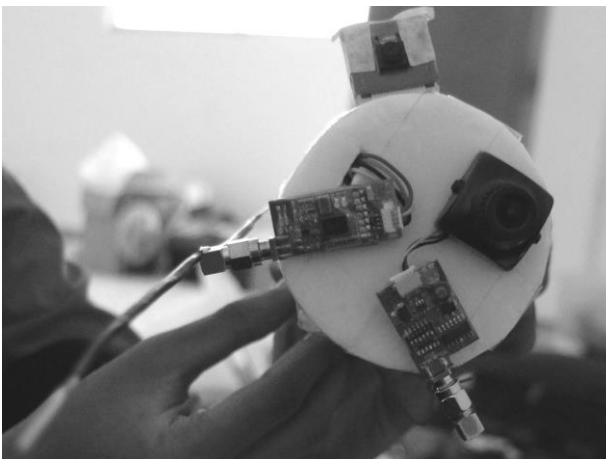


Fig. 5. Video Transmission Section and Telemetry Radio

### III.6. Payload Application Algorithm

Generally designed payload application very straight forward. In microcontroller part regularly request data from each humidity, preassure sensor and GPS. Microcontroller processing data to get appropriate value. Raspberry Pi A+ as SBC collect data from microcontroller and combine with image data capture by Raspberry Pi Camera. After this step, this data feed to telemetry radio. Figure 6 shows flowchart payload application algorithm.

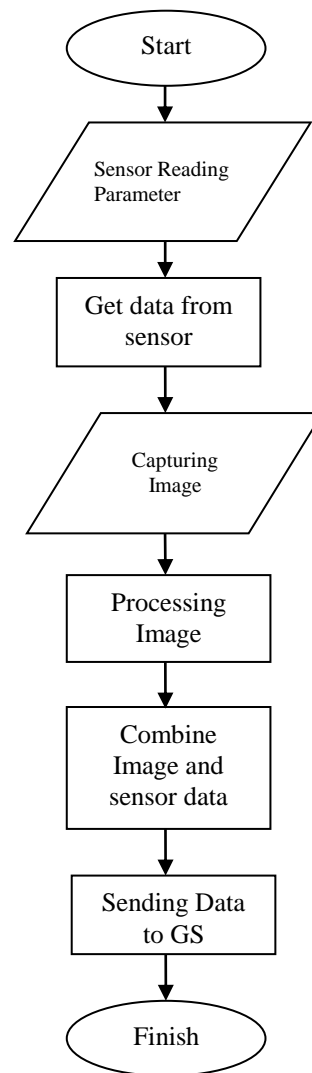


Fig. 6. Payload Application Algorithm Flowchart

## IV. Result

Payload prototype casing is using polyfoam. Polyfoam material is choose because has good thermal isolation, lightweight, easy to work, and give enough protection to all component inside payload. Finished payload shown in Figure 7.



Fig. 7. The Payload

During competition high altitude balloon airs for almost 2 hours with altitude limit 10 km and got 551 series data that can be read. Result are shown on graph figure 8 until figure 11.

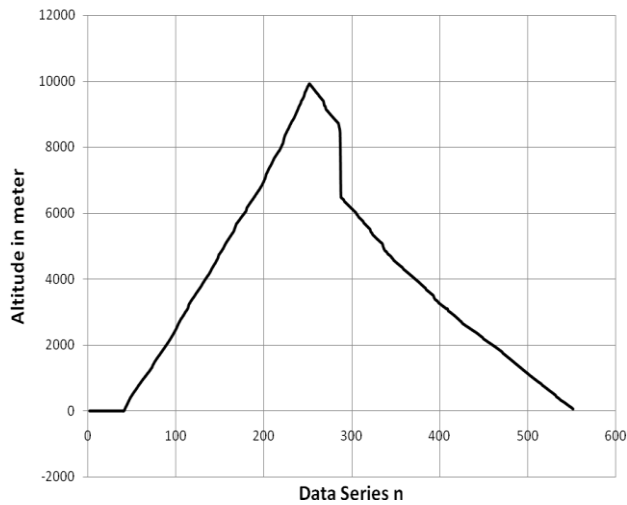


Fig. 8. Altitude Record During Mission

Altitude record during mission shown in figure 8. Maximum altitude reached is 9915 meter above sea level. During payload descending graph seen falls for a moment. This happened because GS cannot receive data from payload for about 10 minutes. Figure 9 shows relation between altitude and air pressure.

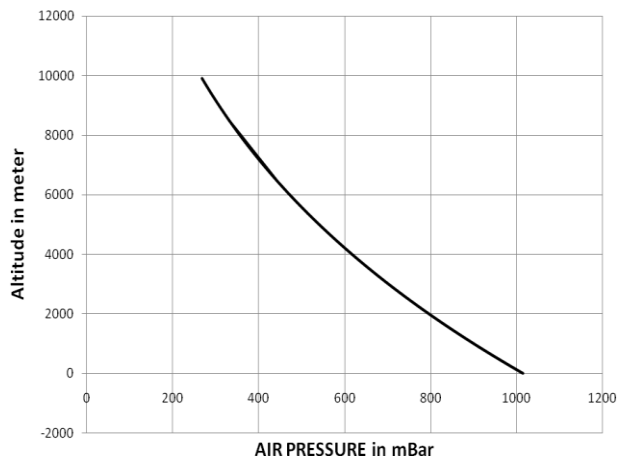


Fig. 9. Altitude vs Air Pressure

At beginning mission air pressure recorded at 1013 mBar. At maximum balloon altitude air pressure drop until 267 mBar. Figure 10 shows recorded temperature during payload ascending and figure 11 shows temperature change during payload descending. Lowest temperature reach  $-29^{\circ}\text{C}$  at maximum balloon altitude or 9915 meter.  $0^{\circ}\text{C}$  reached at about 500 meter altitude. Temperature at earth surface recorded  $25^{\circ}\text{C}$ .

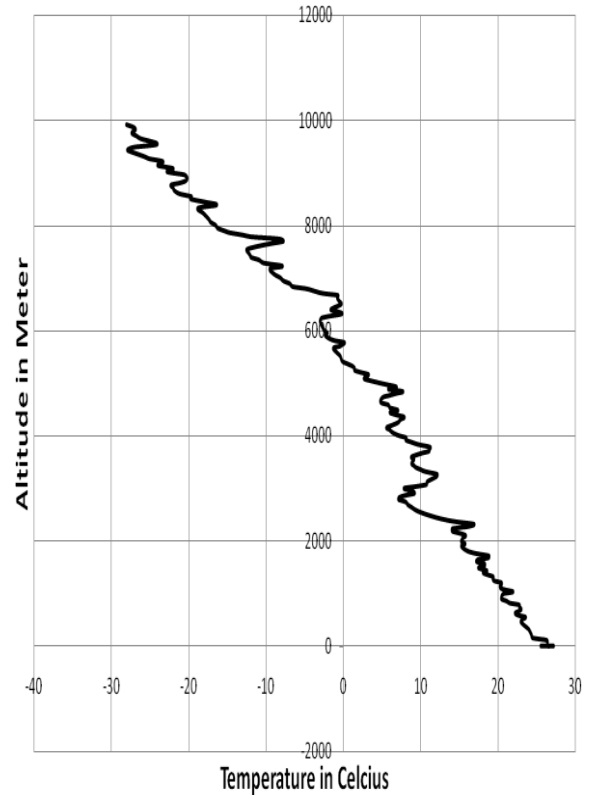


Fig. 10. Temperature Record During Payload Ascending

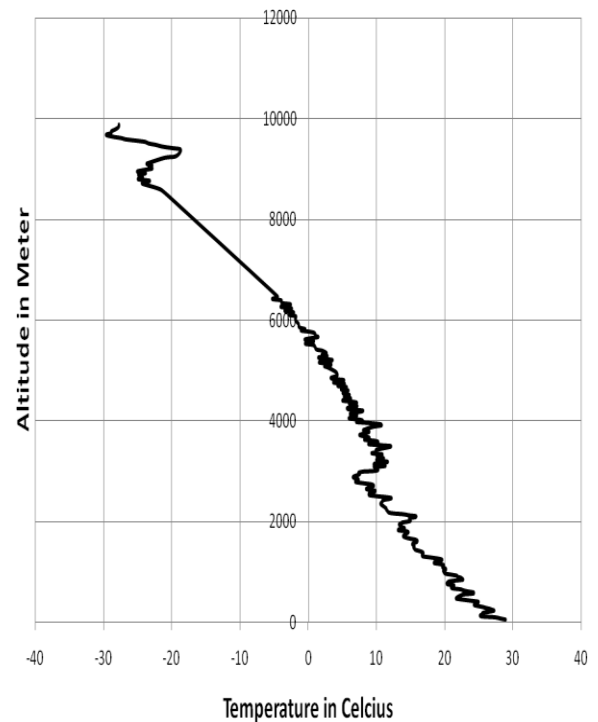


Fig. 11. Temperature Record During Payload Descending

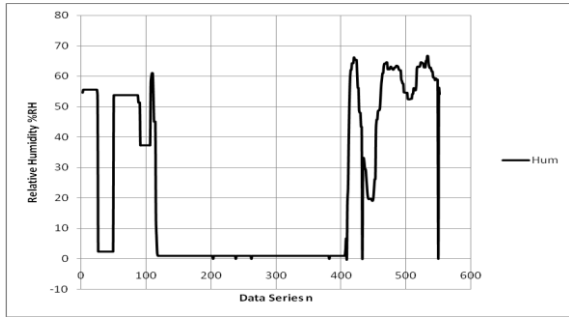


Fig. 12. Temperature Record During Payload Descending

Figure 12 show relative humidity data during mission. Humidity sensor seem not work properly because gives false value during mission.

GS also receive some image that capturing and sending by payload. Figure 13 shows that picture.



Fig. 13. Received Image

In figure 13 show received image from payload during mission. Only few picture can read and provide some information. Most of the picture received by GS become unreadable. Some readable picture show many noise that indicate transmission suffer from interference. Figure 14 shows snap image from video transmission. Although GS can receive video from payload, video quality is poor and shown many noise. This occurred because video transmission still in analog mode. Both image in figure 14 still produce good information, sea surface and costal area still visible. Figure 15 shows high altitude balloon provided by LAPAN.

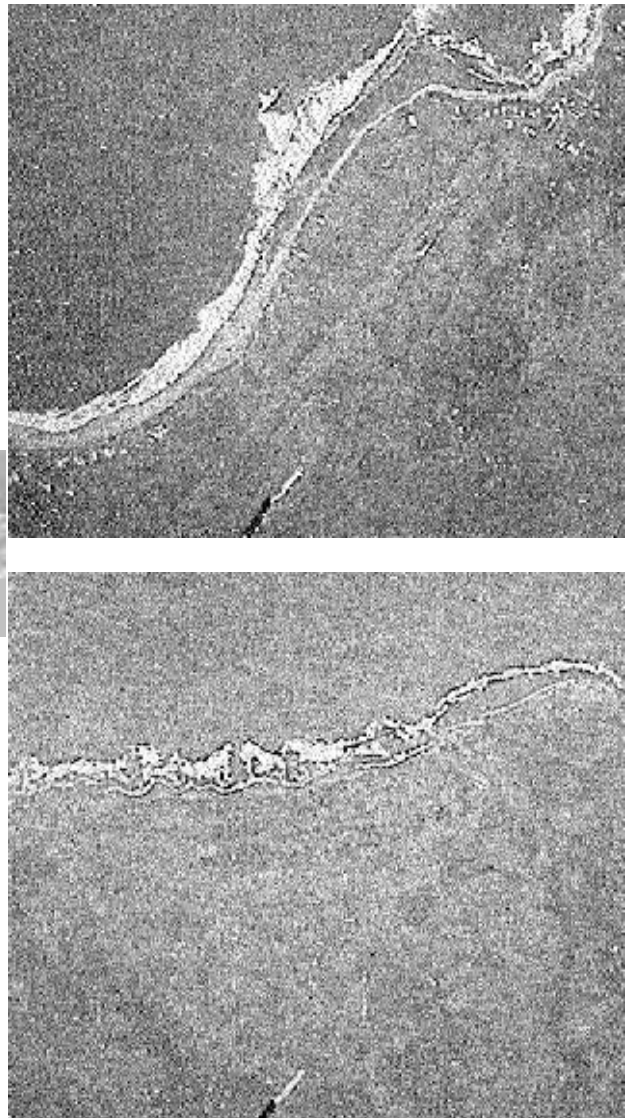


Fig. 14. Snapshot from Video Transmission



Fig. 15. High Altitude Balloon with Payload

## V. Conclusion

High altitude balloon payload designed by Microcontroller Research Group Dept. of Electrical Engineering UMY can work well during competition. Atmospheric data such as air pressure and temperature with altitude can be recorded from ground station. This data shows results that sensors used in the payload are very reliable. Real-time video image transmission can work and gives good early results. Most of the critical components like microcontroller and Raspberry Pi A+ survive during the mission in an extreme environment. Humidity sensors seem not to work properly because they give false values during the mission.

Further research needs to be done to perfect the payload and ground station design. The payload can load more variable sensors so that more atmospheric parameters can be measured. Improvements in algorithms, especially in sending images using low bitrate, can also improve results.

## Acknowledgements

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