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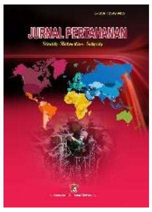

ROCKET LOAD TEST BASED ON INERTIAL MEASUREMENT UNIT SENSOR IN SUPPORTING NATIONAL AIR DEFENSE

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Abstract

The development of rocketry and rocket payload technology is very rapid in the industrial era 4.0. Rockets are usually used as dynamic sensors or carriers for specific missions for sensing and retrieving data from space for meteorological, military, etc. This article aims to design, realize and test a Rocket Payload Monitoring System Based on an Inertial Measurement Unit (IMU) Sensor to monitor the condition of the payload movement behavior. Rocket Payload is a substance carried in a Payload Test Rocket (RUM) in the form of a cylindrical payload. This research focuses on designing a Graphical User Interface (GUI) application to display data in real-time. The type of research used is Research and Development (R&D) with a prototyping development model. The results obtained in the form of Rocket Payload Design and GUI design can be concluded that the GUI application can visualize all sensor and camera data in real-time.

INTRODUCTION

Rocket Payload is a device designed to carry substances inside a rocket, either as the dynamic payload of the missile itself or as a carrier for specific missions, such as for sensing and retrieving data from space for meteorological, military and so on (Seibert, 2006; NASA Goddard Space Flight Center, 2015). Rocket payload technology in Indonesia is still being developed. Its development was carried out by the National Institute of Space and Aviation (LAPAN) (Lembaga Penerbangan dan Antariksa Nasional, 2020). Indonesia is one of the countries that are creating this rocket technology. One of the things that researchers pay attention to is how to lay a satellite on a rocket (Soediatno, Rahadian, & Jalimin, 2011). Before boarding the satellite, the researchers tested the missile by applying it to a device containing sensors so that it could transmit telemetry data (Hidayah, Salamah, & Sasono, 2022). Aviation and space technology is one of the leading technologies for the developed country, especially rocket technology and its control system (Aglietti, 2020). As a large and broad maritime country, Indonesia Should have independence in mastering rocket technology (Putra & Zuhrie, 2019).

The urgency of mastering rocket technology as a system for monitoring given the geographical location of Indonesia, which consists of islands. The importance of mastery of rockets as a deterrent to air defense. But still experiencing problems in terms of sending data that is not real-time from the Payload to the Ground Control Station (GCS), resulting in not being able to retrieve good data during the launch of the rocket payload (Payload) or sometimes the captured data is not sent directly to the GCS or experiences a time lag for delivery. Continuous efforts are needed to realize this independence, one of which is through research and innovation that continues to be carried out in technology development, especially rocket technology, as a means of education and to attract interest as well as prepare prospective researchers and engineers who are reliable in the National rocketry system (Lembaga Penerbangan dan Antariksa Nasional 2020).

The rocket payload used in the Charge Test Rocket research (RUM) is a cylindrical tube containing an electronic circuit that functions as a device equipped with telemetry and uses several sensors to process and transmit data (Susanto, Pramana, & Mujahidin, 2013). Telemetry systems are often used to take measurements in areas difficult to reach by humans, such as mountains, seas, or valleys (Husumardiana, 2015). The telemetry system sends complex sensor measurement data remote from the monitoring center via radio transmission lines (Prinsloo, Mathews, Du Plessis, & Vosloo, 2019).

Through the telemetry system, data from sensor measurements that are complex and far from the monitoring center is sent using a transmission line to the center (Manu, Saha, Hoque, & Hoque, 2019). This greatly facilitates the operator in monitoring and analyzing the data received. The quality of the data transmitted, processed, and visualized is very influential on the data communication system used (Munarso & Suryono, 2014). Sending data through a wireless system is used for real-time monitoring of the condition of the rocket payload (University Space Engineering Consortium, 2017). Communication using telemetry can be done in real-time from the transmitter to the receiver (Al Fadli, Gunawan, & Bura, 2021). The real-time system makes it easy for operators to display data from the results of graphical monitoring of the launch behavior of the payload test rocket from the sensors mounted on the rocket payload according to the conditions experienced by the payload at that time (Mudarris & Zain, 2020). The rocket payload is designed to telecommand for surveillance and monitoring the rocket movement's attitude (Pamungkas, Putra, Puspitaningayu, Fransisca, & Widodo, 2018).

A real-time monitoring system on the payload for a test rocket is a must in knowing the rocket's performance being developed. This system consists of a sensor device and a radio telemetry device. Sensor data is sent from a flying rocket via telemetry media (Lacek, Bryant, Dalvin, & Wolgamott, 2019). Sensor data is observed in graphics and array data (Mudarris & Zain, 2020). Sensors mounted on a minimal payload can provide information regarding the rocket's speed, acceleration, direction, and position (Yogaswara, Hong, Tahk, & Shin, 2017). To measure the rocket's speed, acceleration, and movement, an Inertial Measurement Unit (IMU) sensor module is needed in which the accelerator and gyroscope sensors have been integrated (Kok, Hol, & Schon, 2018). The mission performed by the rocket payload is to monitor the rocket's attitude. The sensor system consists of IMU and Global Positioning System (GPS) (Núñez, Araújo, & Tuñón, 2017). The GPS module transmits position, path, and speed data. While the IMU provides angular movement data (pitch, roll, and yaw), angular movements are usually carried out using accelerometer and gyroscope sensors to obtain 3-dimensional movement data (roll, yaw, and pitch) (Musa, Christie, & Wibowo, 2017). To assess the aerodynamic performance of the rocket, information from the physics-based model of the rocket is combined with dynamic sensor data when the rocket is launched (Huang, 2022).

Sensors mounted on a minimal payload can provide information regarding the speed, acceleration, direction, and position of the rocket. To measure the speed, acceleration, and direction of the missile, an IMU sensor module is needed, which has integrated accelerator and gyroscope sensors and takes into account the angle of impact, acceleration, and field of view limitations. This study will discuss and analyze the Load Test Rocket monitoring system (RUM) based on data taken by the Inertial Measurement Unit (IMU) sensor using several indicators in the sensor, such as speed, altitude, and air pressure. The data is sent and will be visualized in the Graphical User Interface (GUI) application.

METHODS

Rocket payload is the substance carried in the rocket; it can be as the dynamic sensing payload of the rocket itself or as a mission-specific, e.g., sensor payload meteorology (sonda). The rocket payload is a cylindrical tube containing an electronic circuit that serves as a telemetry device for visually monitoring rocket trajectory in 3-dimensional graphic form from launch to landing to earth. (real-time appears on the GCS screen when it is sliding) (Lembaga Penerbangan dan Antariksa Nasional, 2020).

The payload is a cylindrical tube containing an electronic circuit that functions as a telemetry device using multiple sensors, processors, and data senders (Albéri et al., 2017). Rocket Payload is a cylindrical tube with a diameter ± 10 cm, a maximum height of 20 cm, and a maximum total weight of 1 kg. Rocket payload contains electronic circuits, sensors, robotic actuator systems, as well as functioning data as a telemetry device for meteorology, as well as having a -based actuator system robotics to determine the attitude of the rocket when it glides and can take pictures from above earth after separation for monitoring in the air.

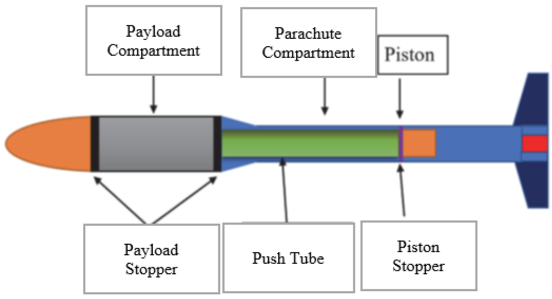

Figure 1. Test Load Rocket Compartment
Source: Mudarris & Zain, 2020

Time and Location

Data collection was carried out during Komurindo-Kombat activities carried out at LAPAN Rocket Production and Testing, Garut on August 25, 2019.

Design Rocket Payload

The rocket payload works system uses the 10 DOF IMU (GY-87) sensor to monitor attitude, temperature, gyroscope, accelerator, and the Global Positioning System (GPS) to know the rocket's position. Data from sensors are transmitted using telemetry devices.

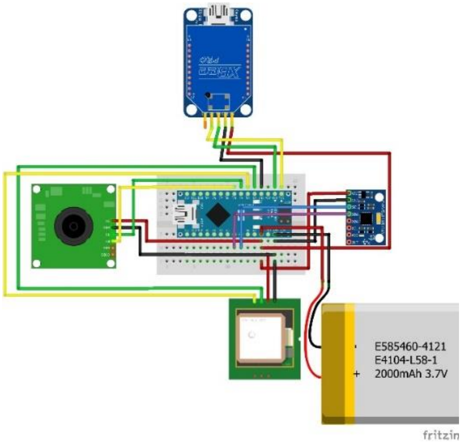

Figure 2. Rocket Payload Schematic
Source: Processed by the Authors, 2019

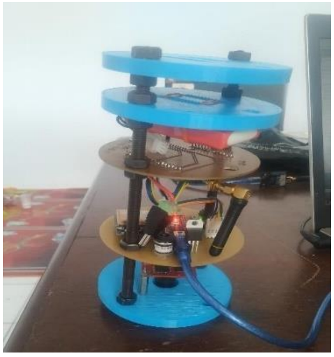

Figure 2. Payload Rocket
Source: Documentation by the Authors, 2019

Figure 3. Payload Test Rocket (RUM)
Source: Documentation by the Authors, 2019

This rocket payload is a prototype of a rocket payload in a cylinder tube containing an electronic circuit that serves as a telemetry device for monitoring rocket dynamics ranging from launch to separation. Payload use three-axis accelerometers and three-axis gyroscopes to define rocket dynamics. Data from the rocket payload is transmitted by wireless serial transmission with Xbee Pro telemetry of 900 Mhz. All components are controlled by a microcontroller automatically. Rocket payload uses five essential components:

a. An Arduino nano microcontroller as the sensor data management center.
b. GPS sensor (Global Positioning System) to obtain the charge's longitude and latitude position data.
c. The IMU (Inertial Measurement Unit) sensor is used to obtain Accelerate, Gyroscope, Compass, Altitude, Temperature, and Air pressure data.
d. Camera sensors are used to take pictures.
e. The Telemetry X-Bee Pro 900 MHz module is a wireless data delivery medium.

RESULT AND DISCUSSION

Result Rocket Payload

A rocket payload is a substance carried inside the rocket. It can be a dynamic sensing payload of the missile itself or a specific mission such as sensing and retrieving data from space for meteorological, military, etc. Technology about the rocket payload itself in Indonesia is still developing, driven by the National Space and Aviation Agency (LAPAN). Based on this, a rocket payload design was created that could later be used to take data from space and payload send the results to the Ground Control Station (GCS) on Earth.

Test Rocket Payload Monitoring System (RUM) Using GUI

The rocket payload contains a series of electronics, sensors, and robotic actuator systems that serve as telemetry devices for meteorology while also having a robotics-based actuator system to determine the rocket’s attitude when it launches from above the earth after separation for aerial monitoring. The rocket payload must provide data in real-time to the ground. Therefore, researchers developed the technology based on GUI Applications.

This device can send data to a GUI that has been created and visualize it in real-time. The tool that becomes a communication line between Arduino and Payload is Telemetry X-Bee which can be connected to a PC/Laptop with a radio signal frequency of 900 MHz. The application used on PC / Laptop is Matlab Application; this application has four buttons, including Start, Pause, Save, Exit, and COM. This application can visualize all sensor data in graphs and numbers.

The development of this rocket charge uses power from a Li-Po battery with a voltage of 7.2 volts connected to the Arduino device with 5 volts of power. The result of this rocket payload uses Arduino Nano microcontroller technology as its control center. Arduino is a controller integrated with a microcontroller. The use of Arduino in the manufacture of this tool as a controller of both serial communication and movement or path that has been arranged and stored in it. To produce an Arduino output (interface) uses a USB cable as a data exchange tool. The resulting data is information that has been integrated with the C# programming language on the Personal Computer (PC), and its connectivity uses the Arduino compiler itself. The source code attachment can see the input and output on the Arduino are made. Use Arduino in the manufacture of this tool as a sensor controller that can produce work according to the feedback generated by each sensor. All sensor data processed by Arduino will be sent wirelessly by a telemetry transmitter mounted on the payload. This device also has a radio Telemetry receiver module, which will receive data from the sensor to the Ground Control Station (GCS) and be visualized on the GUI of each sensor data captured. Based on developing a real-time Payload monitoring system tested on each device. This case tests the GPS sensor and 10 DOF IMU Sensor (Accelerometer, Gyroscope, Compass, Temperature, and Altitude). GPS determines the location of the rocket payload at launch. 10 DOF IMU sensor consisting of an Accelerometer and Gyroscope to determine the angle of tilt and vibration experienced by the rocket payload during launch, Compass to determine the direction of the rocket's charge while gliding, Altitude to define the height of the rocket's payload when gliding, and temperature to determine the temperature when the rocket is drifting. The Sensor Camera does not take pictures of the rocket payload because there is still noise in the data Image data transmission failed to be transmitted because it was caused by noise such as strong winds, and the distance was far enough. The image is not visualized in GUI.

From the results of the launch test, the payload can send real-time data to the Ground Control Station (GCS) so that all necessary sensor data can be displayed in Graphical User Interface, a graphical user interface (GUI) in Figure 4. Data is transmitted at the launch of the payload test rocket until the payload falls into the sea. During the launch test, the load sent the sensor data to the accelerometer (ay, ax, az), gyroscope (gy, gx, gz), magnetometer (compass), altitude, temperature, and barometric pressure—the results of the payload test can be seen in Table 1. When the test payload rocket is launched, all data can be viewed in a single GUI application that displays every chance when the rocket launches. The application shows every change in the payload test rocket in real-time to observe every minor change at the rocket's charge separation.

The payload tracking test was using 3D odometry by Madgwick (2010). The tracking monitors the movement of the payload in real-time, which can be estimated changes in the payload position from time to time. This method is error sensitive because of the integration of velocity measurements over time to evaluate the exact position using an Inertial Measurement Unit (IMU) Sensor. Odometry visualization allows for improving navigation accuracy in Rocket Payload.

Table 1. Field Trial Table

No	Accelerometer			Gyroscope			Altitude (m)	Compass (°)
	ax	ay	az	gx	gy	gz		
1	-132	624	8928	-19878	-1569	12265	35.88	52
2	-984	1804	25096	-31636	-4302	4137	27.71	3
3	572	772	16080	-4135	32767	-13593	91.49	330
4	572	772	16080	-4135	32767	-13593	91.49	330
5	2144	2176	32767	-4808	32767	12745	89.65	326
6	-2048	980	25052	15748	22065	6521	86.13	70
7	740	272	21412	-16365	32767	14453	97.28	330
8	-348	1096	32767	-29325	-2252	2016	96.27	357
9	-1436	3704	32767	-32768	-30520	177	94.68	25
10	-1584	880	28044	-8348	-2074	-16188	113.57	28
11	-976	628	7836	-12967	-14377	-15800	102.4	27
12	-1072	124	5512	-6997	4677	-19247	91.66	342
13	-592	68	7360	-7333	3953	-3223	115.67	15
14	204	196	5496	-1559	8997	-6048	109.03	37
15	828	844	32767	-23664	32767	-549	157.69	45
16	-2276	956	32767	-5590	-15632	-6395	352.12	33
17	-524	1408	22656	-25117	-31867	-1283	547.15	32
	288	696	21388	-12549	-22785	666	861.34	34

Source: Processed by the Authors, 2019

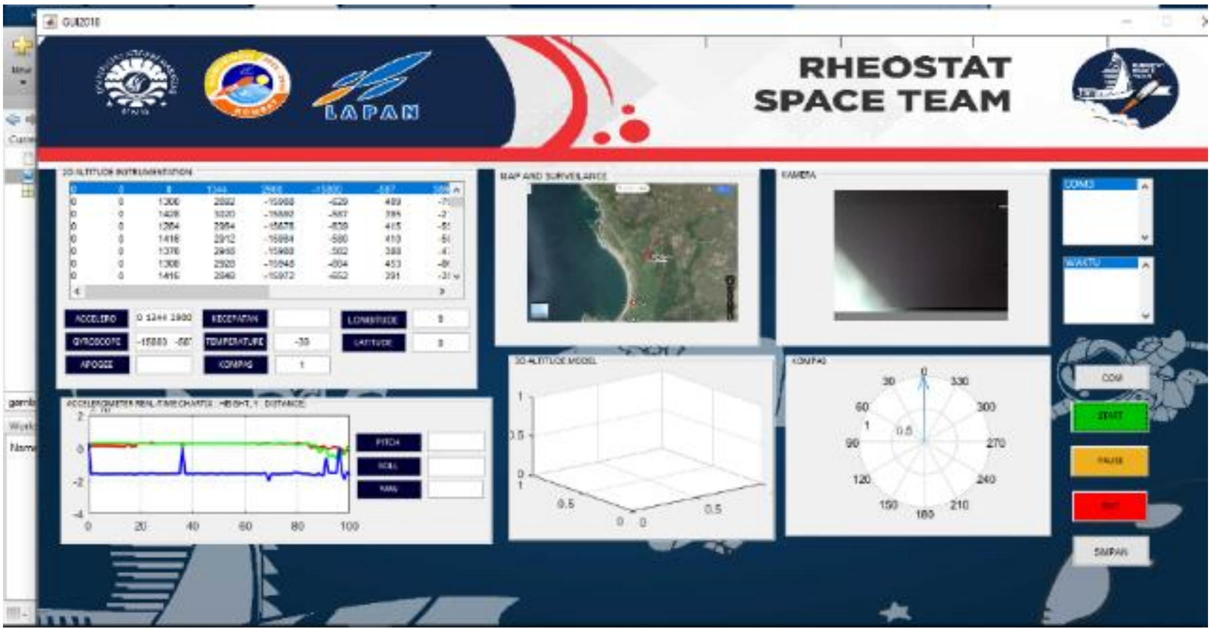

Figure 4. Rocket Payload Monitoring Application
Source: Mudarris, 2019

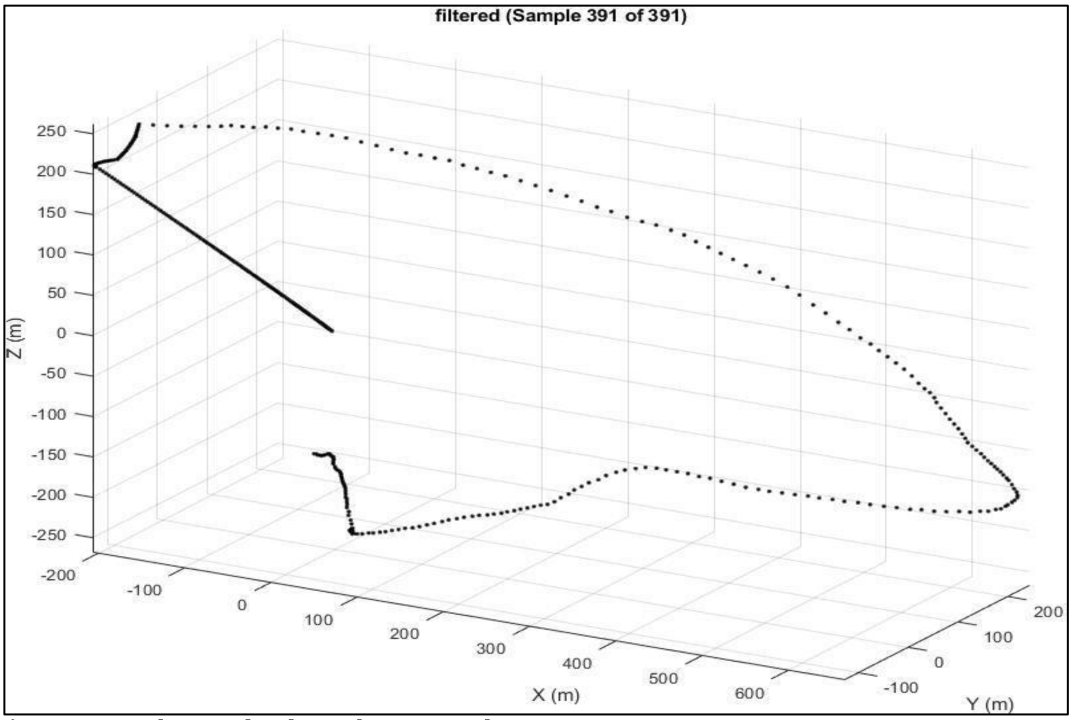

Figure 5. Rocket Payload Tracking Visualization
Source: Mudarris, 2019

The graph in Figure 5 shows that the payload that has come out of the charge carrier rocket will slowly decrease from the maximum height so that the chart experiences a reduction in size from the full peak achieved. The payload falls into the sea so that the size of the load that is read is less than the sea level according to the sensor readings used, as shown in the graph in Figure 5. At the time of testing, the data that can be collected is global positioning system (GPS) data, the direction of the rocket payload (Compass), the vibration of the rocket payload, the maximum height reached by the payload test counter, and the angle of movement of the rocket payload. All data collected by the rocket payload can be displayed on the Graphical User Interface, as can be seen in Figure 4.

CONCLUSIONS, RECOMMENDATIONS, AND LIMITATIONS

Development of a payload test rocket monitoring system (RUM), using Arduino nano as a data processor from GPS sensors, IMU 10 DOF sensors, and Serial Kit cameras and using the X-Bee Pro telemetry module as a wireless communication medium to send data wirelessly, GPS sensors to retrieve the location of the payload at launch. The 10 DOF IMU sensor functions to retrieve Accelero, Gyroscope, Altitude, temperature, and Compass data. As well as a camera sensor to take pictures from a height. All data captured by the rocket payload is visualized in a single graphical user interface application in real-time.

Based on the tests, there are still shortcomings in sending images where image data is not sent because the launch height reaches a maximum point of 861 meters. Image data transmission failed to be transmitted because it was caused by noise such as strong winds, and the distance was far enough. The receiver antenna was unable to capture the transmitted image data. The rocket payload can retrieve data on the movement of the Test Rocket, such as position, speed, angular movement, and maximum altitude, and retrieve methodological data and map the region, to support the country's future defense.

RECOMMENDATION

Academic

Research can be used as an academic reference for further relevant researchers. It also supports the launch of remote-controlled rockets that can be used for national security systems.

Government

For the government, especially the National Aeronautics and Space Administration (LAPAN). Research can be used as material for developing remote control rockets and supporting LAPAN in the independent development of rocket technology in the future, supporting Indonesian air defense.

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