Evaluating the Impact of Flight Basket Materials on GPS Signal Integrity in Kairos UxV/35 Drones

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Abstract

This survey investigates the impact of different materials used in flight baskets on the performance of Kairos UxV/35 GPS modules. Focusing on three materials–stainless steel, carbon fiber, and fiberglass–we test how the material choice affects GPS effectiveness in drone flight systems. From results gathered through a series of field tests, our findings reveal that GPS modules tend to achieve the best precision, accuracy, and number of satellites acquired. This preliminary study presents our methodology, addresses encountered variables, and suggests directions for future research to further clarify the relationship between flight basket materials and GPS effectiveness.

1. Introduction

The purpose of this study is to evaluate the relationship between flight basket materials on GPS performance in drone operations, particularly focusing on the UxV/35 standard. Operator feedback with flight basket drones has indicated significant disruptions to GPS, creating an obstacle to effective mission completion. By recording GPS data from multiple modules tested in various configurations, including stainless steel, carbon fiber, and fiberglass flight basket materials, we aim to identify the configurations under which GPS is most effective. This report details our experimental approach, discusses the challenges in this line of effort (including various confounding factors), and outlines our strategy for mitigating their effects. We conclude with a recommendation based on our findings and propose future studies to further refine our understanding of GPS performance in drone flight systems.

2. Approach

2.1. Time Frame

Our data collection spanned over two days. The initial day was dedicated to fabricating the fiberglass basket and strategizing our survey methodology.

2.2. Equipment

The equipment for these tests is categorized into two groups: 'Flight Baskets' and 'Flight Stacks/Configurations.' We tested three types of baskets–carbon fiber, stainless steel, and fiberglass–in various configurations, with or without an attached motor board. The flight stacks, labeled Stack A, B, and C, were equipped with GPS modules, Flight Controllers, and Radio Modules. The presence of additional components, including Ground Planes and Spacers, was also noted. This section presents an overview, with a comprehensive 'Detailed Equipment List' to follow.

2.3. Relevant Data

Our primary focus was on three GPS performance metrics: Horizontal Dilution of Precision (HDOP), Horizontal Accuracy (HACC), and Satellites Acquired (SATS). Better GPS performance is indicated by lower HDOP and HACC values and a higher SATS count.

2.4. Data Collection Methodology

Data collection was completed manually using the ArduPilot Mission Planner software, which interfaced with each flight stack via telemetry radio. Consistency was ensured by conducting all tests at a designated location, identifiable by an emplaced kairn.

The procedure for each stack and basket combination, including control tests in open air, was as follows:

- Place the power base inside the flight basket.
- Position the basket and power base assembly on the ground.

- Align the power base centrally within the basket using a cardboard cylinder.
- Install the flight stack on the power base, ensuring an initial state of shutdown.
- Connect the flight stack to the power base.
- Simultaneously: activate the power base, start the flight stack, and begin timing.
- Record HDOP, HACC, and SATS values from Mission Planner at one-minute intervals for seven minutes.
- After completion, turn off the power and switch to a different basket type.

This systematic approach allowed us to conduct at least one trial with every stack in each type of flight basket.

3. Limitations

Our study, while extensive in its data collection, encountered several limitations that may have influenced the results. Recognizing these limitations is crucial for understanding the context and scope of our conclusions.

3.1. Variability in Flight Stack Configurations

Each flight stack had unique configurations; for instance, two included GPS ground planes while one did not. This intrinsic variability likely led to differing GPS performances across tests, independent of the basket material used.

3.2. Absence of Motor/Propeller Boards in Testing

Data was gathered with the stacks placed on power boards, excluding the motor/propeller boards. Notably, when the carbon fiber basket was tested with the motor board, it showed a two-fold degradation in GPS signal quality. Electromagnetic interference from motors and electrostatic buildup on basket materials due to propeller rotation could significantly impact GPS performance. This effect might vary with different materials, but it was not accounted for in our setup.

3.3. Weather Variations

Our testing spanned two days with contrasting weather conditions. The cloudy weather during the first day exhibited poorer GPS performance compared to the clear conditions on the second day (during which the trials of the first day were repeated). This suggests that weather factors could have substantially influenced our readings.

3.4. Limited Data Sets

The number of datapoints collected for each configuration ranged from 7 to 14. A larger volume of data would help in reducing variance and providing a more robust analysis.

3.5. Timing and Precision in Data Recording

Data recording involved reading values from Mission Planner at exact minute intervals. However, we observed fluctuations in readings during the process, indicating that we may not have captured a truly instantaneous snapshot of the GPS performance.

3.6. Additional Potential Confounding Variables

- **Environmental Interferences:** Nearby electronic devices or structures could have introduced electromagnetic interference, impacting GPS readings.
- **Battery Performance Variability:** Differences in battery life or performance among flight stacks could have affected GPS module efficiency.
- **Human Error:** Manual data entry and observation could lead to inconsistencies and errors in recording.
- **GPS Satellite Availability:** Variations in the number or position of GPS satellites available during testing times could have altered GPS performance metrics.
- **Altitude and Orientation Fluctuations:** Changes in the altitude or orientation of the flight stacks, even if minimal, could influence GPS signal reception.

These additional factors further highlight the complexity of our testing environment and the need for controlled conditions in future studies to isolate the impact of basket materials on GPS performance.

4. Results

Our comprehensive analysis revealed that fiberglass baskets were superior in minimizing GPS signal degradation compared to other materials tested.

4.1. Data Grouping and Analysis Methodology

To contextualize our findings, we categorized the data into four distinct groups:

- Fiberglass Flight Baskets
- Stainless Steel Baskets
- Carbon Fiber Baskets
- Carbon Fiber Baskets with Motor Board (Additional Analysis)

The primary analysis was conducted on the first three categories. For each group, we aggregated data points for HDOP, HACC, and SATS metrics. Prior to averaging these values, outliers were identified and removed using the Interquartile Range (IQR) metric:

- Lower Bound: Q1 - (1.5 * IQR)
- Upper Bound: Q3 + (1.5 * IQR)

4.2. Graphical Representations and Interpretations

4.2.1 HDOP, HACC, and SATS Analysis

Using Python for data analysis and visualization, we constructed these bar graphs showing each basket type along the x-axis against their respective average values for HACC, HDOP, and SATS.

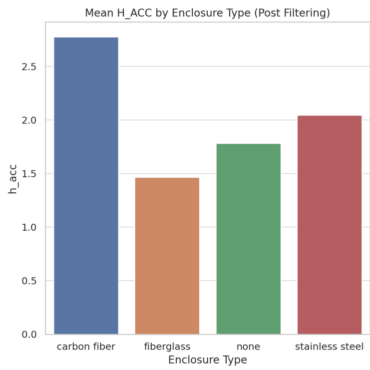

Figure 1. HACC over both collection days

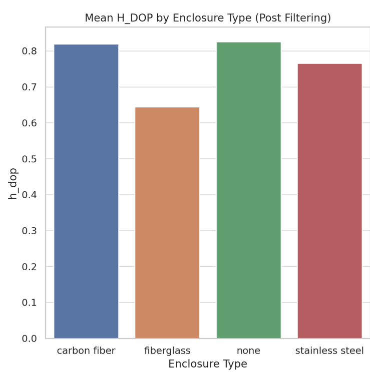

Figure 2. HDOP over both collection days

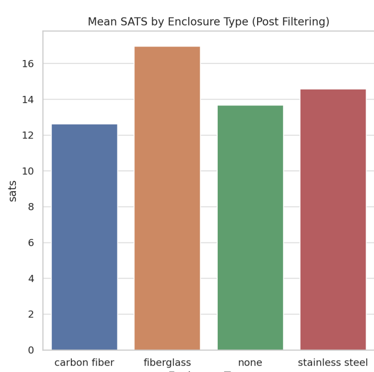

Figure 3. SATS over both collection days

When filtering on only the second day of collection (day 3 overall), the results were even more illuminating.

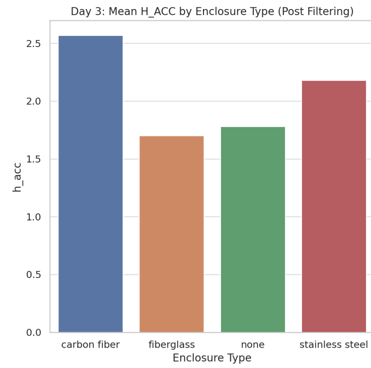

Figure 4. HACC on second collection day

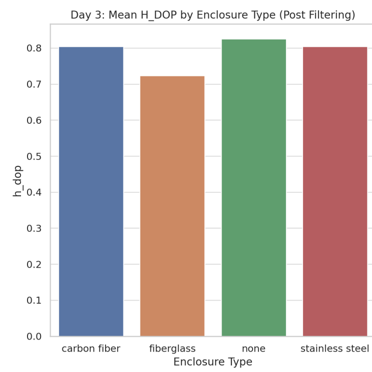

Figure 5. HDOP on second collection day

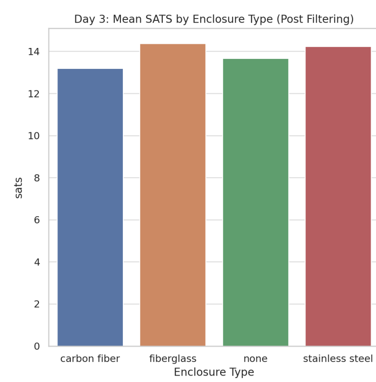

Figure 6. SATS on second collection day

4.2.2 Comparative Analysis of Carbon Fiber Baskets

To further delve into the impact of additional components, we also conducted a separate comparison between Carbon Fiber Baskets and Carbon Fiber Baskets equipped with a

Motor Board. Our results showed better GPS performance on when the GPS module was not attached to a Motor Board.

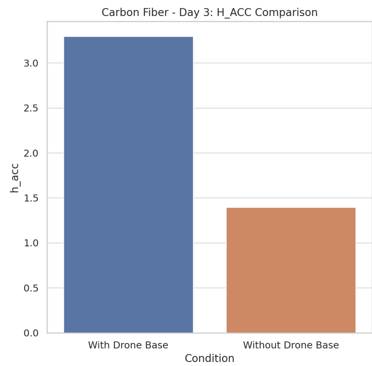

Figure 7. HACC for carbon fiber baskets

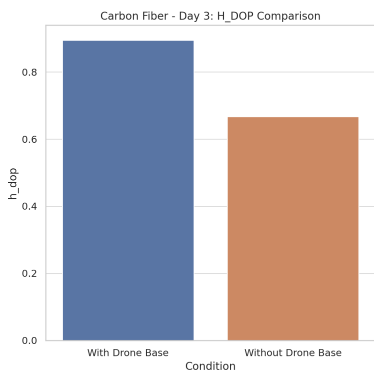

Figure 8. HDOP for carbon fiber baskets

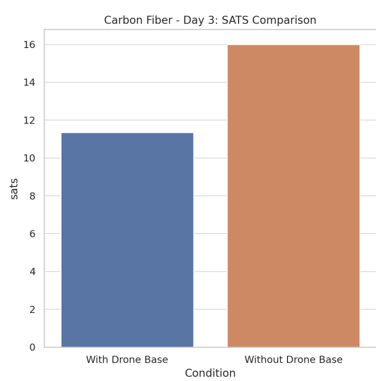

Figure 9. SATS for carbon fiber baskets

5. Conclusions

From these preliminary experiments, the results show the GPS module performance in the fiberglass basket completely surpasses performance in each of the other materials. Furthermore, the GPS module performance in the carbon fiber flight basket without a Motor Board was better than the performance when attached to a Motor Board. Further research is needed to understand some anomalies, such as why GPS performance was worse without any flight basket at all than with the fiberglass flight basket.

6. Future Research Directions

Building upon our current study's findings and acknowledging its limitations, we propose a refined approach for future research. This upcoming study is designed to further limit confounding variables and enhance the reliability of our results.

6.1. Enhanced Equipment Consistency

- Utilization of three identical flight stacks, each fitted with Kairos's latest high-performance GPS modules, to ensure equipment uniformity and attribute GPS performance variations solely to the test conditions.

6.2. Diverse Basket Configurations and Testing Environments

For comprehensive testing, we will include three different basket configurations for each basket type:

1. **Hollow Baskets with Power Base:** Retaining the baseline setup of our current study for comparison.

2. **Baskets with Motor Boards and Propellers:** Conducted in two stages:

   (a) With motors turned off, to assess passive interference.

   (b) With motors active, to understand the impact of operational interference.

3. **Open Area Testing:** Executing tests in large, unobstructed areas like salt flats to establish a control environment for optimal GPS performance.

6.3. Resource Optimization

To ensure consistent and reliable testing conditions, the study will utilize:

- Multiple sets of batteries and battery charging stations for consistent voltage and current output.

- Several laptops to allow simultaneous, spaced-out trials, enhancing data collection efficiency.

6.4. Expanded Data Collection

- Conducting multiple trials for each basket-flight stack combination to enlarge the data pool and minimize result variance.

These methodological enhancements aim to provide more definitive insights into the impact of basket materials and configurations on drone GPS performance, demonstrating our commitment to advancing research in this field.

7. Detailed Equipment List

This section details the specific equipment used in our study, categorized for clarity and organized presentation.

7.1. Flight Baskets

A total of four flight baskets were used, each with distinct materials and configurations:

1. **Carbon Fiber Baskets:**
    - One empty basket.
    - One basket equipped with an internal, attached motor board.
2. **Stainless Steel Basket:**
    - One empty basket.
3. **Fiberglass Basket:**
    - One empty basket.

7.2. Flight Stacks / Configurations

Three distinct flight stack configurations were employed in the study:

1. **Stack A (SA):**
    - GPS Module A with a ground plane, no spacer.
    - Flight Controller A.
    - Radio Module A.
2. **Stack B (SB):**
    - GPS Module B with a ground plane and spacer.
    - Flight Controller B.
    - Radio Module B.
3. **Stack C (SC):**
    - GPS Module C without a ground plane, but equipped with a spacer.

This comprehensive list provides a clear overview of the diverse range of equipment and configurations used in our study.