

Data budget

1. Introduction

This document outlines the methodology, assumptions, and calculated results, providing a clear understanding of the system's data management and limitations. These results are crucial for validating the design and ensuring reliable data transmission for the IEEE Open PocketQube Kit.

Please check the [link budget](#) for additional information regarding COMMS budgets.

2. Methodology

As detailed in the link budget, the simulated nominal scenario for obtaining values and performing computations involves an orbital height of 500 km.

To determine the data budget, we need to calculate the maximum amount of data that can be downloaded in a single pass. This requires computing the capacity for a Spreading Factor (SF) of 11 and a Code Rate (CR) of 4/5. Using the formulation provided in [1], we obtain a rate of 537.11 bps.

After obtaining the data rate, we propagated the orbits using Orbitron [2] to study the initial scenario. This software has an inclination error of 0.1°. The propagation results provided the satellite passes over the Ground Station (GS) at Montsec [3], factoring in the minimum elevation angle. Using the simulated pass durations and the calculated data rate, we calculated the data that can be transmitted during each pass over our ground station.

We then compared the average data that can be transmitted in uplink and downlink with the required data for sending commands from the satellite and the GS. We verified that the available data was sufficient to transmit and receive telecommands and payload results, and ensured that data could be re-sent if needed, as there are no protocols guaranteeing packet reception.

The table below estimates the total data volume needed for transmission during each satellite pass, covering both telemetry/configuration data and payload data for a single measurement.

Downlink	
Telemetry data	48 Bytes
Configuration data	32 Bytes

Payload 1 (L band) data	2831 Bytes
Payload 2 (K band) data	708 Bytes

This data will be stored inside the satellite with up to 1MByte of storage. For the uplink, we have a variety of telecommands available.

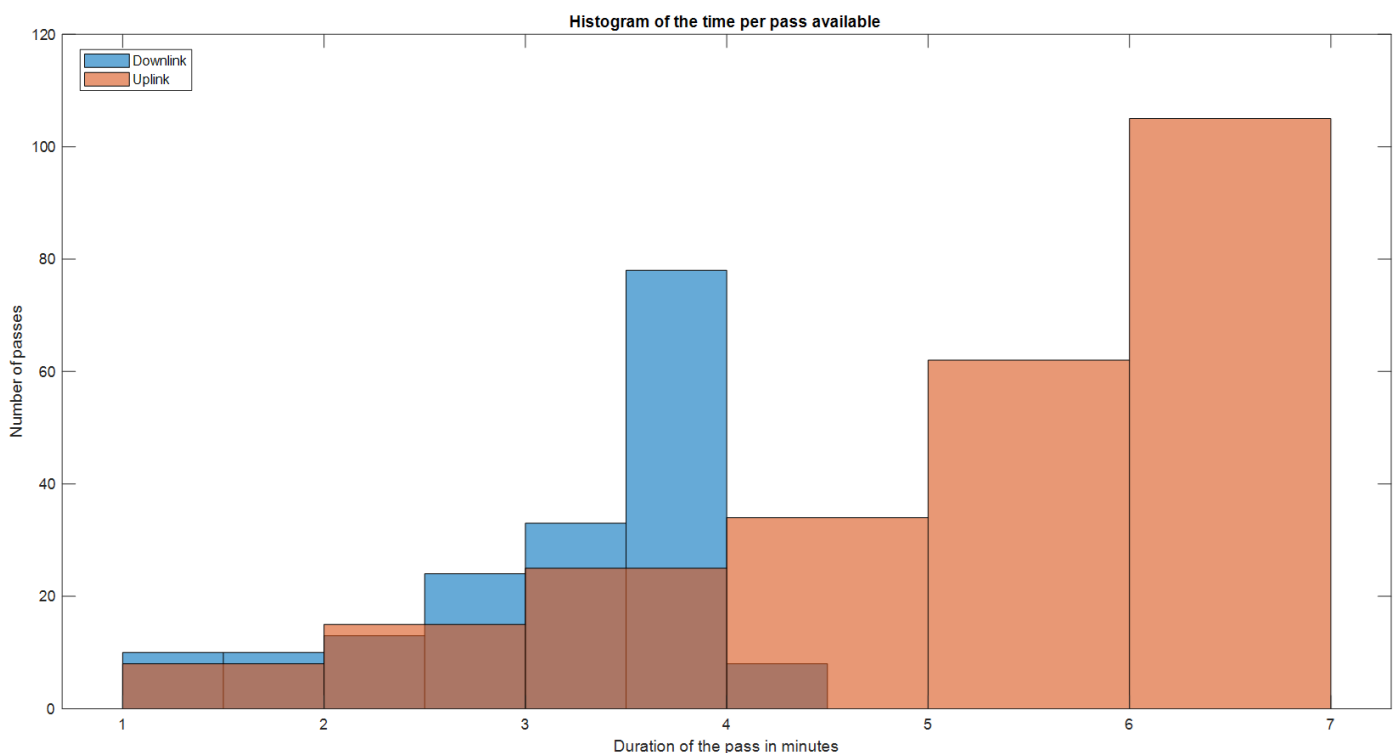
A detailed list of all telecommands, along with the corresponding telemetry, can be found [here](#).

Since the number of bytes required for the uplink will largely depend on the amount of available platform data and the satellite’s latest status, estimating the exact byte count for the uplink is impractical.

However, as indicated in the summary table, the PocketQubes will have a large margin, ensuring that even in a worst-case scenario—where a significant number of commands need to be uploaded during a pass—there will be sufficient time to do so.

3. Results

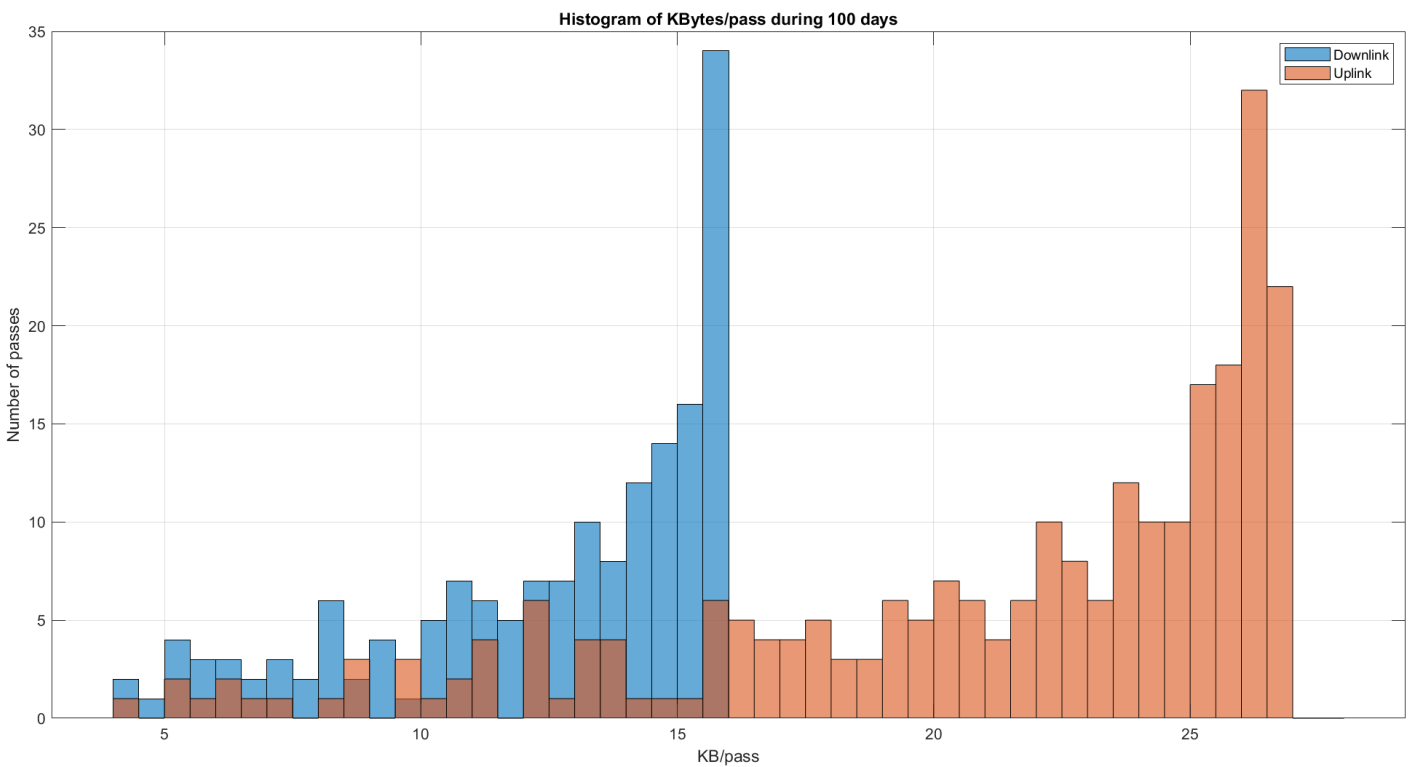
This section presents the results from the Data budget analysis. First, we have computed the number of passes available with its corresponding duration. Figure below shows the number of passes according to its duration for both uplink and downlink in 100 days:



After obtaining the results from Figure G.5, we can compute the data that can be sent during each pass based on the findings presented in [1]. On average, we have 2.49 uplink passes per day over a period of 100 days. For the downlink, we achieve about 1.63 passes per day. Table below presents the results, showing the average duration of the passes for both uplink and downlink.

Average pass time [min]	
Uplink	5.26
Downlink	3.18

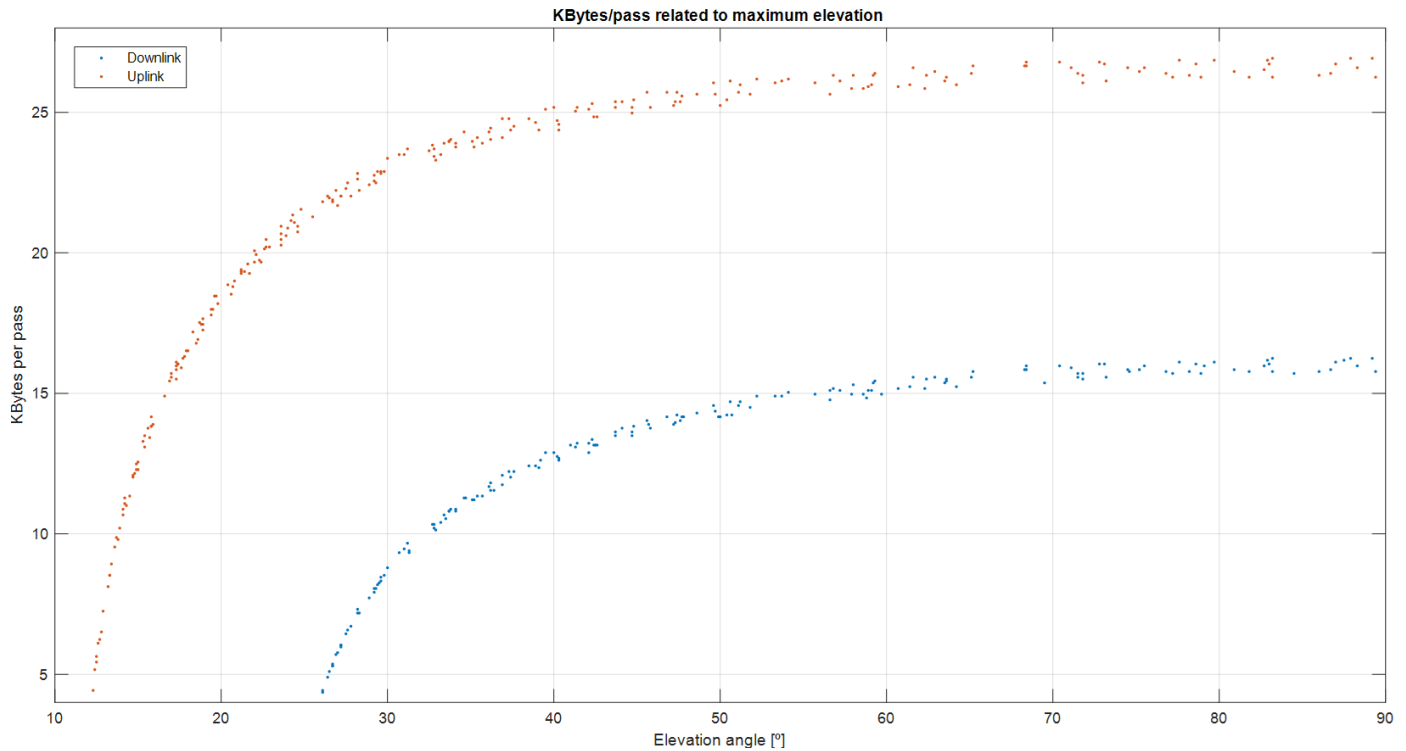
The data was obtained by multiplying the rate by the time per contact, resulting in the outcomes shown in the Figure below. This figure displays the amount of data available for download per pass, revealing the number of contacts related to the downloaded data. To summarize the findings from the Figure below, tables are provided, offering an overview of the average data downloaded per pass using the results from the Table above. The presented results indicate the data downloaded per pass and per day.



Average transmitted Bytes per pass [kBytes]	
Uplink	20.69
Downlink	12.52

Average transmitted Bytes per day [kBytes]	
Uplink	52.05

From the results in the Tables above, we can now gauge the link's capabilities for downloading data. Lastly, Figure below illustrates the kBytes per pass in relation to the maximum elevation angle the satellite reaches during that pass, which directly correlates with the maximum data we can download.



Analyzing the results, we find that the uplink transmission capacity is 20.69 kBytes. For the downlink case, the transmission capacity is 12.52 kBytes, while the L-band payload (which is the payload generating more data) requires 2831 Bytes (2.76 kBytes) to be downloaded from the satellite to the ground station. Therefore, we can conclude that the data budget capabilities are sufficient and that additional stored data could also be transmitted from the satellite to the ground station.

4. Conclusions

Table below demonstrates our capability to transmit at least one image per contact. Additionally, telemetry data can be sent along with the image once per pass. Furthermore, we have the ability to repeat messages if necessary to ensure successful transmission.

	Maximum Data Volume capability per pass [Bytes]	Estimated Data Volume to be transmitted [Bytes]	Additional available Bytes	Feasibility
Uplink	21191	x	20567	TRUE
Downlink PL1	12824	2831	9993	TRUE
Downlink PL2	12824	708	12116	TRUE

Additionally, following the recommendation of ESA's expert, we present a demonstration of the data budget's feasibility, factoring in the time required to transmit all the data. Specifically, the airtime for each packet will be approximately 1478 ms [4].

By adding a few seconds for computation time and a margin of error and considering an average pass, we arrive at:

	Data to be transmitted [Bytes]	Time required to transmit data [s]	Time left [s]	Feasibility
Uplink	500*	18.5 (+2) = 20.5	295.1	TRUE
Downlink PL1	2873	106.2 (+2) = 108.2	82.6	TRUE
Downlink PL2	708	26.2 (+2) = 28.2	162.6	TRUE

It can be observed that both PocketQubes will have sufficient time to communicate and transmit all the necessary data to the ground station, confirming the feasibility of this data budget.

* It is important to note that for the uplink, we have selected a data size of 500 bytes for transmission. As mentioned earlier, the exact amount of data required for the uplink will depend on various factors.

5. References

[1] RF Wireless World. LoRa Sensitivity Calculator. <https://www.rfwireless-world.com/calculators/LoRa-Sensitivity-Calculator.html>, 2024.

[2] Stoff Industries. Orbitron - Satellite Tracking System - Official Website. <https://www.stoff.pl/>, 2024.

[3] Parc Astronòmic Montsec. Parc Astronòmic Montsec. <https://parcastronomic.cat/es/> , 2024

[4] The Things Network. The things network airtime calculator. Online Tool, 2024.

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