## Design Narrative

At the beginning of this group project, the aim of the WUSAT-4 (Warwick University Satellite) mission was to make a 2U CubeSat to carry two experimental payloads from industrial partners to low earth orbit (LEO). The first payload was a beacon from a company called UK Launch Services Limited, and the other was an automated biological experiment from a research group from the University of Leicester called Space Park Leicester. The WUSAT-4 concept would be to take this automated biological experiment[A] to LEO, provide power to it, and provide a way to download the experimental data.

During the initial phases of research towards this project revealed a large learning curve, to adequately design a space ready satellite. The rigorous documentation and strict methods of designing a new satellite we revealed to be vastly different from adding to an existing one. Thus, much of what was needed to be used in the project had to be learned as it went.

Nevertheless, for the 4$^{th}$ WUSAT mission, the starting point for this group project was to learn from the previous years' projects – as such it was decided that the satellite should use an omnidirectional antenna to reduce the complexity of the system. One of the reasons that the WUSAT-3 mission resulted in failure was due to an excessively complex attitude determination and control system (ADCS). The use of an omnidirectional antenna would eliminate the need for any ADCS – this is discussed in[B]. However, given this, one of the major themes of this team's work was designing a communication system which would work without any antenna pointing.

The next step for the team was then to create comprehensive systems requirement documentation based upon the payload and mission requirements. Unfortunately, it was at this stage that UKLSL payload had to be dropped due to a low technology readiness level - hence the satellite form factor was also dropped to 1U.

As the launch of a CubeSat involves many stakeholders, the requirements were taken from a variety of sources. Additionally, systems requirements in the space industry are exceptionally stringent. The systems requirements overview, reformulated after dropping the UKLSL payload, is given in[C].

Following this, the team was split into individual subsystem teams, coordinated by a systems engineer, and these subsystem teams began research into architecture and components which could be used to fulfil the system requirements. Trade-off analyses were used to choose a microcontroller for the on-board computer (OBC)[D], aluminium 6061 as the chassis material[E] and MPPT architecture for the electrical power subsystem (EPS)[F].

Following an analysis of the spatial requirements of the proposed components from each of the subsystems in Week 15[G], it was discovered that the designed satellite would not fit into a 1U form factor. After an additional analysis of the power generation of a 1U and 2U CubeSat[H], it was concluded that a 2U size would be required[I]. Using this information, an exact off-the-shelf component solar panel could be chosen using a trade-off analysis.

Design of the other subsystems continued concurrently; a set of antenna communication tests were created, according to the concept of operations (CONOPS) of the satellite[J], to prove that the microcontroller was suitable and provide a proof of concept[K]. Additionally, the I2C communication protocol was chosen for on-board sensor communication, as shown in[L]. By choosing this communication method it allowed for easy communication between a wide variety of COTS

[A] *In file: Design_Portfolio_Submission>6.FDSPP>FDSPP Data Sheet Summary (005)*
[G] *In file: Design_Portfolio_Submission>9.Subsystems>9.6Systems_Engineering>CubeSat_Initial_Spacial_Requirements_Document*

components as well as being very reserved with the number of pins used by the Arduino when having to connect to so many components.

Once the 2U configuration and material had both been decided upon, FEA could be conducted on the chassis for lightweighting and performance enhancement[M].

For 4 days in Week 20, four members of the team attended a European Space Agency concurrent engineering course, which provided insight from space industry experts into several of the specific problems which the WUSAT-4 mission faces. This team gained a lot of insight from experiences such as this which aided the design of our satellite – a collection of these experiences and how they were used to improve the skills of the team and the satellite design is summarised in[N].

The UHF band was chosen for the uplink and downlink of the communications system based on an analysis presented in[O], and, following a trade-off analysis for the antenna, transceiver and ground station[P], a link budget for the satellite was calculated[R]. This in turn gave the team numbers for the power requirements of the communication subsystem, which were subsequently used to perform battery sizing calculations for the EPS[S], and a trade-off analysis for battery and power conversion and distribution unit[T].

Having the majority of the systems set a design review was held with SPL, where each written requirement was gone over and confirmed it supported their mission objectives.

Though, following concerns raised by the payload suppliers SPL and suggestions from ESA experts, passive magnetic stabilisation was included in the satellite design, after previous consideration[U].

Taking a concurrent engineering approach, as is best-practice in the space industry, was one of the goals set by the team in the Week 4 project brief. This was used throughout the duration of the project. For example, an FMEA analysis which was continually updated was used to analyse failure modes in for the system and provide a driver for iteratively improving subsystem designs.

Finally, once all the subsystems were defined, a configuration model for the satellite was developed and is presented in[V].

**SharePoint Design Portfolio Link:**

Design Portfolio Submission

(https://livewarwickac.sharepoint.com/sites/WUSAT-4/Shared%20Documents/Forms/AllItems.aspx?id=%2Fsites%2FWUSAT%2D4%2FShared%20Documents%2FDesign%20Portfolio%20Submission&p=true&ga=1)