**University of Leicester Future 100 PhD Scholarship**

**Project Reference: RI-SPACE-Bannister**

**Section 1 – *Supervisor Information***

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| **First Supervisor** | Dr Nigel Bannister |
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| **Proposed Second Supervisor** | John Panneerselvam |
| **Additional Supervisor** | Dr Mariano Alvarez Bianco (Siemens) |

**Section 2 – *Project Information***

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| **Project Title** | Model Based Concurrent Engineering: Pre-Phase-A Concept to Digital Twin | |
| **Project Highlights:** | 1. | Proving a new type of mission design capability based around open-source tools, enabling rapid and efficient optimisation and validation of spacecraft and trajectory design. |
| 2. | Demonstration of significant new functionality deployed within the SPL CDF environment and attracting significant ESA interest |
| 3. | Flight demonstration of optimised control software and digital twin capability at SPL in our first CubeSat mission (funded via Wolfson). |
| **Project Overview** | | |
| The objective of this project is to develop a capability for detailed flight dynamics modelling and simulation, and integrate within the recently completed Concurrent Design Facility at Space Park Leicester (running ESA’s Open Concurrent Design Tool, OCDT, and Siemens NX). The project will demonstrate the use of trajectories designed using nonlinear optimisation methods, and attitude control laws implemented in a simulated onboard processor environment, to assess thermal, power and communications subsystem design requirements in order to meet a set of scientific, commercial and/or technology proof-of-concept requirements. The outputs will demonstrate the formalized application of modelling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. In particular the implementation of flight dynamics simulation will extend from the concurrent design environment into the flight software for the CubeSat mission demonstrator being developed by the Wolfson Deep Space Centre, and a corresponding digital twin for the mission. The PhD will be co-supported by Siemens who are experts in model based concurrent engineering approaches. Their software solutions (e.g Siemens NX) are already intrinsic to the engineering infrastructure at Space Park Leicester. They are already collaborating with ESA in the next update to their Open Concurrent Design Tool. Through the University’s ESA\_Lab@Leicester project, collaboration with subject experts at the European Space Agency is anticipated, and additional requirements and objectives may emerge during the course of the project. | | |
| **Methodology** | | |
| A current PhD programme has demonstrated trajectory design using nonlinear optimisation, and interfacing of astrodynamics models with CAD and FEA tools. This project extends that work to demonstrate automated thermal analysis for complex, multi-phase trajectories, with the potential for thermal optimisation for future missions. It then adds attitude dynamics, integrating NASA’s 42 code into the CDF, building on preliminary work conducted previously. Mission attitude control requirements will be modelled, and optimised control laws designed using the application of AI techniques via the HEEDS layer, leading to an end-to-end mission simulation and optimisation capability, and validation of flight control software ready for direct integration into the spacecraft onboard computer and corresponding digital twin, and flight testing in the Wolfson Centre’s first CubeSat mission.  **References**  Value and benefits of model-based systems engineering (MBSE): Evidence from the literature  Henderson, Kaitlin ; Salado, Alejandro  Systems engineering, 2021-01, Vol.24 (1), p.51-66  DOI: 10.1002/sys.21566  Foundations for Model-based Systems Engineering: From patterns to models: From patterns to models  Holt, Jon ; Perry, Simon ; Brownsword, Mike  Stevenage: The Institution of Engineering and Technology (2016)  DOI: 10.1049/PBPC014E  Bannister, N. P., & Neyland, D. L. (2015). Maritime domain awareness with commercially accessible electro-optical sensors in space. *INTERNATIONAL JOURNAL OF REMOTE SENSING*, *36*(1), 211-243. doi:10.1080/01431161.2014.990647 [**This paper demonstrates capability for detailed constellation design and mission performance modelling**]  Bannister, N. P. et al. (2012). Astrophysical objects observed by the MESSENGER X-ray spectrometer during Mercury flybys. Planetary and Space Science, 69(1), 28-39. doi:10.1016/j.pss.2012.05.006 [**This paper is based on a combination of trajectory and spacecraft attitude analysis combined with astrophysical models and instrument performance models to predict scientific performance**] | | |