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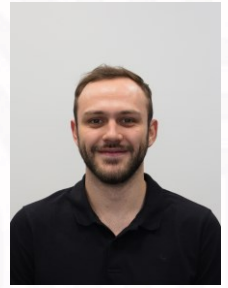
UNISEC Chapter Update

Photo: Stefan Els

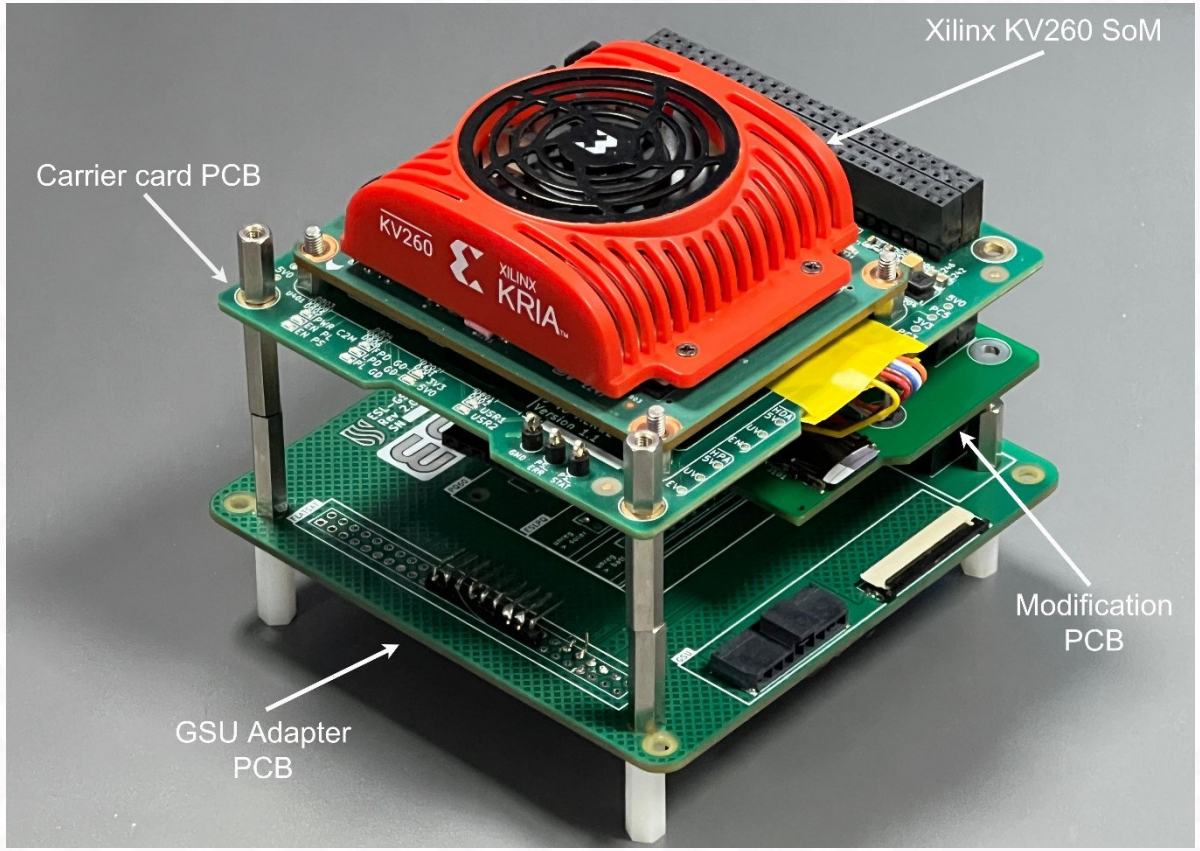
ESL
Electronic Systems Laboratory

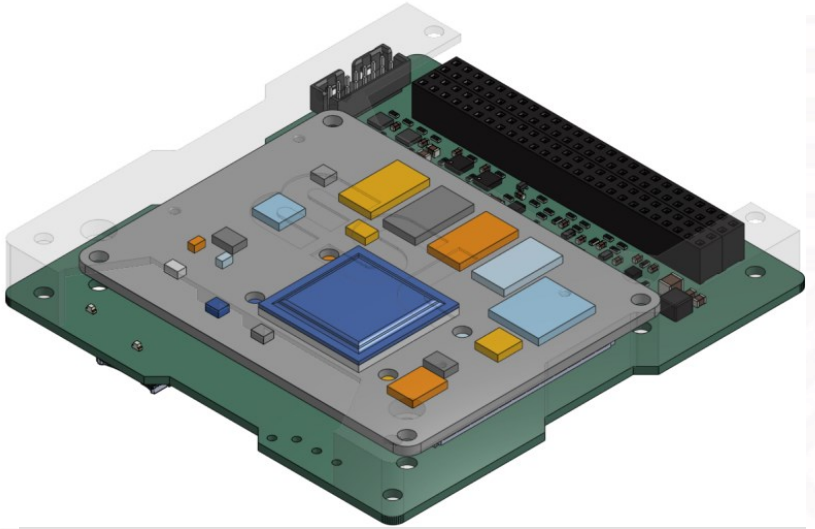
Reconfigurable OBC system for NanoSat application

- Study of Modern CubeSat Processing Units
  - Evaluated high-performance CubeSat On-Board Computers (OBCs) and Data Processing Units (DPUs).
  - Identified the Xilinx Zynq UltraScale+ MPSoC as the optimal architecture.
- Engineering Model
  - Created a CubeSat processing unit using the Kria K26 System-on-Module, matching commercial processing capabilities.
  - Developed firmware to exploit K26 hardware for reconfiguration, file transfers, and FPGA updates.
  - Investigated heat dissipation requirements for reliable operation in space environments.



Reconfigurable OBC system for NanoSat application





DESIGN AND IMPLEMENTATION OF REAL-TIME ON-BOARD SATELLITE IMAGE CORRECTION ALGORITHMS

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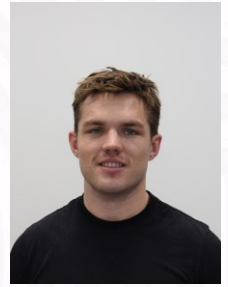
- Aim
  - Develop real-time, on-board image correction algorithms for satellite imaging using FPGAs.
- Imaging Challenges
  - Corrects pixel intensity nonuniformity (CMOS variations) and geometric distortions (lens imperfections).
- FPGA-Based Implementation
  - Inline processing between digitization and storage leveraging FPGA parallel processing.



DESIGN AND IMPLEMENTATION OF REAL-TIME ON-BOARD SATELLITE IMAGE CORRECTION ALGORITHMS

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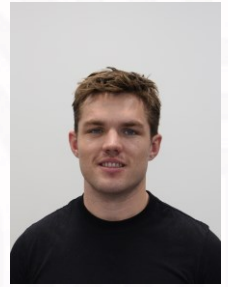
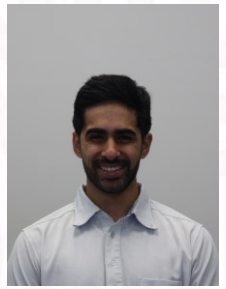
- Results
  - Validated on the PolarFire™ Discovery Kit with significant image quality improvements (e.g., >50% MAE reduction, high SSIM).
  - Efficient resource use (<6% FPGA resources per channel) and real-time processing (>150 megapixels/second).
  - Dynamic correction coefficients allow real-time adjustments to environmental changes.



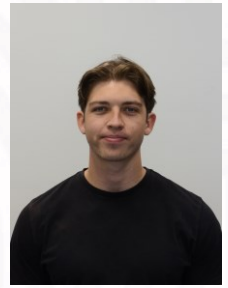
Proton Single-Event Effects Tolerance Testing of a Myriad X Vision Processing Unit

- Objective: Investigate Single Event Effects (SEE) susceptibility of the Intel Movidius Myriad X VPU under 66 MeV proton exposure.
- Test Approach
  - Used YOLOv7-tiny object detection model and custom neural network (PlusOne) for SEE detection and error tracing.
- Key Findings:
  - SEFI cross-sections ranged from 10^{-11} to 10^{-9} cm^2, with functional failure at ~65.77 krad(Si).
  - Post-processing techniques effectively filtered many error-induced predictions.
  - Recurring errors suggested firmware vulnerabilities to SEE.
  - Highlighted opportunities for SEE-aware neural network designs to enhance radiation tolerance.



Robotic Capture Arm for CubeSat Docking

- DockSat
  - Enabling docking for nano satellites to support in-orbit servicing, repair, and debris removal.
  - Limited thrust capacity affects manoeuvrability, requiring innovative solutions.
- Robotic Capture Arm Development
  - A compact, lightweight arm with centralized mass for efficient operations.
- Miniaturized Androgynous Docking Adapter
  - Both chaser and target satellites equipped with this docking mechanism.
- Advanced Camera Control System
  - Hybrid eye-in-hand and hand-in-eye system for precise docking maneuvers.



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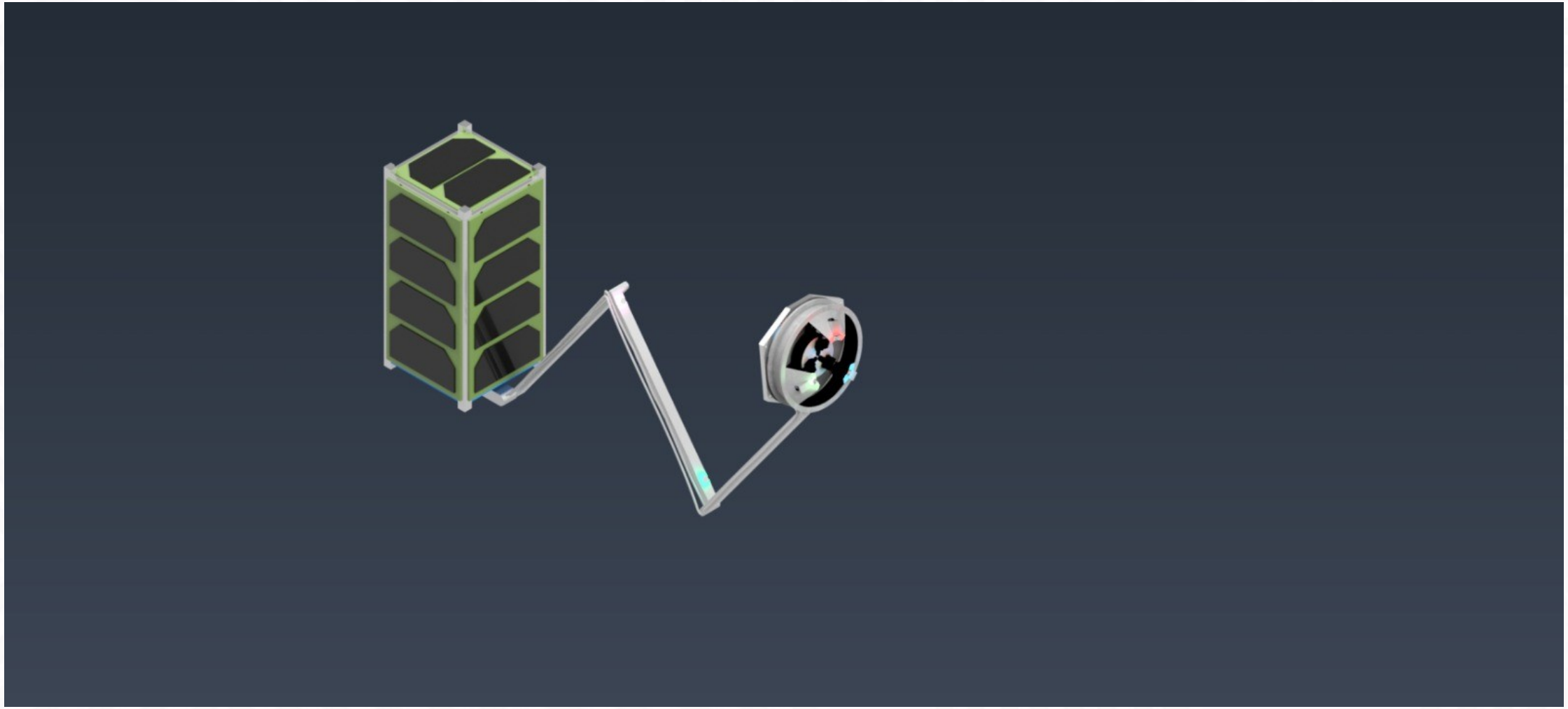

CubeSat Digital Twin to Expedite Nano Satellite Software Development

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- Challenges in Current CubeSat Development
  - Late procurement of subsystems limits time for full software verification and testing.
- Proposed Solution: Digital Twins
  - Allow for development of CubeSat flight software earlier in the timeline to allow extended testing and optimization.
- Application to DockSat Mission
  - Flight software tailored for DockSat's commissioning, beaconing, and detumbling phases.
  - Robust software architecture built on a commercial framework to support mission-specific needs.

CubeSat Digital Twin to Expedite Nano Satellite Software Development

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- Development and Testing Framework
  - Digital twins for antenna, radio, EPS, and ADCS using manufacturer documentation.
  - Testing performed via STM development boards interfacing the On-Board Computer (OBC) with a desktop simulation.
- Results and Impact
  - Demonstrated robust and reliable satellite operation through rapid, repeated orbital scenario testing.
  - Validates digital twins as a time-efficient and effective tool for flight software development.

CubeSat Digital Twin to Expedite Nano Satellite Software Development

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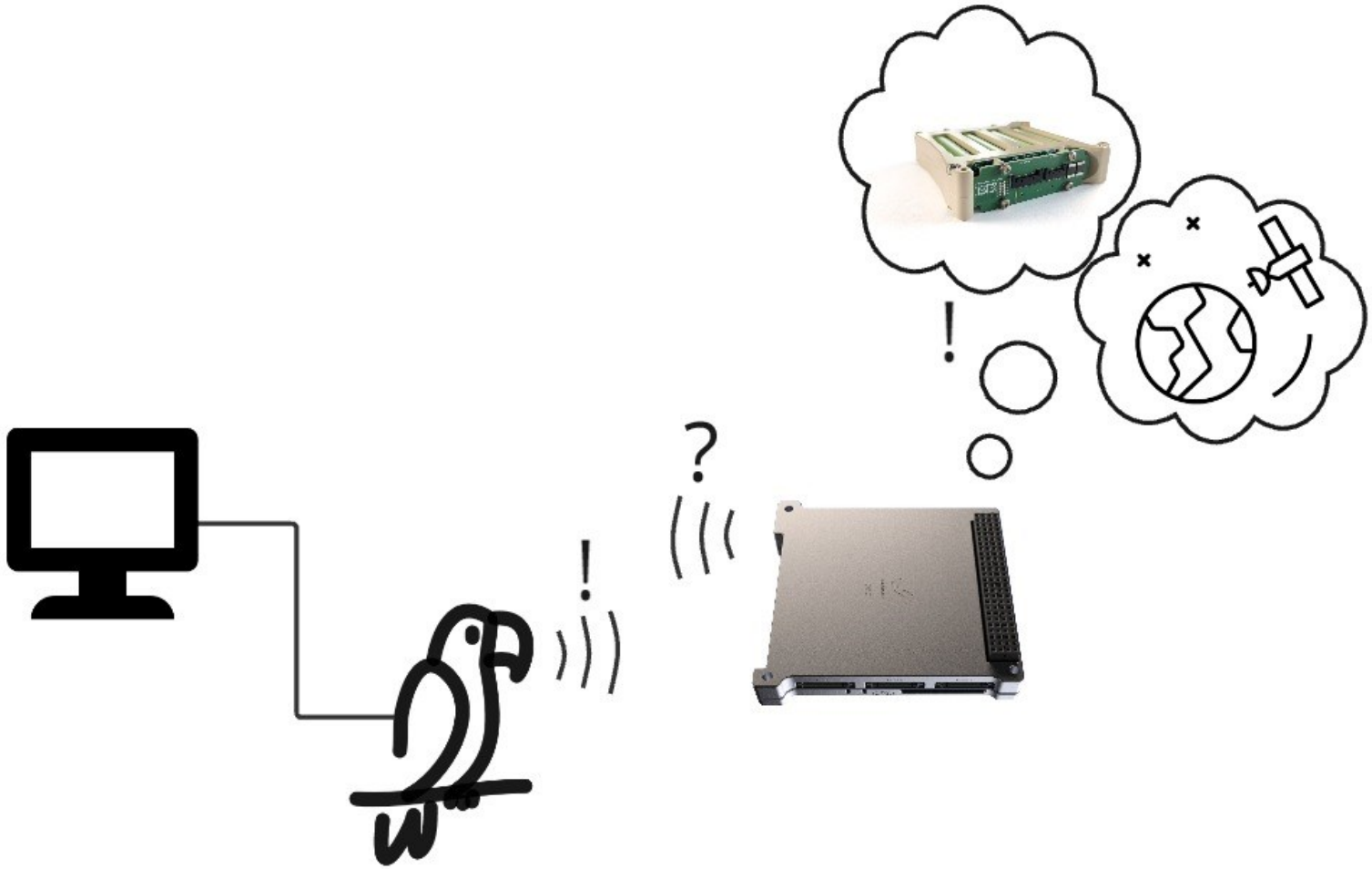

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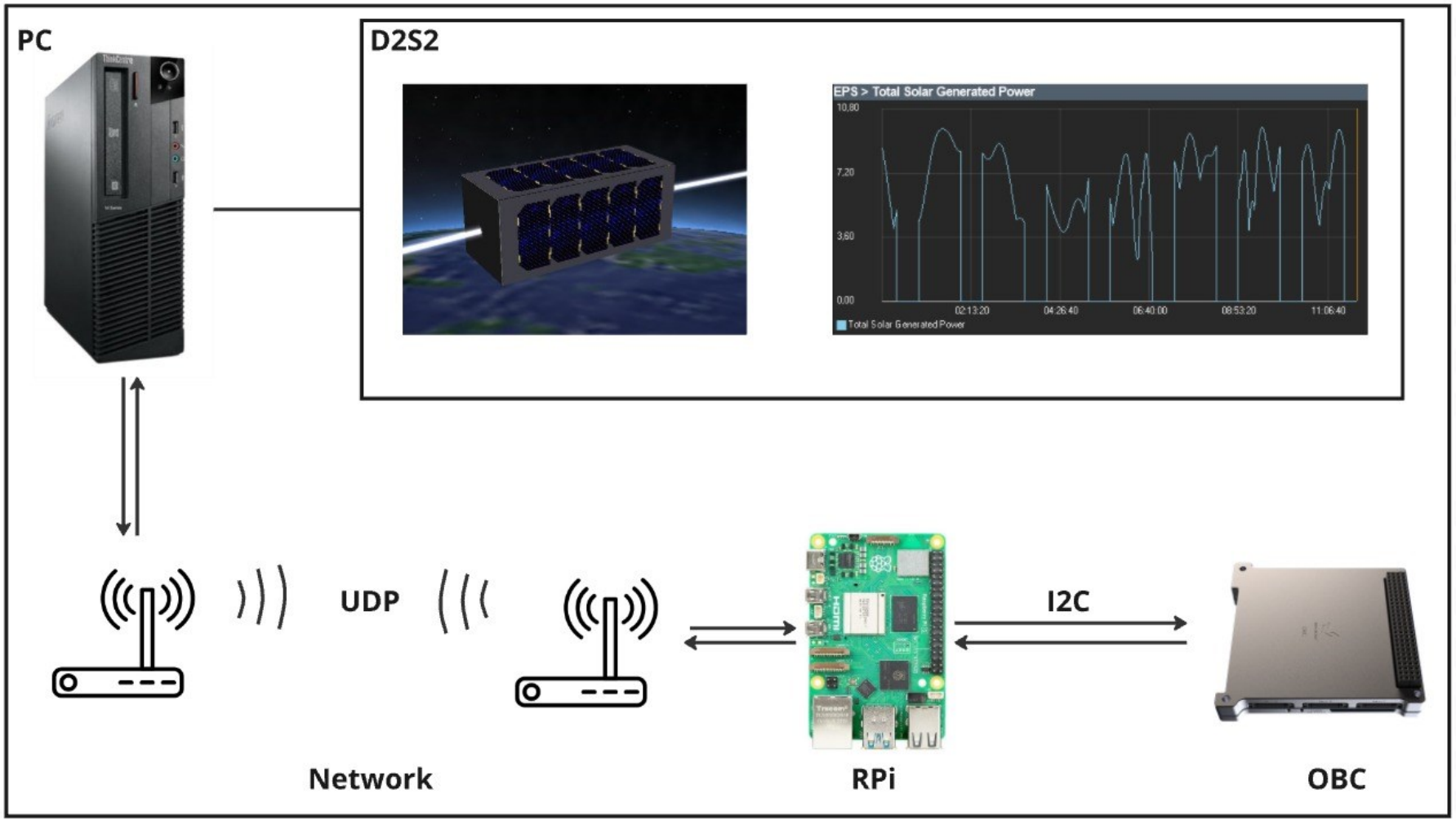
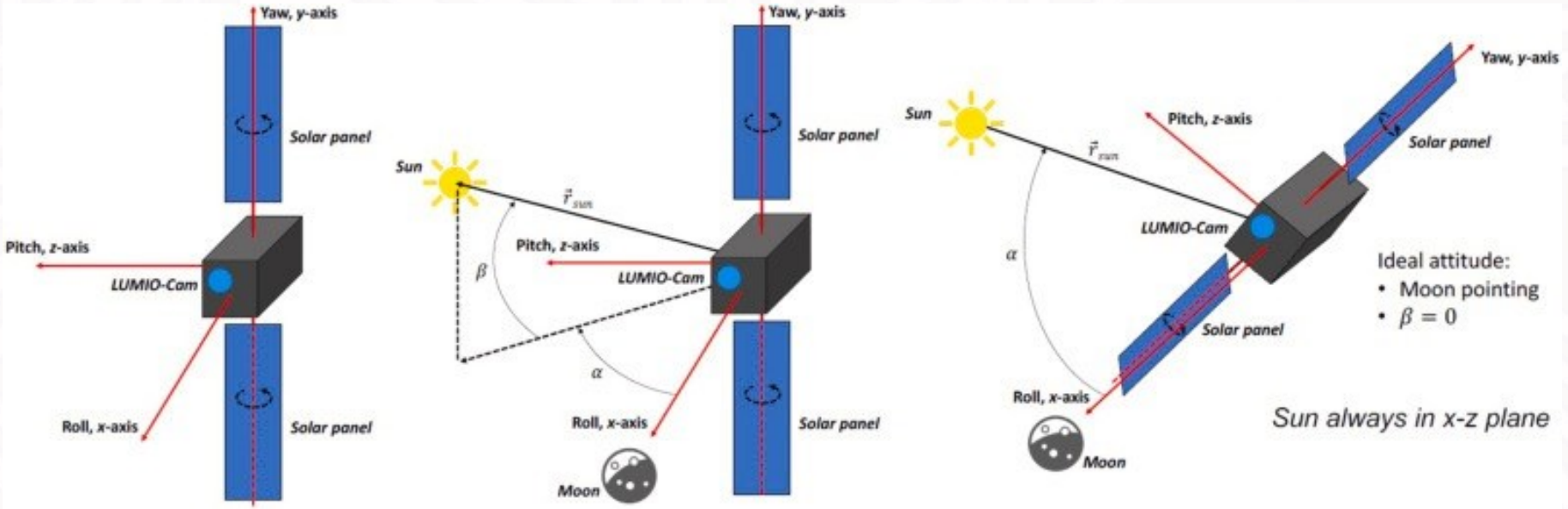


Vacuum Arc Thruster ADCS Analysis

- Lumio Mission
  - ESA's mission to observe meteoroid impact flashes on the Moon's far side, launching in 2027.
  - Understand and simulate the meteoroid flux on the Moon and Earth for predictive modeling.
- Key Payload: Specialized Optics
  - Detects meteoroid flashes in visible and near-infrared; processes data near real-time.
- Current ADCS Limitations
  - LUMIO’s existing system relies on reaction wheels and cold gas thrusters.

Vacuum Arc Thruster ADCS Analysis

- A simplified ADCS setup with Vacuum Arc Thrusters is being investigated
  - A custom algorithm is used to analyse performance, robustness, and connectivity to real hardware



Integration of Wireless Sensor Network with CubeSat Satellite System for Enhanced Agricultural Monitoring

- Agricultural Challenges in Africa
  - Limited access to modern technology, inefficient resource use, and inadequate crop monitoring systems.
- Innovative Integration of IoT and CubeSats
  - Combines Wireless Sensor Networks (WSNs) and CubeSat satellite imaging for enhanced monitoring.
- Comprehensive Data Insights
  - Tracks crop health, soil conditions, and environmental factors to inform decision-making.
- Empowering Smallholder Farmers
  - Affordable and accessible technology tailored for African farming communities.
- Focus on Sustainability and Food Security
  - Promotes optimized resource use and increased agricultural yields.


Thank you
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Dankie
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