Ubotica Technologies Ltd.
Innovation House
DCU Alpha
Old Finglas Road
Glasnevin
Dublin 11
D11 KXN4
Ireland

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Prepared by Javier Parra, Aubrey Dunne
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1 Relevant Background and Reference Documents

2 Acronyms

AI Artificial Intelligence
API Application Programming Interface

COTS Commercial Off The Shelf
CV Computer Vision

ESA European Space Agency

FM Flight Model

IMU Inertial Measurement Unit
IOD In-Orbit Demonstrator
ISP Image Signal Processor

MDK Movidius Development Kit

NN Neural Network

OBC On-Board Computer

USB Universal Serial Bus

3 Brochure

Five different tasks were executed as part of the “For In-Flight Artificial Intelligence Proof-of-Concept Experiments” project. Together these tasks enable effective Artificial Intelligence (AI) inference and Computer Vision (CV) pipeline deployment on a dedicated hardware platform, and simultaneously demonstrated AI inference on an In-Orbit Demonstrator (IOD) cubesat platform.

The CV extensions allows users to easily implement and run their own applications without requiring a deep understanding of the underlying Myriad 2 architecture by decoupling the application development from the Movidius Development Kit (MDK). Some of its main capabilities are: simple user Application Programming Interface (API), use of the available Myriad 2 hardware blocks for CV operations, runtime reconfiguration of processing pipelines and the pre-processing of frames for AI inference, the ability to edit and tune pipelines in a graphical user interface tool, and the facilitation of complete Image Signal Processor (ISP) pipeline construction.

In order to address the increasing interest in Ethernet as an intra-satellite communications layer, Ethernet was added to the list of protocols handled by XLink, the component which handles all communications between the host (e.g., an On-Board Computer (OBC)) and the Myriad 2. To achieve this goal, some of the tasks performed were: to develop and integrate Ethernet in each of XLink’s layers, to configure the different required clocks, to implement a Myriad 2 discovery process, to add XLink with Ethernet to develop a two-stage Ethernet boot process for the Myriad 2.

The integration of CV extensions (part of CVAI Toolkit™) and the Ethernet layer for XLink are shown for a cubesat platform in Figure 1.

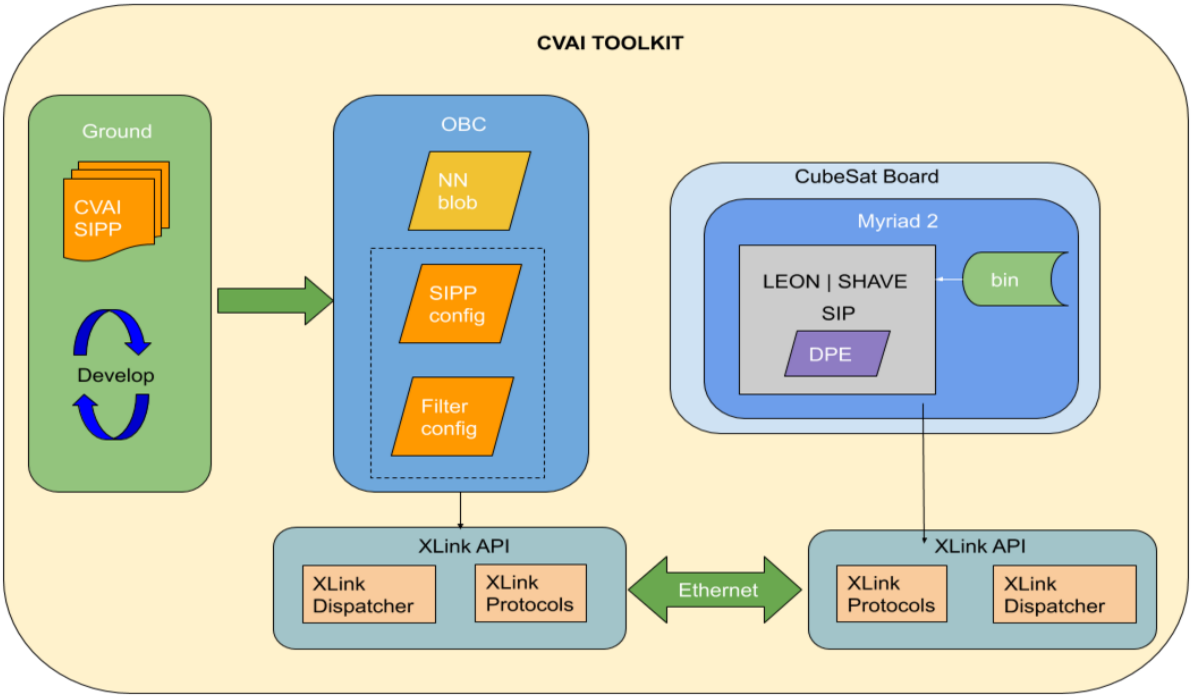

Figure 1: CVAI toolkit and XLink with Ethernet

The CubeSat-grade board was developed as a Myriad 2 CV and AI processing engine for use in cubesats. The design utilses Commercial Off The Shelf (COTS) components, that, where possible, have been radiation characterised or have flown in previous missions, and fully adheres to the European Space Agency (ESA) PC104 form-factor cubesat board requirements. All processing on the board is performed by the Myriad 2, including all communications and peripheral management. The board is designed for application to image processing, AI inference, and combinations of these two operations. Data to be processed can be on-boarded via one of two primary data interfaces (Ethernet and Universal Serial Bus (USB)), or can alternatively be captured directly from an interfaced image sensor (over either serial or parallel interfaces).

Key design features of the CubeSat-grade board are:

- On-board integrated latch-up protection
- Operates from single 5V supply
- Serial NOR flash for boot
- 3.3V I/O voltage
- Parallel and MIPI camera interfaces for direct sensor connection
- microSD card for non-volatile data storage
- Additional integrated satellite-oriented peripherals: Dosimeter & Inertial Measurement Unit (IMU)
- Targets sub 5W power envelope (application dependent)
- Stackable 2x dual row board-edge headers for power delivery and platform/payload communications

A functional overview of the CubeSat-grade board is shown in Figure 2. The CubeSat-grade board is expected to be available commercially in Q1 2020.

The IOD element of the project focused on the integration of a Myriad 2 AI engine payload with a novel hyperspectral sensor (the HyperScout-2) within the PhiSat-1 satellite. The AI engine build and the software integration of the AI engine with the HyperScout-2 payload processor were performed. A pre-existing Myriad 2 development board, was used as the base design for the AI engine, due both to its ready availability and its suitable form factor. All active components on the board were analysed for inclusion in the PhiSat-1 build, both in terms of their functional necessity, and their operational temperature range. Components that either had debug use or were associated with functionality not essential to AI inference were identified, and removed from the final custom board build. Four custom builds were completed, and basic USB connectivity and Myriad 2 operation was verified on each board. Custom libraries for performing AI inference from the HyperScout-2 payload processor were build, and inference was verified for the cloud detection Neural Network (NN) that was to be demonstrated on PhiSat-1. Hardware integration, and environmental testing, were also performed, prior to integration of the Flight Model (FM) AI engine with HyperScout-2. PhiSat-1 was launched on September 3rd 2020, and on September 23rd successfully demonstrated the

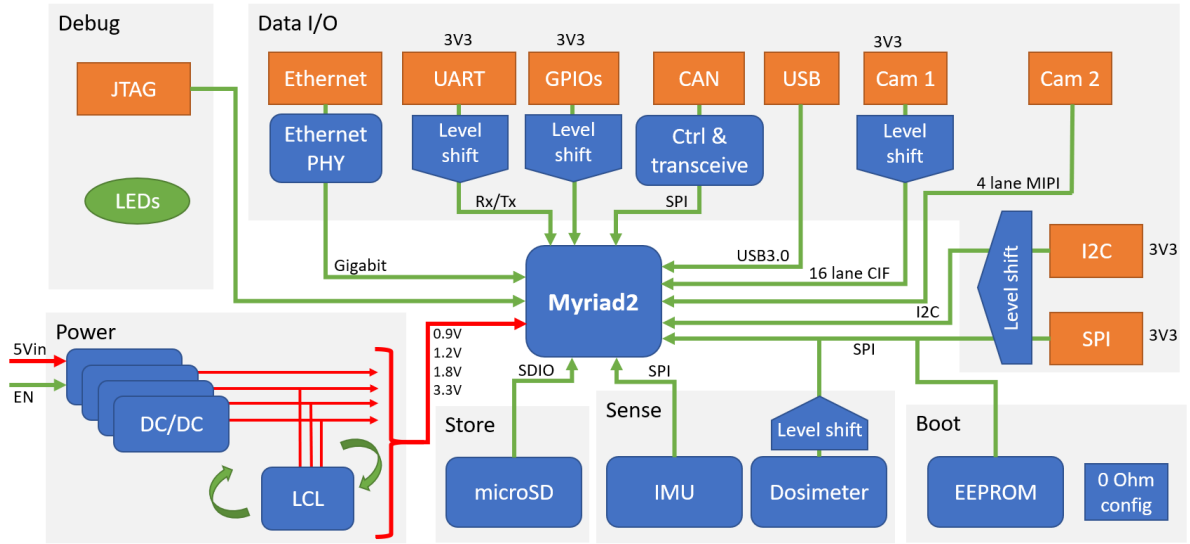

Figure 2: CubeSat-grade board functional block diagram

first ever application of on-satellite AI inference.

Contact point for marketing purposes:

Aubrey Dunne
Ubotica Technologies
DCU Alpha
Old Finglas Road
Glasnevin
Dublin D11KXN4
Ireland

aubrey.dunne@ubotica.com