KP LABS
Mission Complete

WE DELIVER AI COMPUTERS AND SOFTWARE

To bring autonomy into demanding space missions

2023/24

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INTRODUCTION

KP Labs is a leading Polish NewSpace company specializing in the development and provision of advanced **AI computers and software** for demanding space missions. Its expertise lies in creating solutions such as Data Processing Units (DPU, OBC with DPU), machine learning algorithms, and edge processing software tailored for satellite applications. With a primary focus on Earth Observation and hyperspectral data processing, KP Labs strives to deliver reliable and professional services to meet the needs of the evolving space industry.

Our mission is to accelerate space exploration by advancing autonomous spacecraft operation and robotic technology.

Our vision is to become a European Leader in delivering Autonomous Systems for space applications. We believe that space missions can be simple and self-managed. Applying Autonomy in space domains like Earth Observation or Space Robotics is an inevitable step towards reducing the cost of operations and risk of mission failure. Our goal is to make this step possible.

ESTABLISHED IN 2016

80+ SPACE ENTHUSIASTS

2300M² OF PRIVATE R&D FACILITY

GLIWICE, POLAND

COMPETENCES

Imagery

- Image processing.
- Advanced vision-based systems.

Software

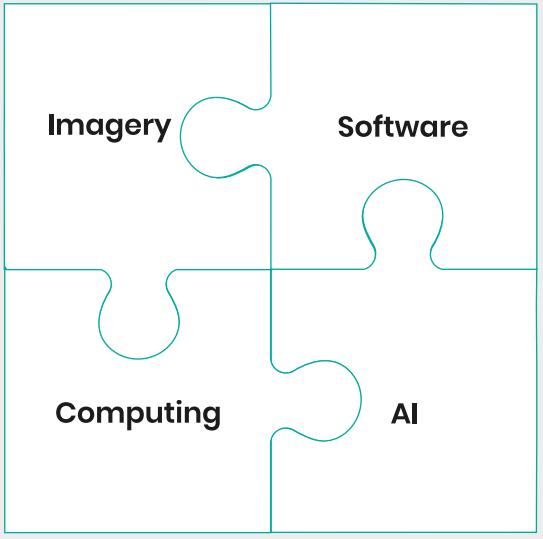
- Flight software & mission automation.
- Testing and simulation.

Computing

- High-performance computing.
- Flight computers.

AI

- Computer vision.
- Machine learning.



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MULTI-DOMAIN PROJECT EXPERTISE

Trough the implementation of wide range of different projects, we have gained valuable experience as a leader, partner or subcontractor. We support project implementation with our knowledge of software, hardware, artificial intelligence and hyperspectral imaging, in the following areas:

Electronic design:

- Schematics and PCB (high-speed circuits with FPGA, SoCs, DDR4, etc),
- Preparation of platforms for Xilinx SoCs (bitstreams +embedded linux, including Vitis AI for ML acceleration),
- FPGA IP Cores development (Xilinx, Microchip).

Software development:

- Extensive experience in software development (C, C++17, Python3, Lua, .NET, JavaScript, TypeScript),
- Experience in developing and operating flight software (PW-Sat2, KRAKsat).

Artificial Intelligence (ML&DL) and data analysis:

- Image pre-processing, super-resolution reconstruction, image analysis (focus on MSI/HSI),
- Anomaly detection in telemetry data (signal processing),
- Verification and validation.

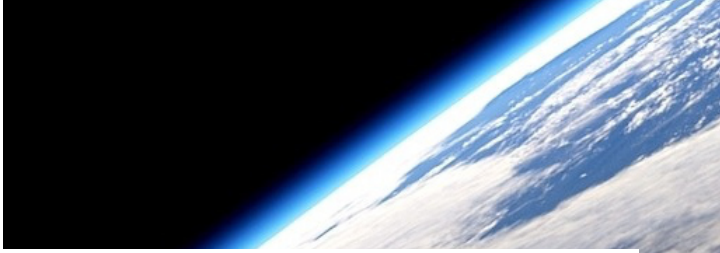
Mechanics, thermal and optic design:

- Opto-Mechanics and optics design for catadioptric optical tracks,
- Design, testing and production of thermal systems for space electronics.

Mission analysis and system engineering:

- Mission definition, ConOps and feasibility study,
- Space segment & ground segment architecture planning,
- System engineering.

TECHNOLOGY PILLARS



SPACECRAFT MANAGEMENT

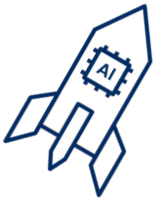
Embedded software for spacecraft operations

IN-ORBIT DATA PROCESSING

On-board extraction and data processing

SPACECRAFT AUTONOMY

Telemetry analysis and decision-making



INTUITION-1

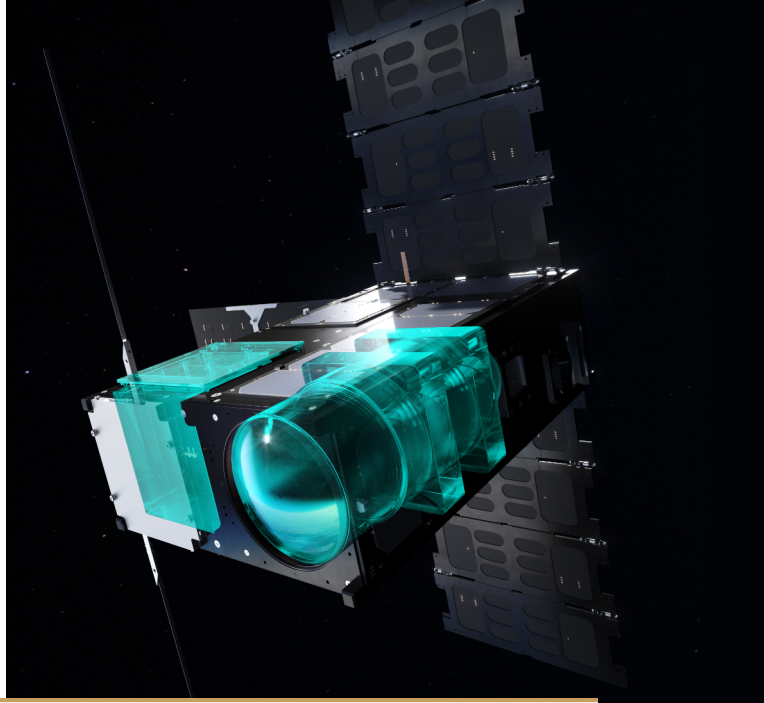
PROCESSING OF HYPERSPECTRAL IMAGES IN-ORBIT

Intuition-1 is the flagship project of KP Labs. The mission aims to bring a satellite for Earth observation into low orbit, which thanks to innovative solutions in the field of **artificial intelligence and a specially prepared on-board computer,** will automate the process of obtaining images in orbit.

The images do not need to be sent to Earth for processing, but **will be analysed on-board the satellite**, speeding up the whole process of acquiring information from the data.

Intuition-1 will be **a 6U-class satellite with a data processing unit** enabling on-board data processing acquired via a hyperspectral instrument with spectral resolution in the range of visible and near infrared light. The applied neural networks can be reconfigured during the mission to ensure adjustment to current needs. Thanks to the **neural network-based analysis** and processing of images in orbit, the amount of data sent to the ground station will be reduced by up to 100 times.

Raw frames from the spatio-spectral scanning sensor are coregistered and assembled into the **hyperspectral cube Leopard.** This hyperspectral cube is segmented using **deep convolutional networks.** The frames from all spectral ranges will have to be assembled and processed by the data processing unit – Leopard - which will also store images in a non-volatile memory. Intuition-1 will be managed by the modular software **Oryx,** and tested with **Oasis EGSE** to speed up the integration.



Intuition-1 = **Leopard DPU*** enabling on-board data processing + **The Herd** AI-powered algorithms + **Hyperspectral camera** with 192 spectral bands in the range of 465 nm - 940 nm.

* Data Processing Unit

MISSION GOALS

1 PRIMARY GOAL:
TECHNOLOGY VERIFICATION

- Flight tests of Leopard DPU, Oryx OBCS and algorithms (The Herd) for the hyperspectral data processing

2 SECONDARY GOAL:
POC FOR SOIL MAPPING PURPOSES

- Remote detection of the soil parameters such as pH, potassium, magnesium, phosphorus
- Demonstration of VIS-NIR usage feasibility for macro elements detection
- Real problems solver for the farmers - in cooperation with ESA & QZ Solutions, agritech company from Poland

DATA PROCESSED THIS WAY CAN BE USED IN NUMEROUS SECTORS, SUCH AS:

AGRICULTURE

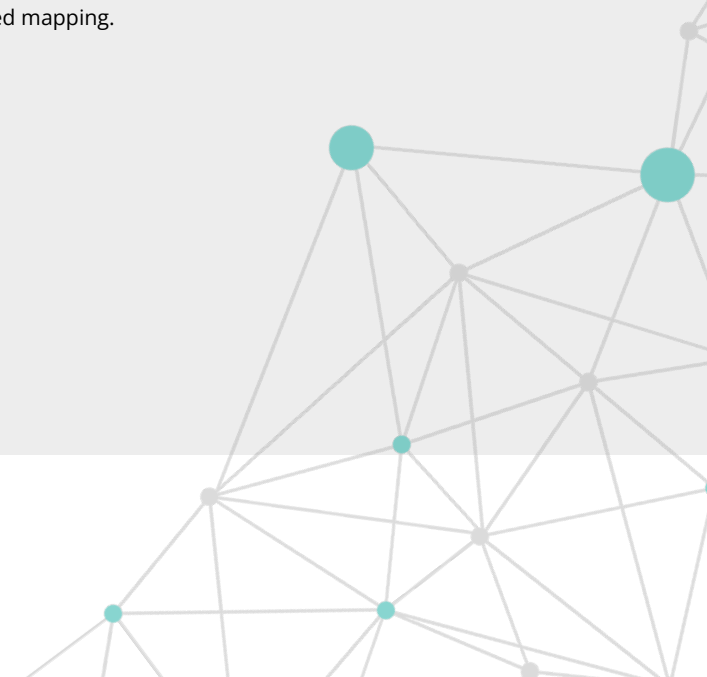
Land coverage classification, crop forecasting, crop maps, soil maps, plant disease detection, biomass monitoring, weed mapping.

FORESTRY

Forest classification, identifying species and the condition of forests, forestation planning.

ENVIRONMENTAL PROTECTION

Water and soil pollution maps, land development management and anlysis.



Intuition-1 project has been commisioned by The National Centre for Research and Development.


PRODUCTS

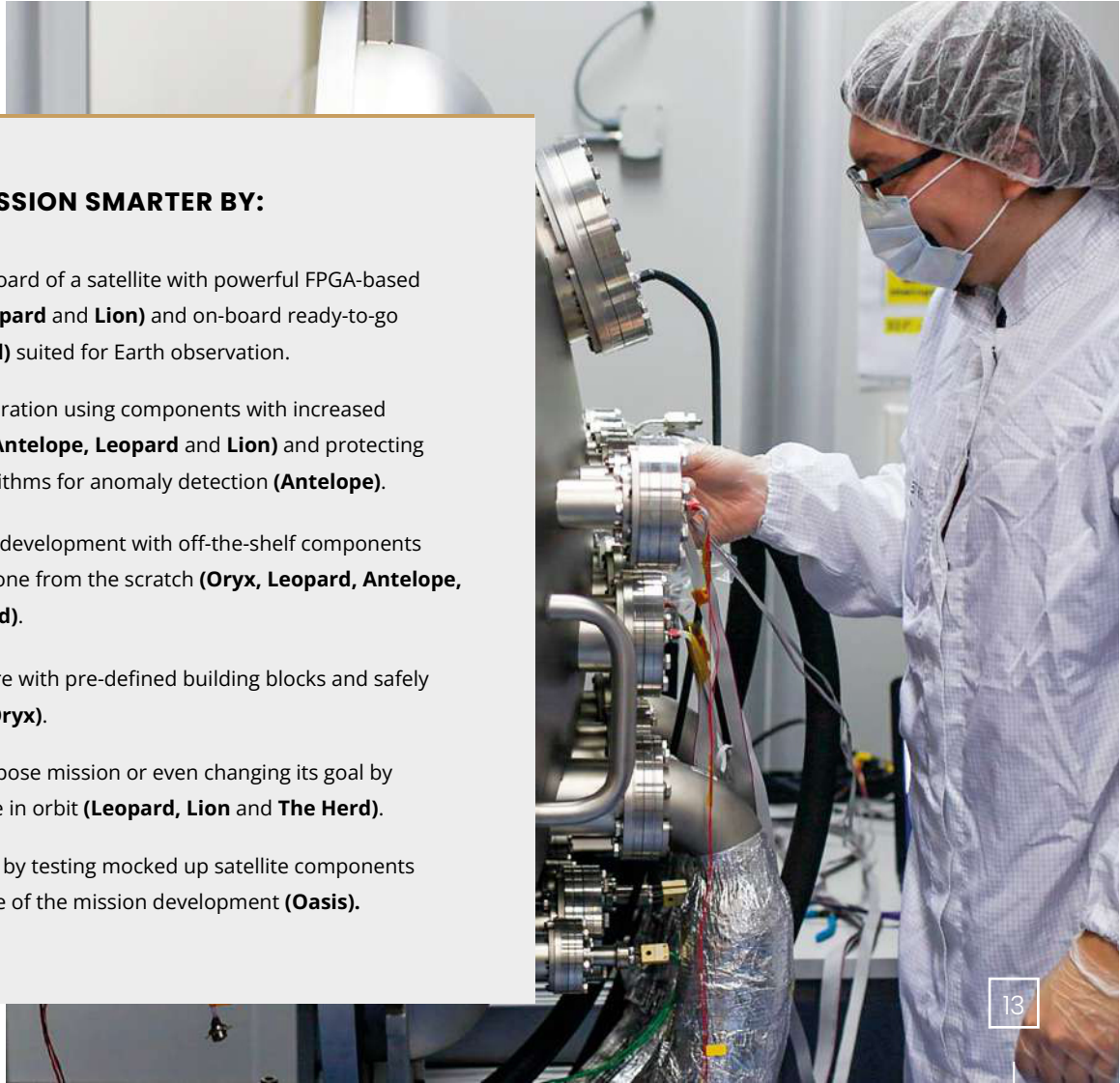
SMART MISSION ECOSYSTEM

For the mission integrators and operators who need to build advanced spacecrafts, **Smart Mission Ecosystem (SME)** brings together hardware, software and AI-powered algorithms. Unlike fragmented and unintegratable solutions, the SME was designed with the holistic approach to enable on-board data processing on the payload and satellite level, as well as to make the mission more fault-tolerant and safer.

SME supports the complete lifecycle of advanced missions from the analysis and design, through faster satellite integration thanks to the built-in algorithms, software and hardware- in-the-loop tests to the increased reliability of operations in space and the on-board data processing supported by the artificial intelligence.

MAKE YOUR MISSION SMARTER BY:

- Processing data on board of a satellite with powerful FPGA-based chips **(Antelope, Leopard** and **Lion)** and on-board ready-to-go algorithms **(The Herd)** suited for Earth observation.
- Extending mission duration using components with increased radiation tolerance **(Antelope, Leopard** and **Lion)** and protecting it with AI-based algorithms for anomaly detection **(Antelope)**.
- Speeding up mission development with off-the-shelf components instead of designing one from the scratch **(Oryx, Leopard, Antelope, Lion, Oasis, The Herd)**.
- Creating OBC software with pre-defined building blocks and safely updating it in orbit **(Oryx)**.
- Making it a multi-purpose mission or even changing its goal by reconfiguring satellite in orbit **(Leopard, Lion** and **The Herd)**.
- Saving time & money by testing mocked up satellite components at the very early stage of the mission development **(Oasis).**



Smart Mission **Ecosystem** by KP LABS Mission Complete

HARDWARE, SOFTWARE AND AI-POWERED ALGORITHMS DESIGNED TO COMPLETE YOUR MISSION

ORYX

Modular on-board software

ANTELOPE

On-board computer with data processing capabilities

LEOPARD

High-performance data processing unit for AI applications

LION

High-performance DPU for more advanced missions

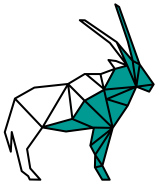
THE HERD

AI-powered algorithms for Earth Observation

OASIS

Eletrical Ground Support Equipment created to test satellite on the Earth

- Flight heritage
- Flight heritage Q4 2023



ORYX OBCS

MODULAR FLIGHT SOFTWARE TAILORED FOR YOUR MISSION

Oryx OBCS is a **modular flight software** tool developed for the mission control of small satellites. It manages all satellite tasks – namely, **processing telecommands sent by the operators, monitoring the power budget, executing pre-defined schedules, managing emergencies and handling data from all the sensors on board.**

Oryx utilises an innovative framework that facilitates the customised development of your own mission. Thanks to its **modular architecture**, based on building blocks, it supports the rapid development of the mission's software by using a vast **library of components - logging, scheduling, testing and communicationton** to name but a few.

The ease at which a testing environment and software simulator can be set up ensures in-depth evaluation of your applied solutions from the onset of the project. Should your component not be supported by Oryx, you can simply **extend your simulation by creating customised drivers.** Our on-board **software exposes an API** that can be accessed by the small Luascripts, providing access to selected sensors and peripherals, which is definitely a game changer!

Oryx is a part of **Smart Mission Ecosystem**– hardware, software and AI-powered algorithms designed to complete your mission.

FLIGHT SOFTWARE

SOFTWARE DEVELOPMENT KIT

OBCS with a set of libraries and tools supporting:

- telemetry and telecommands service,
- hardware abstraction layer,
- drivers for popular subsystems.

TESTING & SIMULATION

A framework for systems simulators and automated tests. Allows testing the flight software either locally using QEMU or by connecting to hardware engineering model (using Oasis EGSE board).

EGSE

A single-board, PC-104 compatible EGSE (Electrical Ground Support Equipment). An interface between PC-running simulators and hardware engineering model.

CASE STUDY

Oryx will be the heart of the Intuition-1 mission, which is planned for launch at the turn of 2023/24. Intuition-1 is a 6U-class satellite with a data processing unit enabling on-board data processing acquired via a hyperspectral instrument with spectral resolution in the range of visible and near infrared light.

ORYX CAPABILITIES:

Satellite management
Telemetry, tracking and command handling.

Fault detection
Isolation and recovery support.

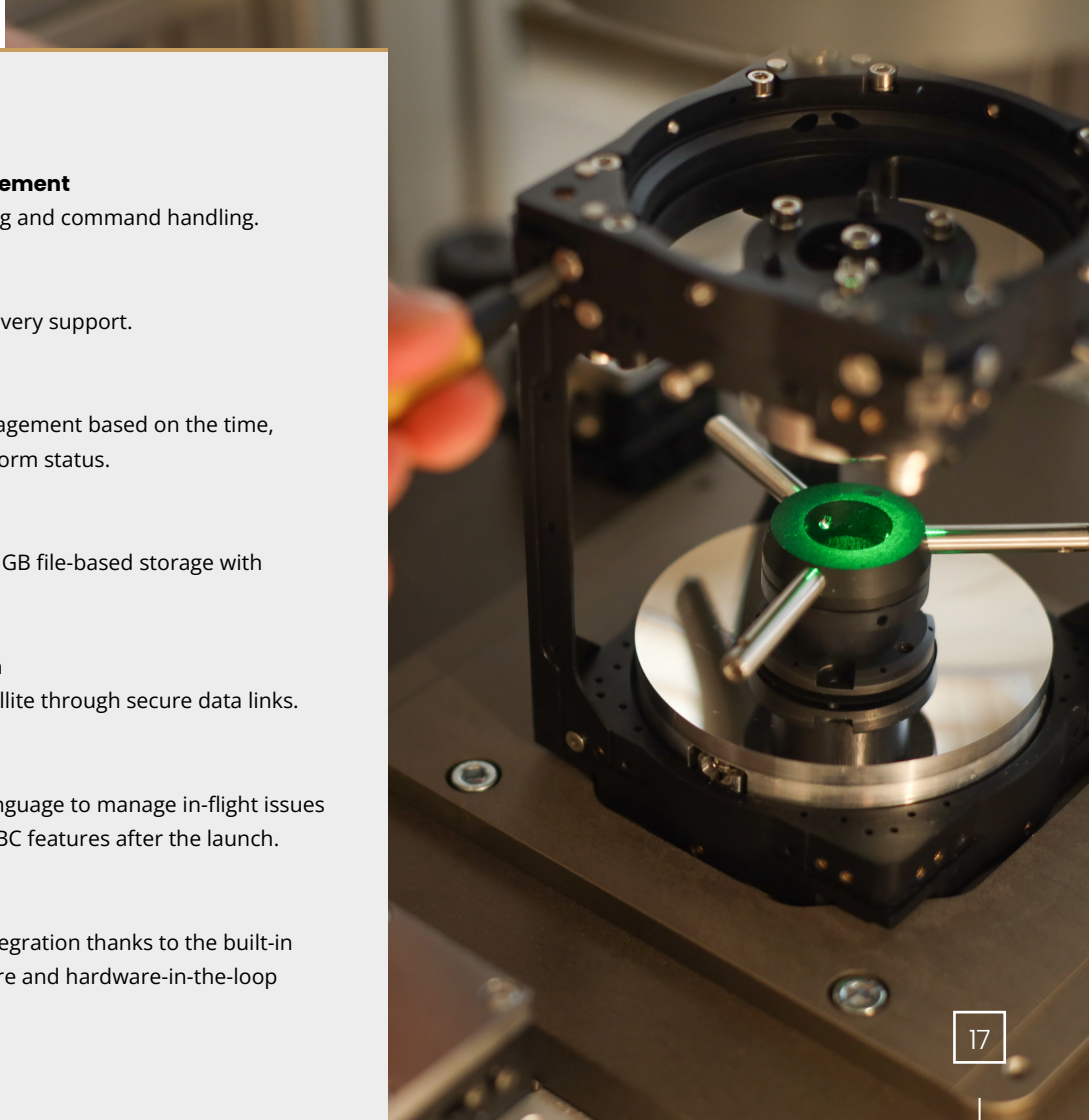
Task scheduling
Flexible task management based on the time, position and platform status.

Data storage
Managing up to 4 GB file-based storage with a short boot time.

Communication
Access to the satellite through secure data links.

Extensibility
Using scripting language to manage in-flight issues and extend the OBC features after the launch.

Testability
Faster satellite integration thanks to the built-in algorithm, software and hardware-in-the-loop tests.



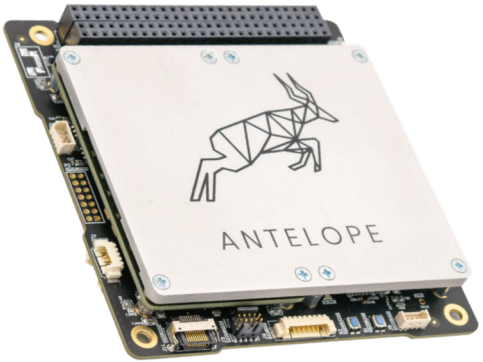
TECHNICAL SPECIFICATION	
MEMORY	▪ Min. 1 MB (code) (depending on the selected features) ▪ Min. 1 MB (data) (depending on the selected features)
SUPPORTED MCU's	▪ ARM Cortex-M, ARM Cortex-R
RECOMMENDED MINIMUM CLOCK	▪ 50 MHz
STORAGE	▪ Data storage: NAND flash memory up to 4 GB ▪ High reliability FRAM-based storage
DEVELOPMENT TOOLS	▪ Open-source, cross-platform tools: CMake, GCC, Python ▪ Modern technologies: C++17
GROUND SOFTWARE SUPPORT	▪ XTCE and SEDS-compiliant spacecraft database ▪ YAMCS integration ▪ Easy integration with any MCS during the whole process (from mission development to in-orbit operations)

TECHNICAL SPECIFICATION cont.	
SUPPORTED OFF-THE-SHELF SUBSYSTEMS	▪ Kryten M3 by ACC Clyde Space ▪ EPS (STARBUCK) + Batteries by ACC Clyde Space ▪ ADCS by ACC Clyde Space ▪ UHF Transceiver by CPUT ▪ Leopard DPU by KP Labs ▪ UVTRX by ISIS ▪ IMTQ by ISIS ▪ ANT module by ISIS ▪ uCam III camera module by 4D Systems ▪ Q20 HD GPS by QinetiQ and all NMEA-based receivers ▪ EWC27-SRX X/S Transceiver by Syrlinks ▪ Easy to add support for any subsystem using I2C, UART, CAN, SPI
GROUND SEGMENT COMMUNICATION	▪ AX.25 based modules ▪ S/X stream-based modules (CCSDS compliant) ▪ Flexible communication stack ▪ Optional: encryption, authentication

ANTELOPE

ON-BOARD COMPUTER OR DATA PROCESSING UNIT? YOU CHOOSE!

Antelope has two versions and can work as an **On-Board Computer (OBC)** with an optional **Data Processing Unit (DPU)** or as a **DPU** payload module. OBC is the powerful heart of the satellite, responsible for satellite control and basic task performance such as communication handling, monitoring the satellite's subsystems, handling the classic **Fault Detection, Isolation and Recovery (FDIR)** mechanism and performing planned tasks. Thanks to the powerful **FPGA system (160 GOPS)** DPU can also handle complicated on-board data processing tasks enabling Earth Observation (EO), telecommunication and other demanding data processing applications.



Antelope is a perfect solution for anyone who wants to run their algorithms and perform data or signal processing on board. This DPU gives infinite possibilities when it comes to processing in space – the analysis of images from cameras connected to Antelope or telemetry from other satellite's subsystems has never been so easy. Additionally, Antelope can be equipped with SATA SSD extra storage that allows to keep all the data needed for the smooth space missions' completion. You can also use algorithms from The Herd by KP Labs that are 100% compatible with this solution.

Antelope is part of the **Smart Mission Ecosystem** –hardware, software and AI-powered algorithms designed to complete your mission.

CASE STUDY

Antelope will be utilized by the PW-Sat3 satellite, coupled with KP Labs's on-board computer software - Oryx. **PW-Sat3** is an in-orbit demonstrator of a new cold gas propulsion and is planned to be launched in late 2024. Antelope will be responsible for satellite management and mission safety.

KEY ADVENTAGES:

1 Mission Safety

- 20 kRad tolerance and SEE protections.
- Classic FDIR mechanisms.
- Optional Artificial Intelligence for preventive failure detection of all types of anomalies: point, contextual, collective.

2 Mission Power

- 160 GOPS of computing power enables exciting possibilities in Earth observation, telecommunication and AI-based applications.

3 Mission Extensibility

- Compatibility with Leopard Data Processing Unit. By pairing Antelope and Leopard you can extend the on-board processing power by 3000 GOPS to enable the processing of more demanding calculations.

OBC TECHNICAL SPECIFICATION	
PROCESSING CORES	RM57 Hercules microcontroller: ▪ Dual 300 MHz ARM Cortex-R5F with FPU in lock-step
MEMORY	▪ 8 or 16 MB of MRAM ▪ 64 MB of redundant NOR ▪ 4 or 8 GiB SLC flash-based filesystem NAND storage with ECC
INTERFACES	▪ Interfaces: CAN, I2C, GPIO, SPI, RS422/485, UART, GPS PPS
SPECIFICATIONS	▪ Supply Voltage: 6 to 14 V (VBAT) or 5V regulated ▪ Operating Temperature: -40 to 85 °C ▪ Supercap-powered RTC
SOFTWARE ECOSYSTEM	▪ Custom embedded software ▪ KP Labs's On-board Computer Software - Oryx
FORM-FACTOR	▪ PC-104 board

DPU TECHNICAL SPECIFICATION	
PROCESSING CORES	Equipped with Zynq UltraScale+ MPSoC ZU2/ZU3/ZU4/ZU5: ▪ Quad ARM Cortex-A53 CPU up to 1.5 GHz ▪ Dual ARM Cortex-R5 in lock-step ▪ FPGA for custom function implementation
MEMORY	▪ 8GiB DDR4 with ECC ▪ 4 GiB SLC NAND Flash ▪ Optional SATA SSD
INTERFACES	▪ Interfaces: LVDS, SPI, USB 2.0, USB 3.0, UART, CAN, Ethernet, GTH transceivers ▪ LVDS interfaces compatible with X/S-Brand radios and CCSDS-compatible communication channel upon request
SPECIFICATIONS	▪ Supply Voltage: 6 to 14 V (VBAT) ▪ Operating Temperature: -40 °C to 85 °C ▪ FPGA bitstream (reconfigurable in orbit)
SOFTWARE ECOSYSTEM	▪ 64-bit Linux or bare-metal applications
FORM-FACTOR	▪ Daughterboard - 70 mm x 40 mm

LEOPARD DPU

A NEW CHAPTER IN ON-BOARD DATA PROCESSING

Leopard is a CubeSat standard compliant Data Processing Unit which enables mission designers to apply Artificial Intelligence solutions in space. It was designed to support capturing, managing and processing of data in orbit. Leopard redefines the current approach to remote sensing. Now, instead of sending huge, unprocessed sets of data to ground stations, Leopard uses **Deep Neural Networks** to process data on-board and therefore only sends the most important and valuable insights to the ground. By reducing the time and cost of data transfer and processing, it enables you to focus on a rapid response to any detected phenomena.

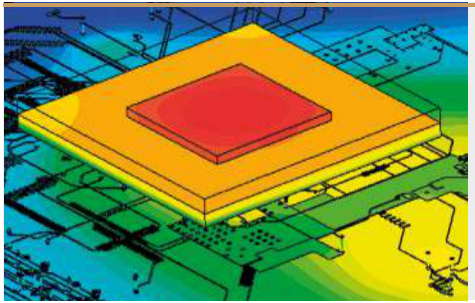
Leopard is integrated with a powerful FPGA to accelerate execution of deep learning algorithms and has a through put of up to **3 Tera Operations Per Second.** A number of hardware and software measures protect the computer against the influence of radiation.

With its extraordinary capabilities-to-size ratio **(less than 1U)**, wide supply voltage range and universal interfaces, it is compatible with most CubeSats platforms. Its scalable and customisable architecture makes it possible to create larger and more powerful versions dedicated to bigger platforms as well.

CASE STUDY

Leopard will be utilized by the Intuition-1 satellite, coupled with a **192-band hyperspectral sensor** to perform image segmentation and object detection. For the purpose of on board data processing during the mission, we will use two high performance nodes for redundancy and parallel operation. **The launch of Intuition-1 is planned at the turn of 2023/2024.**

TECHNICAL SPECIFICATION	
PROCESSING CORES	Zynq UltraScale+ MPSoC **ZU6EG I ZU9EG I ZU15EG** ▪ Quad ARM Cortex-A53 CPU up to 1.5 GHz ▪ Dual ARM Cortex-R5 in lock-step ▪ FPGA for custom function implementation
MEMORY	▪ 4-16 GiB DDR4 providing with ECC ▪ 4-16 GiB SLC flash-based file system storage (EDAC) ▪ Up to 2x256 GiB SLC flash-based data storage
INTERFACES	▪ Interfaces: CAN, LVDS, SPI, RS422/485, UART, GTY and GTH transceivers ▪ Additional customisable interfaces upon request: SpaceWire, Ethernet ▪ LVDS/RS422 interfaces compatible with X/S-Band radios and CCSDS-compatible ▪ Communication channel upon request
SPECIFICATIONS	▪ A radiation hardened Payload Controller ▪ Supply Voltage: 6.5 to 14 V (VBAT) ▪ Power Consumption: 7.5 W to 40 W - depending on workload and specified processing speed ▪ Computational Throughput for Neural Networks: up to 3 TOPS ▪ Thermal interface customisable for satellite architecture
SOFTWARE ECOSYSTEM	▪ 64-bit Linux ▪ Deep Learning Accelerator fed with Caffe or TensorFlow models ▪ Fully reconfigurable in orbit
REDUNDANCY	▪ Possibility to introduce additional redundancy to each version
FORM-FACTOR	▪ PC-104 board

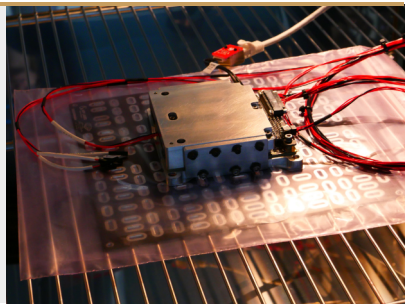


THERMAL MANAGEMENT OF ELECTRONICS

Our Engineers and Scientists pay special attention to all the demanding requirements which stem from the application environment. We ensure maximum care of the proper thermal management of IC components and system-level behaviour to safeguard reliability in terms of the space mission lifetime.

MECHANICAL ENCLOUSURES FOR ELECTRONIC SYSTEMS

Our electronic products are supported by exclusively designed housings that take into account: required mechanical vibration resistance, form factor and coatings. We perform a wide spectrum of environmental tests which can satisfy the challenging expectations of our customers.



LION DPU

MORE AI POWER LOCKED IN THE HARDWARE

Lion is a **data processing unit for advanced operations** with the use of artificial intelligence and on-board data processing. The Lion DPU is dedicated to micro and small satellites weighing **between 50 and 500kg.**

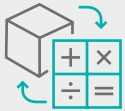
Lion is developed to process multi-dimensional and multi-sensor data in orbit and is composed of high-performance COTS components that satisfy the processing power, high reliability and memory bandwidth demands for a wide range of missions. Combined with **The Herd** (our library of AI-powered on-board data processing algorithms), this technology will connect the eyes (sensors) with the brain (DPU), thus enabling artificial intelligence to ensure **autonomous decision making in situ.**

It supports challenging activities allowing, for example, close-proximity operations through vision-based relative navigation between two spacecrafts for active debris removal or in-orbit servicing.

The Lion DPU hardware platform is composed ofthe Kintex Ultrascale FPGA with an accompanying external supervisor which provides **single-event effects (SEE) andsingle-event functional interrupt (SEFI) protections,** including configuration memory scrubbing and specialized watchdogs.

Thanks to the built-in bootloader, the external supervisor can update itself and reprogram the Kintex Ultrascale FPGA in-flight. Lion is also equipped with up to 8 GiB of DDR4, up to 16 SLC NAND Flash and up to 1 TiB of SSD storage. The developed thermal storage system can extend theon-orbit operation of the DPU to **at least five years.**

LION IS BUILT OUT OF 3 KEY ELEMENTS:



Data Processing Unit

The DPU allows uninterrupted operation in orbit. Thanks to being equipped with specialised components it is **able to perform continuous and dynamic correction of errors** which may occur in space.

Thermal Accumulation System

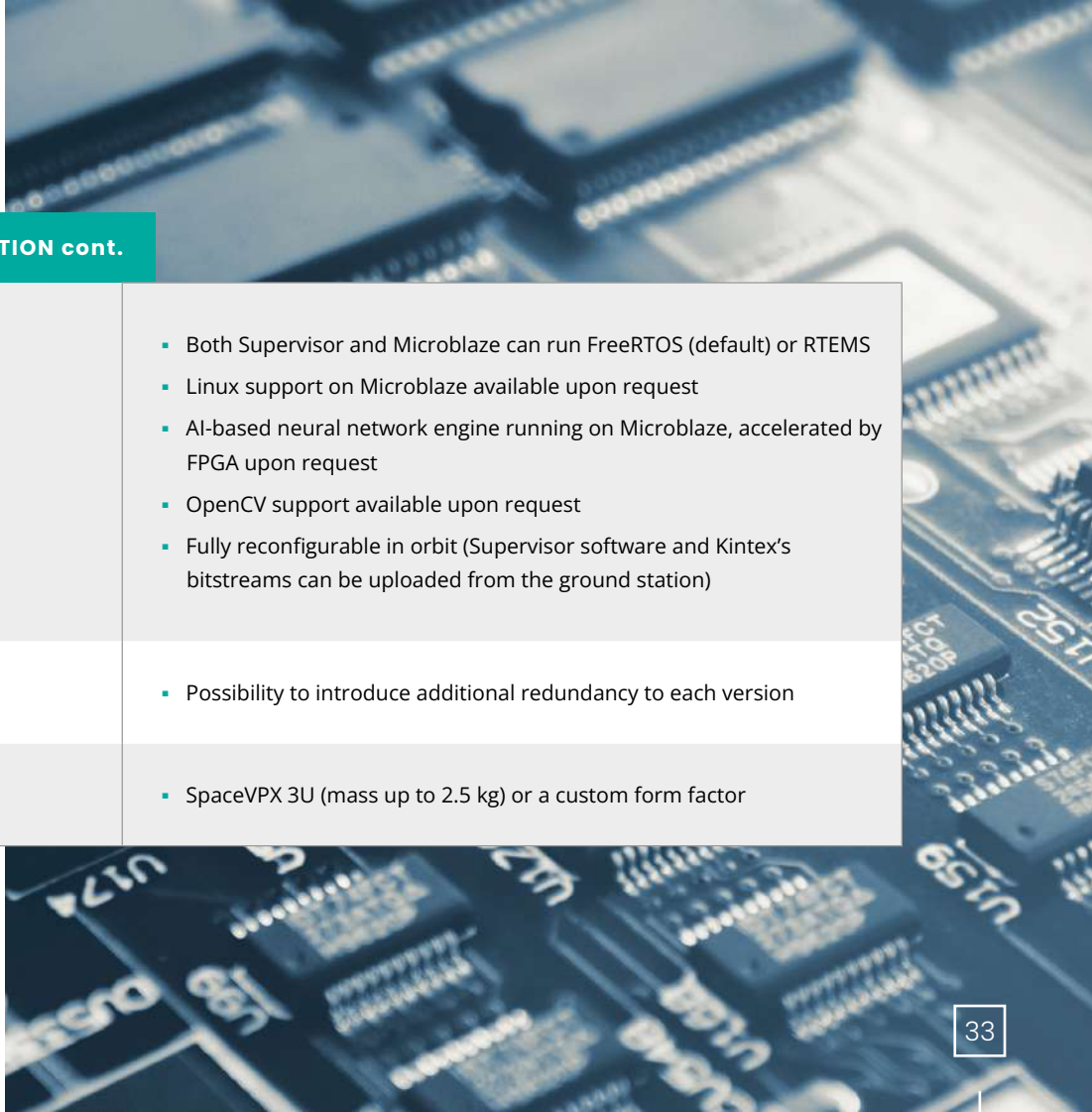
The system **reduces the adverse effects of temperature cycling** on the risk of failure. The optional Phase Change Material-based TCS **enables the averaging of temperatures and thus prolongs lifetime.**

Customised DPU management software

The customised software delivers the following: smooth communication with other satellite subsystems; **telemetry data collection, monitoring and provision; the management and running of data processing algorithms** provided by the customers.

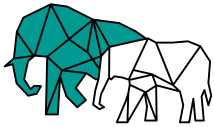
TECHNICAL SPECIFICATION

PROCESSING CORES	Xilinx Kintex Ultrascale FPGA **KU035 I KU040 I KU060** ▪ Kintex Ultrascale FPGA for custom function implementation ▪ Optional Microblaze soft-core running on Kintex equipped with an external 4 MiB of MRAM in which the application software may be loaded by an external supervisor ▪ 3x64 MiB of NOR Flash to store FPGA bitstreams ▪ Multiple FPGA bitstreams can be stored and selected for in-flight loading
MEMORY	▪ 2-8 GiB DDR4 providing with ECC ▪ 4-16 GiB SLC flash-based file system storage (EDAC) ▪ Up to 4x256 GiB SLC flash-based data storage (possible redudancy)
INTERFACES	▪ Exposed interfaces: CAN, LVDS, SPI, RS422/485, UART , GTH transceivers ▪ Additional customisable interfaces upon request: SpaceWire Lite, SpaceWire RMAP, Gigabit Ethernet ▪ LVDS/RS422 interfaces compatible with X/S-Band radios ▪ CCSDS-compatible IP-cores for X/S/Ku-Band radios upon request
SPECIFICATIONS	▪ Up to 15W at the KU035 version with the option of scaling up for a more powerful FPGA ▪ TID resistance - minimum 20kRad ▪ Embedded SEU and SEFI mitigation techniques – MRAM-equipped supervisor, Kintex's CRAM scrubbing by external supervisor, SEFI detection, RAM scrubbing, etc. ▪ Thermal control system for SpaceVPX version heatsink with wedge locks that provide a thermal interface to a carrier box ▪ Client-driven customisation available upon request ▪ A PCM-based thermal control system available upon request



TECHNICAL SPECIFICATION cont.

SOFTWARE ECOSYSTEM	▪ Both Supervisor and Microblaze can run FreeRTOS (default) or RTEMS ▪ Linux support on Microblaze available upon request ▪ AI-based neural network engine running on Microblaze, accelerated by FPGA upon request ▪ OpenCV support available upon request ▪ Fully reconfigurable in orbit (Supervisor software and Kintex's bitstreams can be uploaded from the ground station)
REDUNDANCY	▪ Possibility to introduce additional redundancy to each version
FORM-FACTOR	▪ SpaceVPX 3U (mass up to 2.5 kg) or a custom form factor



THE HERD

AI-POWERED ALGORITHMS TO PREPARE AND ANALYSE EARTH OBSERVATION DATA

The Herd is a set of **AI-powered algorithms designed to facilitate Earth Observation data analysis.** It comprises three elements – data pre-processing techniques, approaches to spatial resolution enhancement of image data, and data analysis algorithms. The Herd fully supports the EO processing chain – from optical data acquisition, through data preparation and manipulation, up to data classification, segmentation, unmixing, compression, and much more.

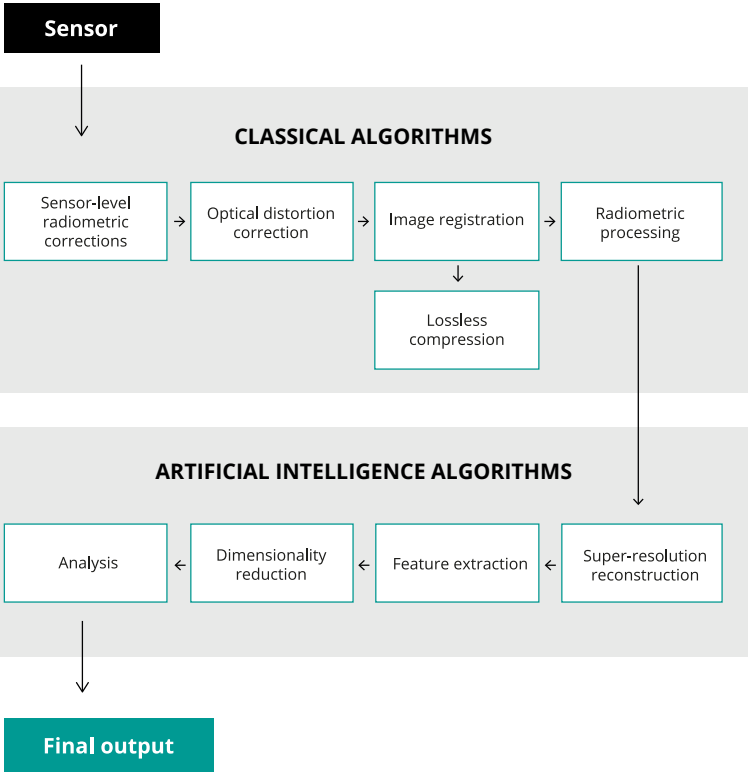
All key elements of The Herd were designed to be used both on Earth and on-board the satellite – they fit FPGA processors and are compatible with the Xilinx-based Data Processing Units.

The full power of The Herd can be unchained in high-dimension al data analysis – it handles hyperspectral, multispectral, and time-series data.

WHAT OUR ALGORITHMS CAN DO?

- Image pre-processing.
- Super-resolution reconstruction.
- Image analysis.
- Thorough quantitative, qualitative & statistical validation.

THE HERD FULLY AUTOMATES THE FOLLOWING STEPS OF THE PROCESSING CHAIN:



CASE STUDY

The Herd will be used in the Intuition-1 mission, which is planned for launch **at the turn of 2023/2024.** Intuition-1 is a 6U-class satellite with a data processing unit – Leopard – enabling on-board data processing acquired via a hyperspectral instrument with spectral resolution in the range of visible and near infrared light.

OASIS EGSE

TEST MOCKED-UP SATELLITE COMPONENTS FROM THE INITIAL STAGE OF THE MISSION DEVELOPMENT

Oasis is a single-board, CubeSat PC-104 compatible **electrical ground support equipment** that serves as an interface between the PC-running satellite systems simulators and the hardware engineering model. It **enables the running of a complete flight version of on-board computer software on actual hardware before the subsystems are physically present.**

Safety is crucial while developing space missions. Thanks to Oasis, it is possible to **integrate and validate the work of satellite subsystems before launch** and guarantee their smooth opera tion in orbit. Testing a mocked-up satellite and continuous inte gration at the initial stage of the mission development is crucial to ensure faster spacecraft integration – saving time and money.

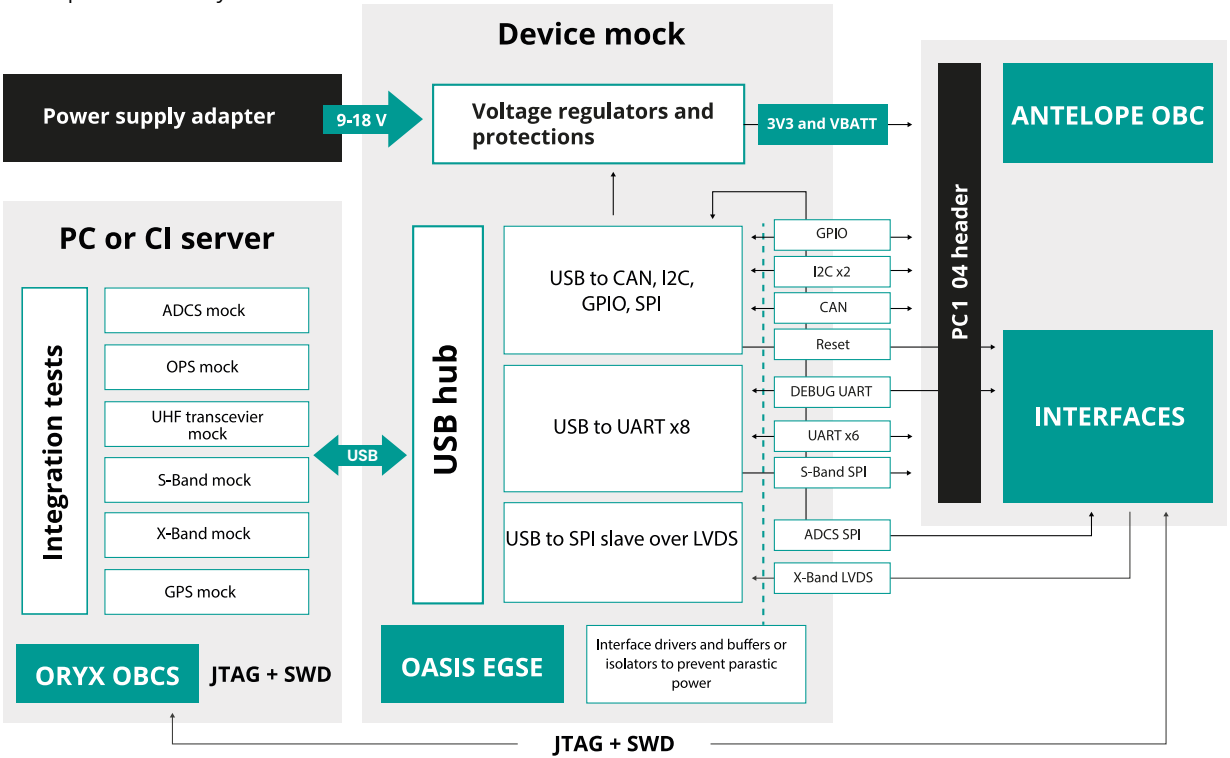
CASE STUDY

Coupled with the Antelope on-board computer, Oasis will be utilized to develop the PW-Sat3 mission. Oasis will support testing mocked up satellite components from the very early stages of the mission development and Antelope will be responsible for satellite manage ment and the mission safety. **PW-Sat3 is an in-orbit demonstrator of a new cold gas propulsion and is planned to be launched in late 2024.**

OASIS SETUP:

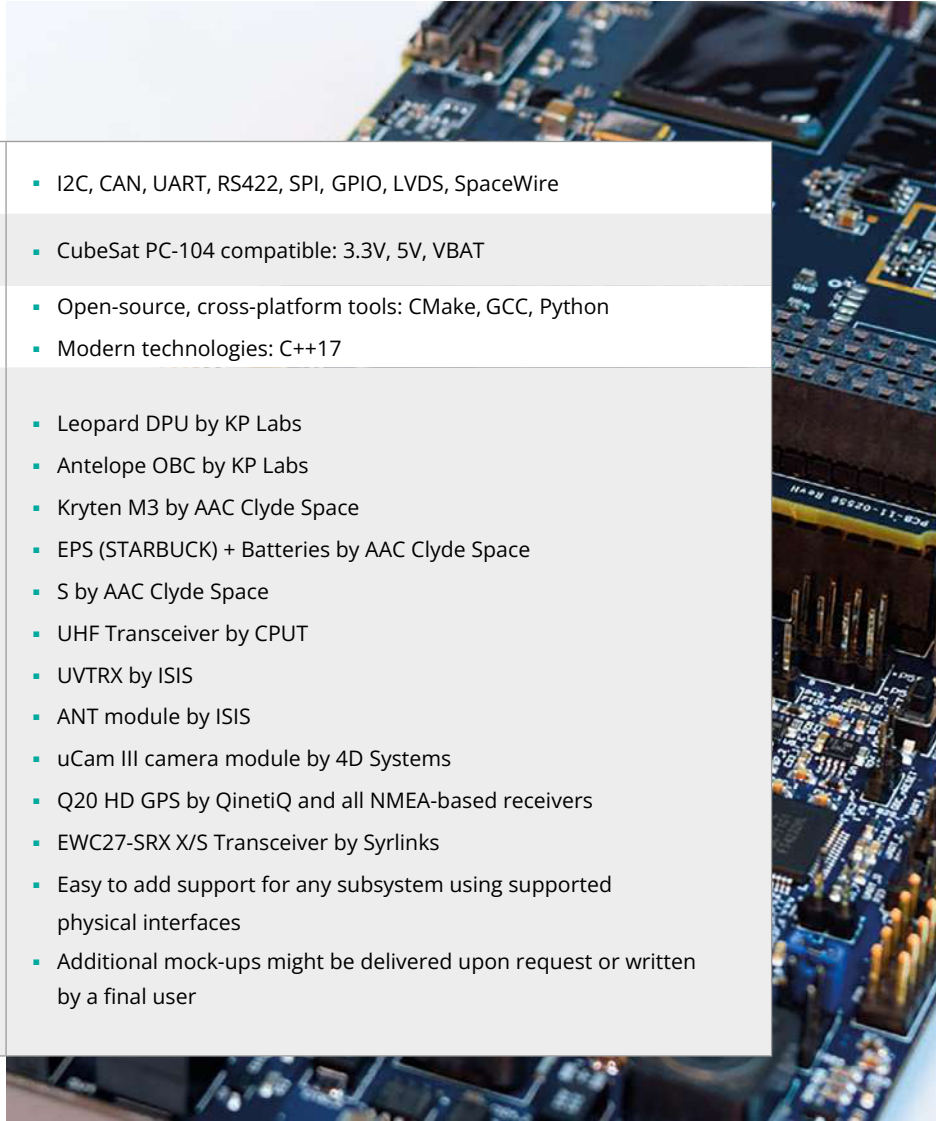
Oasis can be setup with other KP Labs' subsystems –

Antelope OBC and Oryx OBCS.



TECHNICAL SPECIFICATION

SUPPORTED PHYSICAL INTERFACES	▪ I2C, CAN, UART, RS422, SPI, GPIO, LVDS, SpaceWire
AVAILABLE CONTROLLED SUPPLY LINES FOR A TESTED BOARD	▪ CubeSat PC-104 compatible: 3.3V, 5V, VBAT
DEVELOPMENT PLATFORM	▪ Open-source, cross-platform tools: CMake, GCC, Python ▪ Modern technologies: C++17
SUPPORTED OFF-THE-SHELF SUBSYSTEMS	▪ Leopard DPU by KP Labs ▪ Antelope OBC by KP Labs ▪ Kryten M3 by AAC Clyde Space ▪ EPS (STARBUCK) + Batteries by AAC Clyde Space ▪ S by AAC Clyde Space ▪ UHF Transceiver by CPUT ▪ UVTRX by ISIS ▪ ANT module by ISIS ▪ uCam III camera module by 4D Systems ▪ Q20 HD GPS by QinetiQ and all NMEA-based receivers ▪ EWC27-SRX X/S Transceiver by Syrlinks ▪ Easy to add support for any subsystem using supported physical interfaces ▪ Additional mock-ups might be delivered upon request or written by a final user




PROJECTS

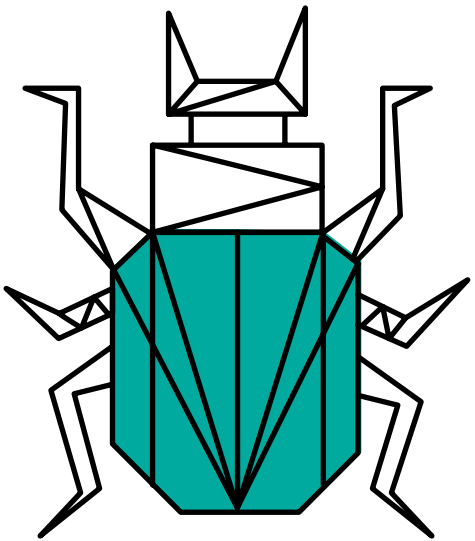
ARTIFICIAL INTELLIGENCE

BEETLES

ROBUST AND RESOURCE-FRUGAL DEEP NEURAL NETWORKS FOR HYPERSPECTRAL IMAGE SEGMENTATION

Project purpose: The objective of this project is to design, implement, and evaluate deep learning algorithms for effective hyperspectral image analysis that are ready to be deployed in target hardware environments, and are robust against noise, low-quality image data and other real-life acquisition settings.

Project output: KP Labs developed a battery of deep learning-powered algorithms that allow us to build robust and hardware-efficient hyperspectral image analysis pipelines (especially hyperspectral image segmentation and unmixing) that generalize well over unseen data. The algorithms are use case agnostic and may be easily exploited in emerging applications, hence significantly accelerating the adoption of on-board deep learning for Earth observation.



Project implementation: KP Labs.

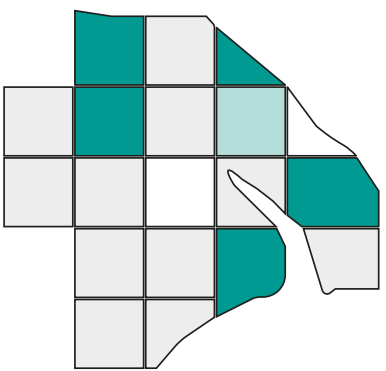
Project duration: 04.2020 - 05.2021.

Project commissioner: The European Space Agency.

GENESIS

ESTIMATING MACROELEMENTS AND PH IN SOIL WITH THE USE OF ON-BOARD DEEP LEARNING AND HYPERSPECTRAL IMAGES

Project purpose: Farmers and field owners need information about the soil parameters to optimize the fertilization process. This may ultimately lead to a selecting a better mix of fertilizers, and a reduction in their the overall amount of use. The current approach toward quantifying the soil parameters (e.g., macro elements) is very user-dependent, laborious, time-consuming, vastly manual – we have to gather and mix soil samples in the field and pass them to the lab for further chemical analysis. Also, this process does not allow us to accurately capture the information concerning the macroelements, and the number of sampling points in the field is commonly limited.



Project output: KP Labs and QZ Solutions intend to use the hyperspectral data to remotely detect soil parameters (specifically: potassium – K2O, phosphate – P2O5, magnesium – Mg and pH) using machine learning techniques.

Project implementation: KP Labs + QZ Solutions.

Project duration: 06.2021 - 06.2022.

Project commissioner: The European Space Agency.

Φ-SAT-2

ESA CUBESAT MISSION

Project purpose: The objective of this project is to develop a new generation Artificial Intelligence (AI) satellite mission for the European Space Agency - ESA. The Φ-sat-2 mission will be used to demonstrate the AI enabling capability for new useful innovative EO techniques of relevance to EO user communities. The overall objective is to address innovative mission concepts, foster novel architectures or sensors that enable the realisation of user-driven science and/or applications by means of onboard processing. The latter will be based on state-of-the-art AI techniques and onboard AI-accelerator processors.

Project output: During its phase of the Project, KP Labs will develop and implement Cloud Detection app based on the Convolutional Neural Networks.

Project implementation: KP Labs.

Project duration: 06.2021–06.2023.

Project commissioner: The European Space Agency.

AI-DRIVEN IMAGE PROCESSING AND SUPER-RESOLUTION RECONSTRUCTION

SATELLITE IMAGE SPATIAL RESOLUTION ENHANCEMENT

Project purpose: The project's primary purpose is to advance the field of artificial intelligence-based image processing, specifically focusing on the enhancement and analysis of satellite imagery. The project aims to develop innovative methodologies and algorithms to address various challenges in this domain, including hyperspectral image analysis, noise-resistant deep learning, soil parameter estimation, and super-resolution reconstruction. Furthermore, it aims to facilitate objective benchmarking and evaluation of image analysis and super-resolution algorithms in the context of Earth observation tasks.

Project duration: 2017 - 2023

6 projects financed by the European Space Agency.

Project output:

- Advanced image analysis algorithms for hyperspectral and multispectral satellite data.
- Comprehensive validation pipeline for benchmarking image analysis algorithms.
- Noise-resistant deep learning algorithms and hardware-efficient pipelines.
- Machine learning techniques for soil parameter estimation from hyperspectral data.
- Successful organization of the HYPERVIEW Challenge at IEEE ICIP 2022.
- Super-resolution algorithms for enhancing spatial and spectral resolution in satellite imagery.
- Evaluation pipelines and benchmark datasets for assessing super-resolution algorithm performance.

SATELLITE TELEMETRY ANALYSIS AND ANOMALY DETECTION

Project purpose: The overarching purpose of this project is to advance the field of signal processing and anomaly detection through the application of artificial intelligence. Through practical projects and collaborative efforts, the project seeks to build expertise and competence in this domain.

Project duration: 2020 - 2024.

Financed by: the Polish National Center for Research and Development and the European Space Agency.

Project output:

- Advanced Anomaly Detection Systems for multi-channel satellite telemetry data.
- Application of Few-Shot Learning techniques to enhance anomaly detection adaptability.
- Successful On-board Implementation of Anomaly Detection Algorithms on OPS-SAT and Intuition-1 missions.
- Development of Visualization Tools (oxi.kplabs.pl) and Benchmarking Datasets (ESA Anomalies Dataset) for critical assessment of anomaly detection techniques.

HARDWARE

LION DPU

Project purpose: The primary aim of the Lion DPU project is to revolutionize the capabilities of on-board data processing in satellites weighing up to 500kg. As the market for small satellite missions expands rapidly due to their reduced costs and mission flexibility, there's a pressing need for reliable and efficient data processing units. Lion DPU seeks to meet this need, offering a backplane-standardized solution designed for missions akin to ESA Class IV and feasible for Class III requirements.

Project output:

- **Efficient On-board Data Processing:** The Lion DPU will stand out by supporting demanding missions like the Clearspace-1, providing high-performance and reliable on-board data processing.
- **Longevity and Reliability in Orbit:** Thanks to its radiation protection measures and advanced thermal management system, the Lion DPU promises at least 5 years of uninterrupted operation in space. This, coupled with its quality housing that meets aerospace industry standards, assures that it will withstand space's harshest conditions.
- **Affordability and Accessibility:** One of the key takeaways is that the Lion DPU will harness commercially available, affordable components. By blending innovative design with "off-the-shelf" components, the project aims to deliver a high-reliability product at a reduced cost, making it an attractive solution for a broad spectrum of customers.

Project duration: 2021 - 2023.

Financed by: Polish National Center for Research and Development.

MICRO-G DISTURBANCE CHARACTERIZATION AND MITIGATION IN PULSATING HEAT PIPES (MITIGATE)

Project purpose: The goal of this project is to understand the mechanics of Pulsating Heat Pipes (PHPs) and the intricate thermo-fluid dynamics they exhibit. This involves studying design intricacies to cool down electronics and enhancing the thermal performance of hardware components.

Project output: The results of the project will provide experience in designing cooling solutions for space applications. Through a comprehensive set of tasks and a robust evaluation framework, the use of PHP will help improve the reliability of our products and enable our hardware to achieve better computing performance.

Project duration: 2023 - 2025.
Financed by: European Space Agency.

Techniques applied:

- **Thermo-fluid Analysis:** Conducting detailed studies on the fluid behavior and heat transfer within PHPs.
- **Design Engineering:** Adjusting the internal and external structures of PHPs to achieve the best thermal performance
- **Testing:** Thermal testing of various PHP breadboards including tests in thermal vacuum chamber (TVAC) to verify the performance expectations in spacelike environment

OPS-SAT VOLT

Project purpose: The goal of the mission is to demonstrate various products and services at the Versatile Optical Laboratory for Telecommunications. The payload consists of a Quantum Classical Optical Communications Transceiver, an AI computer, and a hyperspectral Imager developed by a British consortium led by CPL and KP Labs in Poland. The mission aims to conduct several demonstrations of capabilities in providing quantum keys, optical communications, and hyperspectral image capture for climate resilience applications.

Project duration: 2023 - 2025.

Financed by: the European Space Agency.

Project output: The OS2-VOLT mission is expected to be a significant advancement in the space field, demonstrating the potential for quantum key delivery and onboard artificial intelligence processing. It aims to demonstrate end-to-end services using optical communications, integrate space segments with rapidly deployed Nomadic OGS, and demonstrate the added value of autonomy, artificial intelligence, and machine learning systems.

SOFTWARE

GLOBAL SOLAR WIND STRUCTURE (GLOWS)

Project purpose: The goal of this project is to understand the global structure of the solar wind and observe its evolution throughout the solar cycle. Operating as an experiment under NASA's IMAP (Interstellar Mapping and Acceleration Probe) mission, GLOWS aims to scrutinize the distribution of interstellar neutral hydrogen and investigate the influence of solar radiation on ISN H. The project is led by the Space Research Centre of the Polish Academy of Sciences. GLOWS will launch in 2025 and will operate in the L1 Lagrange point.

Project output: The software developed will facilitate efficient data collection, providing accurate insights into the global structure of the solar wind and its interaction with neutral interstellar hydrogen. It will also play a key role in handling telemetry operations, providing robust support for the satellite during its mission.

Techniques applied:

- **Onboard Software Development:** Developing onboard software tailored for the satellite's ultraviolet photometer. This software will manage telecommand and telemetry, supporting various operational modes for data collection and analysis.
- **Hardware/Software Interface Integration:** Creating key interfaces between the GLOWS hardware platform and software to ensure reliable integration and system performance.

Project duration: 2021 - 2024.

Financed by: NASA.

SMART MISSION LAB (SML)

Project purpose: The goal of the project is to provide an innovative service-based model that allows customers to remotely access and test our hardware components and artificial intelligence algorithms. This service, named Smart Mission Lab, is designed to ensure cost efficiency and enhance customer experience by bridging the gap between theoretical needs and practical requirements.

Project duration: 2023 - 2024

Financed by: the European Space Agency

Project output: The result of the project will be the ability to test different product configurations which will ensure that customers order exactly what they need, eliminating guesswork and reducing waste. After testing and deciding to purchase the actual equipment, customers receive a rebate corresponding to the costs incurred during the testing phase.By integrating this approach, Smart Mission Lab aims to revolutionize the way customers access, test and purchase equipment and artificial intelligence algorithms, ensuring a secure, cost-effective and efficient process from start to finish.

ORCHESTRATION OF RELIABLE COMPUTING ON HETEROGENEOUS INFRASTRUCTURES AT THE EDGE

Project purpose: The essence of this project lies in the development of a groundbreaking software solution tailored for on-board satellite systems. This software aims to empower satellites with the ability to upload, execute, schedule, and orchestrate image processing applications dynamically, throughout the duration of their mission. The project's vision is to provide a seamless and agile environment for application providers and end-users, ensuring optimal performance, adaptability, and security in processing satellite data.

Project duration: 2023 - 2026.

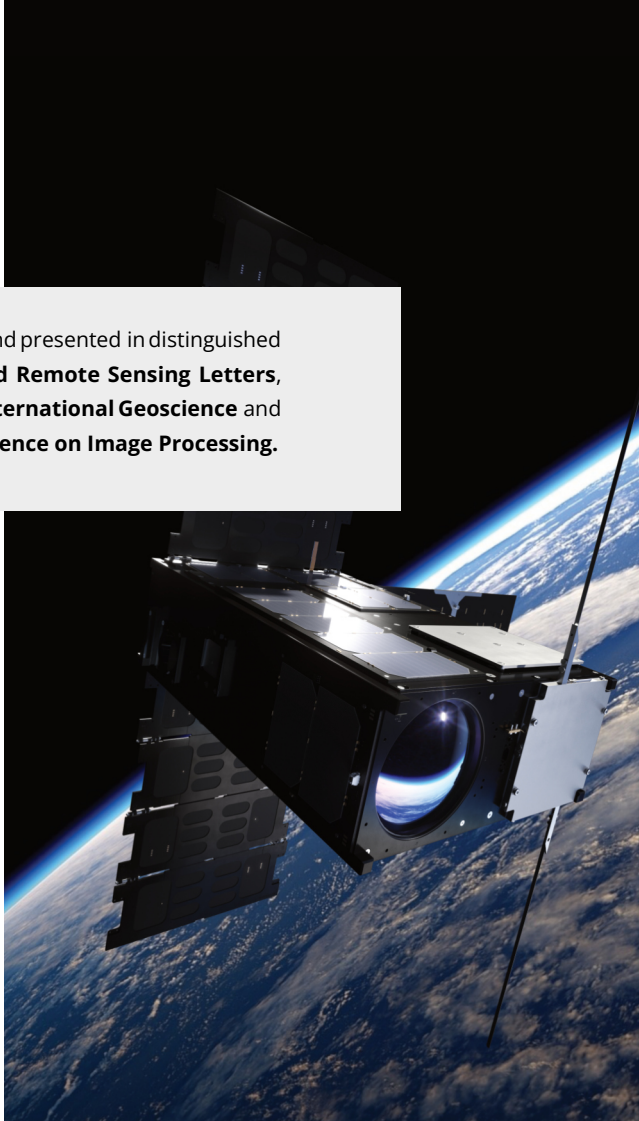
Financed by: Horizon Europe.

Project output: The project has delivered a versatile Unikernel-Based Software Framework for on-board data processing, especially for Artificial Intelligence applications. It also includes Distributed Orchestration Software to coordinate data processing, Smart Resource Optimization Algorithms for efficient resource use, robust Safety and Security Protocols, and Dynamic User-Centric Reconfiguration for improved responsiveness. These outputs collectively enhance on-board data processing within Earth Observation Systems, making it more adaptable, efficient, and secure.

PUBLICATIONS

Several papers, in which we describe our approaches, have been published and presented in distinguished journals and conferences, including, among others - **IEEE Geoscience and Remote Sensing Letters**, **Neurocomputing, Soft Computing, Artificial Intelligence Review, IEEE International Geoscience** and **the Remote Sensing Symposium** as well as **the IEEE International Conference on Image Processing.**

IF YOU WANT TO KNOW MORE,
YOU CAN DO IT VIA THE QR CODE BELOW:



KP LABS
Mission Complete

CONTACT US FOR MORE INFORMATION

Please get in touch to discuss the needs of your business and find out how we can facilitate your future.

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