COGNITIVE CLOUD COMPUTING IN SPACE

DUAL-CAMERA SATELLITE SYSTEM WITH ON-BOARD AI-BASED DECISION MAKING CAPABILITIES

EDHPC2023, JUAN-LES-PINS, FRANCE
3.10.2023

AGENDA

- Company Presentation
- Introduction
- Mission Analysis
- Active Fire Detection Demonstration
- Use Case Demonstration Setup
- Evaluation
- Discussion

SPACE SYSTEMS

OHB System AG
Bremen & Oberpfaffenhofen, Germany
100%

OHB Sweden AB
Stockholm,Sweden
100%

OHB Italia S.p.A
Milan, Italy
100%

LuxSpace Sarl
Betzdorf, Luxembourg,
100%

Antwerp Space N.V.
Antwerp, Belgium
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OHB Hellas mon.E.P.E.
Athens, Greece
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OHB Czechspace s.r.o.
Brno, Czechia, 100%

AEROSPACE

MT Aerospace AG
Augsburg, Germany, 70%

Rocket Factory Augsburg AG
Augsburg, Germany, 55%

Aerotech Peissenberg GmbH & Co. KG
Peissenberg, Germany, 34.3%

ATC Space s.r.o.
Klatovy, Tschechien,
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AT ENGINE MEXICO SAPI DE C.V.
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DIGITAL

OHB Digital Connect GmbH
Bremen, Mainz & Gelsdorf, Germany
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OHB Teledata GmbH
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MT Aerospace Guyane S.A.S.
Kourou, French Guiana, 100%

OHB Chile SpA
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Blue Horizon Sarl
Betzdorf ,
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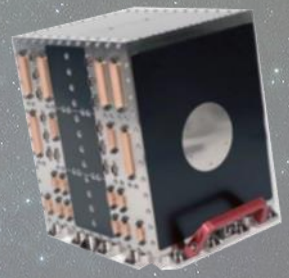
OHB Infosys GmbH
Bremen & Oberpfaffenhofen, Germany 100%

OHB Digital Solutions GmbH
Graz, Austria 100%

OHB Hellas provides a scalable and flexible offer

Advanced Space Algorithm

HW Acceleration solution



HPDP Sub-system

Innovative Space Mission

- AI at the Edge
- Market Analysis
- HW selection & benchmarking

- HW implementation
- Software Design and Development
- DevOps CI/CD onto specialized data processing HW targets
- Independent Software Verification and Validation

- Program Management, Systems Engineering, Mission Assurance, Procurement
- Integration and Test
- End to End quick Demonstration, IOD
- Use Case Provider

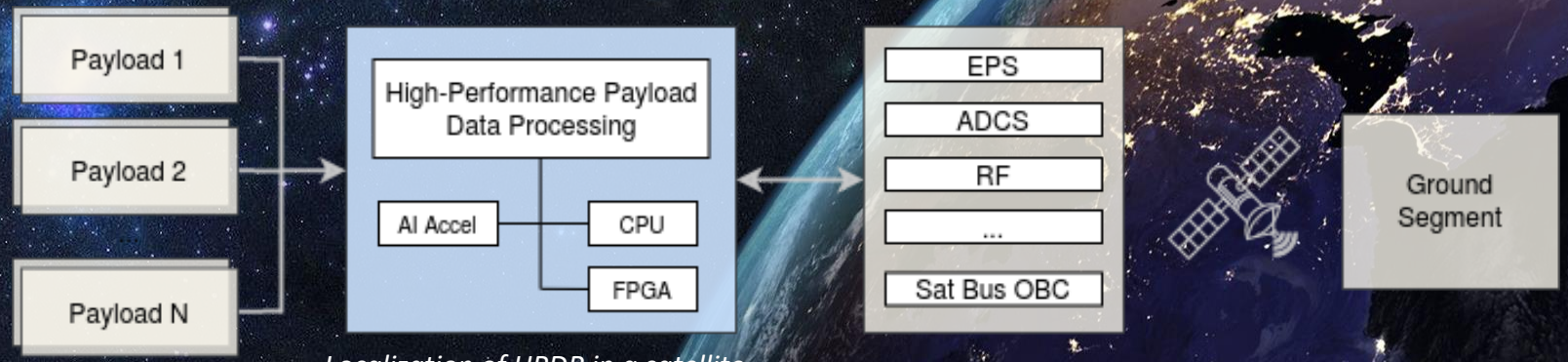
PROPOSED SOLUTION

Win/Win/Win situation!

High Level Objectives

Enhanced Missions

HPDP Subsystem



Localization of HPDP in a satellite

INTRODUCTION

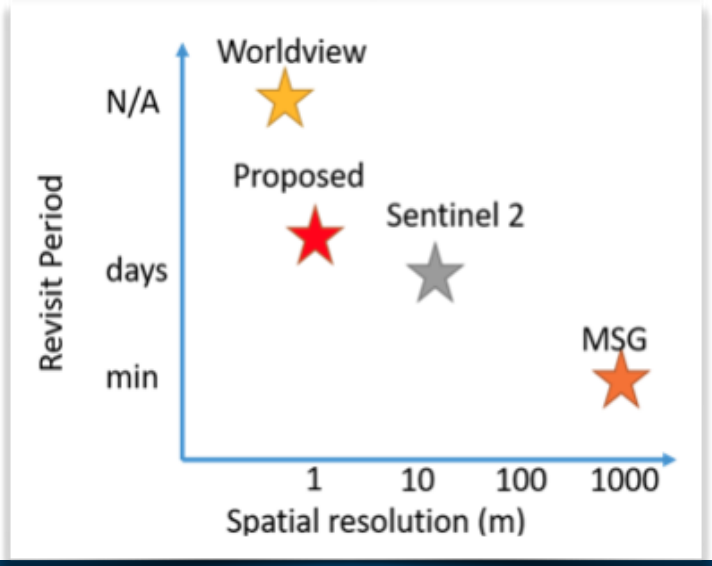
PROPOSED APPROACH

Objective

- Demonstrate a novel class of mission where imaging with two cameras is controlled by an AI-enabled real-time scheduling mechanism

Approach

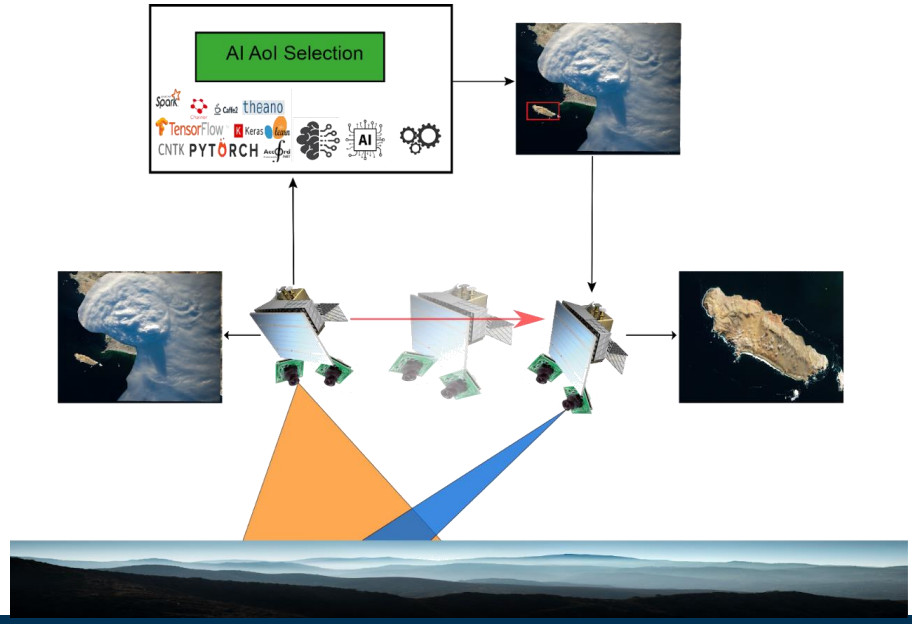
- 1st satellite: a low-resolution wide-swath optical camera -> maximum coverage
- 2nd satellite: a high-resolution narrow-swath camera -> maximum spatial resolution
- Target: the best possible image of Area of Interest (AoI).



Team:

- **OHB Hellas**
  - **Project lead**
  - **System design and analysis**
  - **Demonstration**

- **Foundation for Research and Technology Hellas**
  - **State of the art and Market analysis**
  - **Cognitive AI software design**



MISSION ANALYSIS

TWO-SATELLITE SYSTEM

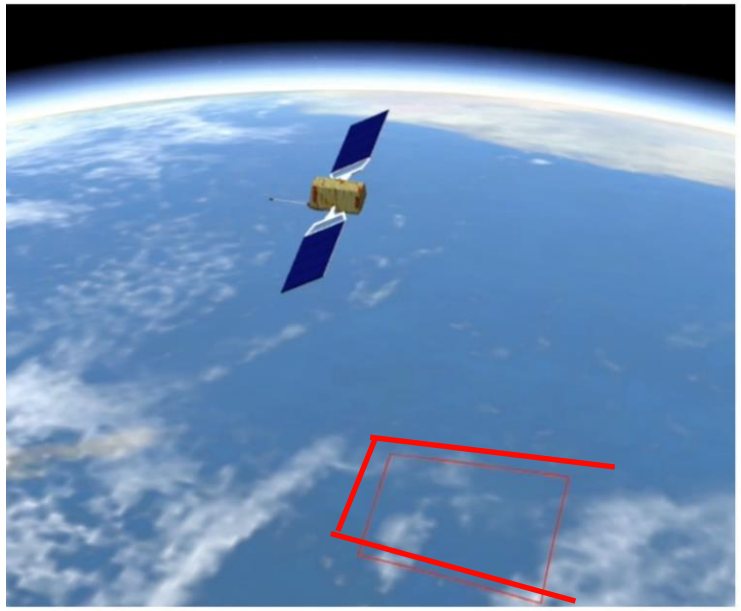
Two-satellite system, main mission parameters

- **Time required:**
  1. **AI** processing
  2. satellite attitude **change**
  3. settling
  - ➢ **defined by the distance between the satellites**

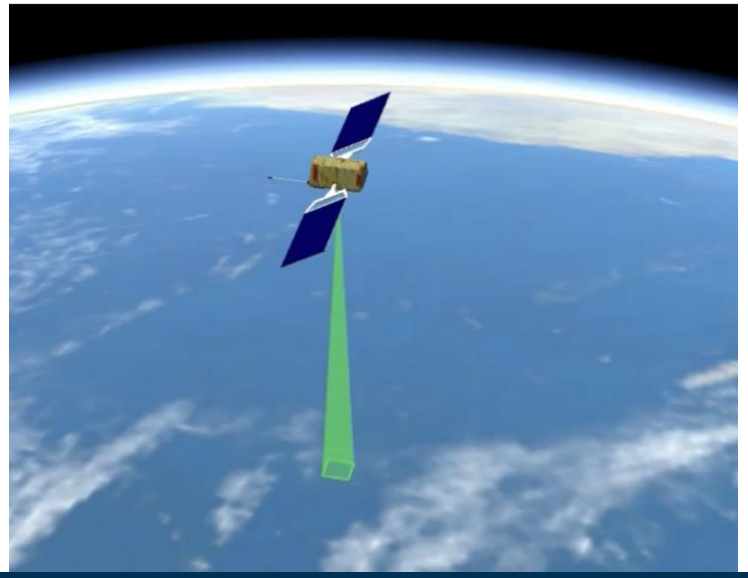
- Maximum line-of-sight distance constrained by the ISL capabilities**.** For example, the Antwerp Space LEO – LEO Ka Band ISL can provide a satellite distance of 4700 km within its specification

- The time available for AI processing and attitude adjustment in this case will be 630 seconds **feasible** for the AI processing and the attitude change + settle time in this context

- The angle between the two satellites will be 0.7 radians or 40°. In terms of Keplerian orbital elements, this translates to a True Anomaly difference of 40°



One camera **large swath** (120Km) and low resolution (30m at 500km orbit)
in red

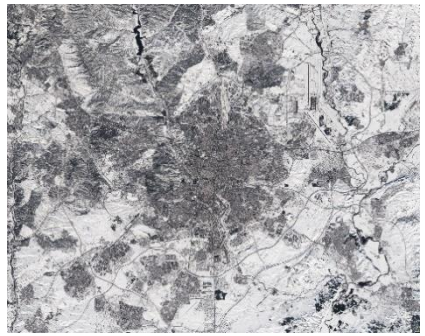


One camera **small swath** (20km) and **High resolution (5m at 500km orbit)** in green

ACTIVE FIRE DETECTION DEMONSTRATION

APPLICATIONS CONSIDERED – OBJECT / TARGET DETECTION

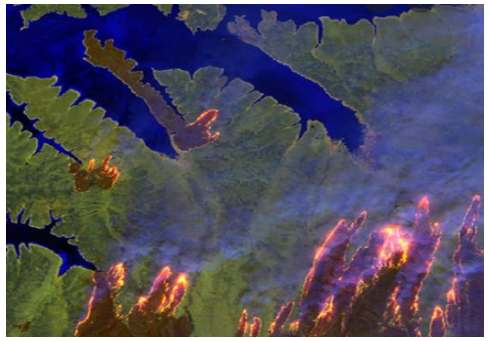
- Floods



- Oil spills

- Solar PV parks

- **Active fire**



- Floating plastic litter (distribution)

- Volcanic eruption

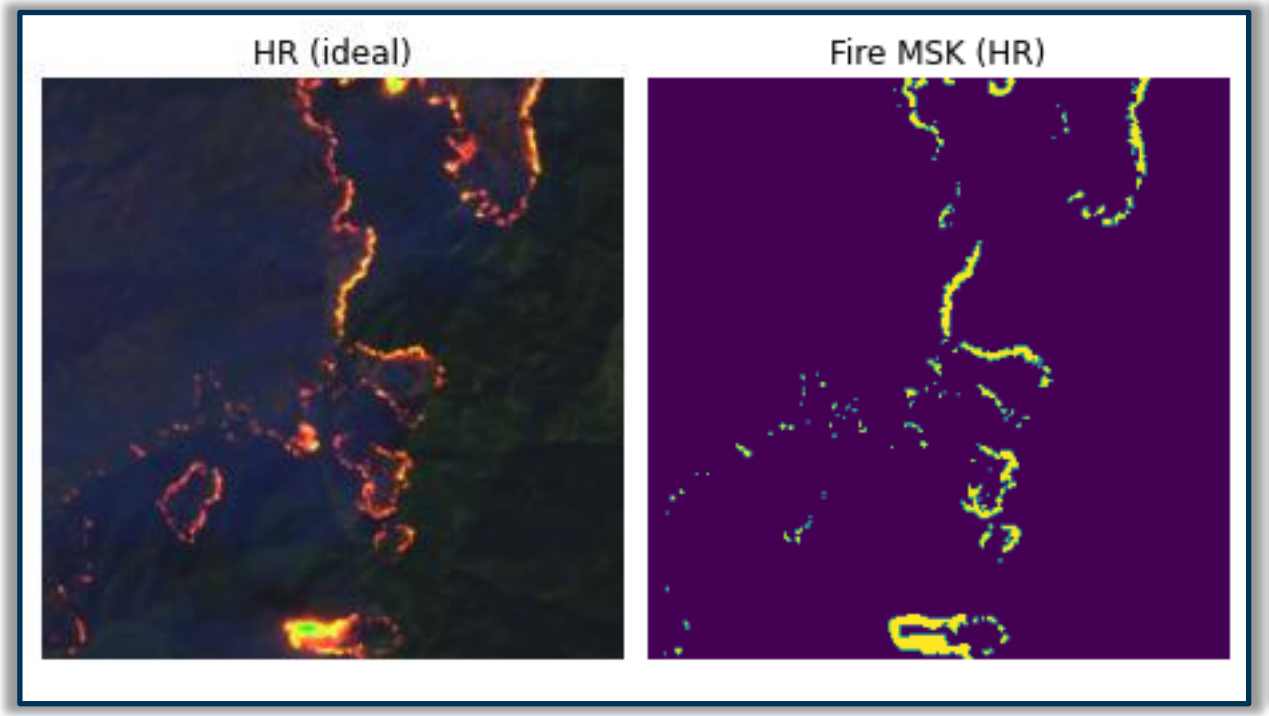
VIDEO

https://youtu.be/8mbTV7h6Sj0?si=eEjCHQbgX0zBJh5_

ACTIVE FIRE DETECTION DEMONSTRATION

SELECTED APPLICATION: ACTIVE FIRE DETECTION

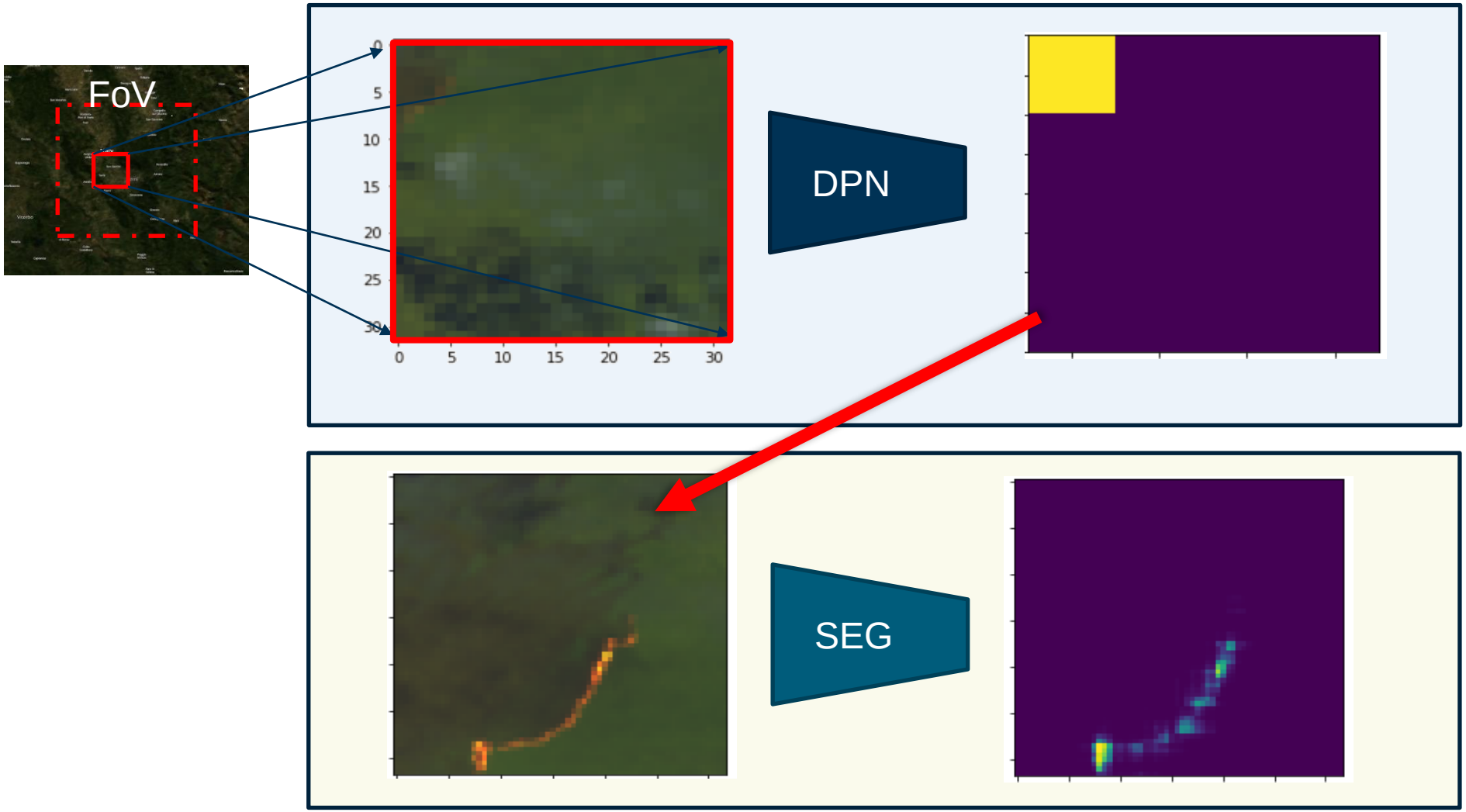
- Input: Landsat 8, 3 band: 6(1570nm), 5(850nm), 1(430nm)
- Labels: Manual annotations



de Almeida Pereira, Gabriel Henrique, et al. "Active fire detection in Landsat-8 imagery: A large-scale dataset and a deep-learning study." *ISPRS Journal of Photogrammetry and Remote Sensing* 178 (2021): 171-186.s

ACTIVE FIRE DETECTION DEMONSTRATION

SYSTEM OVERVIEW



Scout Satellite
1st Camera (LR)

Deep Policy Network: divide into 8x8=16 patches -> Select 0 or 1 patch per image

Fine Pointing Satellite
2nd Camera (HR)

Active fire mask (per pixel classification 0/1)

USE CASE DEMONSTRATION SETUP

SELECTED EMBEDDED DEVICES

- **Kria KV260 (**Zynq UltraScale FPGA, Neural Network Programmable Engine (DPU)):
  - Demonstrates the scout satellite → Executes the LR network (**ResNet**)
  - Need for model quantization → Xilinx's Vitis-AI
  - Sends the predicted HR tile to the fine-pointing satellite

Coral Dev Board (TPU):

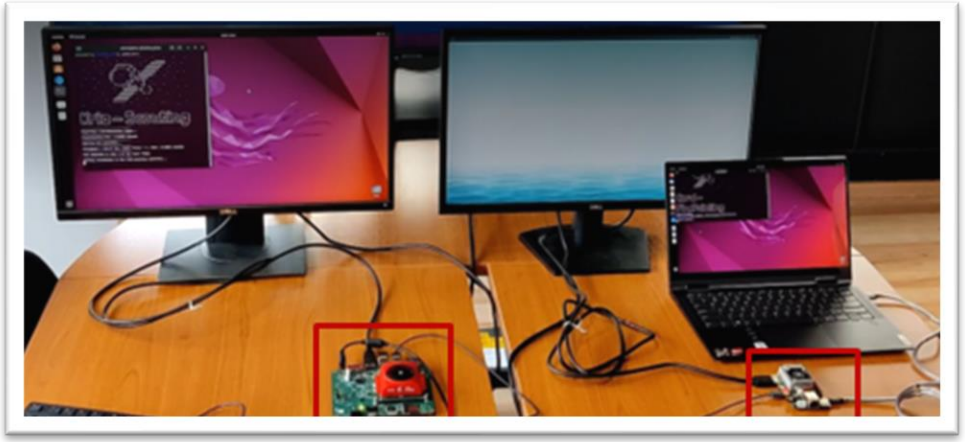
- Demonstrates the fine-pointing satellite → Executes the HR network (**Unet**)
- Need for model quantization → TensorFlow Lite Converter
- Finds the segmentation fire mask

USE CASE DEMONSTRATION SETUP

IMPLEMENTATION PROCESS

Kria KV260

- The original float model is quantized into INT8 precision to be executed on the DPU
- Then, the quantized version of the model is compiled into an XMODEL file → use of the DPU's highly efficient instruction set and dataflow model
- Python and the Vitis AI unified Python high-level API were used to execute the quantized XMODEL

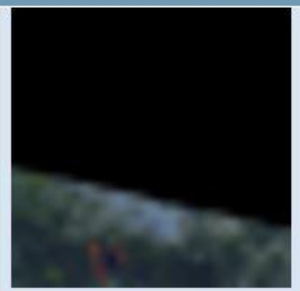
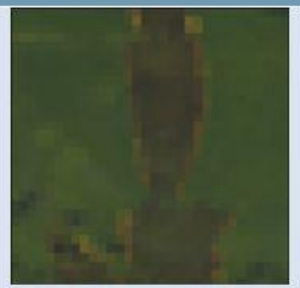
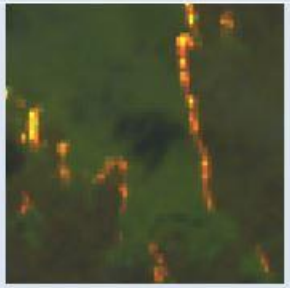
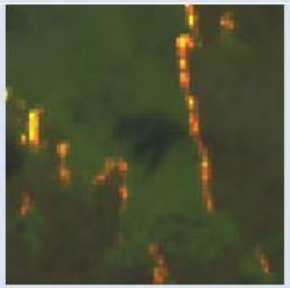


Coral Dev Board

- The Edge TPU supports only TensorFlow Lite models that are fully 8-bit quantized and then compiled specifically → the model cannot be trained directly with TensorFlow Lite
- TensorFlow Lite Converter was used → TensorFlow model conversion to a TensorFlow Lite
- Application of the quantization and compiling steps

EVALUATION

PERFORMANCE EXAMPLES

	Sample 1	Sample 2	Sample 3
LR-Input			
Ground Truth Fire Patch		*No Fire*	
Fire Patch Predicted – Float Model		*No Fire*	

EVALUATION

PERFORMANCE EXAMPLES

	Sample 1	Sample 2	Sample 3
Fire Patch Predicted – Quantized Model		*No Fire*	
Ground Truth Fire Mask		N/A	
Fire Mask Predicted – Float Model		N/A	
Fire Mask Predicted – Quantized Model		N/A	

EVALUATION

RESULTS

- The results indicate that the quantized LR model is performing well, as it has a 91% match on the AoI patches prediction in relevance to the float model
- Regarding the HR model, the float model is capable of capturing the main features of an active fire, resulting in the mask extraction which depicts the fire fronts
- On the other hand, the absence of previously predicted fire pixels in the quantized model predictions, indicates that some information loss occurred during the quantization process, as expected

	Latency (Seconds)	**Throughput (FPS)**
	Inference	
Kria KV260	0.0031	319.91
Coral Dev Board	0.0675	14.81
	Pre-Processing	
Kria KV260	0.0645	15.50
Coral Dev Board	0.0528	18.94

Power (Watt)	
Kria KV260	6.6 (5.3 Idle)
Coral Dev Board	5

DISCUSSION

Takeaways

- Two-satellite concept: scout satellite / LR images, fine-pointing satellite / HR images
- Mission feasibility was demonstrated at this preliminary level via orbital analysis and active fire use case implementation

Challenges

- Resolution limits
- Limited amount of “appropriate” datasets available for DL model training
- HW Compatibility and different AI frameworks

Opportunities

- New business models such as satellite-as-a-service may leverage this technology to meet user needs via intelligent tasking and scheduling

Acknowledgments

- Thanks to Max Pastena (ESA)

THANK YOU!

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