

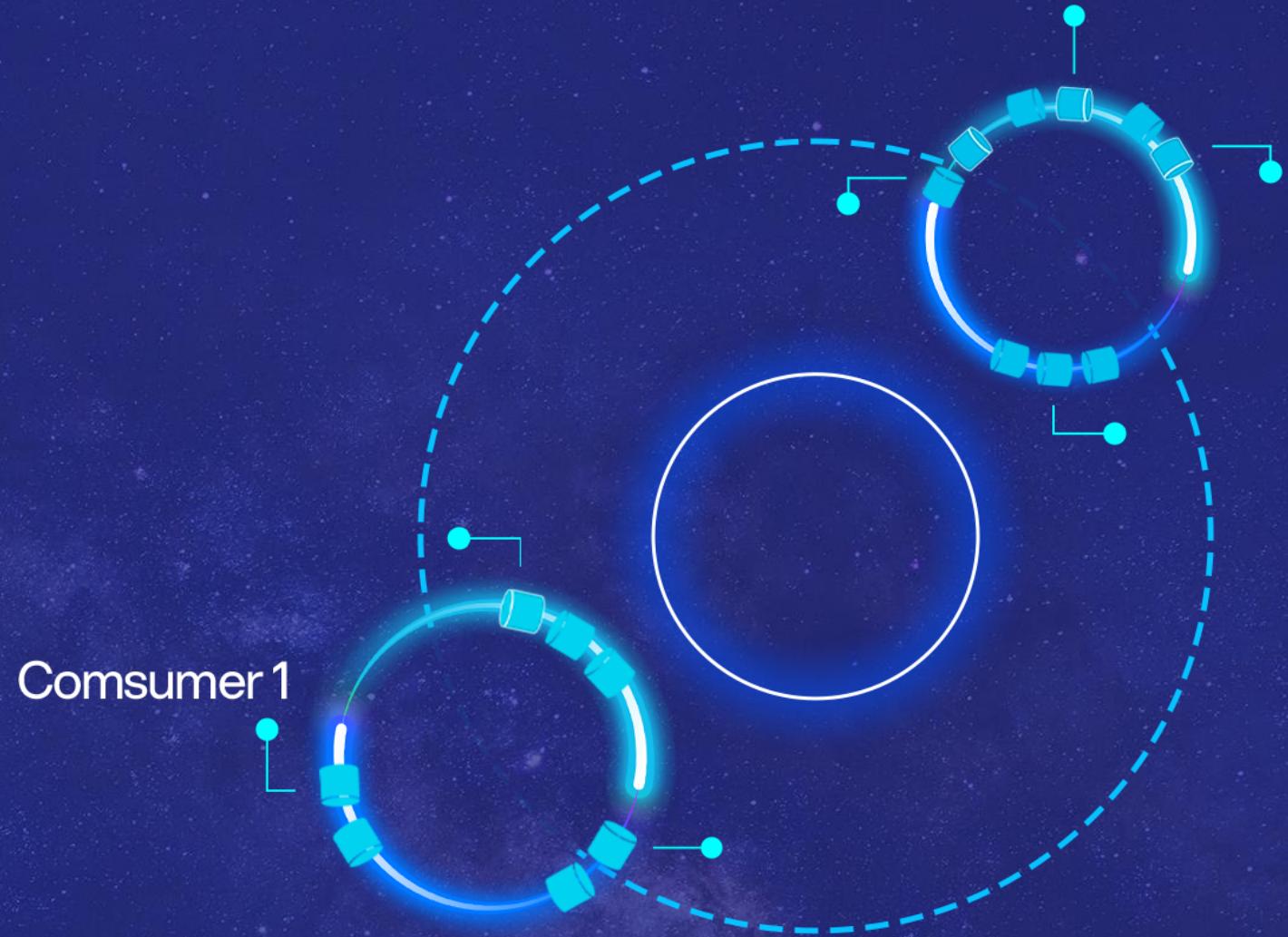
# AI/ML for Space Applications on RISC-V: A Fully European Technology Stack Analysis

**R** **RISC-V**  
**IN SPACE**

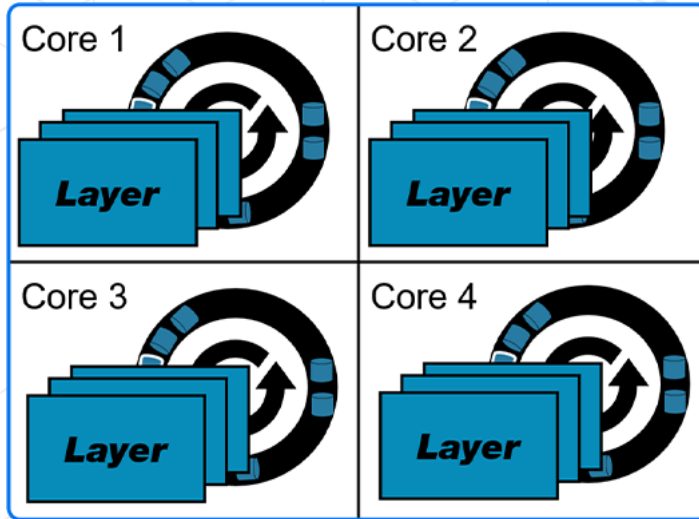
Pablo Ghiglino

Mar 18<sup>th</sup>, 2025

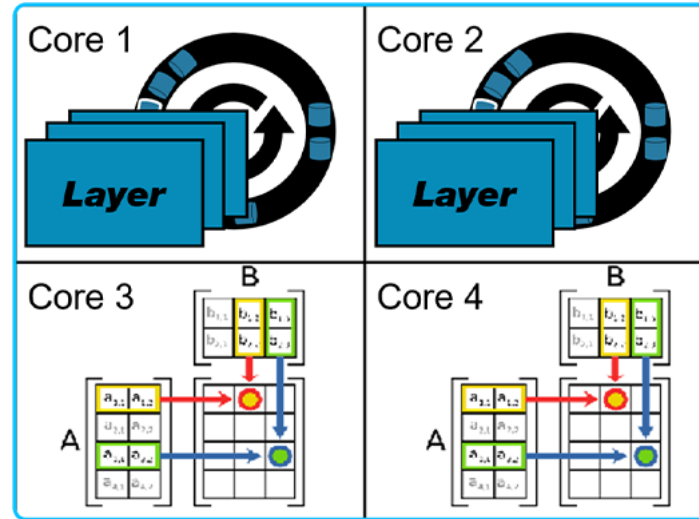
# Two Main Data Processing Approaches



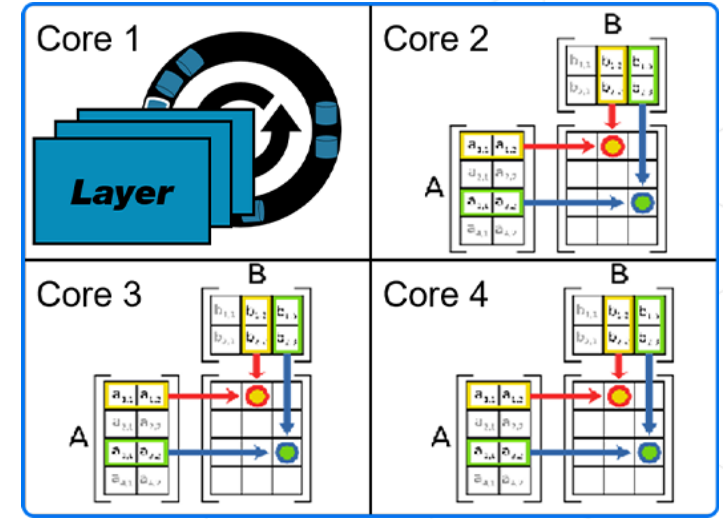
# 2-DIM Threading Model



- > Low CPU power
- > Mid throughput CPU
- > High latency



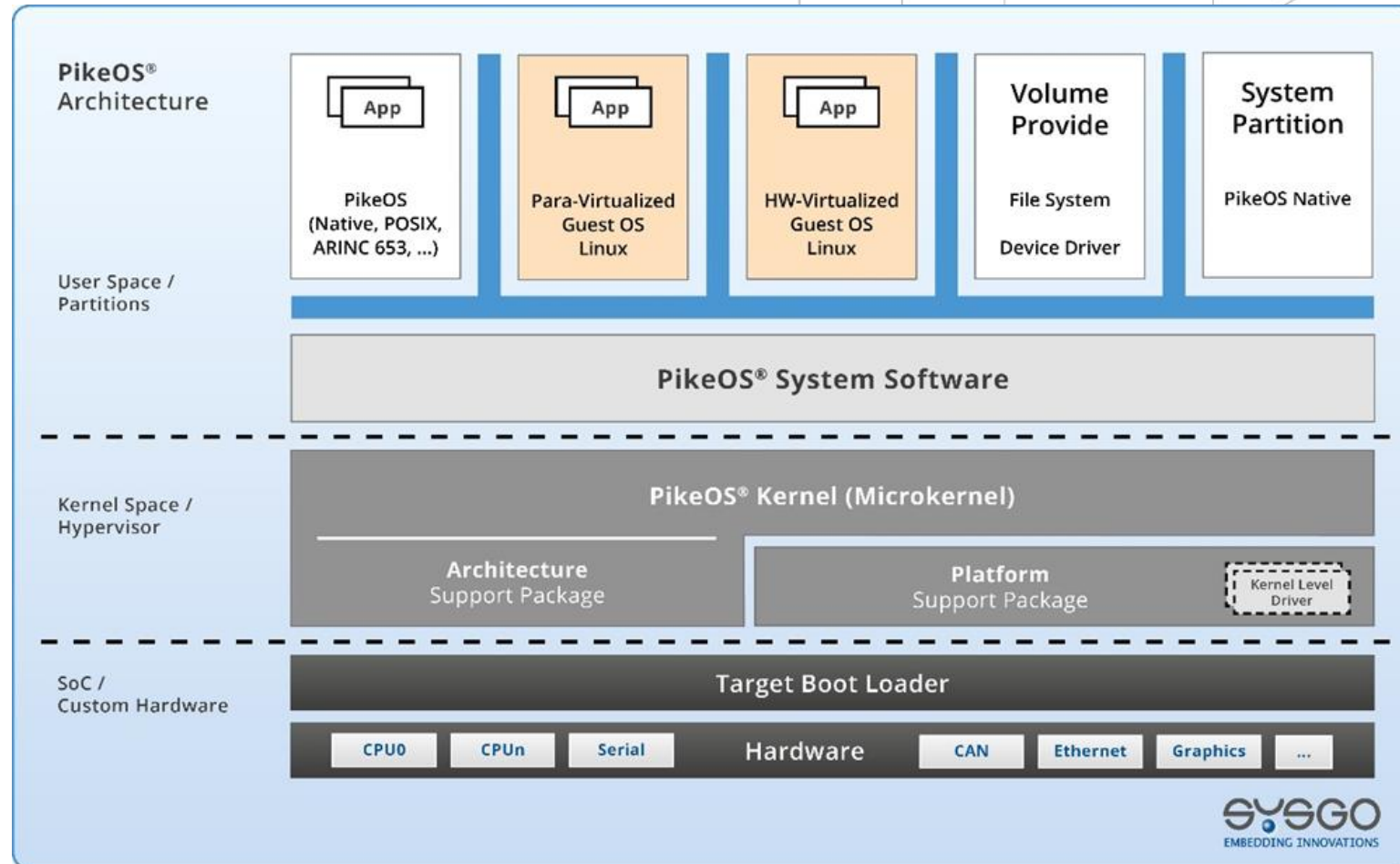
- > Mid CPU
- > High throughput CPU
- > Mid latency



- > High CPU
- > Mid throughput CPU
- > Low latency

- With safe and secure certified virtualization
  - Up to **ECSS Cat-A**, DO178C DAL-A, **EAL5+**, ISO26262 ASIL-D..
- **Microkernel** architecture
- **Strict spatial and time partitioning**
- **MILS**: Multiple Independent Levels of Security and Safety with multiple guest operating systems
  - Linux, POSIX, ARINC-653, AUTOSAR, Windows
- **Multi-core** processor support
- **No export restriction**

## Hard Real-Time Operating System and Hypervisor

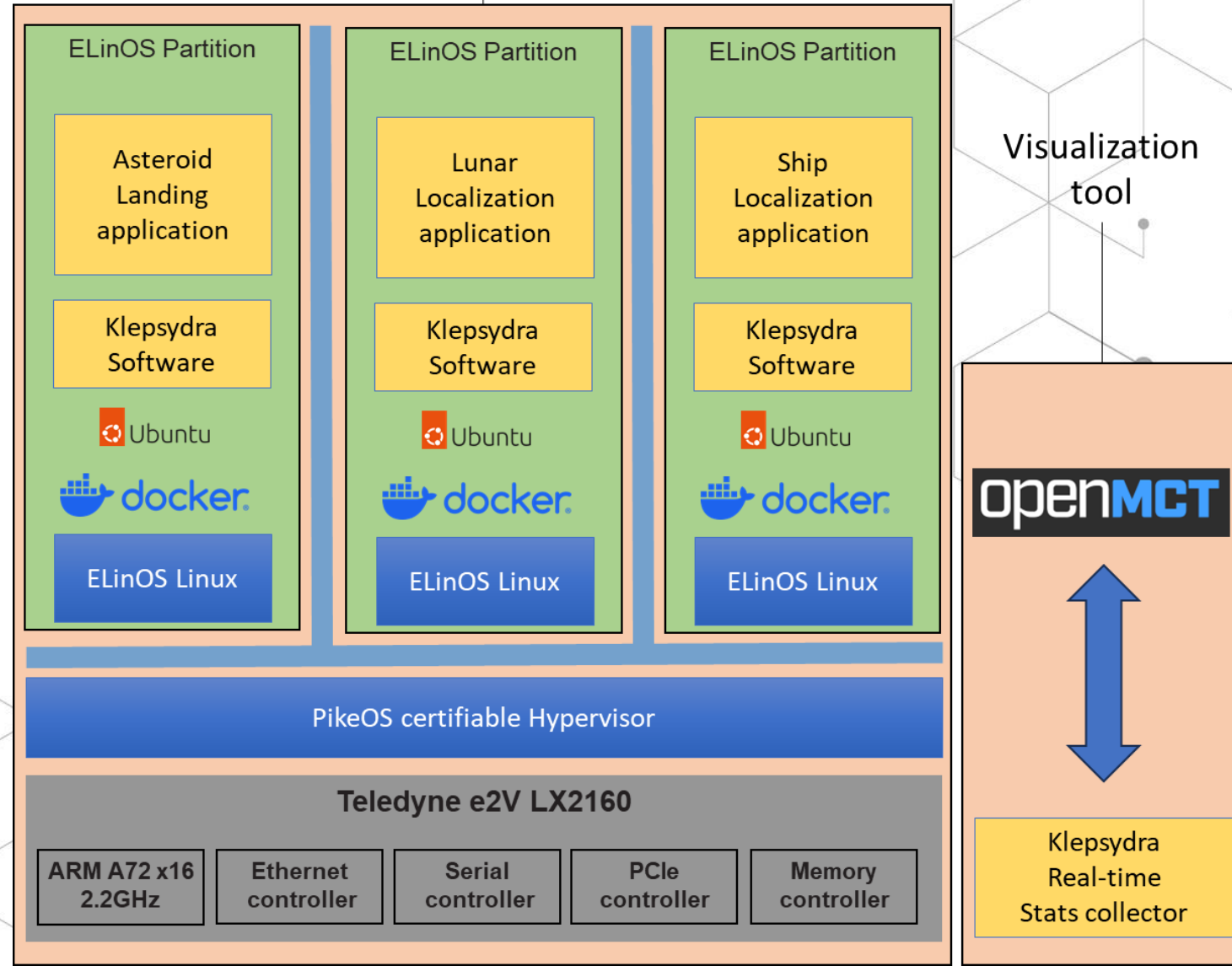


On-Board  
computer

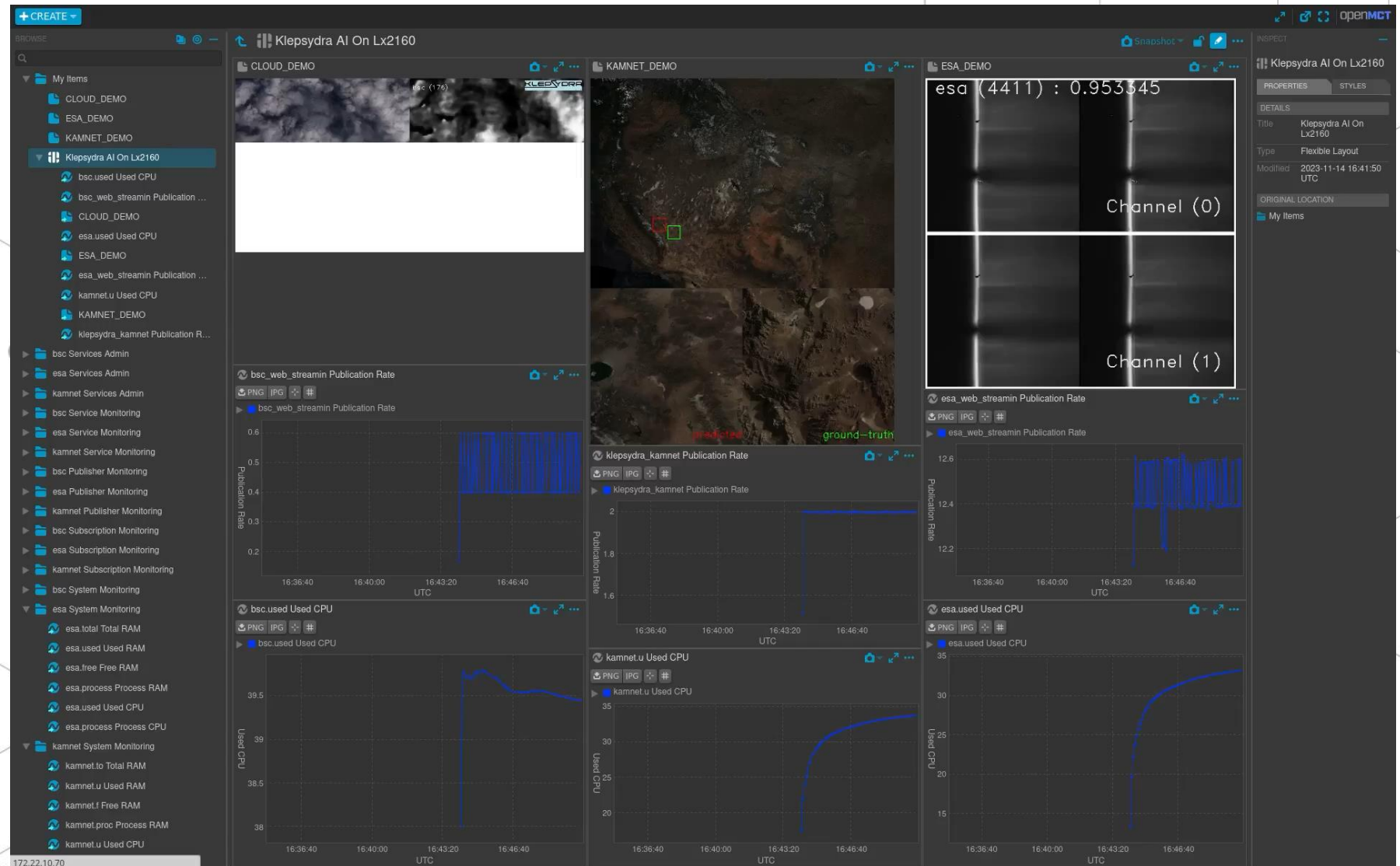
**SYSGO**  
EMBEDDING INNOVATIONS

**KLEPSYDRA**  
TECHNOLOGIES

The **LX2160**  
Space Cloud  
Demo using  
Klepsydra AI and  
SYGO PikeOS



# The LX2160 Space Cloud Demo using Klepsydra AI and SYGO PikeOS



# Klepsydra Performance Benchmarks

## Advanced Analysis:

- Layer-wise latency breakdown
- Core load distribution

## Comparison Capabilities:

- Benchmarks Klepsydra AI against leading inference engine:
- TensorFlow Lite

## Future support:

- ONNX Runtime
- OpenCV CNN
- ARM-NN

# Klepsydra Performance Benchmarks



## Performance Self-tuning Tool

[New analysis](#)

**List of configurations**

- mobilenet2Quantized | 10-02-2025 23:37 PM
- esaModel | 10-02-2025 18:07 PM
- esaQuantized | 10-02-2025 17:44 PM
- ship-detect | 10-02-2025 15:18 PM
- ship-detect | 09-02-2025 20:22 PM
- BSCUnetAlpha1 | 09-02-2025 19:43 PM
- mobilenetv1 | 09-02-2025 13:33 PM
- alexnet | 09-02-2025 12:48 PM

Target computer:  Software version:

Other information:

Deep Neural Network model file:

Data publishing period (milliseconds):  TO  steps (min: 1 | max: 2000000)

(min: 1 | max: 20)

Matrix height:  (min: 1 | max: 2048) Matrix width:  (min: 1 | max: 2048)

Number of channels:  Memory object pool size range:

Range of cores for pipelining:  1 Cores  2 Cores  3 Cores  4 Cores  
Select at least one option.

Range of parallel calculation threads:  1 Threads  2 Threads  3 Threads  4 Threads

[Start self-tuning](#)



Model tested  
**esaQuantized**  
10-02-2025 17:44 PM

Target Computer: **RPI5** Software version: **v18.3.0**

List of configurations

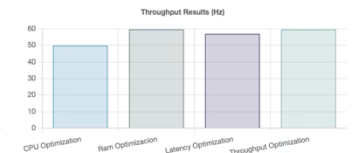
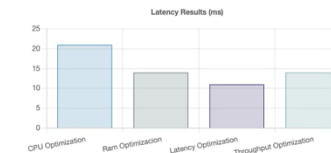
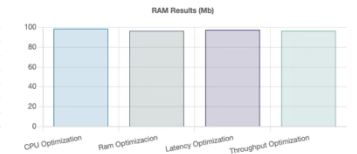
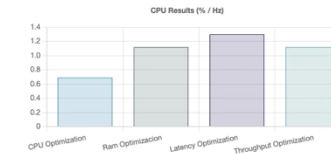
[Download log execution](#)

Publishing Rate: <b>1333</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>0</b>   Num Cores: <b>1</b>   Num Threads: <b>4</b>   Data Proc Type: <b>tf</b>	↓	✓
Publishing Rate: <b>1333</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>0</b>   Num Cores: <b>1</b>   Num Threads: <b>2</b>   Data Proc Type: <b>tf</b>	↓	✓
Publishing Rate: <b>1000</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>0</b>   Num Cores: <b>1</b>   Num Threads: <b>4</b>   Data Proc Type: <b>tf</b>	↓	✓
Publishing Rate: <b>2000</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>1</b>   Num Cores: <b>1</b>   Num Threads: <b>3</b>   Data Proc Type: <b>eventloop</b>	↓	✓
Publishing Rate: <b>1000</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>1</b>   Num Cores: <b>1</b>   Num Threads: <b>4</b>   Data Proc Type: <b>eventloop</b>	↓	✓
Publishing Rate: <b>1333</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>0</b>   Num Cores: <b>1</b>   Num Threads: <b>3</b>   Data Proc Type: <b>tf</b>	↓	✓
Publishing Rate: <b>1333</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>0</b>   Num Cores: <b>1</b>   Num Threads: <b>1</b>   Data Proc Type: <b>eventloop</b>	↓	✓
Publishing Rate: <b>1333</b>   Height: <b>224</b>   Width: <b>224</b>   Pool Size: <b>0</b>   Num Cores: <b>1</b>   Num Threads: <b>3</b>   Data Proc Type: <b>eventloop</b>	↓	✓

[Check results](#)

### Configurations

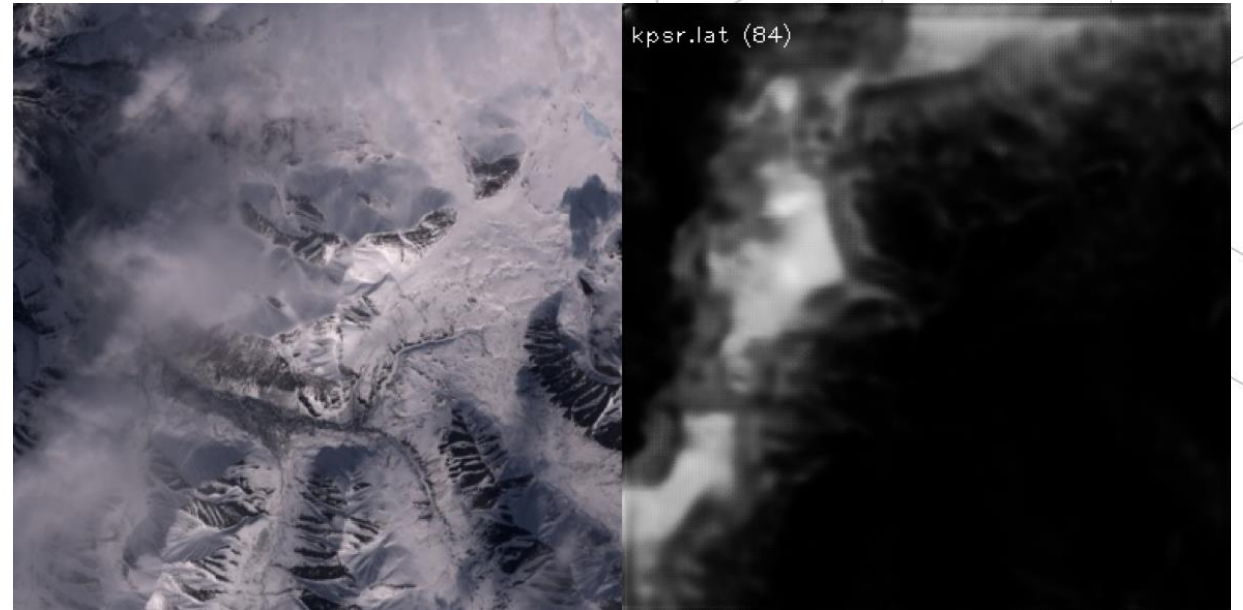
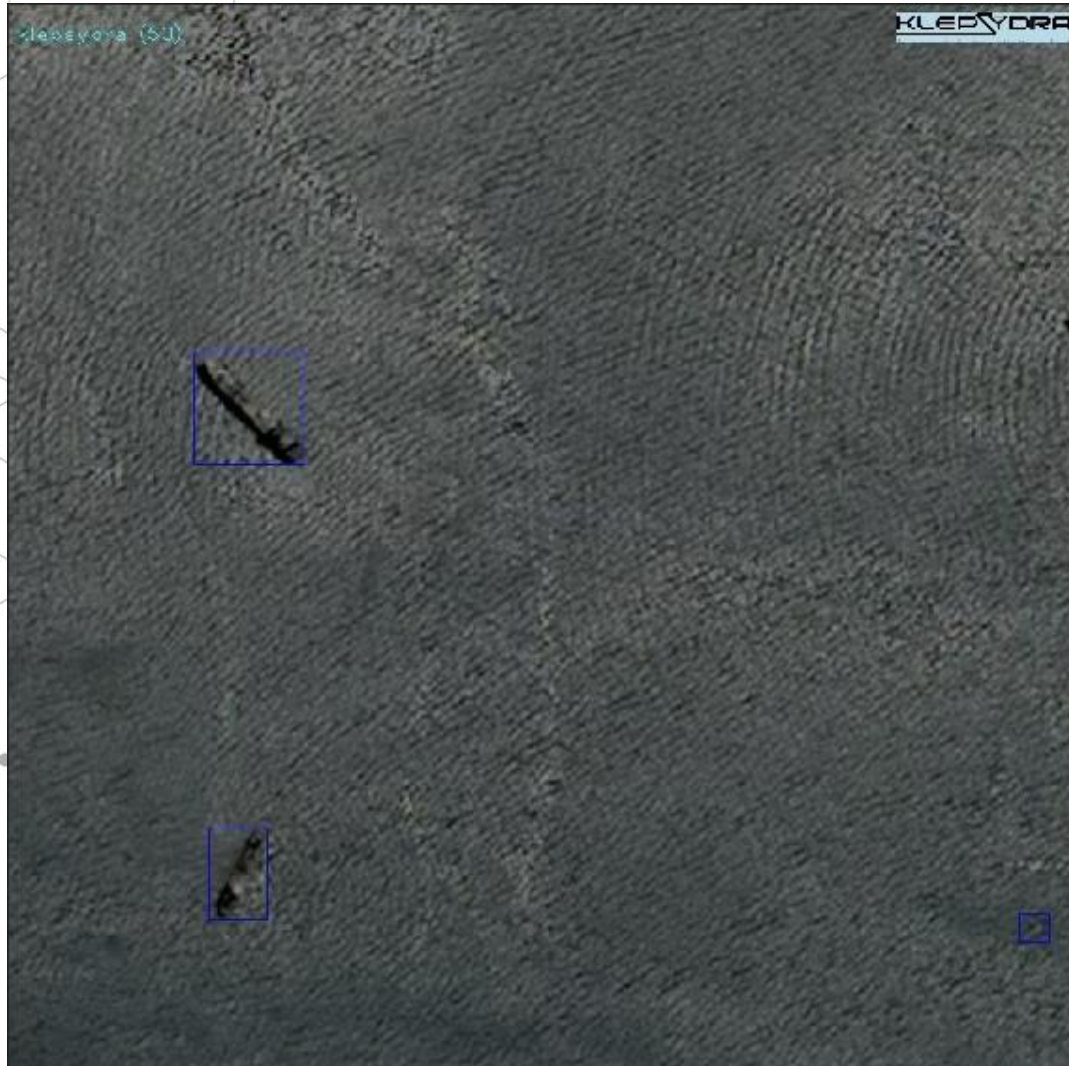
- CPU Optimization: **1 Cores - 1 Threads - 0 Pool Size** [Top Results](#) [Download](#)
- Ram Optimization: **1 Cores - 2 Threads - 0 Pool Size** [Download](#)
- Latency Optimization: **1 Cores - 3 Threads - 0 Pool Size** [Top Results](#) [Download](#)
- Throughput Optimization: **1 Cores - 2 Threads - 0 Pool Size** [Top Results](#) [Download](#)



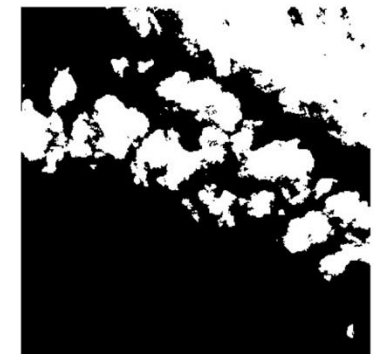
Configuration	CPU Results (% / Hz)	RAM Results (Mb)	Latency Results (ms)	Throughput Results (Hz)
CPU Optimization	0.69	98.64	21	49.82
Ram Optimization	1.12	96.42	14	59.61
Latency Optimization	1.30	97.39	11	56.99
Throughput Optimization	1.12	96.42	14	59.61
<b>Best Overall</b>	<b>2.78</b>	<b>113.94</b>	<b>32</b>	<b>21.25</b>



# OBPMark-ML Framework from ESA



4 Channel Input Image

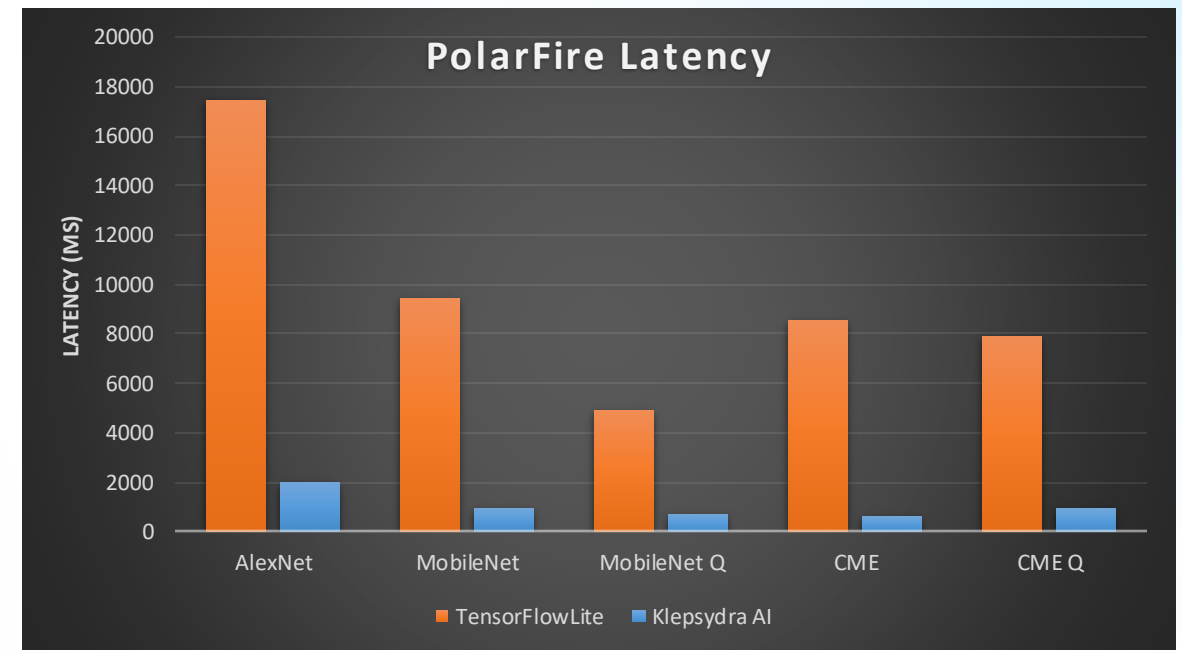
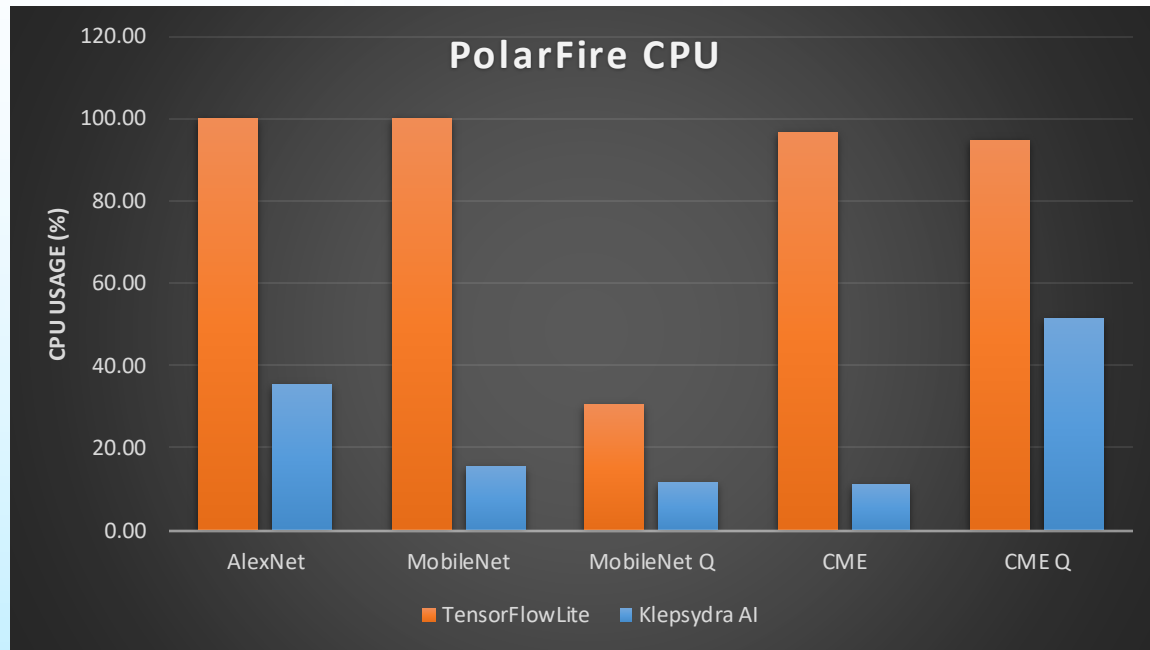


Binary Segmentation Mask

# Klepsydra AI Benchmarks

## PATTERN Project: Klepsydra AI ported to RISC-V

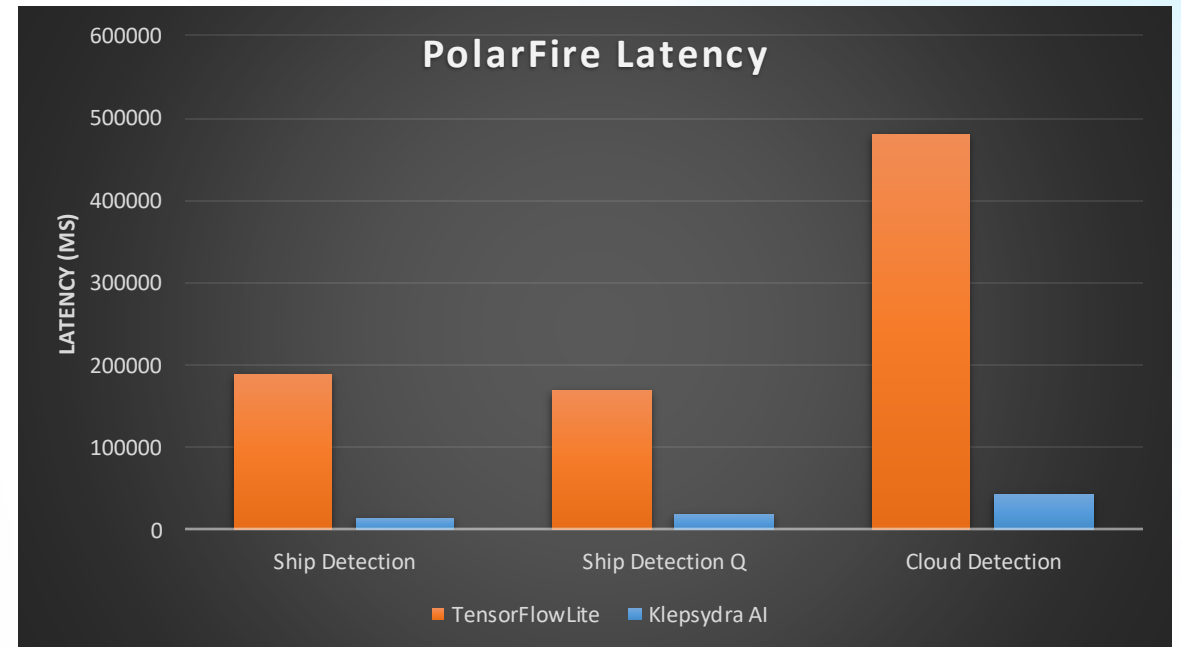
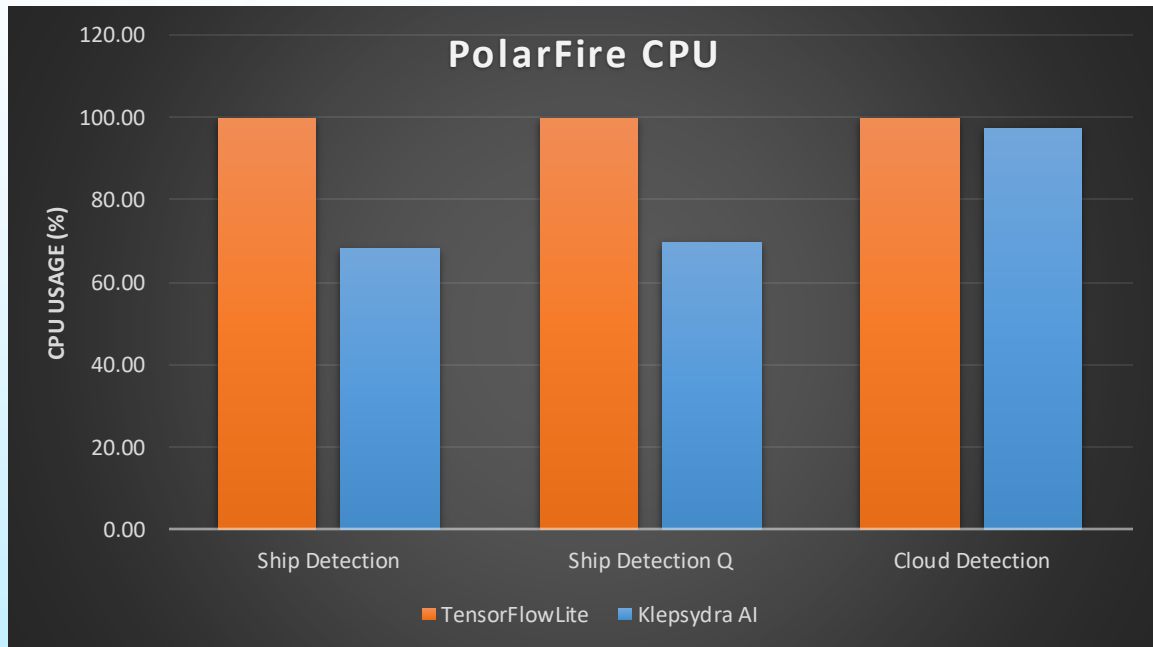
Performance comparison Klepsydra AI / TensorFlowLite (TFL) for lightweight models



# Klepsydra AI Benchmarks

## PATTERN Project: Klepsydra AI ported to RISC-V

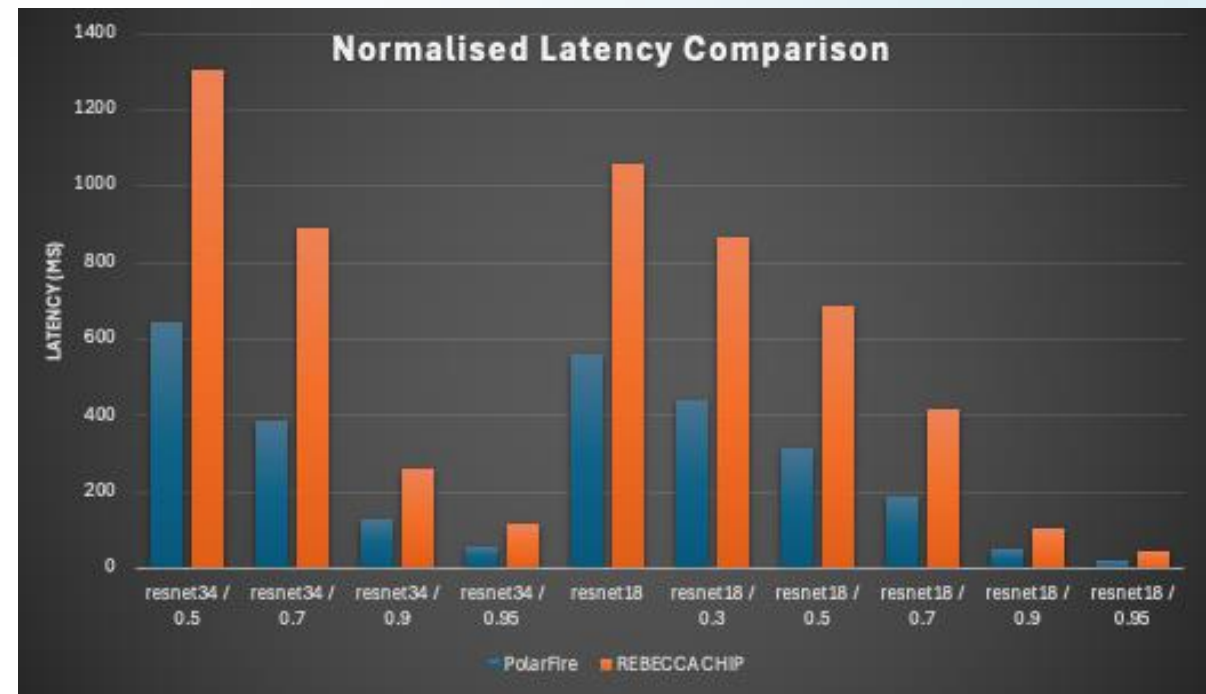
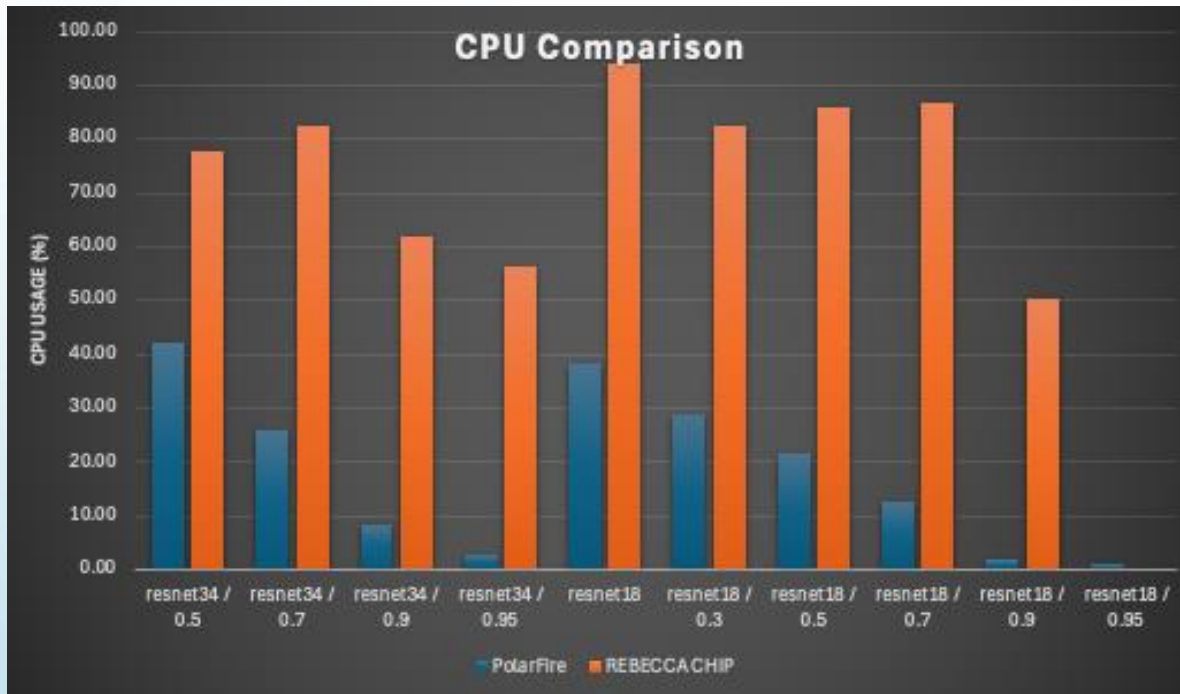
Performance comparison Klepsydra AI / TensorFlowLite (TFL) for heavyweight models



# Klepsydra AI RISC-V Benchmarks

## REBECCA Project: Lightweight models

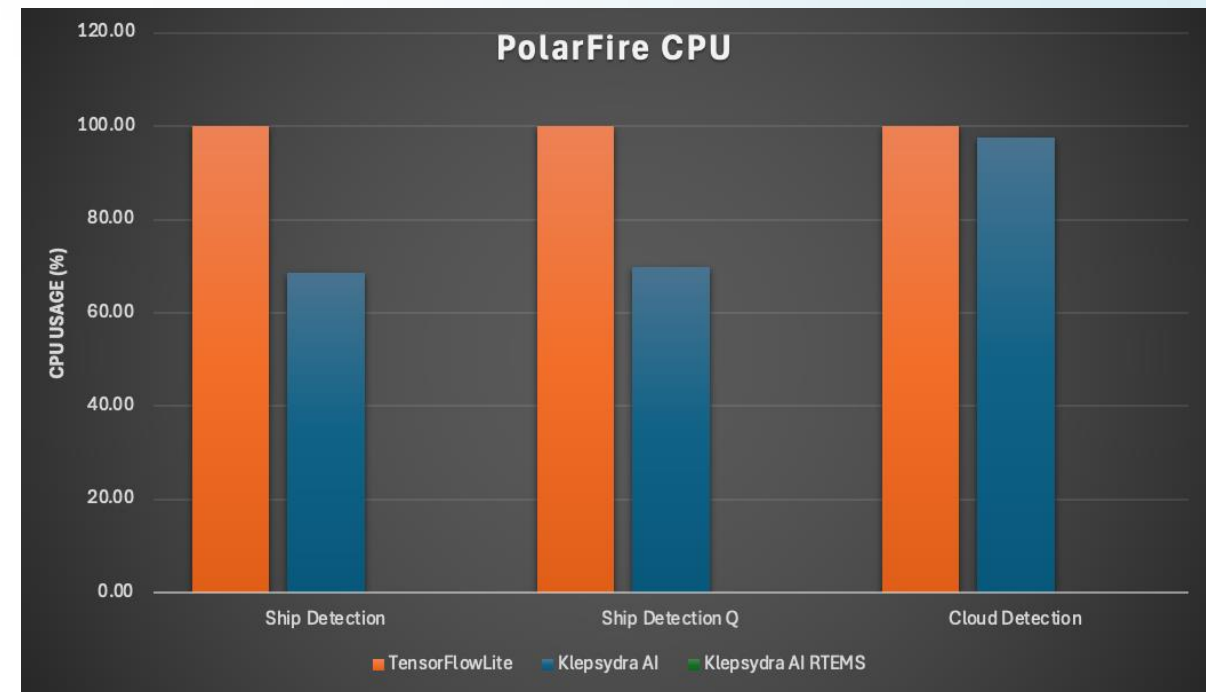
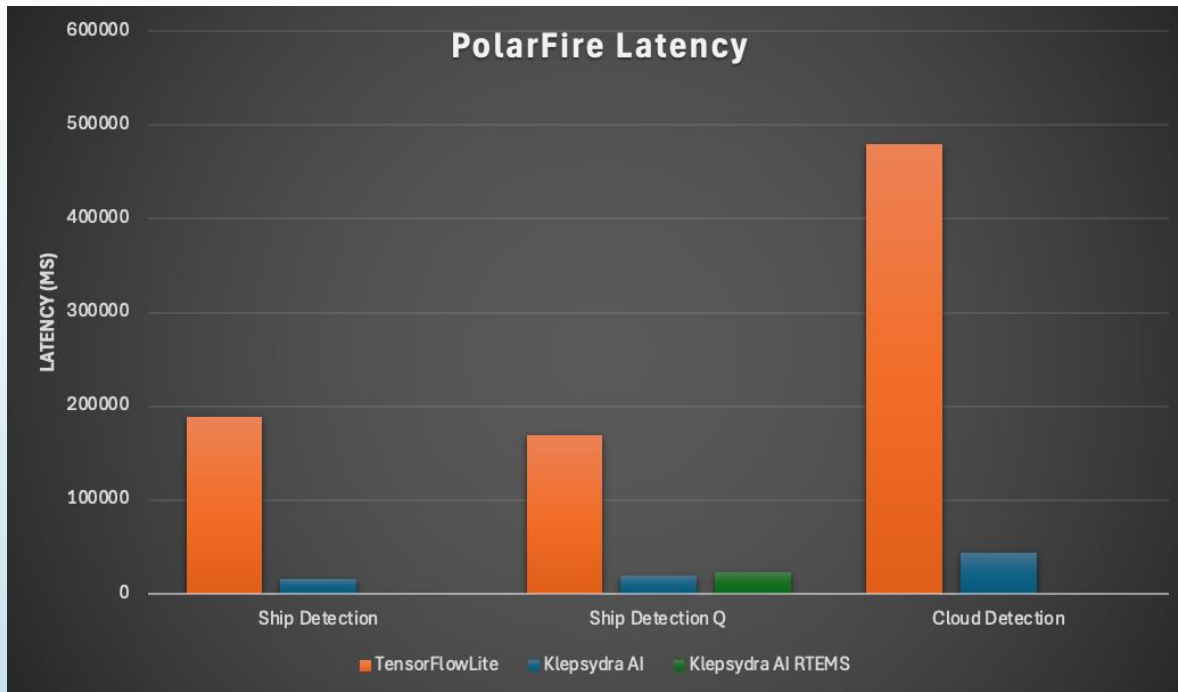
Performance comparison Klepsydra AI REBECCA / Polarfire



# Klepsydra AI RISC-V Benchmarks

## REBECCA Project: Heavyweight models

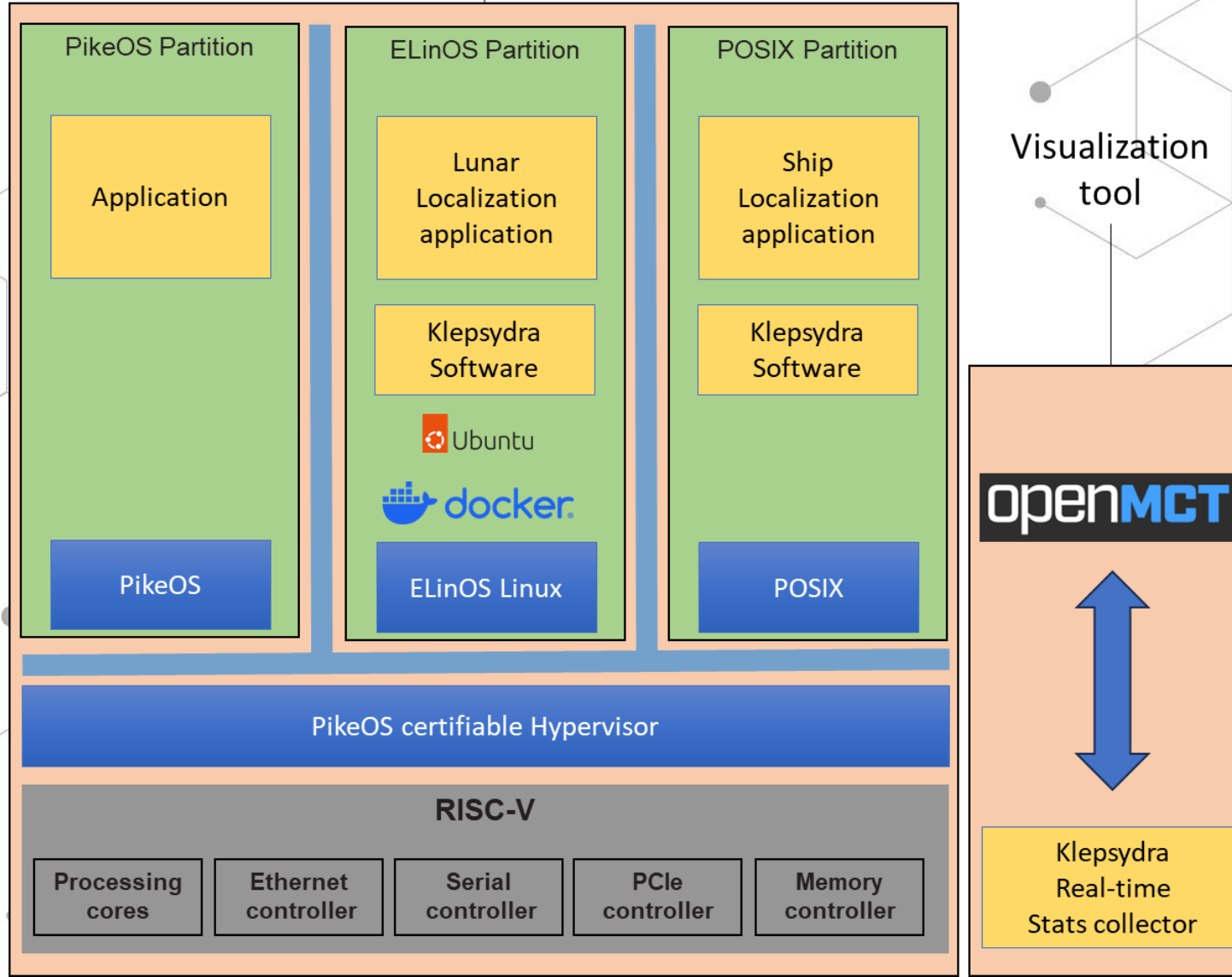
Performance comparison Klepsydra AI REBECCA / Polarfire



On-Board  
computer

**SYSGO**  
EMBEDDING INNOVATIONS

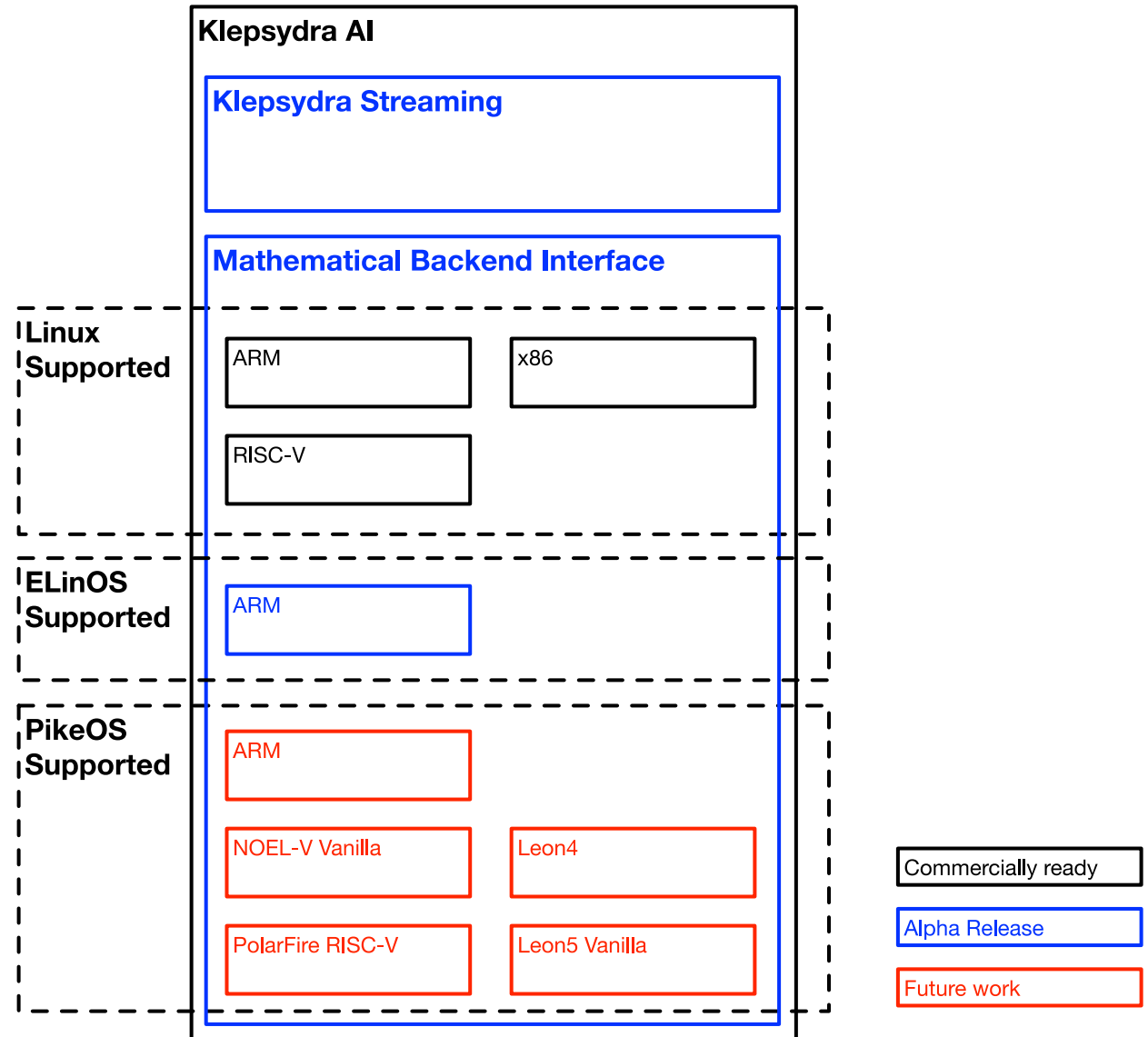
**KLEPSYDRA**  
TECHNOLOGIES



# Klepsydra and SYSGO, Integration roadmap

## Breakdown by board:

- > ELinOS support to ARM
- > Porting of Klepsydra to several CPU-only processors:
  - > GR740, GR765 (LEON5/NOEL-V)
  - > RISC-V
  - > ARM Cortex
- > On PikeOS operating system.
- > Adoption of Klepsydra SDO to optimize multi-core execution of AI and classical algorithms.





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