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CloudNativeCon

Europe 2026

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Bringing Cloud-Native PaaS to Space: Onboard Edge Computing for Satellites



WHO WE ARE



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leading the European ORCHIDE project and pioneering cloud-native, unikernel-based orchestrators for space systems

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CONTEXT



INTRODUCTION – CONTEXT IN EARTH OBSERVATION DOMAIN



Sequential tasking - Single mission per satellite/instrument

High mission cost - Specific systems

Difficult on-orbit modification - ground intervention

Complex payload - Growing number of instruments

Limited downlink bandwidth – High amount of data collected stored onboard aging and losing value

NEW SPACE & KEY TECHNOLOGY ENABLERS

NEW SPACE PARADIGM

MORE COMMERCIAL &
PRIVATE SPACE ACTORS

COST REDUCTION AND
REUSABILITY : CUBESATS &
SMALLSATS

NEW BUSINESS MODELS
AND APPLICATIONS

GLOBAL ACCESS AND
DEMOCRATIZATION OF SPACE

TECHNICAL ENABLERS

CLOUD TECHNOLOGIES AND
VIRTUALIZED ARCHITECTURES

HIGH-THROUGHPUT
COMMUNICATIONS

AUTONOMOUS
OPERATIONS AND AI

HARDWARE ACCELERATORS:
GPUs, DPUs, FPGAs



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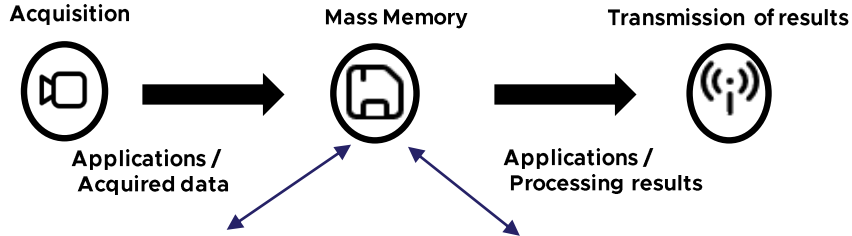
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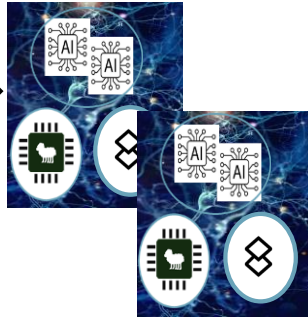
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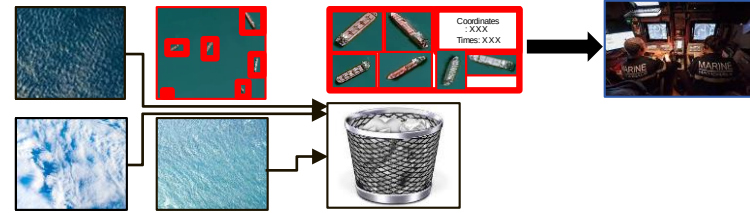
NEW SPACE PARADIGM - OBJECTIVES



Master Node: Orchestrator acting as an intelligent router and resource manager



Processing Nodes: Processing / AI / compression



- Improve on-board data processing with AI and alert instantly
- Multi-application and flexibility throughout the life of the satellite
→ Fewer satellites for more missions
- Optimize the volume of information to be transmitted to the ground
- Access to reliable information

CASE STUDY – ORCHIDE PROJECT SUMMARY

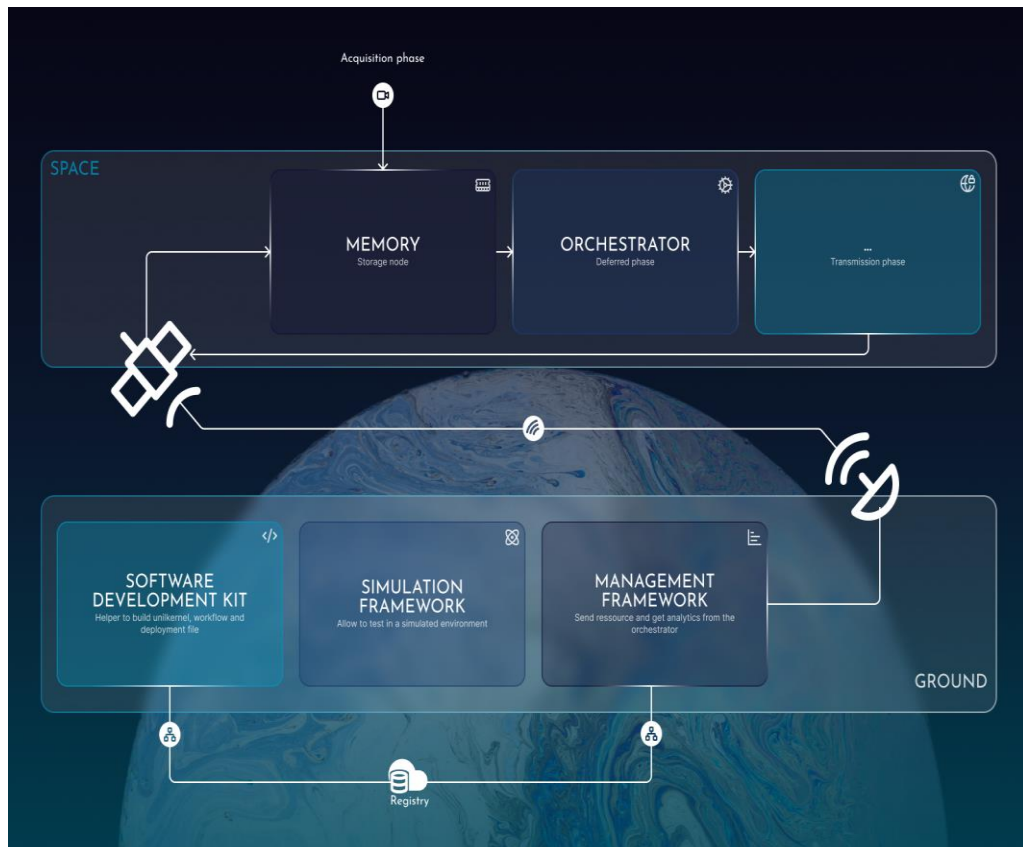
*Orchestration of **Reliable**
Computing on
Heterogeneous **Infrastructures**
Deployed
at the **Edge***
3 years: Dec 2023 – May 2026
Co-funded EU project



*The **ORCHIDE** project answers to the New Space
strategy of on board processing*

ORCHIDE Components:

- **GROUND LEVEL**
 - Software Development Kit
 - Management Framework
 - Simulation Framework
- **SPACE LEVEL**
 - Orchestrator





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SPACE EDGE PLATFORM AS A SERVICE



SATELLITE AS A SERVICE

The path for Autonomous Earth Observation Satellites – Satellite As A Service:

- Satellites follow a structured mission plan
- New capabilities added to specify AI Services to be launched for each acquisition - with a given priority.

Event type:

- ACQ : Satellite acquisition
- DOWNLOAD: Transmission window

Instrument ID:

- One satellite can have multiple INST_1, INST_2,...

Station visibility:

- NA: acquisition
- 1: Transmission window

Workflow priority:

- 1 to 4: 1 being highest priority

DATESZ	ORBIT	EV	DT_EV	INST	TYPE_D1	TYPE_D2	TYPE_D3	TYPE_D4	VISI	WORKFLOW_D1	WORKFLOW_D2	WORKFLOW_D3	WORKFLOW_D4	PRIORITY_D1	PRIORITY_D2	PRIORITY_D3	PRIORITY_D4
10/06/2029 00:23		1ACQ		4INST_1	O	O	O	O	MS	MS	MS	MS		1	1	1	2
10/06/2029 00:23		1ACQ		4INST_1	O	O	O	O	MS	MS	MS	MS		1	1	1	2
10/06/2029 00:23		1ACQ		2INST_1	O	O	O	O	MS	MS	MS	MS		1	1	1	2
10/06/2029 00:23		1ACQ		2INST_1	O	O			MS	MS	CD	CD		1	1		
10/06/2029 00:23		1ACQ		2INST_1	O	O			MS	MS	CD	CD		1	1		
10/06/2029 00:23		1ACQ		2INST_1	O	O			MS	MS	CD	CD		1	1		
10/06/2029 00:23		1ACQ		2INST_1	O	O	O	O	MS	MS	MS	MS		1	1	1	2
10/06/2029 00:23		1ACQ		50INST_1	O	O	O	O	MS	MS	MS	MS		1	1	1	2
10/06/2029 00:24		1ACQ		2INST_1	L	L	L		FD	FD	FD	CD		3	2	3	
10/06/2029 00:30		1ACQ		102INST_1	L	L	L	L	FD	FD	FD	FD		1	3	1	1
10/06/2029 01:58		2DOWNLOAD		268					1								

Event duration in seconds:

- If ACQ : acquisition duration
- If DOWNLOAD: Transmission window duration

Detector landscape type:

- O: Ocean
- L: Land

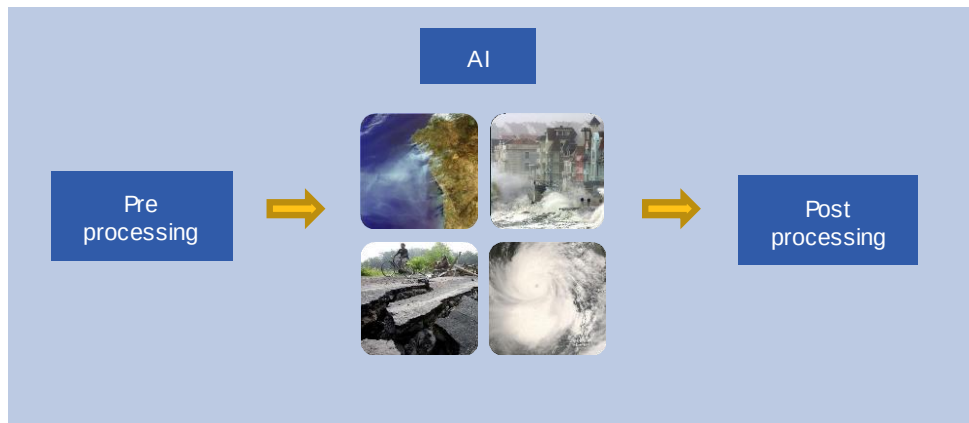
Workflow ID:

- MS: Maritime Surveillance
- FD: Fire Detection
- CD: Cloud detection

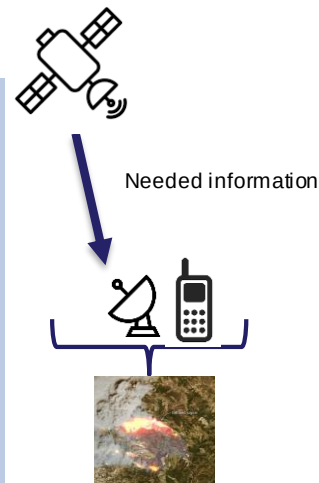
WORKFLOW SERVICES

Each AI Service is composed of several applications configured to be launched sequentially or in parallel.

DATESZ	ORBIT	EV	DT_EV	INST	TYPE_D1	TYPE_D2	TYPE_D3	TYPE_D4	VISI	WORKFLOW_D1	WORKFLOW_D2	WORKFLOW_D3	WORKFLOW_D4	PRIORITY_D1	PRIORITY_D2	PRIORITY_D3	PRIORITY_D4
10/06/2029 00:23	1	ACQ	4	INST_1	O	O	O	O		MS	MS	MS	MS	1	1	1	2
10/06/2029 00:23	1	ACQ	4	INST_1	O	O	O	O		MS	MS	MS	MS	1	1	1	2
10/06/2029 00:23	1	ACQ	2	INST_1	O	O	O	O		MS	MS	MS	MS	1	1	1	2
10/06/2029 00:23	1	ACQ	2	INST_1	O	O				MS	MS	CD	CD	1	1		
10/06/2029 00:30	1	ACQ	102	INST_1	L	L	L	L		FD	FD	FD	FD	1	3	1	1
10/06/2029 01:58	2	DOWNLOAD	268						1	AI Service							



Example of an applications workflow

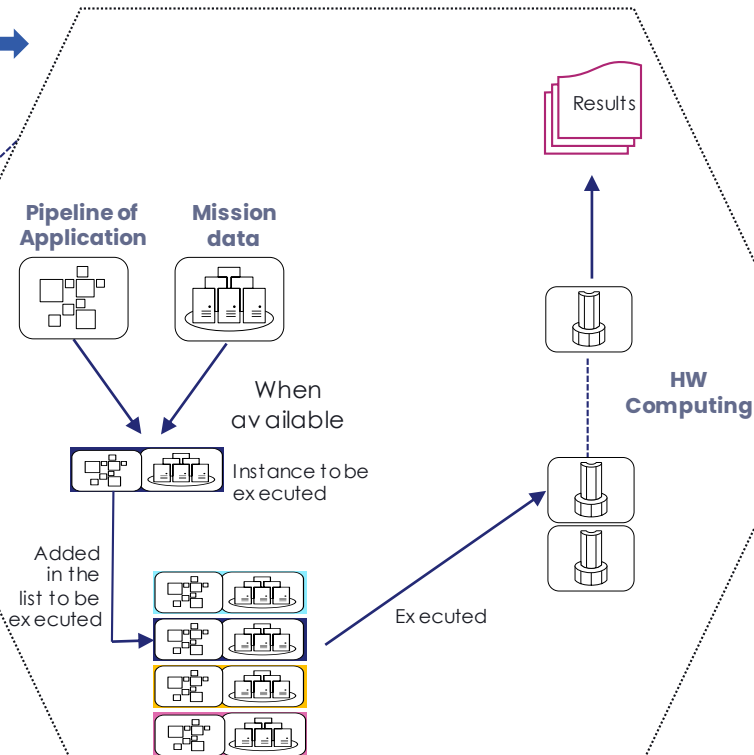


ORCHESTRATION – SATELLITE AS A SERVICE

DATESZ	ORB IT	EV	DT EV	INST	TYPE_D1	TYPE_D2	TYPE_D3	TYPE_D4	VISI	WORKFLO W_D1	WORKFLO W_D2	WORKFLO W_D3	WORKFL OW_D4	PRIORIT Y_D1	PRIORITY_D2	PRIORIT Y_D3	PRIORI TY_D4
10/06/2029 00:23	1	ACQ	4	INST _1	O	O	O	O		MS	MS	MS	MS	1	1	1	2
10/06/2029 00:23	1	ACQ	4	INST _1	O	O	O	O		MS	MS	MS	MS	1	1	1	2
10/06/2029 00:23	1	ACQ	2	INST _1	O	O	O	O		MS	MS	MS	MS	1	1	1	2
10/06/2029 00:23	1	ACQ	2	INST _1	O	O				MS	MS	CD	CD	1	1		
10/06/2029 00:30	1	ACQ	102	INST _1	L	L	L	L		FD	FD	FD	FD	1	3	1	1
10/06/2029 01:58	2	DOWNL OAD	268														

Example of mission plan

Processing steps on satellite



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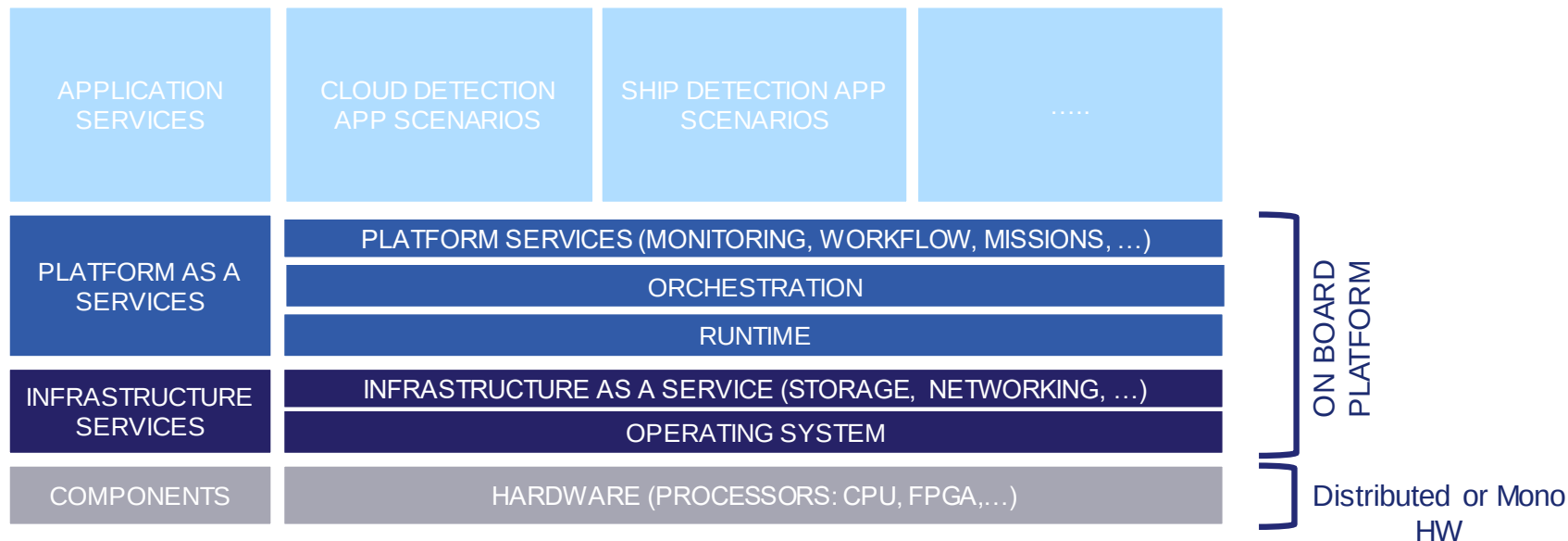
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ONBOARD PLATFORM OVERVIEW

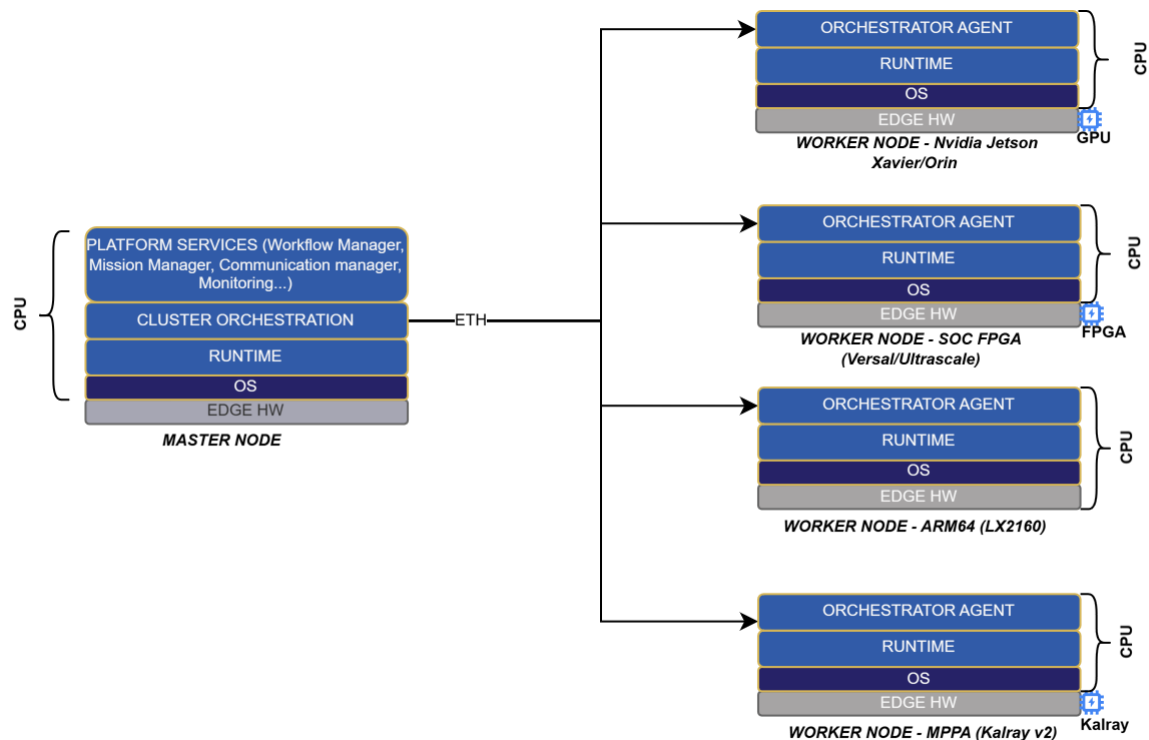


ONBOARD DISTRIBUTED PLATFORM

Hardware Diversity - Works with single-node and multi-node clusters

Scalability - Dynamic node management (availability, reintegration).

Efficient Resource Usage - Enables parallel execution and optimal accelerator assignment



ORCHIDE Distributed Setup

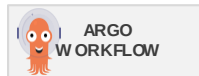
PAAS – TECHNICAL ECOSYSTEM

SATELLITE AS A SERVICE PLATFORM

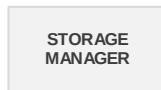
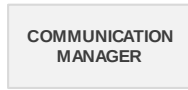
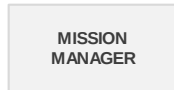
PLATFORM AS A SERVICE

Services Platform

CotS



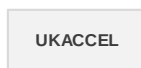
Specific Services



Orchestration



Runtime Environments





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PLATFORM AS A SERVICES LAYERS



PAAS – APPLICATION RUNTIME

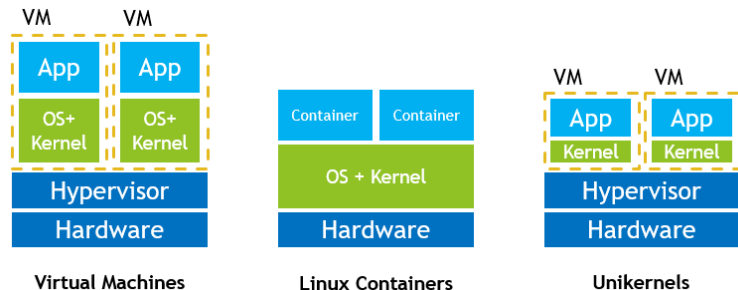
Unikernels quick primer:

- Package program and needed OS code (only) together
- Resulting image is executed directly as hypervisor guest

Why:

- Binary size: orders of magnitude smaller
- Performance: enables global code optimization
- Security: reduces attack surface

Chosen Framework: MirageOS & Unikraft



Technology stack comparison

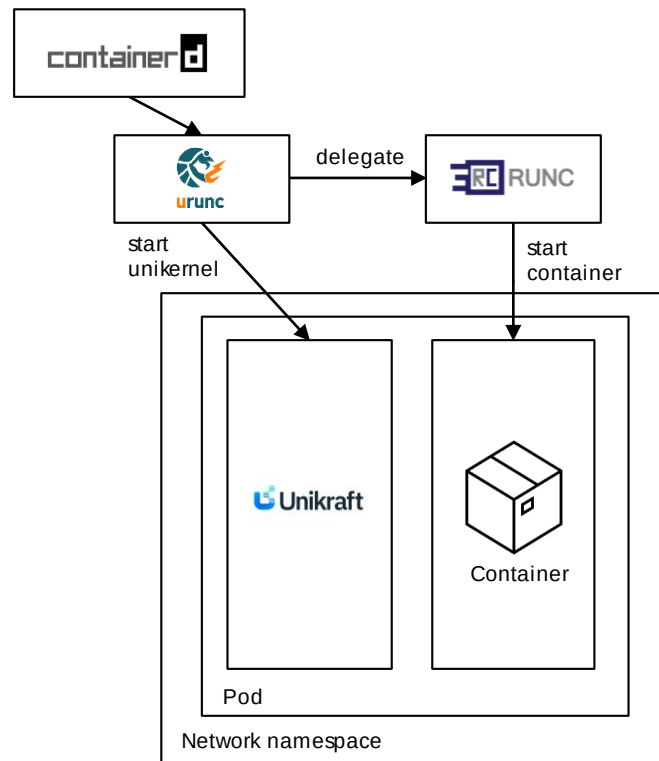
PAAS – UNIKERNEL RUNTIME

OCI runtime for unikernels:

- Run unikernels as if they are containers
- Needs MirageOS and Unikraft compatibility
- Plugs into K8s and derivatives

Urunc:

- Open source runtime
- Compatible with MirageOS, Unikraft
- Runs over QEMU/KVM on x86_64 and aarch64
- Support OCI images



Launching unikernels

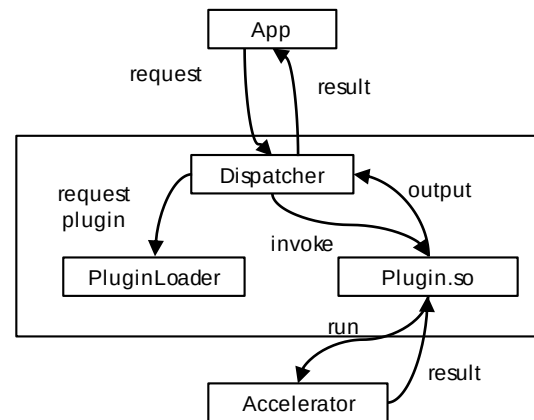
PAAS – ACCELERATORS FROM UNIKERNELS

Emerging Hardware Capabilities for OnBoard Processing:

- Higher performance for heavy processing workloads
- Integrated in next-generation satellites
- Containers require interfaces to access accelerators
- Unikernels currently lack this capability

Our platform Solution – ukAccel:

- TCP interface to load blobs in accelerators
- Built in-house component
- Based on vAccel but doesn't require dynamic linking



ukaccel Architecture

PAAS – CONTAINER ORCHESTRATION SOLUTION

K3s chosen as Cloud Native orchestration solution: Lightweight | Simple setup | Modular

	KubeEdge	K3s	K0s	MicroK8s	Oakestra
Automated install	No	Yes	Yes	Yes	No
Federation support	No	No	No	No	Yes
Unikernel Support	No	No	No	No	No
Security Features	Yes	Yes	Yes	Yes	No
Resource Tracking	Yes	Yes	Yes	Yes	Yes
Resource Limit	Yes	Yes	Yes	Yes	Yes



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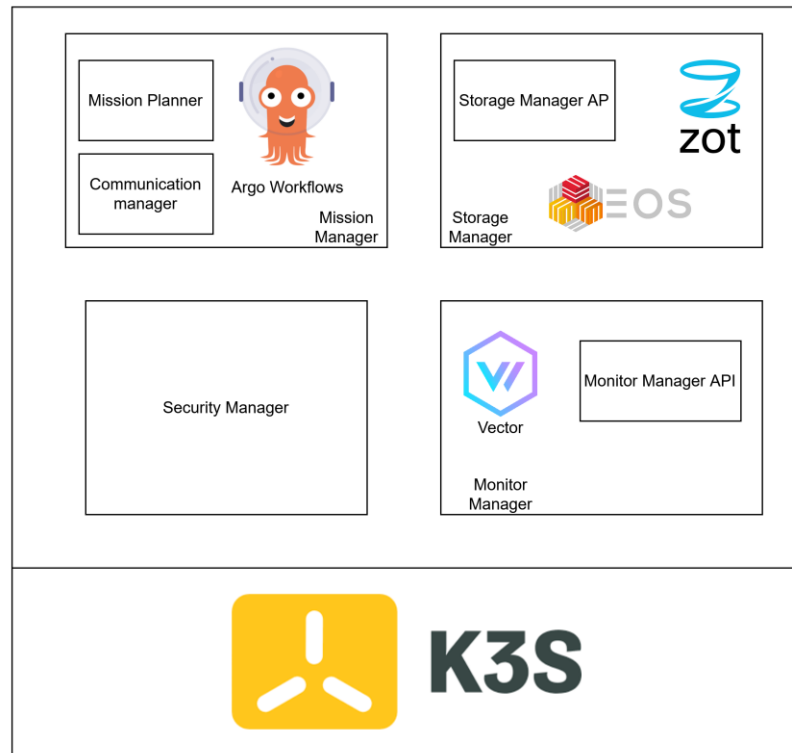
PLATFORM SERVICES – ON ORCHESTRATOR NODE

COTS integration with mission critical functionalities require glue code

On orchestrator node:

Managers are required to get inputs, outputs and transfer data:

- **Storage Manager:** Keeps track of files
- **Monitor Manager:** Aggregates and stores monitoring files
- **Security Manager:** Ensures on-satellite security posture
- **Mission Manager:** Receives workflow schedules and translates them to Argo Workflow while managing inputs and outputs



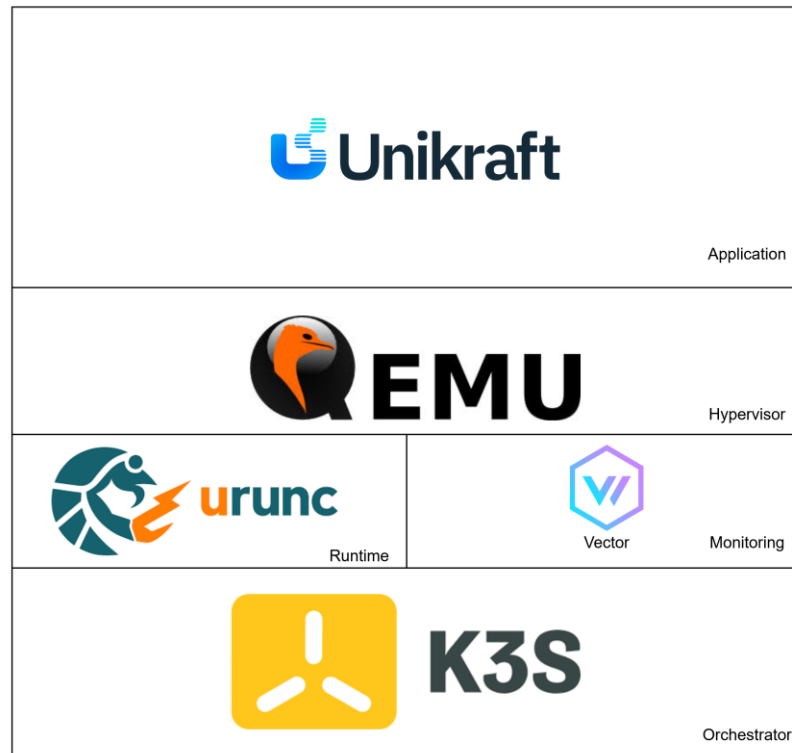
Platform components deployed on orchestrator node

PLATFORM SERVICES – ON COMPUTE NODE

COTS integration with mission critical functionalities require glue code

On compute node:

All is managed through K3s and urunc, no glue code required.

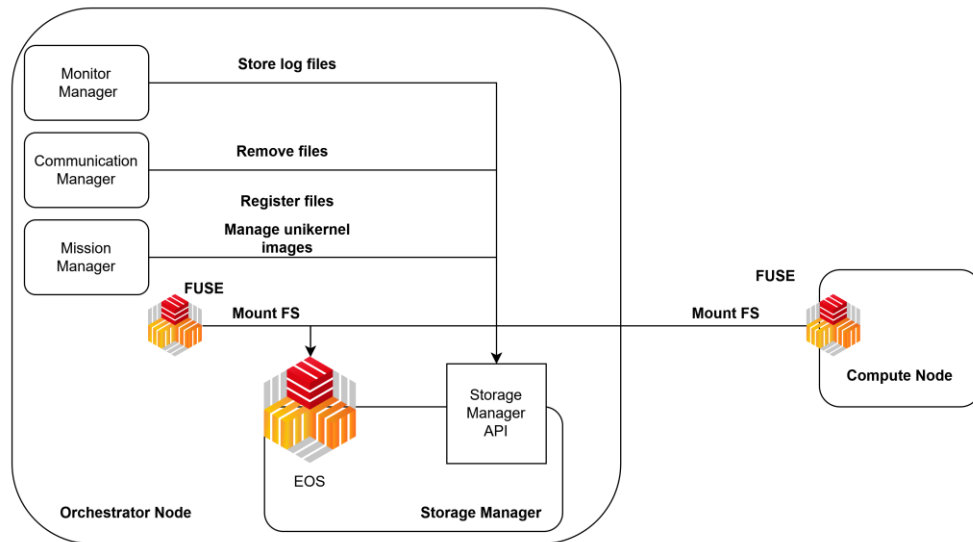


Platform components on the compute node

PAAS – SHARED STORAGE SOLUTION

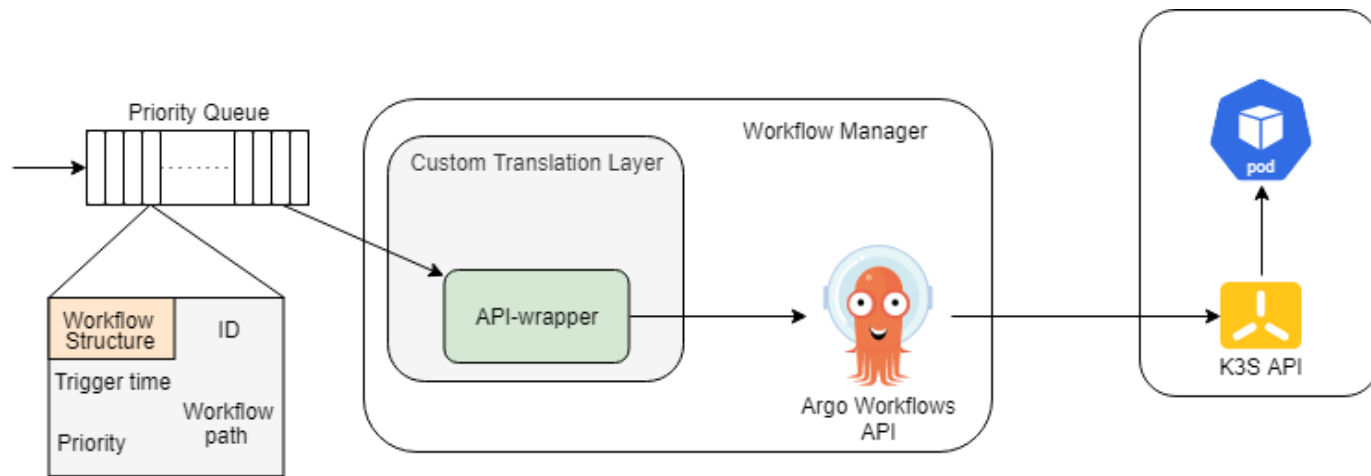
Distributed processing requires a shared storage solution:

- POSIX FS required for interoperability: EOS
- Store apps in Zot registry
- Implements DB for file and app management
- Monitors FS for discrepancies



ORCHIDE Storage Manager Architecture

PAAS – WORKFLOW MANAGEMENT

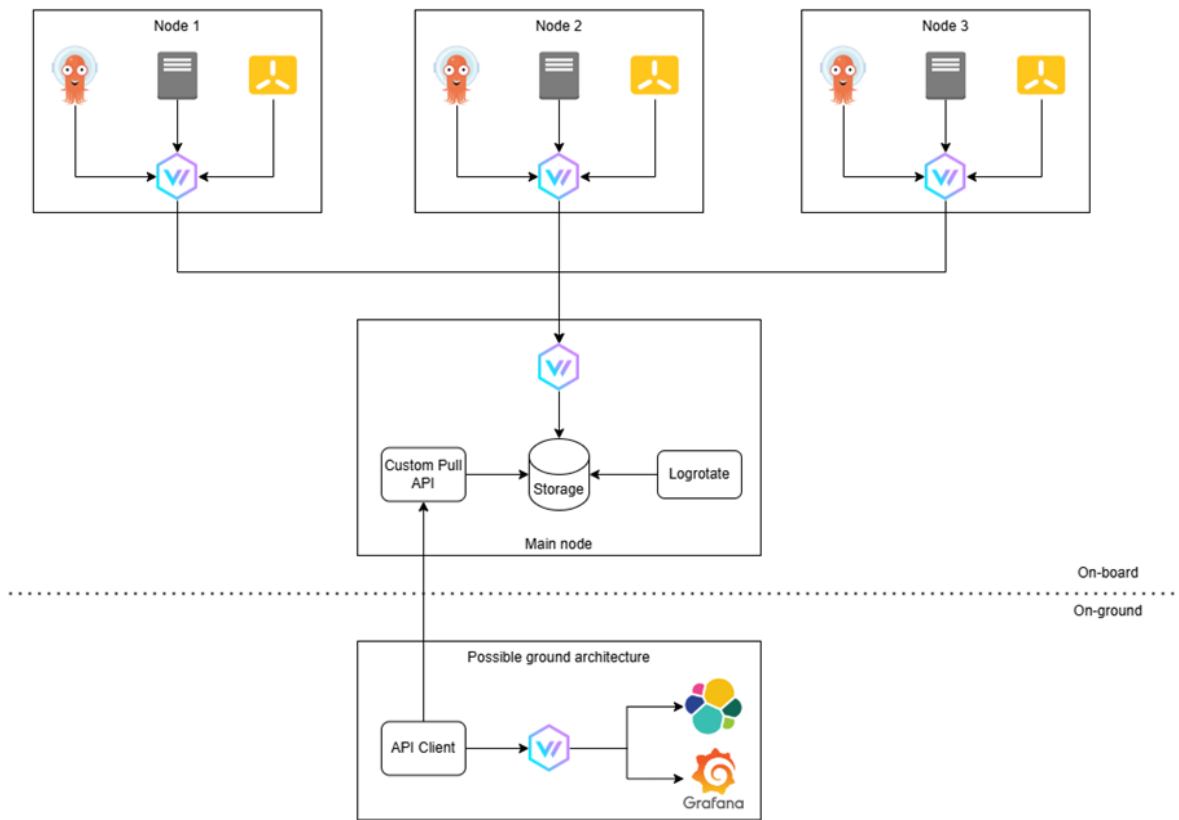


ORCHIDE Workflow Steps

- Implemented a translation from Mission Plan to Argo workflow
- Argo Workflows are triggered and executed on node
- Glue code was implemented to handle inputs, outputs and task preemption based on priority

PAAS – MONITORING

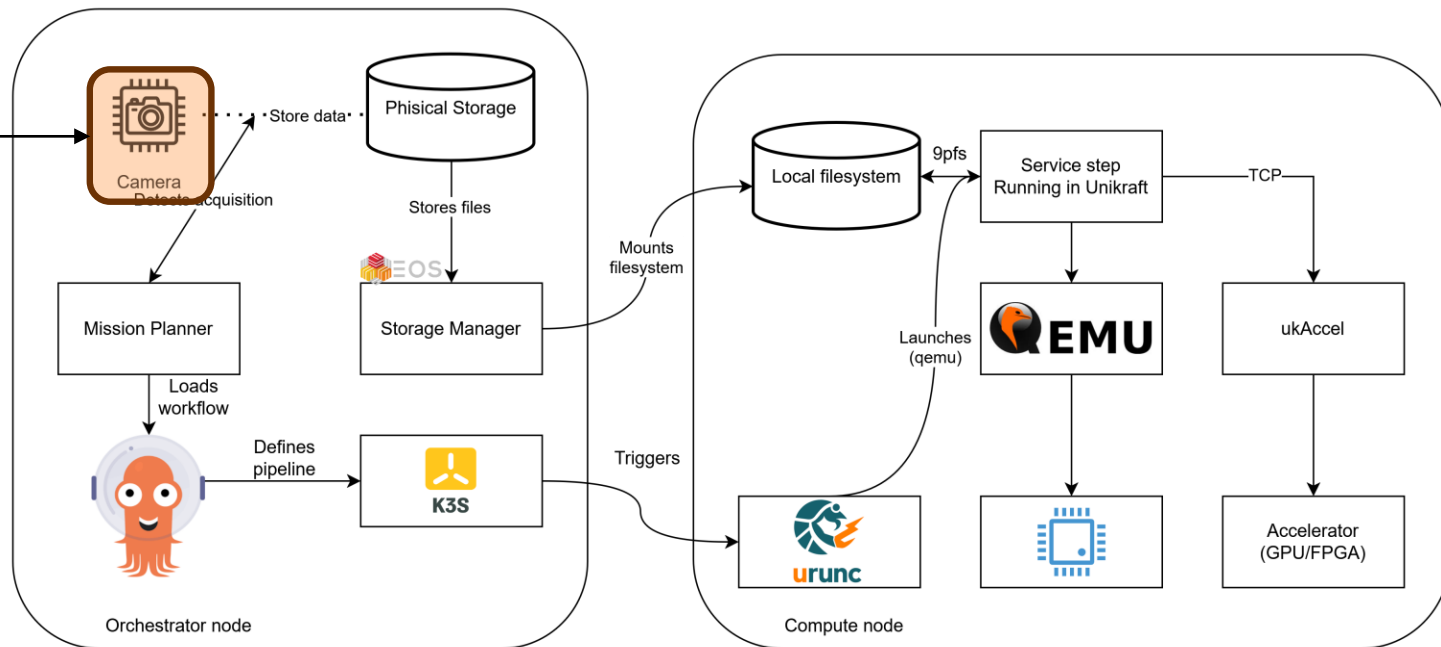
- Collected logs and metrics aggregated on host
- Aggregated logs and metrics sent to ground and deleted
- Once on ground logs ingested in OpenSearch and metrics in Prometheus



ORCHIDE Monitoring Setup

PAAS – END TO END DEMONSTRATION

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10/06/2029 00:23	1	ACQ	2	INST_1	O	O	O	O		MS	MS	CD	CD	1	1	1	2
10/06/2029 00:30	1	ACQ	102	INST_1	L	L	L	L		FD	FD	FD	FD	1	3	1	1
10/06/2029 01:58	2	DOWNLOAD	268						1								



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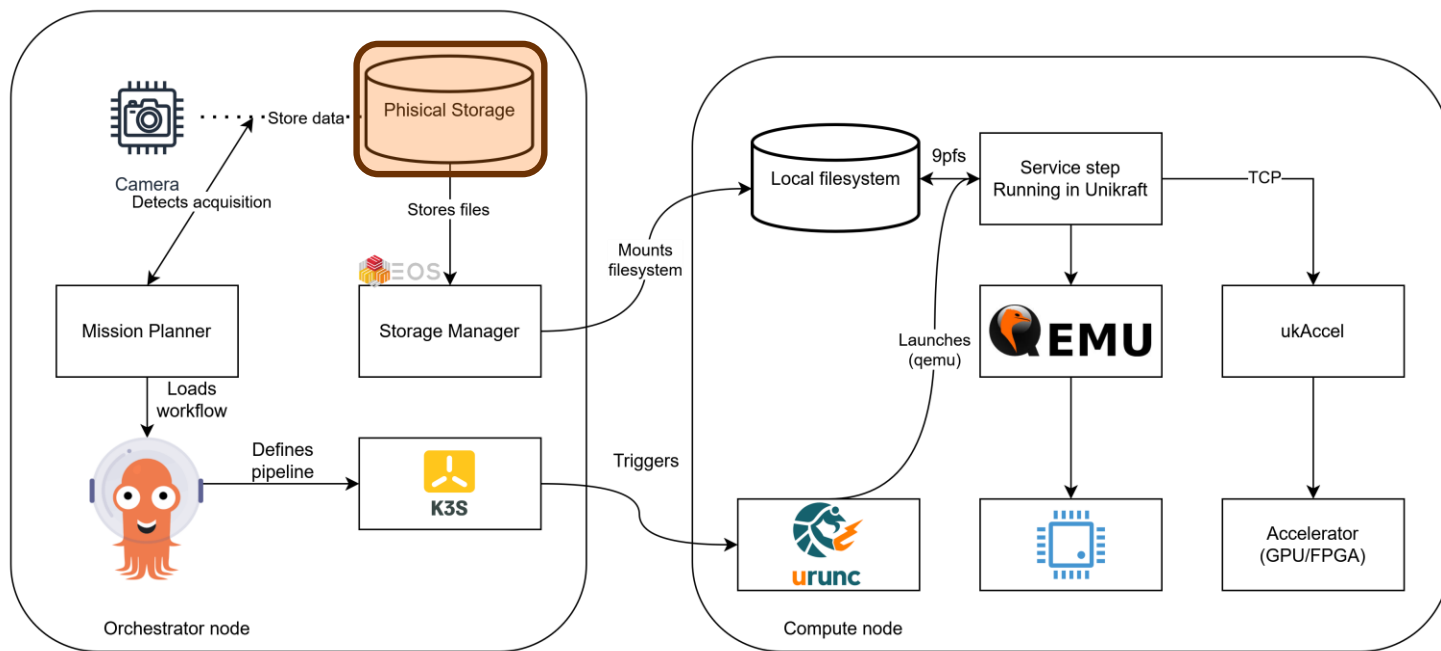
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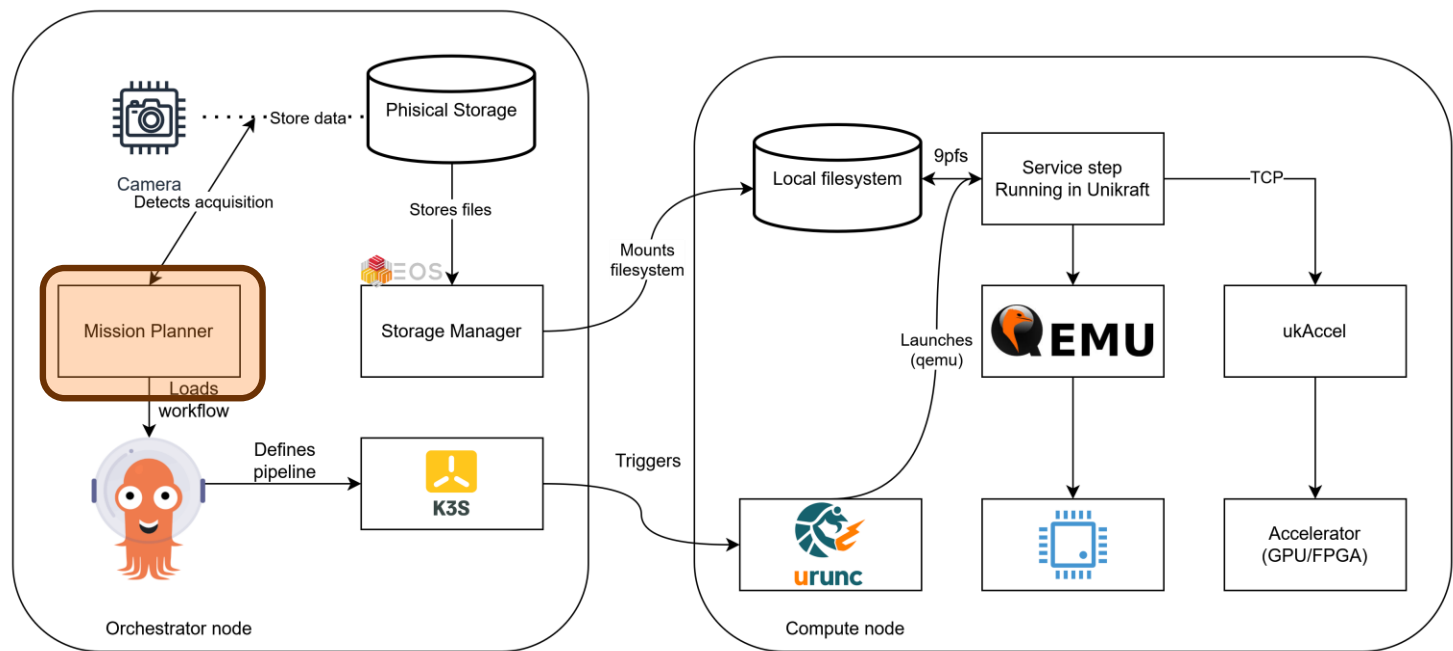
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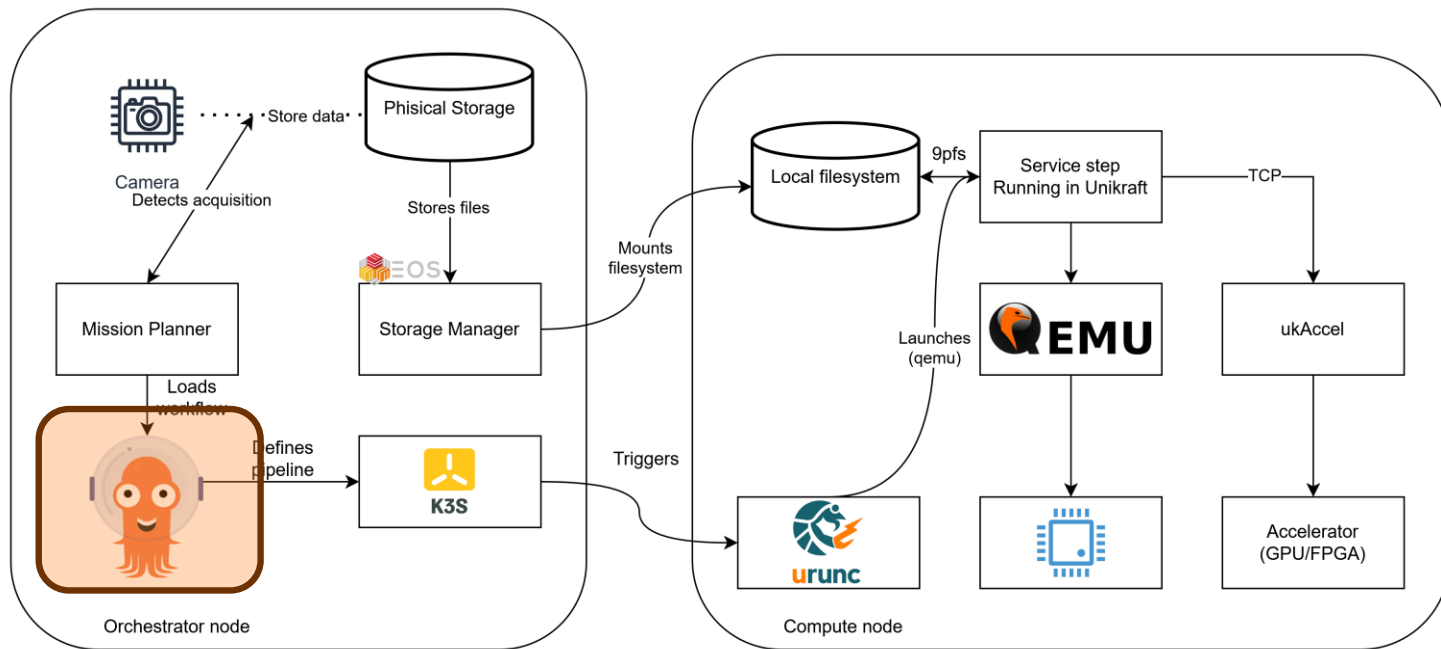
PAAS – END TO END DEMONSTRATION



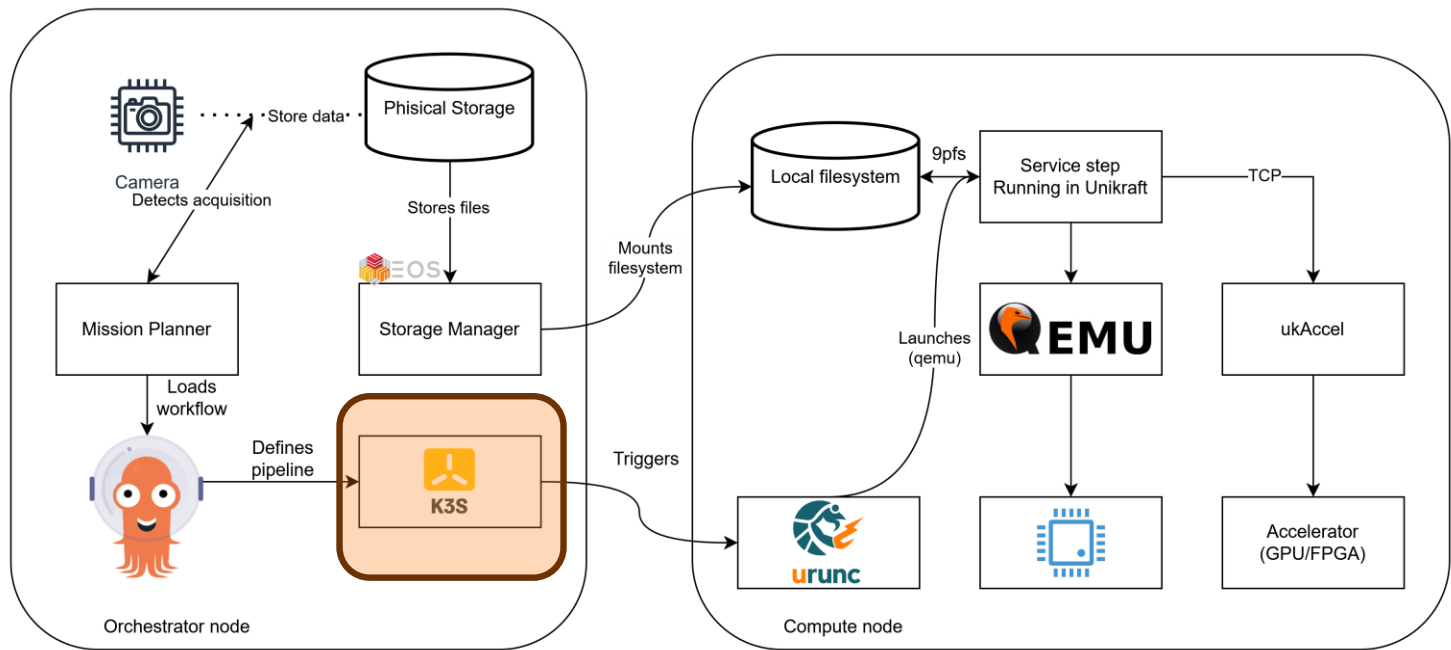
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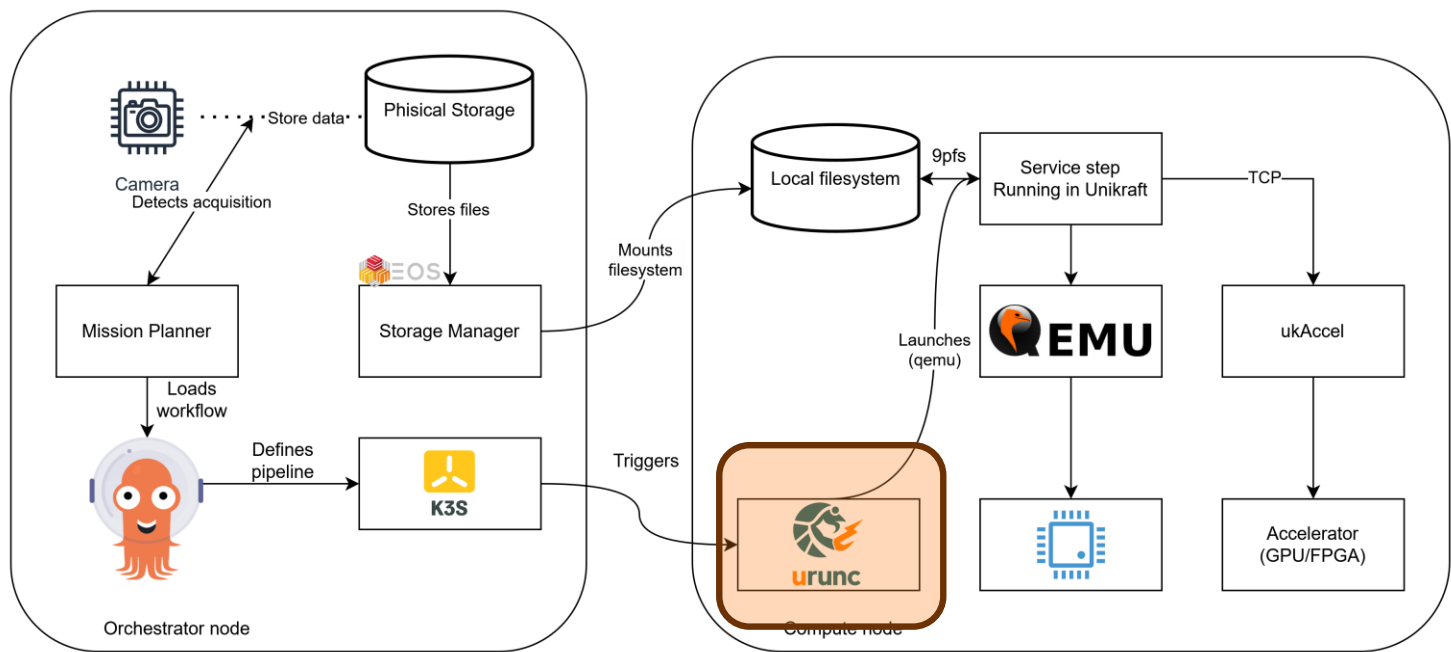
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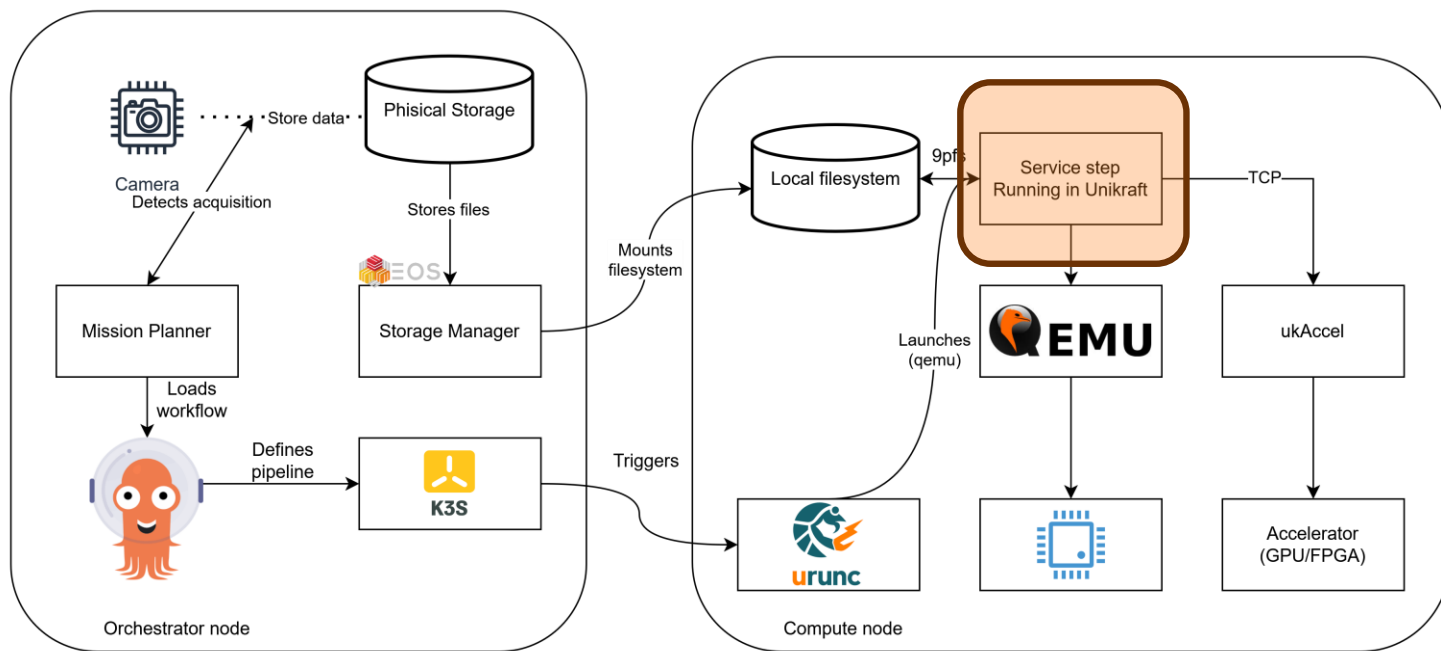
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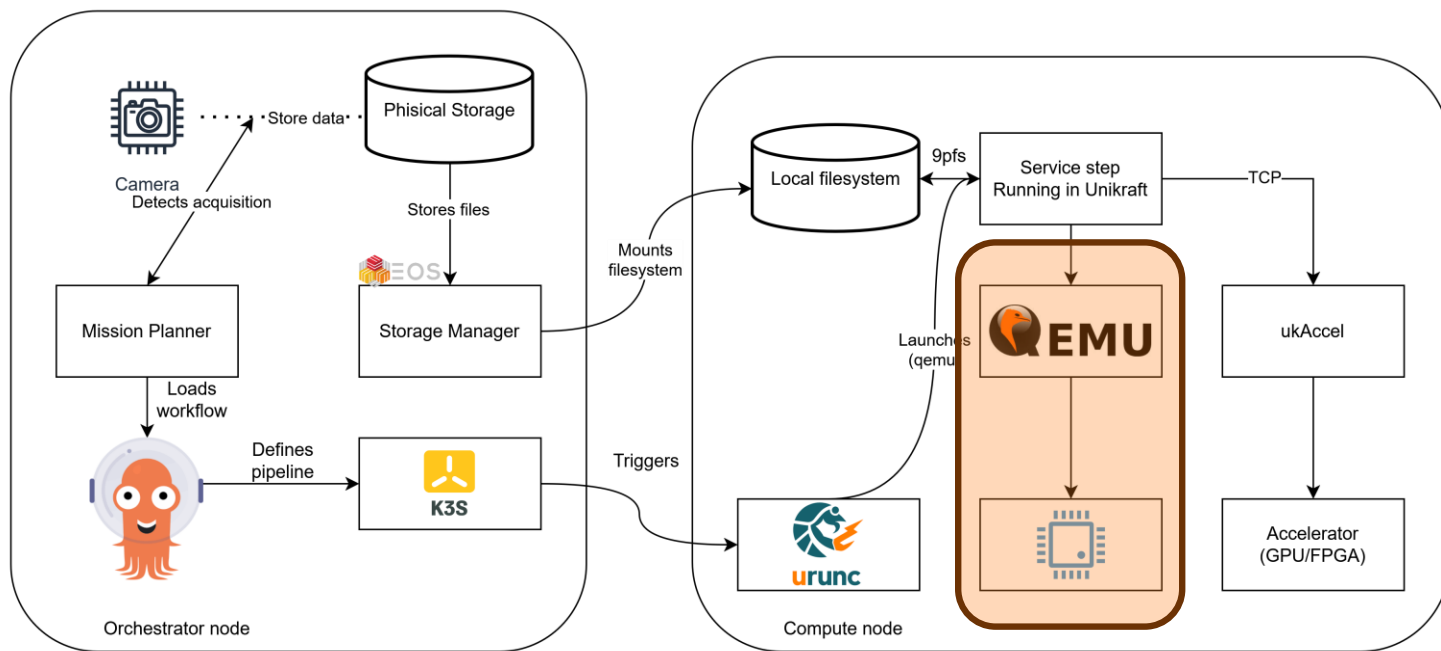
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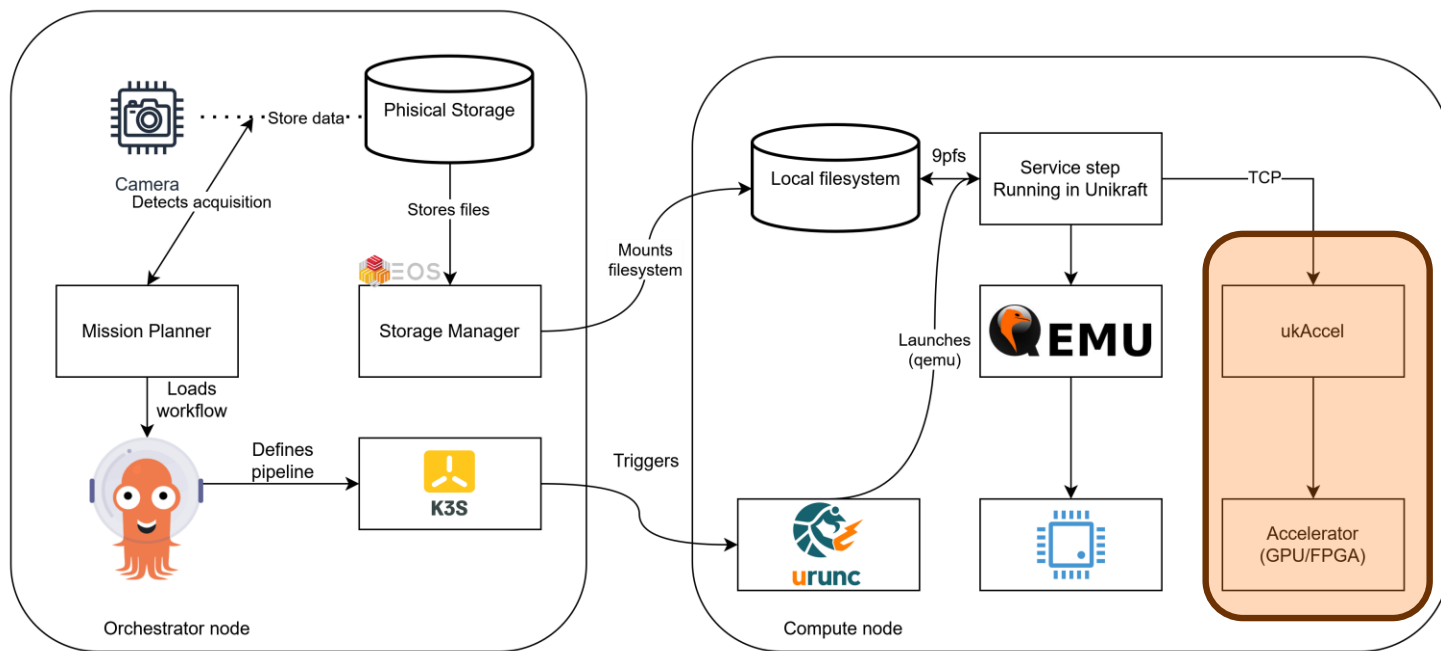
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PAAS – END TO END DEMONSTRATION



PAAS – END TO END DEMONSTRATION



Follow Us !

The ORCHIDE project will be made available to the community as an open-source project — stay tuned and follow us to contribute to the journey!



ORCHIDE project LinkedIn



Conclusion



Achievements

Designed a distributed architecture for onboard software platform

Addressed scheduling heterogeneous computing, data exchange
=> TRL6

Future Vision

From edge computing in a single satellite → to federated multi-satellite systems.

Cross-satellite workload distribution & inter-satellite communication protocols.

Impact

Unlocks new mission capabilities and involves new companies

Autonomous spacecraft

In-orbit servicing
Exploration missions

THANK YOU !

Q&A



Bringing Cloud-Native PaaS to Space: Onboard Edge Computing
for Satellites

