

# Reference architectures for cloud continuum:

## Convergence VS. Diversification

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# Agenda

1. Steppingstones  
to reference architectures

2. Smart, orchestrated  
reference architectures

3. Applications/development of reference architectures

...focusing on Cyber-Physical Systems





# Industry 4.0 in Europe: Initiatives on Digitizing Industry

## EU-level initiatives

- **Digitising European Industry Initiative (COM(2016)180)**
- **Multi-region Initiatives**
- **Vanguard**

### Netherlands

- Smart Industry (NL)

### Belgium

- Made Different
- Flanders Make (Flanders)
- Marshall 4.0 (Wallonie)

### France

- Nouvelle France Industrielle
- Industrie du Futur
- Transition Numérique
- Le Programme des Investissement d'Avenir
- **Plan Industries Île-de-France**

### Spain

- Industria Conectada 4.0
- **Basque Industry 4.0**

### Portugal

- Indústria 4.0

### Denmark

- **MADE**

### Sweden

- Smart Industry (SE)

### Germany

- Plattform Industrie 4.0
- Mittelstand 4.0
- **It's OWL (Ostwestfalen-Lippe)**
- **Allianz Industrie 4.0 (Baden-Württemberg)**

### Czech Republic

- Průmysl 4.0

### Slovakia

- Smart Industry (SK)

### Austria

- Plattform Industrie 4.0

### Hungary

- IPAR4.0 Platform

### Italy

- Piano nazionale Industria 4,0

European initiatives  
National initiatives  
Regional initiatives

Source: <https://ec.europa.eu/futurium/en/system/files/ged/backwall-booth.pdf>

**IPAR** 4.0  
NATIONAL TECHNOLOGY PLATFORM



 **SZTAKI**

➔ <https://www.i40platform.hu/en>

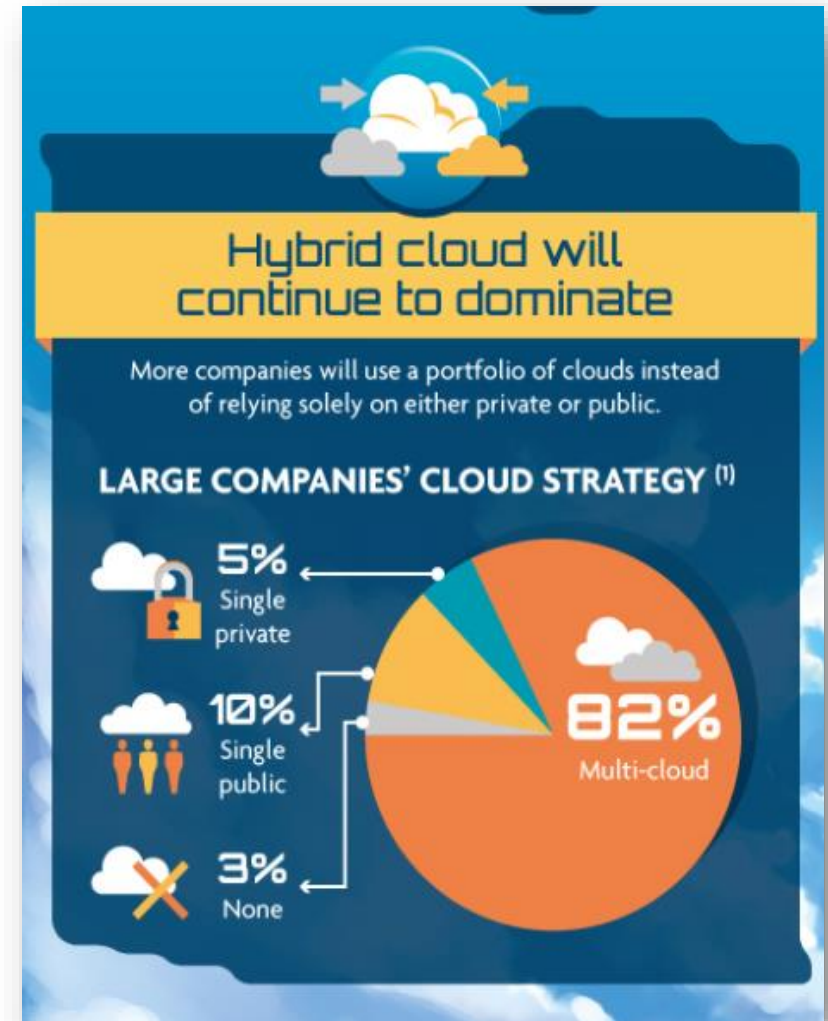
# Recent trends

- Several solutions are already available from public cloud providers for **Internet of Things (IoT)** and **Big Data** application areas.



- **Private** clouds have significant benefits in terms of security and integrability into the enterprise environment but **hybrid** and **multi-clouds** are also widespread.

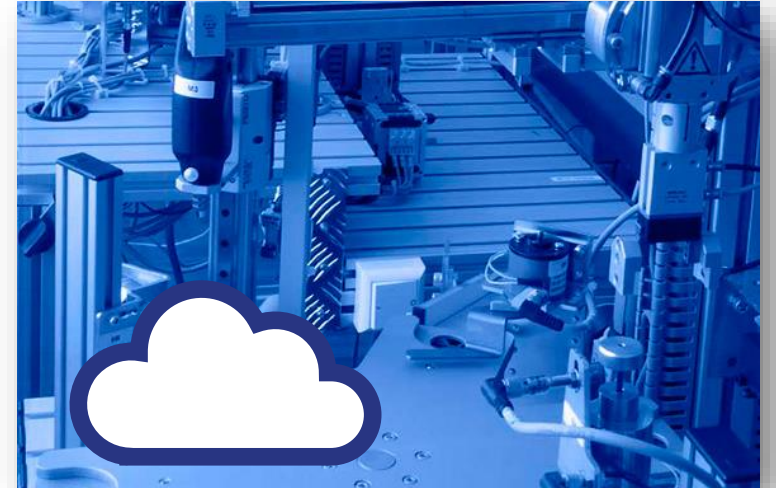
➔ Growing demand for cloud **orchestrators** tools



Source: [www.computerzone.org](http://www.computerzone.org)

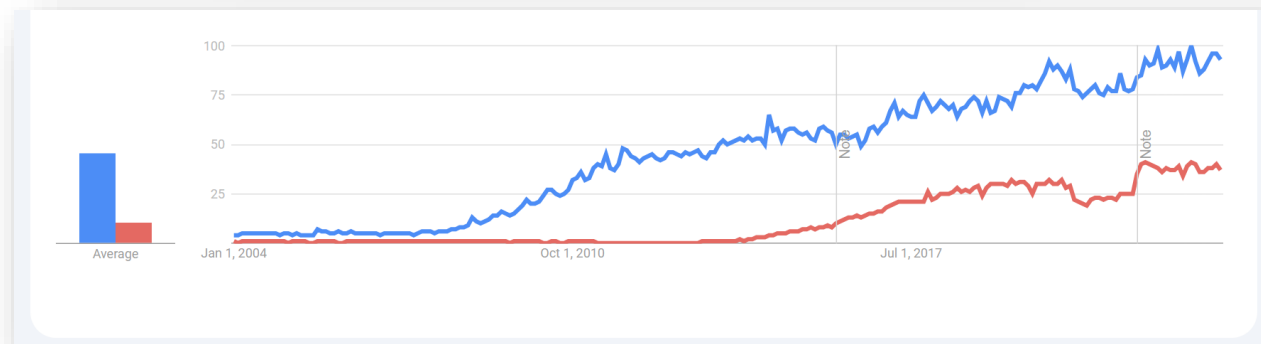
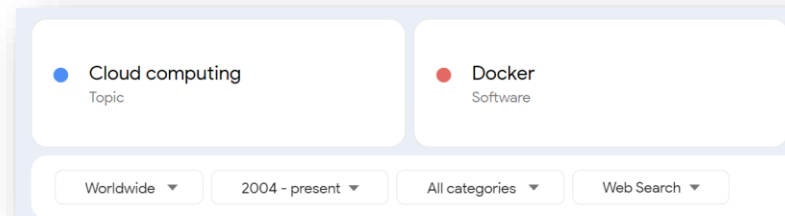
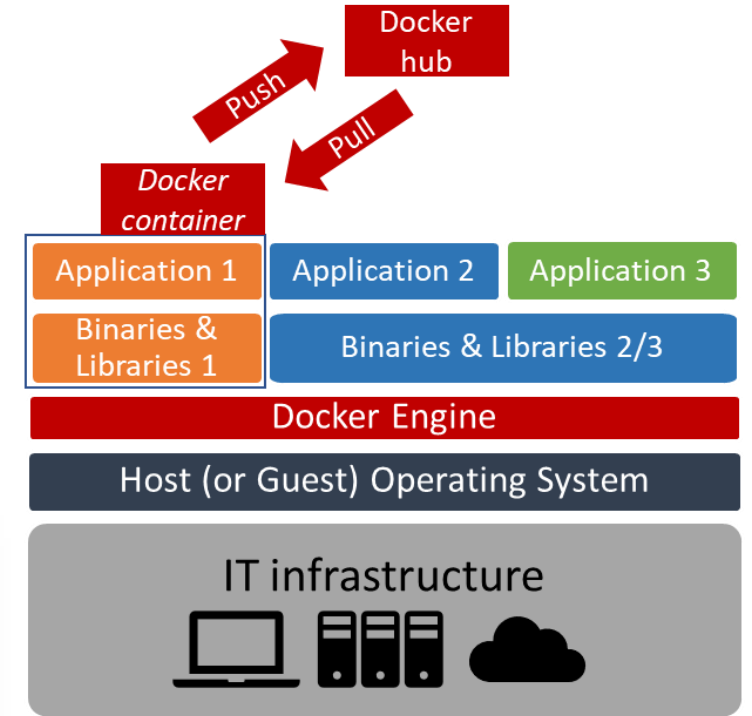
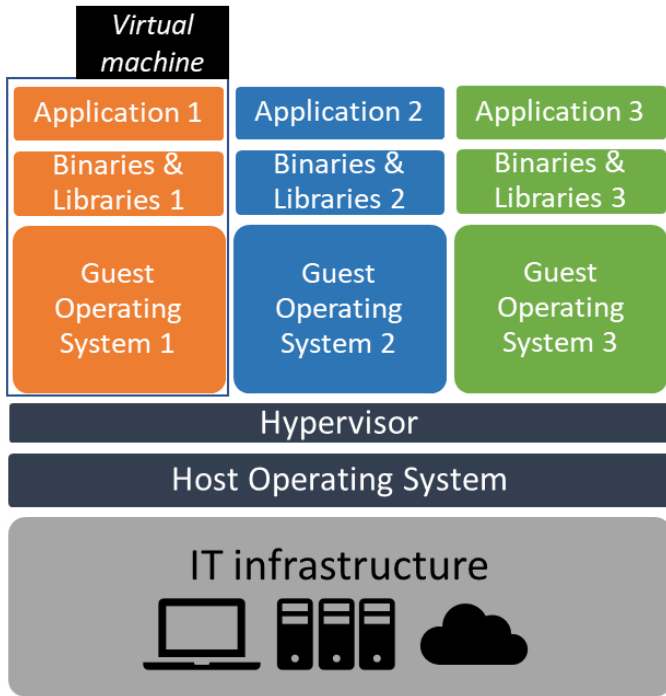
# Clouds in production systems: some non-trivial problems

- Application areas:
  - Store and process **sensor data**
  - Historical **analysis**, simulations, predictions, etc.
  - **Visualisation**
- Industrial users face challenges when they intend to benefit from cloud computing:
  - **migration** of *legacy and new applications* into clouds
  - their **orchestrated** deployment/maintenance,
  - their on-demand **scaling**,
  - **portability**, when a cost-efficient hybrid cloud or cloud agnostic (vendor independent) solution is needed, etc.



➔ emerging new software container and orchestrator solutions

# Trends: cloud vs. container technologies



Source: Google trends

# Emerging cloud orchestration tools

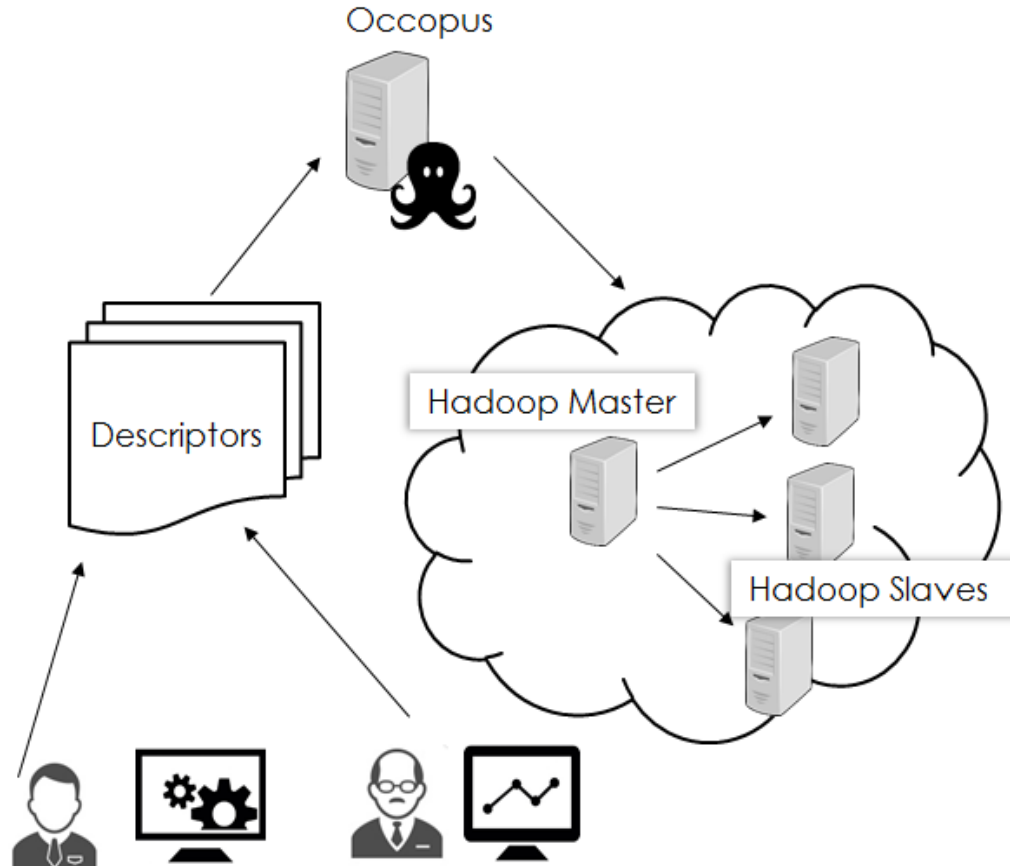
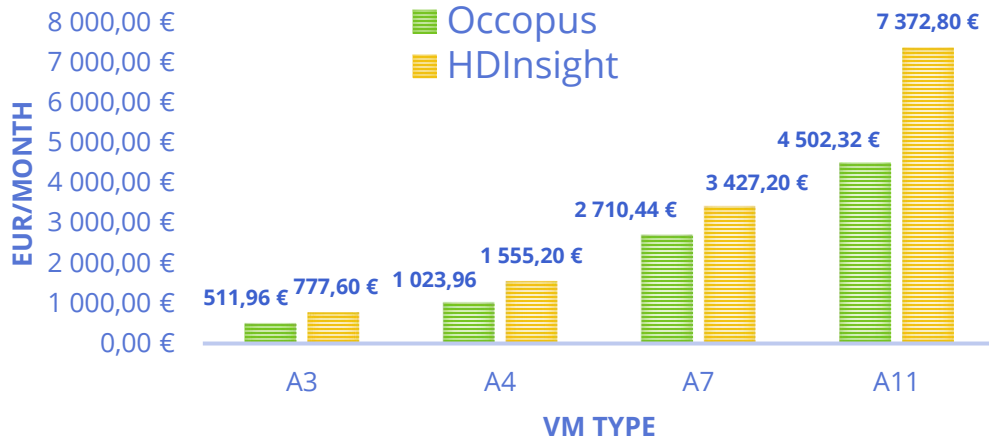
- “**Orchestration** is the automated configuration, coordination, and management of computer systems and software.” (including the deployment and maintenance, i.e. the entire life-cycle)
- A number of tools exist for automation of **server configuration** and management
  - Ansible, Puppet, Salt, Terraform, AWS CloudFormation, etc.
- For **container orchestration** there are different solutions
  - Kubernetes or
  - managed services such as AWS EKS



# Occopus hybrid cloud / container orchestrator

- Multi-cloud solution
- Contextualization
- No vendor lock-in
- Portable descriptor file
- Big Data support
- Enable auto-scaling

MONTHLY FEE: 4 NODE HADOOP CLUSTER



→ [occopus.lpds.sztaki.hu](http://occopus.lpds.sztaki.hu)



# What is the next step?

NEW GENERATION OF  
REFERENCE ARCHITECTURES

with advanced, smart orchestration methods

...along with new wave of AI tools and platforms



# Background: Reference architectures for AI/ML

- For the various AI application scenarios, the major cloud providers offer **reference architectures with building blocks/connections recommended practices**, along with considerations for
  - **scalability**,
  - **availability**,
  - **manageability**,
  - and **security**.

The image shows two screenshots of cloud provider reference architecture centers. The left screenshot is from the Azure Architecture Center, titled "Browse Azure Architectures". It features a search bar, a "Filter by" section with "Products" (Azure, Bing, Dynamics 365, GitHub, Microsoft Defender, Microsoft Entra, Microsoft Graph, Microsoft Power Platform, Office) and "Categories" (AI + Machine Learning, Analytics, Compute, Containers, Databases, Developer Tools, DevOps) lists. The main content area shows a search result for "Analyze call center recordings using text analysis Service" with a diagram illustrating the architecture flow from storage to analysis and back to storage. The right screenshot is from the AWS Architecture Center, showing a search bar with the text "Search the AWS Architecture Center", a "Filter by" section with "Content Type" (Patterns, Reference Architecture Diagrams, AWS Solutions, Guidance, Technical Guides, Videos, Whitepapers), "Methodology" (AWS Well-Architected, Cloud Adoption Framework), and "Technology Categories" (Analytics & Big Data, Application Integration, Blockchain, Cloud Financial Management, Compute, Containers, Databases, Developer Tools, End-User Computing, Front-End Web & Mobile, Internet of Things (IoT), Machine Learning & AI). The main content area shows two reference architecture diagrams: "DescribeForMe Web App" (labeled "NEW") and "Revenue Management Architecture for Airlines" (labeled "UPDATED").

➔ NOT ONLY “GLUING” TOGETHER SERVICES BUT STRONG FOCUS ON **NON-FUNCTIONAL** REQUIREMENTS AND FEATURS

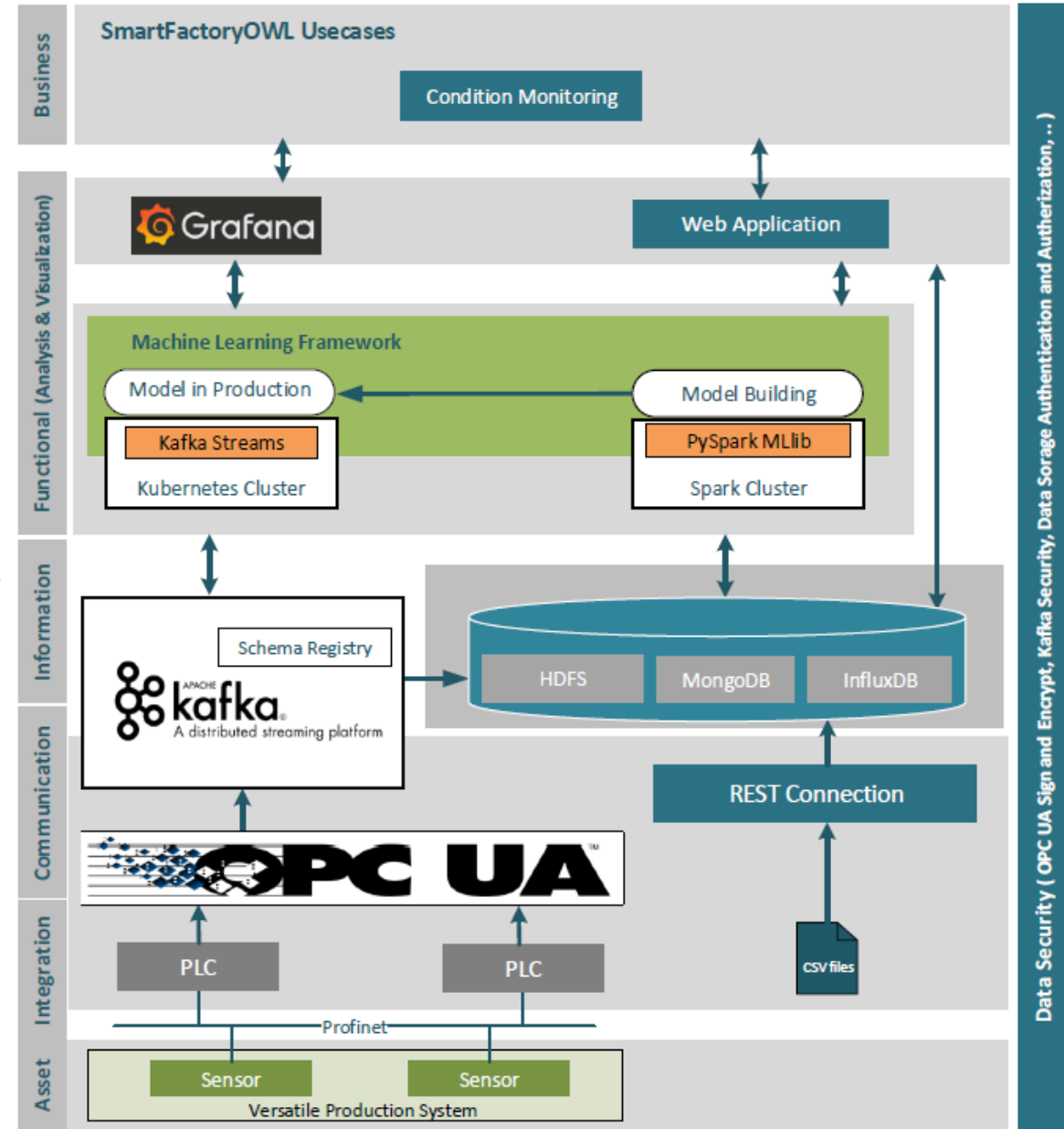
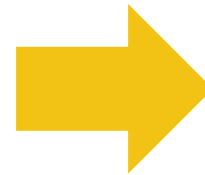
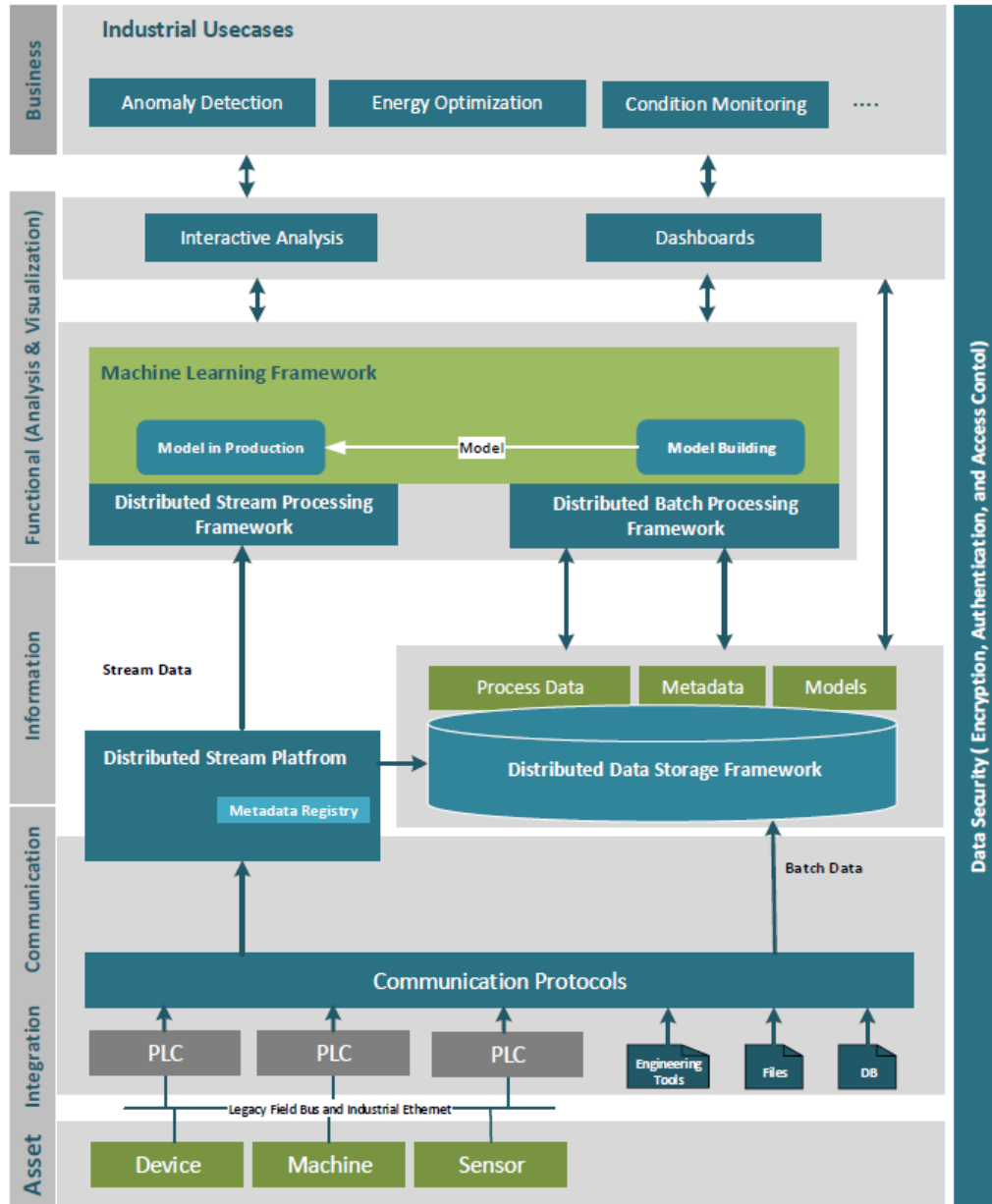
## Background: Reference architectures for AI/ML (cont.)

- Commercial reference architectures are available from several **HPC vendors**:
  - Hewlett Packard Enterprise elaborated its reference architecture for AI (inc. HW)
  - IBM and other vendors provide similar solutions, etc.
- Concentrating on the **manufacturing sector**, a reference architecture has been published by Fraunhofer IOSB.
  - Designed for scalable data analytics in smart manufacturing systems, and complies with the higher-level *Reference Architecture Model for Industrie 4.0* (RAMI 4.0).
  - Implemented and validated in the Lab Big Data at the SmartFactoryOWL based on various open-source technologies (Spark, Kafka, Grafana).

All these approaches leverage mostly on open source tools and frameworks, such as TensorFlow or Apache Spark.

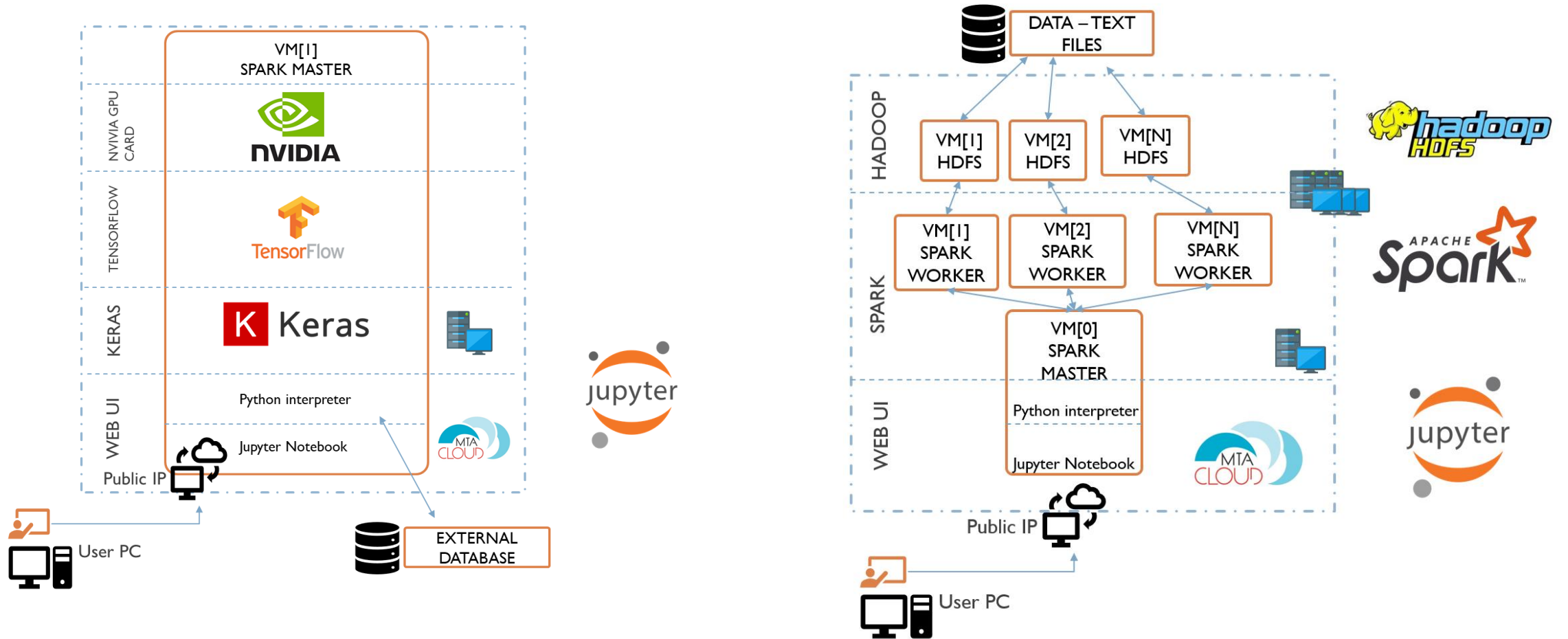
# A reference architecture and its implementation

## from Fraunhofer IOSB





# Orchestrated AI/ML reference architectures



# Towards smart orchestration of reference architectures

## ➔ higher reliability by detecting/predicting critical failures

*"Modelling and enhancement of orchestration methods for virtual research platforms with machine learning" project (2019-2023)*

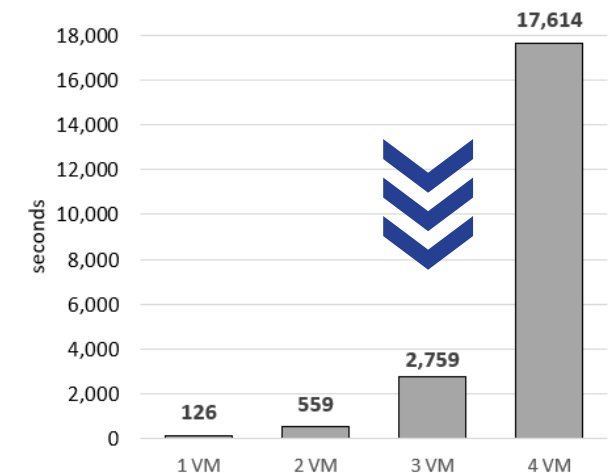
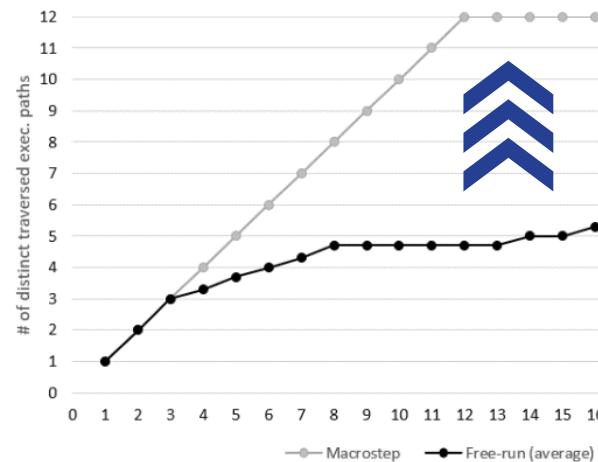
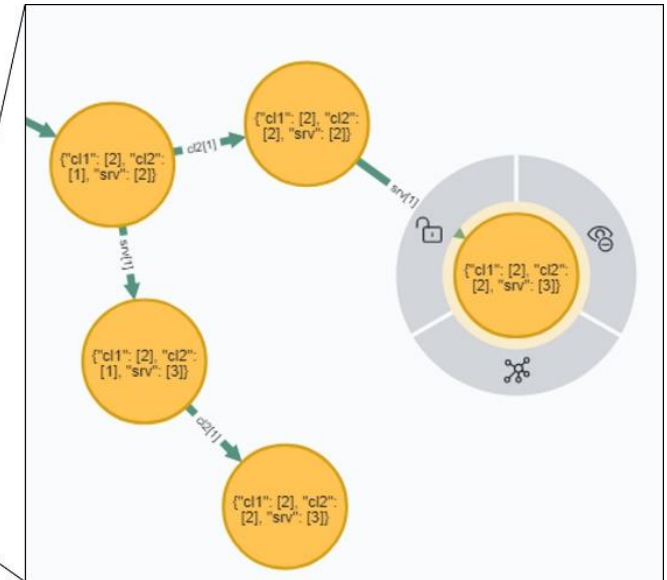
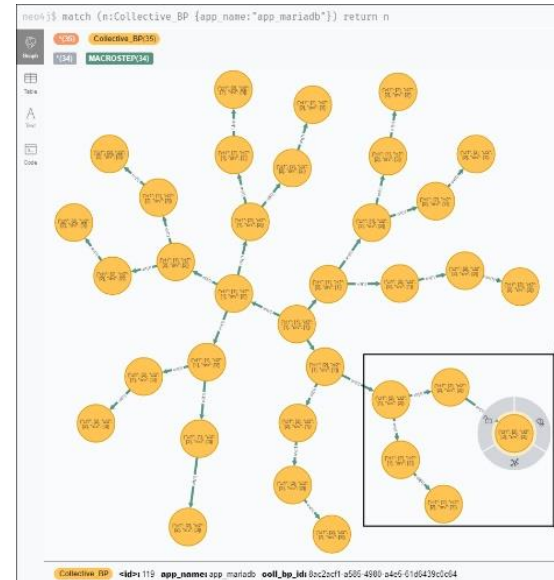
supported by



The research addresses the following phenomena and methods:

1. Large number of hierarchical orchestration steps with dependencies
2. The non-deterministic and dynamic behaviour of cloud (and similar) environments with probe-effect

➔ Steered, automated traversing and verification of consistent global states (based on machine learning)



**What is the next step?**

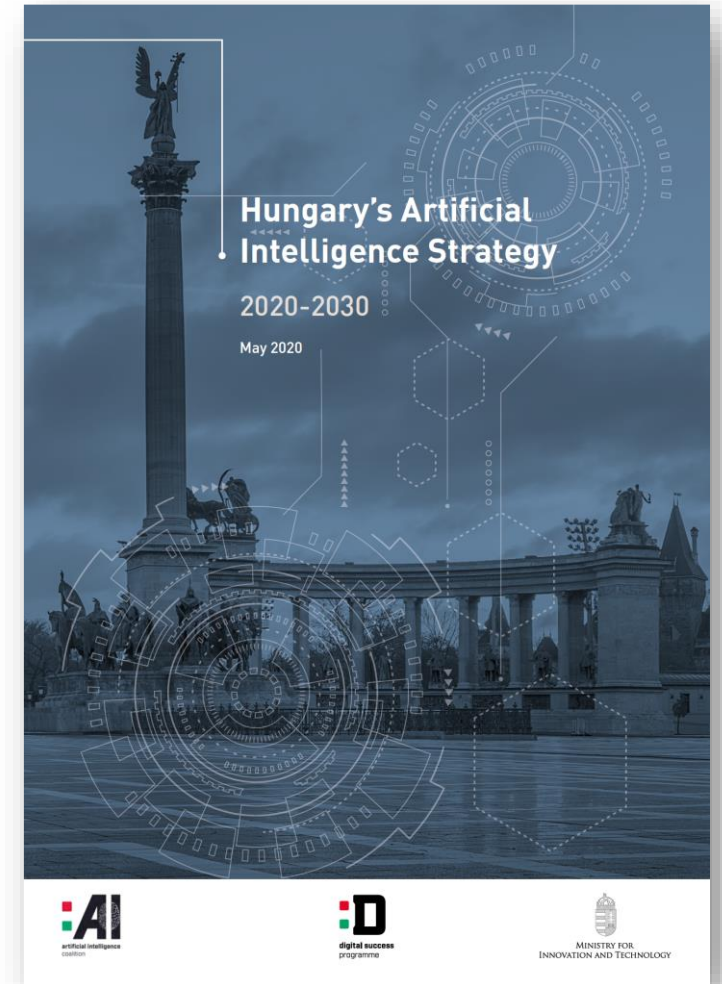
**APPLICATION &  
DEVELOPMENT OF**

**REFERENCE ARCHITECTURES**



... WITH THE CLOUD OF HUNGARIAN RESEARCH NETWORK

- Build a European-level computing infrastructure
- Open the existing cloud not only for ELKH-affiliated researchers but also for **university research** groups
- Provide advanced support for **AI research**
- Assist researchers to adapt their applications to ELKH Cloud by providing **reference architectures**
- Engage in the ecosystem of the **European e-infrastructure** developments





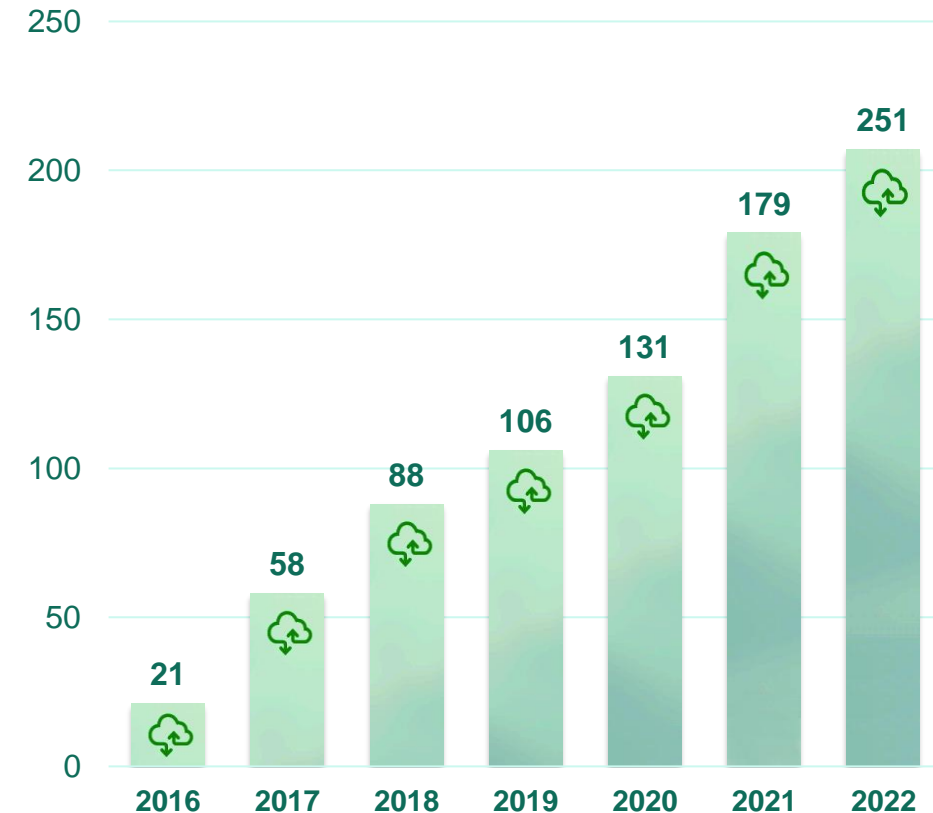
# Capacity upgrade and user community statistics



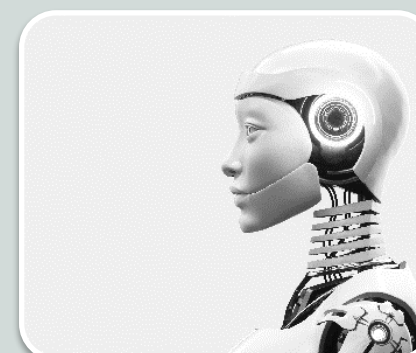
	MTA Cloud	ELKH Cloud
<b>vCPU</b>	1356	5900
<b>vGPU</b>	12	512*
<b>RAM</b>	3.25 TB	28 TB
<b>SSD</b>	0 TB	338 TB
<b>HDD</b>	527 TB	1250 TB
<b>Network speed</b>	10 GBPS	100 Gbps

\*theoretical maximum 2060

## Aggregated number of supported projects



# Dissemination and utilization



**133**

Scientific publications

2021-22: **58**

**18**

Online training events

 **900+**  
trainees

**28**

Supported research institutes

 **250+**  
projects

**9**

Supported universities

BME    ÓÉ    SE  
DE    PE    SZE  
ELTE    PTE    SZTE

**3**

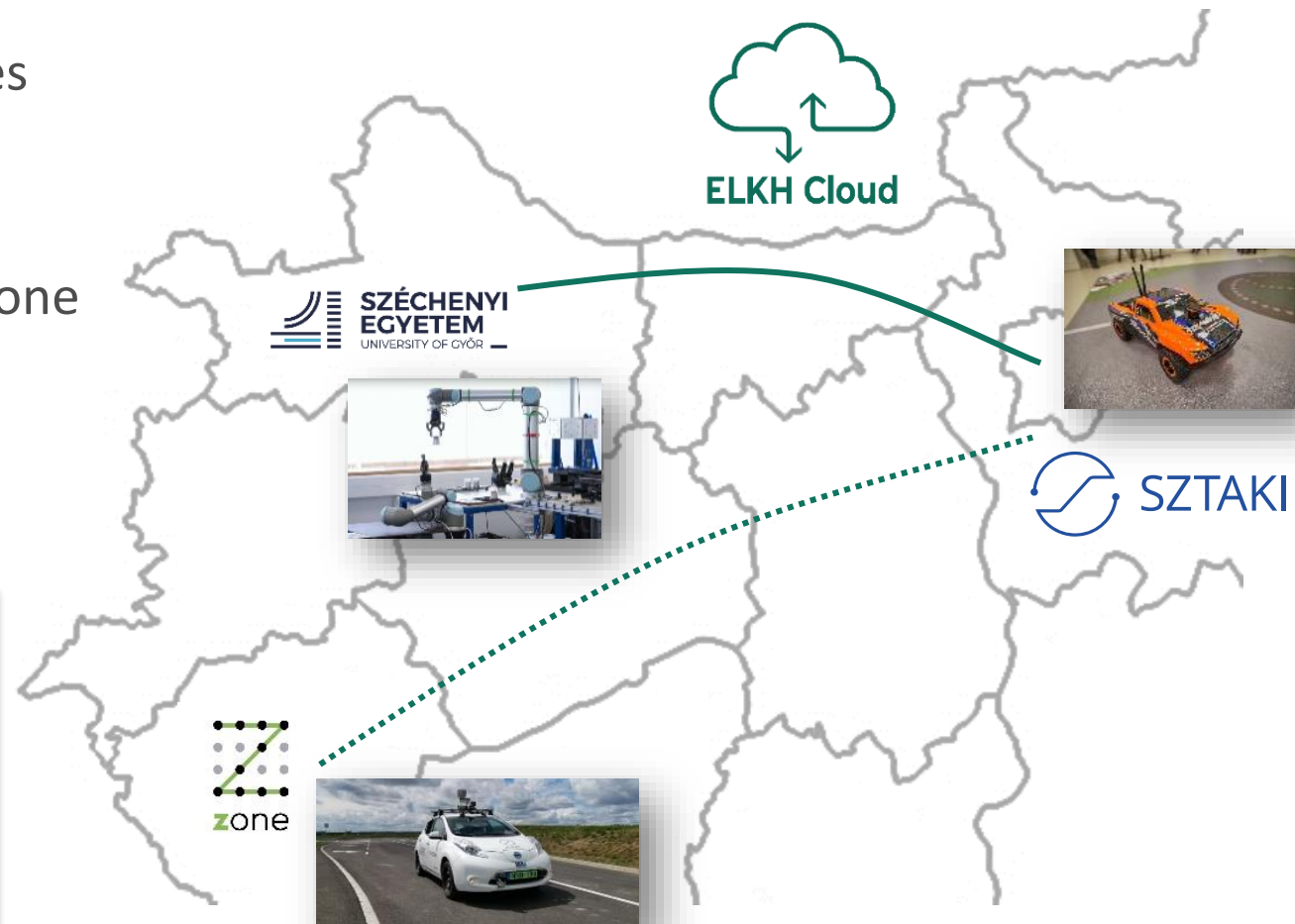
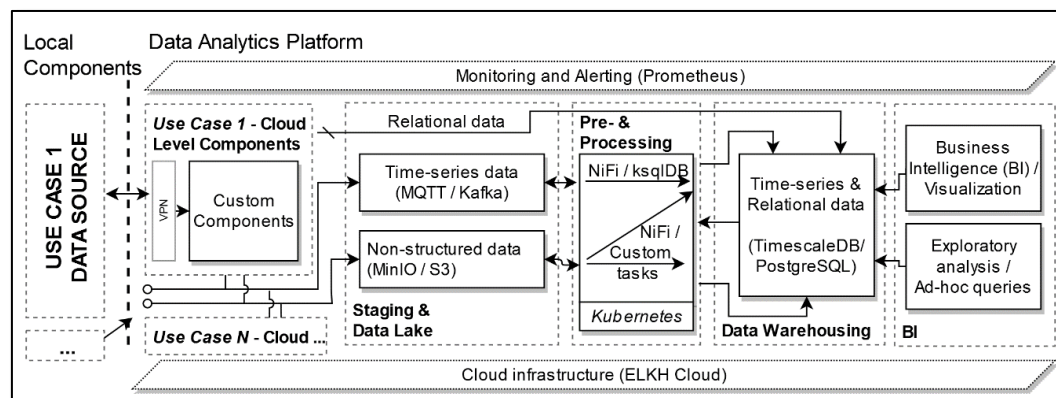
Supported national labs

MILAB    ARNL  
DH-LAB

# Research on Cloud-based Big Data platform for Autonomous Systems



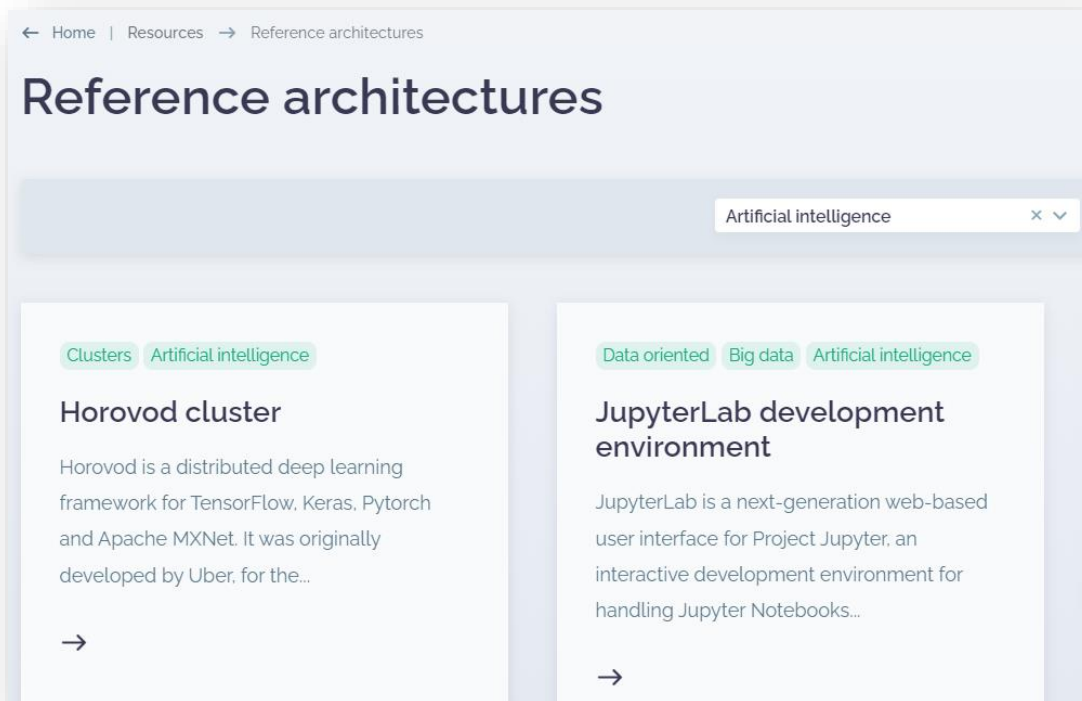
- Component and functional design of vehicles
- Cyber-physical manufacturing and logistics systems
- Infrastructure development related to Zalazone
- Operation of autonomous systems
- Testing and validation in industrial environment



# Reference architectures



- Reference architectures are pre-made software environments that
  - serve for well-defined application areas
  - can be set up rapidly with an orchestrator
  - are well documented, tested, and reliable

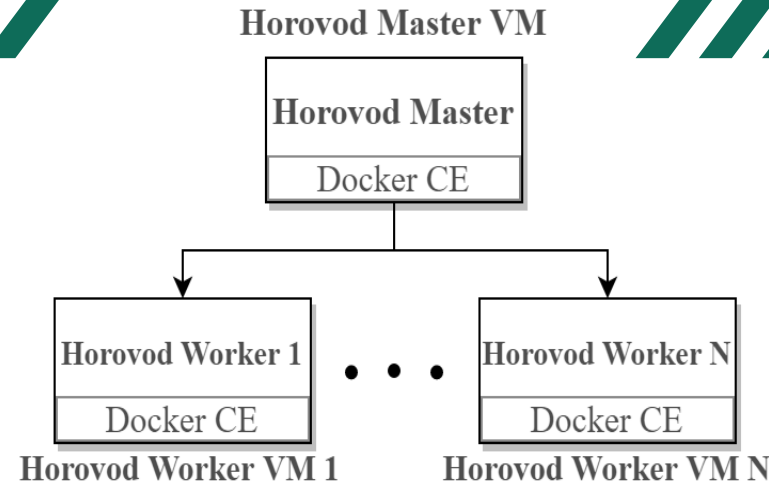
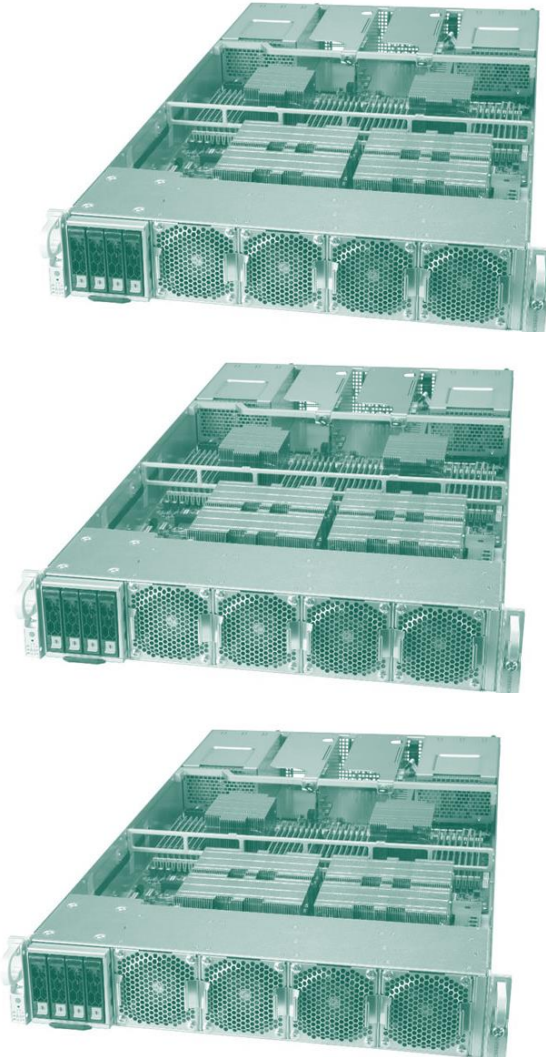


	Generic	Cluster	Big Data	Machine learning	Data-oriented
4	✓	✓			
3		✓	✓	✓	✓
2	✓				
2				✓	
1		✓		✓	
1			✓	✓	✓
1		✓	✓		
1					✓
1	✓				✓

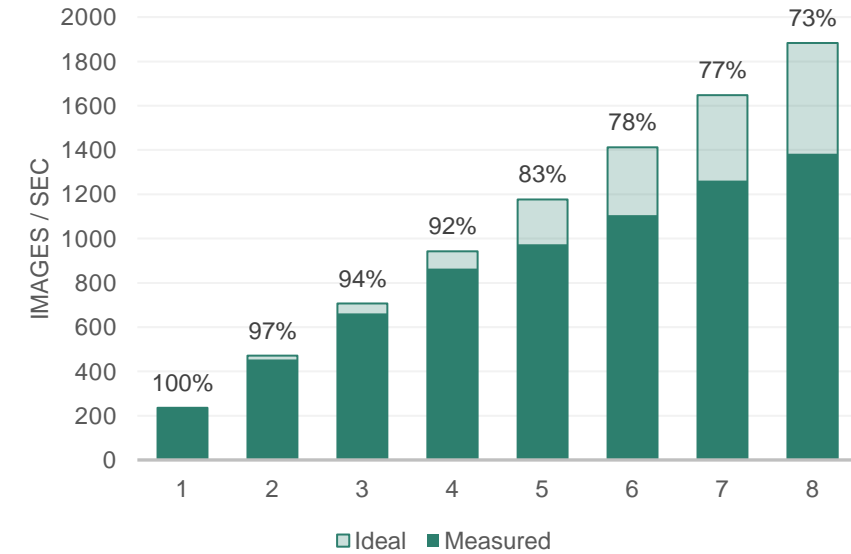
**16 reference architectures**



# Distributed deep learning on virtualized multi-GPU platform



ImageNet - Resnet101  
196 Batch Size



# H2020 NEANIAS: EOSC services for underwater, space & atmosphere research



Underwater



Space



Atmosphere



# NEANIAS

→ <http://neanias.eu>



***HOROVOD service  
„on-boarding” for EOSC***



**EUROPEAN OPEN  
SCIENCE CLOUD**



Funded by the Horizon 2020  
Framework Programme of the  
European Union



EUROPEAN OPEN  
SCIENCE CLOUD

All resour... ▾



My EOSC Marketplace

🏠 > Resources > Access physical & eInfrastructures > Compute > Job Execution > Distributed Deep Learning by Horovod



## Distributed Deep Learning by Horovod

DDLbH

deep learning, distributed, horovod

Organisation: **INSTITUTE FOR COMPUTER SCIENCE AND CONTROL**

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ABOUT

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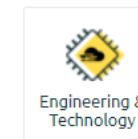
REVIEWS (0)

## Distributed Deep Learning by Horovod

**Providing researchers a reliable platform designed for performing distributed deep learning operations with great scaling efficiency**

The Distributed Deep Learning by Horovod service aims to provide the infrastructure, resources and libraries to its users in order to perform effective distributed training of deep neural networks.

### SCIENTIFIC CATEGORISATION



- Joining EGI Cloud federation as a provider
- Supporting Hungarian and European researchers as cloud provider:
  - OpenBioMaps
  - AI4PublicPolicy
- Future plan: Supporting Hungarian and European researchers as *data repository provider*



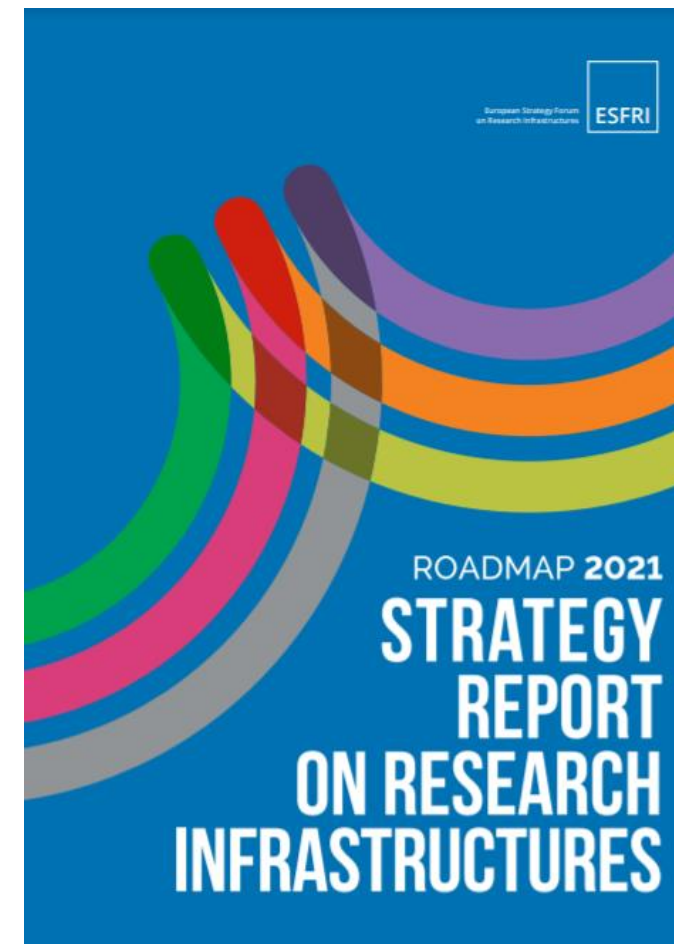
**EUROPEAN OPEN  
SCIENCE CLOUD**



SLICES, **first in digital sciences** to entered the ESFRI Roadmap 2021

Launched in 2017 SLICES is an RI to support the academic and industrial research community that will design, develop and deploy the **Next Generation of Digital Infrastructures**

- **SLICES RI** is a **distributed RI** providing several specialized instruments on challenging research areas of Digital Infrastructures, by aggregating
  - networking, computing and storage resources across countries, nodes and sites
- **Scientific domains** networking protocols, radio technologies, services, data collection, parallel and distributed computing and in particular cloud and edge based computing architectures and services





# ELKH Cloud in the SLICES ESFRI programme



- The SLICES ESFRI program builds an international digital infrastructure to enable IT-oriented research and experiments
- Current infrastructures in the program:
  - SILECS-FIT / OneLab, France
  - NITOS – UTH, Greece
  - Open5GLa - EURECOM, France
  - PIONIER-LAB, Poland
  - 5TONIC, Spain
  - LeonR&Do - COSM, Greece
  - 5G Test Network (5GTN), Finland
  - FIT-R2lab - INRIA, France
  - **ELKH Cloud – SZTAKI, Hungary**
  - TUM lab, Germany
  - CNR lab, Italy



Scientific Large-Scale Infrastructure for Computing & Communication Experimental Studies – Starting Community (**SLICES-SC**) project builds a community of researchers around SLICES-RI, which offers the necessary solutions to create and manage efficiently IT-related experiments.

- SLICES-SC investigates a facilitated access for the experiments
- Ensures the reproducibility of the research experiments
- Validates experiment results
- Publishes results in open data access

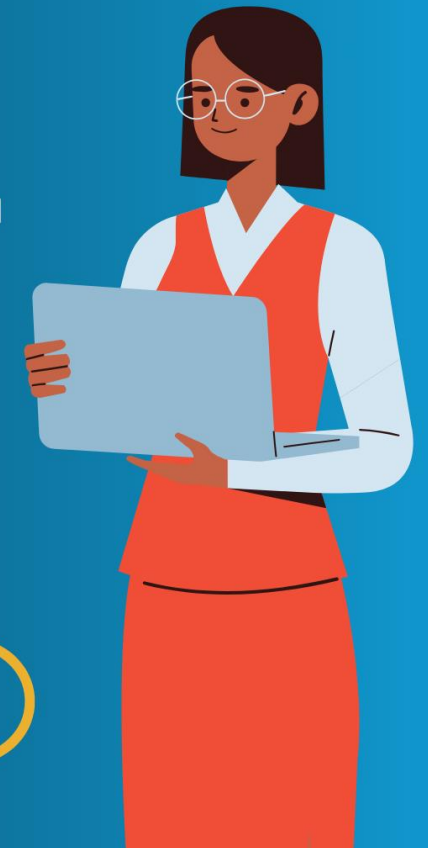
SLICES-SC provides free of charge *physical or remote access to its available infrastructures for selected user groups.*

slices sc **OPEN CALL**

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# Conclusion

- **Divergence:** cloud providers, open-source / proprietary code, software stack
  - **Convergence:** standards, containers, orchestration, **reference architectures**
1. Potential advantages of orchestrated reference architectures:
    - faster development/delivery
    - lower costs at each stages
    - higher quality (user satisfaction)
  2. ... still several challenges: how to make them really **“smart”** by
    1. addressing *all* the typical non-functional requirements, and
    2. covering *every* complex application areas/sectors

Thank you for your attention!



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