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Privacy-Enhancing Technologies Toolbox

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Towards Privacy-Aware Federated Data Lakes

Privacy-preserving technologies are indispensable tools in **data-driven applications**, especially in settings where **sensitive data** needs to be **protected**, while maintaining their **utility**.

Three key technologies are:

- Secure Multi-Party Computation (MPC),
- Trusted Execution Environments (TEEs),
- Zero-Knowledge Proofs (ZKPs).

Overall, these technologies make it possible to perform **generic computations** on sensitive data without compromising its **confidentiality**.

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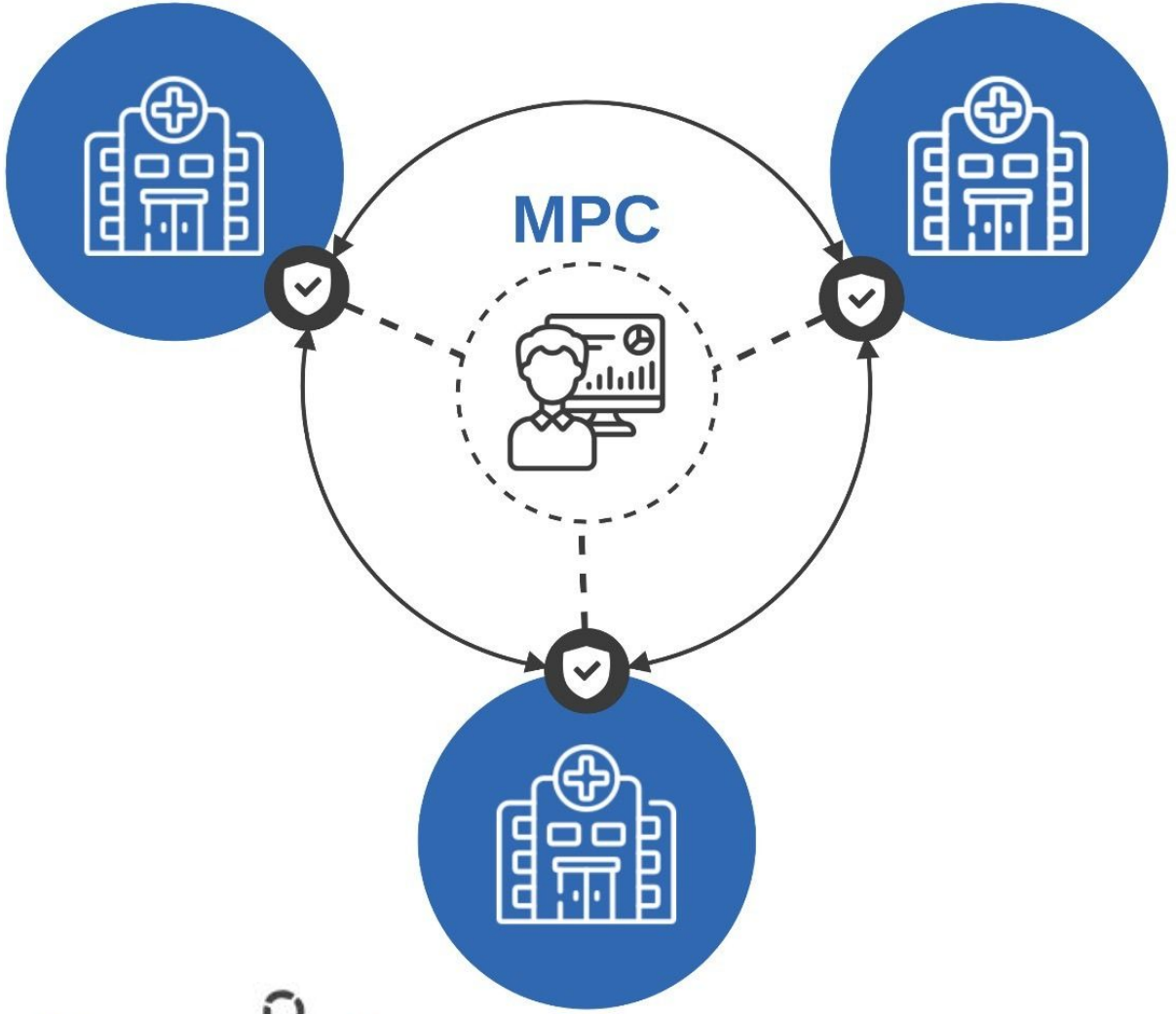
Secure Multi-Party Computation (MPC): Combining Data Without Compromise



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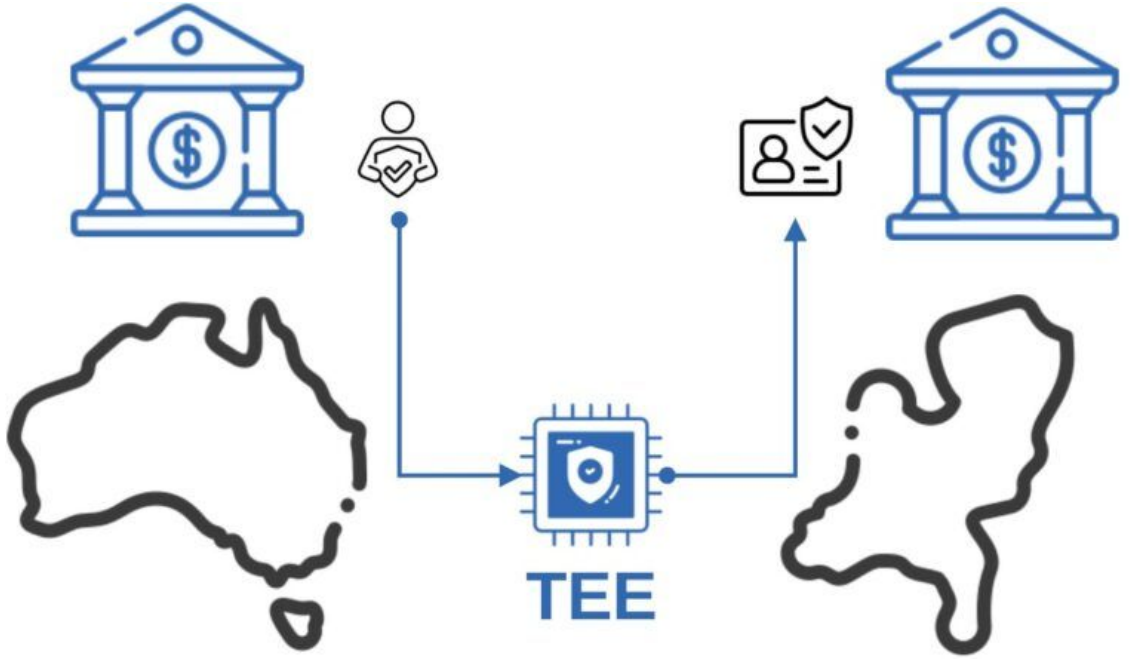
Trusted Execution Environments (TEEs): Ensuring Confidentiality in Data Insights



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Zero-Knowledge Proofs (ZKPs): Concealing Details, Proving Validity

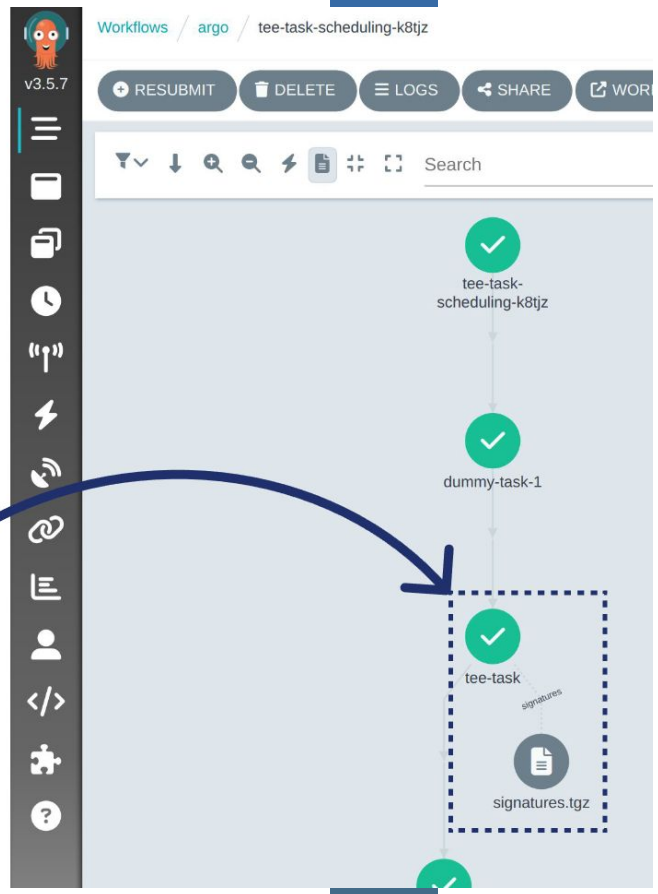
ZKSC ZK-SecreC

Sharemind MPC tooling and technology

We have successfully demonstrated **Sharemind MPC** runtime integration with TEADAL baseline technologies.

We demonstrated how to encode privacy-preserving computations in the **SecreC** programming language and ran the demonstrator with three computing nodes, generating a large **output** dataset from three **private** input datasets.

```yaml
apiVersion: argoproj.io/v1
kind: Workflow
...
templates:
- name: tee-workflow
  steps:
  - - name: dummy-task-1
      template: dummy-task-1
    - name: tee-task
      template: tee-task
    - name: dummy-task-2
      template: dummy-task-2
...
- name: tee-task
  podSpecPatch: '{"runtimeClassName":"kata-qemu-tdx"}'
  container:
    image: nixos/nix:latest
    command: [sh, -c]
    args: [
      "nix-shell trustops.nix && zip signatures.zip signature.*"
    ]
    volumeMounts:
    - name: workdir
      mountPath: /tmp/vol
  outputs:
    artifacts:
    - name: signatures
      path: /tmp/vol/{{workflow.name}}/signatures.zip
...
```

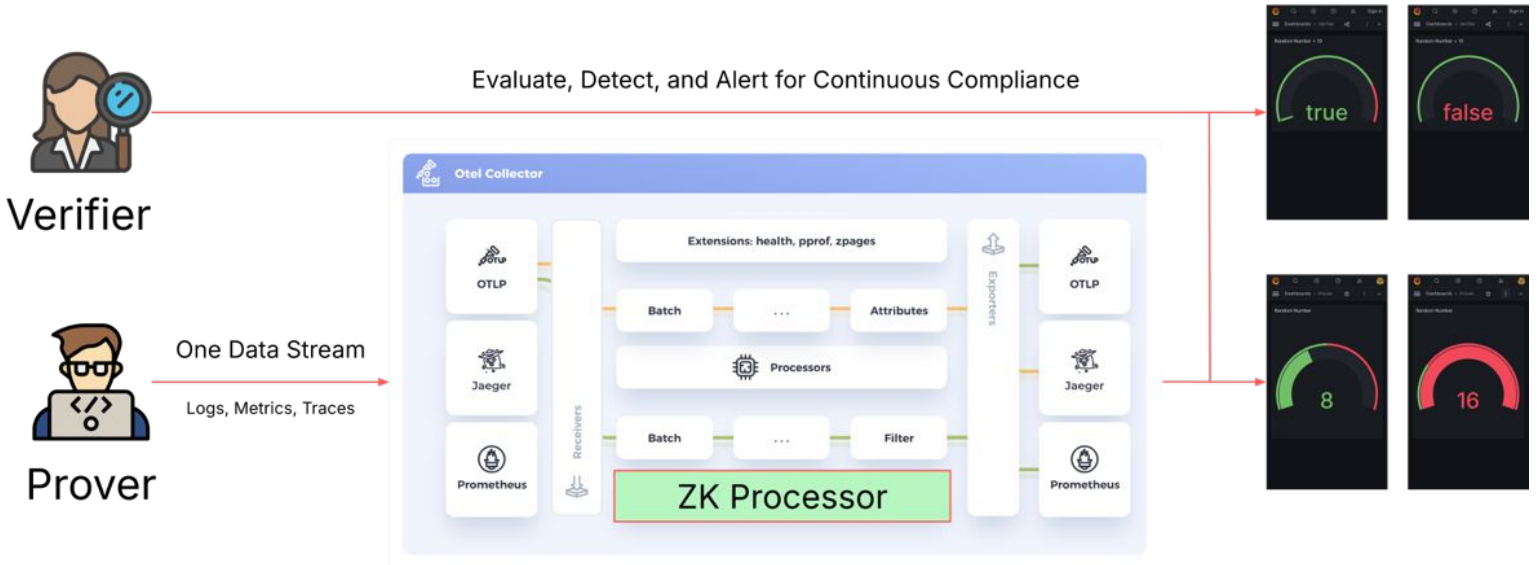


TEE-based Pipelines

We demonstrated the programmability, integration, and execution of **privacy-preserving data pipelines**, in a distributed setting consisting of a multi-node Kubernetes cluster.

Private tasks in a pipeline are **offloaded and orchestrated** to run on trusted confidential computing units, even if the host system is untrusted.

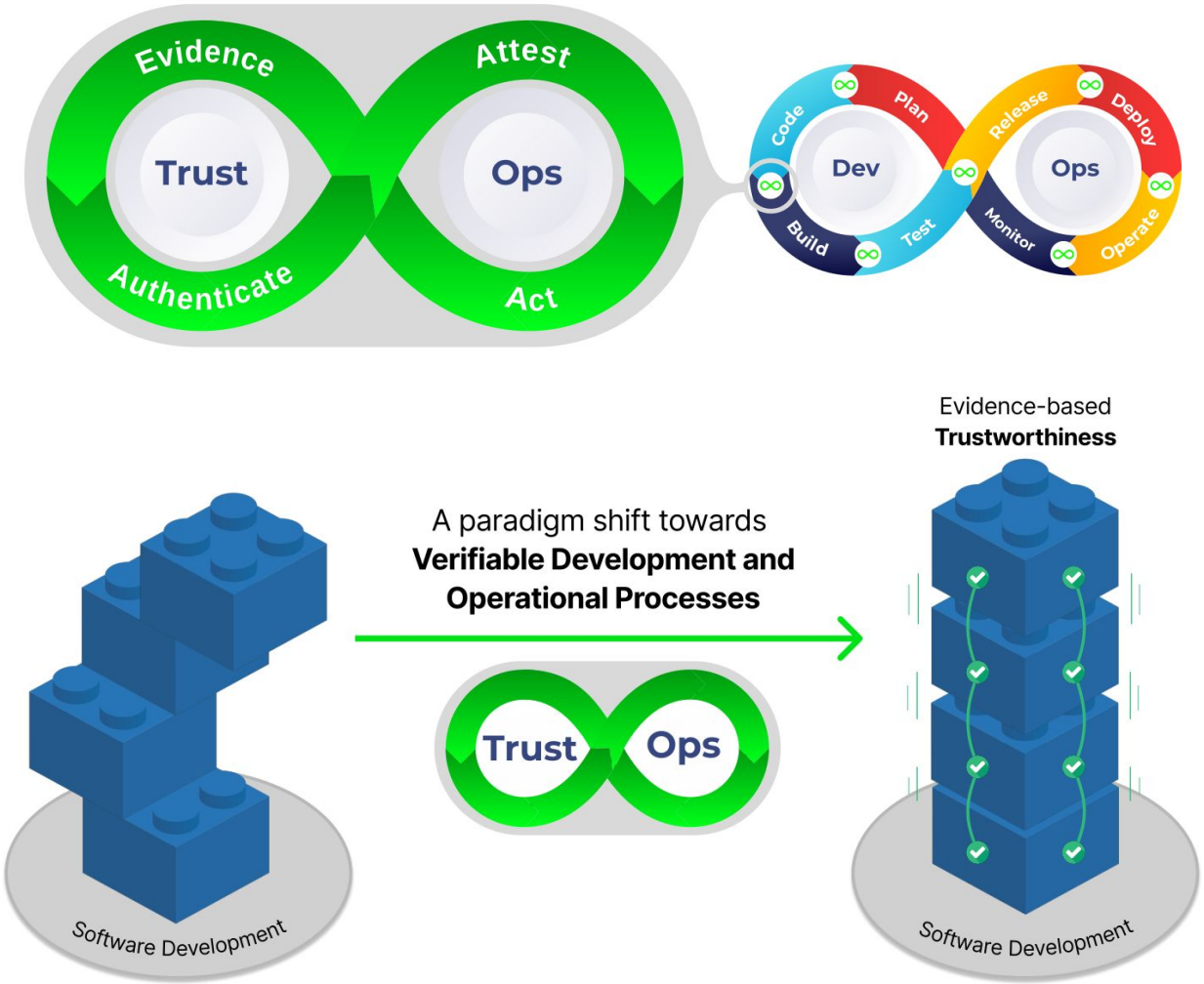
ZK-enabled Monitoring



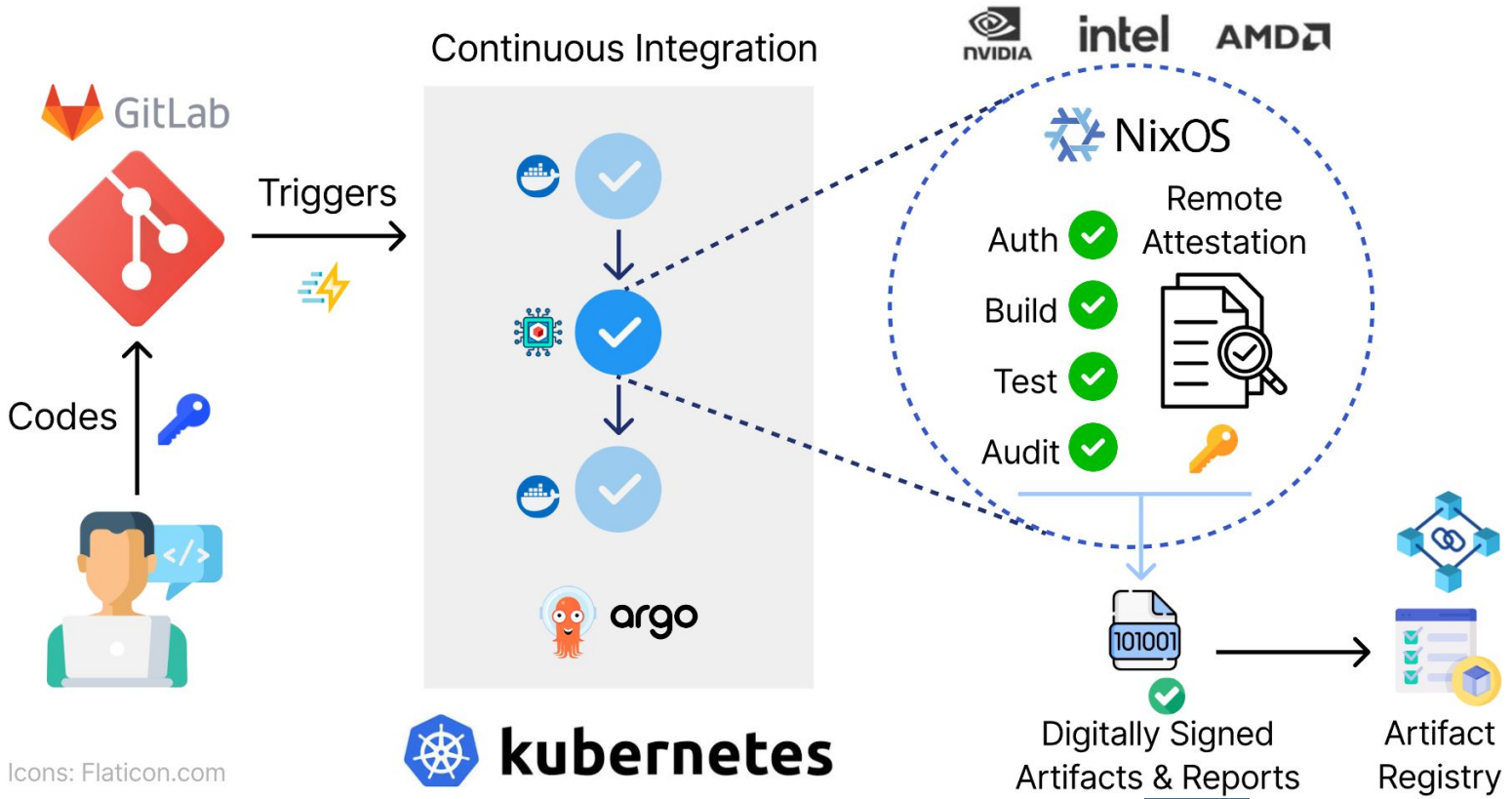
We have successfully encoded **verifiability statements** in ZK-SecreC, specifically for SLA verification.

We created an initial prototype and demonstrated its integration with **monitoring and observability** tooling used in TEADAL.

TrustOps: Continuously BuildingTrustworthy Software



Brito, Eduardo, et al. "Trustops: Continuously building trustworthy software." *International Conference on Enterprise Design, Operations, and Computing*. Cham: Springer Nature Switzerland, 2024.

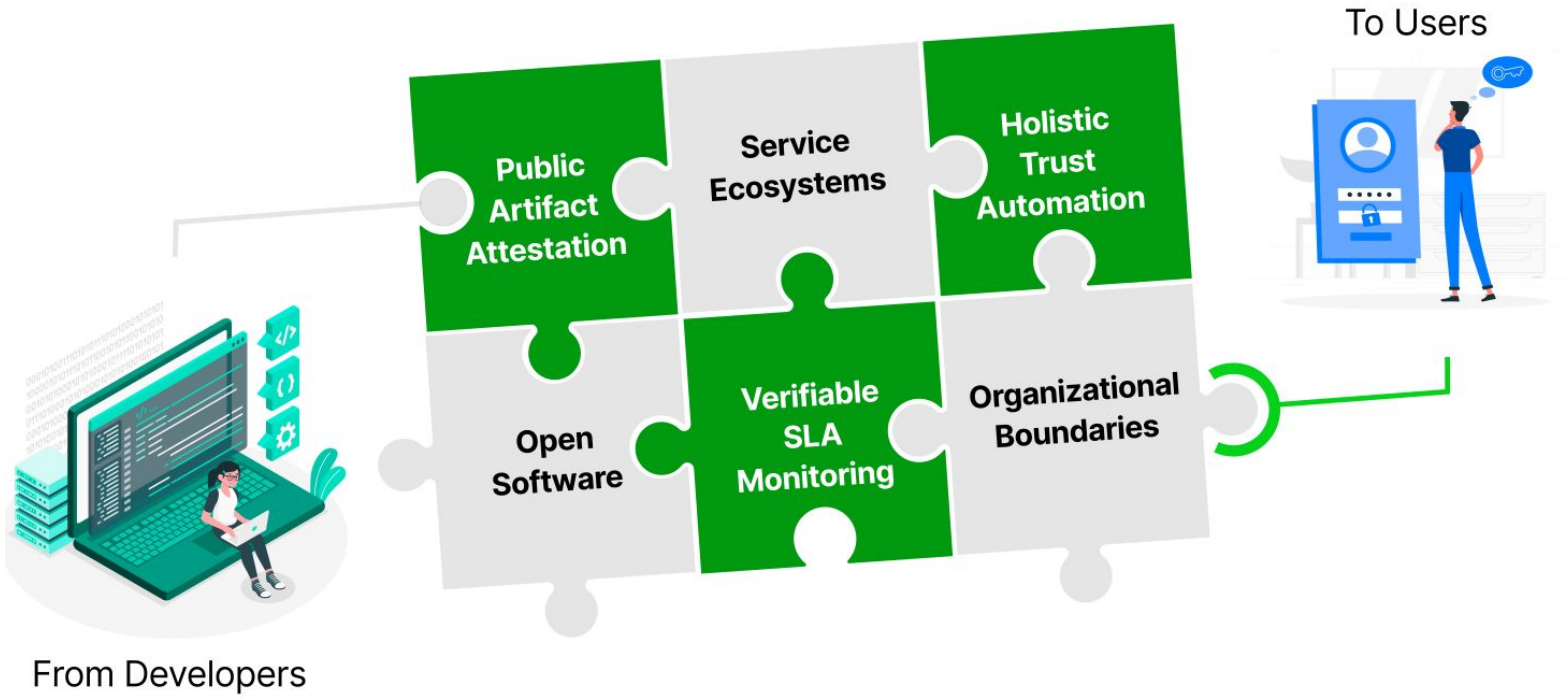


Trustworthy CI Pipelines

Following **TrustOps** principles, we created a first prototype of a **Trustworthy CI pipeline** and demonstrated its potential integration with TEADAL-related baseline tooling.

We developed a prototypical scenario for generating **attestable artifacts** from build, test, and audit phases of a piece of software.

Towards Securing the Software Supply Chain



TEADAL work opened **new research directions and collaborations** towards exploring the mechanisms prototyped within **new domains** such as software supply chain security.

This work also inspired collaboration within **upcoming HE proposals** and **cross-project exploitation** of TEADAL results.

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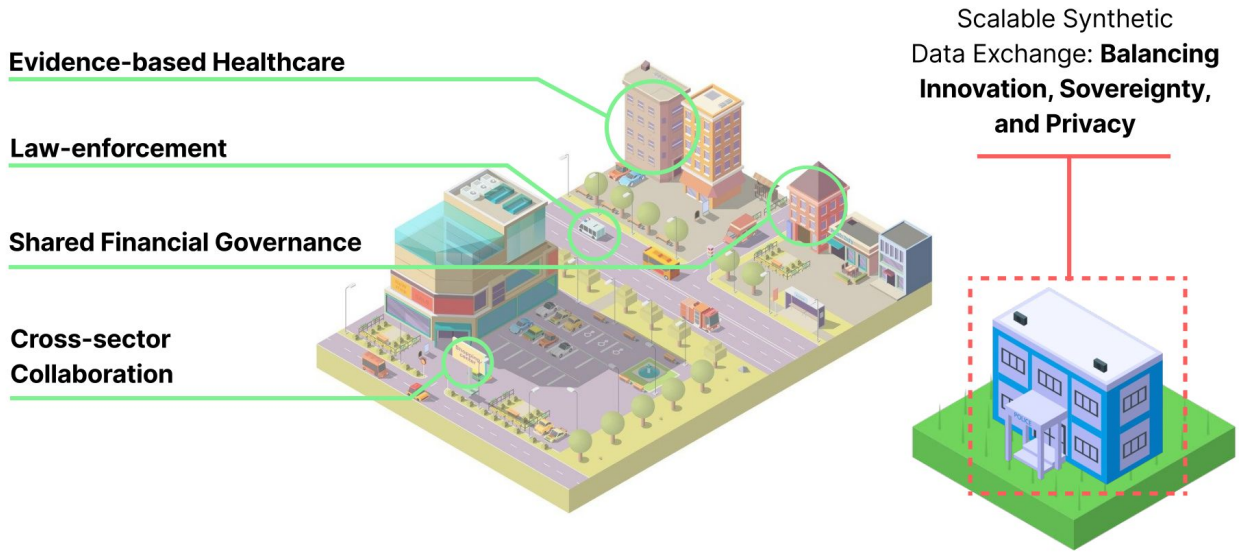
SynthGuard: Redefining Synthetic Data Generation with a Scalable and Privacy-Preserving Workflow Framework

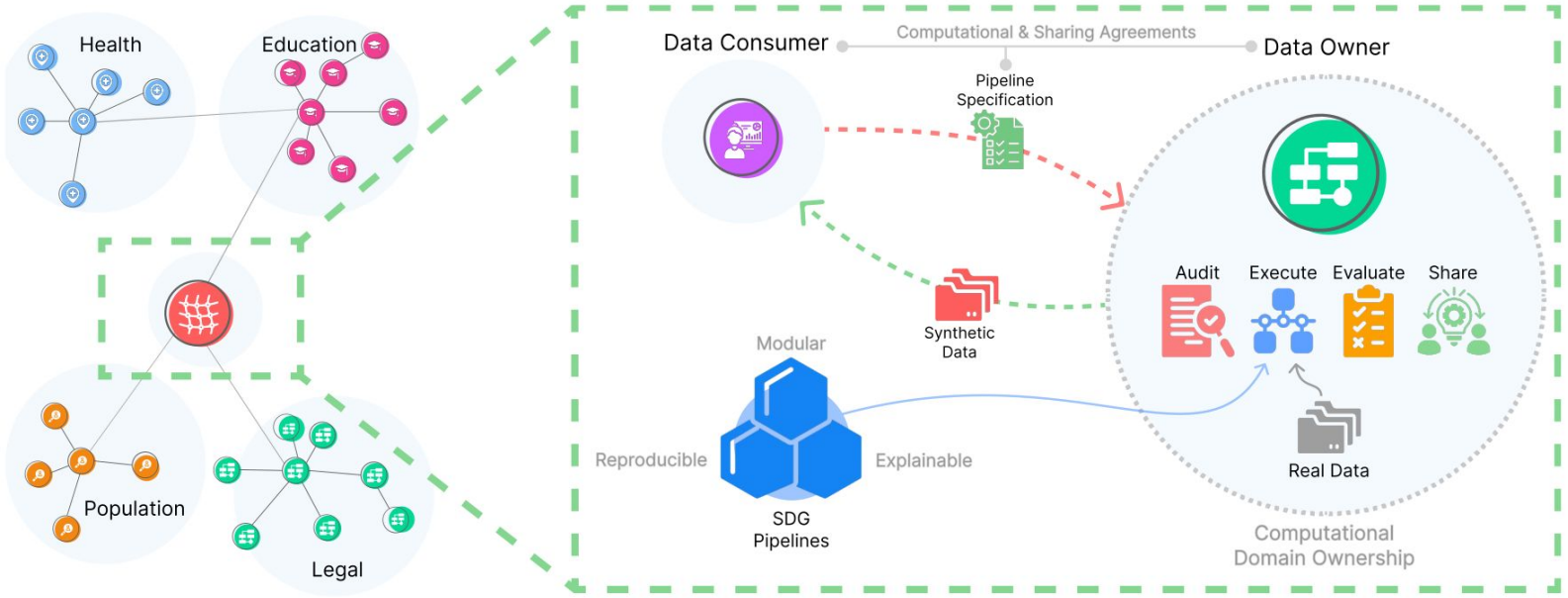
Brito, Eduardo, et al. "SynthGuard: Redefining Synthetic Data Generation with a Scalable and Privacy-Preserving Workflow Framework." International Conference on Availability, Reliability and Security. Cham: Springer Nature Switzerland, 2025.

Legally Constrained Heterogeneous Data Silos



SynthGuard

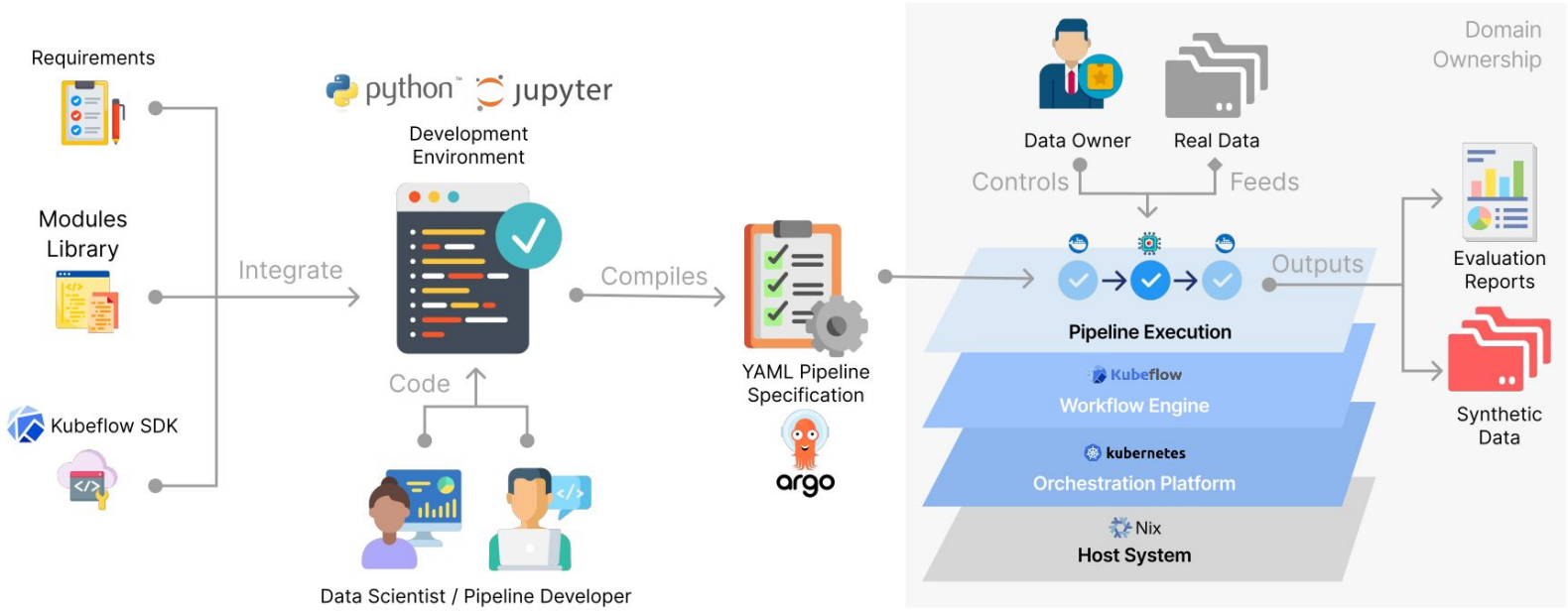
Synthetic Data Generation & Sharing



Inspired in TEADAL methods, we developed a synthetic data generation **architectural approach** for secure synthetic data sharing in constrained data domains.

Our approach targets **data mesh** principles of domain ownership, data sovereignty, and computational governance to enable generating and sharing synthetic datasets.

Synthetic Data Generation Workflow



We demonstrated technological and integration **feasibility** with TEADAL tools and architecture.

In the early project phases, we generated synthetic data for **pilots** and modelled **pipelines** and datasets based on pilot requirements, real dataset schemas, and use case goals. These datasets supported ongoing **validation**.

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Conclusion

- *Demonstrated PETs technological and integration feasibility with TEADAL tools and architecture*
- *Successfully generated synthetic datasets aligned with pilot requirements and real data schemas*
- *Established pipelines and workflows for ongoing validation and use case goals*
- *Opened pathways for secure, privacy-preserving data sharing and future applications*

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THANKS

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