Hybrid Cloudification of Legacy Software for Efficient Simulation of Gas Turbine Designs

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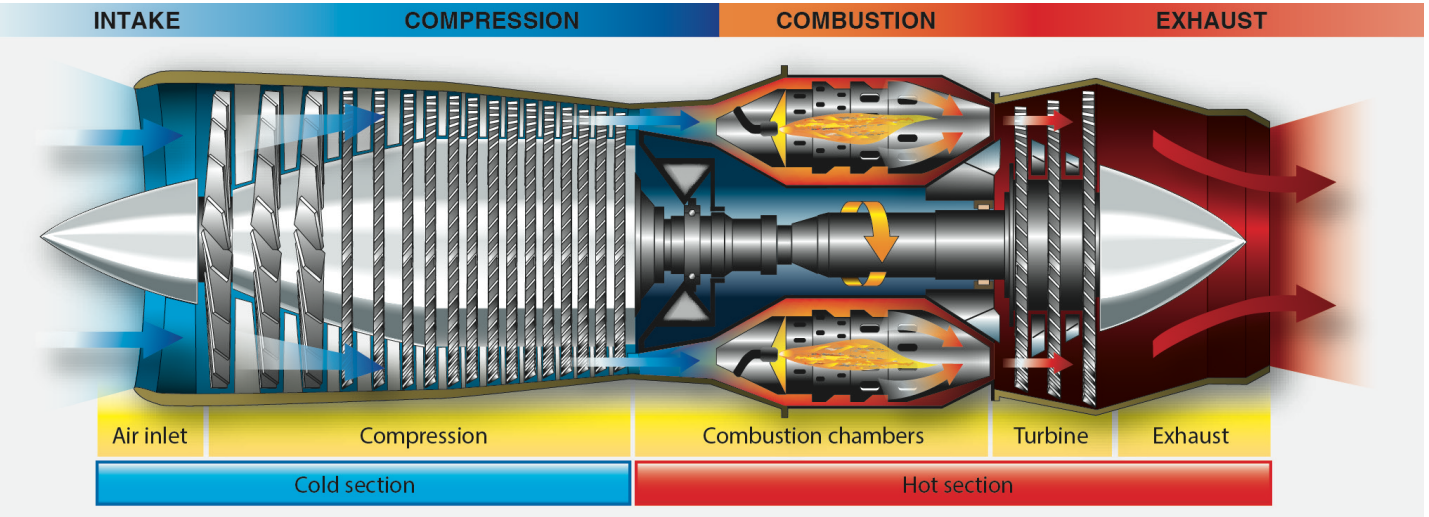
Aeroderivative Gas Turbines (AGTs)

AGT: power generation gas turbines built using *aircraft engines*

- They can ramp up and down very rapidly (within seconds)
- Help manage grid demand variations and peaks



A complex aircraft engine with multiples shafts and blades[1]

1. Federal Aviation Administration, *Airplane Flying Handbook (FAA-H-8083-3A)*

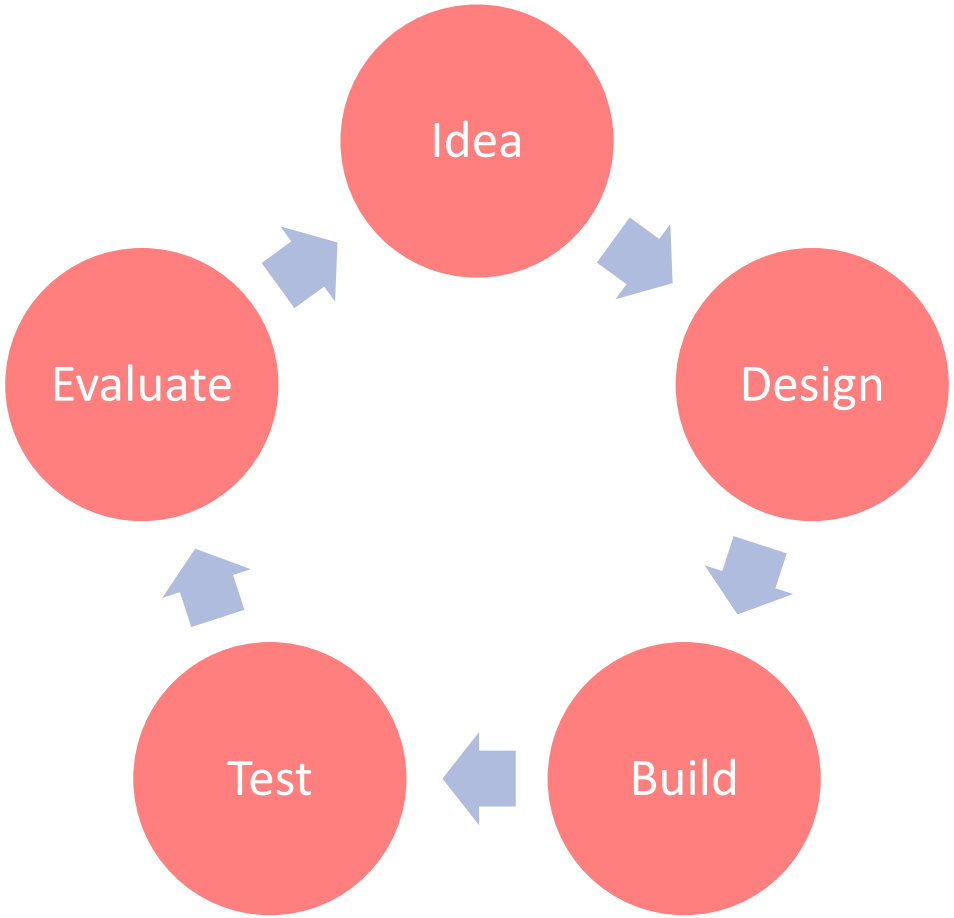
AGT Design Process

Concept:
An iterative process where AGT models are incrementally improved

Continuous testing:
Validates new designs against performance requirements and objectives

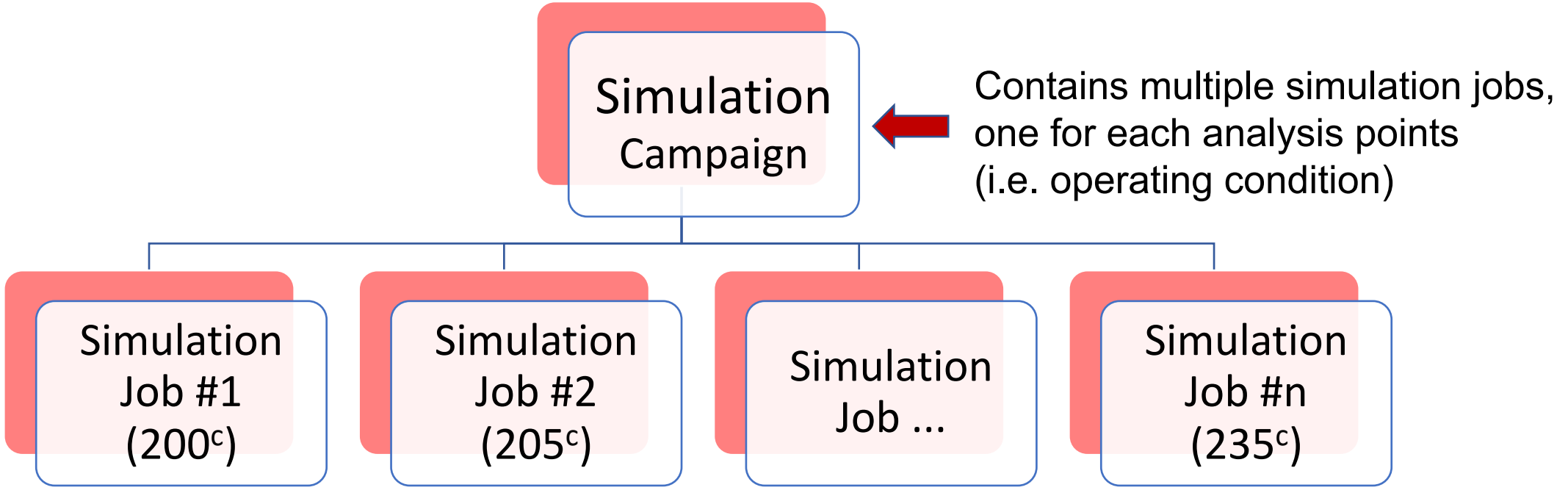
Concern:
Building physical prototypes is very costly

Solution:
AGT digital twins are developed which can be tested by a simulation software



Critical Design Step

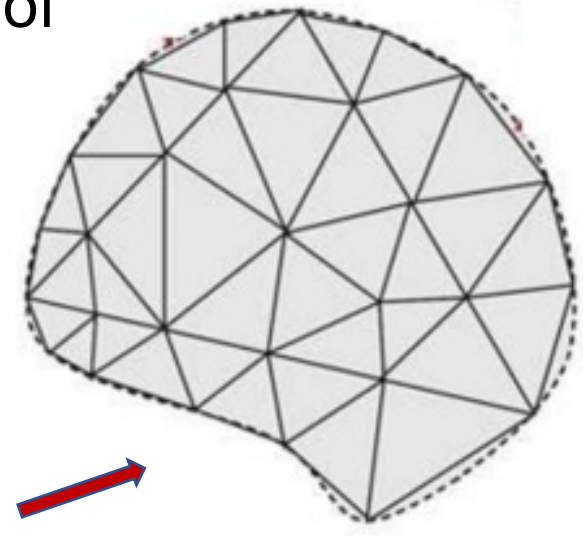
Simulations are performed by large-scale *simulation campaigns* on thermomechanical AGT models for multiple operating conditions.



Legacy Simulation Software

Legacy simulation software ***must be*** used for finite element analysis (FEA) in AGT design

Rationale:
Institutional understanding of the capabilities and limitations of software



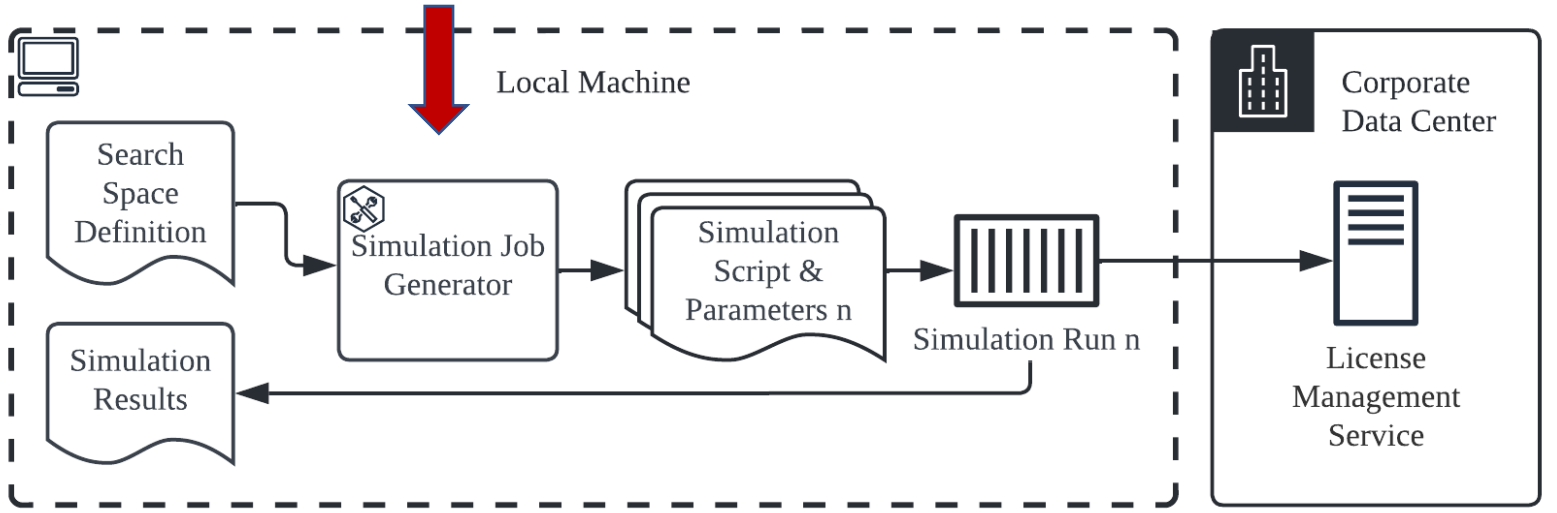
Result:
Allows for reliable estimates of the real physical engine performance through their simulations

2. Polyzos, Konstantinos D.. (2019). Detection and recognition of aerial targets via RADAR data processing, machine learning techniques and neural networks.

Existing Simulation Pipeline

2. Programmatically generate simulation jobs based on search space

1. Engineers define the search space



Existing engineering practice for simulation based FEA

3. The engineer has to ***set up*** simulation software locally and ***manually*** run all jobs and aggregate their results

Research Motivation

The legacy simulation software has the following bottlenecks:

1. Manual installation on each engineers' computer

2. Single computer execution with limited automation

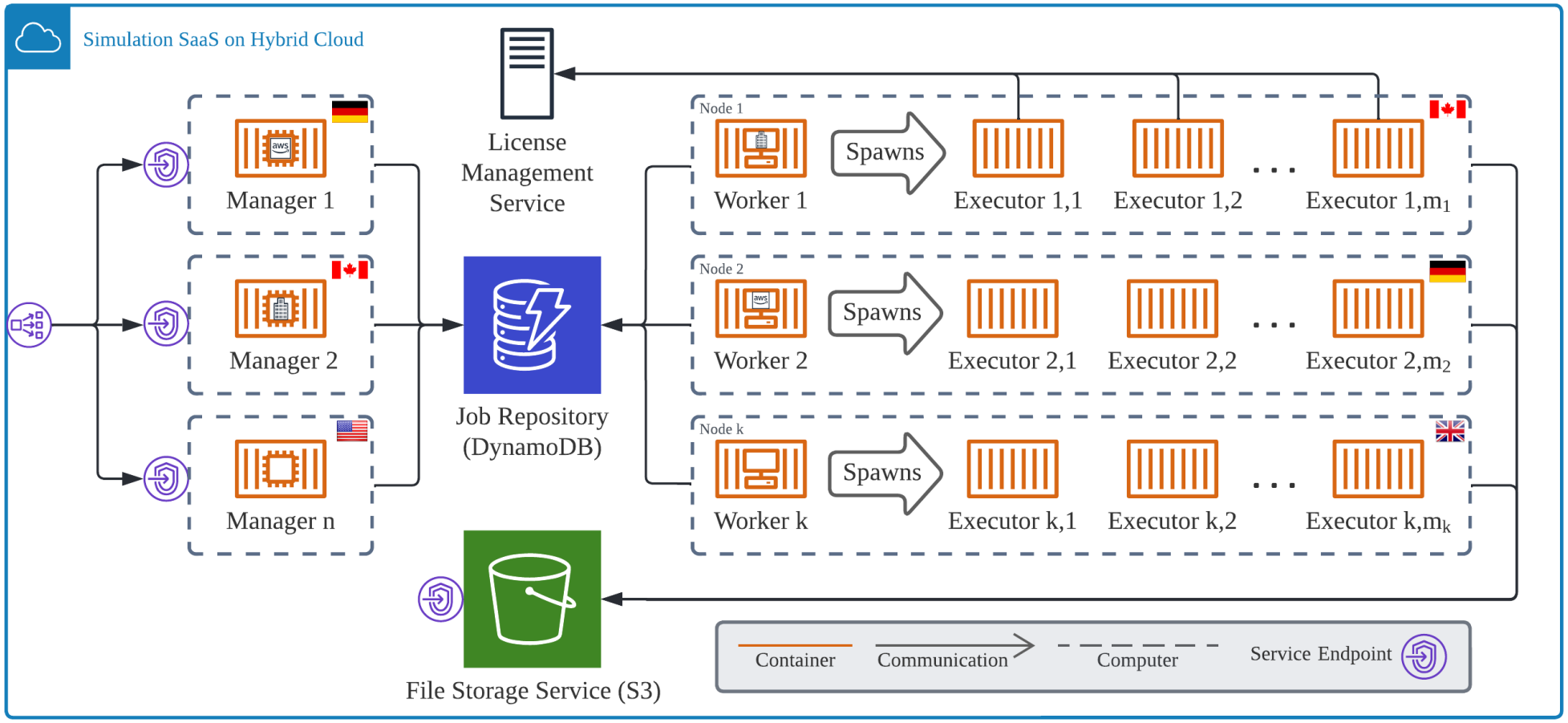
3. External code base with minor updates only

Research Objectives

Our research is a software modernization project that aims to turn a legacy simulation software into a scalable and easily accessible SaaS.

- O1. Design and develop a simulation software as a service
- O2. Provide automated execution of simulation campaigns
- O3. Enable parallel computation of jobs within a campaign
- O4. Distributed service execution over hybrid cloud platform
- O5. Geographically restrict data for export control compliance

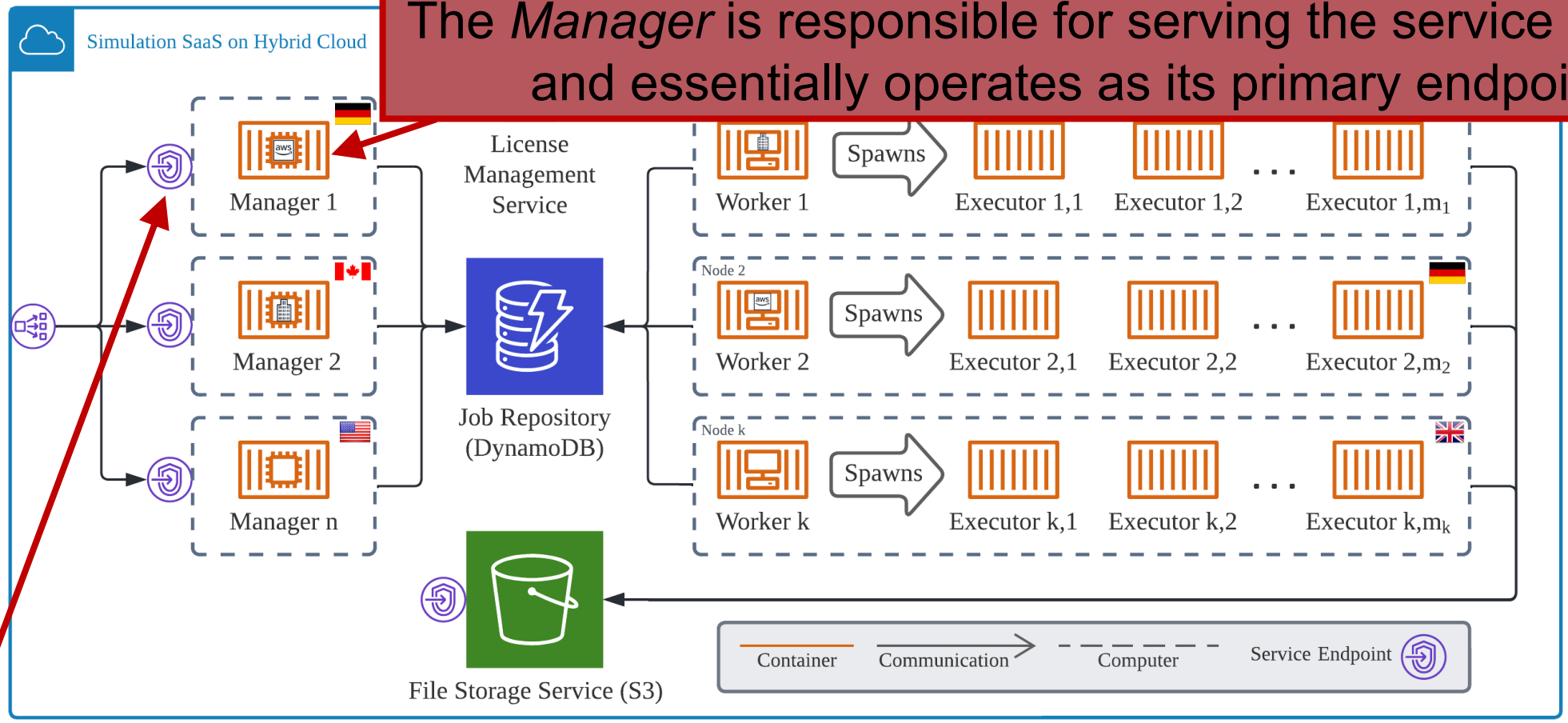
Proposed Service Architecture



Architecture for Simulation SaaS over a hybrid cloud platform

Proposed Service Architecture

The *Manager* is responsible for serving the service to users and essentially operates as its primary endpoint.



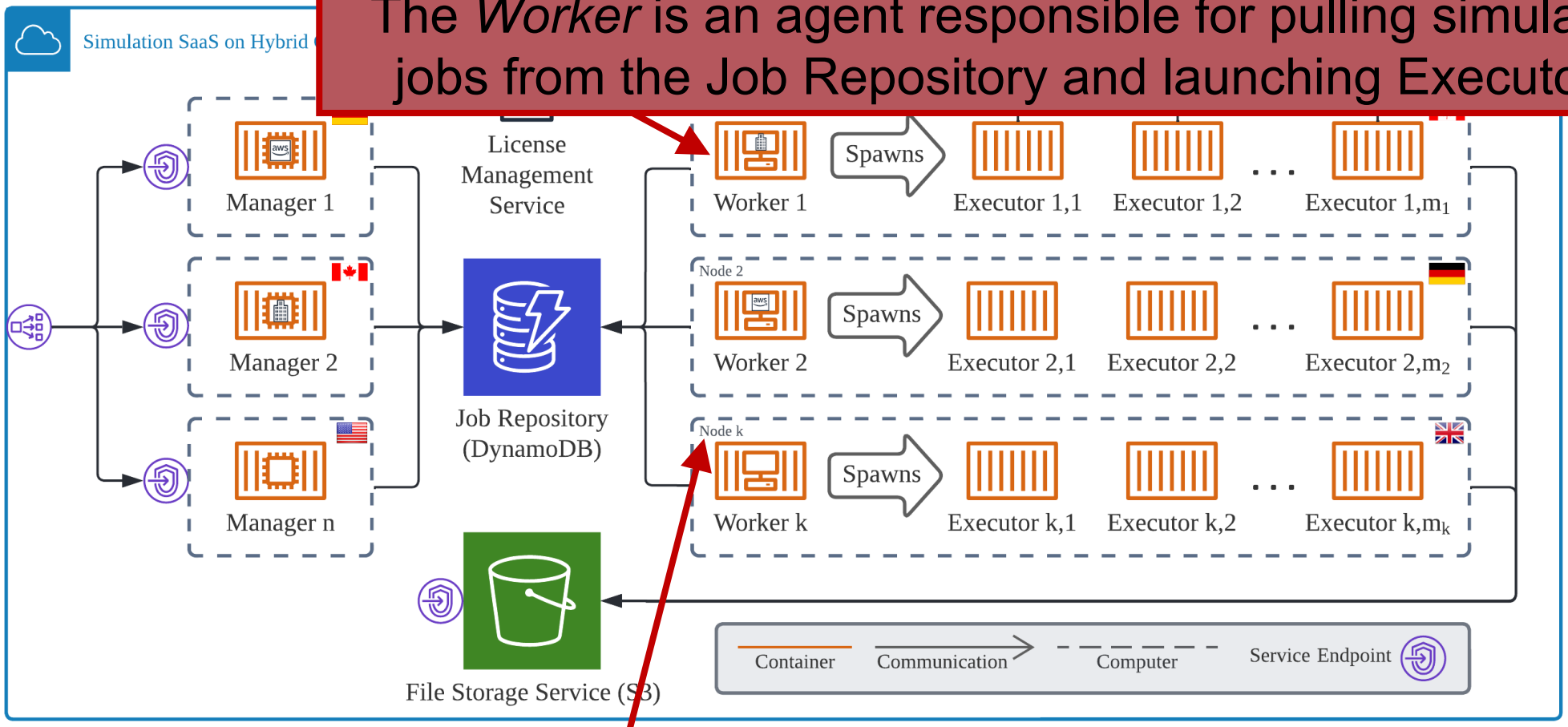
Architecture for Simulation SaaS over a hybrid cloud platform

The *Manager* exposes a web-based RESTful Service API

O2. Provide automated execution of simulation campaigns

Proposed Service Architecture

The *Worker* is an agent responsible for pulling simulation jobs from the Job Repository and launching Executors.



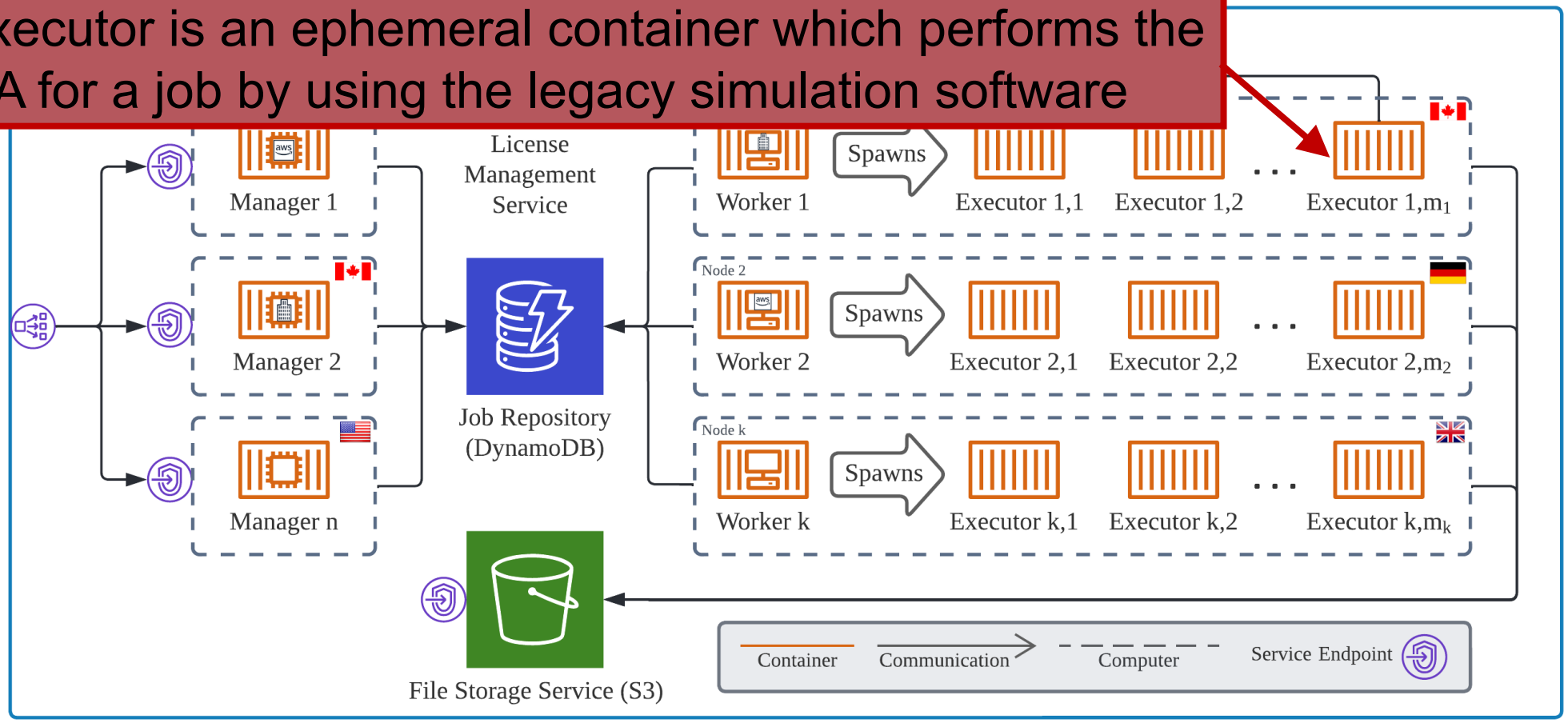
Architecture for Simulation SaaS over a hybrid cloud platform

Worker agents are installed on nodes (computers/servers for the service)

O3. Enable parallel computation of jobs within a campaign

Proposed Service Architecture

The Executor is an ephemeral container which performs the FEA for a job by using the legacy simulation software

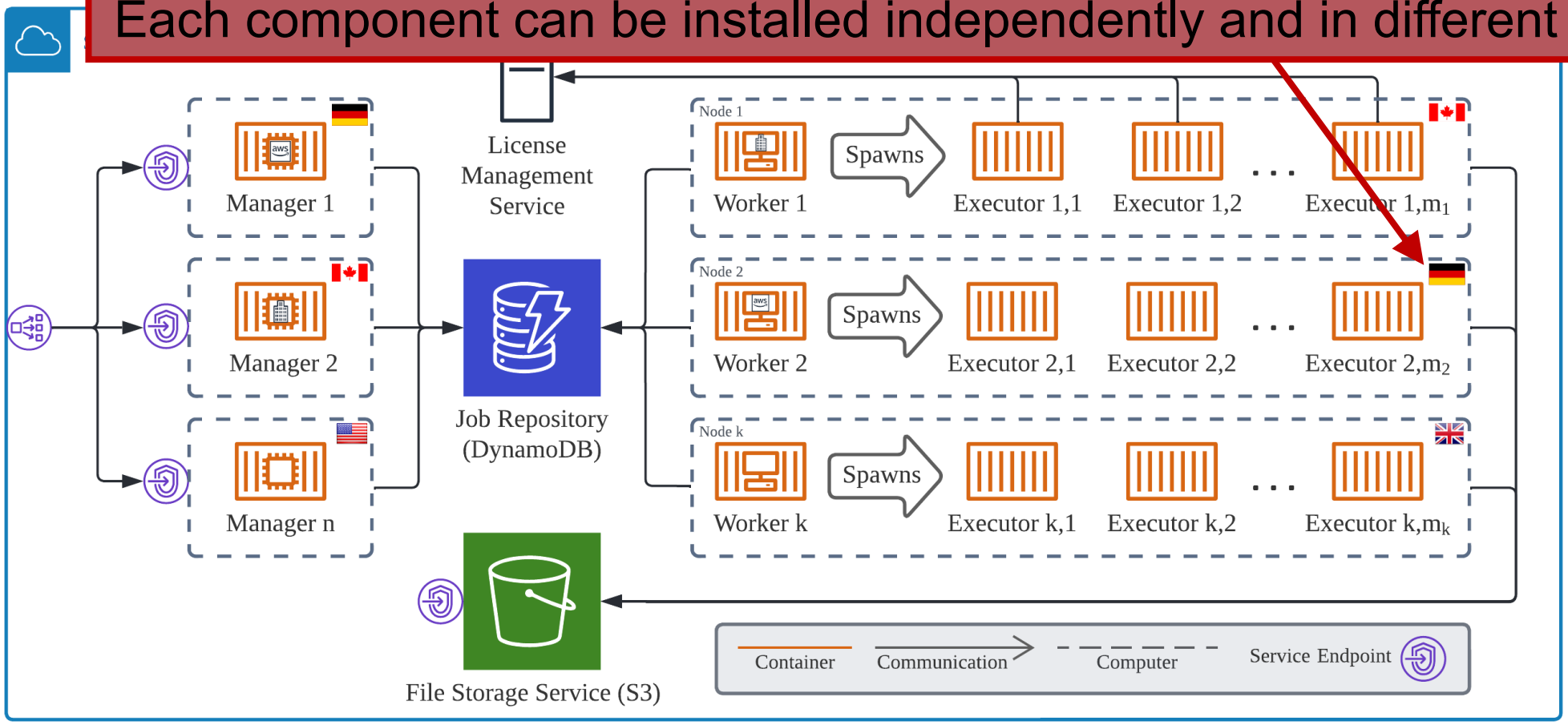


Architecture for Simulation SaaS over a hybrid cloud platform

O5. Geographically restrict data for export control compliance

Proposed Service Architecture

Each component can be installed independently and in different regions



Architecture for Simulation SaaS over a hybrid cloud platform

Evaluation: Research Questions

RQ1: What is the runtime overhead of executing a simulation job?

RQ2: What is the wait time of jobs in a campaign on public v. hybrid cloud?

RQ3: What is the performance of a hybrid configured simulation service for a campaign compared to the legacy setup?

Node Types: Hybrid (HYB) → Mix of AWS & OP

Job Capacity: 6 concurrent simulation jobs

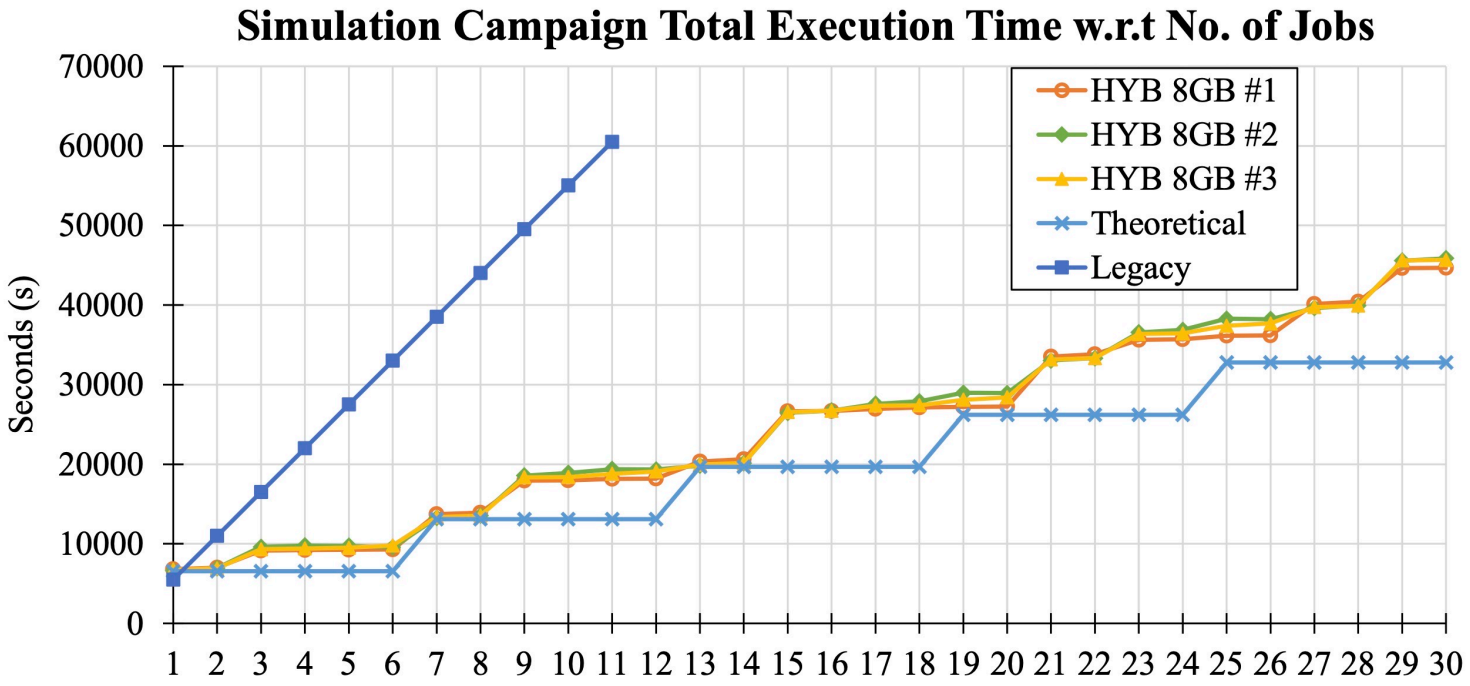
Job Config: 8GB RAM Allocation

RQ3: Hybrid Simulation SaaS vs Legacy

Total Execution Time: time it takes to run entire simulation campaign

Legacy Time: the minimum amount of time it would take to run an entire simulation campaign with the legacy simulation pipeline

Theoretical Time: the theoretical minimum amount of time required to run an entire simulation campaign with the new simulation SaaS



Our new service offers 3-4 times speedup for a simulation campaign compared to the legacy pipeline with a negligible service overhead.

Benefits for Siemens Energy

1. Significantly makes the engineers job easier

2. Reduces time spent on repetitive tasks

3. Provides more time to explore innovative designs

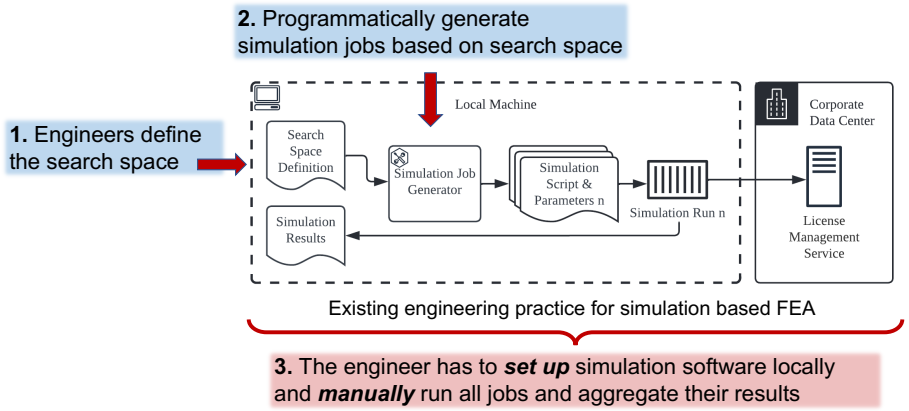
4. Increases product quality by more thorough analysis and better data quality for ML pipelines

Follow-Up Work

1. Integration into engineers' workflow
2. Expanded features for campaigns
3. New tool integrations
4. Software usage monitoring

Summary

Existing Simulation Pipeline



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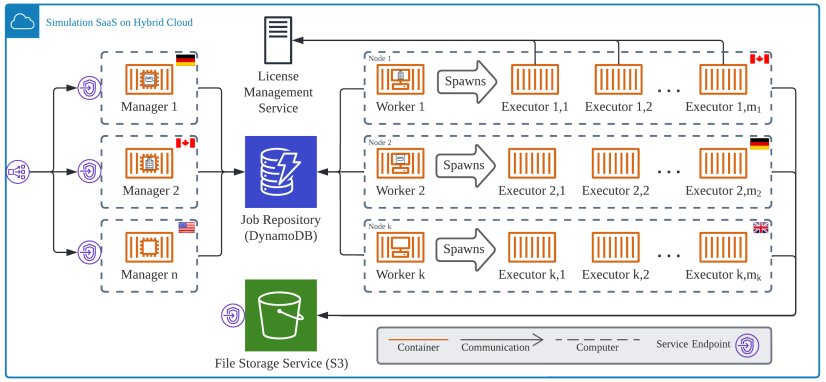

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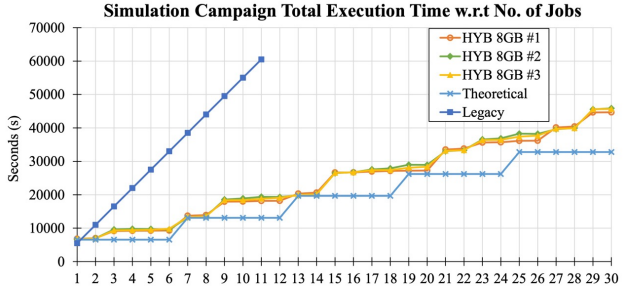

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