Beyond Container CVE Analysis: A GitOps-Based Attestation and Sandbox Framework for Container Supply Chains

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P2CODE

Under P2CODE

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Introduction & Related Work

Introduction

Software Containers Industry:

- **87%** of enterprises adopted Kubernetes of, with **66%** using it in prod [1]
- **$16.32 billion** by 2030, outpacing security practices [2]

Security Issues in Software Containers :

- **604+ CVE** per container image on average [3]
- **87%** of container images running in production have high-severity CVEs [4]

Related Work

Why Existing Solutions Fall Short ?

S.1 - Static CVE Scanners (*Trivy, Clair, Grype*):

- Detect 95-99% overlap on known CVEs
- Miss Runtime threats, zero-day exploits, behavioral anomalies

S.2 - SBOM/SLSA Compliance Frameworks :

- *Limited adoption due to a visibility gap in the supply chain*
- Implementation barriers due to complex implementations and unclear communications of primary challenges [5]

S.3 - Hardened Base Images :

- Reduce the known vulnerability area and dependencies

SLSA = Supply Chain Levels for Software Artifacts

SBOM = Software Bill of Material

This Paper's Research Scope

DevSecOps Framework

Introduce a Framework for proactive docker container images analysis

Static & Runtime

Combine static & runtime analysis of Docker container images of unknown individual contributors

Standard Compliant

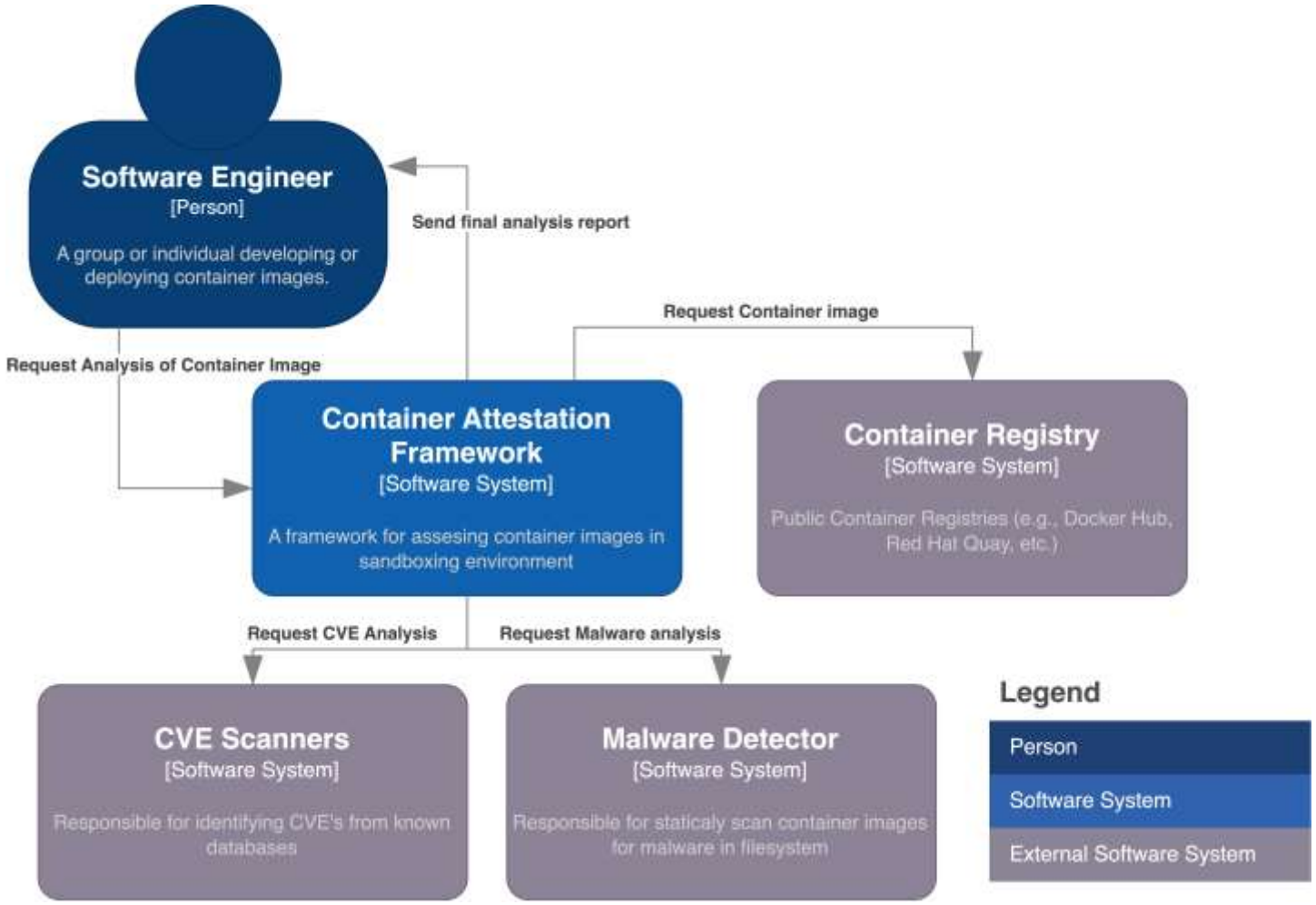
Structure and evaluate static CVE reports & runtime behavioral analysis into STIX format

Extendable

Kubernetes-ready via *admission controller* in production pipelines

Proposed Architecture

Framework Architecture

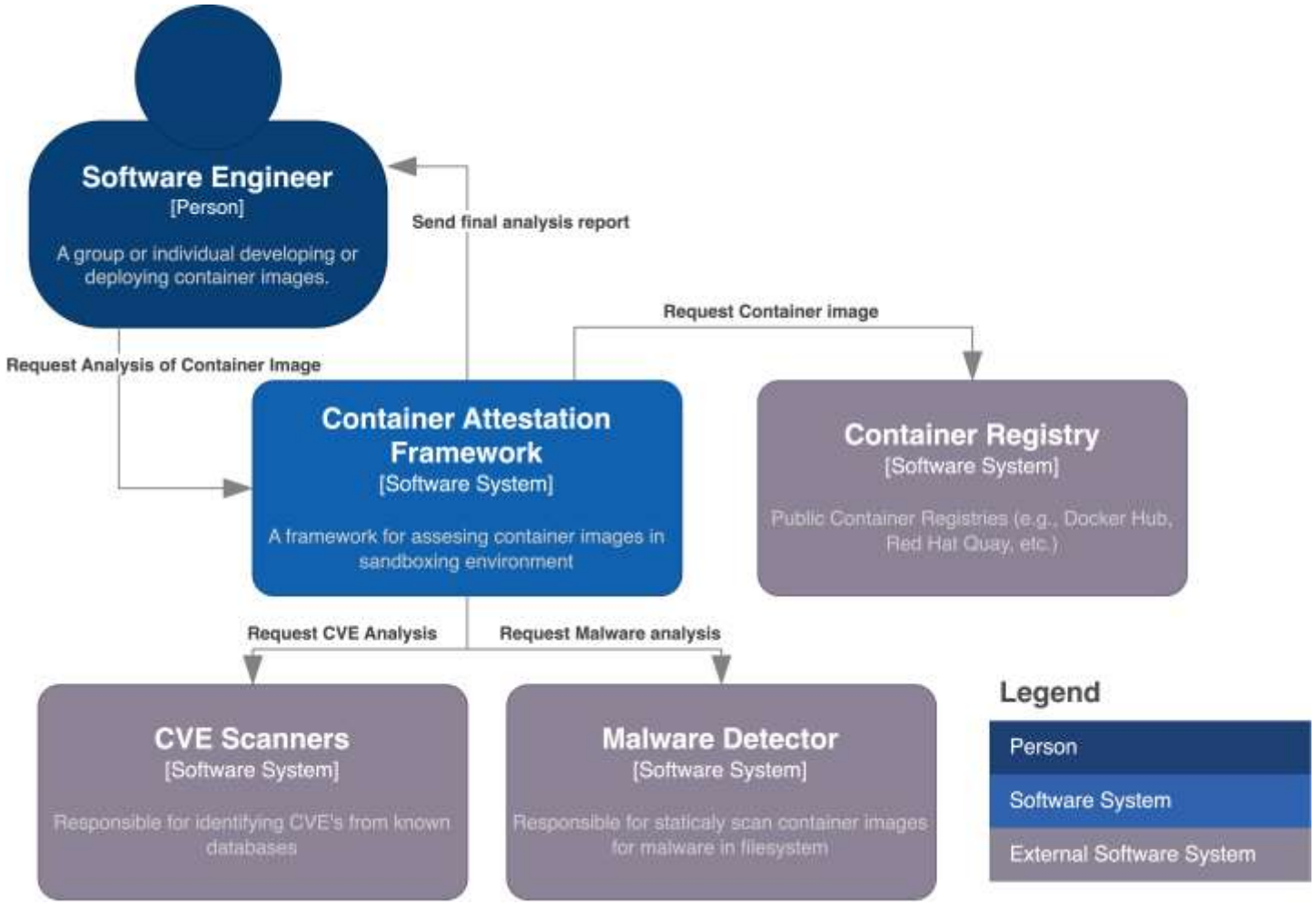


Abstraction levels via C4 model

1 Context-Level

Complexity + Interaction

Framework Architecture



Abstraction levels via C4 model

1 Context-Level

2 Container-Level

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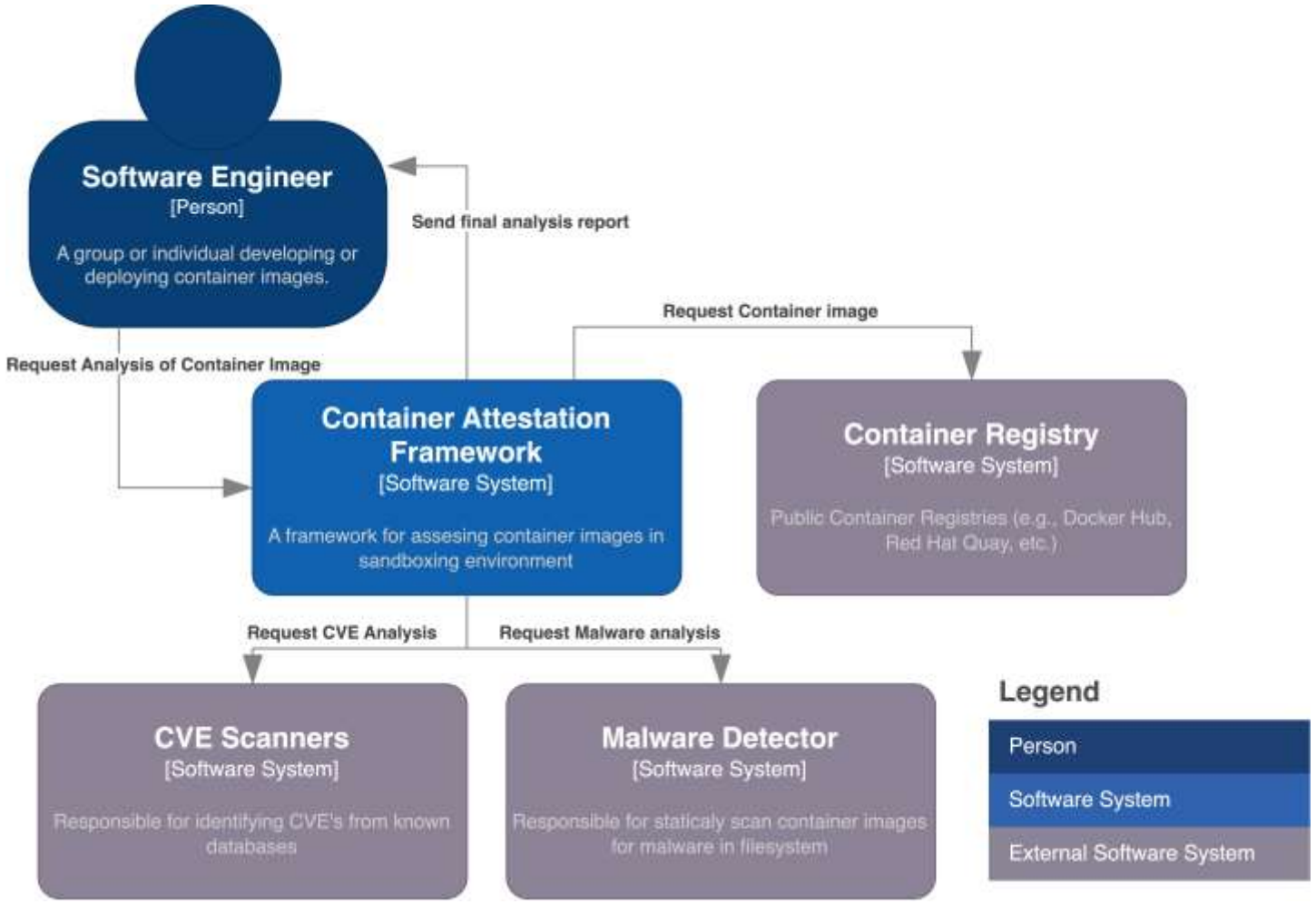

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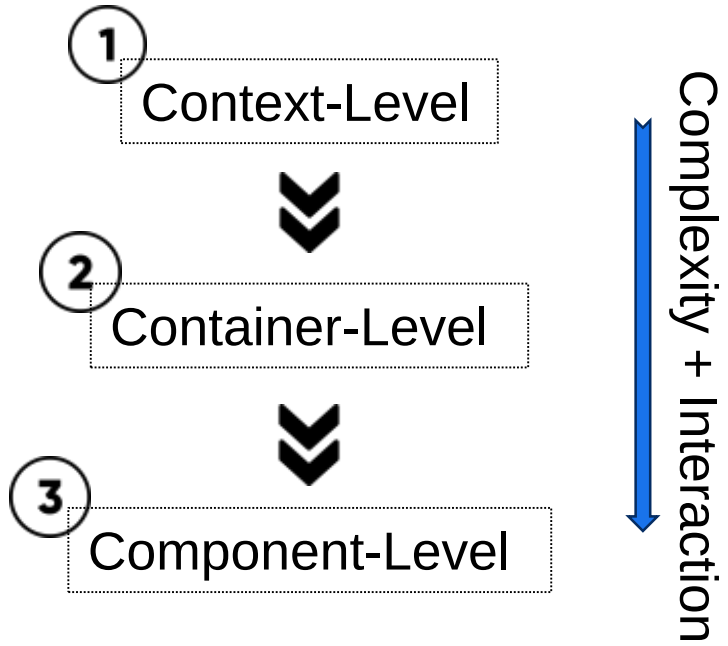

Context-Level

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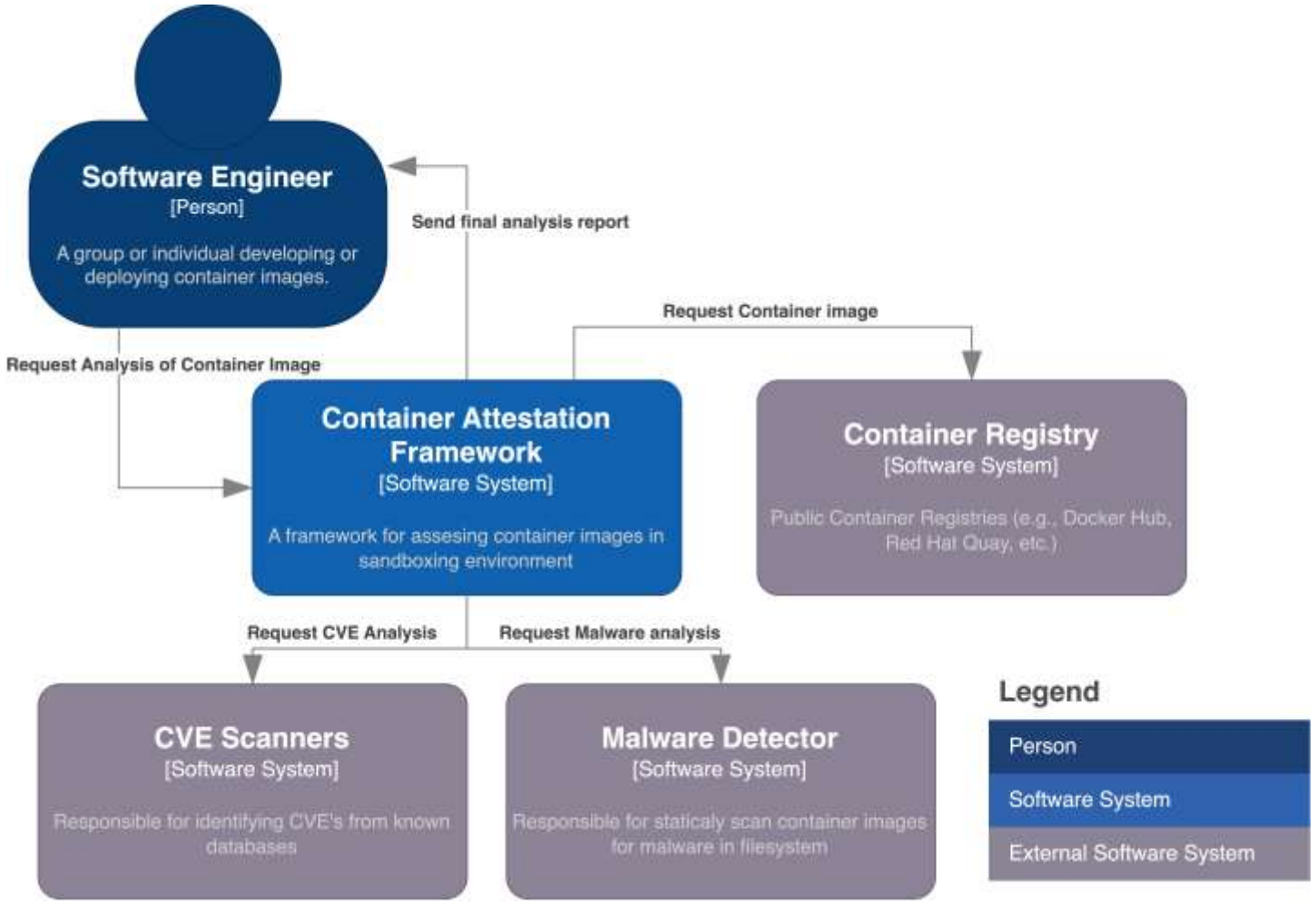


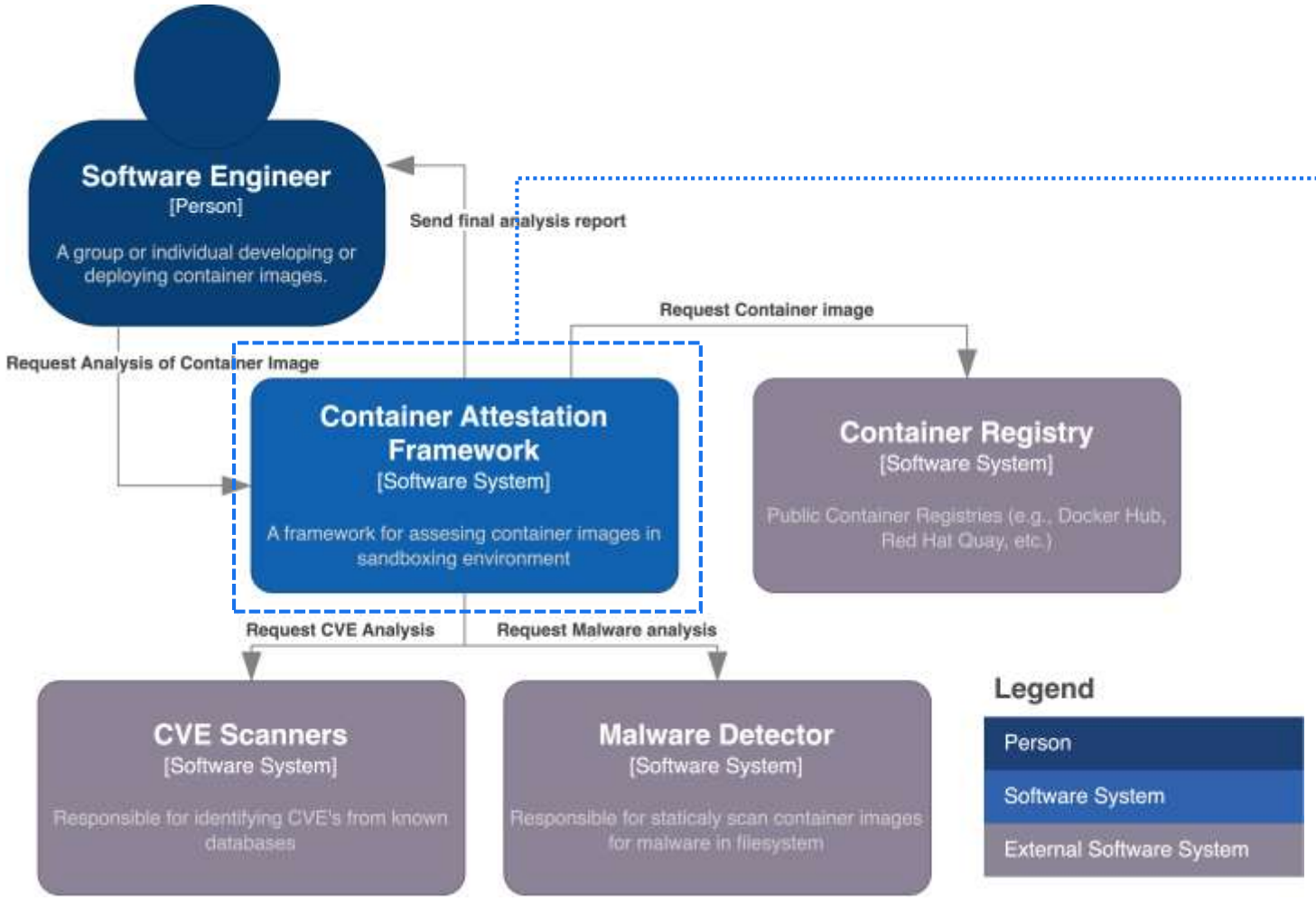
Software System

- ❑ Container Attestation Framework

External Software Systems

- ❑ Container Registry
- ❑ CVE Scanners
- ❑ Malware Detector

Context-Level



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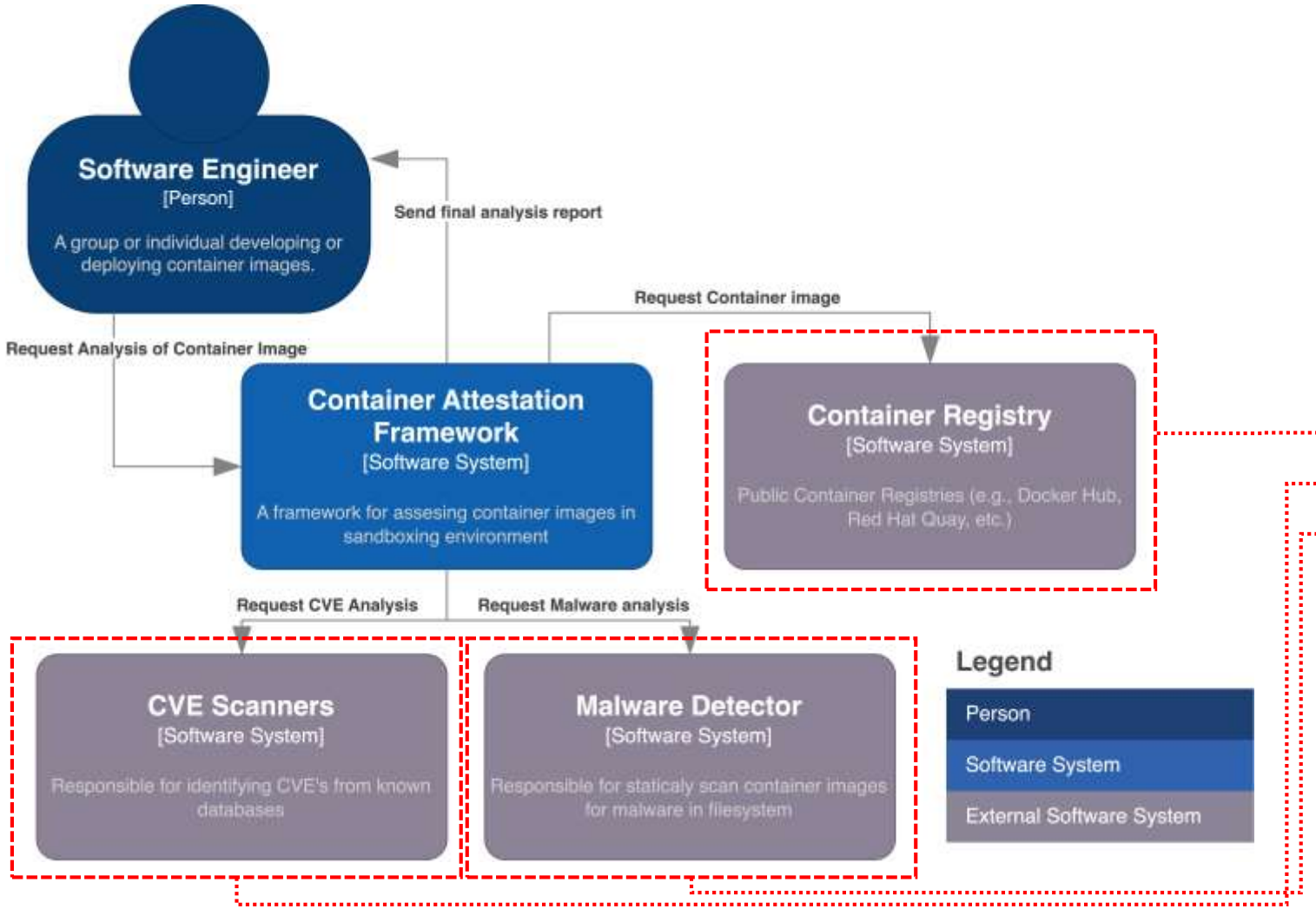

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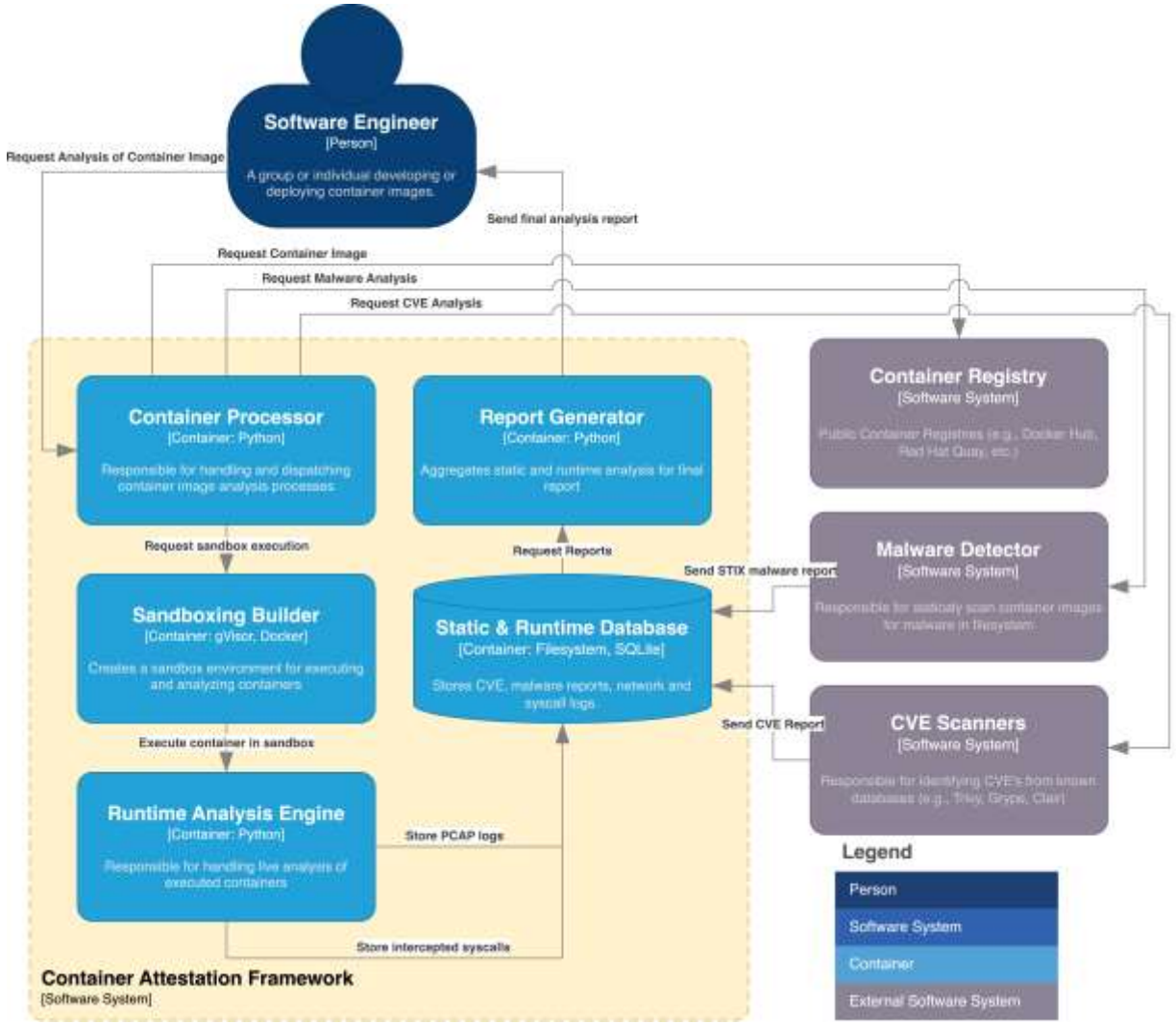
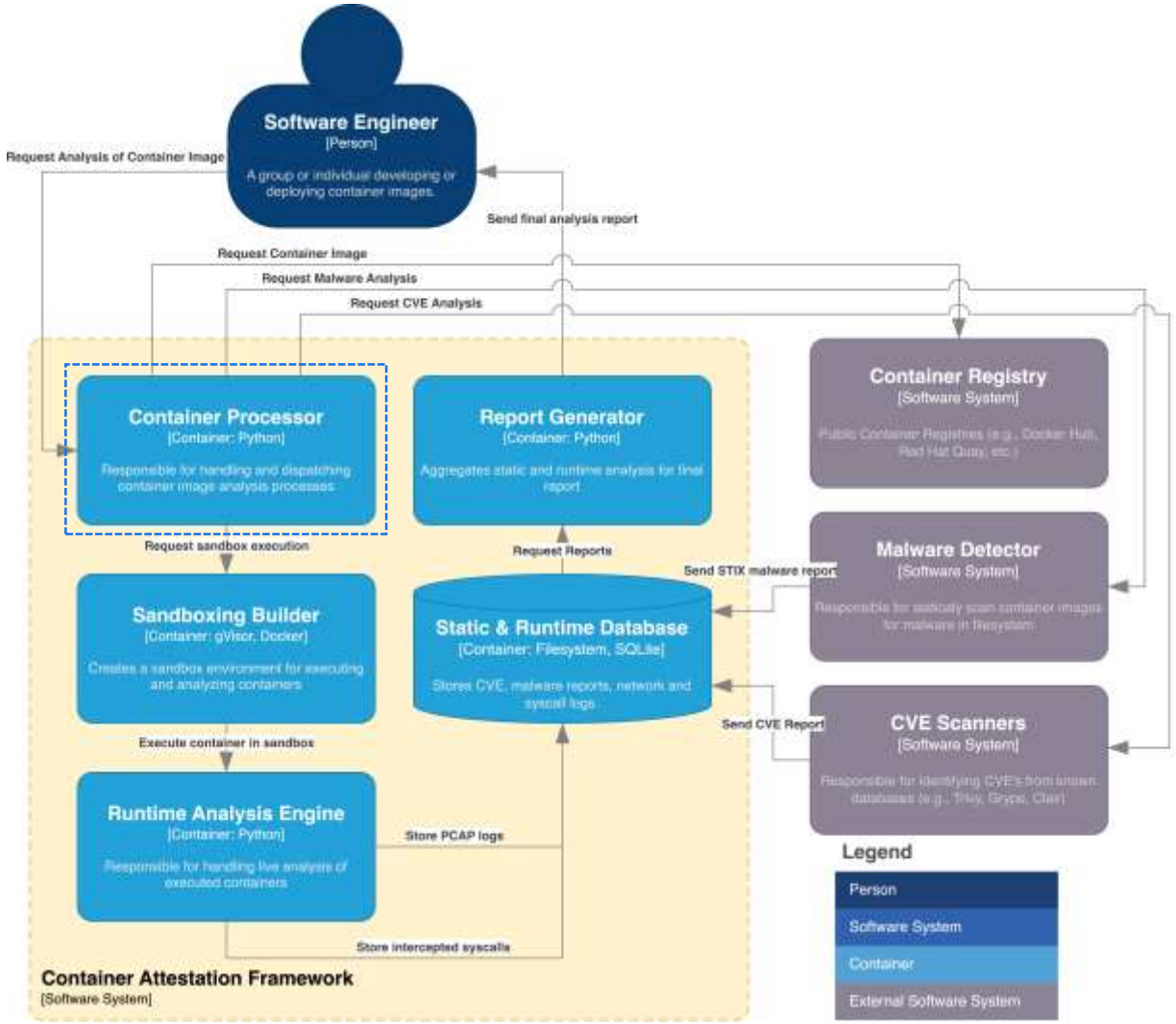


Container Attestation Framework

- ❑ Container Processor
- ❑ Sandboxing Builder
- ❑ Runtime Analysis Engine
- ❑ Static & Runtime Database
- ❑ Report Generator

Container-Level



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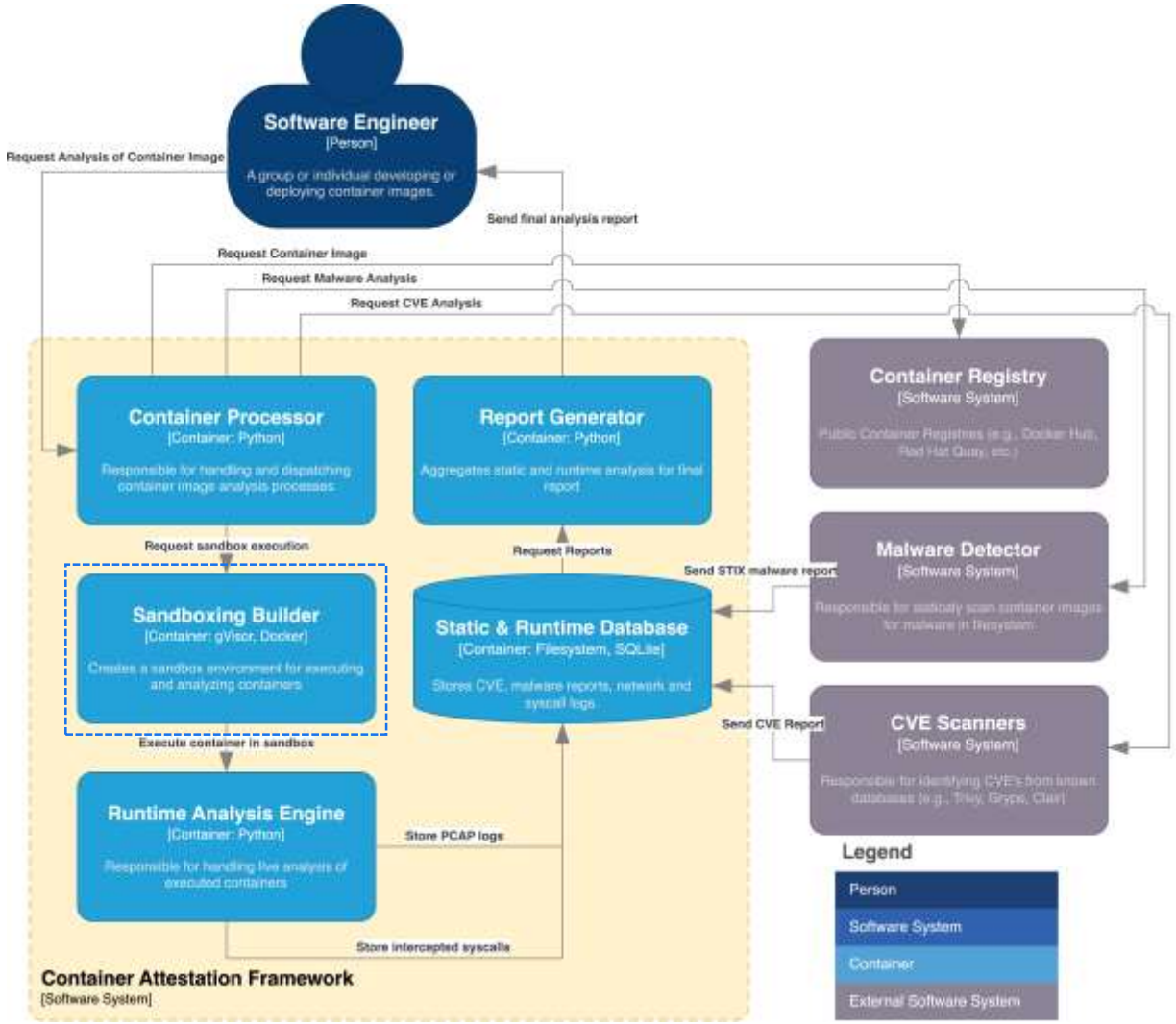
Operation

Dispatching container image analysis

Container-Level



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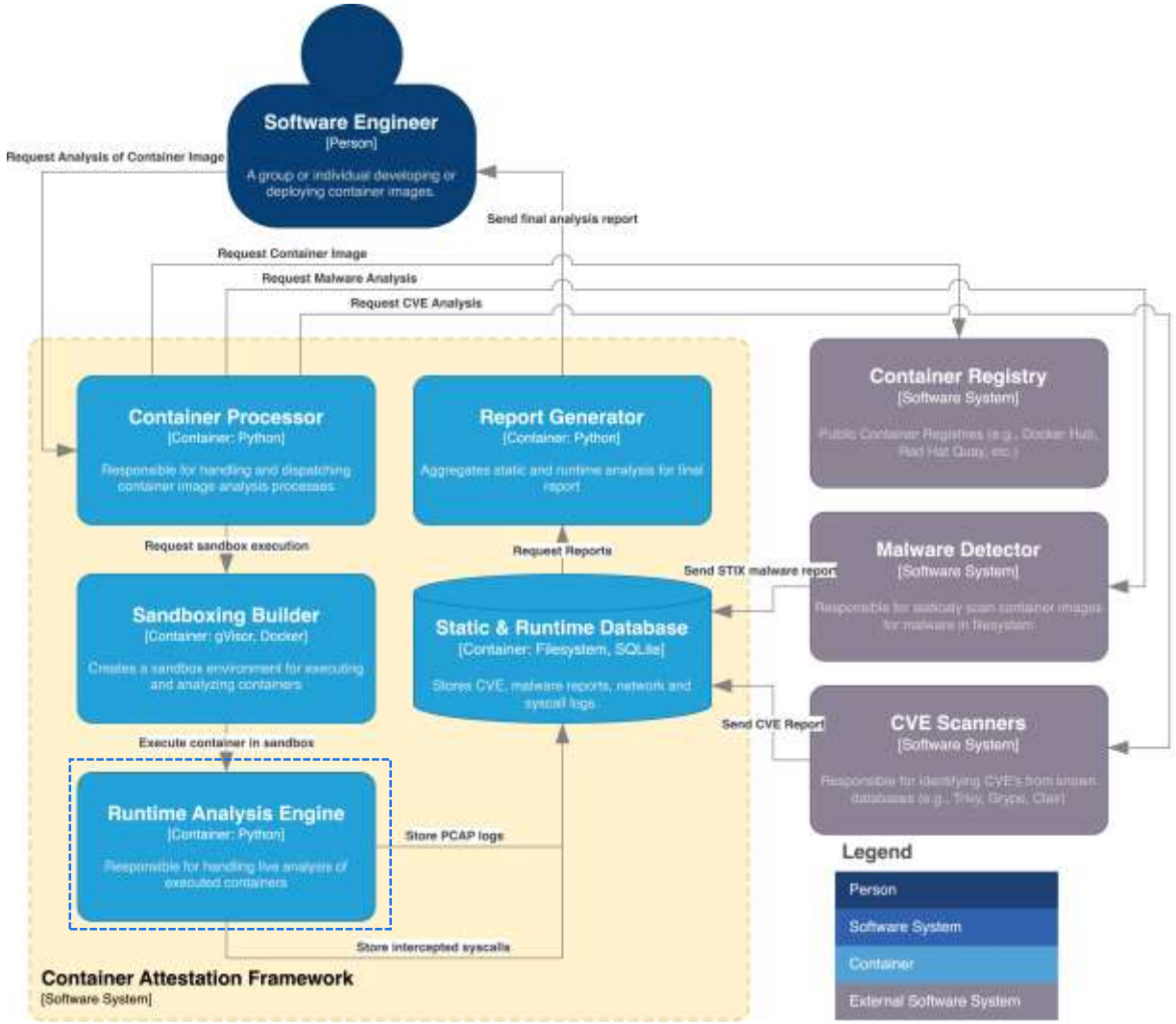
Operation

Create a sandboxing environment for analysis

Container-Level



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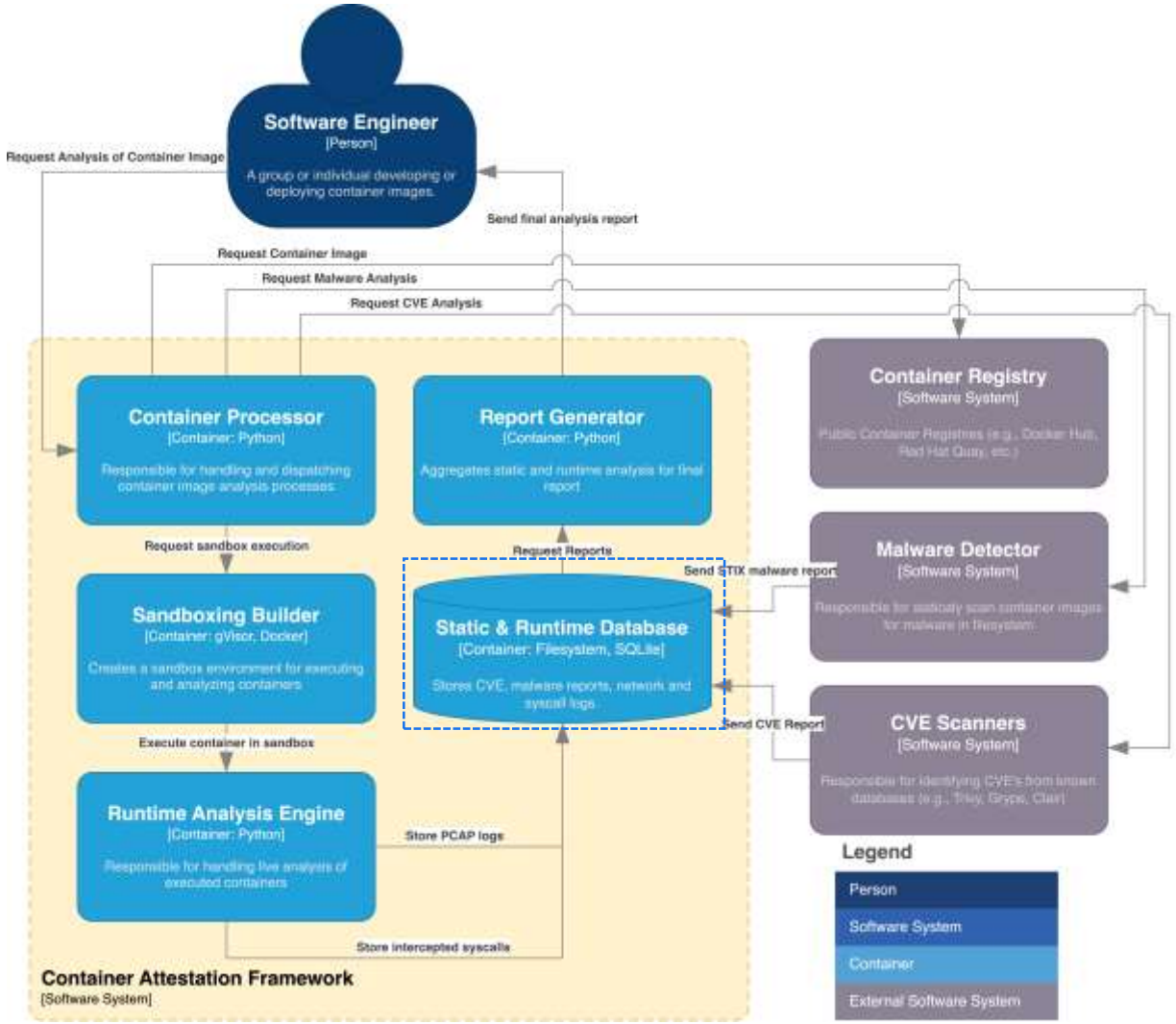
Operation

Execution and monitoring of the sandboxing environment

Container-Level



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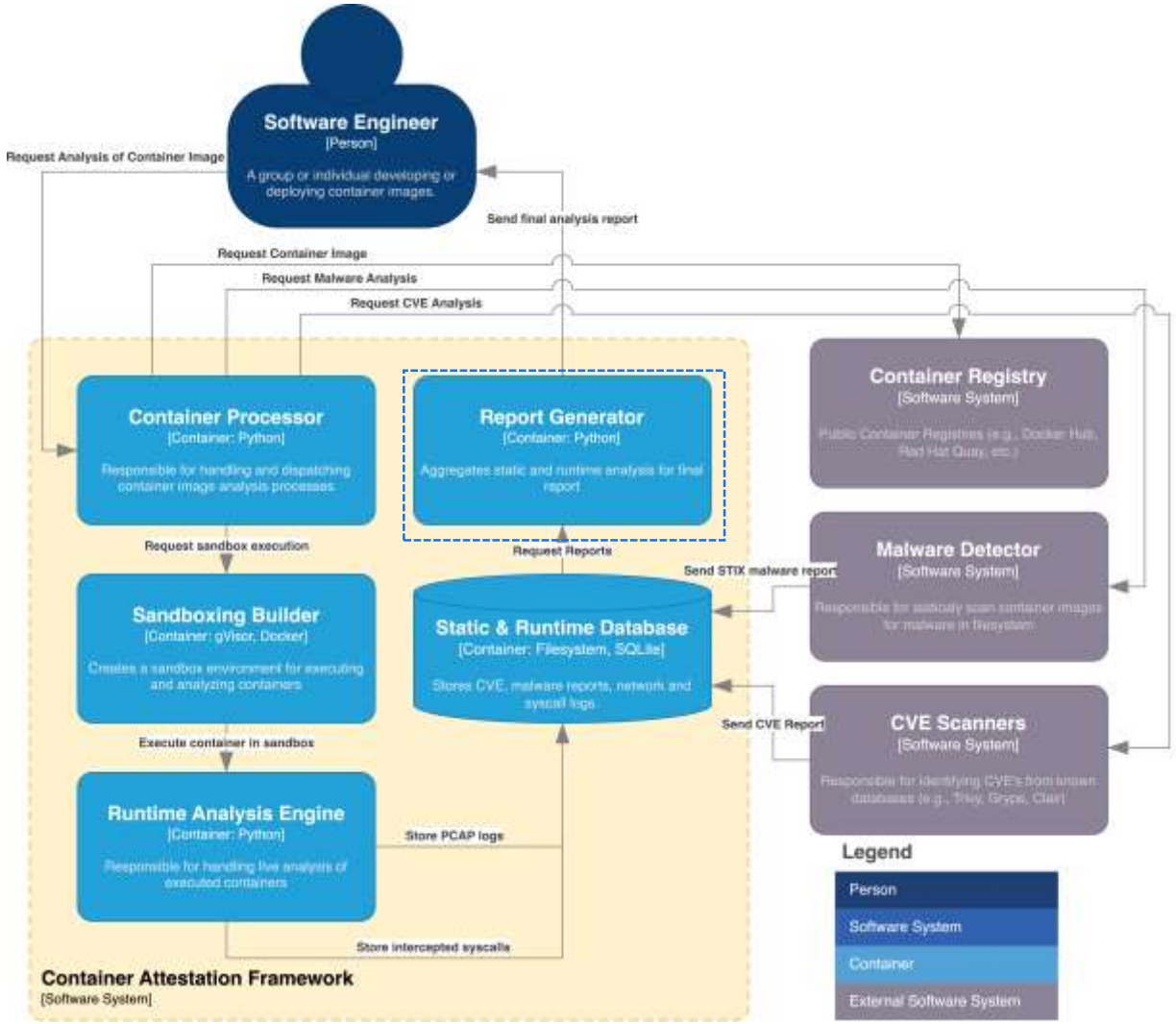
Operation

Store CVE reports and sandboxing metadata (network & syscalls)

Container-Level



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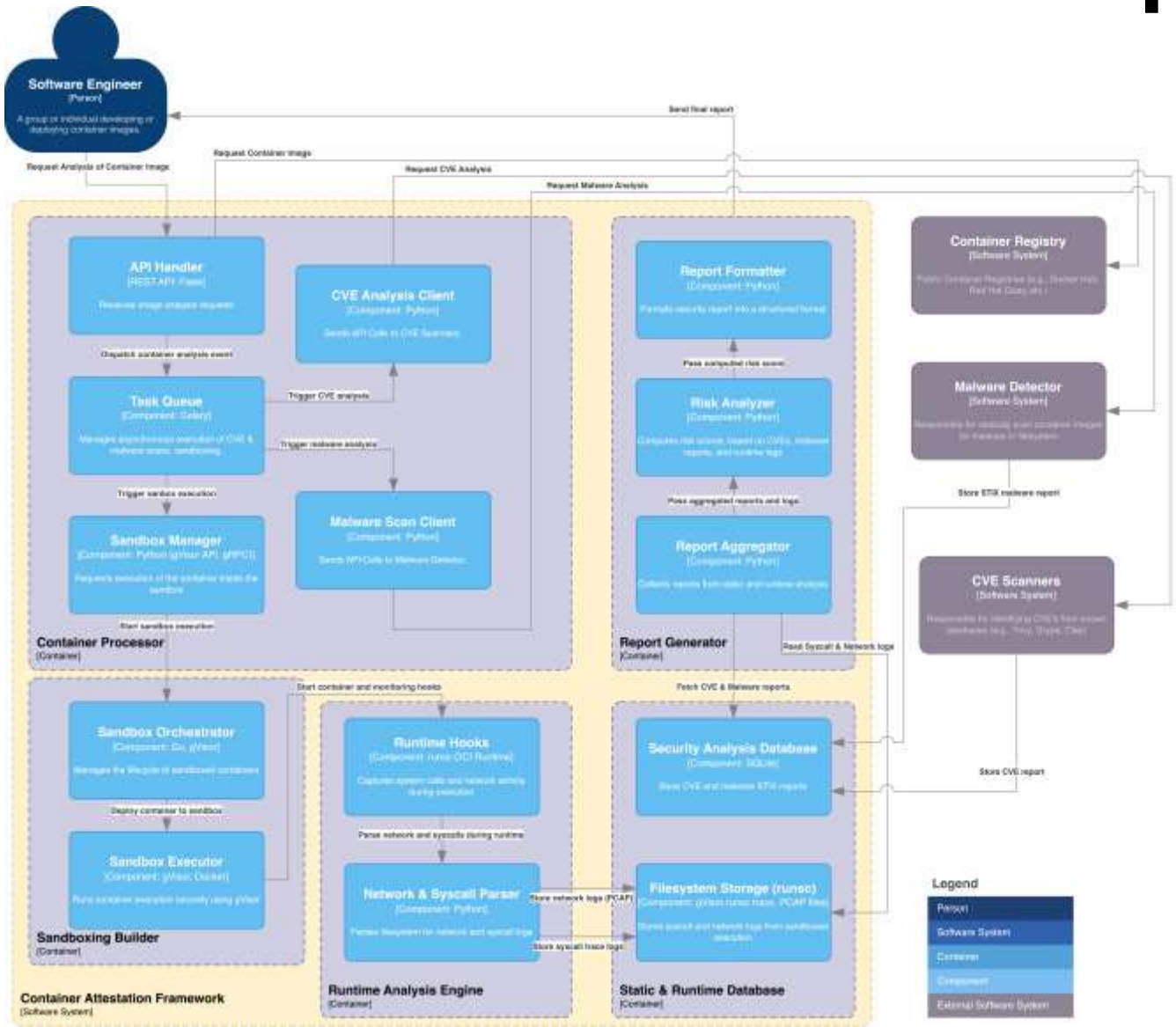
Operation

Construct a STIX report with CVE and runtime analysis information

Component-Level

Component-Level



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- ❑ Sandbox Executor

Runtime Analysis Engine

- ❑ Runtime Hooks
- ❑ Network & Syscall Parser

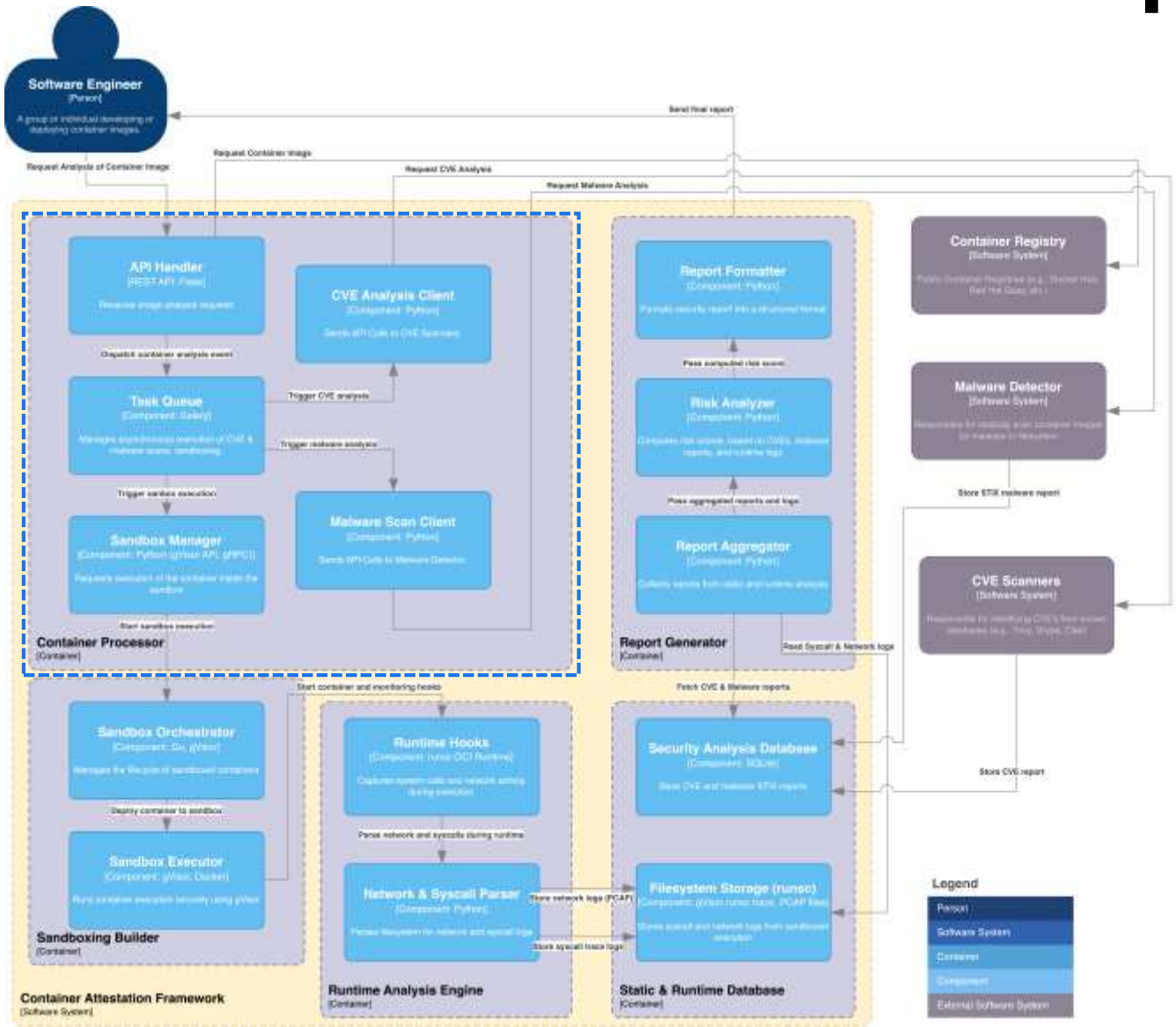
Report Generator

- ❑ Report Aggregator
- ❑ Risk Analyzer
- ❑ Report Formatter

Static & Runtime Database

- ❑ Filesystem Storage (runsc)
- ❑ Security Analysis Database

Component-Level



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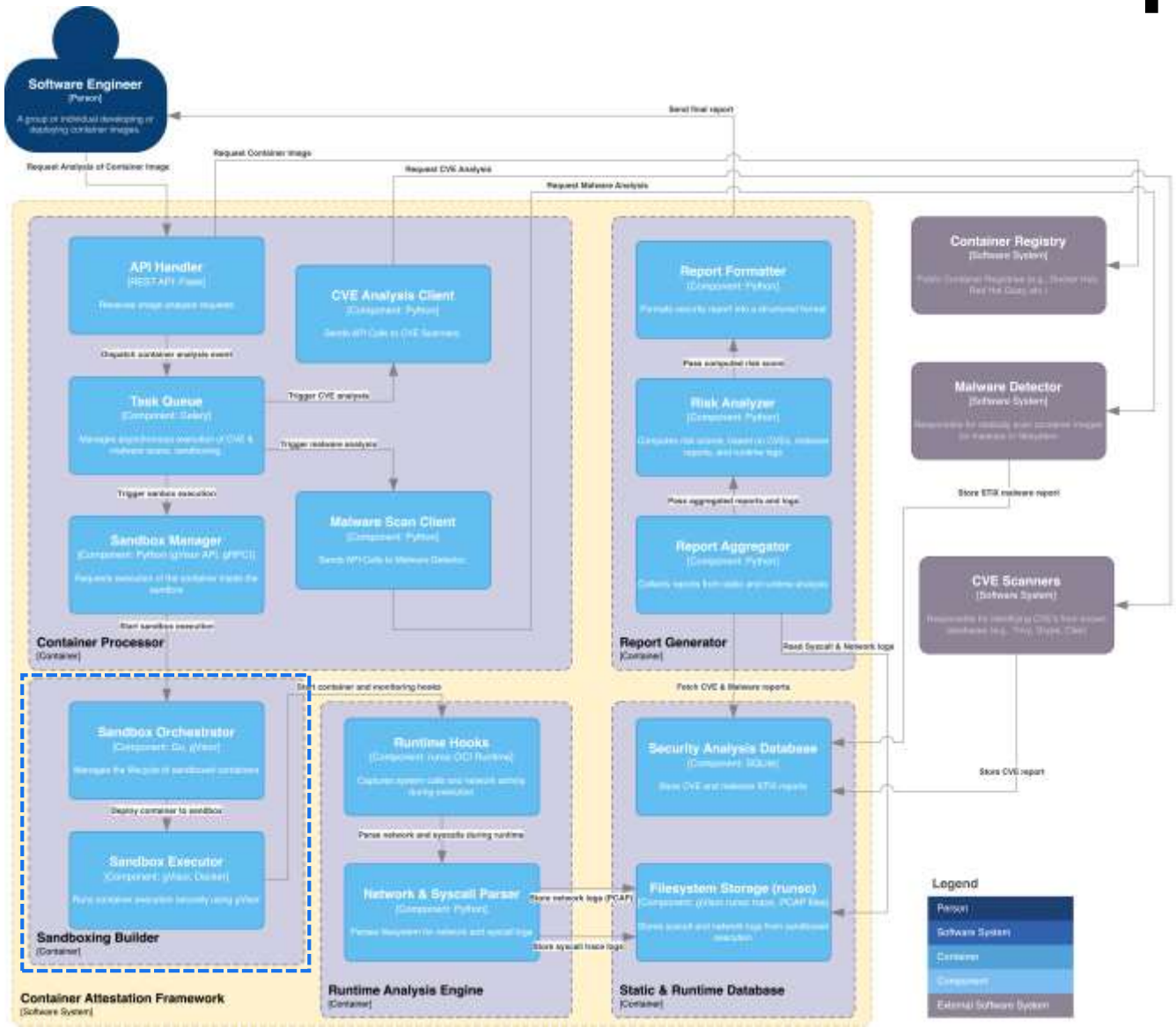

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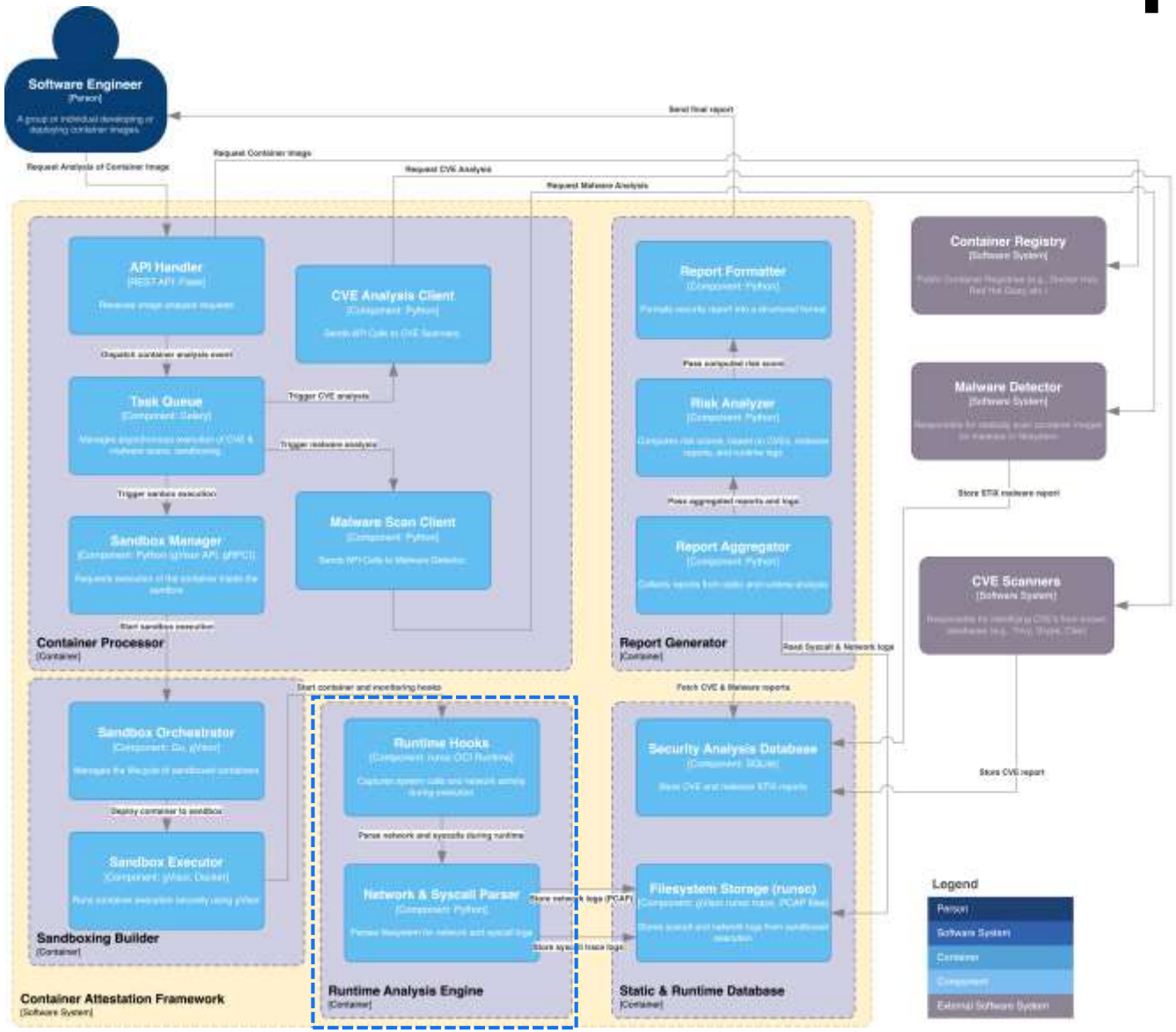

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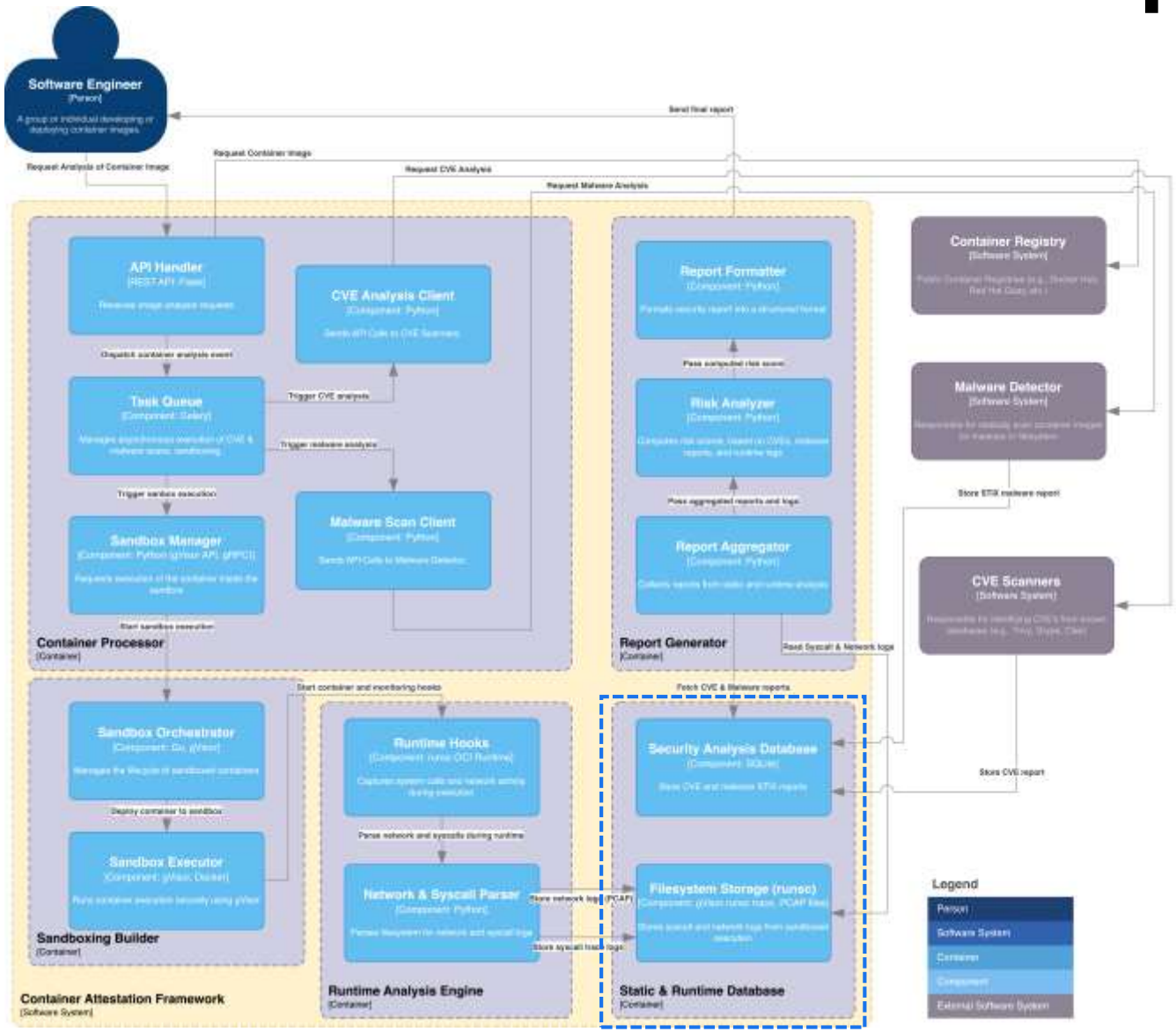

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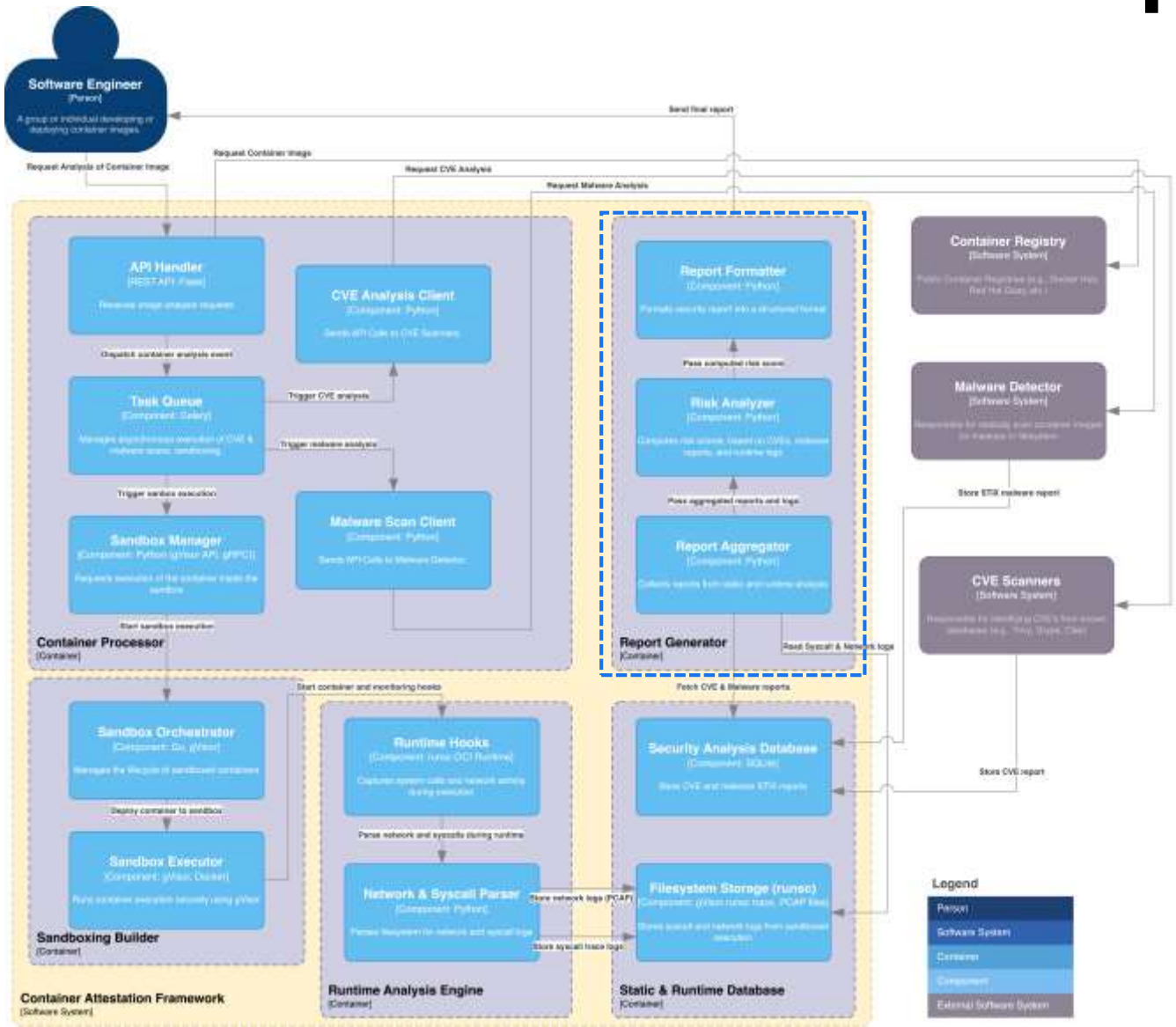

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Conclusion & Future Work

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- Introduced first GitOps-native framework combining CVE scanning with runtime behavioral analysis
- Demonstrated architecture supporting compliance standards while addressing SBOM/SLSA coverage gaps
- Proposed a practical solution for organizations delaying deployments due to container security concerns

Future Work

- Production deployment validation and performance benchmarking
- ML-based anomaly detection for behavioral patterns
- Extended ecosystem integration and automated policy enforcement

Appendix & Refs

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[1]: https://edgedelta.com/company/blog/kubernetes-adoption-statistics
[2]: https://www.mordorintelligence.com/industry-reports/docker-container-market
[3]: https://www.helpnetsecurity.com/2024/12/11/containers-security-concerns/
[4]: https://www.darkreading.com/vulnerabilities-threats/87-of-container-images-in-production-have-critical-or-high-severity-vulnerabilities
[5]: https://arxiv.org/abs/2409.05014