DOPSY group

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Wiesbaden Rüsselsheim

An Approach for Knowledge-Based IT Management of Air Traffic Control Systems

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Air Traffic Control (ATC) Systems

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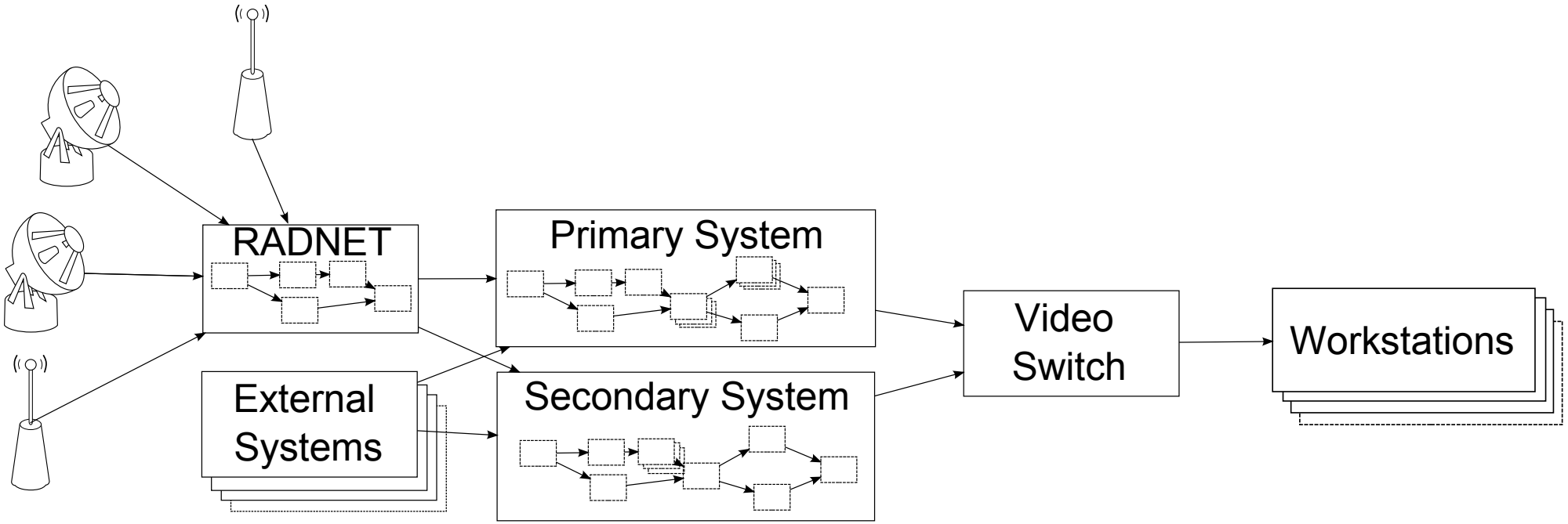
- Tasks
  - Collection of sensor data
  - Data transfer
  - Data fusion (e.g. track estimation)
  - Situation visualization for controllers
- Subsystems



Administrative Tasks in ATC Systems

- Monitoring
  - Log data
  - Monitoring interfaces
  - Observations from controllers
  - etc.
- Analysis of the system's state
  - Statistics (e.g. number of track drops)
  - Quality of Service (QoS) assessment
    - Conformance to fault tolerance requirements
    - Output quality
    - Time to delivery
    - etc.
- Planning and reconfiguration of the system

Administrative Problems

- High requirements on reliability and traceability
- Administration of steadily-growing ATC systems has become a
  - Time-intensive and
  - Cost-intensive task.
- Similar problems in almost every domain
  - IT applications/infrastructure essential for business goals
  - IT systems have grown over years
  - Heterogeneous components from different vendors
  - High requirements on reliability and robustness

→ High demand for intelligent, overarching, automated management tools

Ontology-based IT Management (1/2)

- Recent advances of Semantic Web technologies
- Ontologies experienced revival as domain spanning knowledge models
  - Web Ontology Language (OWL)
  - Semantic Web Rule Language (SWRL)
  - SPARQL Protocol And RDF Query Language (SPARQL)
- Advantages of ontologies in IT Management
  - Integration of different domains
  - Semantics are part of the model (no hard-coded logic)
- First applications
  - Mapping of existing models to OWL (CIM, MOF, GMDO, SMI) [1]
  - Ontology-based network management [2]
  - Architecture for automated knowledge-based IT management [3]

Ontology-based IT Management (2/2)

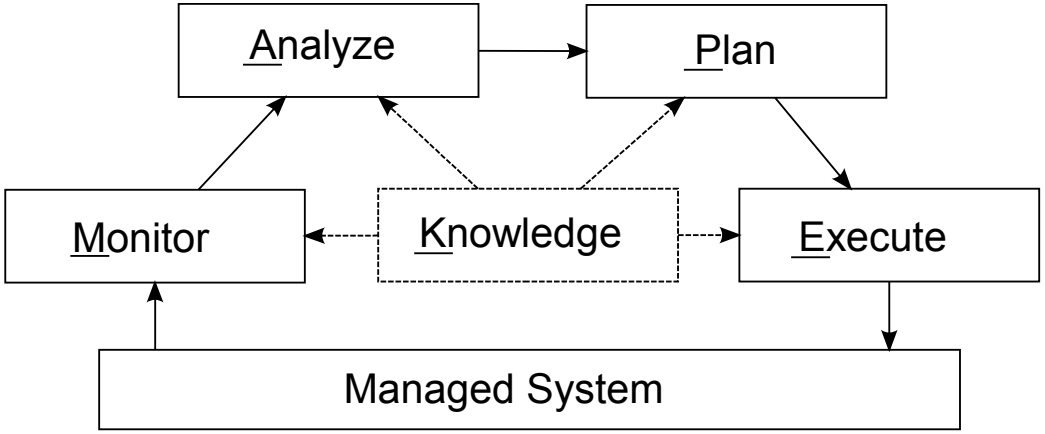
- Performs well for small, timeless models
- Real systems are complex, dynamic and have various timing aspects
- That leads to the following problems:
  - Reasoning complexity of OWL ontologies is NP-hard
  - There is no concept of time in ontologies

➔ These two characteristics turn the **exclusive** use of ontologies for IT Management of complex systems infeasible

Approach

- Combination of
  - Ontologies as a domain spanning semantic model for low-frequency data
  - Complex Event Processing (CEP) for the processing of high-frequency data
- Central requirement:

  All components of the Management System are configured by one homogeneous model to
  - Avoid inconsistencies
  - Avoid knowledge fragmentation
- Architecture based on IBM's MAPE-K Loop



Knowledge Component

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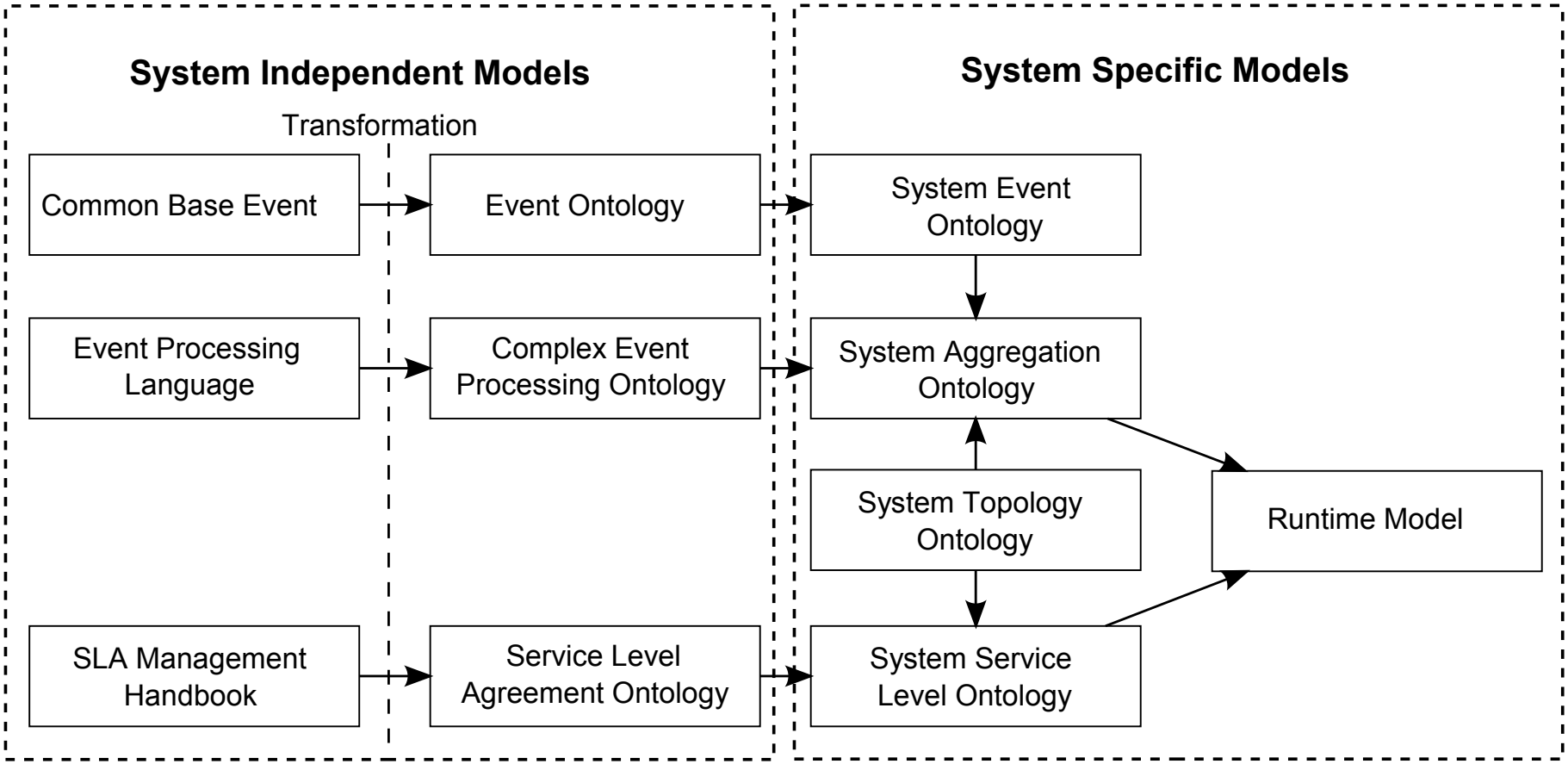
- Data storage for models used in the management cycle
- Can be queried or updated
- Models divided into system-independent and system-specific



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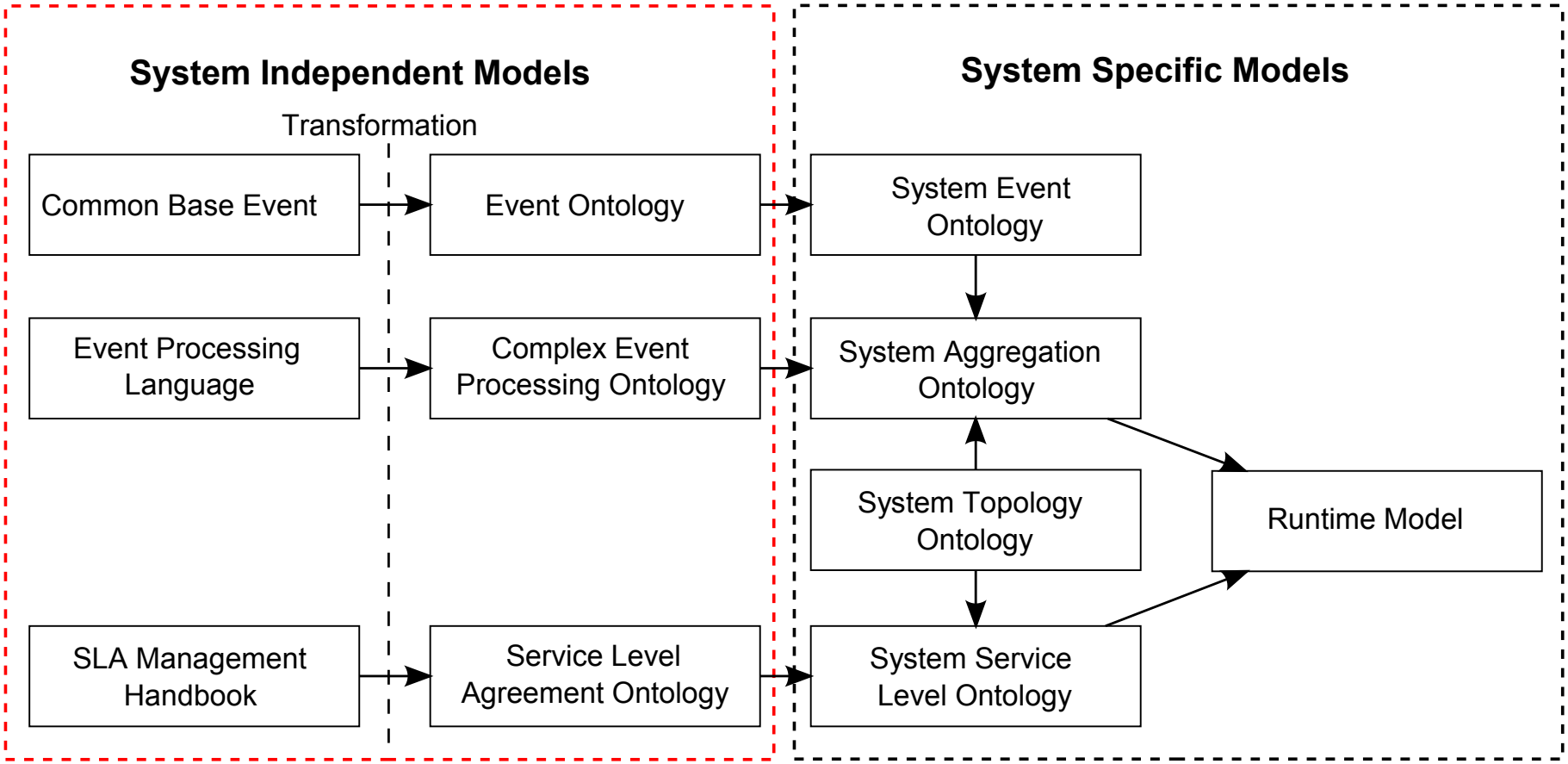

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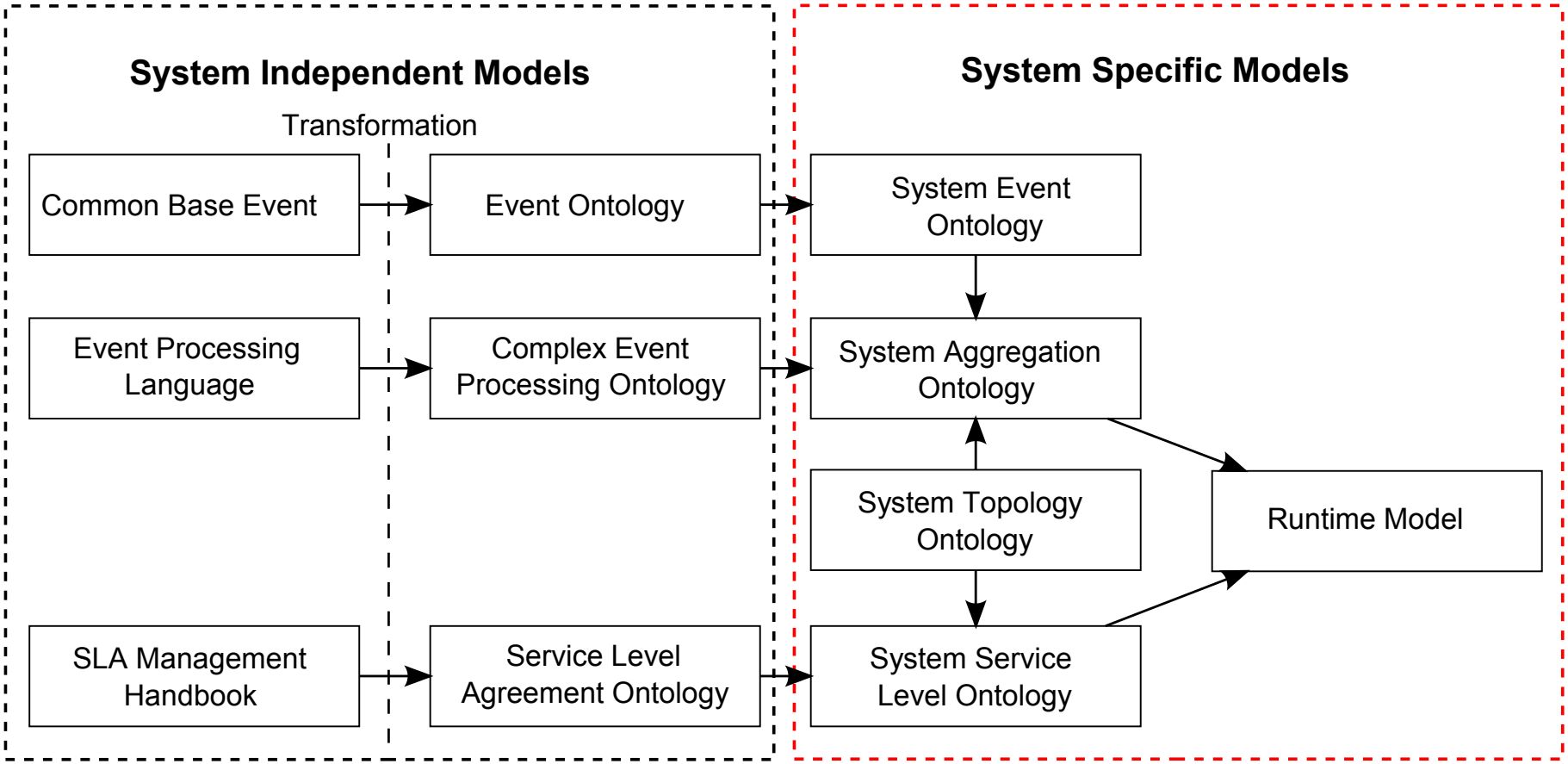

Composed Architecture

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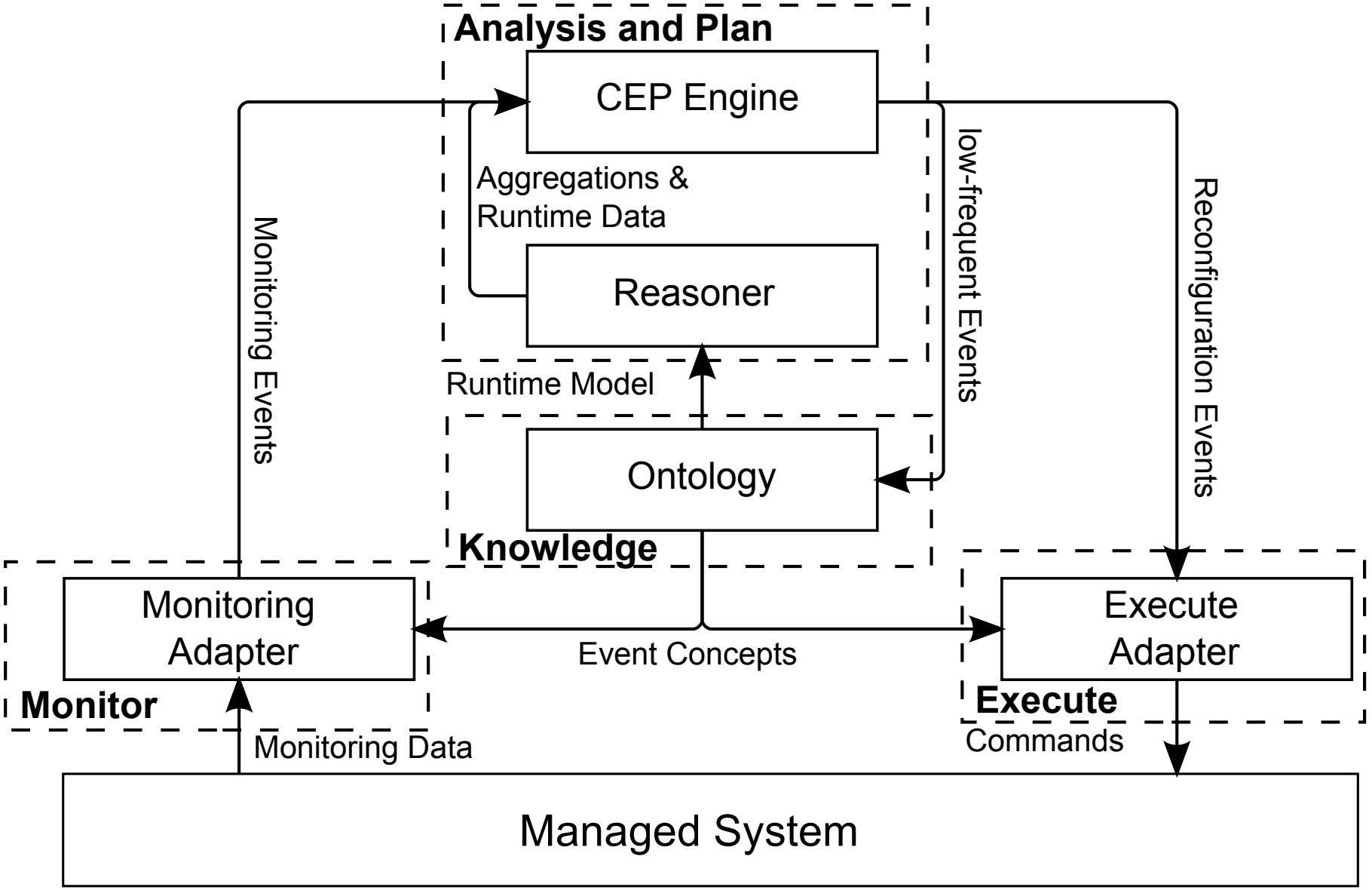
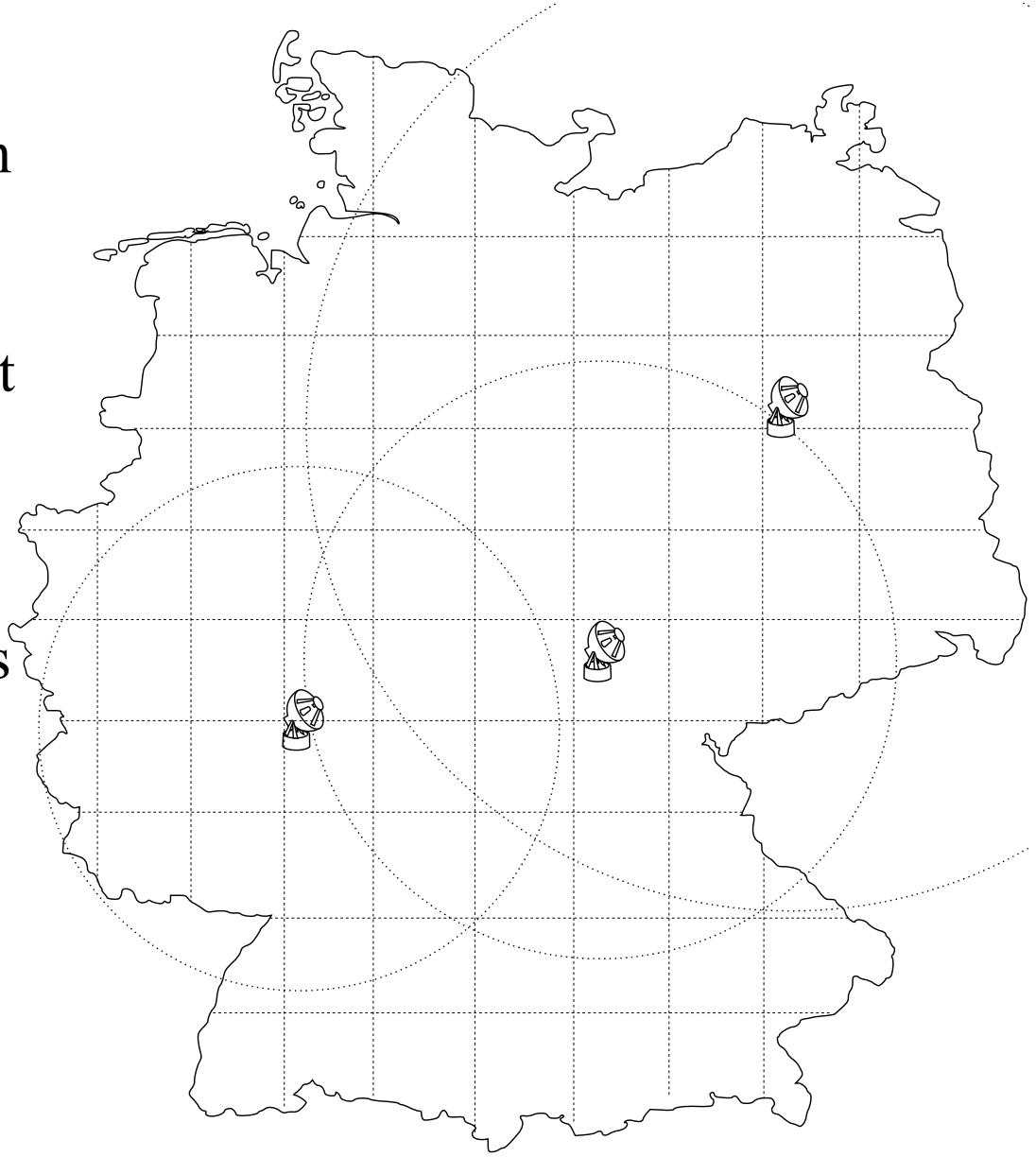


Application on the ATC System

- Use case:
  Automated radar reconfiguration in case of underperforming radars
- Subject: Air Traffic Management (ATM) System PHOENIX of DFS Deutsche Flugsicherung GmbH
- Map is split into geographic tiles



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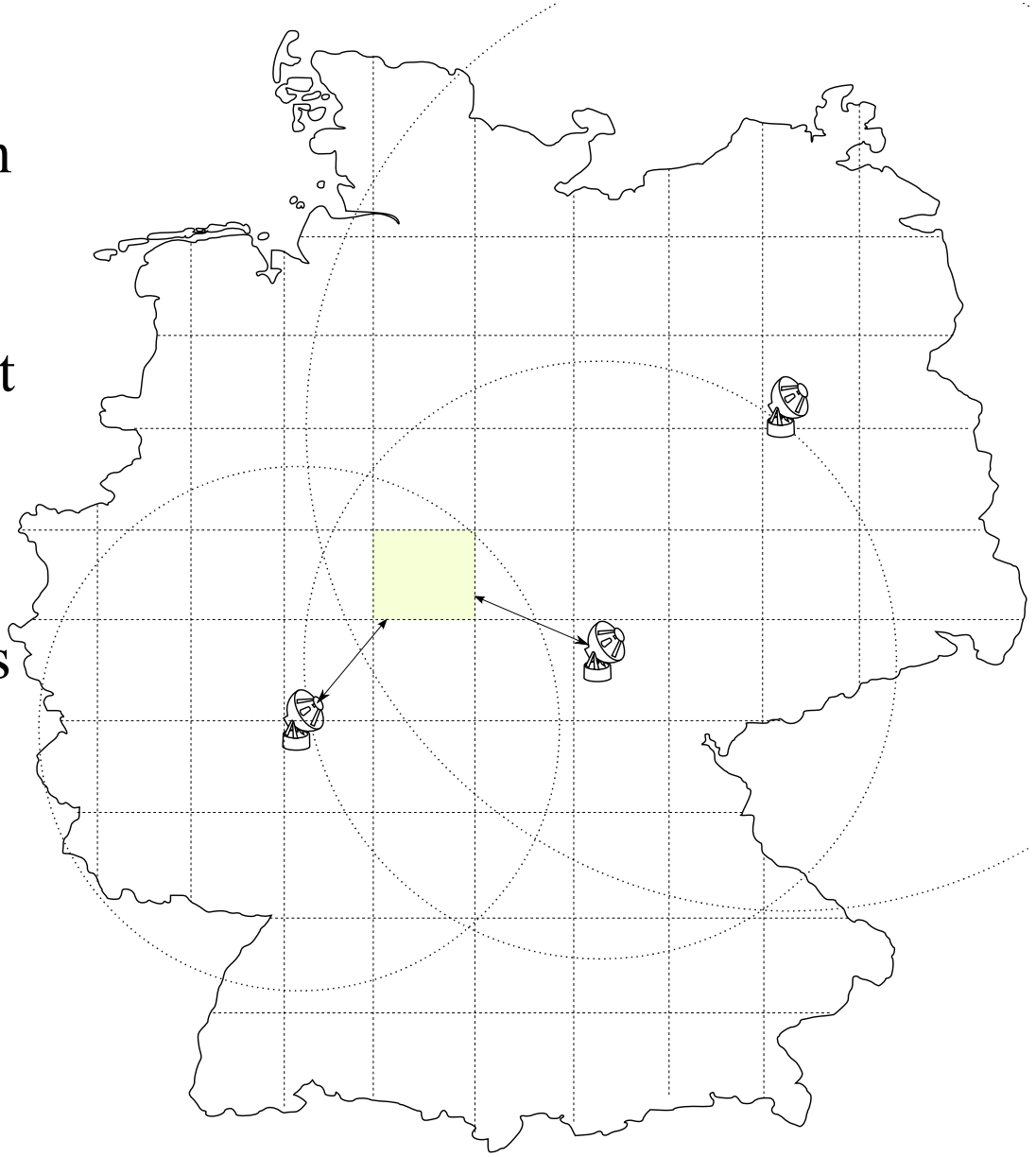

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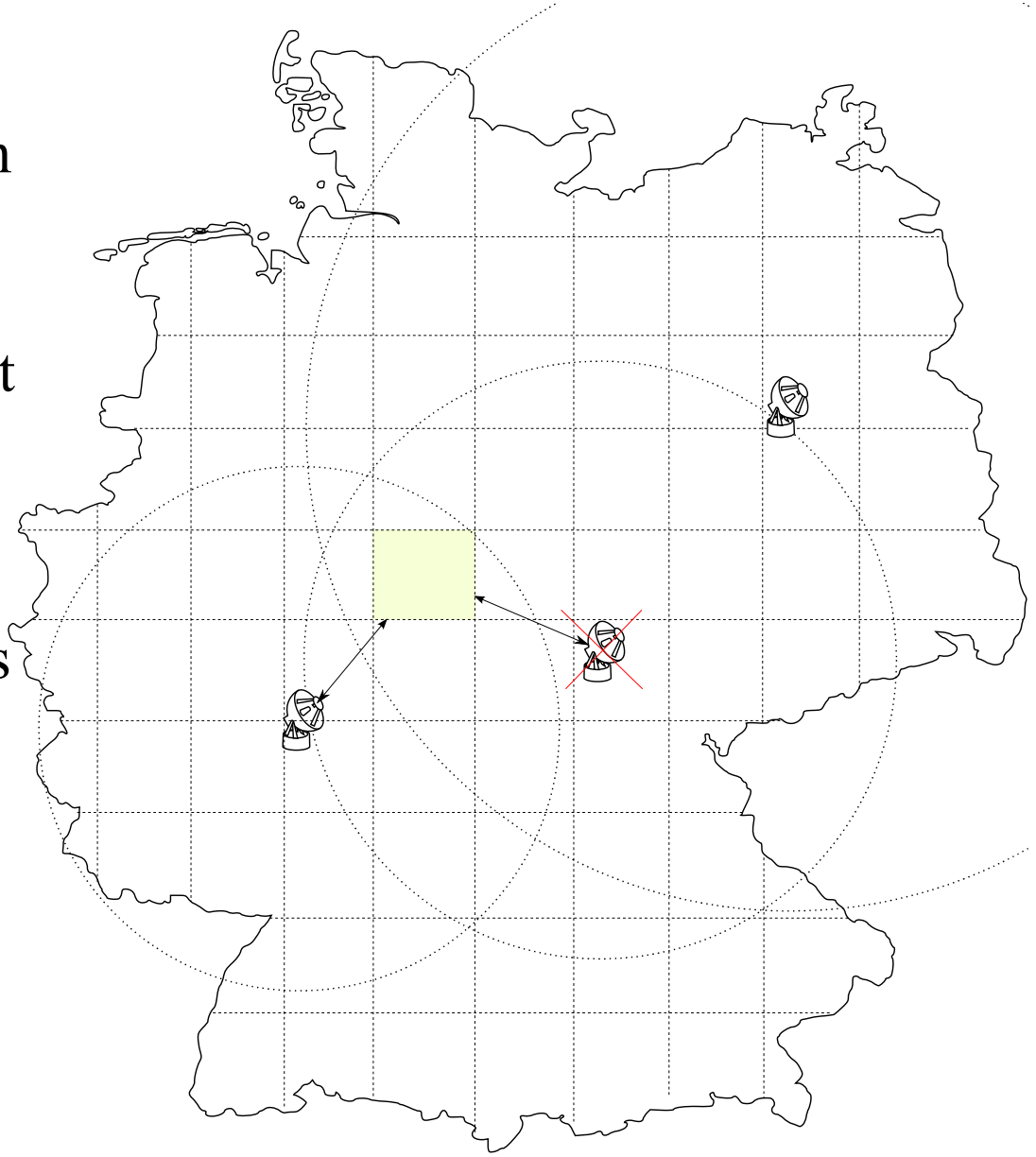
- Underperforming radar is detected



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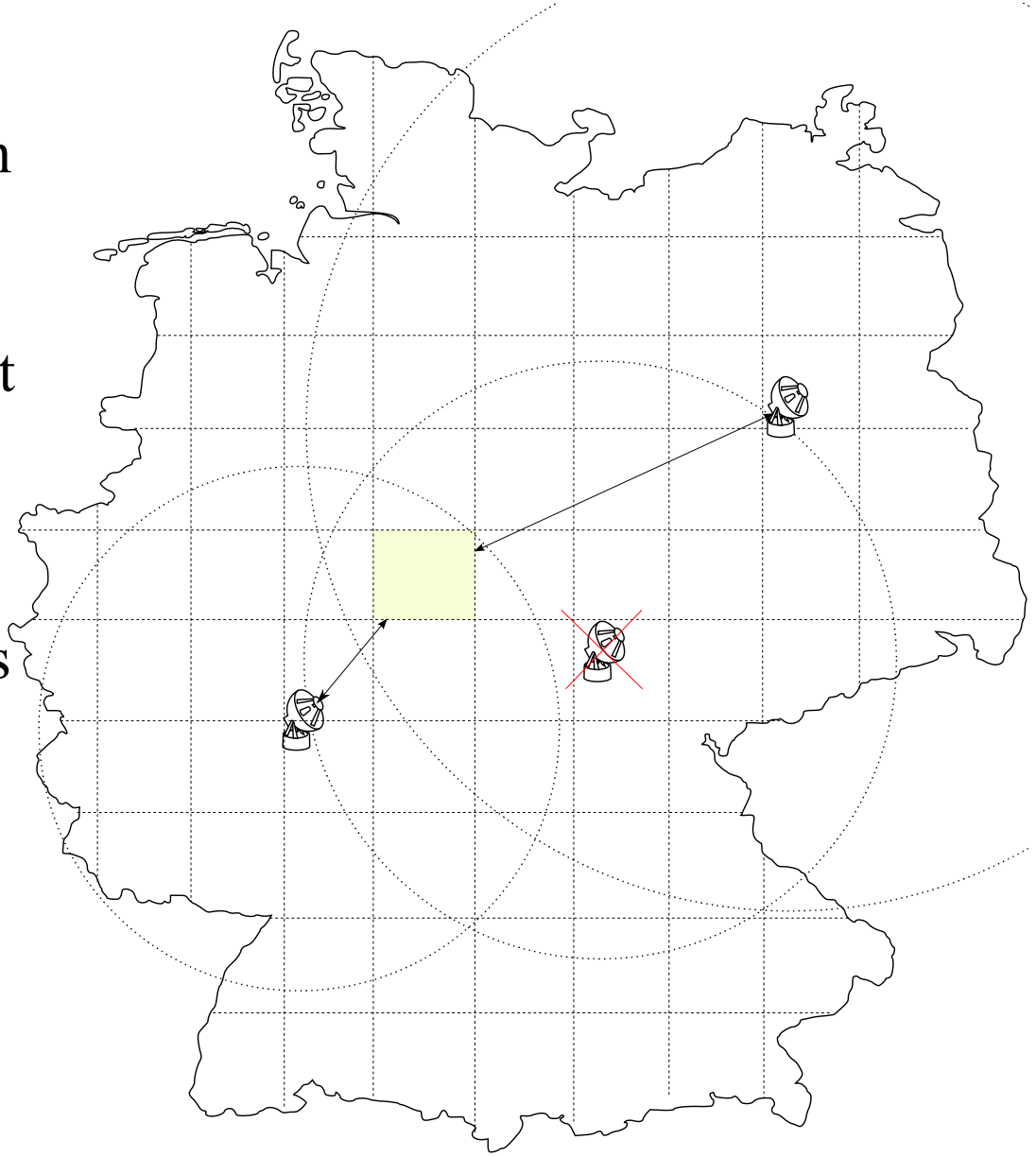
- Map is split into geographic tiles
- Tiles have assigned radars
- Underperforming radar is detected
- Potential radar is assigned



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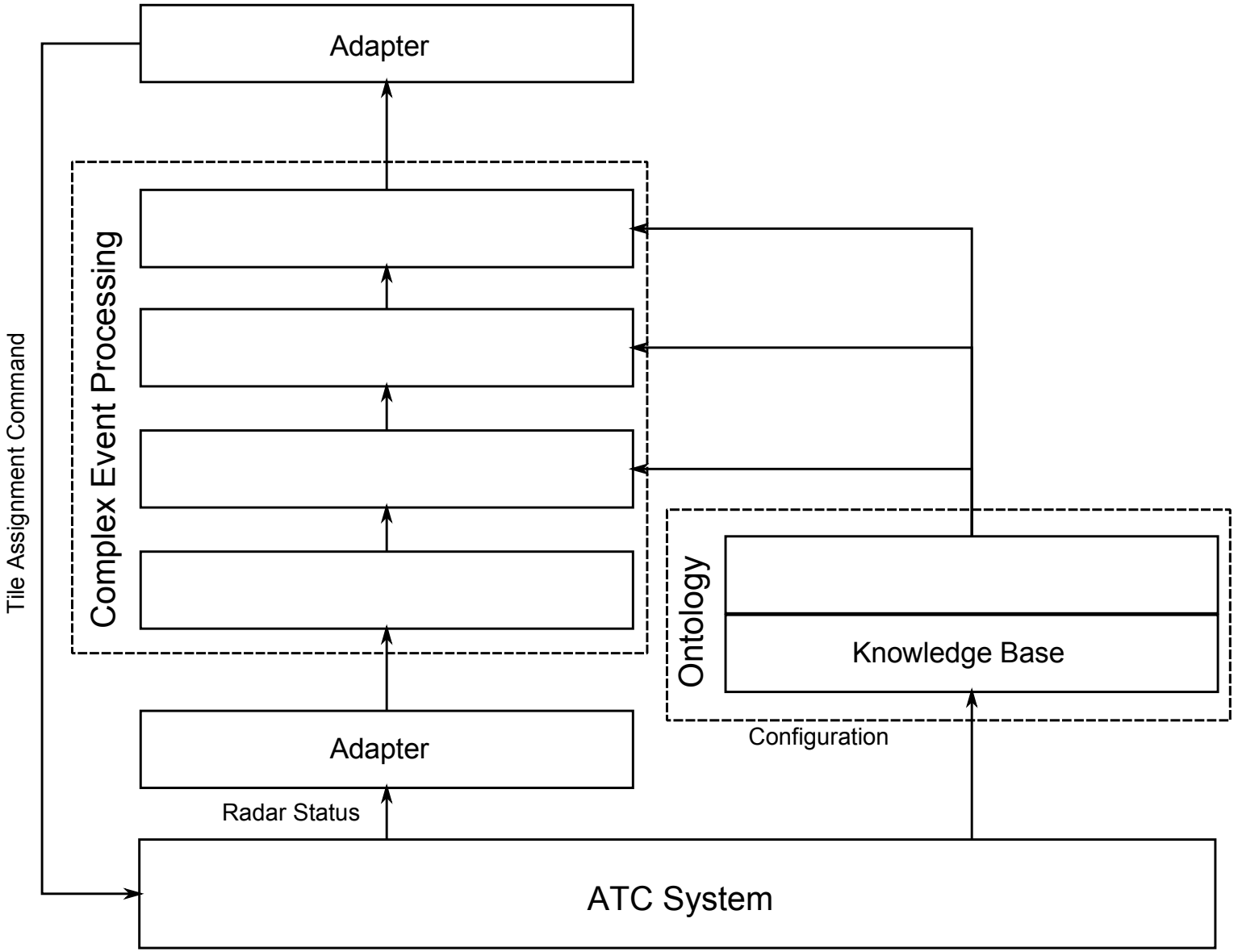

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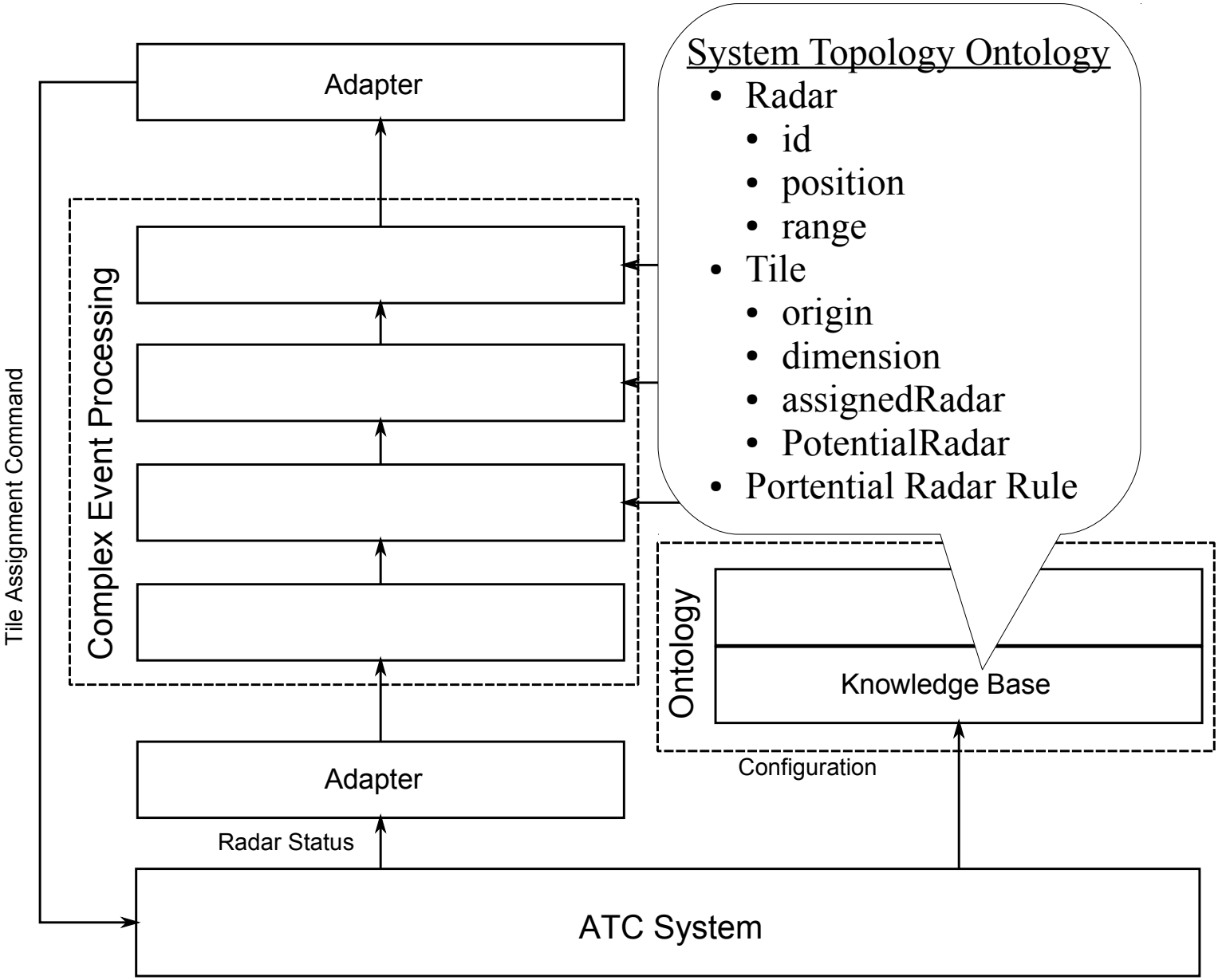

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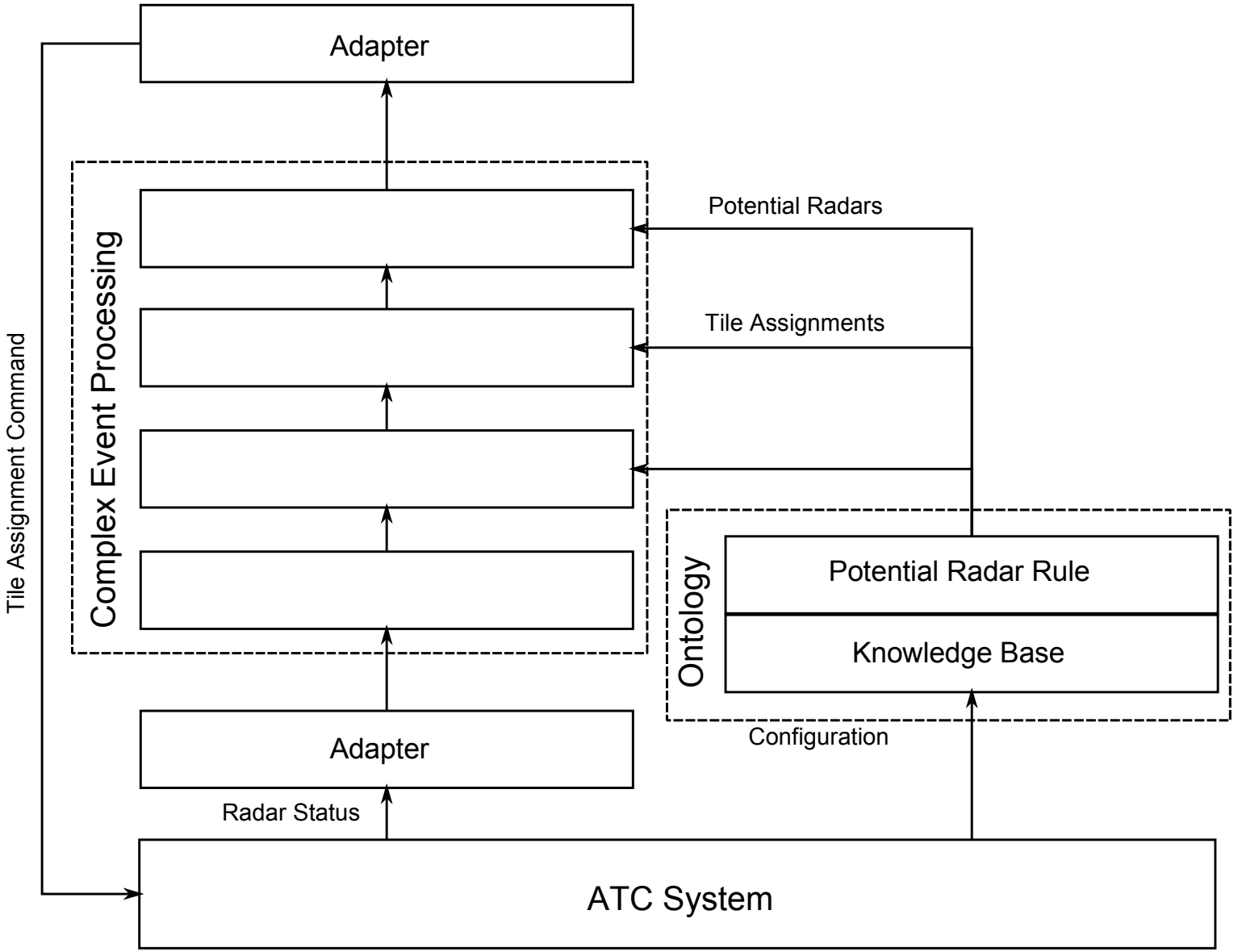
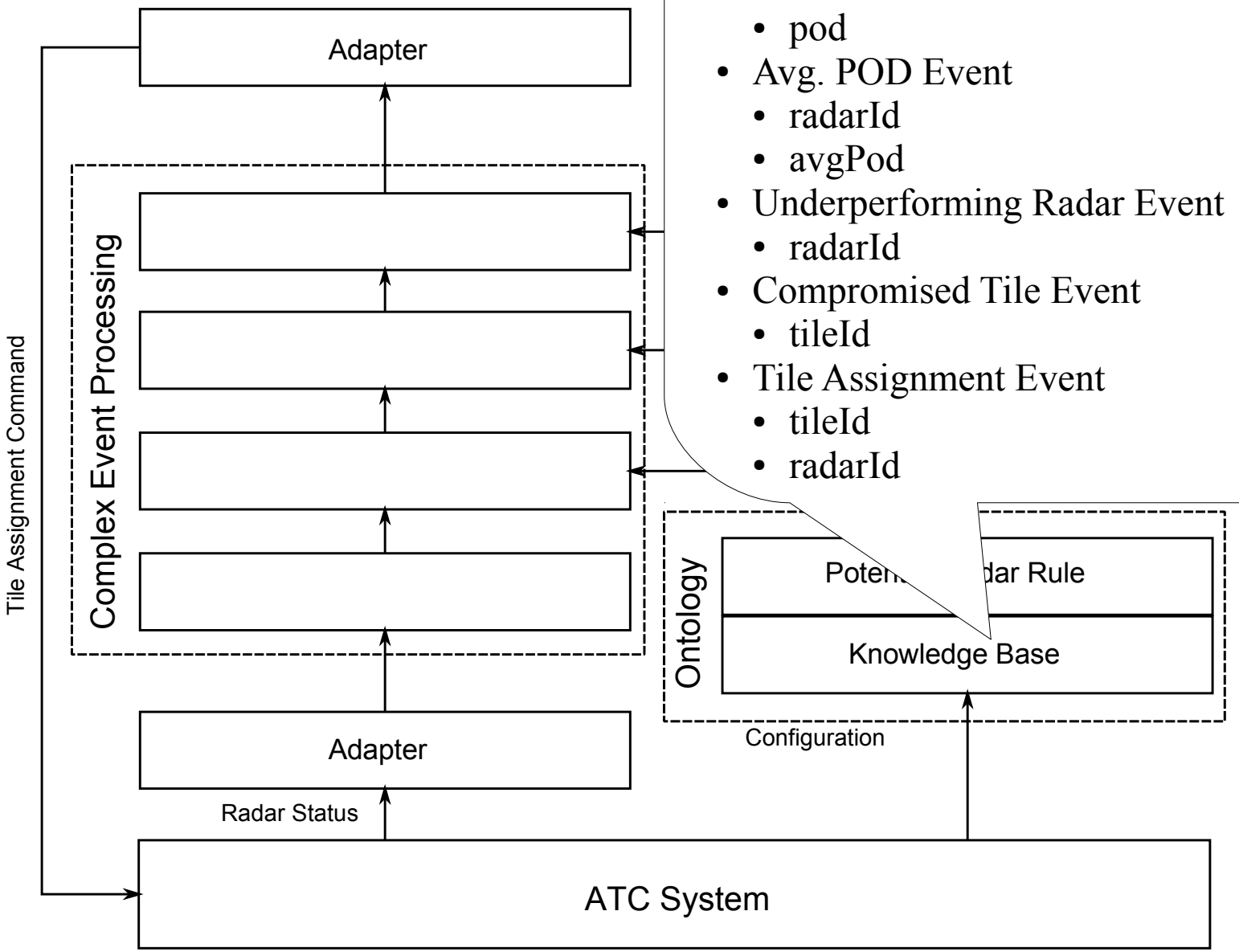


Application on the ATC System

System Event Ontology

- POD Event
  - radarId
  - pod
- Avg. POD Event
  - radarId
  - avgPod
- Underperforming Radar Event
  - radarId
- Compromised Tile Event
  - tileId
- Tile Assignment Event
  - tileId
  - radarId



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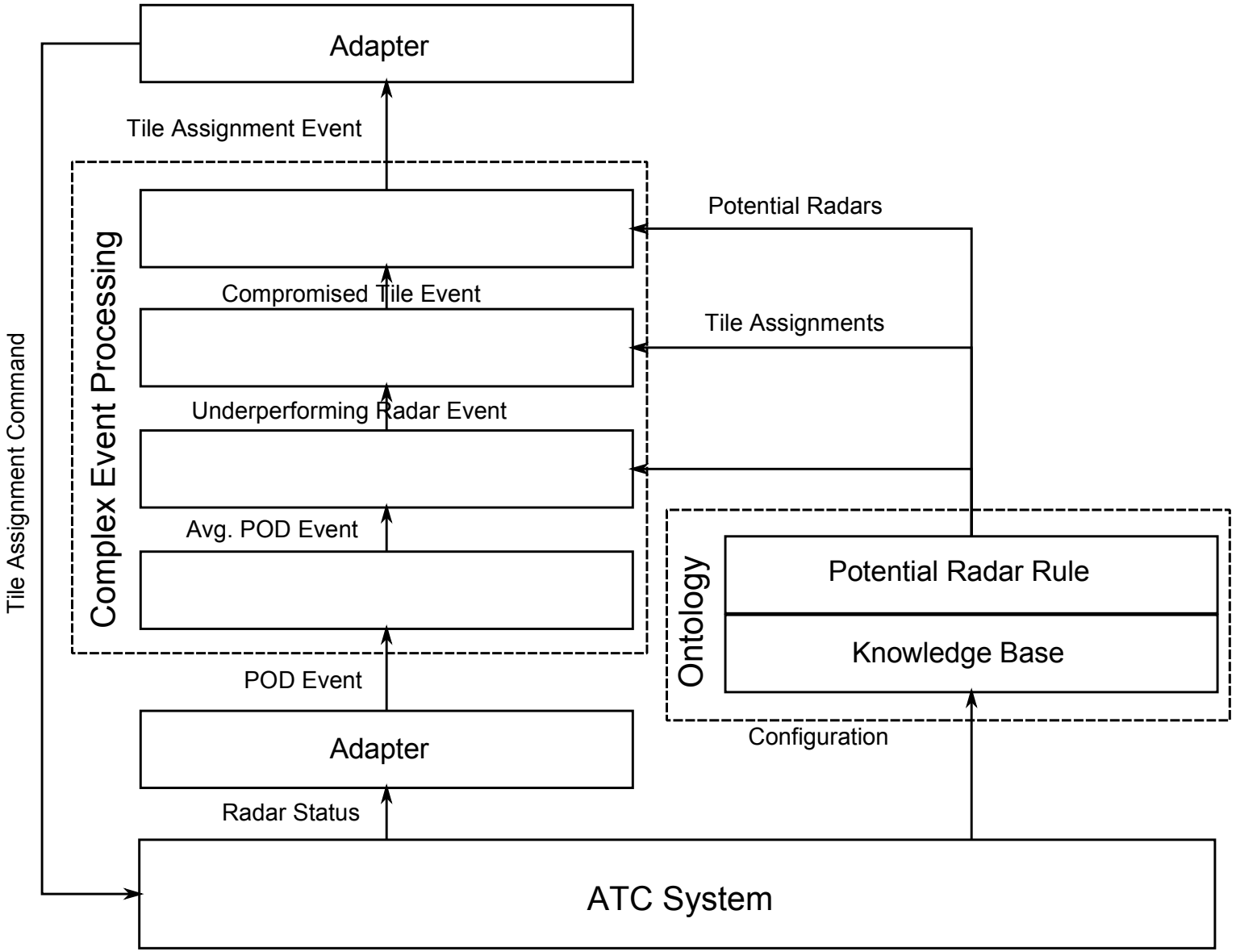

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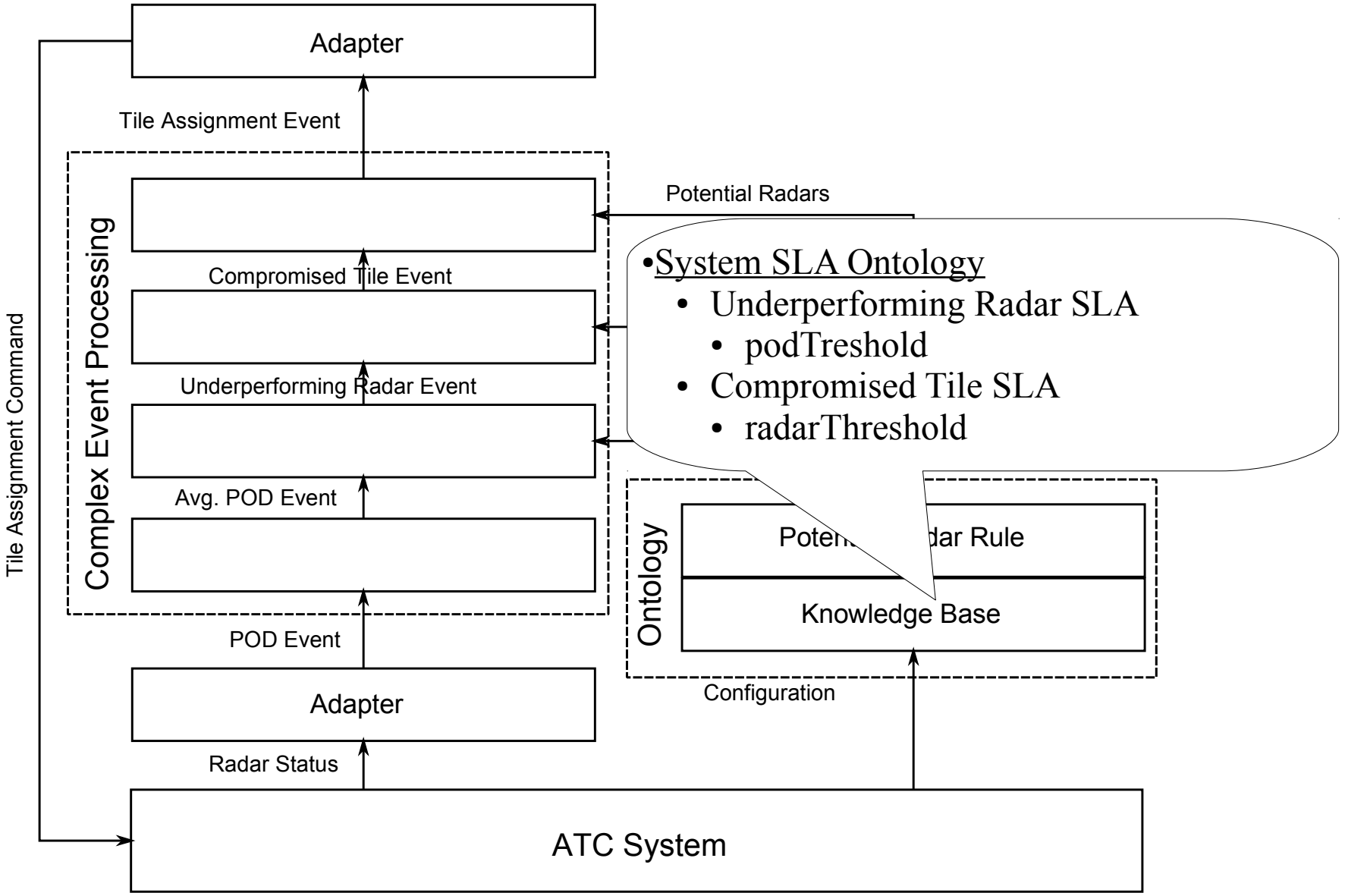

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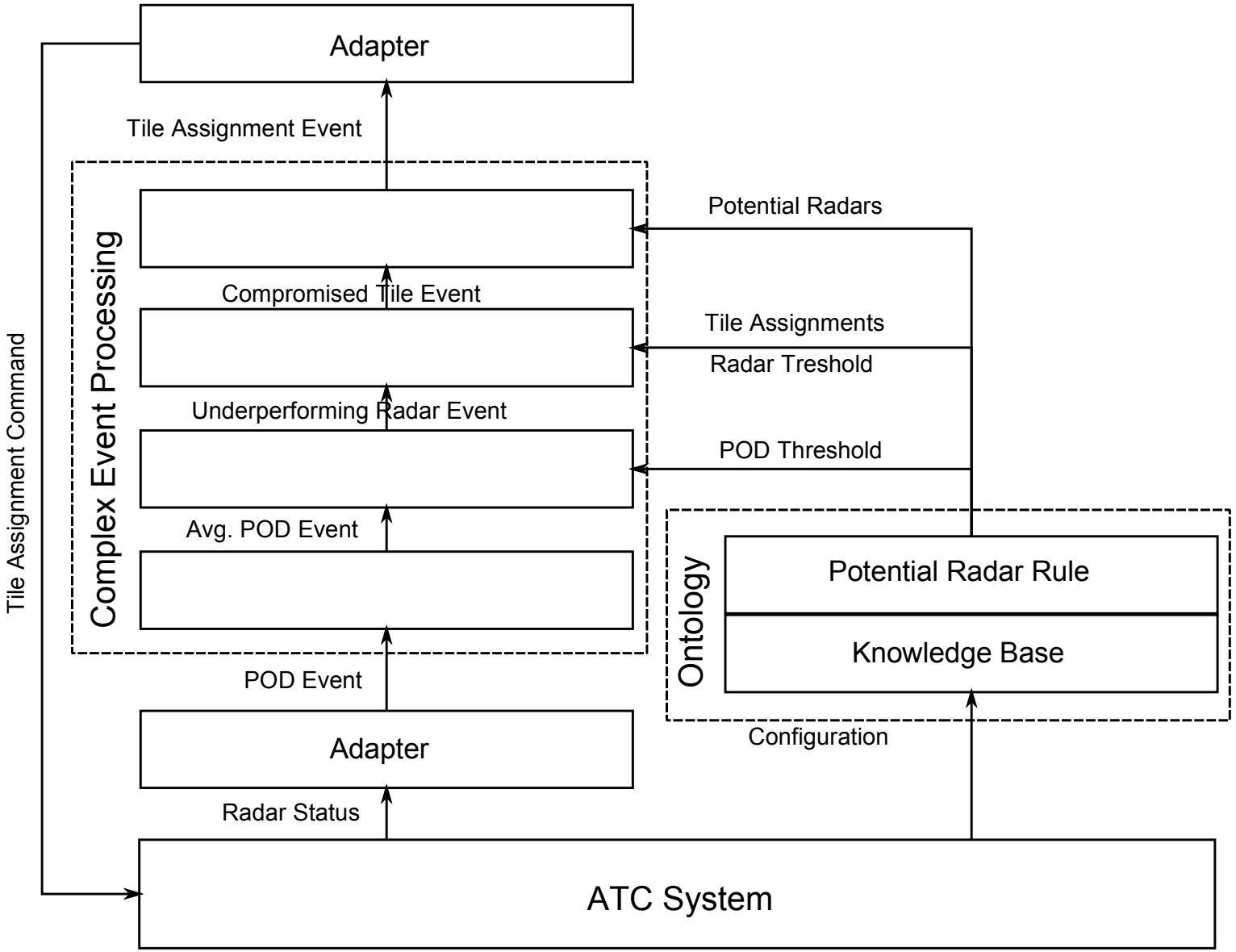

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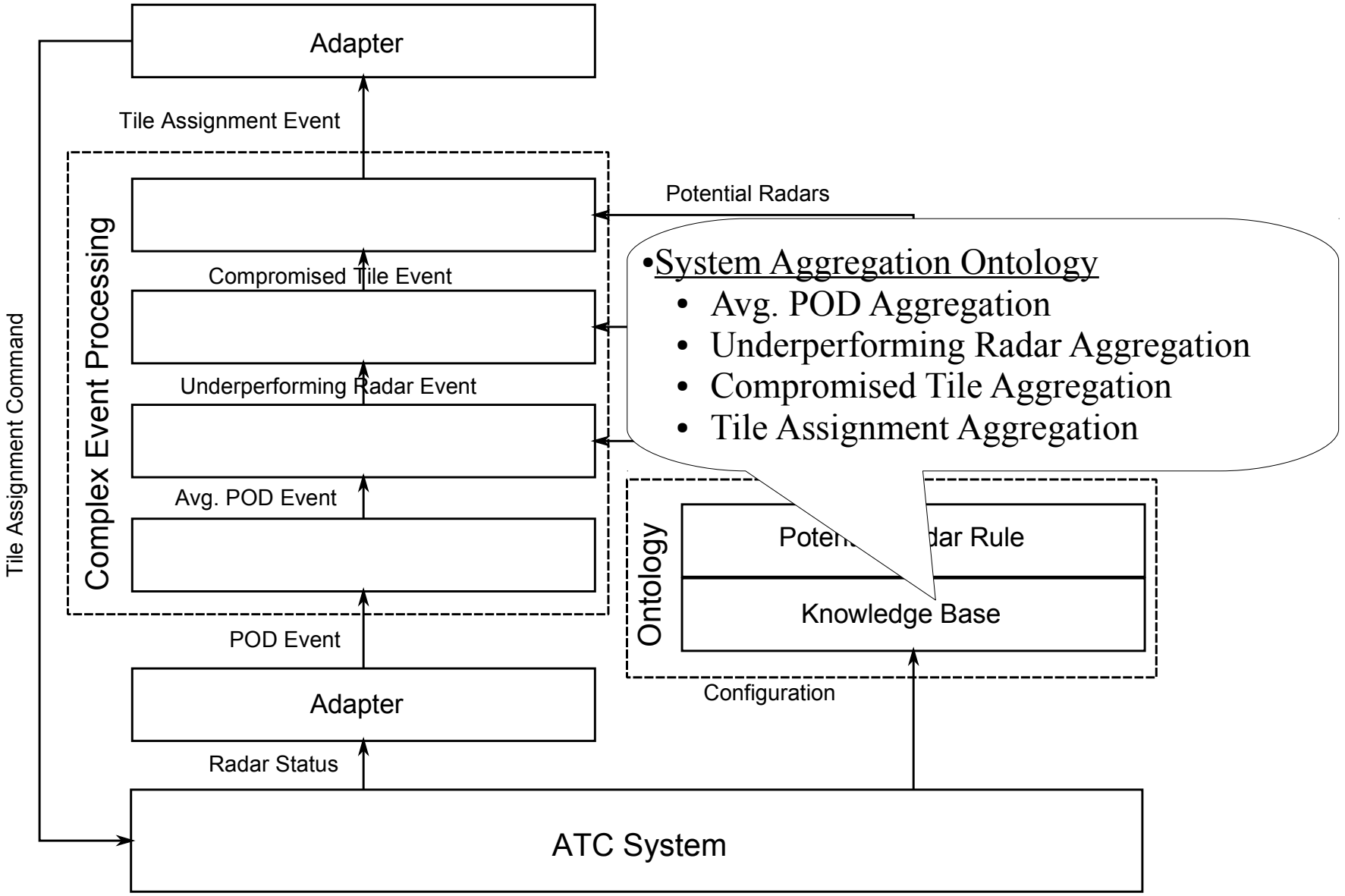

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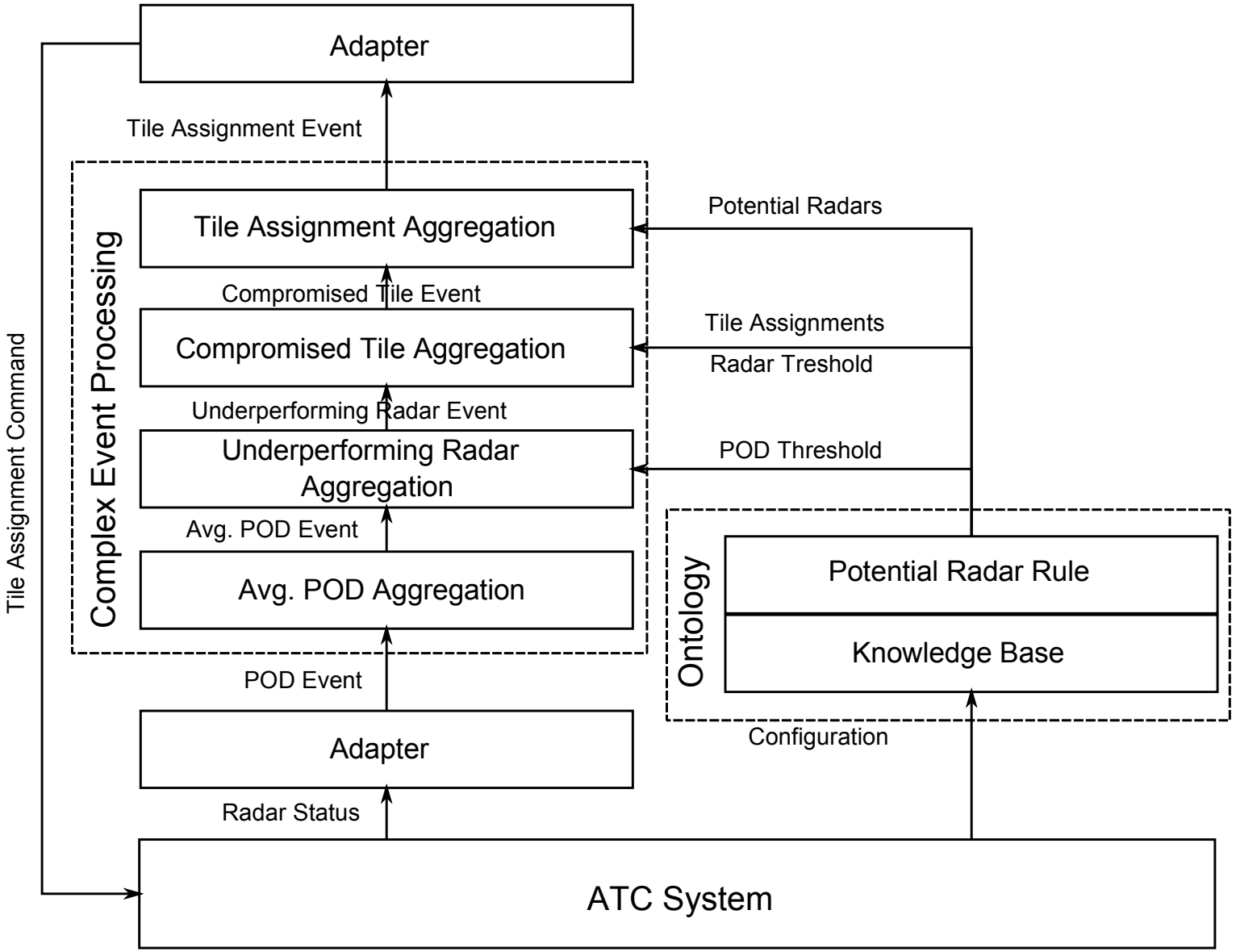

Status

- Modeling of ontologies partially done
- Management software implemented prototypically using
  - OSGi as component framework
  - OWL API for ontology handling
  - Pellet as semantic reasoner
  - Esper as CEP engine
- Monitoring adapter to ATC system is implemented
- Presented use case was implemented

Lessons Learned and Future Work

- Finalization of the ontologies
- Data interchange between reasoner and CEP engine difficult
  → Transfer to Drools rule engine
  - Drools Expert as OWL-RL reasoner
  - Drools Fusion as CEP engine
  - Drools Planer for optimization
- Modeling of aggregations in ontology complex and time-consuming
  → Domain Specific Language (DSL) for easier modeling of aggregations under development

Thank you for your attention!

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