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Complex Event Processing 101

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TIBCO Software Inc.


Presenter

- **Paul Vincent, CTO Business Rules and CEP, TIBCO Software**
  - Part of TIBCO Business Optimization product team
  - Member OMG PRR and W3C RIF rules standards bodies
  - Co-author CEP Blog http://tibcoblogs.com/cep

- **TIBCO Software Inc.:**
  - Provides enterprise software that helps companies achieve service-oriented architecture (SOA) and business process management (BPM) success
    - Event distribution via high performance messages / message buses
    - Event processing for humans via BPM
    - Event processing for real-time operations and analytics
      - Complex Event Processing (CEP) product is TIBCO BusinessEvents
  - Headquartered in Palo Alto, California
  - Over 3,000 customers and offices in 40 countries

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Audience

- Interest in new buzzwords
  [PHB]
- Need to understand what this might mean or where it might apply
  [Software Architects]
- Need to know what problems this might solve
  [Business Analysts]
- Need to know where IT is historically going wrong and what might help solve future IT problems
  [MBA / Comp Sci majors]

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Agenda

- Introduction to CEP concepts, where it fits, etc
- Brief backgrounder
- Business view of Events and CEP
- Definitions / Glossary walk-through (courtesy EPTS)
- Applicable Technologies
- “Advanced” CEP
- Follow-up Q&A

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Agenda

- **Introducing CEP**

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Real-world Events

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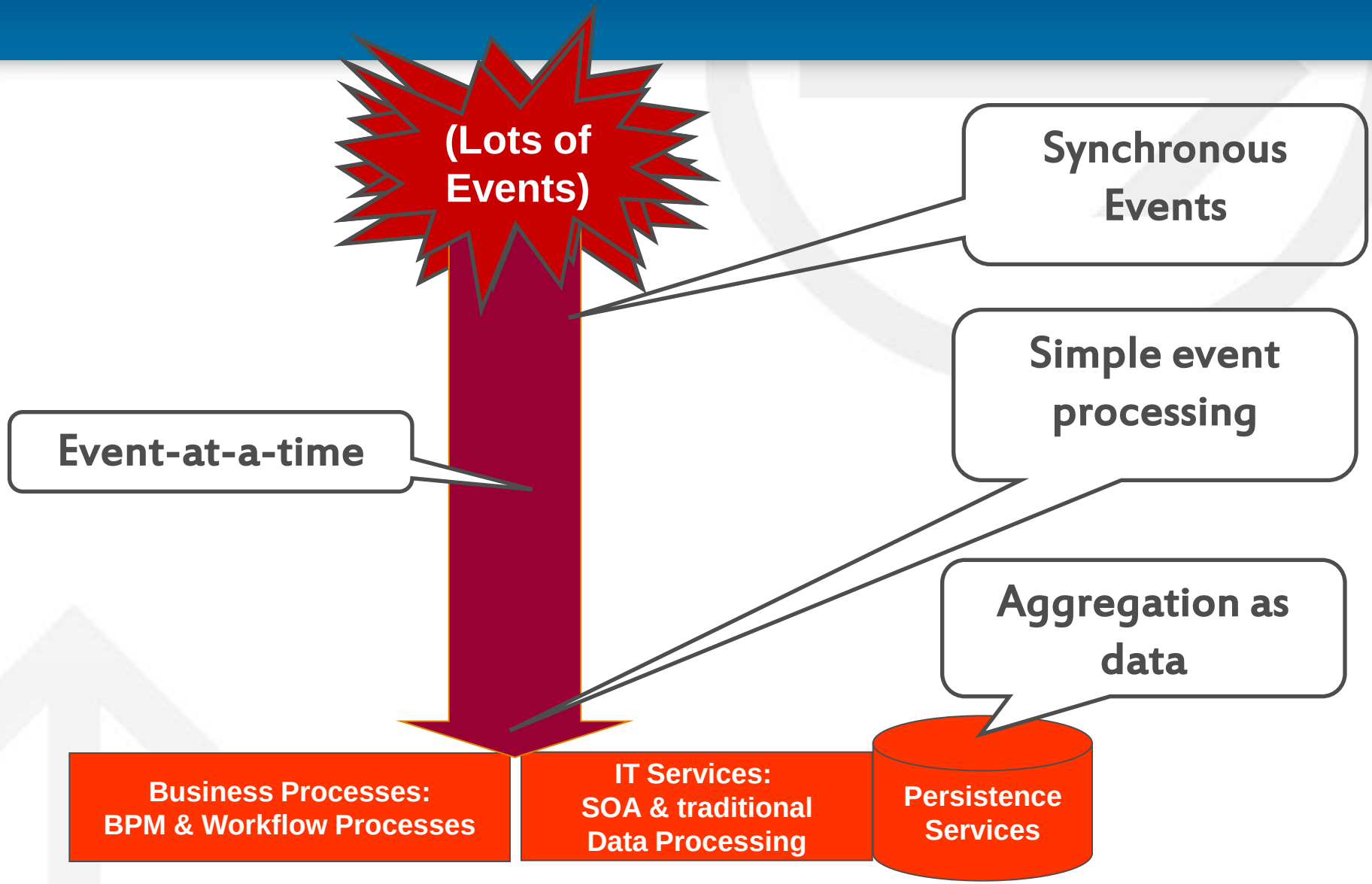
Customer Logon
Fed Base Rate Increase
Customer Checks Close Account Web Page
New Order
Production Item Arrives at Store
New Liability Added
Mobile Call from CT @11.13
Contract Submitted
Rental Car Crashed
Rental Car Returned
Contract Returned thru EDI


Fraud Risk!
Risk of Customer Defection
Customer CrossSell Opportunity
Change in Product Sales Trend
Contract Validated
Employee Over hours
Compliance Limit Approached
Cell phone fraud alert
Contract Valid
Rental Contract Complete
Customer now rated Gold

Conventional Event Processing



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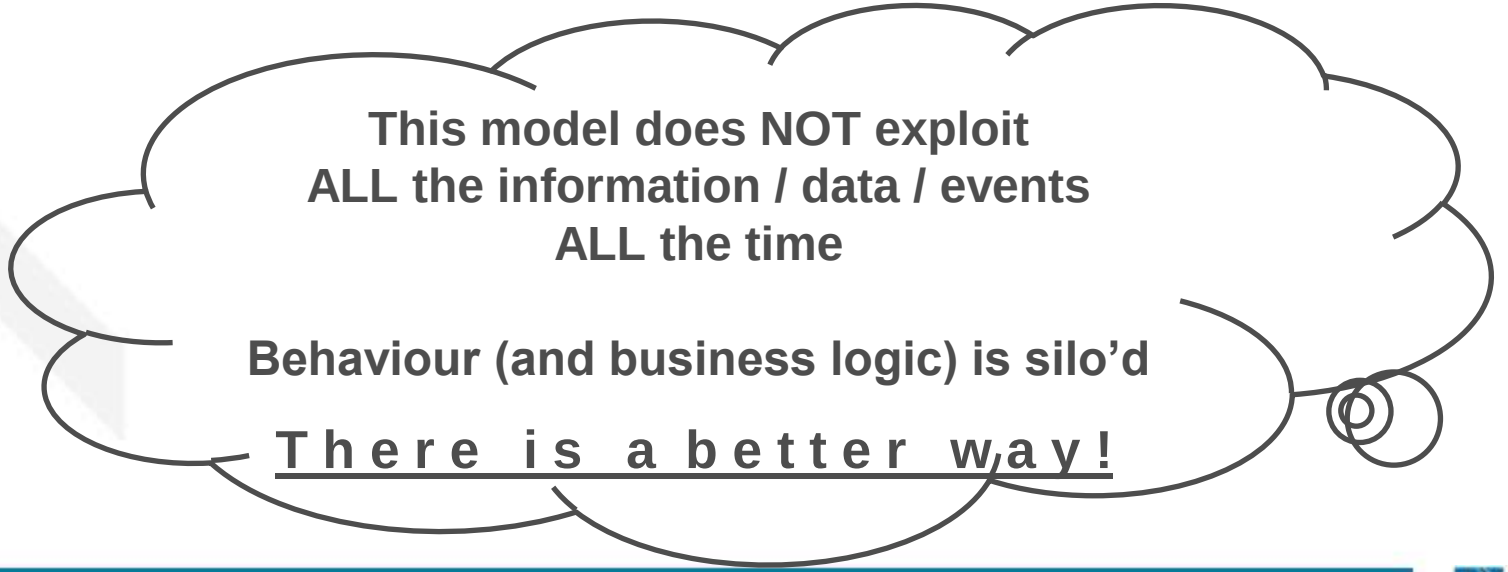
Simple EP = default IT Model, 1950-now

- **Based on "human workflow": one thing at a time**
  - Processes handle cases 1 at a time ← office clerk
  - Use database and refer to it where necessary ← card index
  - Provide some service flexibility with middleware ← internal mail
  - Use BPM to document / manage / automate processes
  - Use SOA to distribute / manage / automate services



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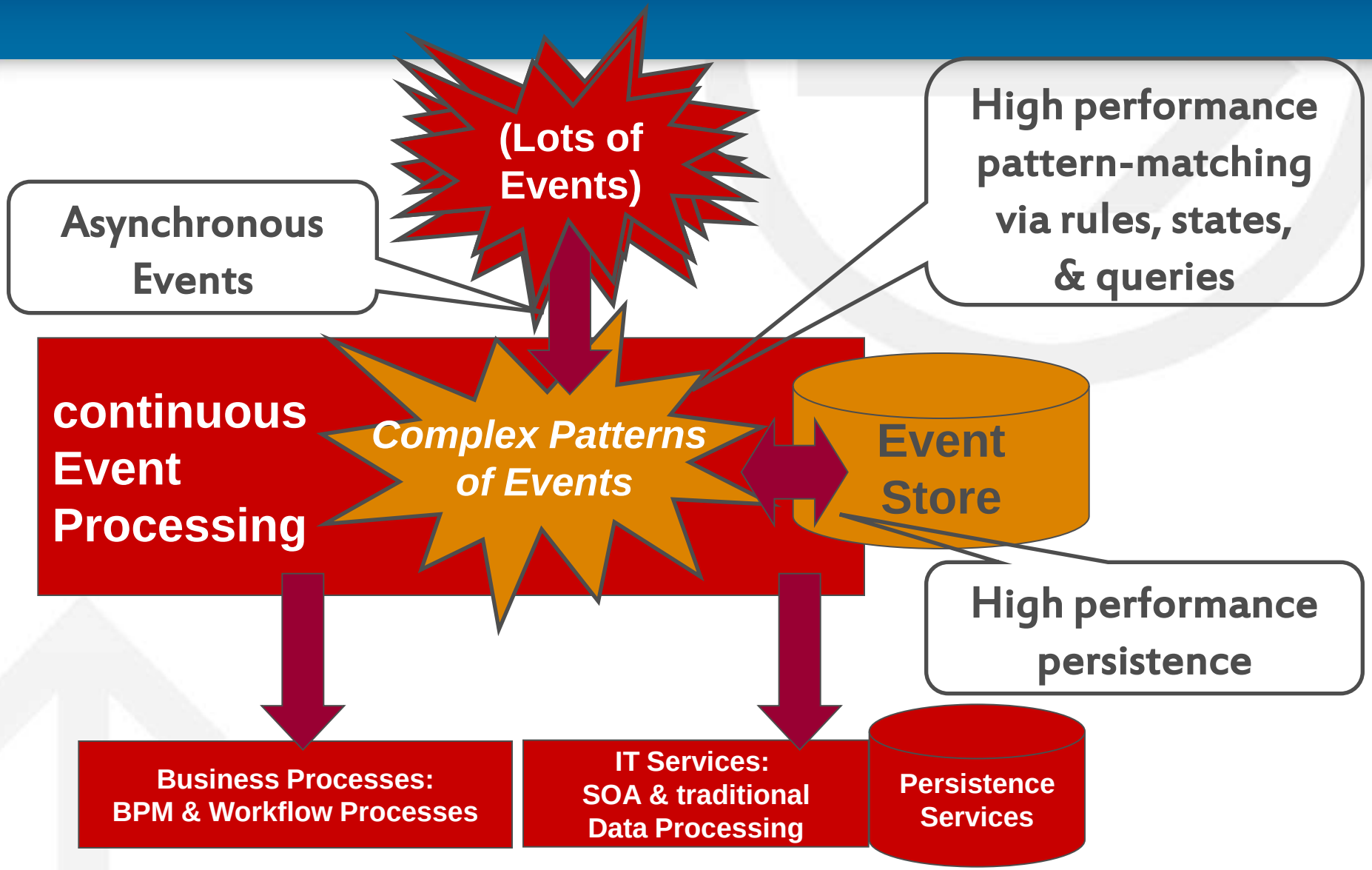
Complex Event Processing



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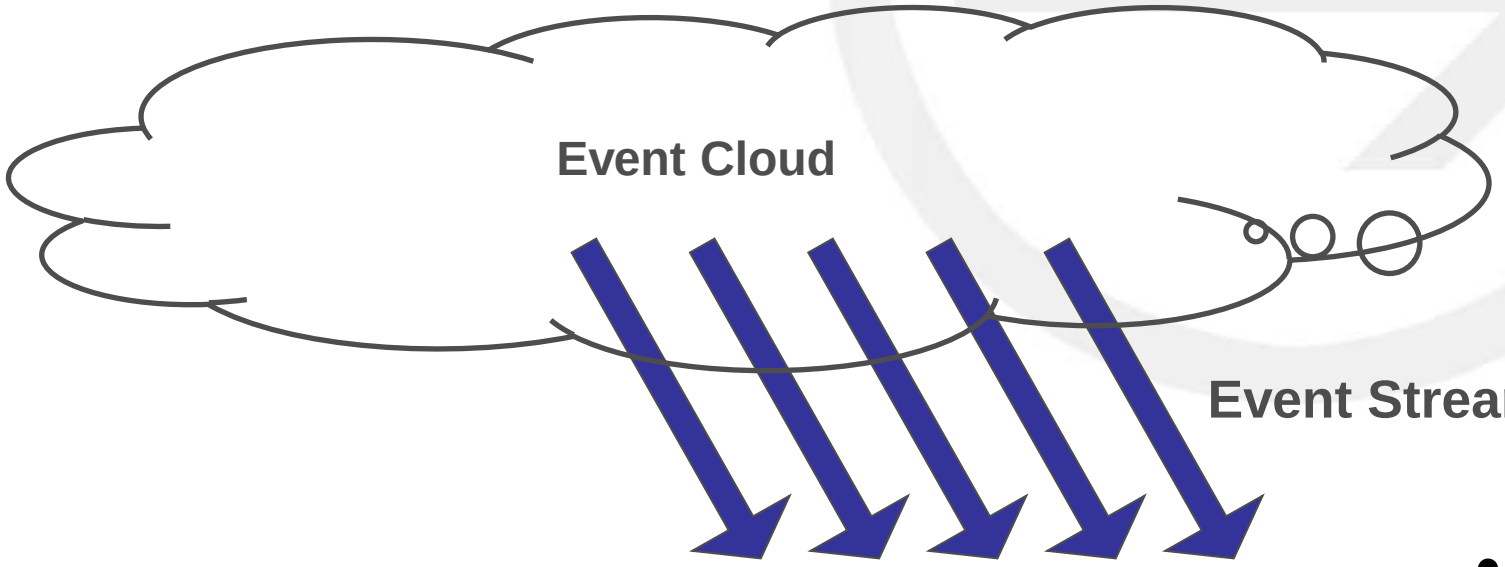
CEP Terminology



- CEP (technology) applies pattern detection & filtering to the event clouds & streams and their histories
- Multiple modelling / execution paradigms are available for pattern detection

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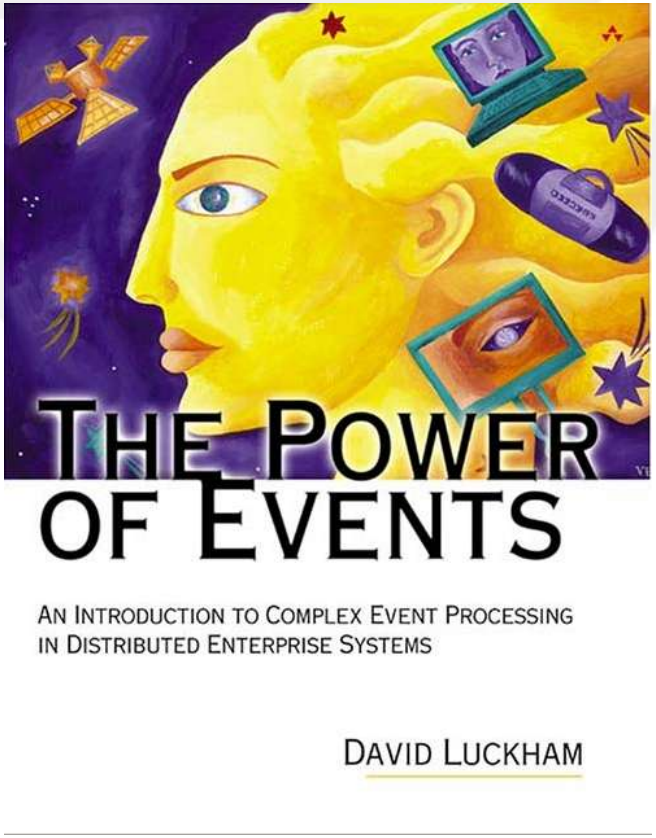
What does CEP cover?

"CEP applies to a very broad spectrum of challenges in information systems. A short list includes:"

- Business process automation
- Computer systems to automate scheduling and control network-based processes and processing
- Identifying when complex contracts are fulfilled
- Detection intrusion, fraud and other network attacks
- C3I



The Power of Events, Addison Wesley, ISBN: 0-201-72789-7, 2002

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What does CEP Solve?

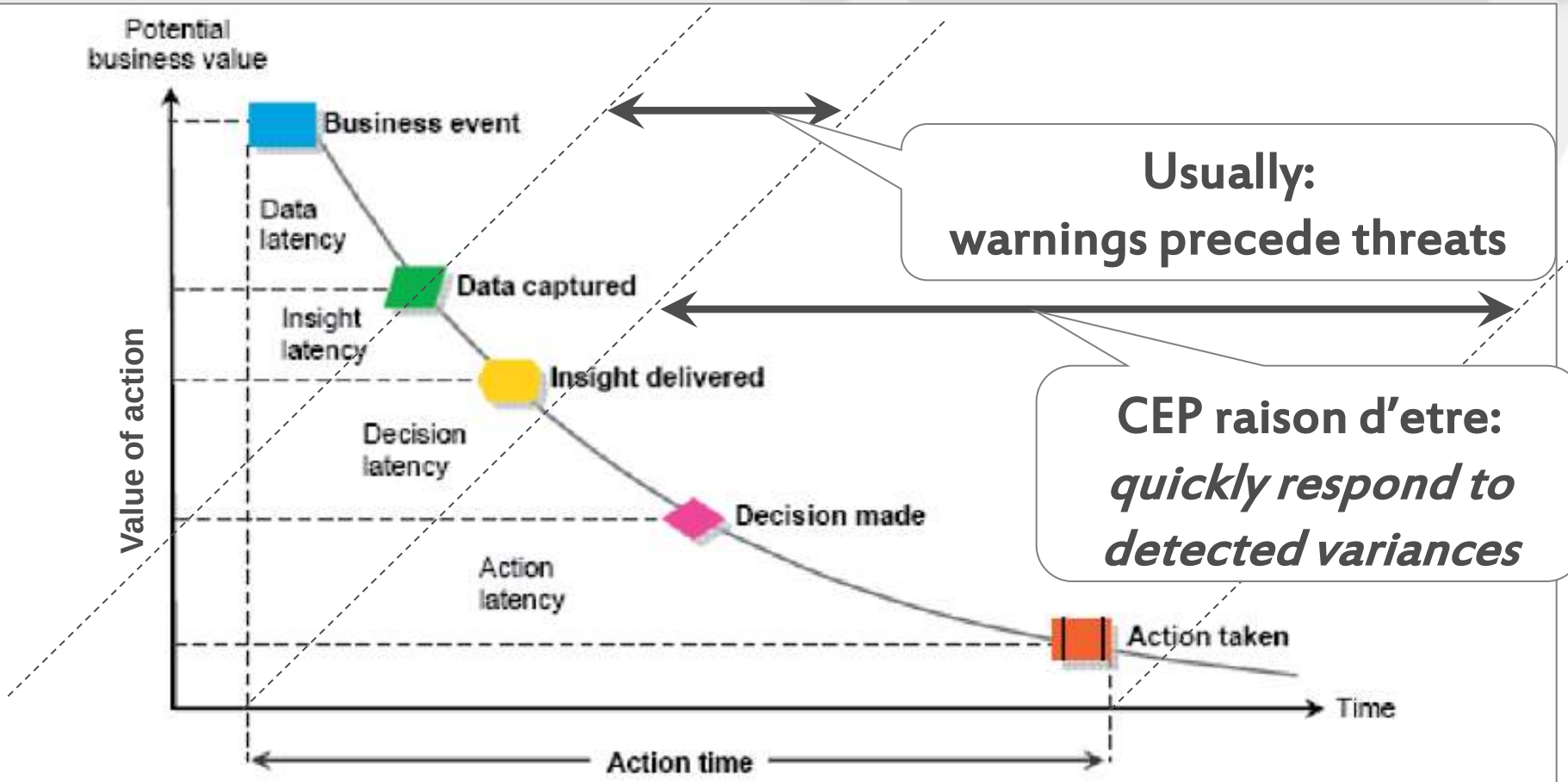

Figure 1: The steps involved in taking action to respond to business events

the "Latency Problem"

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What CEP provides

“Situational Awareness”

“Sense and Respond”

“Track and Trace”

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- History

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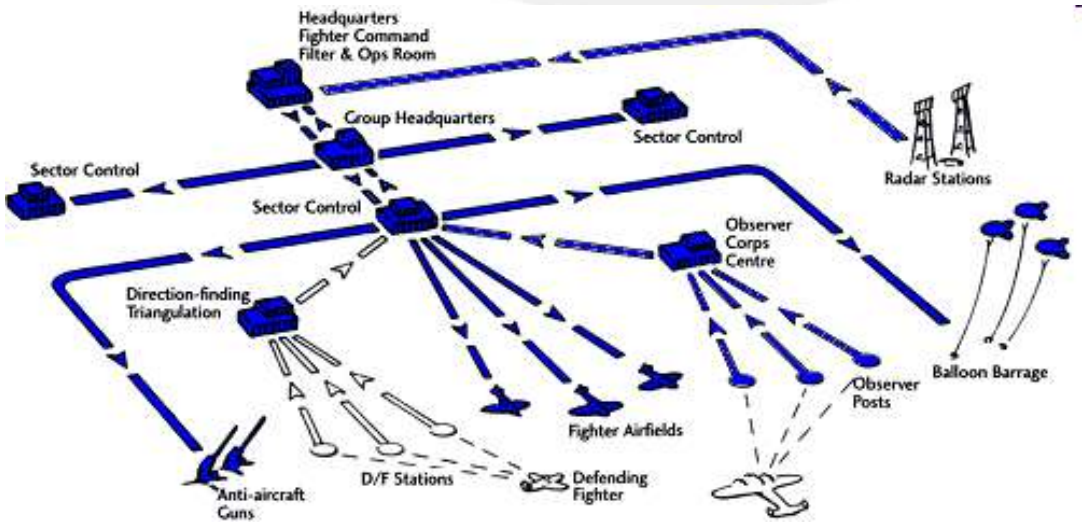
Command and Control

- **Command and Control**
  - Correlate all available information
  - Determine tactics based on strategy and up-to-date information



-- from RAF Battle of Britain Fighter Control System 1940
http://www.raf.mod.uk

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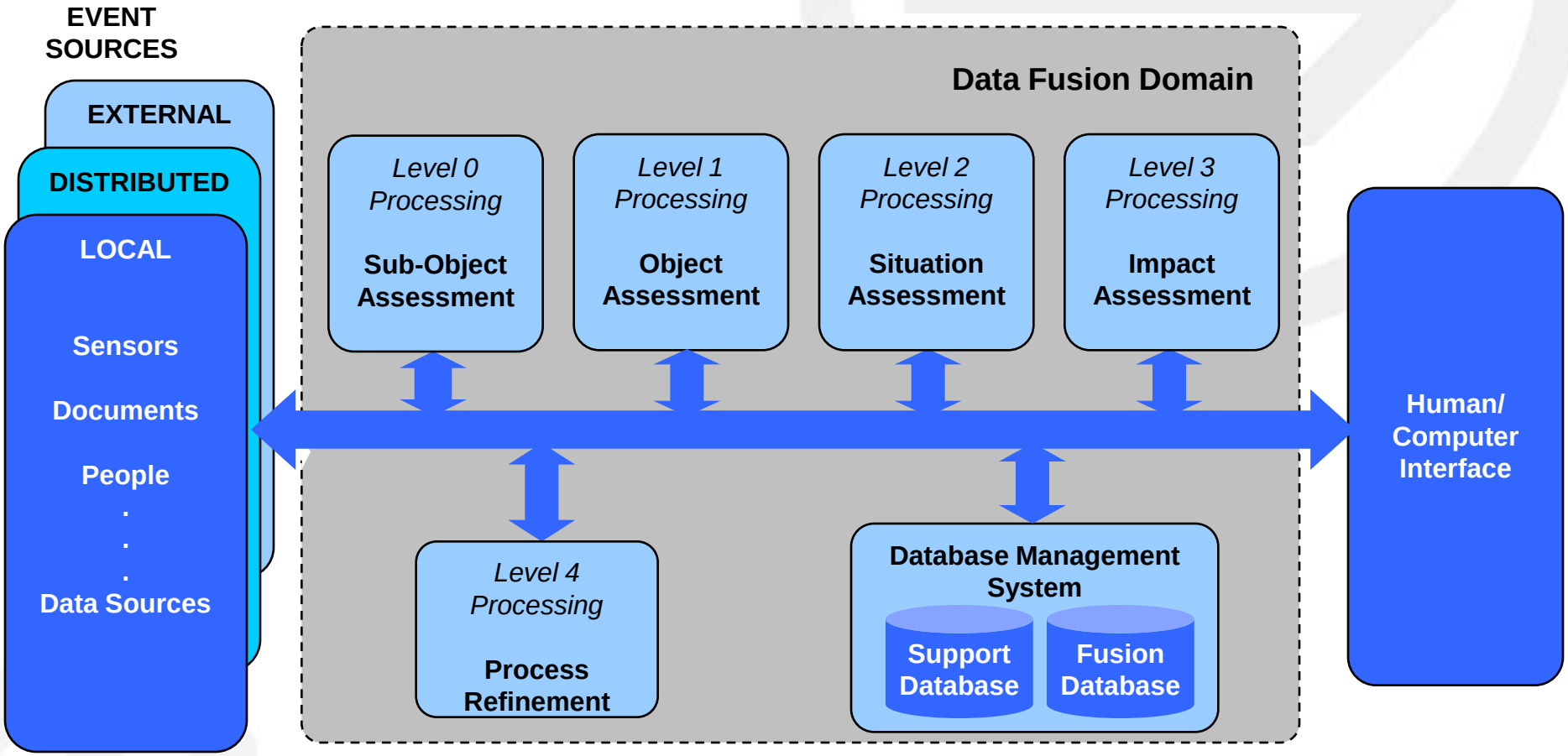
Data Fusion



-- Revised JDL data fusion model, 1998
Steinberg, A., & Bowman, C., Handbook of Multisensor Data Fusion, CRC Press, 2001

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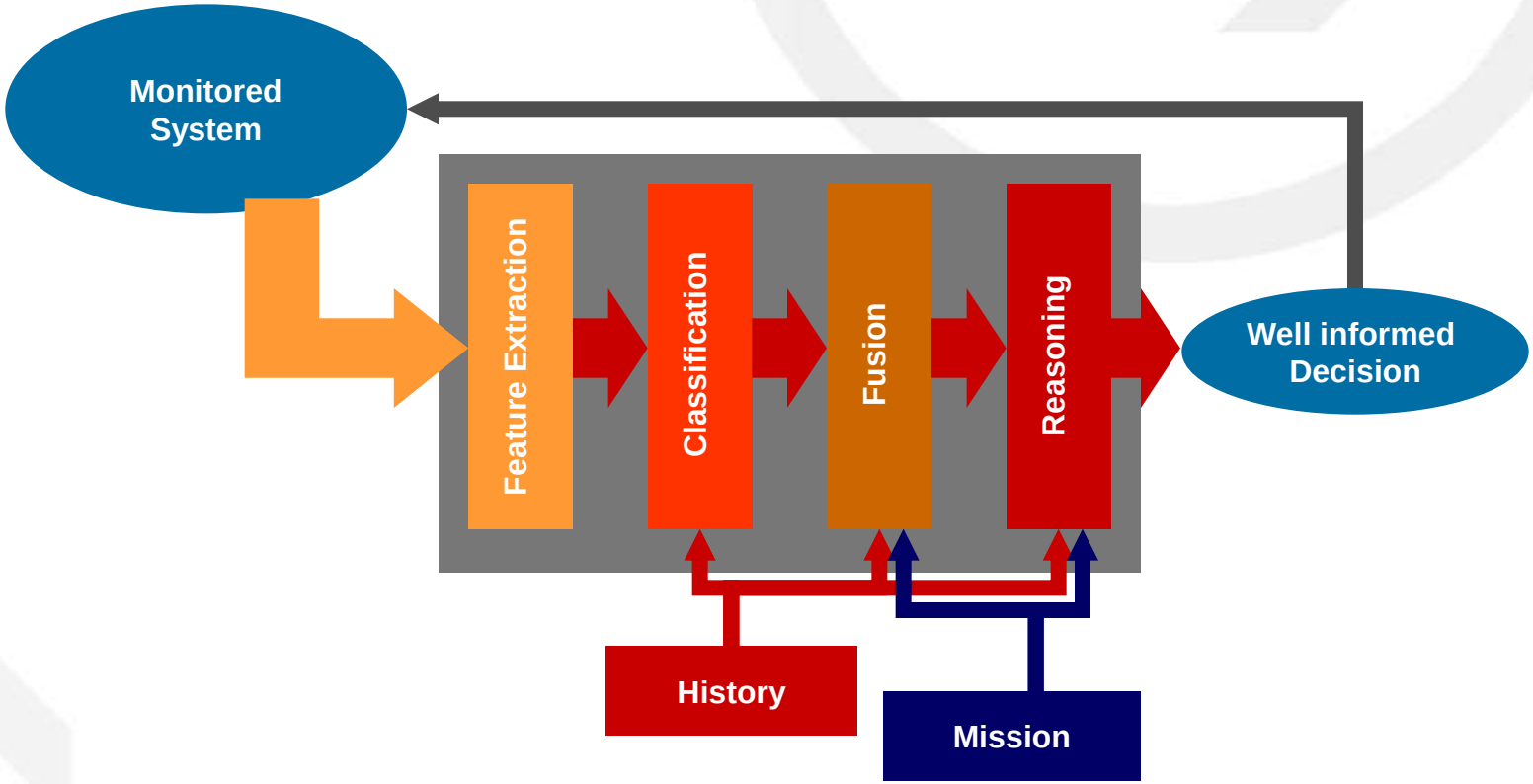
Condition Based Maintenance



-- from “Data Fusion for Developing Predictive Diagnostics for Electromechanical Systems”
Steinberg, A., & Bowman, C., Handbook of Multisensor Data Fusion, CRC Press, 2001

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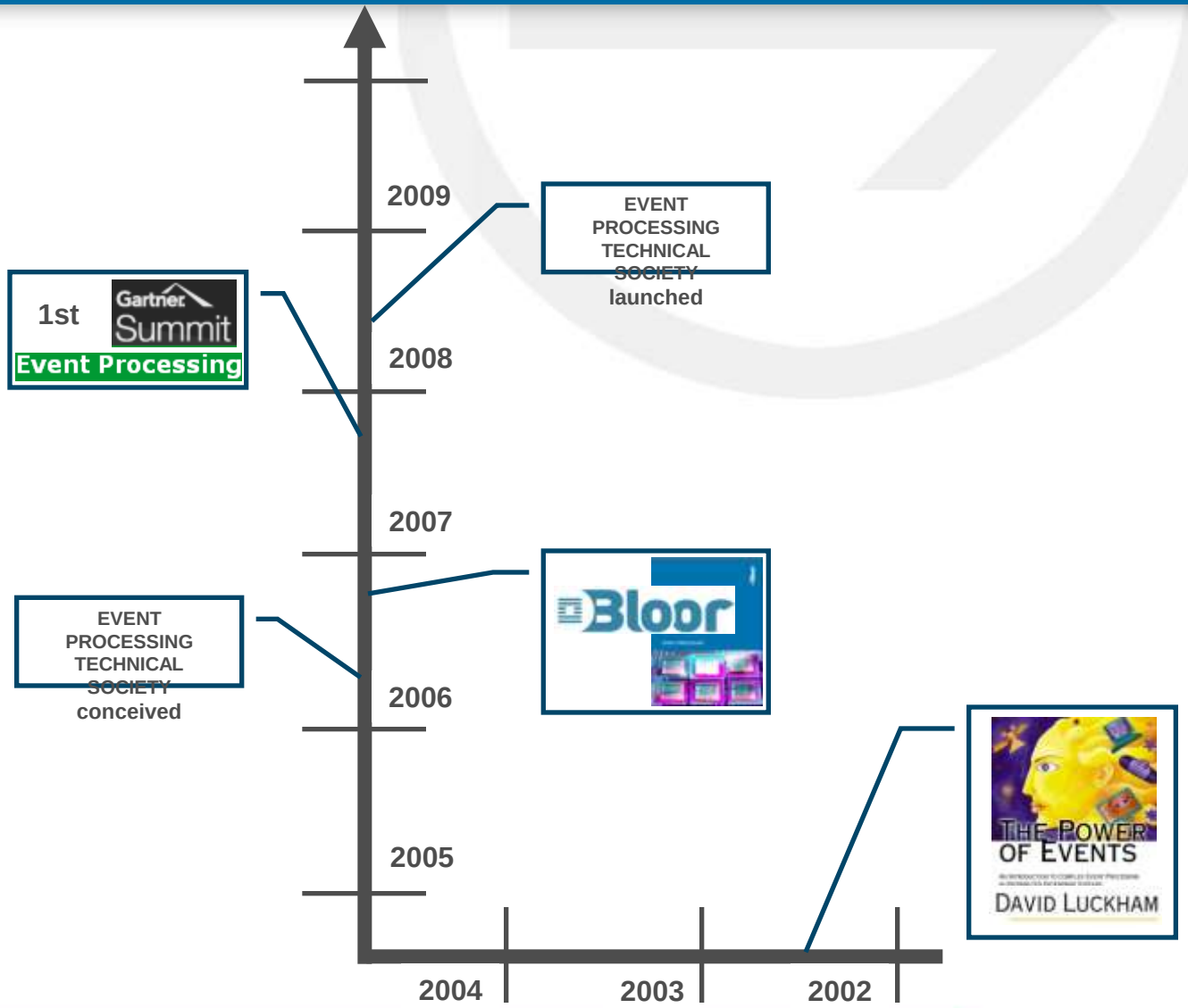
CEP Past History



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- **Events and CEP**

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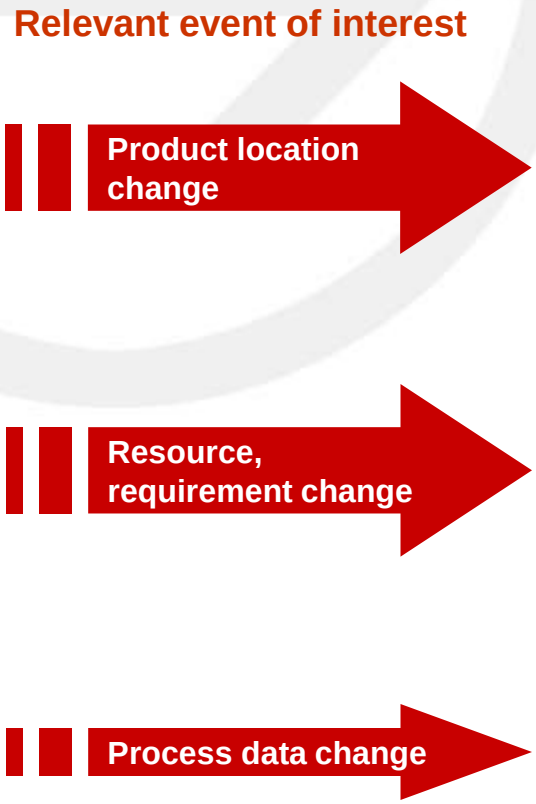
Complex Business Problems

- **Fraud / Theft**
  - Thousands-to-millions of high-value small-size product items or transactions
  - How do you identify known patterns of “suspicious” behavior?
- **Logistics / Scheduling**
  - Raw material, production & delivery scheduling and resources are complex and prone to change
  - How do we reallocate resources to handle business and production changes?
- **Activity Monitoring**
  - Complex production and supply process with multiple actors
  - How to measure and action Key Performance Indicators?



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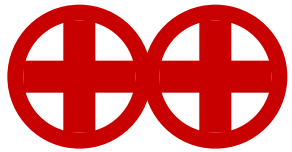
Associated Events

- **Positive Events**
  - Product item X arrives at Production station S from Store T
  - Production worker Y arrives at Production station S
  - Production contract for item Z by time T is posted

- **Negative Events**
  - Product item X has been in transit to Store T for >15 minutes
  - Subcomponent Y hasn't arrived at the Production station by the ETA
  - Delivery of contract Z has not taken place

- **Sets of Events**
  - 5+ items of Product item type Y failed to arrive at destination
  - Supplier Y was 5 mins late for 1 delivery, but made it early to the next
  - Return rate on component Z exceeds SLA %



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Significant features of these Events

- **Time Sensitivity**
  - A thief may leave the building at the same time as stolen product
  - A product should take 40 minutes to travel a given production line segment
- **Distributed Event Sources**
  - A series of produced items fails at various QA stages, and their common attribute was a storage location
  - Multiple suppliers for a subcomponent are reporting delivery delays

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What *is* an “event”?

- **Change of state in some entity**
  - Customer call
  - Bank debit
  - Aircraft movement
- **Observation of some entity**
  - CRM record of a customer call
  - ATM report of debit transaction success
  - Radar plot update of an aircraft
- **IT Message**
  - Queued point-to-point message
  - Publish / subscribe message

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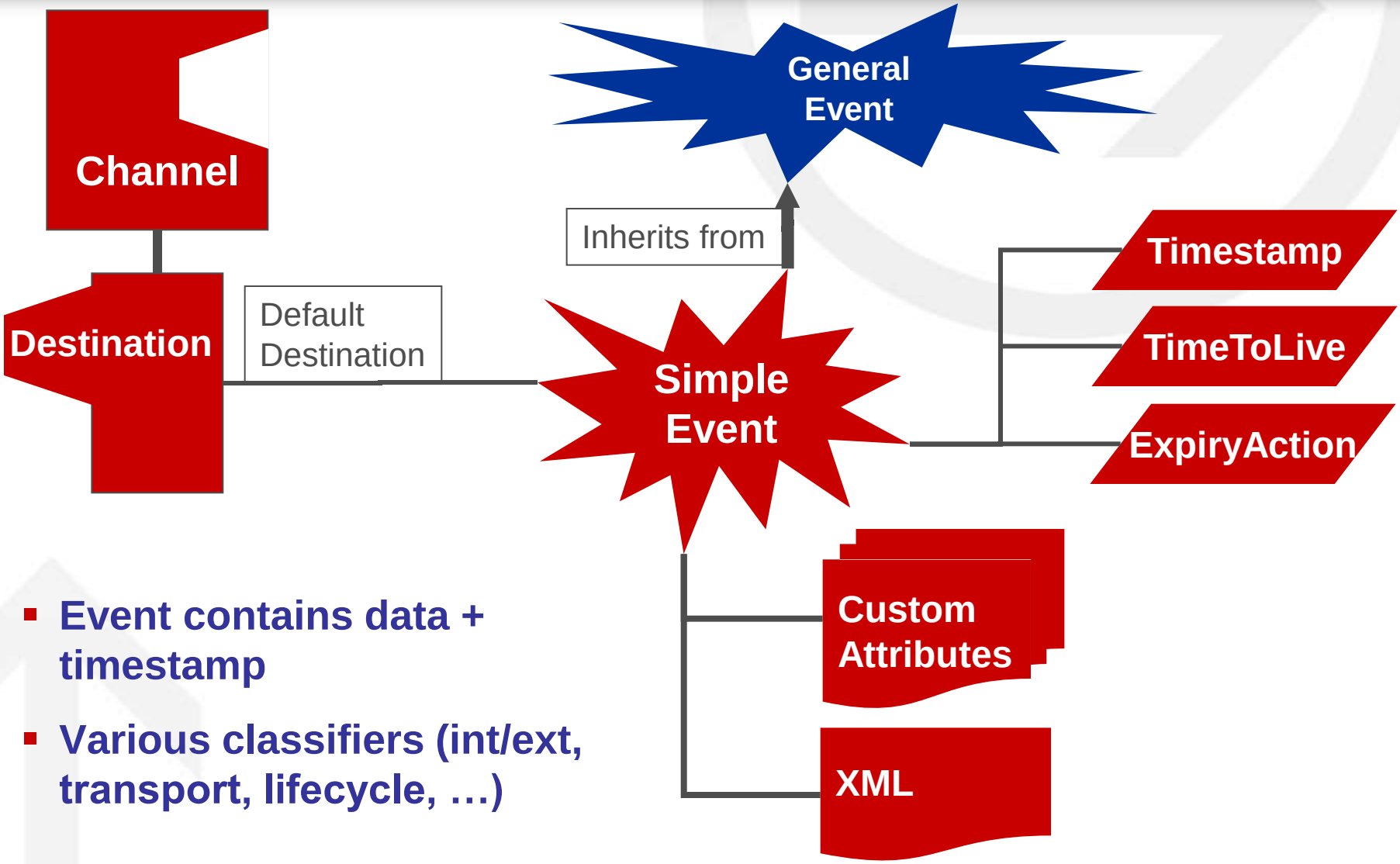
Sample Event Metamodel



- Event contains data + timestamp
- Various classifiers (int/ext, transport, lifecycle, …)

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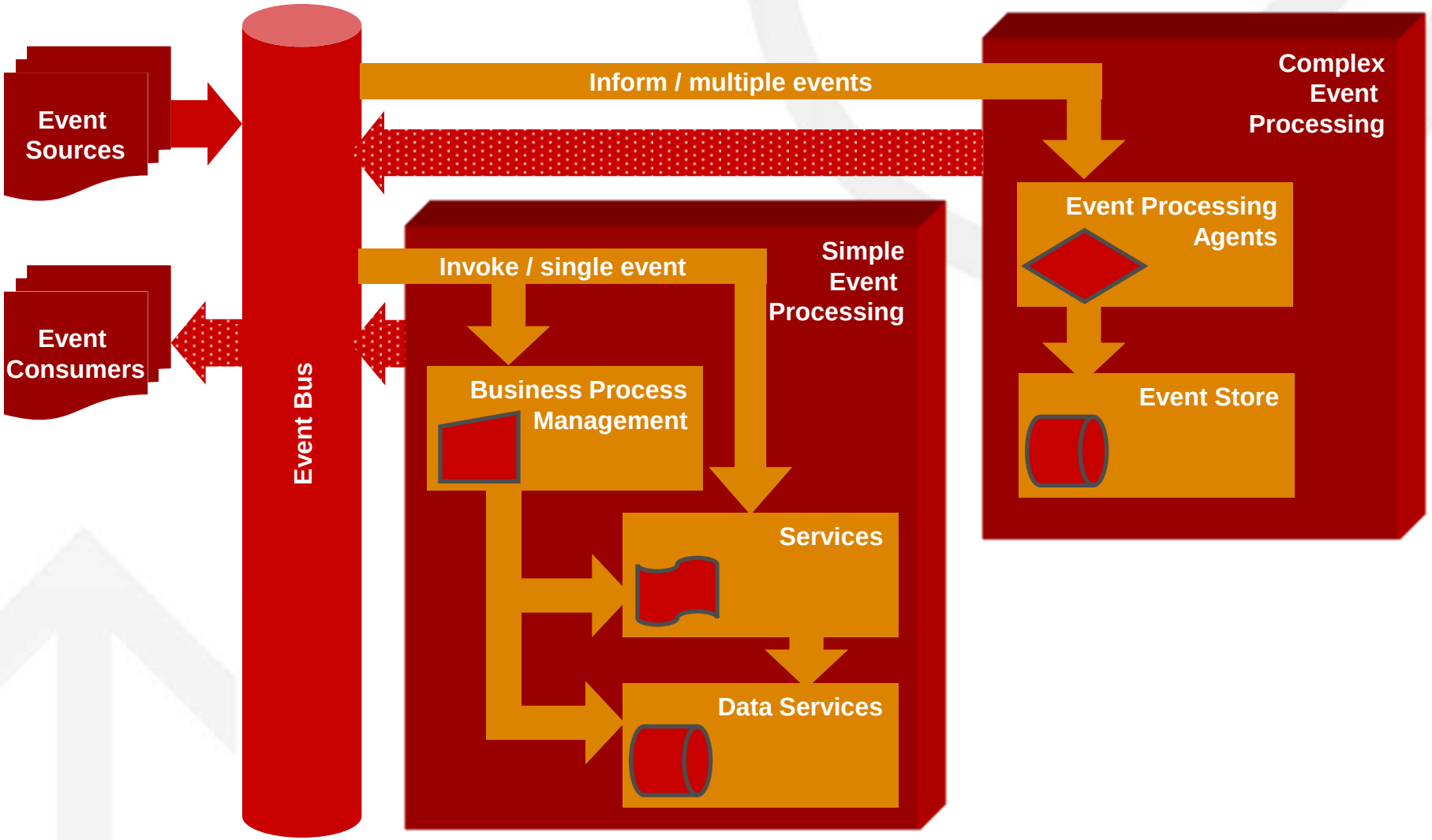
Event-driven vs Event Processing



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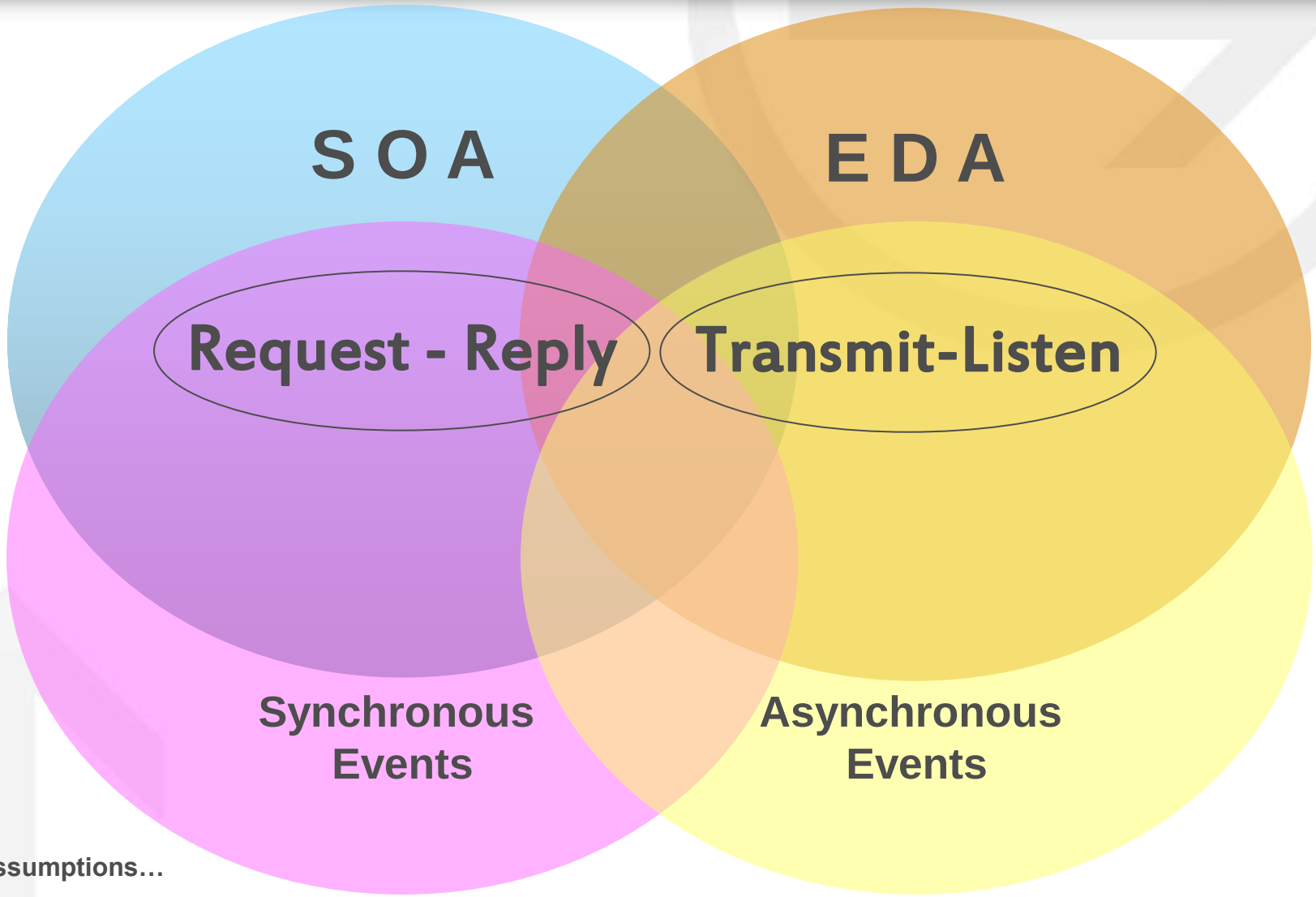
Event Driven Architecture



Assumptions…

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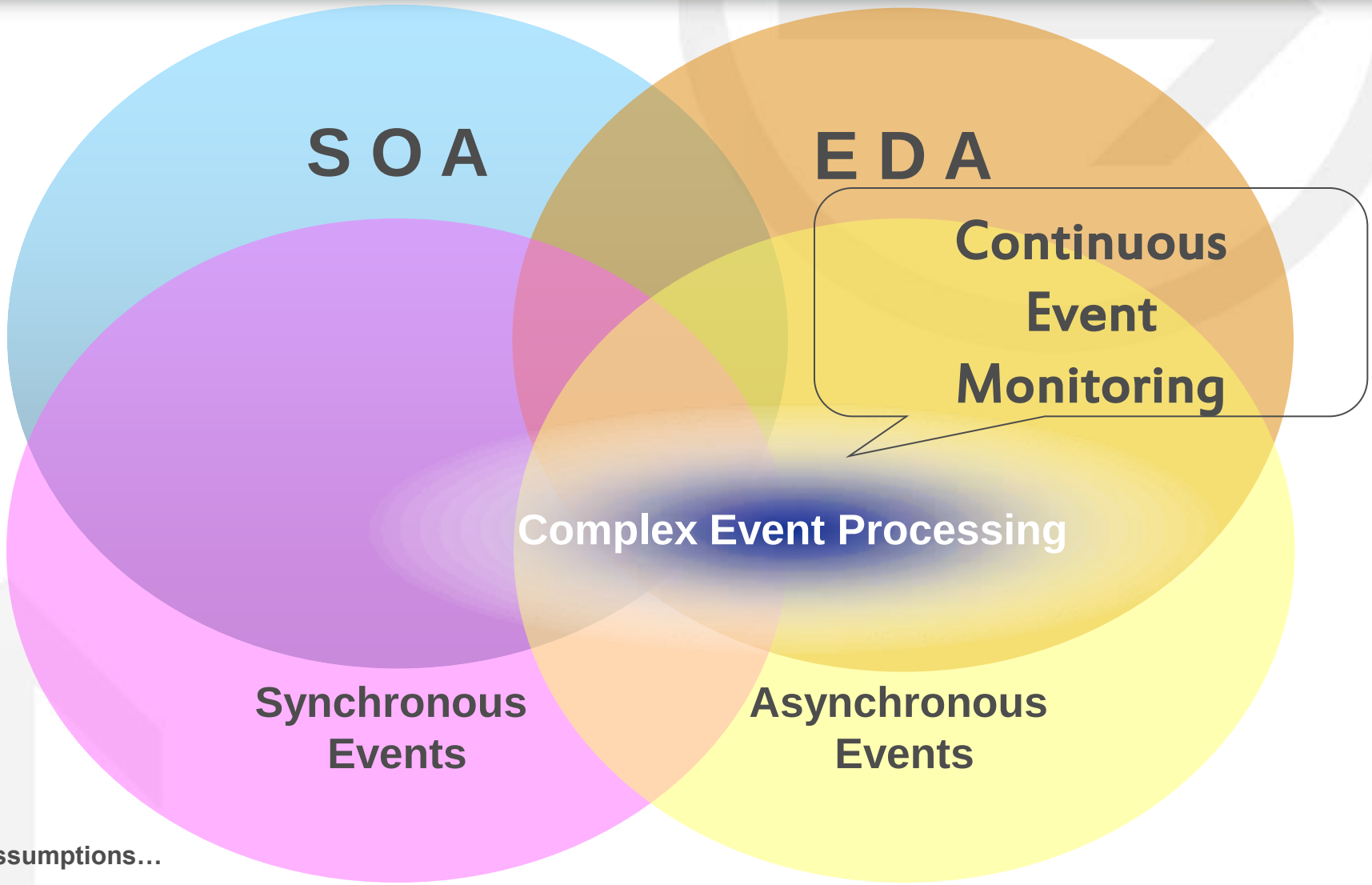
CEP in the Event Driven Architecture



Assumptions…

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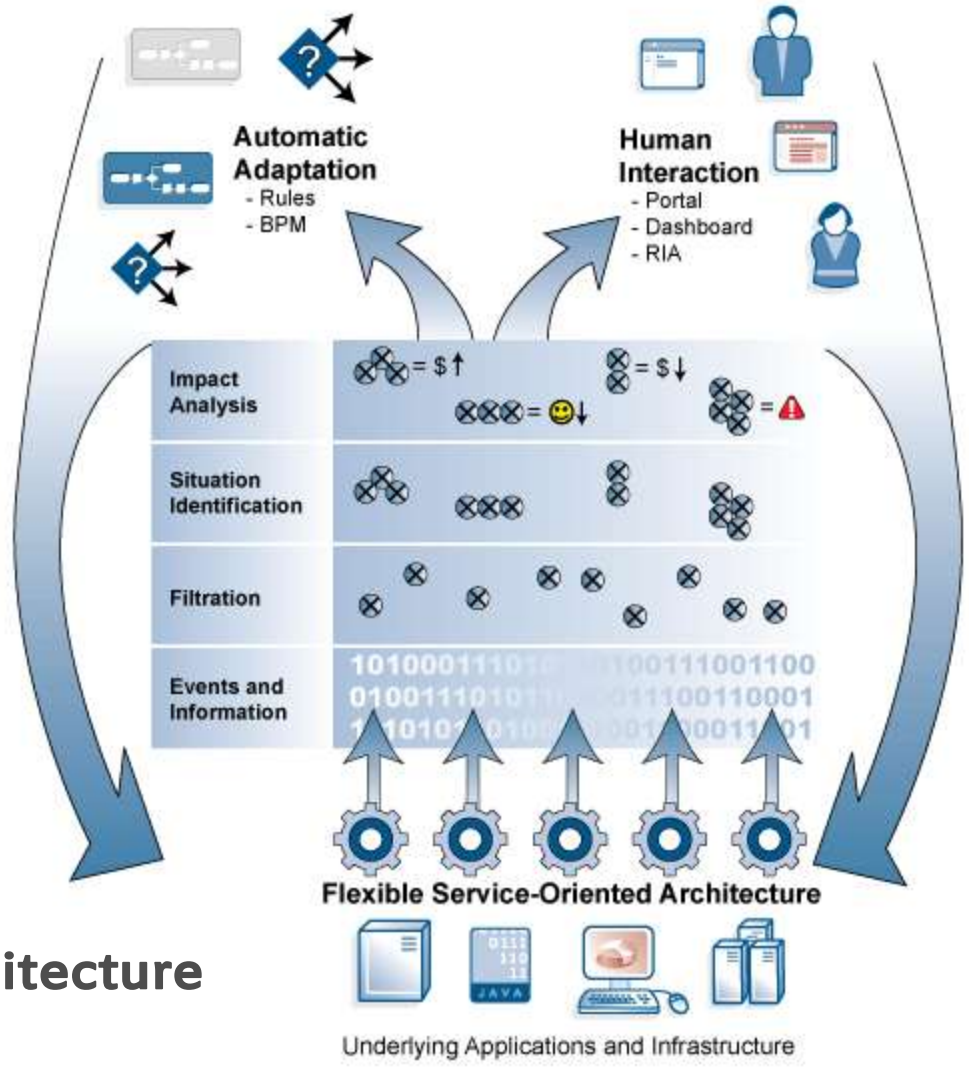
Complex Event Processing

Sense and Respond / Track and Trace / Situational Awareness



Processing type:

Decision Processing

Event Processing

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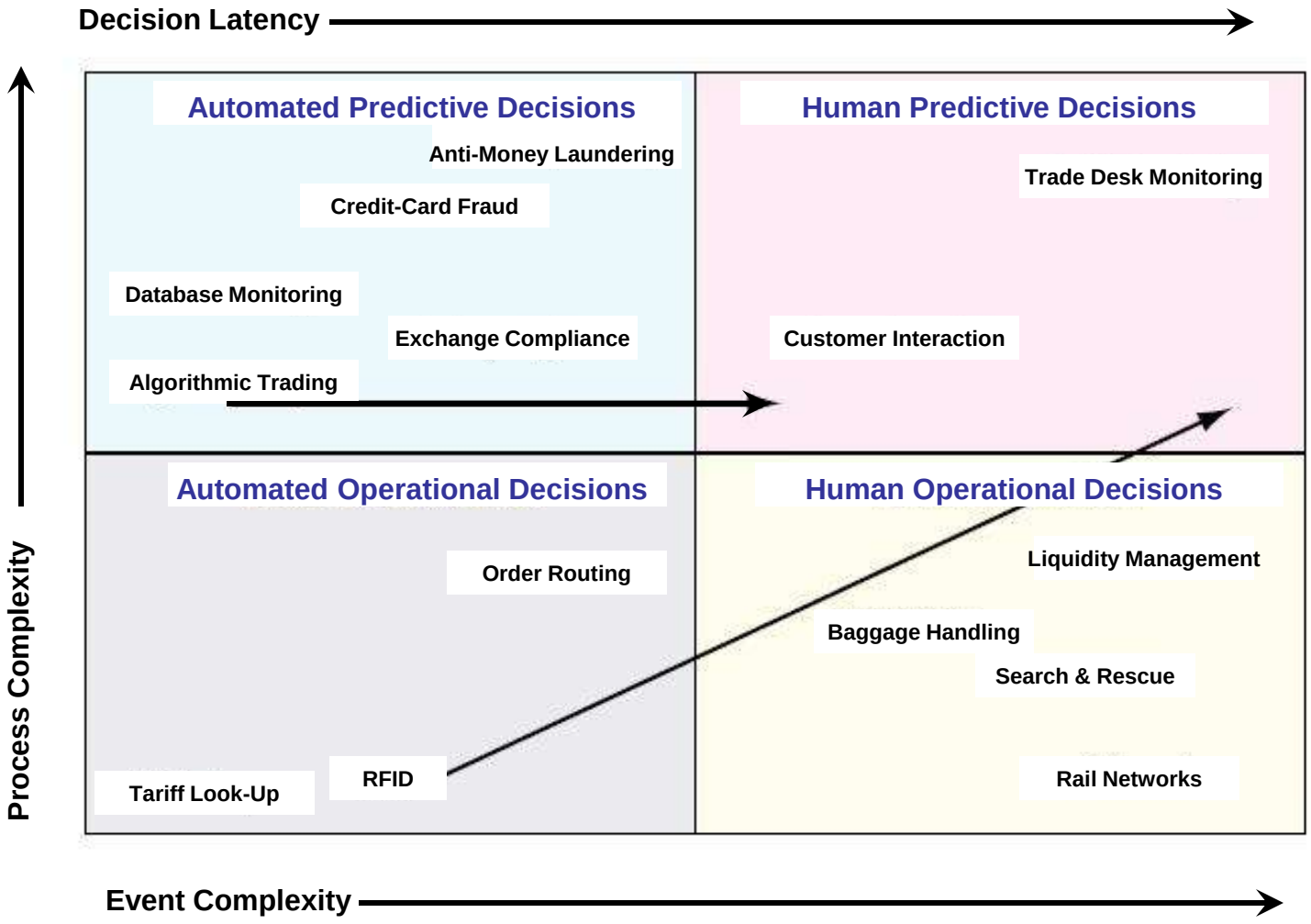
Analysts on CEP



Pattern Matching and Inferencing

--- Bloor Report on Event Processing Nov 2006

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Why CEP?

- **Detecting event patterns across multiple event types + time is difficult for simple event processing solutions**
- **Computers can correlate across large volumes of events at high speed, identifying patterns that are not conventionally visible**
- **The architecture pattern of "continuous event processing" applies to many business domains such as BAM**
- **Examples in use:**
  - **Track and Trace** of RFID data
  - **Situation Assessment** of airline operational delays (+ their causal events)
  - **Sense and Respond** to fraud indicators in internet transactions

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Agenda

- **CEP Glossary**

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EPTS

- Event Processing Technical Society
- Vendor group + interested parties (e.g. David Luckham, Gartner)
- Website: http://www.ep-ts.com
- Glossary: http://complexevents.com/?p=361

Following definitions are (re-ordered, mostly without change) from the EPTS glossary web site

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The need for Situational Awareness

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Event

- **Event***: anything that happens, or is contemplated as happening.*
  - *Examples:*
    - a financial trade,
    - an airplane lands,
    - a sensor outputs a reading,
    - a change of state in a database, a finite state machine,
    - a key stroke,
    - a natural occurrence such as an earthquake,
    - a social or historical happening, e.g., the abolition of slavery, the battle of Waterloo, the Russian revolution, and the Irish potato famine.
- **Event** (also **event object**, **event message**, **event tuple**): an object that represents, encodes or records an event, generally for the purpose of computer processing.
  - *Examples:*
    - a purchase order (records a purchase activity),
    - an email confirmation of an airline reservation,
    - stock tick message that reports a stock trade,
    - a message that reports an RFID sensor reading,
    - a medical insurance claim document .

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Notes on Events

- Events are **processed** by computer systems via their representations as "**event objects**".
  - The same activity may be represented by more than one event object
  - Each event object might record different attributes of the activity.
- In many event processing systems, for example simulation systems, events are **immutable**.
  - A modification or transformation of an event must be achieved by creating a new event object
    - not by altering the original event.
  - Deletion would entail removing an event from further processing.
- ***Overloading**:* event objects contain data. The word "event" is overloaded so that it can be used as a synonym for event object.
  - The term "**event**" is used to denote both the everyday meaning (anything that happens) and the computer science meaning (an event object or message). The context of each use indicates which meaning is intended.

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Event Types and Attributes

- **Event type** (also **event class**, **event definition**, or **event schema**): An event type is a class of event objects.
  - *Examples:*
    - the type of all price quotations,
    - the type of all sensor readings for any kind of sensor.
  - *Notes:*
    - All events must be instances of an **event type**.
    - An event has the structure defined by its type.
    - The structure is represented as a collection of event **attributes**.
    - Event types should be defined within the type definition system of a modern strongly typed computer language such as XML Schema or Java.
- Events will usually specify certain standardized data attributes, such as:
  1. a unique event identifier by means of which the event can be referenced,
  2. the type of the event,
  3. its creation time stamps,
  4. its source of creation.
- **Event Attribute** (also called **event property**): a component of the structure of an event.
  - *Note:* An attribute can have a simple or complex data type.

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Simple and Raw Events

- **Simple event***:* an event that is not an abstraction or composition of other events.
- **Raw event**: an event object that records a real-world event.
  - *Note:* A raw event may represent a simple real-world event (e.g. the phone rang) or a complex real-world event (e.g. the stock market crash of 1929 was a complex real world event that can be recorded as a “complex raw event”).

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Instantaneous and Virtual Events

- **Instantaneous event:** an event whose duration is less than the granularity of any clock that is applied in the system.
  - has a single timestamp signifying when the event happened.
  - the time interval of the event has a measured length of zero (i.e. the start and end times are the same).
  - *Note*: an instantaneous event may have other attributes as timestamps for other information, e.g., arrival time.
- **Virtual event*:*** an event that does not happen in the physical world but appears to signify a real world event; an event that is imagined or modeled or simulated.
  - *Examples:*
    - instruction executions modeled by a hardware design simulation,
    - events predicted by a weather simulation,
    - events modeled by a war game,
    - events that take place in a dream (”these dreams of you, So real and so true” ― Van Morrison),
    - events in Virtual Reality.

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Event Relationships

- **Cause**: an event A is a cause of another event B if A had to happen in order for B to happen.
  - *Examples:*
    - the birth of a father and the birth of a son of the father,
    - sending an email and a reply to that email.
  - *Note:* this is a definition of *computational causality*. It requires A to be necessary for B to happen. Other definitions of causality are possible, e.g., *probable cause*.
- **Abstraction**: an event is an abstraction of a set of events if it summarizes, represents, or denotes that set of events.
- **Related events**: events are related by *time, causality, abstraction* and other relationships.
  - Time and causality impose partial orderings upon events.

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Derived and Composite Events

- **Derived event** (also **synthesized event**): an event that is generated as a result of applying a method or process to one or more other events.
  - *Example*:
    - A “Company B is a good buy” event may be derived from “Company B price has dropped where Company A price has risen within 5 minutes”
  - *Note*: The absence of an event, say in a given time interval, can lead to a derived event for the missing event.
- **Composite event**: a derived, complex event that is created by combining base events using a specific set of event constructors
  - Operators include disjunction, conjunction, sequence, etc.
  - A composite event always includes the base (member) events from which it is derived.
  - *Note:* A derived event may not be a composite event if its method of derivation lies outside a specified set of allowed constructors.
- *Note*: The term ***aggregate event*** is sometimes used for some forms of composite or derived event.

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Complex Events

- **Complex event**: an event that is an abstraction of other events
  - Abstracted events are the *members* of the complex event
  - *Examples:*
    - the 1929 stock market crash (an abstraction denoting many thousands of member events),
    - the 2004 Indonesian Tsunami (an abstraction of many natural events) ,
    - a completed stock purchase (an abstraction of the events in a transaction to purchase the stock).
    - a successful on-line shopping cart checkout (an abstraction of shopping cart events on an on-line website).
  - *Note:* a complex event *denotes* or *signifies* the set of its member events. This may or may not include references to individual member events.
- A composite event or a derived event is a **complex event**. The converses are not necessarily true.

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Timestamps

- **Timestamp**: a time value attribute of an event, recording the reading of a clock in the system in which the event was created or observed.
  - *Examples:*
    - creation time: the time interval or time at which an event was created,
    - arrival time: the time at which an event arrived at a point of observation.
  - *Note:* An event can contain timestamps according to one or more clocks. For example it could contain both its creation time according to a clock where it was created and its arrival time at a system location according to a clock at that location.
- In systems with **multiple clocks**, the issue of clock **synchronization** is an ongoing topic of research
  - *Example:* clocks in a distributed computer system
- Not all time attributes are “timestamps”
  - *Example:* Derived events’ times may be derived from their source events.

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Sources and Sinks

- **Event source** (also **event emitter** or **event producer**): an entity that sends events.
  - *Examples:*
    - a software module,
    - sensor,
    - clock.
- **Event sink** (also **event consumer**): an entity that receives events.
  - *Examples:*
    - a software module,
    - database,
    - dashboard,
    - person
- **Event channel** (also **event connection, event pathway, event topic**): a conduit in which events are transmitted from event sources (emitters) to event sinks (consumers).
  - *Notes:*
    - A channel can carry events of multiple types.
    - An event channel may be public (without access restrictions), or controlled.
    - An event channel is a medium for delivering one or more event streams.
    - A single event channel may be consumed by multiple event consumers.

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Streams and Clouds

- **Event stream**: a linearly ordered sequence of events.
  - *Notes:*
    - Usually, streams are ordered by time, e.g., arrival time.
    - An event stream may be bounded by a certain time interval or other criteria (content, space, source), or be open ended and unbounded.
    - A stream may contain events of many different types.
- **Window**: a bounded portion of an event stream.
  - *Example:* The events in the last ten minutes - i.e., a ten-minute moving window.
  - *Notes:* Windows define sub-sequences of an event stream typically to focus the event processing on specific data, or to improve event processing performance, but may also have other uses.
- **Event cloud**: a partially ordered set of events (poset), either bounded or unbounded, where the partial orderings are imposed by the causal, timing and other relationships between the events.
  - *Notes:*
    - Typically an event cloud is created by the events produced by one or more distributed systems.
    - An event cloud may contain many event types, event streams and event channels.
    - The difference between a cloud and a stream is that there is no event relationship that totally orders the events in a cloud. A stream is a cloud, but the converse is not necessarily true.
  - CEP usually refers to event processing that assumes an event cloud as input, and thereby can make no assumptions about the arrival order of events.

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Event Processing

- **Event processing**: computing that performs operations on events, including reading, creating, transforming and deleting events.
  - *Note:* The overloaded meaning event object processing is intended in this context.
- **Complex-event processing (CEP):** Computing that performs operations on complex events, including reading, creating, transforming or abstracting them.
  - *Note:* CEP results in creating complex events even if some or all of the source events are simple events
- **Event Stream Processing (ESP):** Computing on inputs that are event streams.
  - *Examples:* Applications that use stock market feeds as inputs and process events in their order of arrival to compute running average stock prices, volume weighted average prices over time windows, etc.
  - *Notes:* ESP has its origins in Active Databases and Data Streams Management. The terminologies ESP and CEP are conceptual classifications. They can be useful in delineating philosophies of event processing and intended applications, but do not specify precisely the underlying capabilities of event processing engines.

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Event Processing Patterns

- **Event template**: an event form or descriptor where some of its parameters are variables. An event template matches single events by replacing the variables with values.
  - *Example:* Send of Any Msg: String Msg; Send(John, Msg)
- **Event pattern**: a template containing event templates, relational operators and variables. An event pattern can match sets of related events by replacing variables with values.
  - *Examples:*
    - a pattern of events defining those sets of events in a completed sales transaction.
    - a pattern of events in an email correspondence:
      String Msg, Time T1, T2 ; Send(John, Msg, T1) and Receive(John, Msg, T2);
    - a pattern defining the events in any successfully resolved customer complaint.
      Customer C, Agent A, Problem P, Time T1, T2, T3; Complain(C, P, T1) -> Engage(A, C, T2) -> Resolved (P, T3);
  - *Note:* event patterns can often be specified graphically.
- **Pattern Instance** (also **event pattern instance**): a set of related events resulting from an event pattern by replacing the variables by values.
  - *Examples:*
    - Send(John, “See the NYT today”, 15.00 EST) and
      Receive(John, “See the NYT today”, 12.05 PST);

Event Processing by Rules

- **Constraint** (also **event pattern constraint**): A Boolean condition that must be satisfied by the events observed in a system.
  - *Examples:*
    - A service level agreement limiting the time taken to complete a mortgage transaction from the time an application is received.
- **Rule** (in event processing): A prescribed method for processing events.
  - *Examples:*
    - Whenever three timeouts have happened send an alert to the network manager.
    - If more than ten shopping carts have been active for more than five minutes then activate the website reaction time monitor and display an amber alert on the dashboard.
    - Whenever IBM trades 2% above its 1 hour VWAP and then within 15 minutes trades 5 points below then buy 1000 shares IBM.
  - *Notes:* Event processing rules may be prescribed in many different ways, including by finite state machines, activity diagrams, Java code, SQL code, ECA (event-condition-action) rules or reactive rules that are triggered by event patterns.
- **Event pattern triggered reactive rule**: a rule that prescribes actions to be taken whenever an instance of a given event pattern is detected.

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Event Processing Languages, Agents, Networks

- **Event Processing Language (EPL)**: a high level computer language for defining the behavior of event processing agents.
- **Event Processing Agent (EPA)** (also **event processing component**, **event mediator**): a software module that processes events.
  - *Notes:* Event source and event sink are roles that an EPA may play. One EPA could act in both roles - it could be an event source at one moment, an event sink at another time.
- **Event Processing Network (EPN)**: A set of event processing agents (**EPA**s) and a set of **event channels** connecting them.
  - *Notes:*
    - the set of EPAs can be dynamic, i.e., EPAs can be created and destroyed
    - the set of channels can be dynamic, i.e., channels can be created and destroyed
    - dynamic behavior may controlled by patterns of events occurring in the network
    - an EPN need not be an acyclic directed graph, e.g., feedback loops (cycles) are possible
    - the runtime deployment of an EPN may be distributed across multiple physical networks, computers and software artifacts.

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Agenda

- **CEP Technologies**

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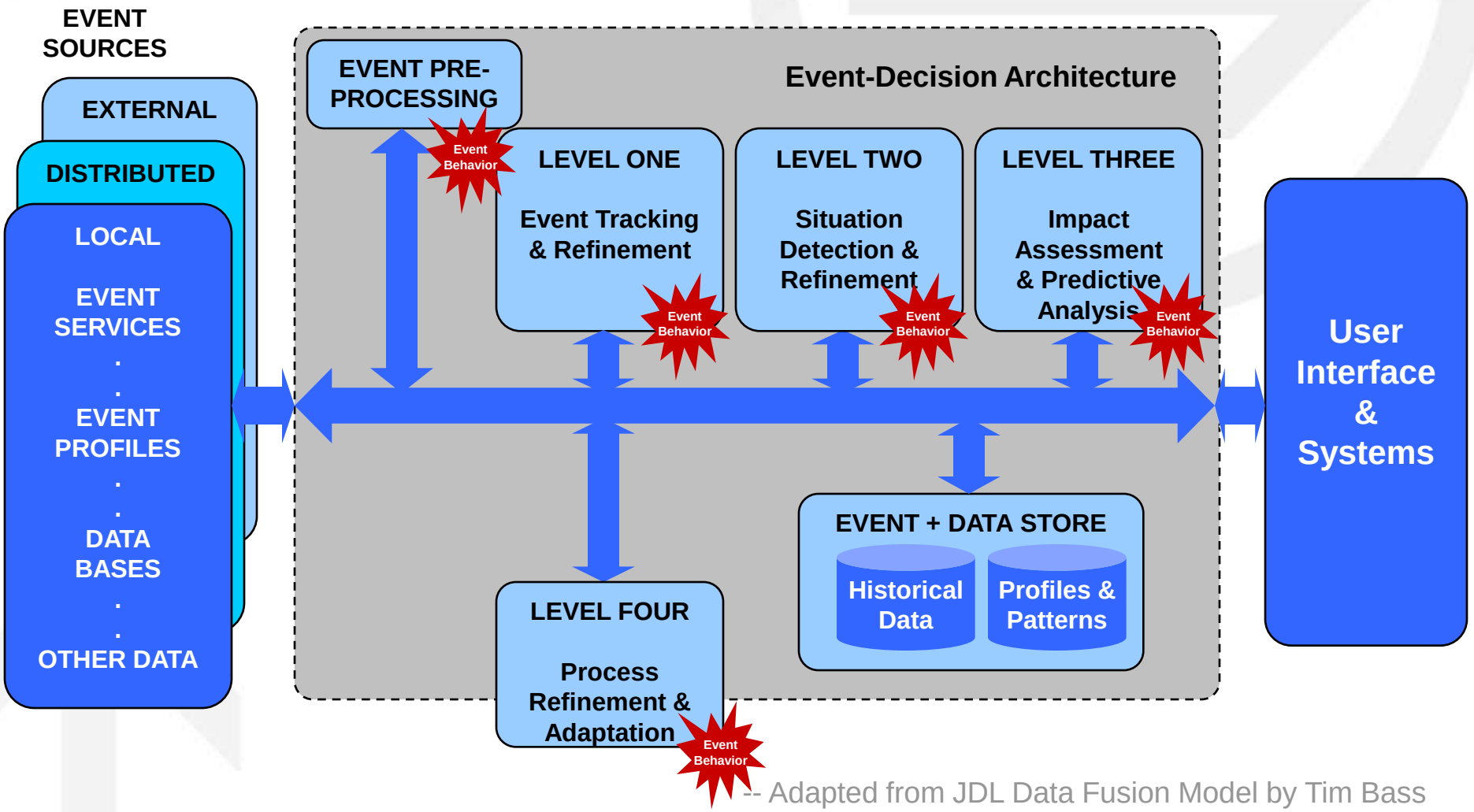
CEP = an Event-Decision Architecture



-- Adapted from JDL Data Fusion Model by Tim Bass

Steinberg, A., & Bowman, C., Handbook of Multisensor Data Fusion, CRC Press, 2001

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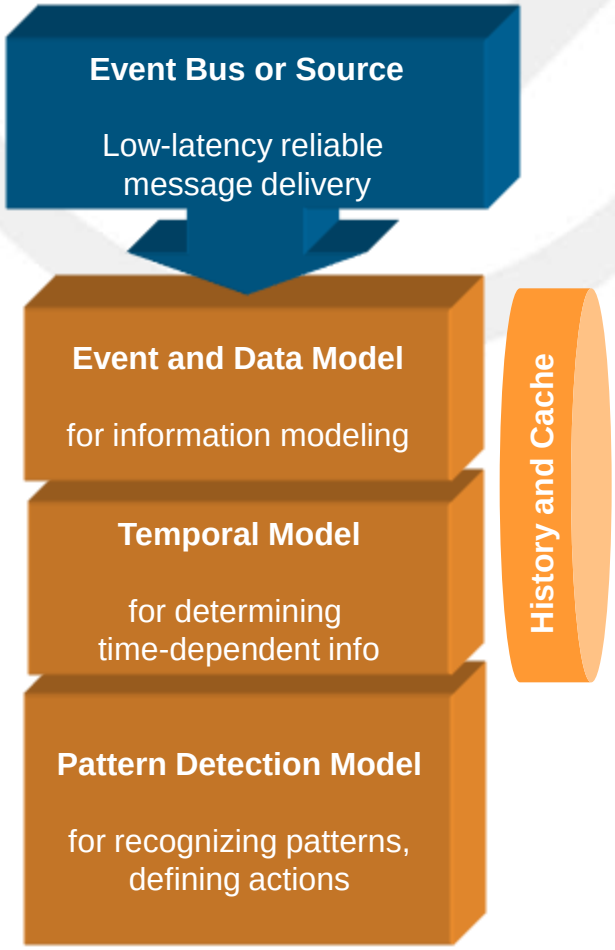
Requirements for CEP Technology

- **Access and Monitor the "Event Cloud"**
  - JMS, RV, MQ, TCP/IP, etc…
  - Timers to detect lack of events
  - Determine event state changes
- **Match Patterns, Apply Business Logic**
  - Detect events
  - Detect event patterns
  - Maintain State and Facts over time
  - Update Detection algorithms as events change



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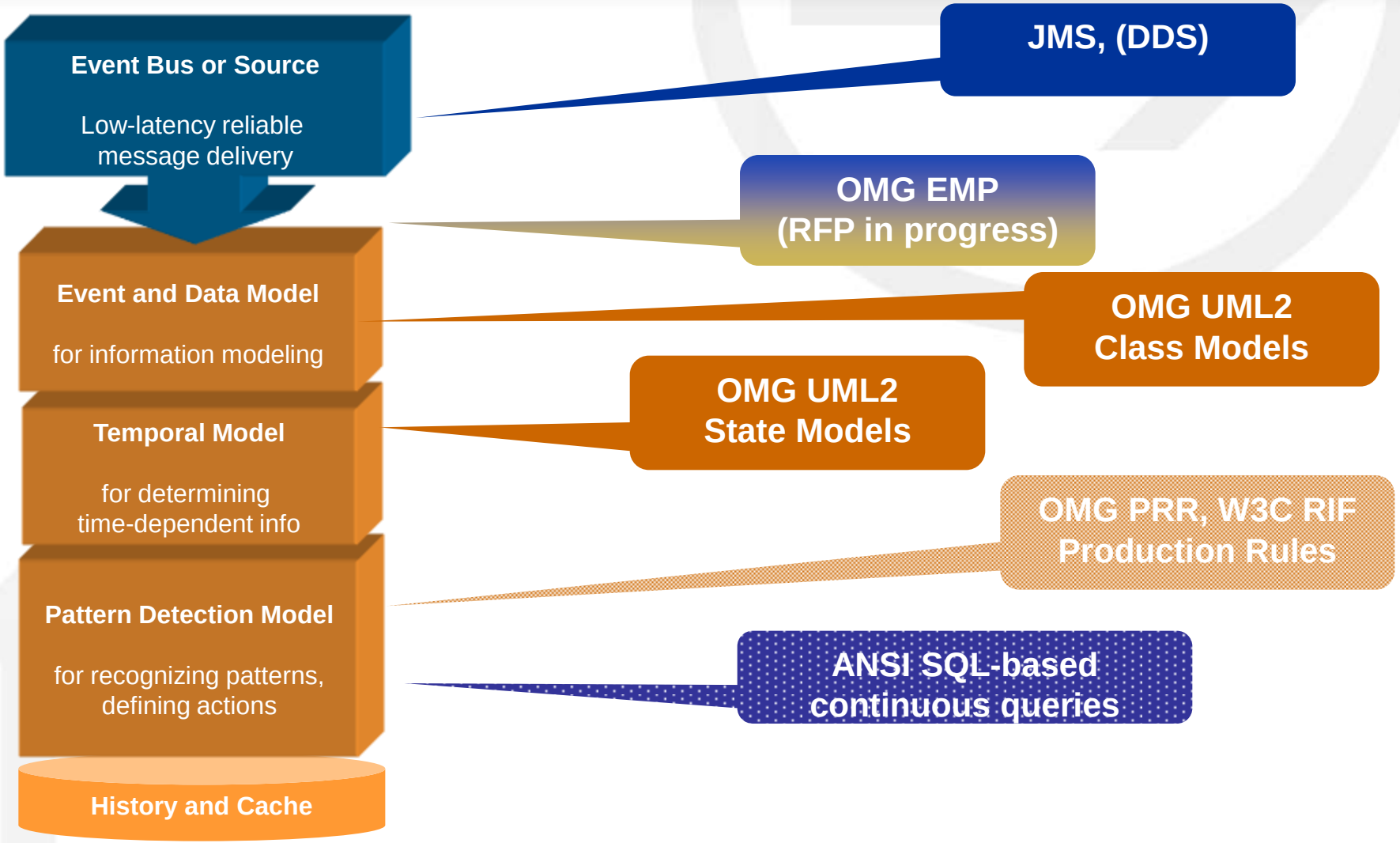
CEP-Related Standards



* = in devt

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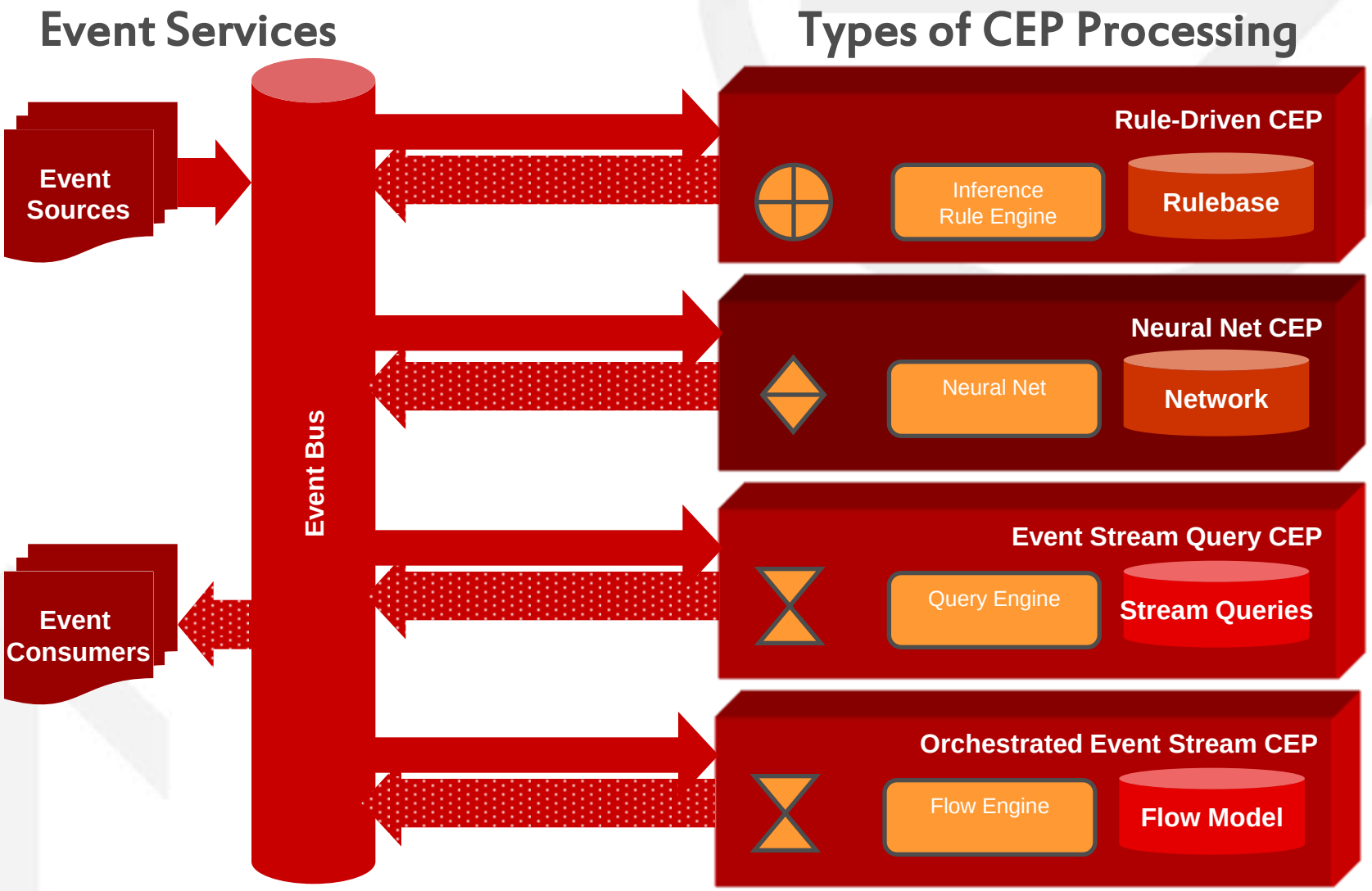
Example CEP Technologies



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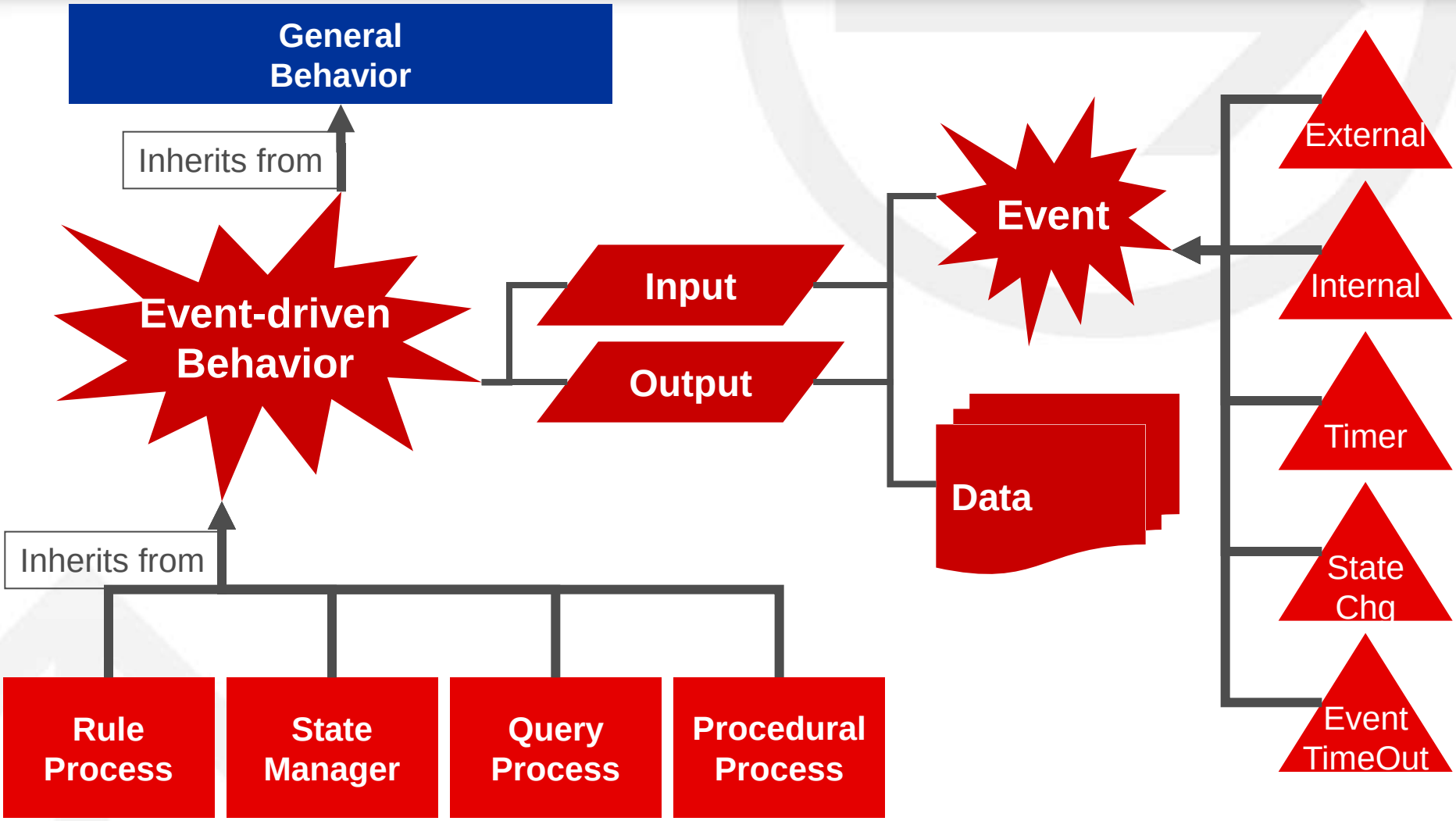
Sample Event Processing Metamodel



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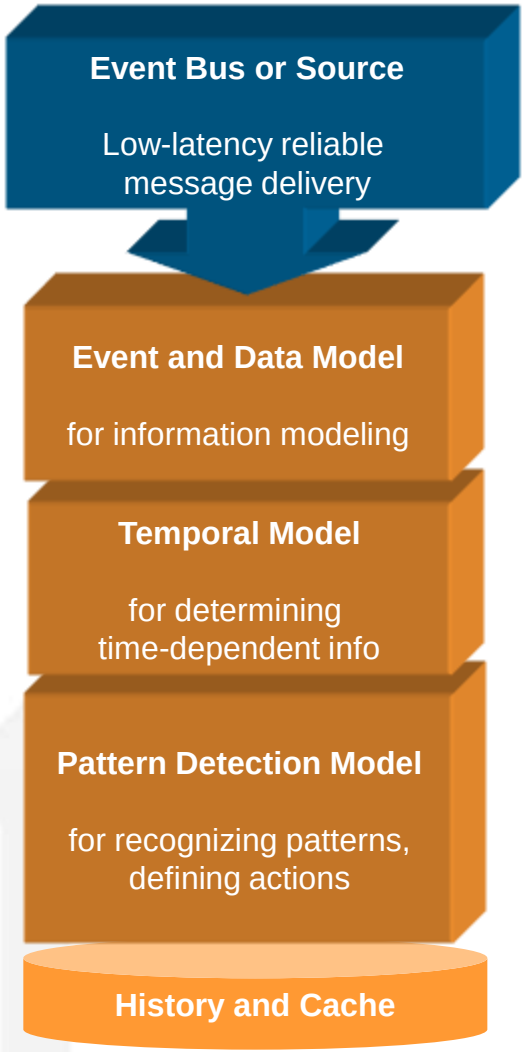
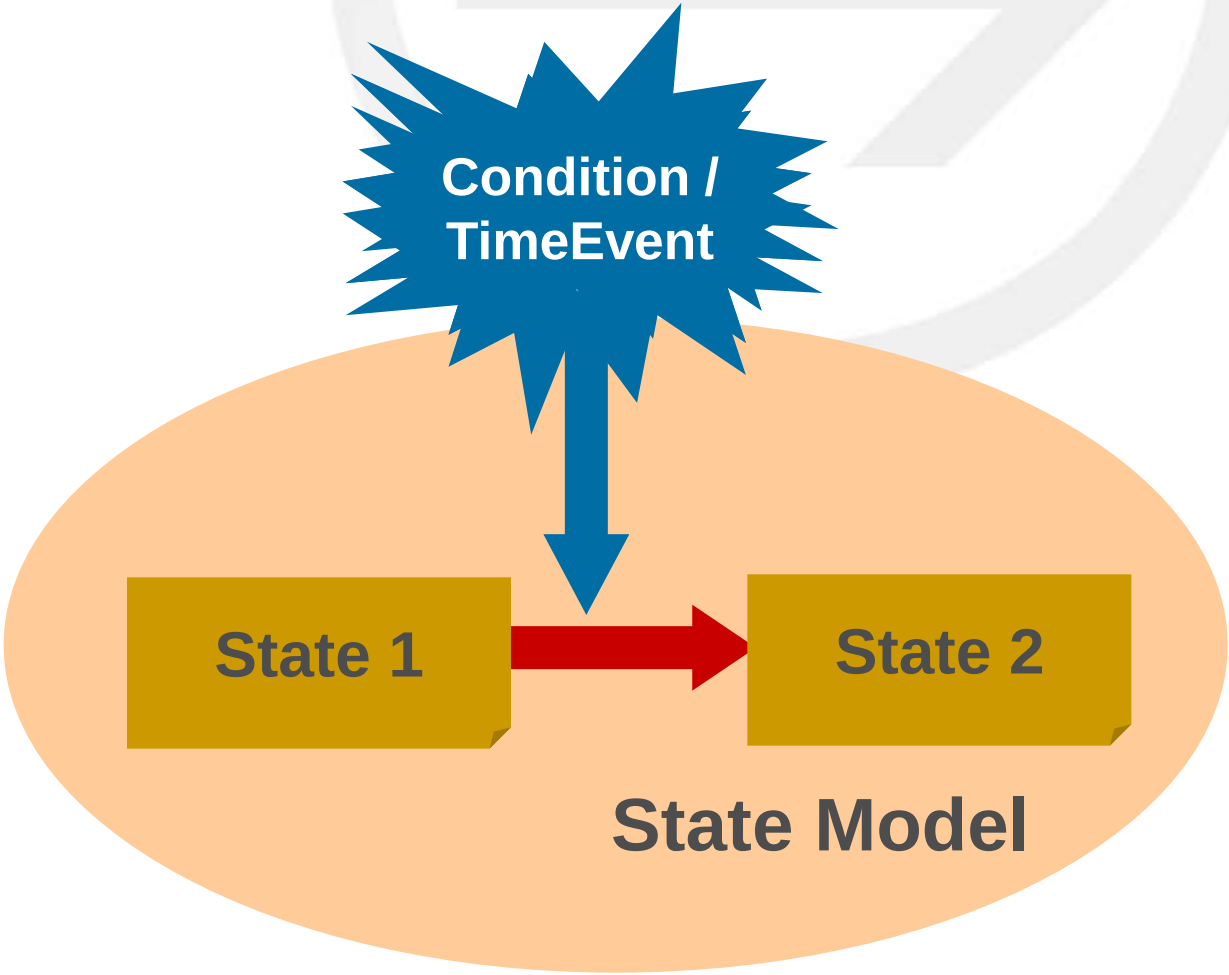
CEP Behavior: State-oriented





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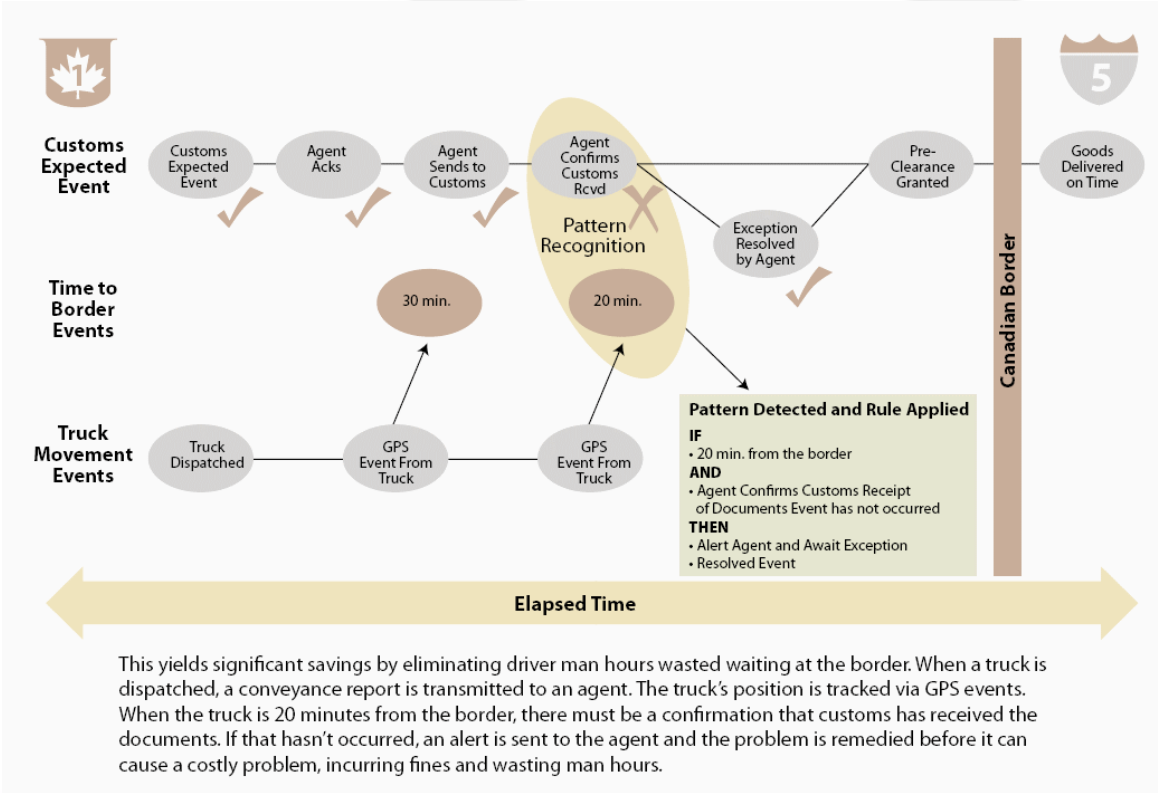
State Model / Process Flow CEP Agent features

1. **Visual modeling metaphor**
   - State diagram / flow diagram is simple to follow
2. **State / flow transitions can be time-related**
   - Can model missing events through time-outs etc



This yields significant savings by eliminating driver man hours wasted waiting at the border. When a truck is dispatched, a conveyance report is transmitted to an agent. The truck's position is tracked via GPS events. When the truck is 20 minutes from the border, there must be a confirmation that customs has received the documents. If that hasn't occurred, an alert is sent to the agent and the problem is remedied before it can cause a costly problem, incurring fines and wasting man hours.

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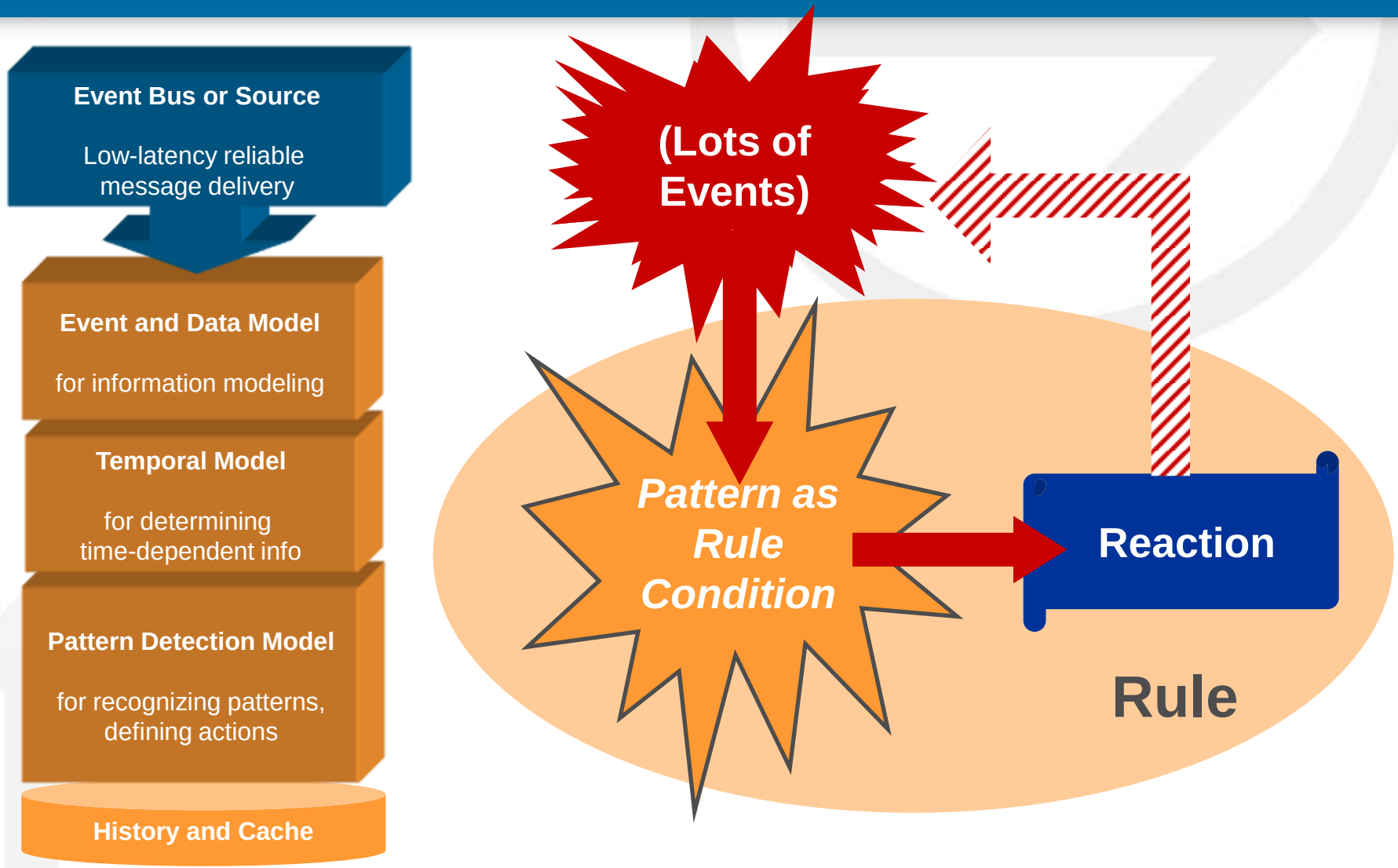
CEP Behavior: Rule-oriented



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Inference Rule CEP Agent features

1. High performance pattern matching

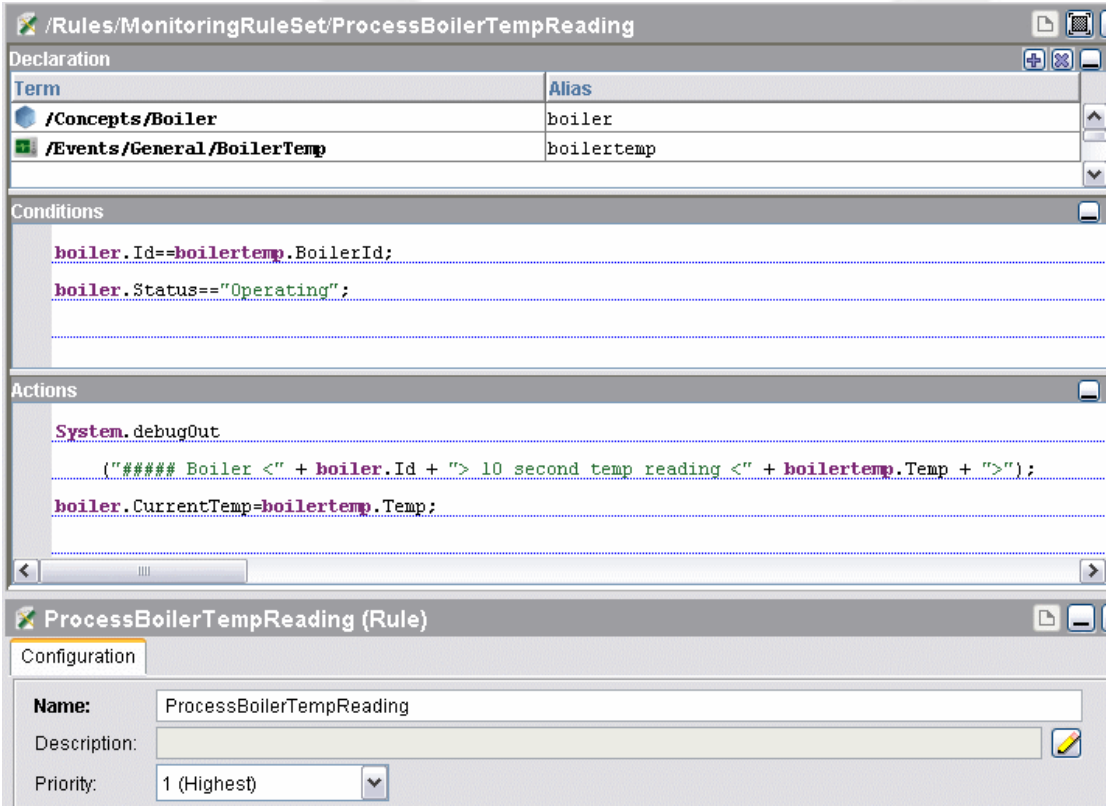
- Rete algorithm determines rules that are executable based on underlying data changes

2. Declarative + Inferencing

- Rules defined in terms of classes:
  can be relevant
  for any # instances
- Rules' actions can cause other rules to fire automatically

3. In-memory

- Limited only by
  JVM / process memory



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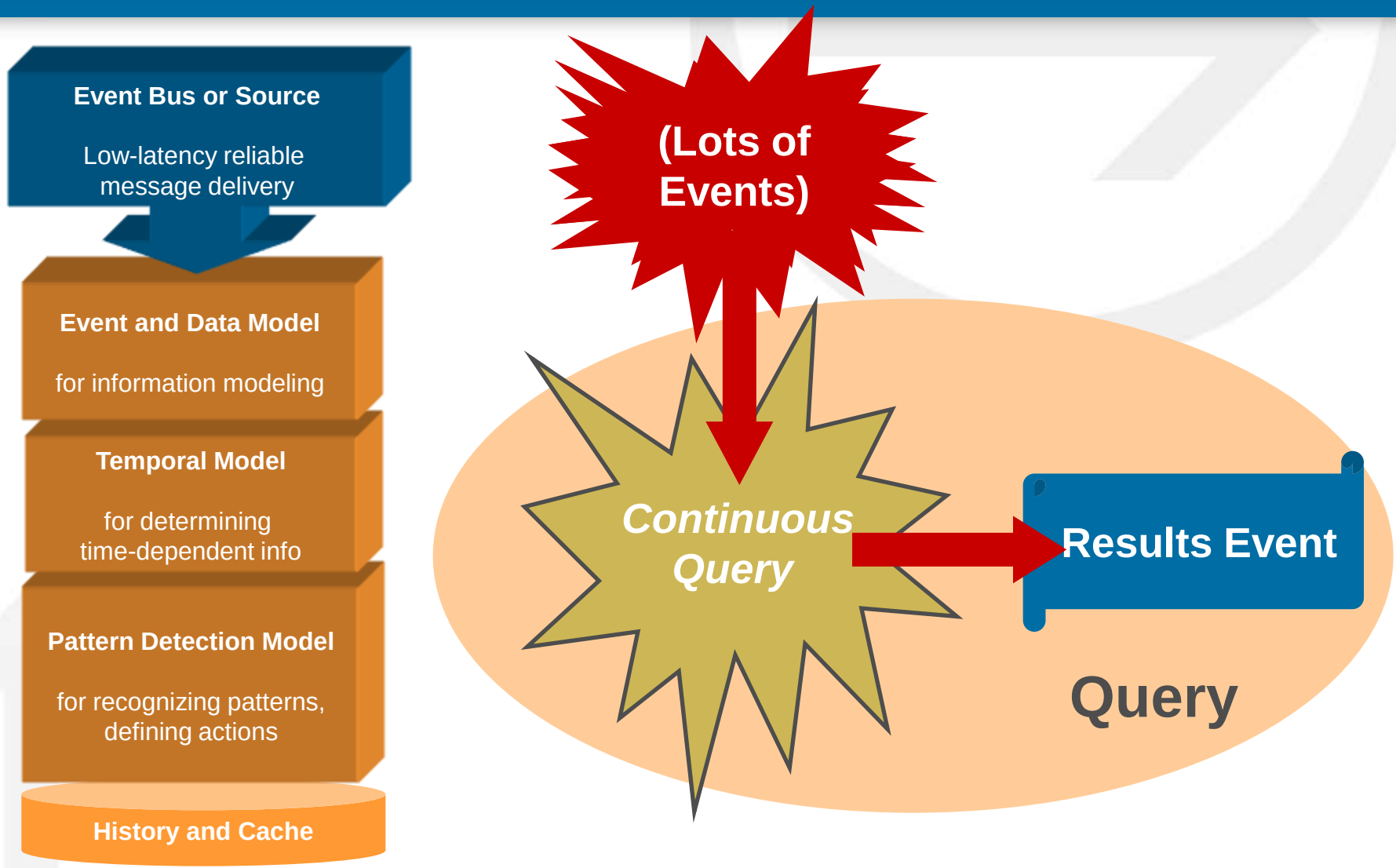
CEP Behavior: Query-oriented



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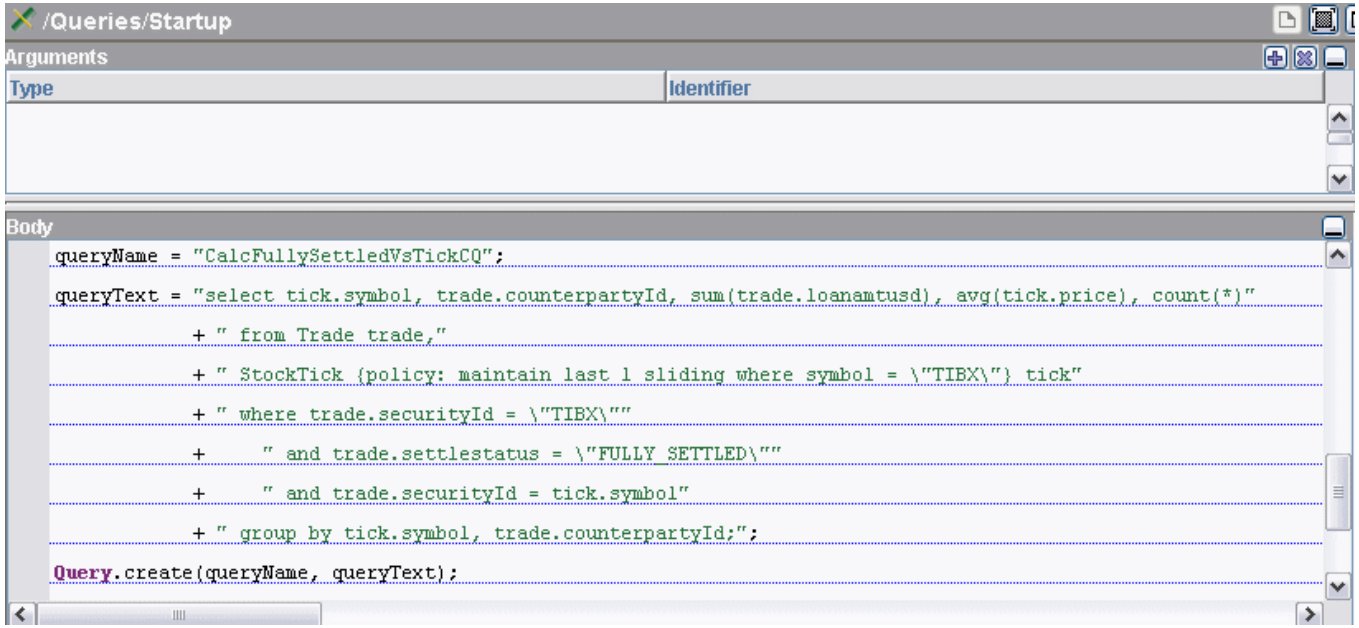
Query CEP Agent features

1. Common query language

- Usually SQL-based – widely used language
- May be in-memory, in-file or both
- Can include query optimizers

2. Continuous

- Extensions usually support time windows for the query to operate over



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Agenda

- **Examples**

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Typical Business Situations for CEP

Detected Business Situation	Resulting Situation-Decision
User X is behaving suspiciously (high likelihood of fraud)	Investigate for fraud manually
Subcomponent delivery Y is slightly late	Issued an automated reminder to supplier
Customer Y payment for policy P is very late	Alert Customer Agent
Orders for product Z are up >20%	Alert manufacturing and marketing

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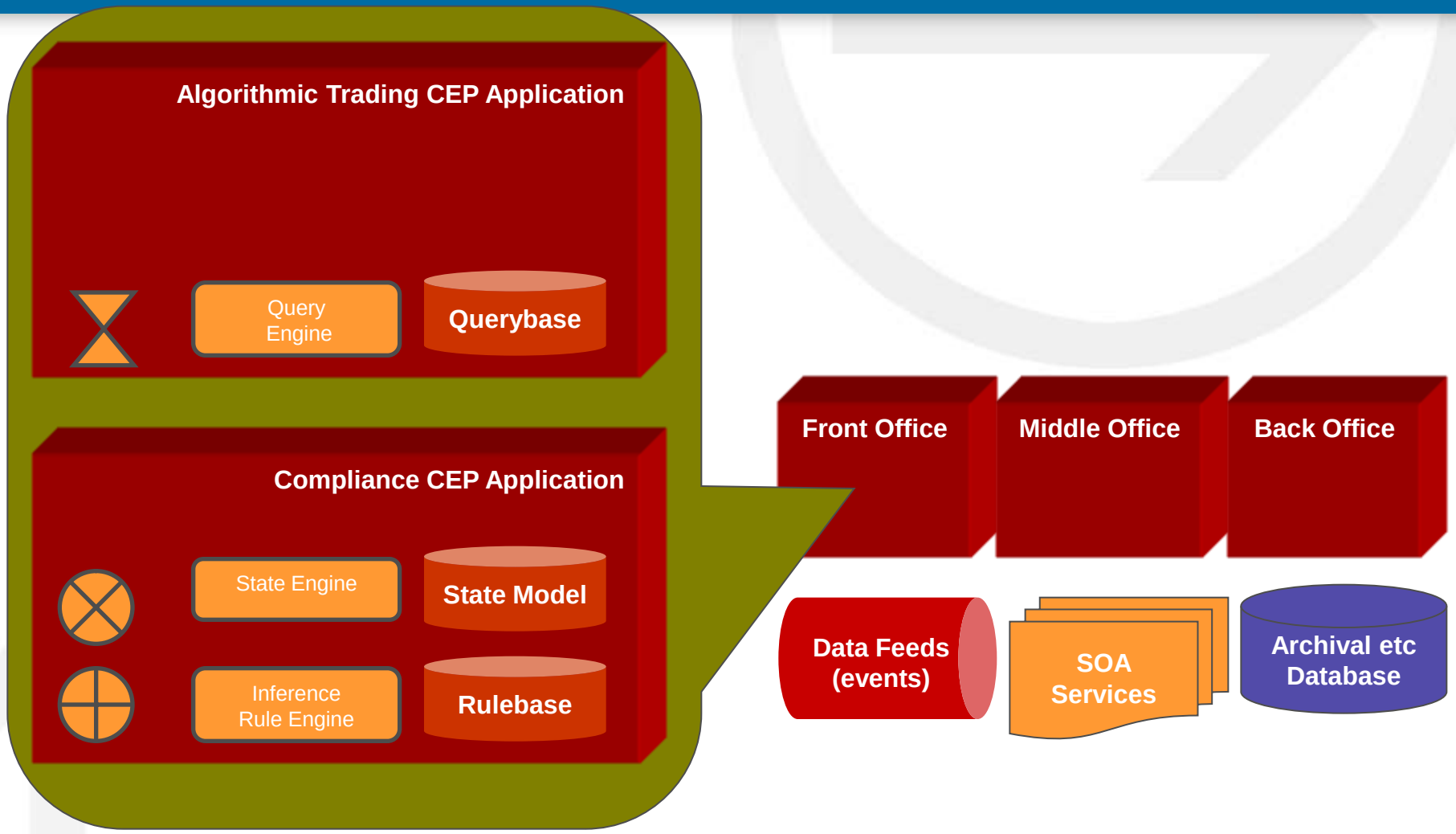
CEP in Action: Investment Banking



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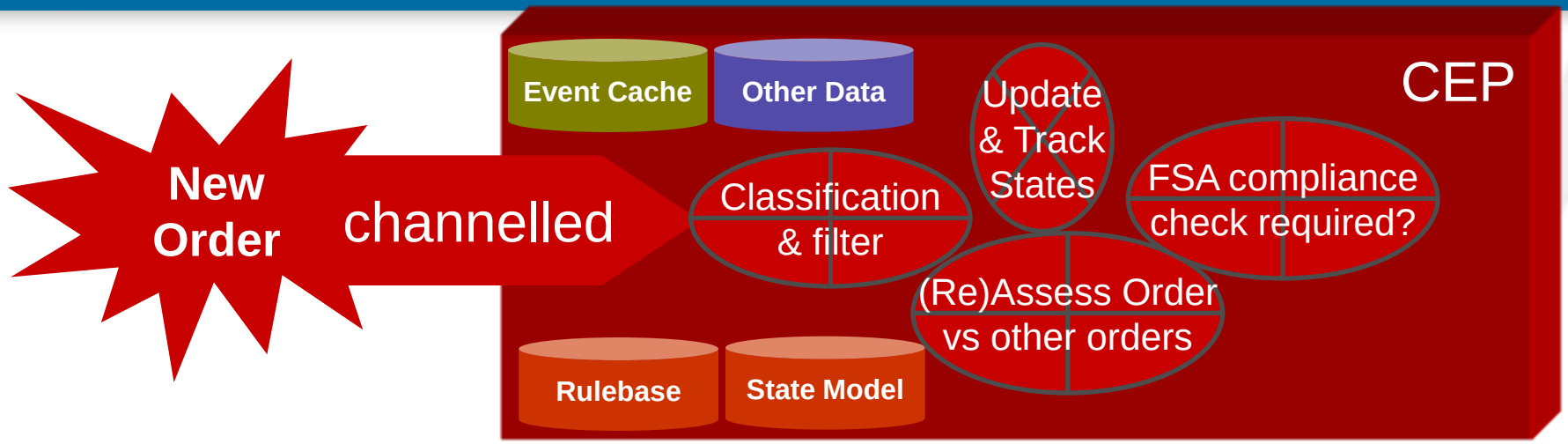
CEP Processing



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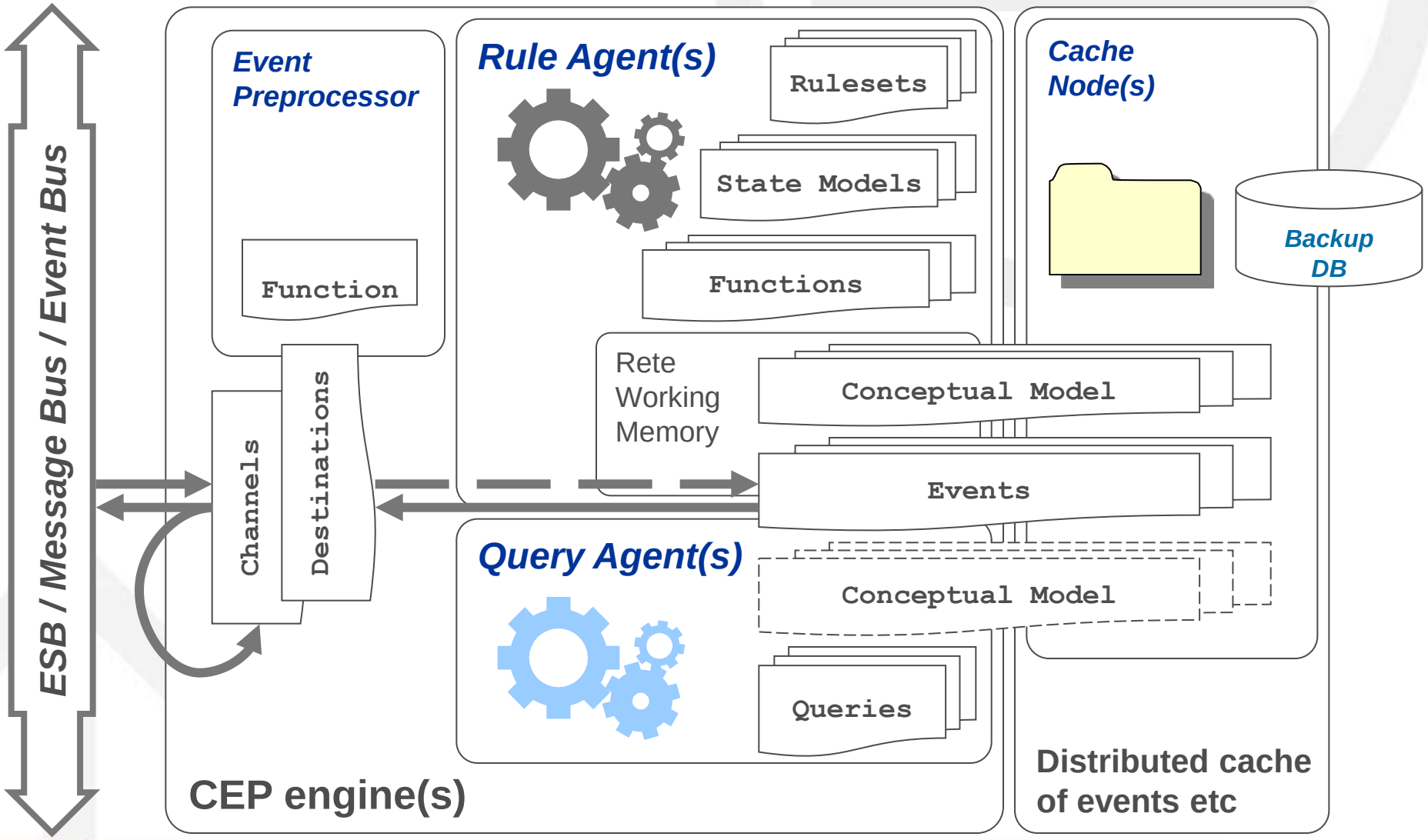
Example CEP Product Architecture



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Agenda

- **“Advanced” CEP**

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The need for advanced Situation Awareness

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“Advanced” CEP defined in many ways

- **Intelligent CEP**
  - Adaptive
  - Learning
  - Logic
  - AI
- **Semantic CEP**
  - Ontologies + Logic
  - Text / language interpretation
- **Multiple CEP**
  - Including all types of data processing paradigm (transactional, CLP, inference, mathematical methods, …)

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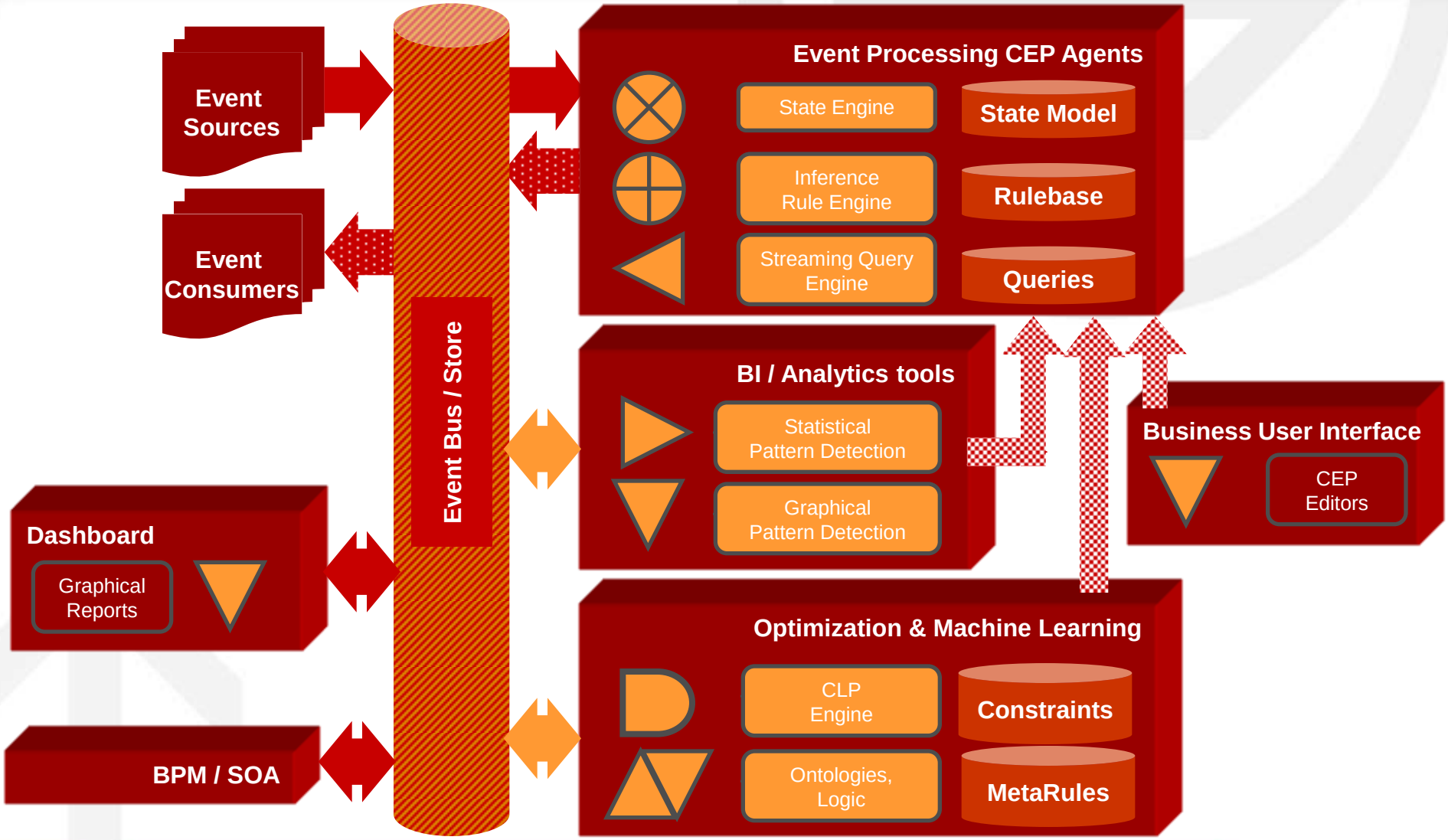
Advanced CEP Infrastructure



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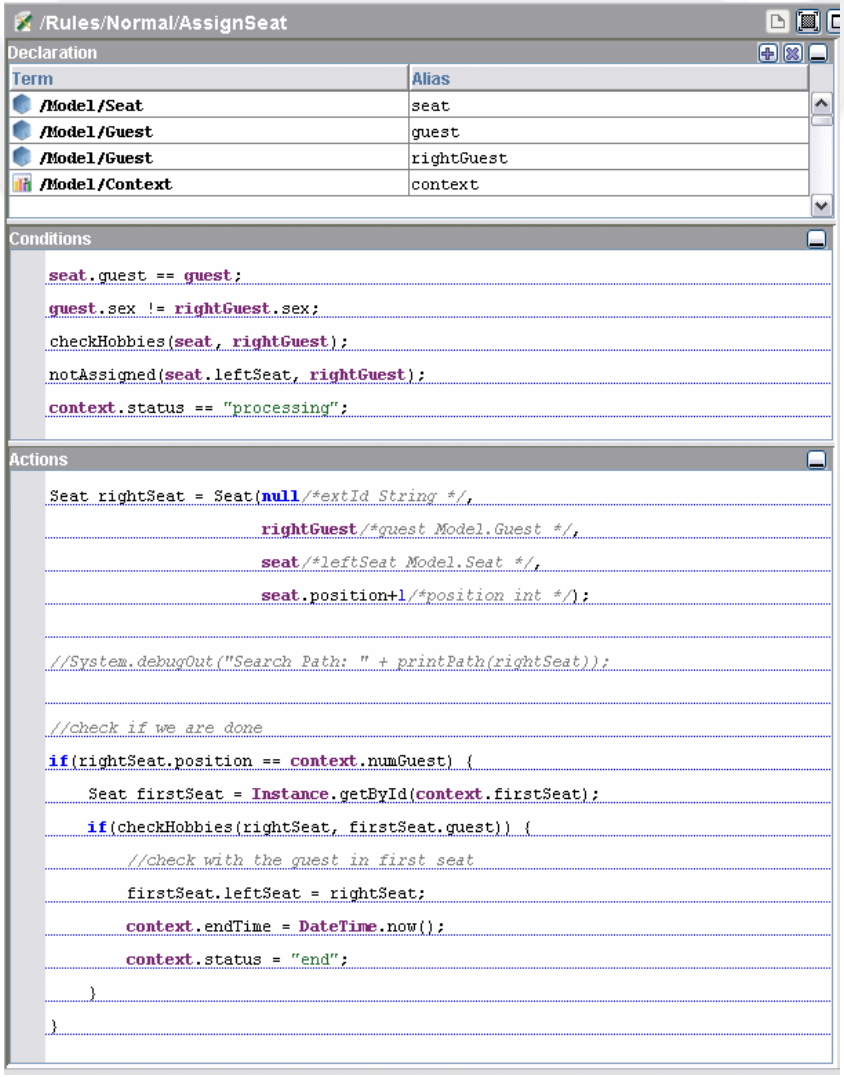
Advanced Patterns & Event Behaviors

- **Many EP apps fit the standard CEP patterns:**
  - Filter interesting rules
  - Detect predefined patterns / state changes
  - Update data / invoke processes and services based on business rules and high level events
- **Advanced EP:**
  - Apply interesting statistical functions to event data to detect new / complex trends
  - Apply different algorithms to event data
  - Modify parameters used in other rules (“metarules”)



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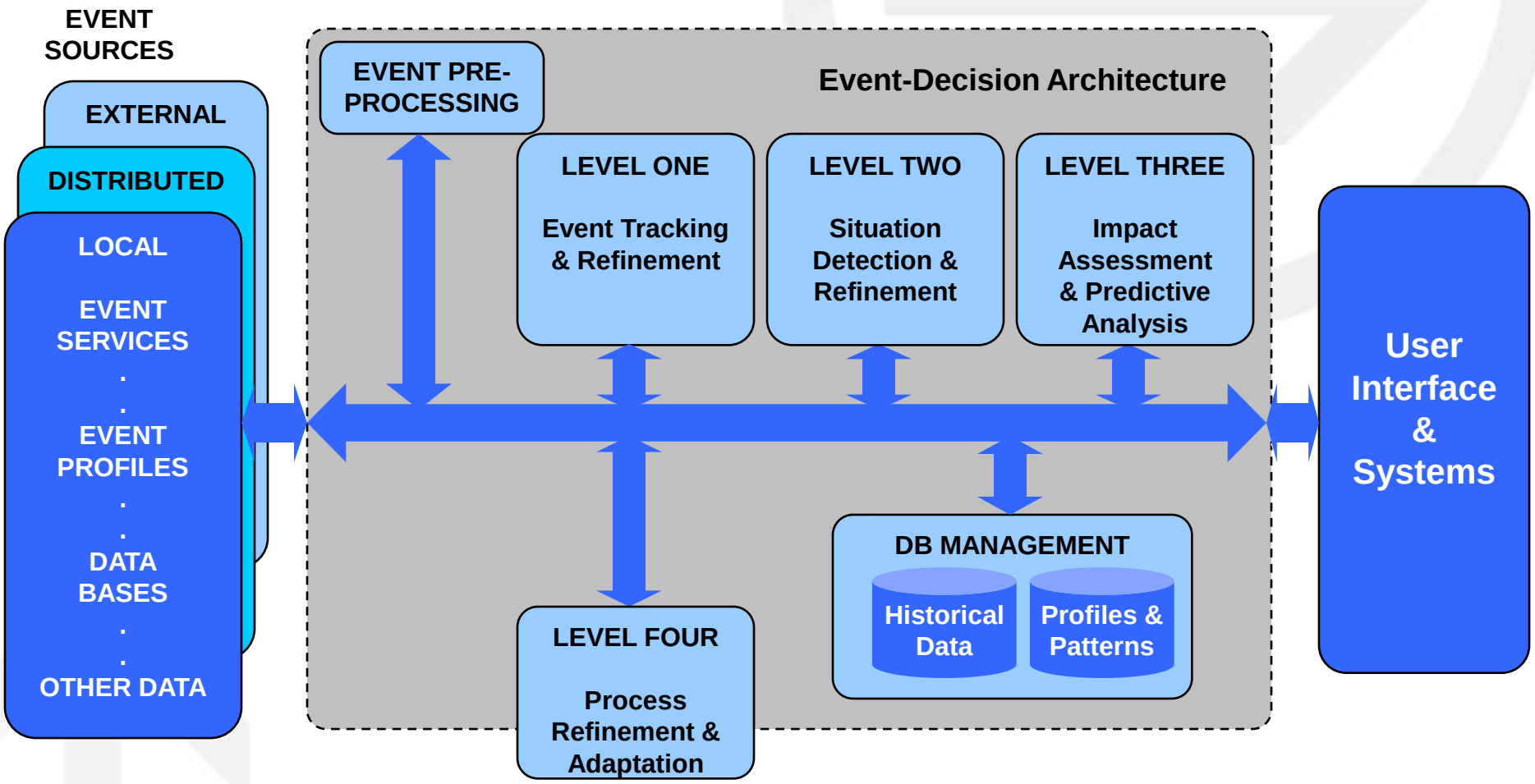
“Event-Decision” Architecture



-- Adapted from JDL

Steinberg, A., & Bowman, C., Handbook of Multisensor Data Fusion, CRC Press, 2001

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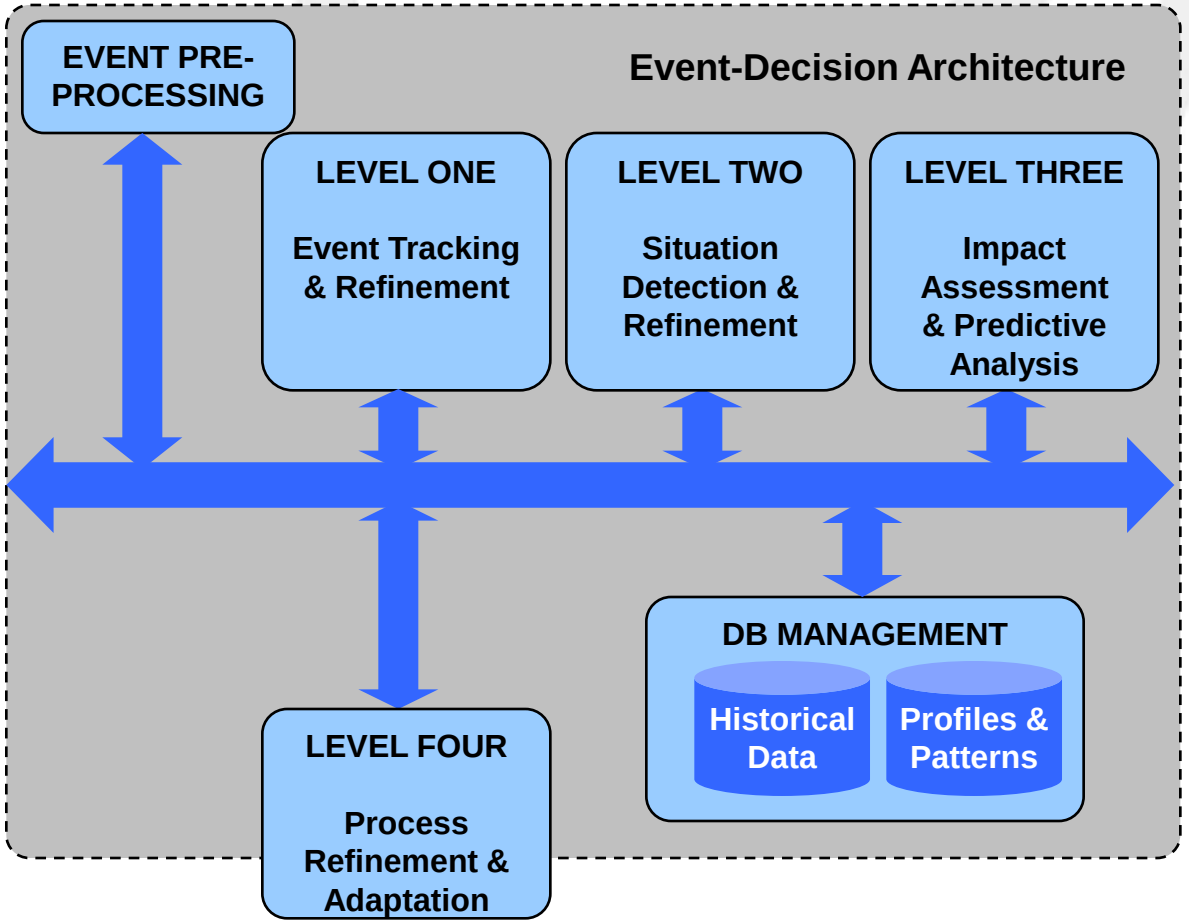
Self-Modifying “Event-Decision” Rules

- *What are the variables that can be adjusted in real-time to optimize system performance?*



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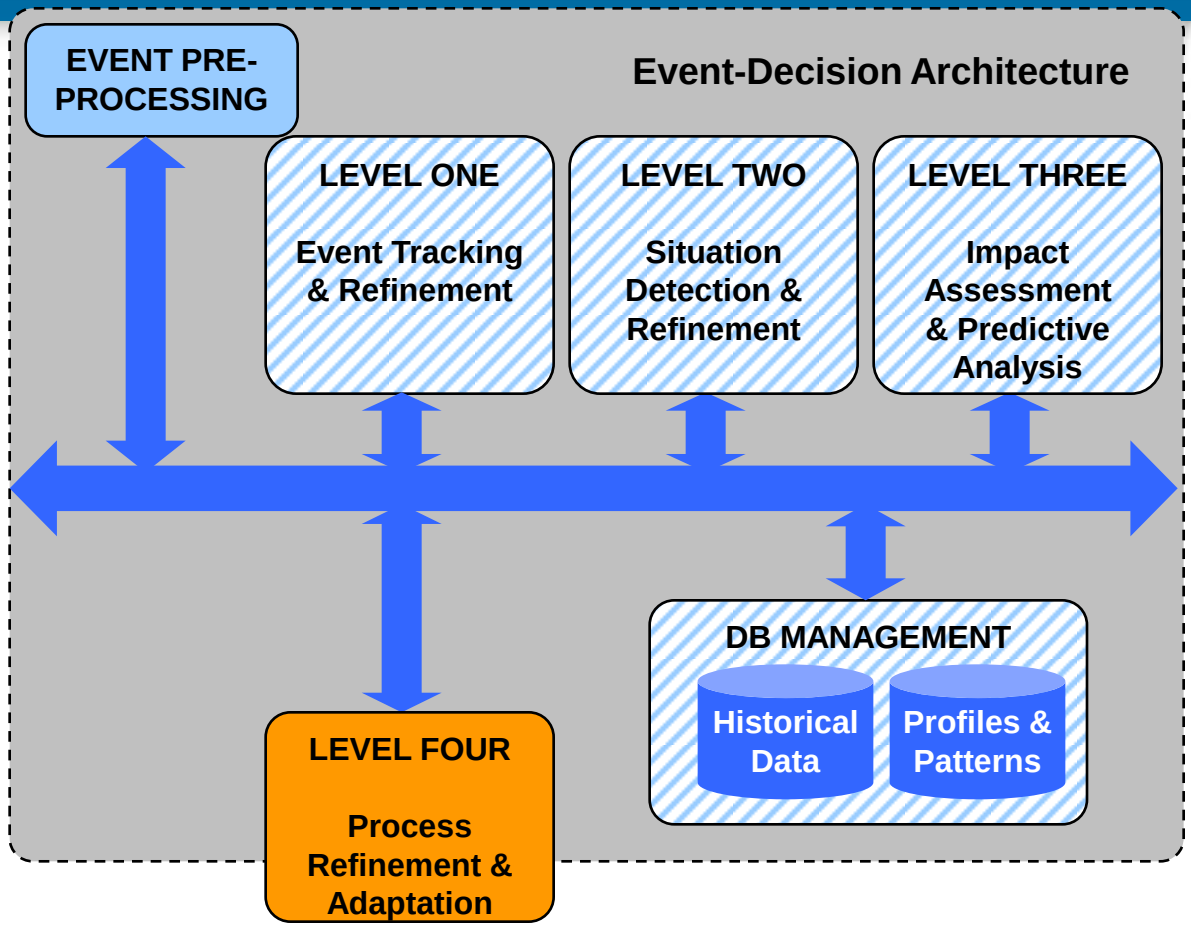
Pre-Processing Event Filtering Rules

```
If RFID event for
  product X
Then
  monitor, else
  ignore
```

Becomes

```
If RFID event for
  product in list Y
  where cost > Z
Then monitor, else
  ignore
```



Updated by

```
If average loss increase
  for all products in Y > 2%
Then reduce Z by 5%
```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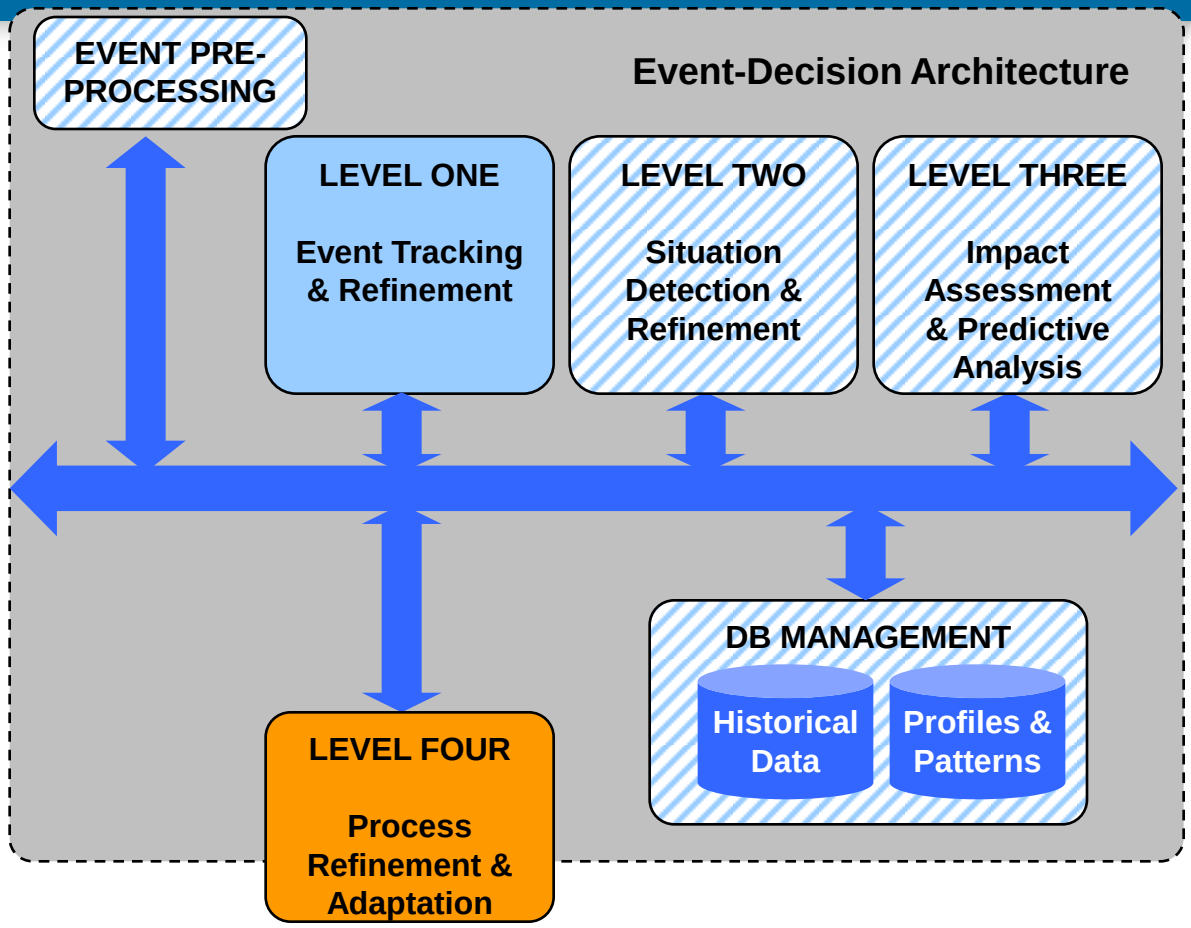
Event Tracking and Refinement Rules

```
If drug class X
  and dose > 200ml
Then
  move to monitored
  drug state
```

Becomes

```
If drug class X
  and dose > Y ml
Then
  move to monitored
  drug state
```

Updated by




```
If clinical negative events for
  drug class X increase
Then reduce Z by 10ml
```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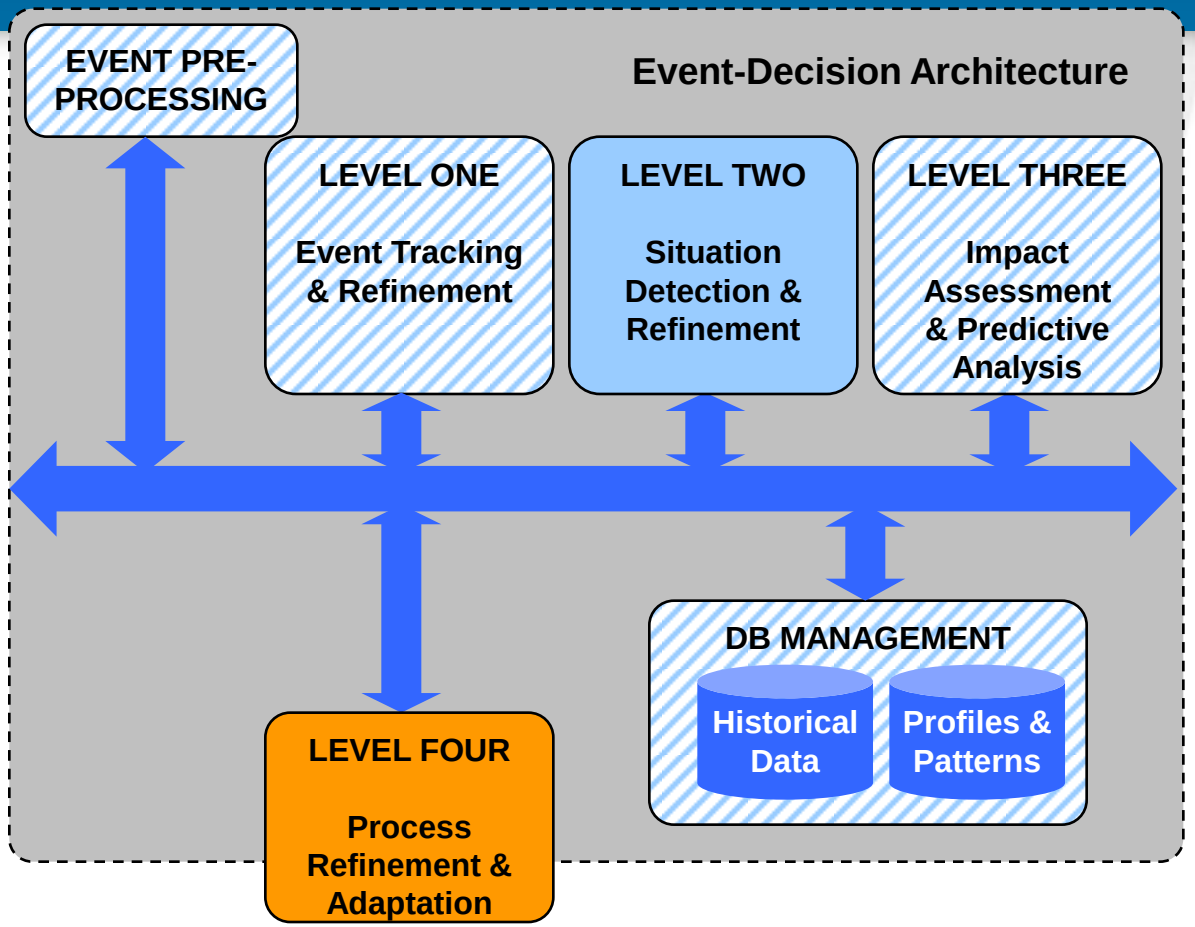
Event Tracking and Refinement Rules

```
If bag X is not on
  prescribed flight
  at (depart – 20)
Then
  move X state to
  MissedFlight
```

Becomes

```
If bag X is not on
  prescribed flight
  at lastBagTime
Then
  move X state to
  MissedFlight
```



Updated by

```
If flight NOT international
Then set lastBagTime to
  carrier's min( DoorCloseTime)
```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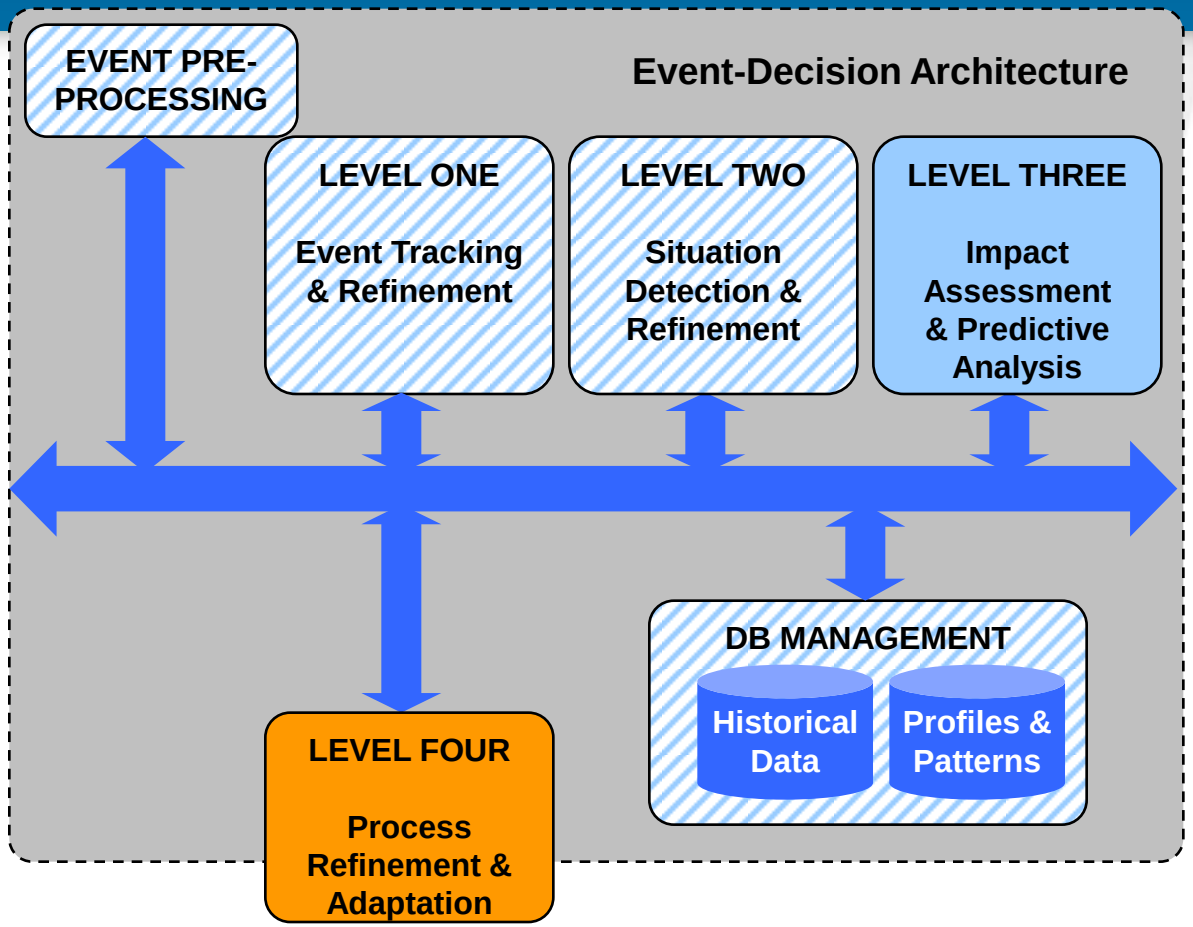
Event Tracking and Refinement Rules

```
If
  product.ShipDelay
  > 1 days
Then
  contactLegal
```

Becomes

```
If
  product.ShipDelay
  > contract.SLA
  MaxDelay -
  AllowedShipLag
Then
  warnLegal
```



Updated by

```
If contract.customer.status = Hi
Then set AllowedShipLag to 2
  days
```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Issues

- **Needs constraints**
  - Eg Cannot reduce discount to <0 or increase above>25
  - Can handle as “change events” and rules to test…
- **Difficult to test**
  - May be based on statistical functions – implies complex test regimes (or test-specific rules)
- **Complex to prove ROI / value**
  - End-user may not be able to source or validate the advanced rules
- **Requires statistical function libraries / analytics**

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Other sources for “advanced rules”

- **Uncertainty**
  - Scoring
- **Generating rules**
  - Machine learning
  - Predictive Analytics
  - Reasoning + Ontologies
- **Other types of rules**
  - Constraint Logic Programming

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Scoring

- Simple technique to handle “variable” decisions
- Rules update a score
- Example: insurance scoring
- Typically handled in a special ruleset (or decision table)
- Good as a KPI in a scorecard
- Typically used with an aggregation rule

Object Property	Condition	Score Effect
Age	<18	-10
Age	19 to 26	-15
Age	27 to 49	+5
Age	50 to 69	0
Age	70+	-5

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Machine Learning

- Given a set of data, deduce classification patterns and hence rules
- Requires sophisticated algorithms

data				result
A	A	A	A	1
A	B	A	B	2
B	A	B	A	3
other	other	other	other	4

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Predictive Analytics

- **Analyze data to deduce segmentation breaks for tasks like customer classifications**
  - Eg: Which customers should be offered what interest rate to maximise profit?
- **Typically using specialist data mining tools**
  - Exports decision tree, rules etc in varieties of PMML
- **Overlaps with BI (eg custom reports on historic data)**
- **Analytical functions may also be mapped to a ruleset in CEP for real-time analytics**

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Reasoning + Ontologies

- **“Semantic Event Processing”**
- **Use Semantic Web technologies to augment CEP**
  - Textual news etc analysis
  - Use of deeper ontology relationships
- **Example components**
  - OMG Ontology Definition Metamodel ODM joins W3C OWL to UML concept models
  - OWL, RDF, RDFS for terminology, relationships
  - Logic languages/rules to reason about truth over event types and metadata

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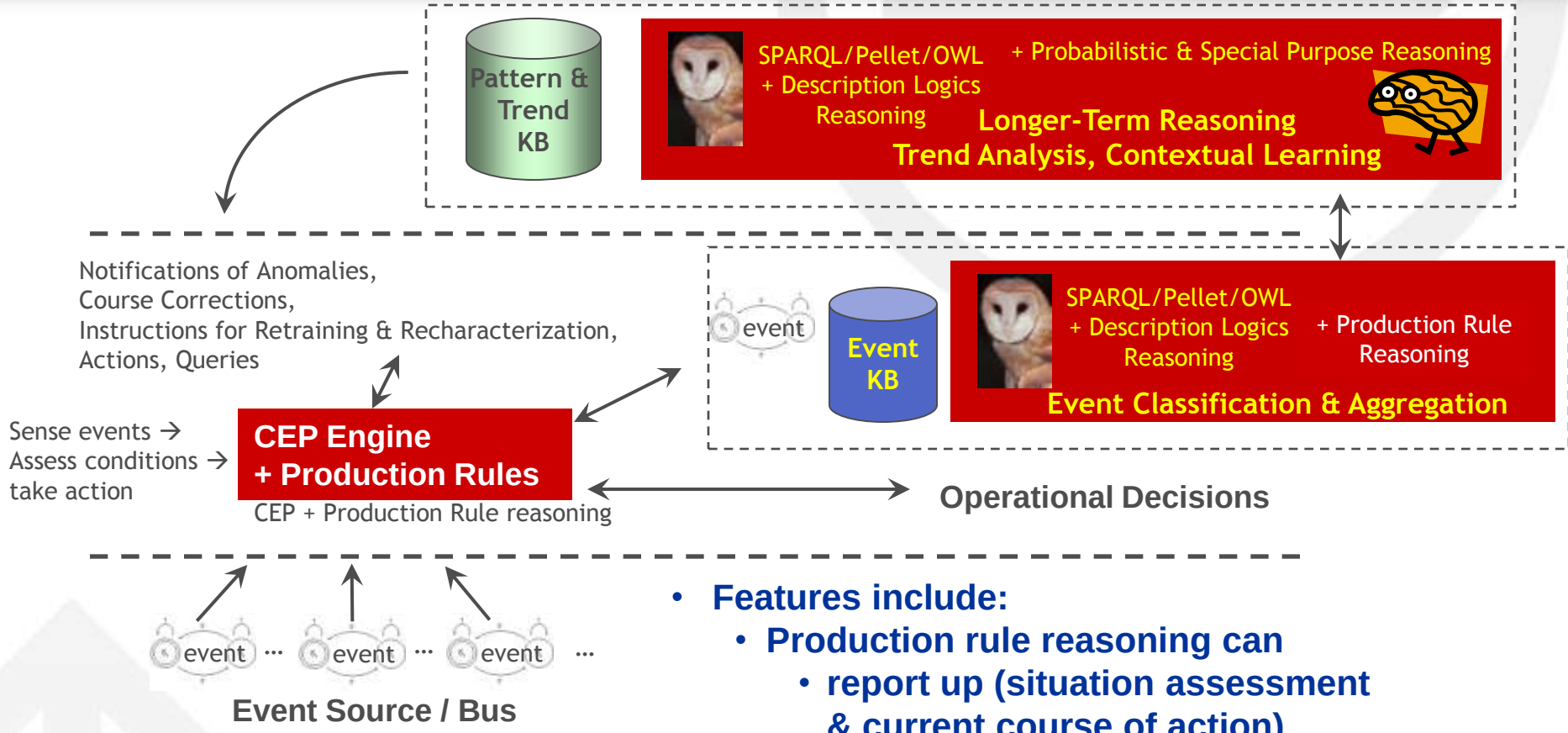
Example: Semantic Technology to Refine CEP

Semantic Networking Event Monitoring Architecture



- **Features include:**
  - **Production rule reasoning can**
    - **report up (situation assessment & current course of action)**
    - **report laterally (situation assessment, & sensed changes, etc.)**
    - **report down (initiating actions, querying)**
  - **Adaptive capabilities are possible at all levels**

-- courtesy of Sandpiper Software

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Constraint Logic Programming

- **Constraint rules for systems**
- **Constraint solver to find best values (eg optimize price)**
  - With response time as a system constraint!
  - Goal-driven
- **Uses:**
  - Maximizing value of inventory
  - Scheduling the best routes for trucks
  - Maximizing probability for SLA achievement

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Agenda

- **The End**

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Agenda

- Q & A

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APPENDICES

A. Appendices & Back-up Information

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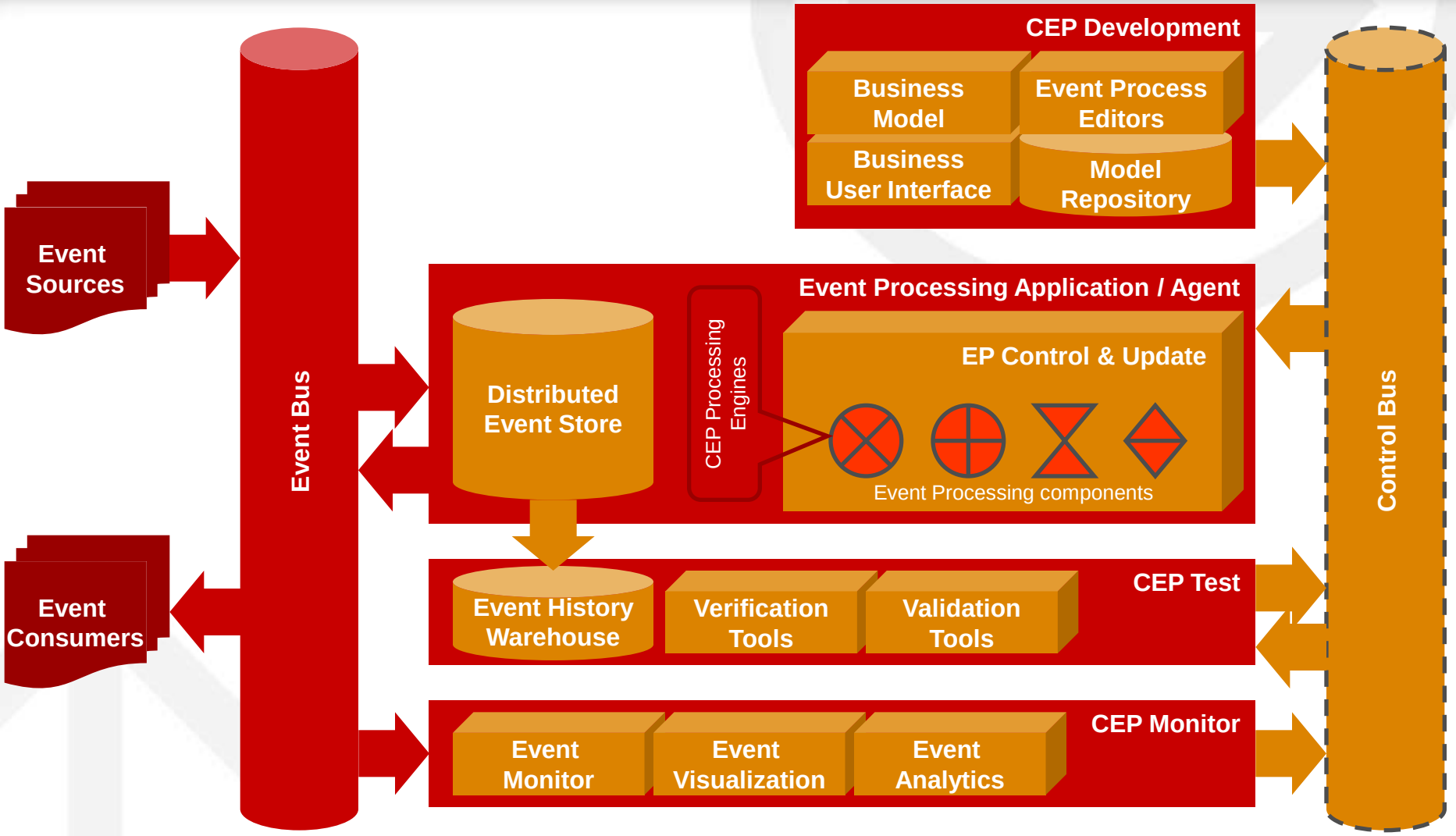
Appendix: Generalized Architecture for CEP



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Appendix: Useful web resources

- **Event Processing Technical Society EPTS**
  www.ep-ts.com
- **Luckham's web site**
  complexevents.com
- **Various vendor blogs (reference from complexevents.com)**

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