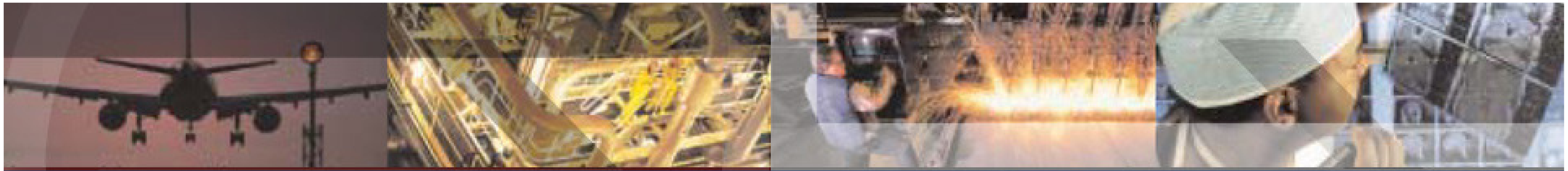


OBJECT MANAGEMENT GROUP

Workshop on Distributed Object Computing for Real-time and Embedded Systems

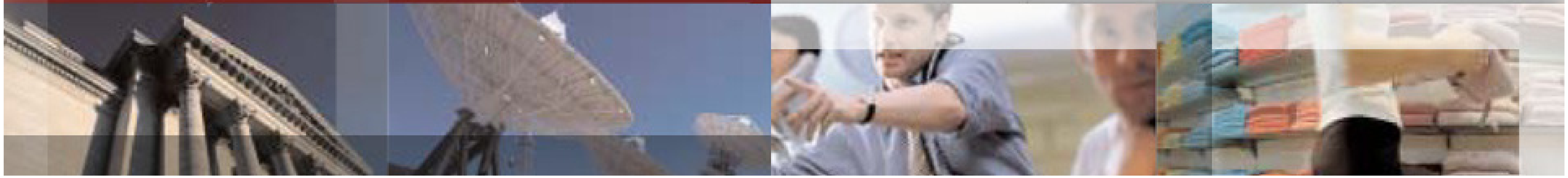
July 14 – 16, 2008, Washington, DC, USA

TIBCO®

The Power of Now®

Complex Event Processing Tutorial

Paul Vincent
TIBCO Software Inc.



Presenter

- **Presenter:**
  Paul Vincent, CTO Business Rules and CEP, TIBCO Software
  - 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
  - Headquartered in Palo Alto, California
  - Over 3,000 customers and offices in 40 countries
  - CEP product is TIBCO BusinessEvents
    - Developed from a customer solution and launched 2005
    - Currently at Release 3.0

Agenda

- Introducing CEP

Real-world Events

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

Contract Returned thru EDI

Rental Car Crashed

Rental Car Returned

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

Cell phone
fraud alert

Employee
Over hours

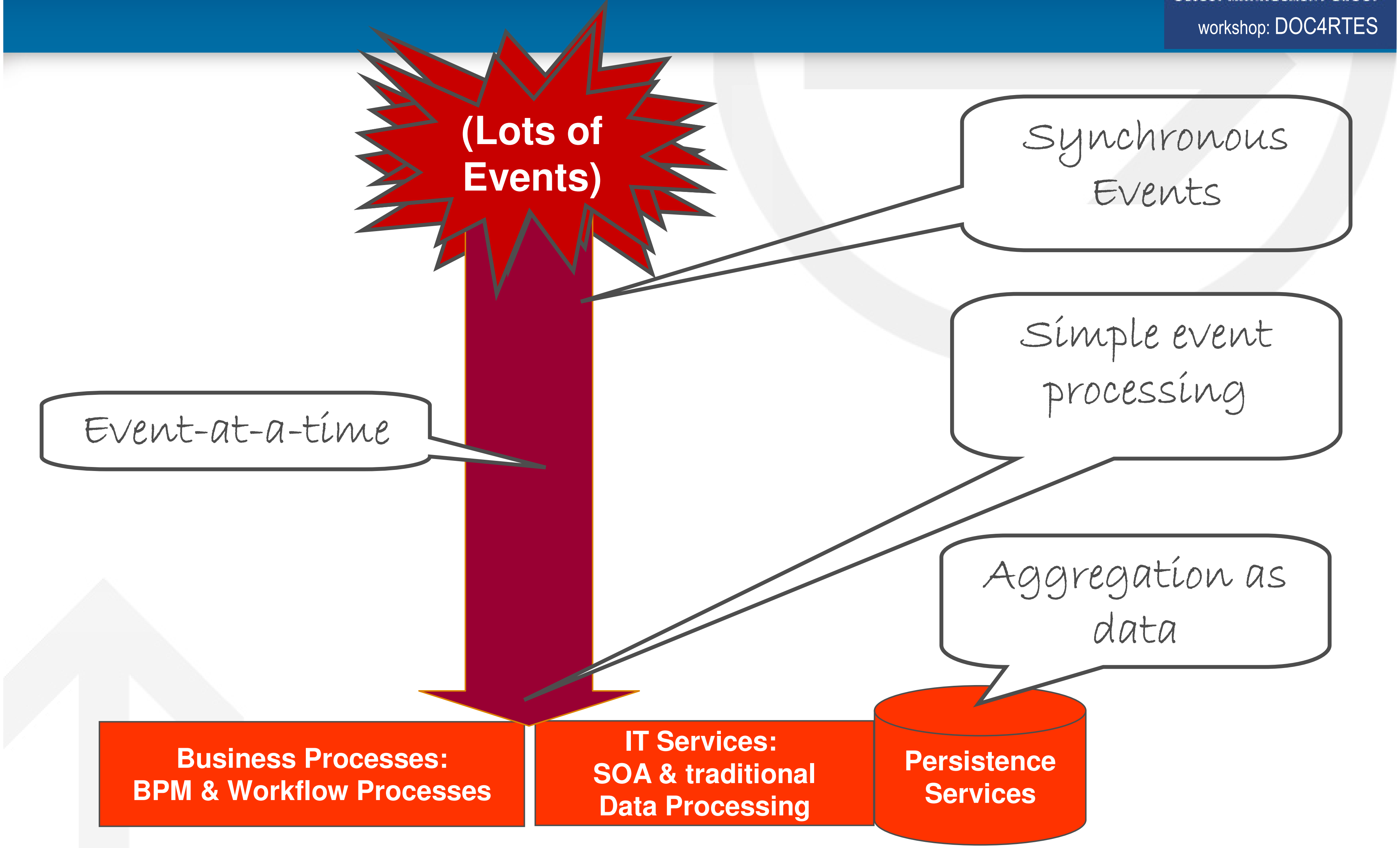
Compliance
Limit
Approached

Contract
Valid

Rental
Contract
Complete

Customer
now rated
Gold

Conventional Event Processing



Simple EP = default IT Model, 1950-now

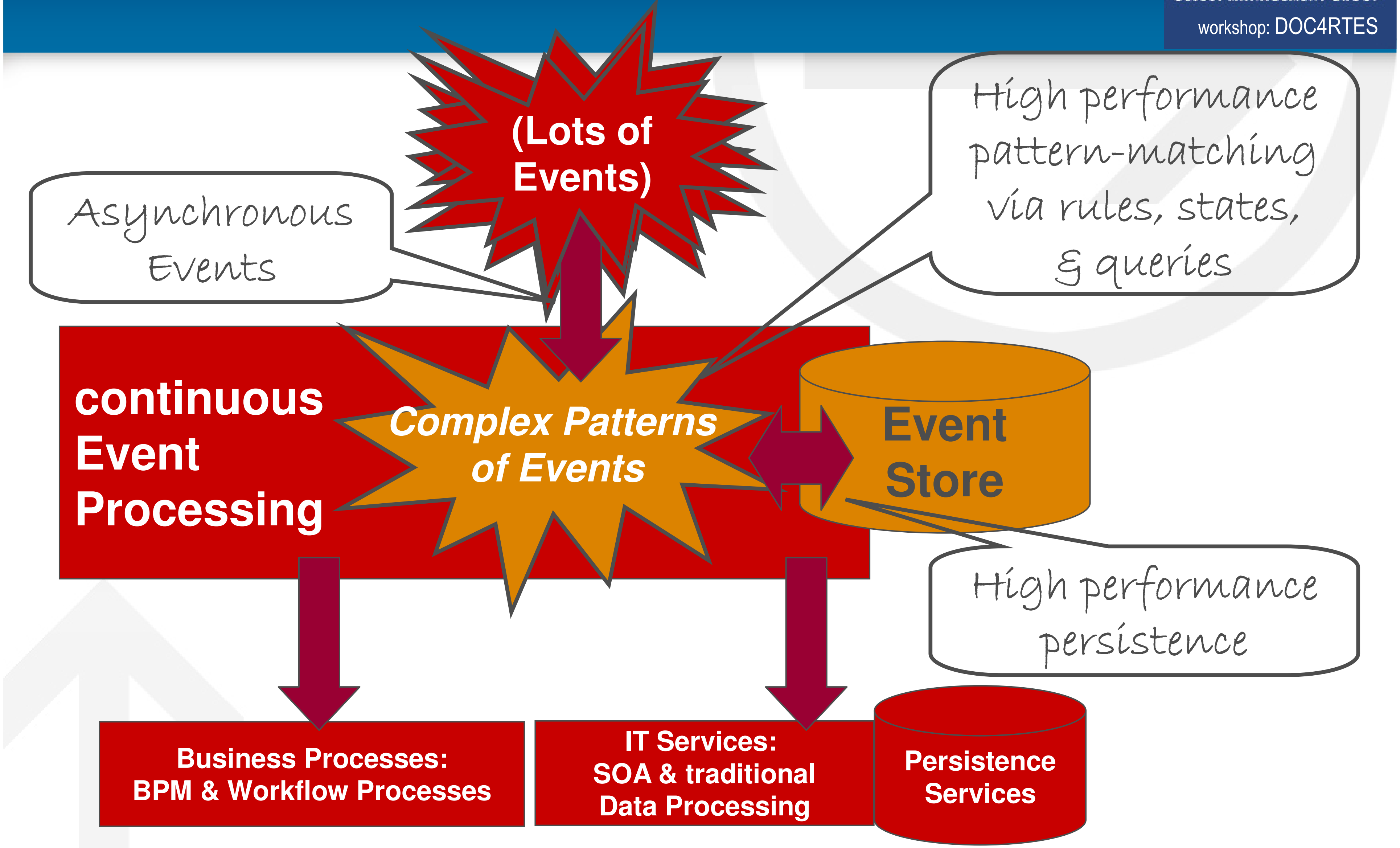
- **Based on “human workflow”: one thing at a time**
  - Processes handle cases 1 at a time ← office clerk
  - Use database and refer to it where necessary ← card index
  - Provide some service flexibility with middleware ← internal mail
  - Use BPM to document / manage / automate processes
  - Use SOA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

This model does NOT exploit
ALL the information / data / events
ALL the time

Behaviour (and business logic) is silo’d

There is a better way!

Complex Event Processing



(Lots of Events)

Asynchronous Events

High performance pattern-matching via rules, states, & queries

continuous Event Processing

Complex Patterns of Events

Event Store

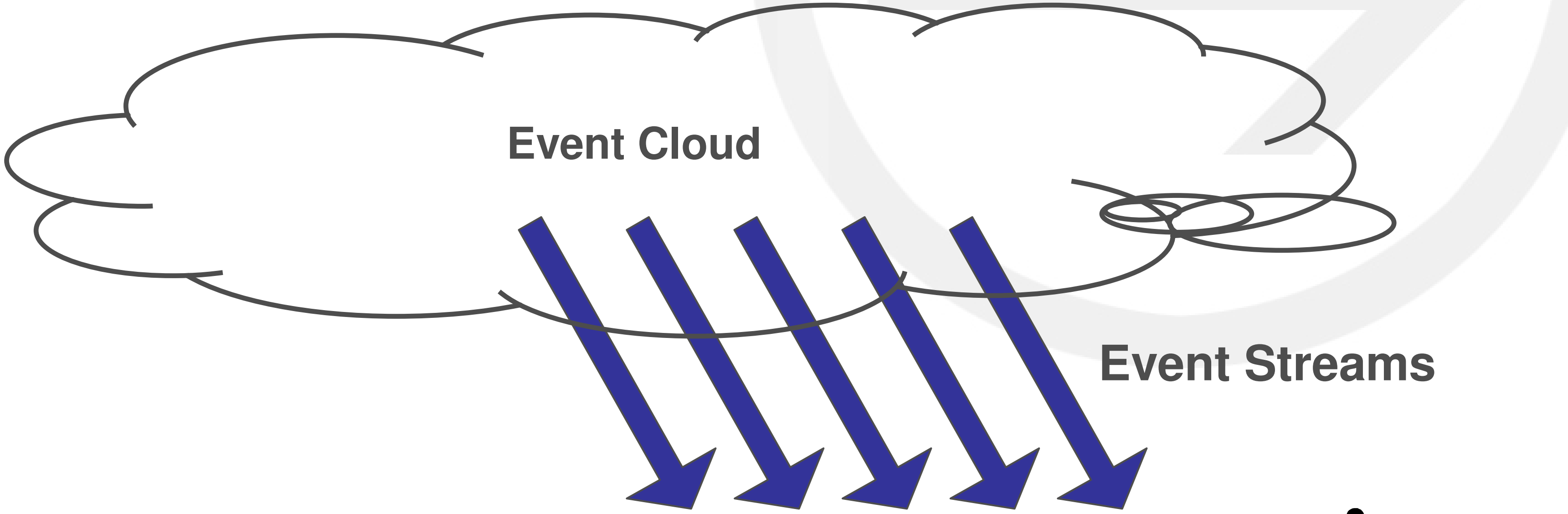
High performance persistence

Business Processes: BPM & Workflow Processes

IT Services: SOA & traditional Data Processing

Persistence Services

CEP Terminology

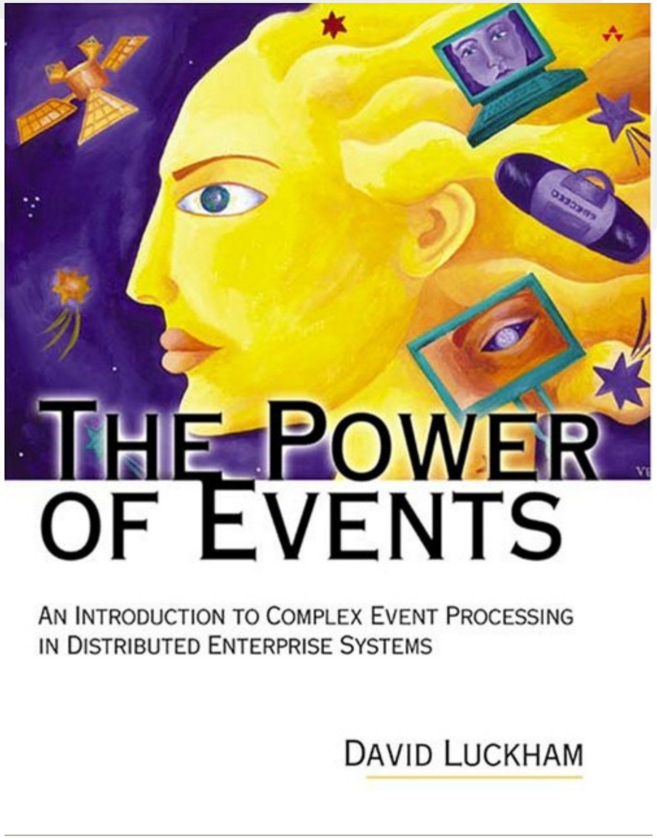


- CEP (technology) applies pattern detection & filtering to the event clouds & streams and their histories
- Multiple modelling / execution paradigms are available for pattern detection

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
AN INTRODUCTION TO COMPLEX EVENT PROCESSING IN DISTRIBUTED ENTERPRISE SYSTEMS
DAVID LUCKHAM

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

What does CEP Solve?

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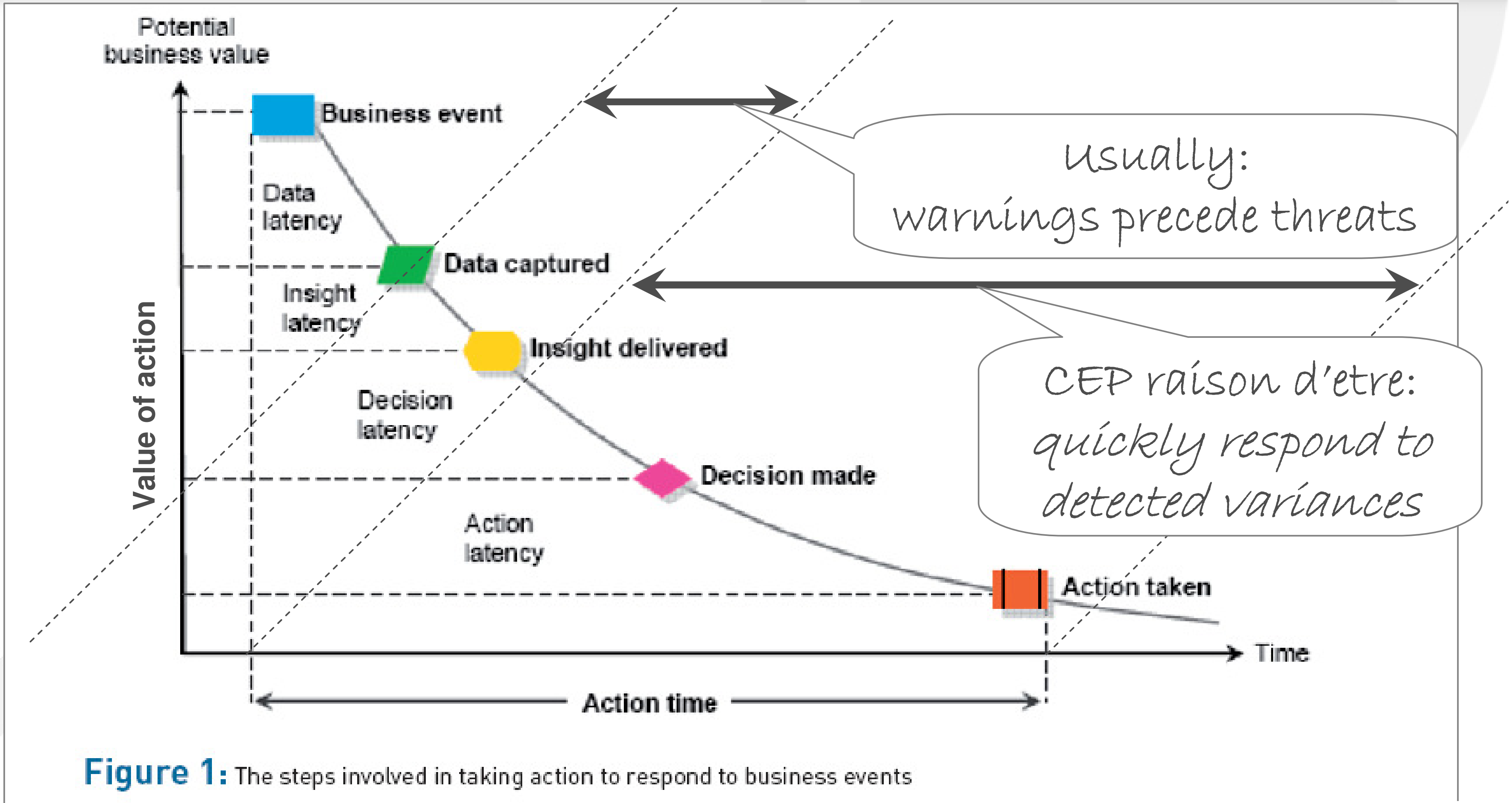


usually: warnings precede threats

CEP raison d'etre: quickly respond to detected variances

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

the "Latency Problem"

What CEP provides

“Situational Awareness”

“Sense and Respond”

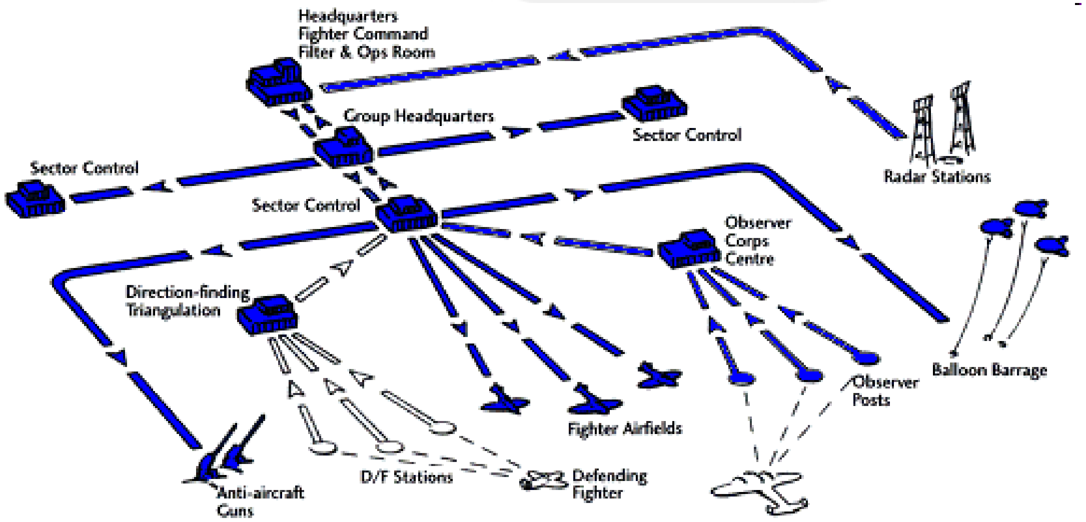
“Track and Trace”

Agenda

- History

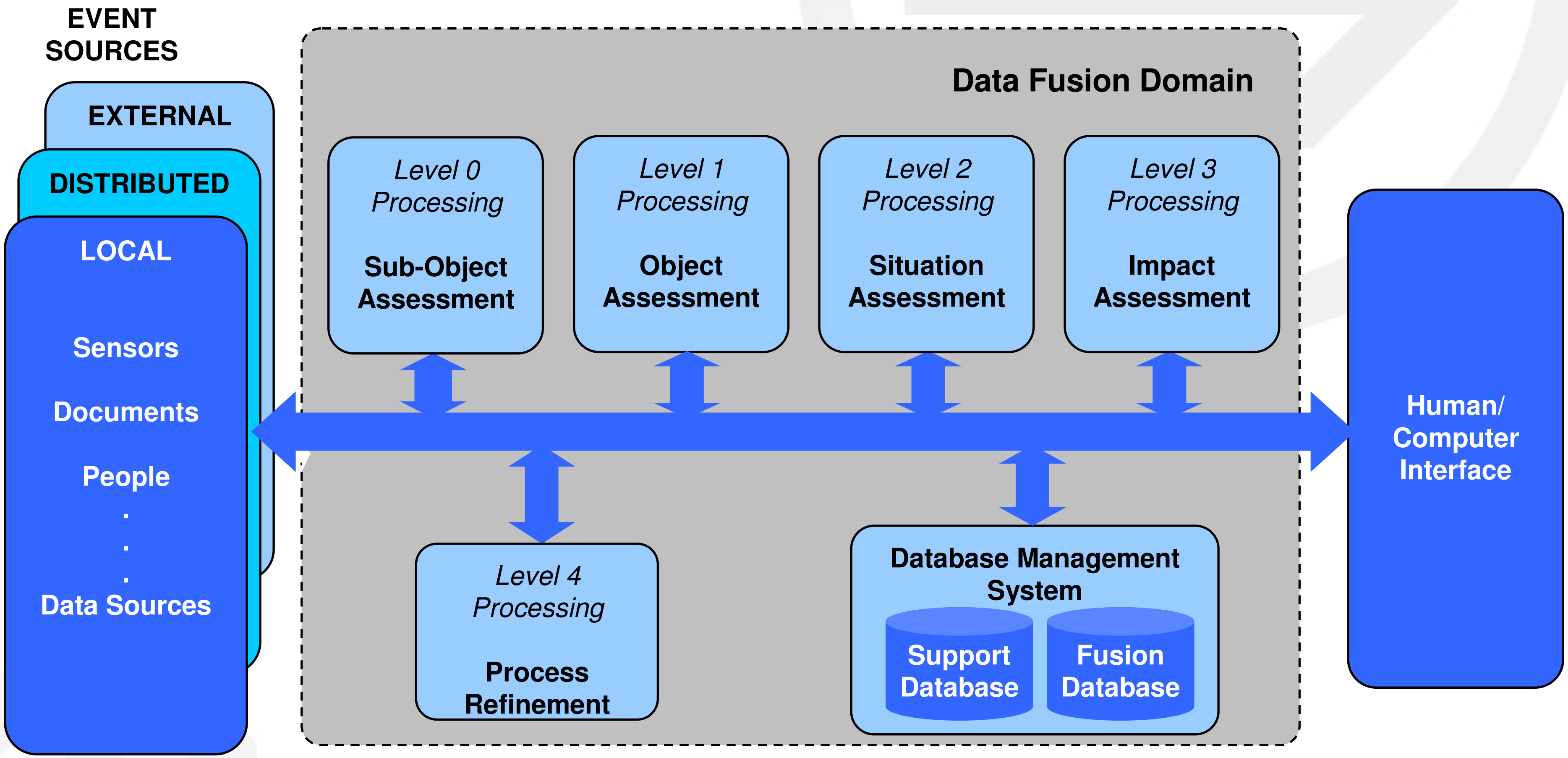
Command and Control

- **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

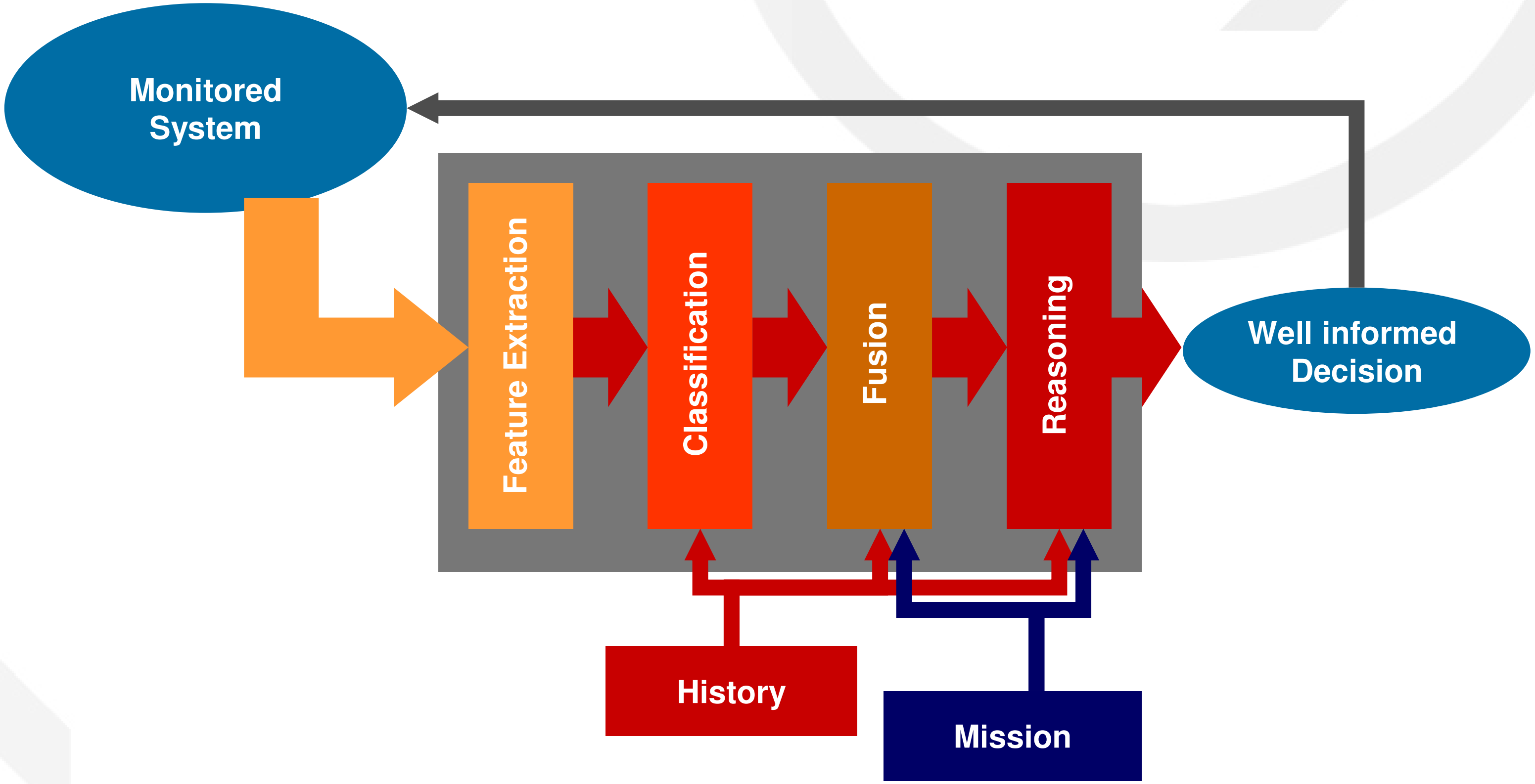
Data Fusion



-- Revised JDL data fusion model, 1998

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

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

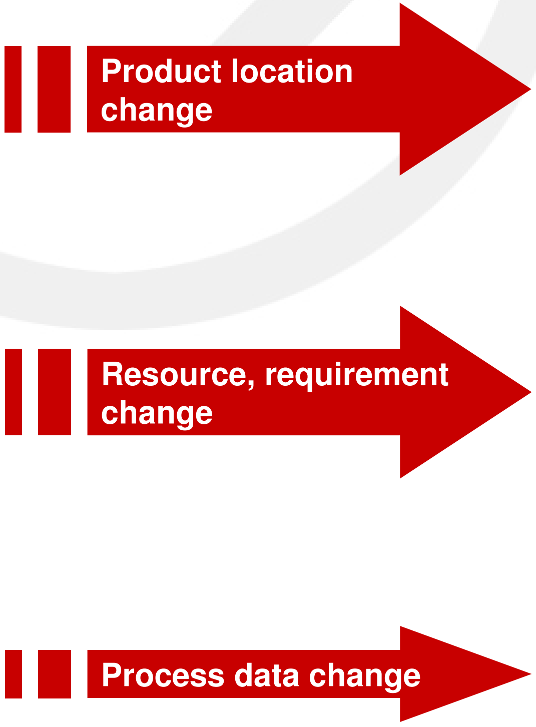
Agenda

- Events and CEP

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?

Relevant event of interest



Product location change

Resource, requirement change

Process data change

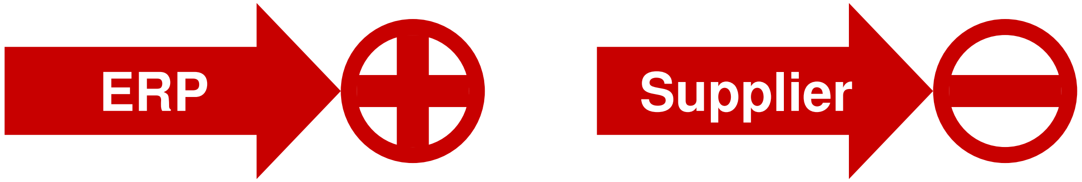
Associated Events

- **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 %

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

15:39:26.413
Dec 24



What *is* an “event”?

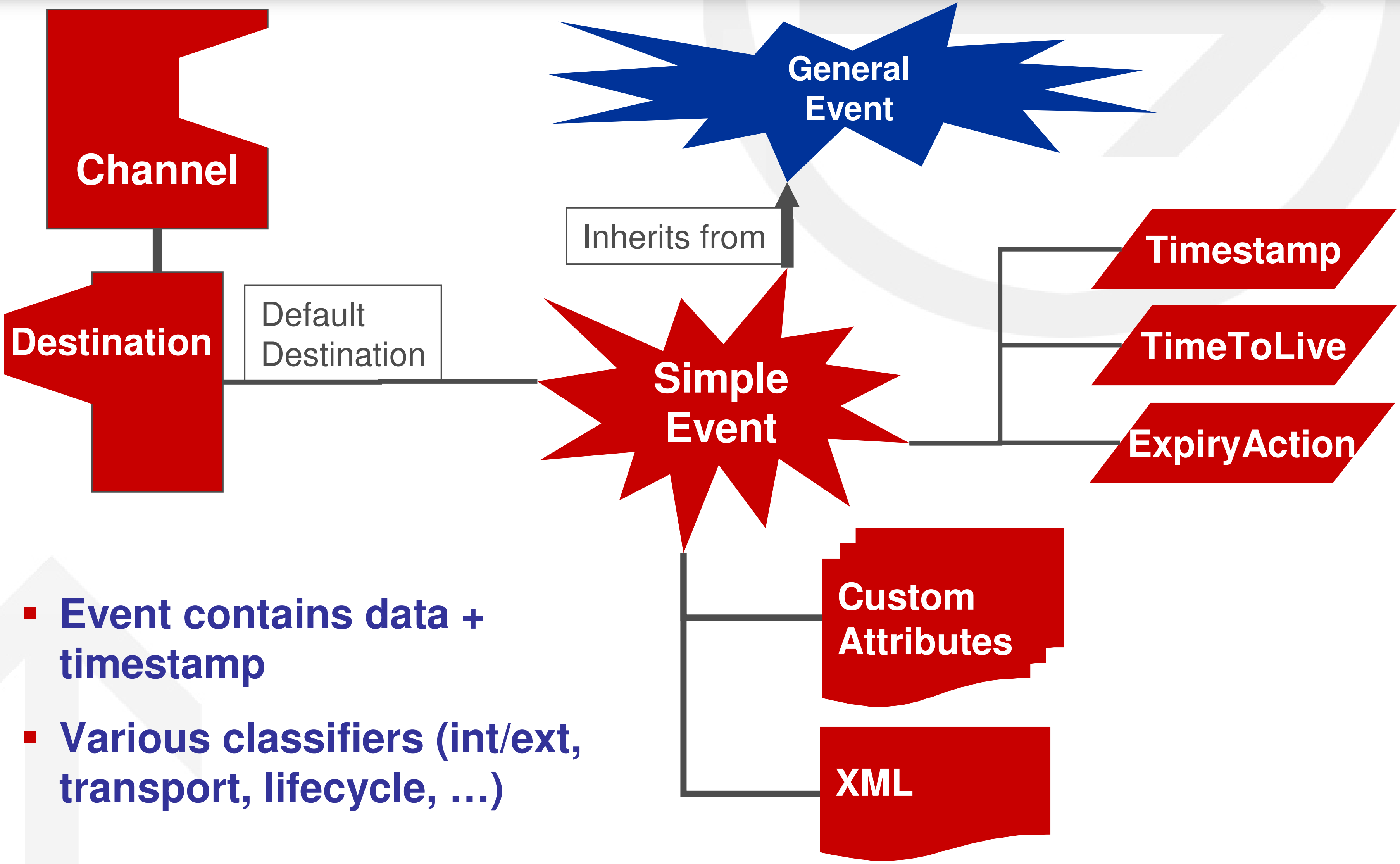
- **Change of state in some entity**
  - Customer call
  - Bank debit
  - Aircraft movement
- **Observation of some entity**
  - CRM record of a customer call
  - ATM report of debit transaction success
  - Radar plot update of an aircraft
- **IT Message**
  - Queued point-to-point message
  - Publish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

“Happening”

Observation

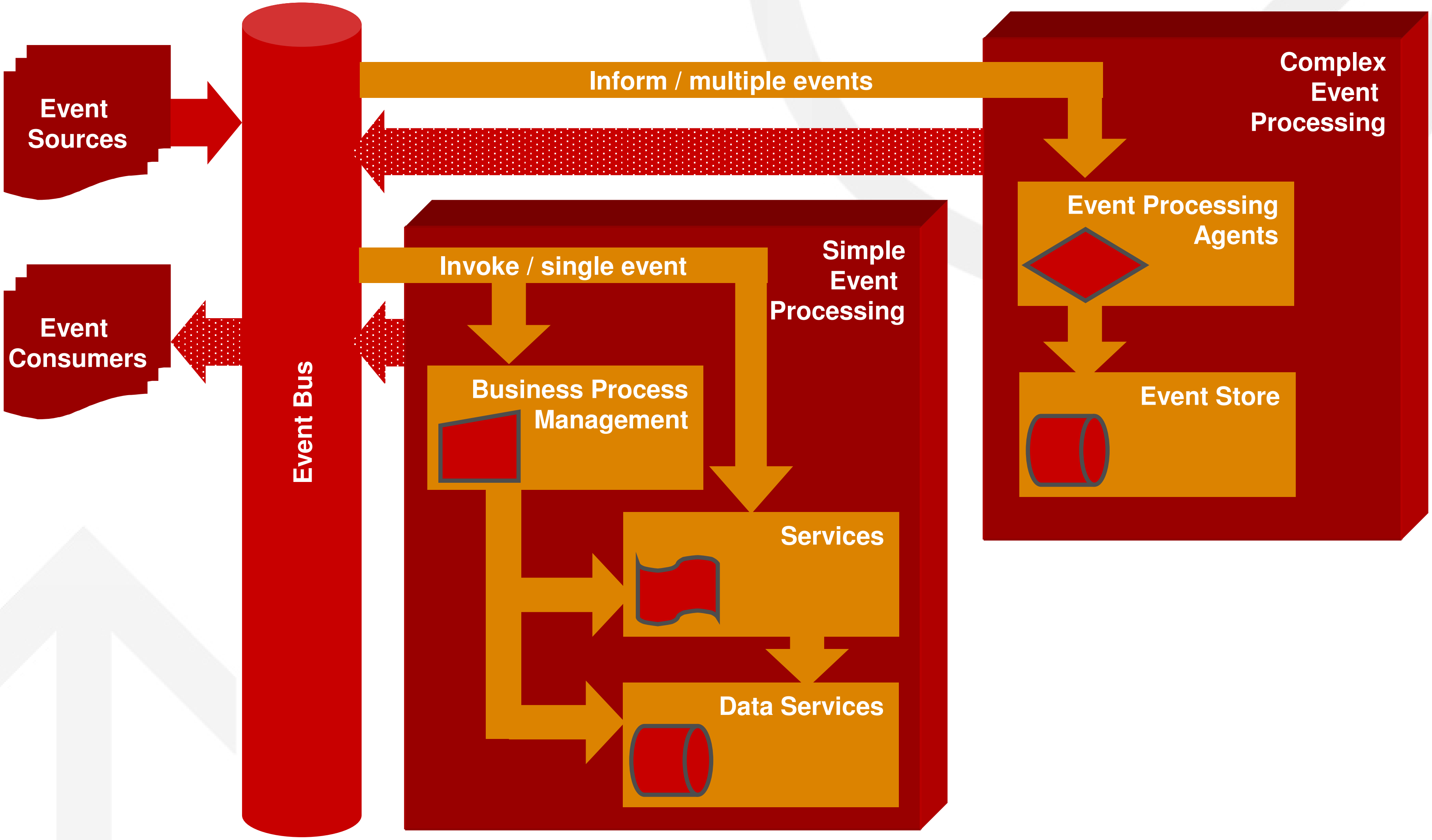
IT Message

Sample Event Metamodel



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

Event-driven vs Event Processing



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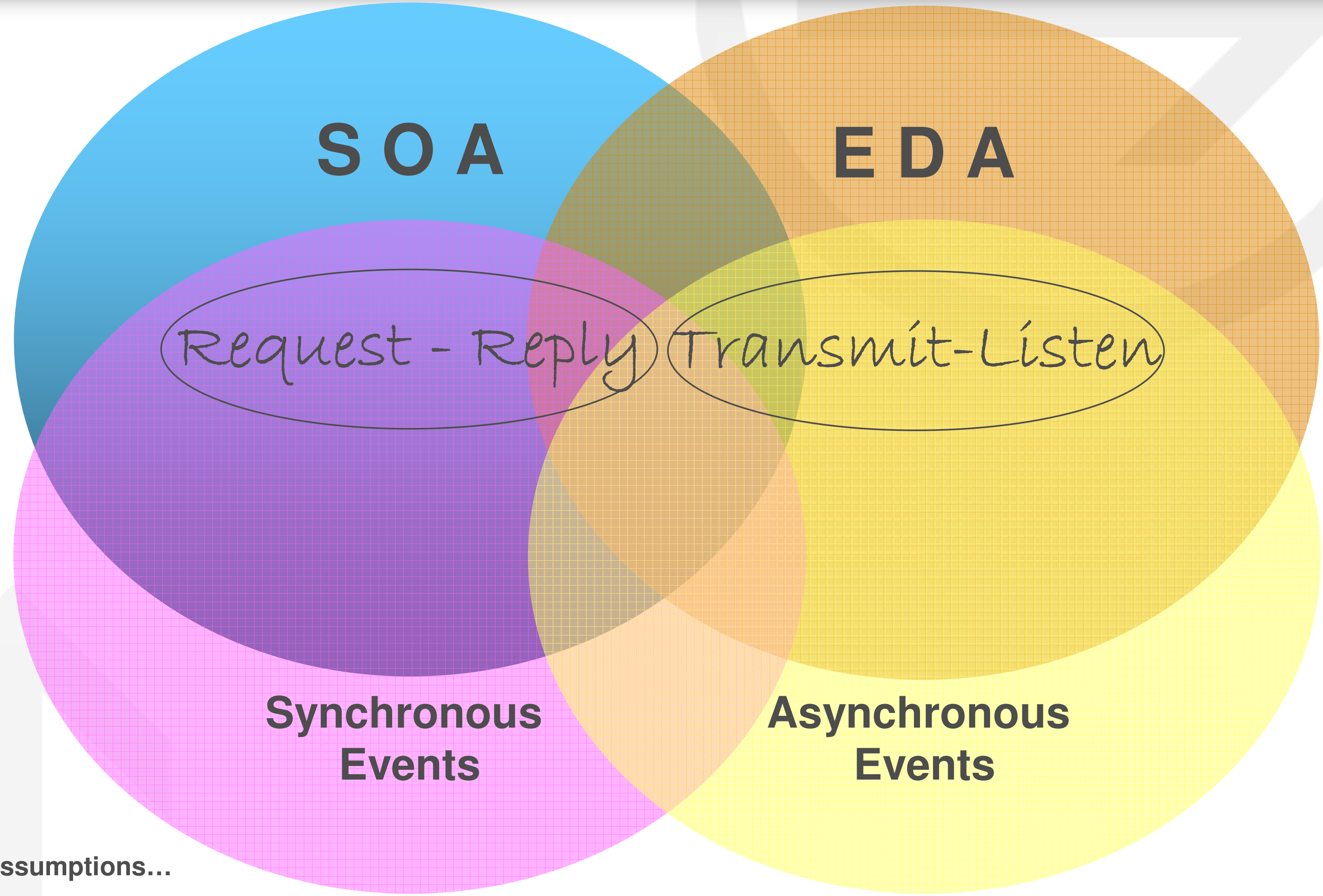
Event Driven Architecture



Assumptions…

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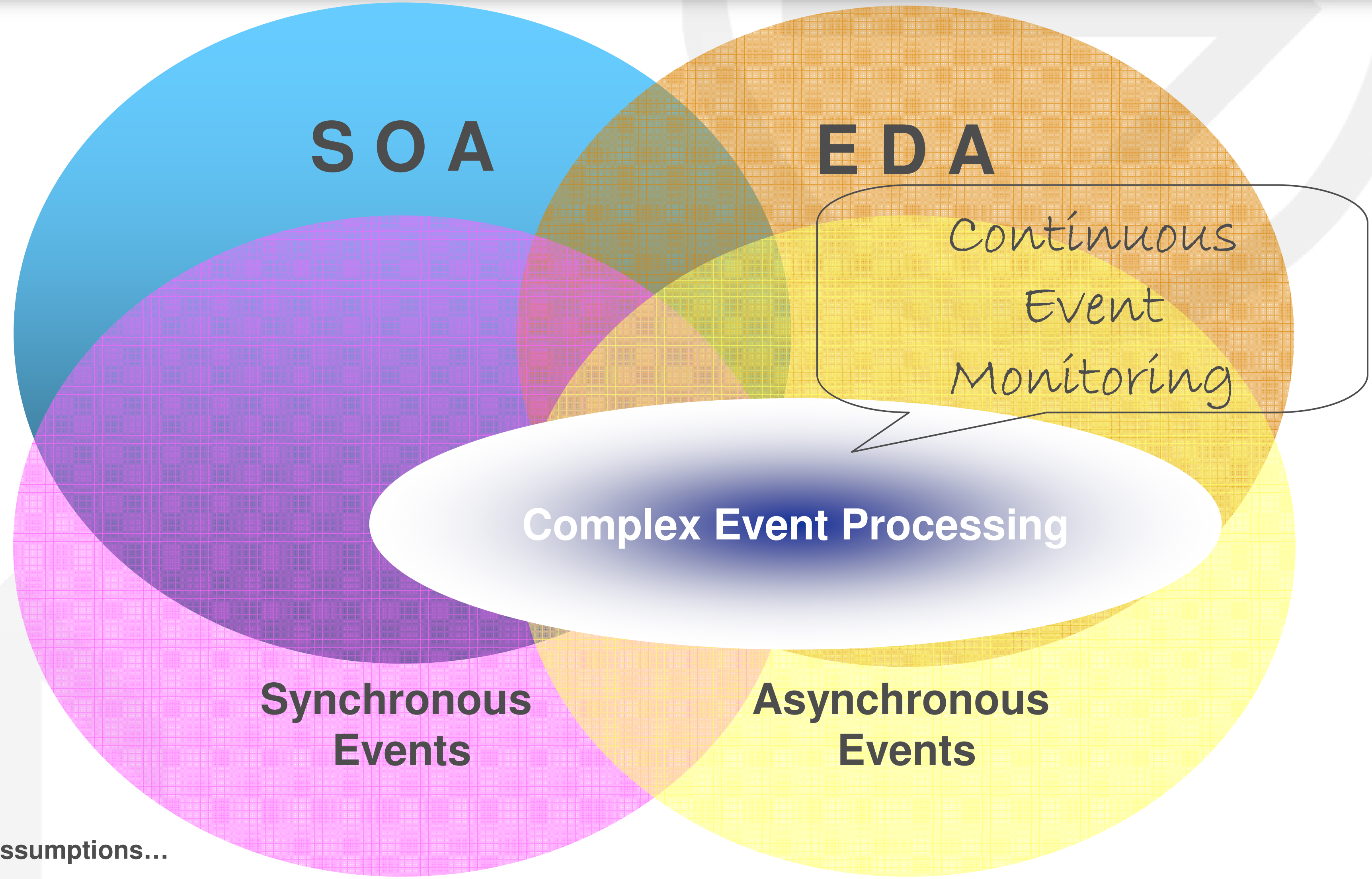
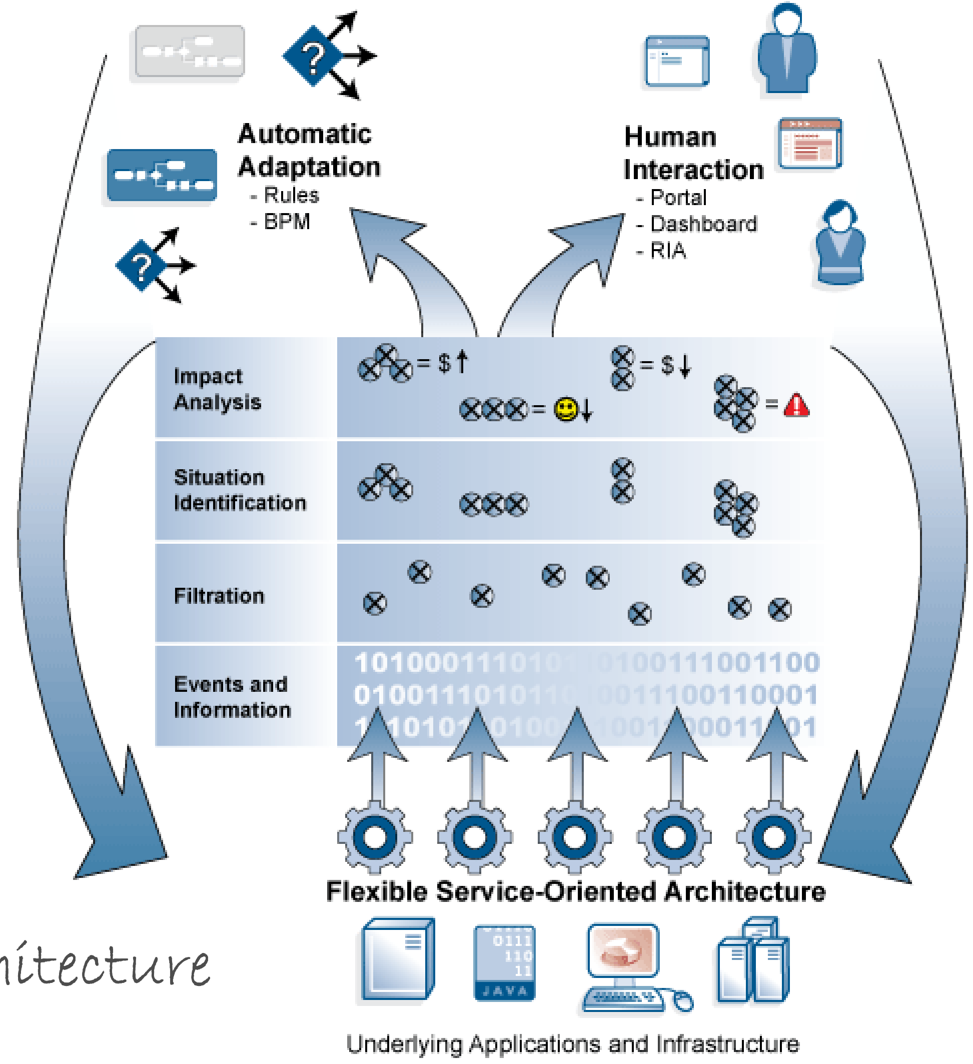
CEP in the Event Driven Architecture



Assumptions…

Complex Event Processing

Sense and Respond / Track and Trace / Situational Awareness



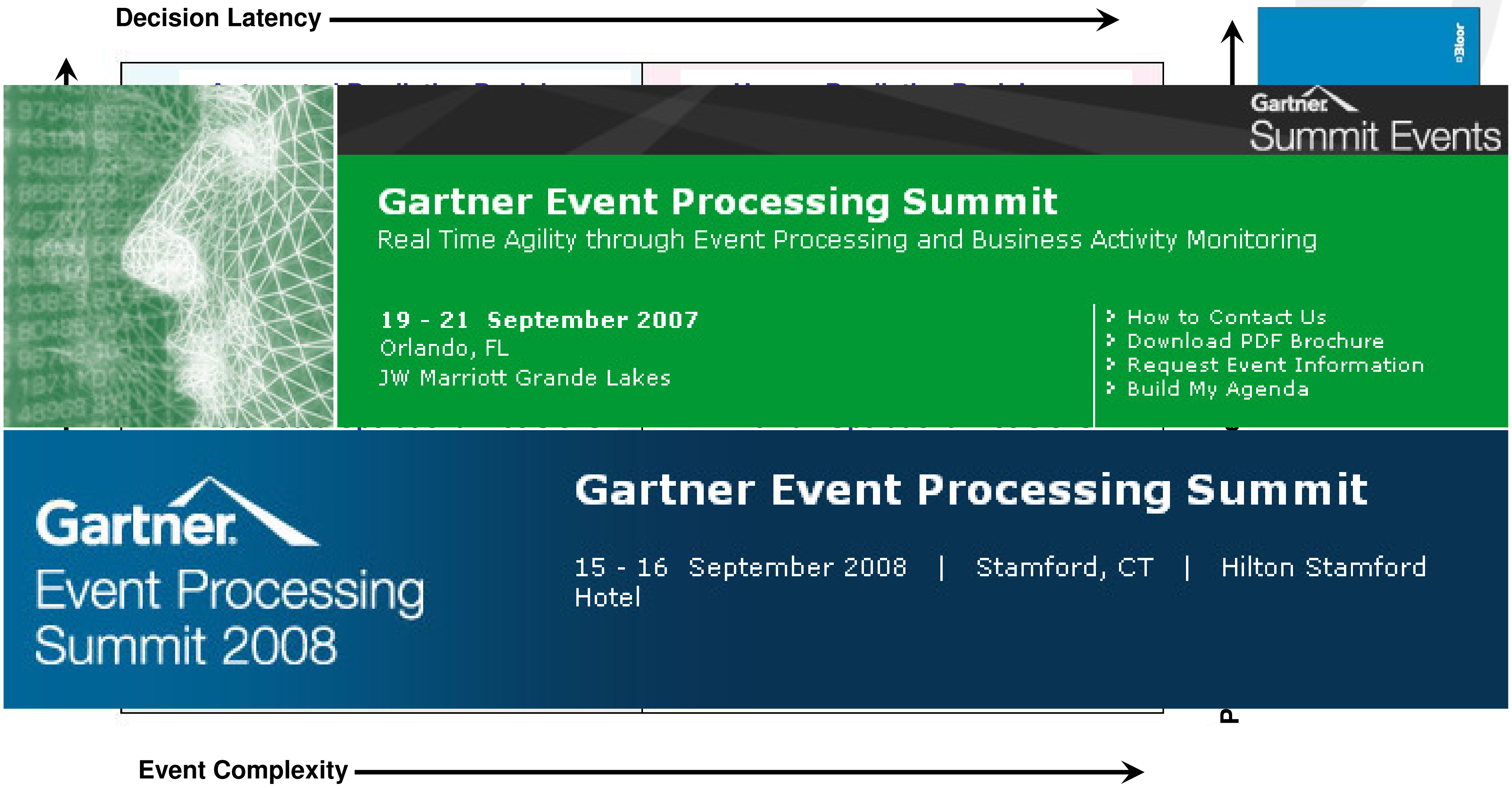
Processing type:

Decision Processing

Event Processing

TIBCO Reference Architecture

Analysts on CEP



Gartner Summit Events

Gartner Event Processing Summit

Real Time Agility through Event Processing and Business Activity Monitoring

19 - 21 September 2007
Orlando, FL
JW Marriott Grande Lakes

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Gartner
Event Processing
Summit 2008

Gartner Event Processing Summit

15 - 16 September 2008 | Stamford, CT | Hilton Stamford Hotel

Why CEP?

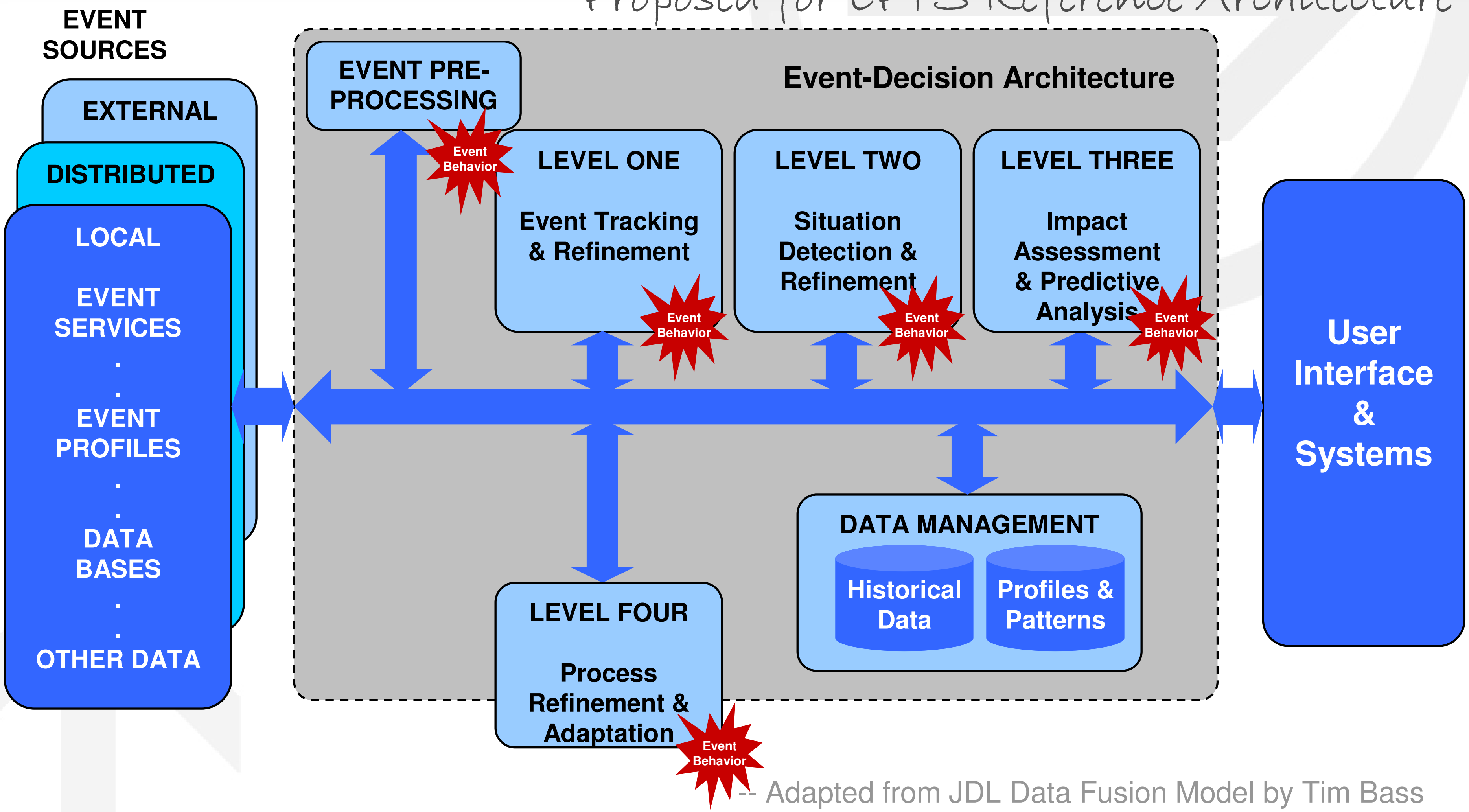
- **Detecting event patterns across multiple event types + time is difficult for simple event processing solutions**
- **Computers can correlate across large volumes of events at high speed, identifying patterns that are not conventionally visible**
- **The architecture pattern of “continuous event processing” 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

Agenda

- CEP Technologies

CEP = an Event-Decision Architecture

Proposed for EPTS Reference Architecture

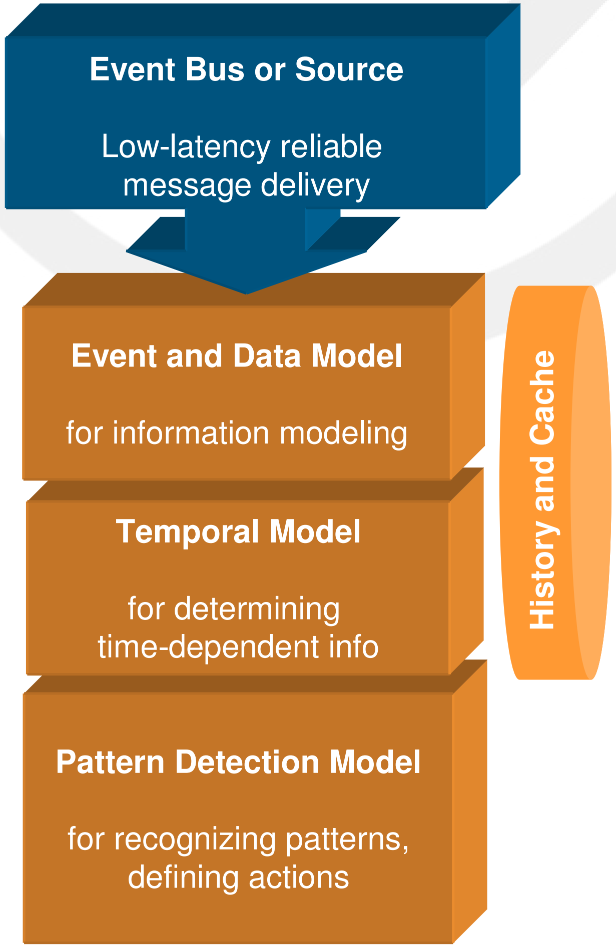


-- Adapted from JDL Data Fusion Model by Tim Bass
Steinberg, A., & Bowman, C., Handbook of Multisensor Data Fusion, CRC Press, 2001

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



Event Bus or Source

Low-latency reliable message delivery

Event and Data Model

for information modeling

Temporal Model

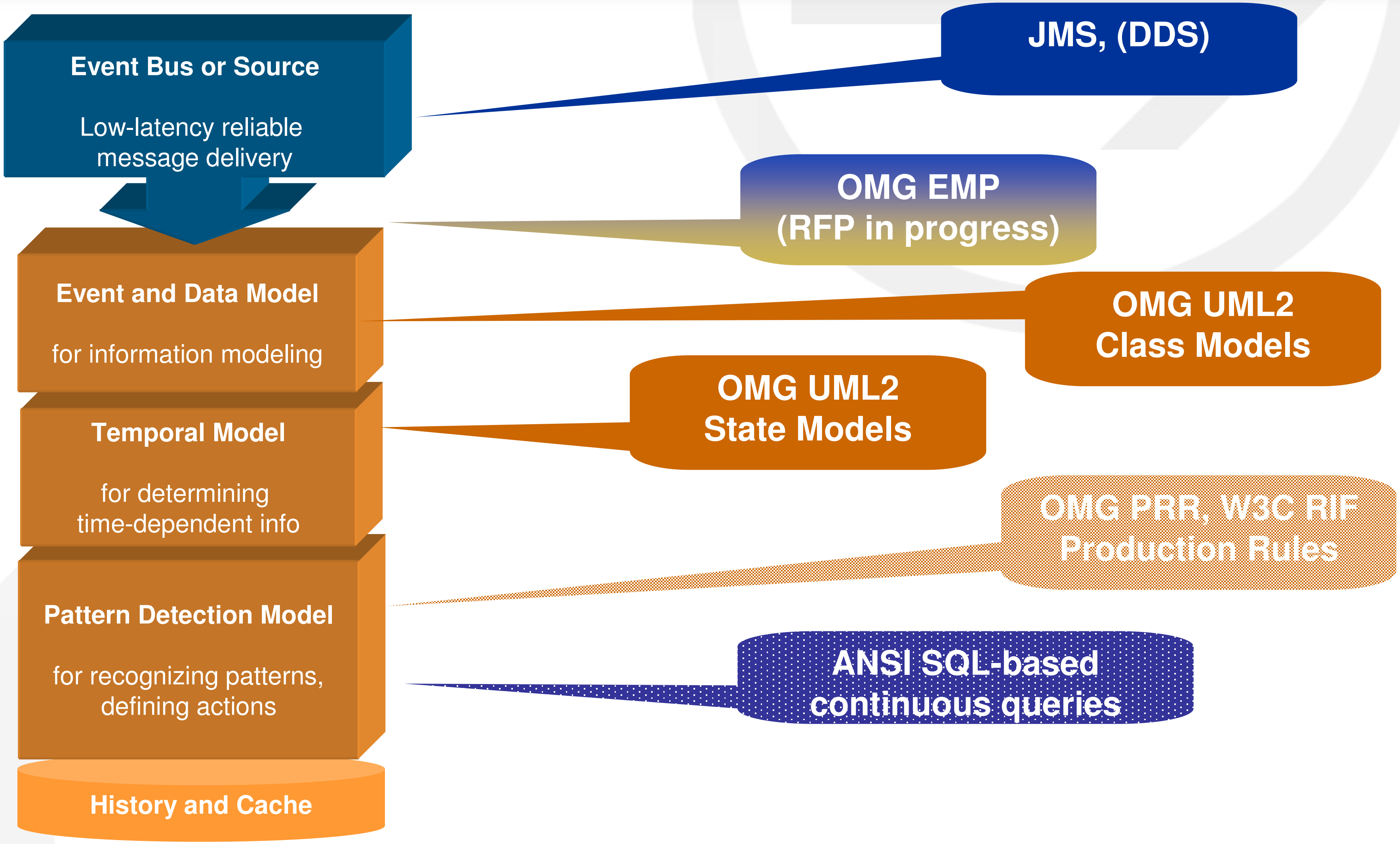
for determining time-dependent info

Pattern Detection Model

for recognizing patterns, defining actions

History and Cache

CEP-Related Standards



* = in devt

Example CEP Technologies

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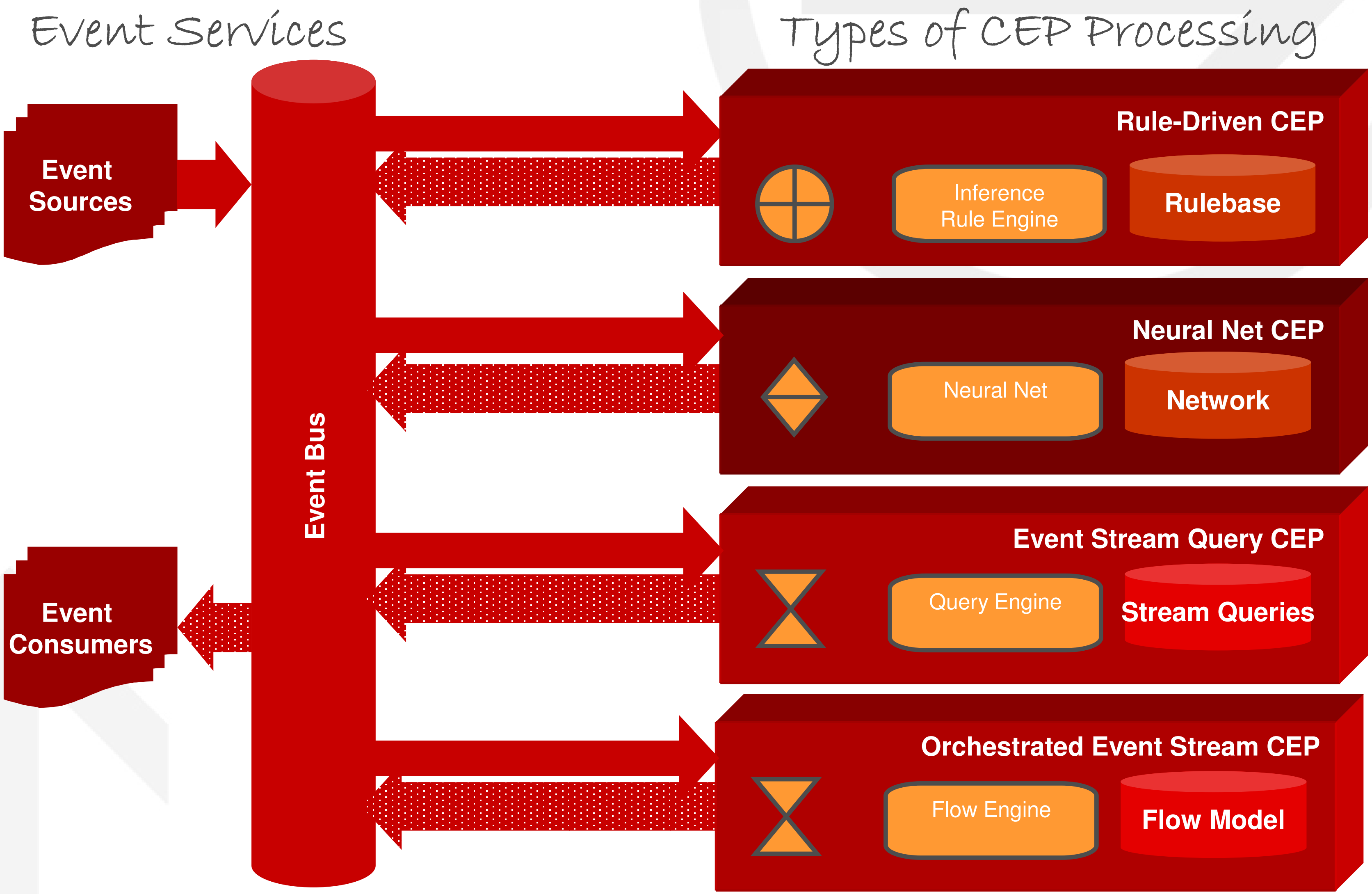

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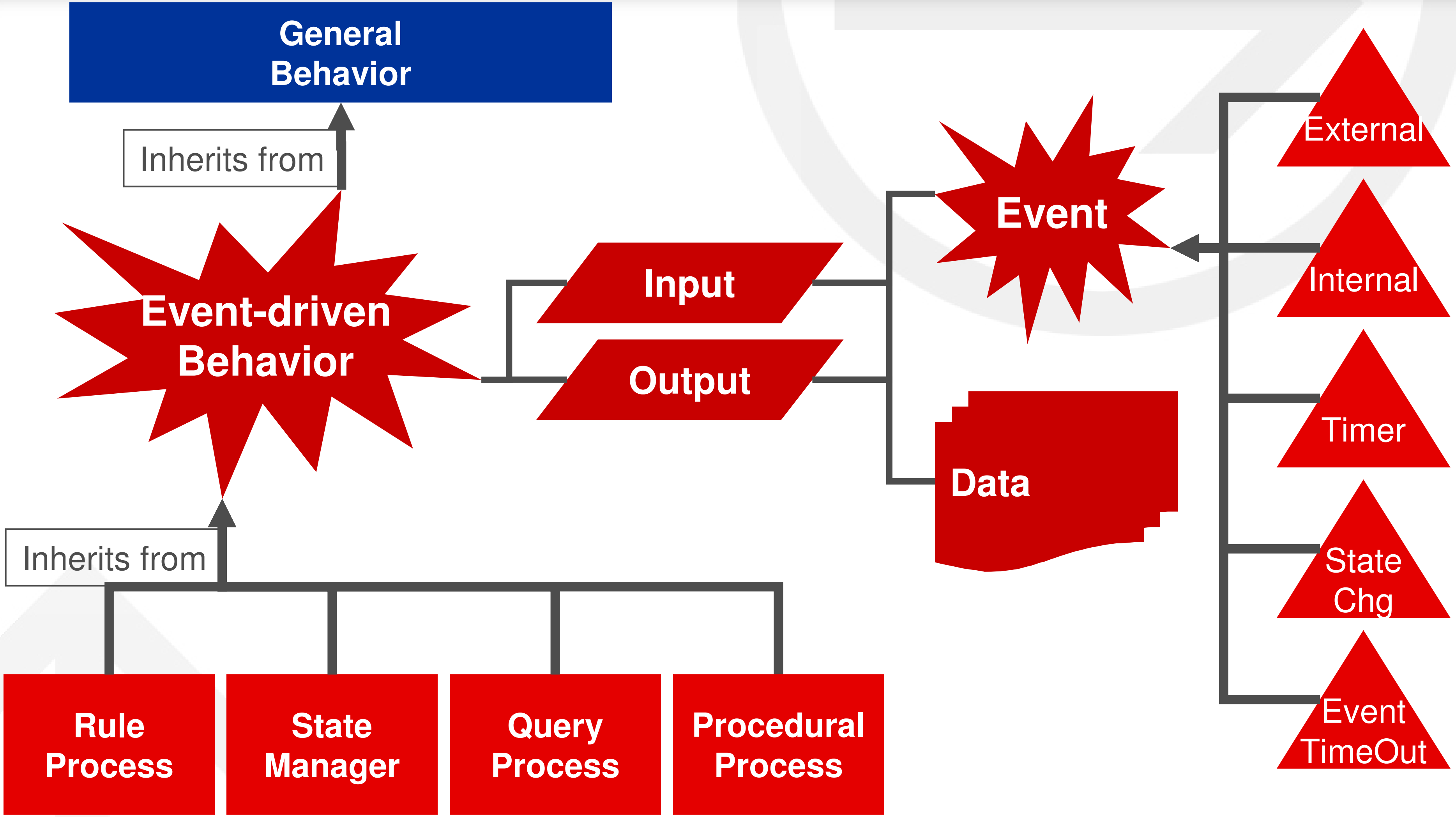
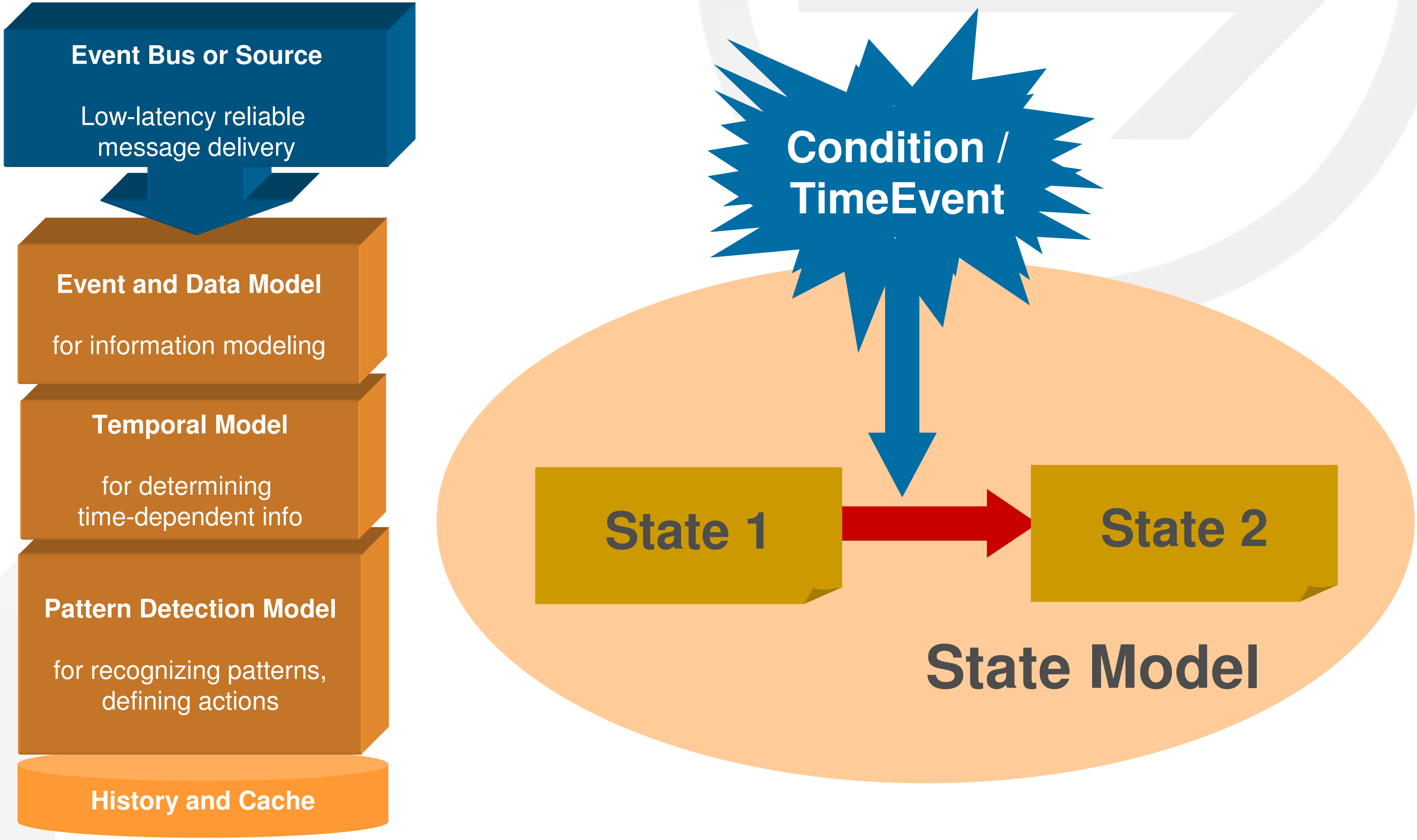
Sample Event Processing Metamodel



CEP Behavior: State-oriented



Event Bus or Source

Low-latency reliable message delivery

Event and Data Model

for information modeling

Temporal Model

for determining time-dependent info

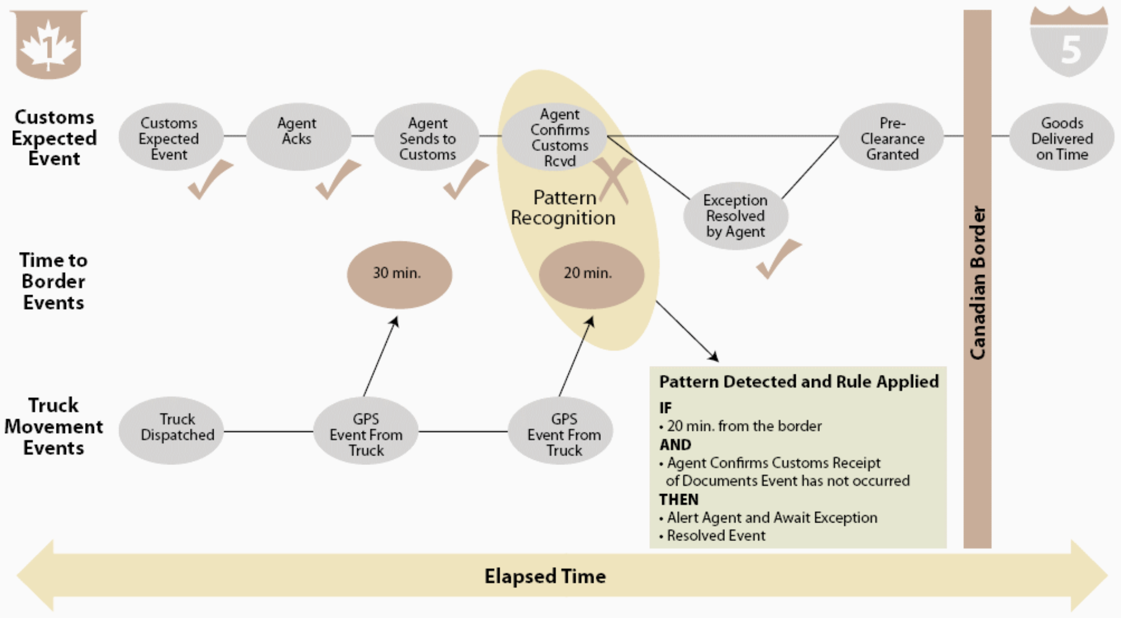
Pattern Detection Model

for recognizing patterns, defining actions

History and Cache

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



Pattern Detected and Rule Applied

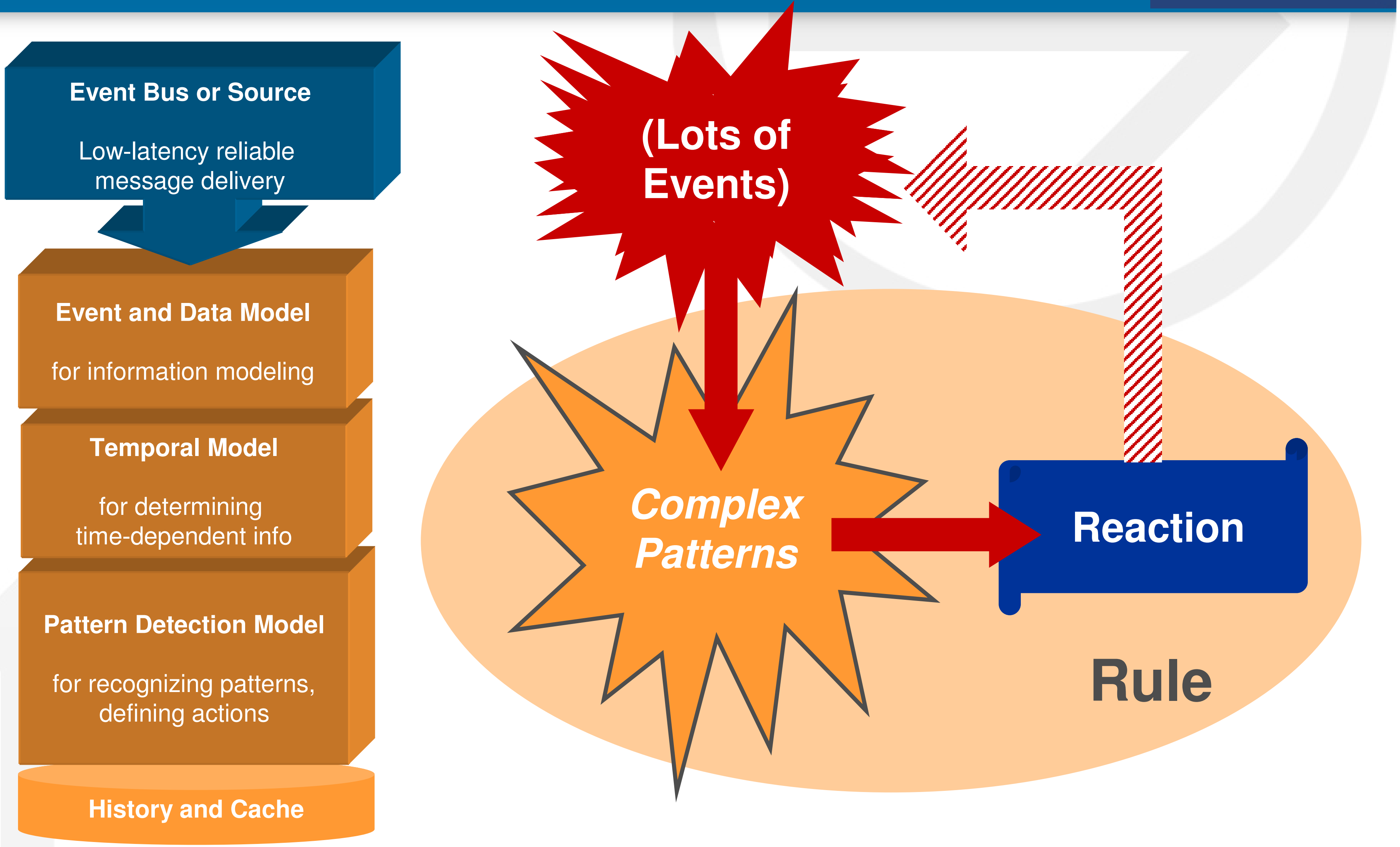
IF
- 20 min. from the border

AND
- Agent Confirms Customs Receipt of Documents Event has not occurred

THEN
- Alert Agent and Await Exception
- Resolved Event

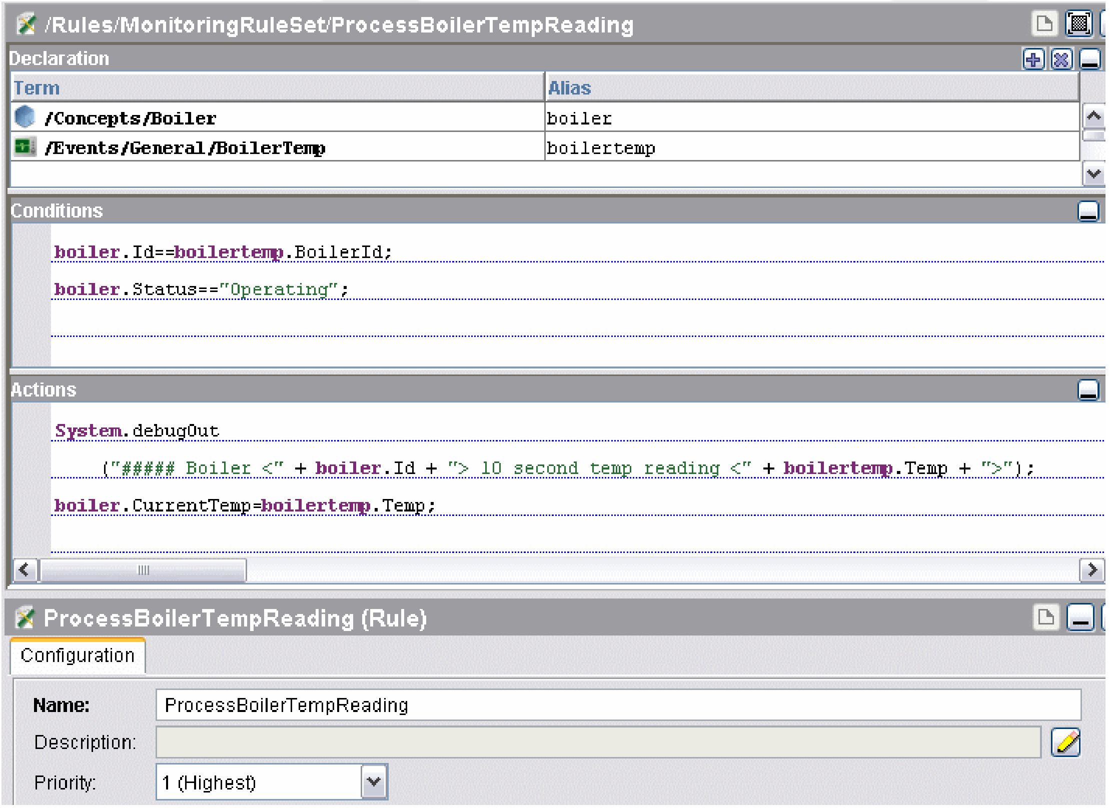
This yields significant savings by eliminating driver man hours wasted waiting at the border. When a truck is dispatched, a conveyance report is transmitted to an agent. The truck's position is tracked via GPS events. When the truck is 20 minutes from the border, there must be a confirmation that customs 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.

CEP Behavior: Rule-oriented



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



/Rules/MonitoringRuleSet/ProcessBoilerTempReading

Declaration

Term	Alias
/Concepts/Boiler	boiler
/Events/General/BoilerTemp	boilertemp

Conditions

```
boiler.Id==boilertemp.BoilerId;
boiler.Status=="Operating";
```

Actions

```
System.debugOut
    ("##### Boiler <" + boiler.Id + "> 10 second temp reading <" + boilertemp.Temp + ">");
boiler.CurrentTemp=boilertemp.Temp;
```

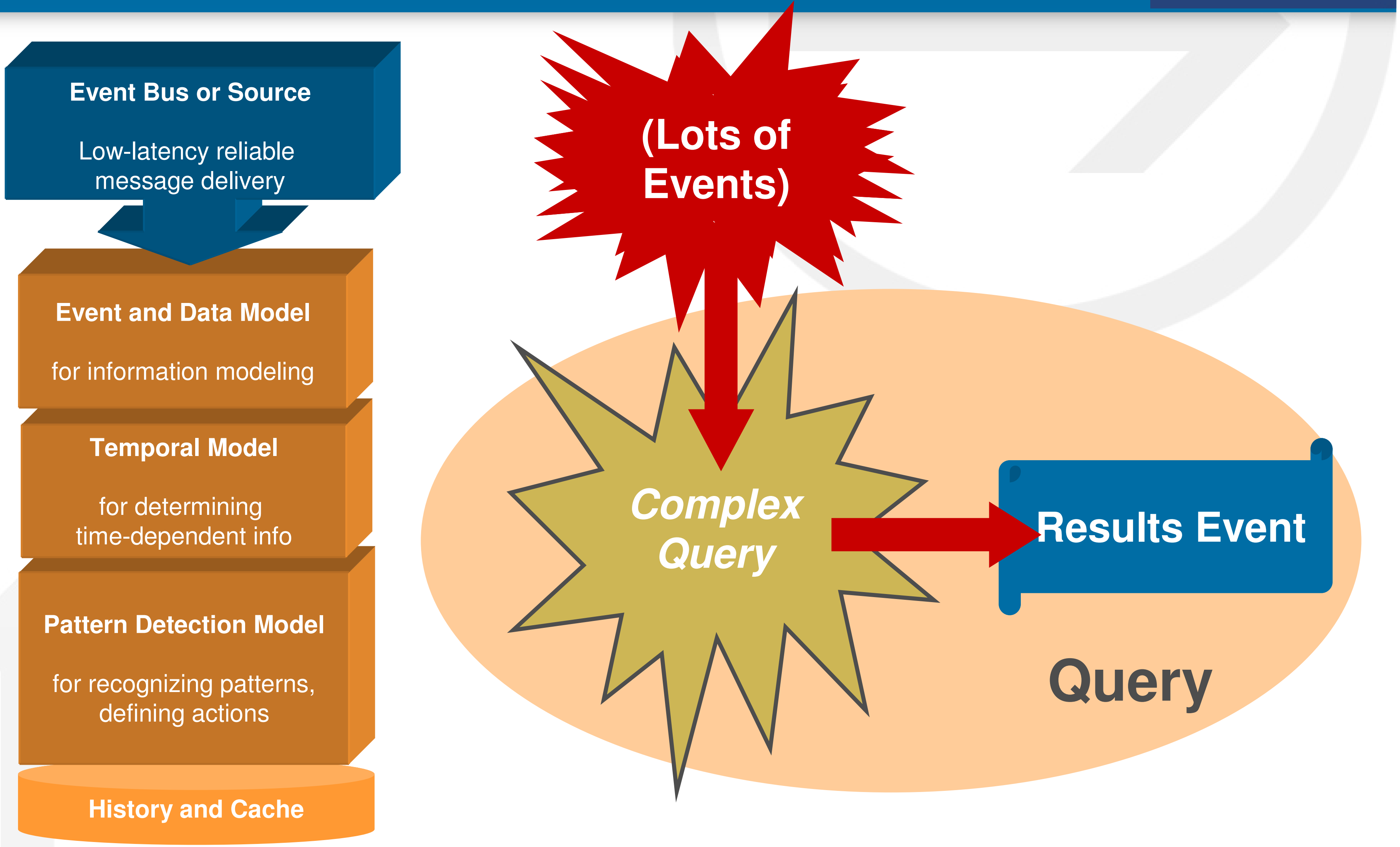
ProcessBoilerTempReading (Rule)

Name: ProcessBoilerTempReading

Description:

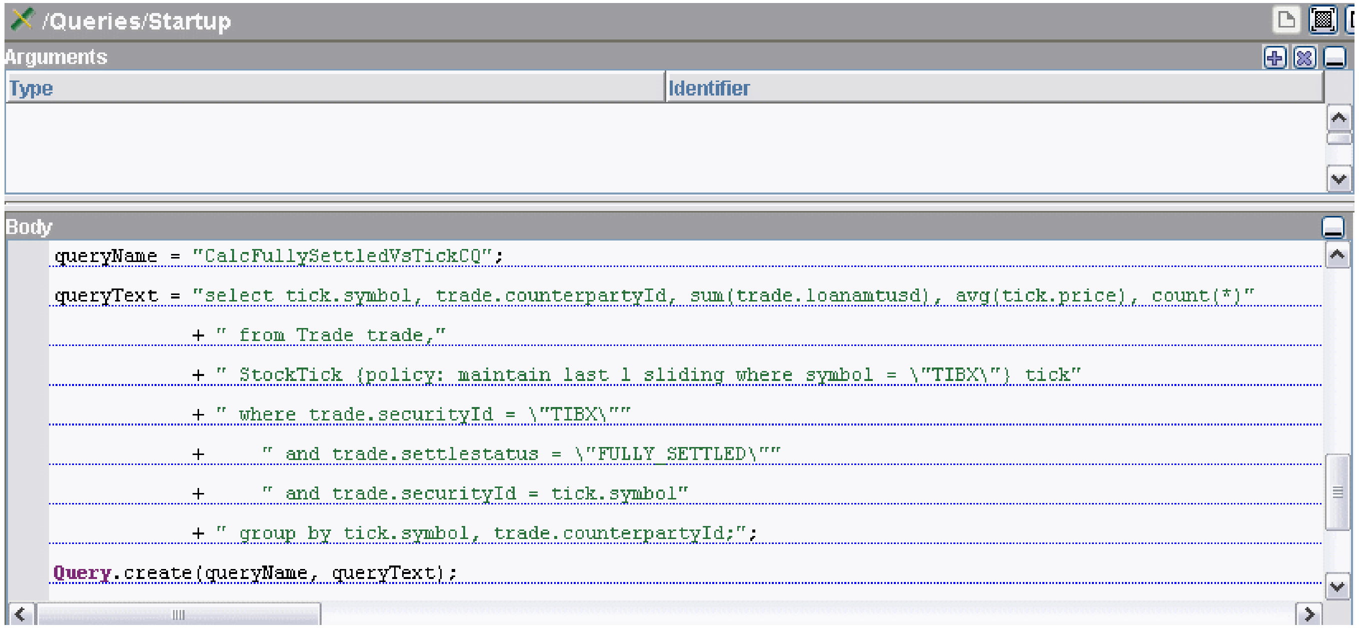
Priority: 1 (Highest)

CEP Behavior: Query-oriented



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



```
queryName = "CalcFullySettledVsTickCQ";
queryText = "select tick.symbol, trade.counterpartyId, sum(trade.loanamtusd), avg(tick.price), count(*)"
            + " from Trade trade,"
            + " StockTick {policy: maintain last 1 sliding where symbol = \"TIBX\"} tick"
            + " where trade.securityId = \"TIBX\""
            +     " and trade.settlestatus = \"FULLY_SETTLED\""
            +     " and trade.securityId = tick.symbol"
            + " group by tick.symbol, trade.counterpartyId;";
Query.create(queryName, queryText);
```

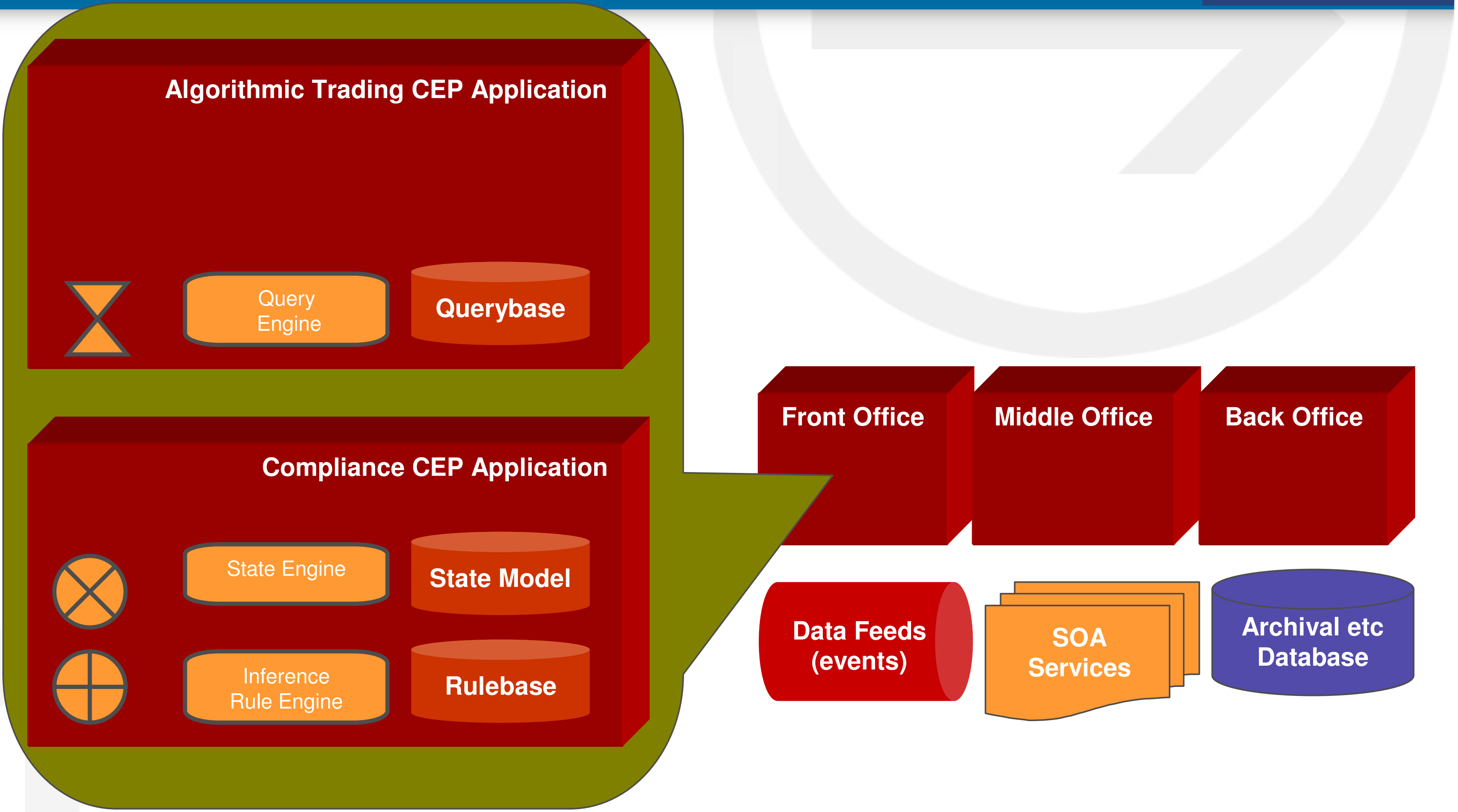
Agenda

- Examples

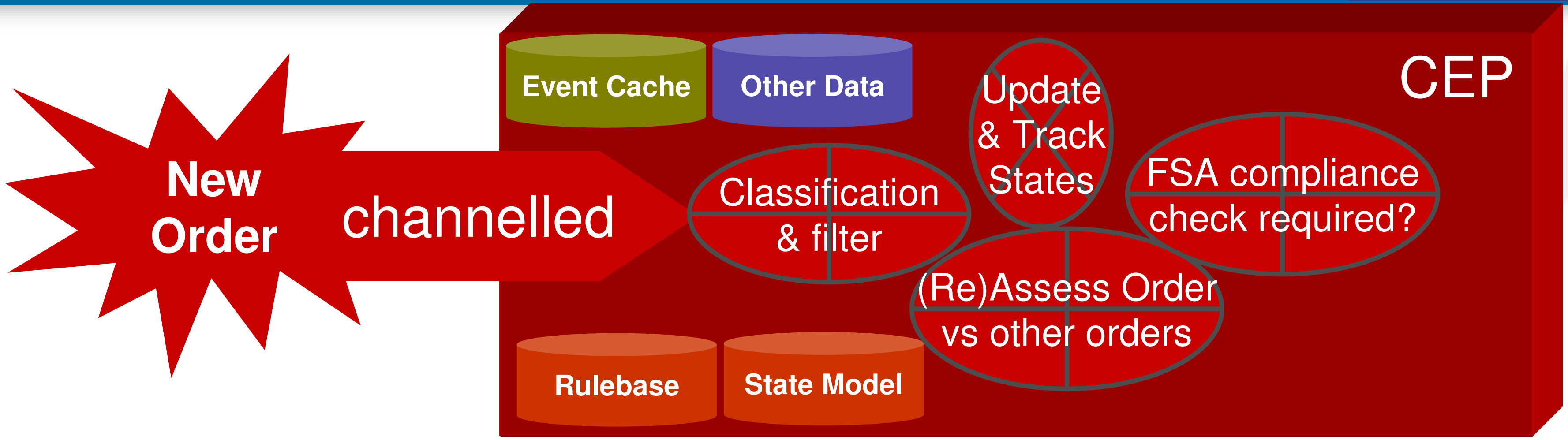
Typical Business Situations for CEP

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

CEP in Action: Investment Banking



CEP Processing



Example CEP Product Architecture

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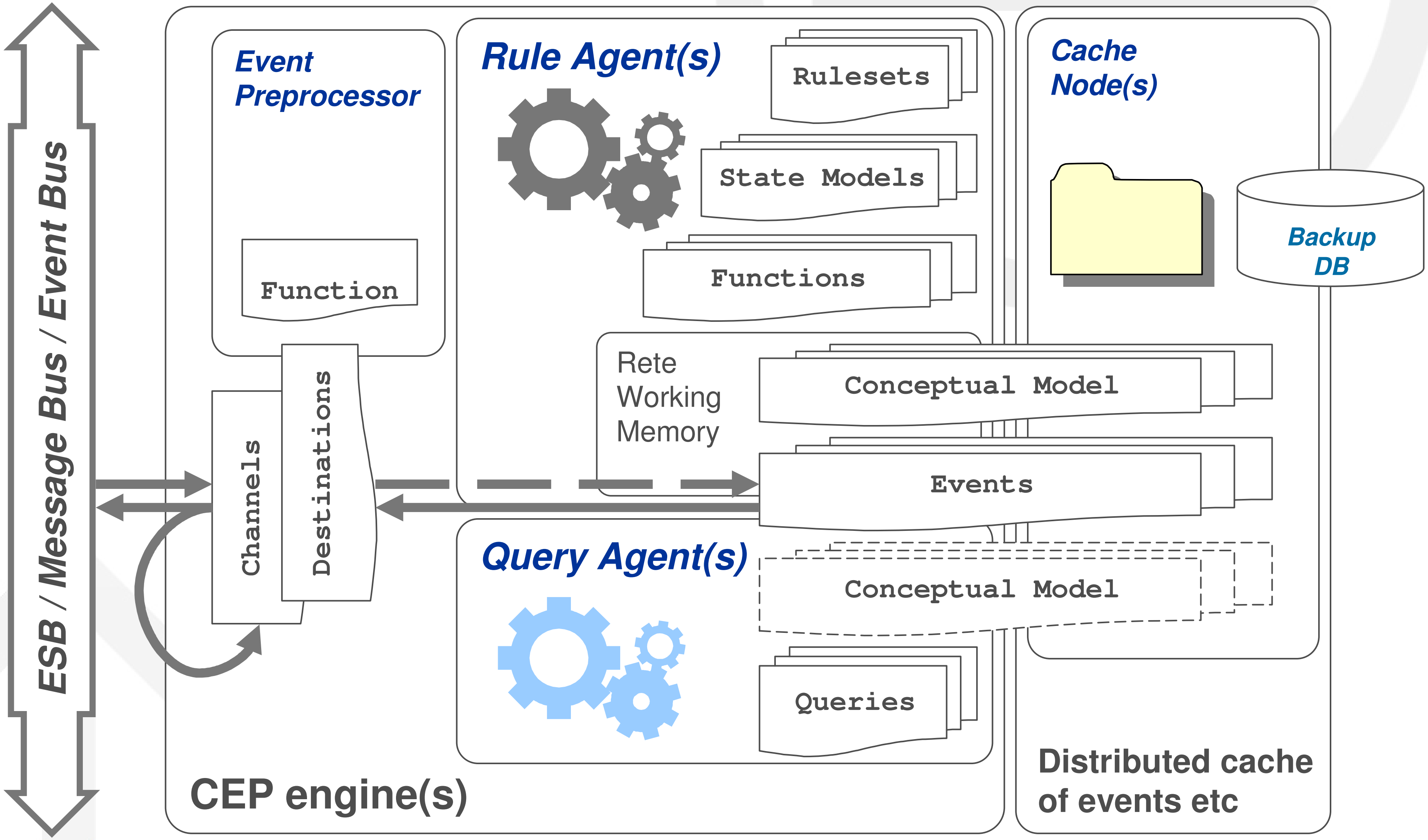

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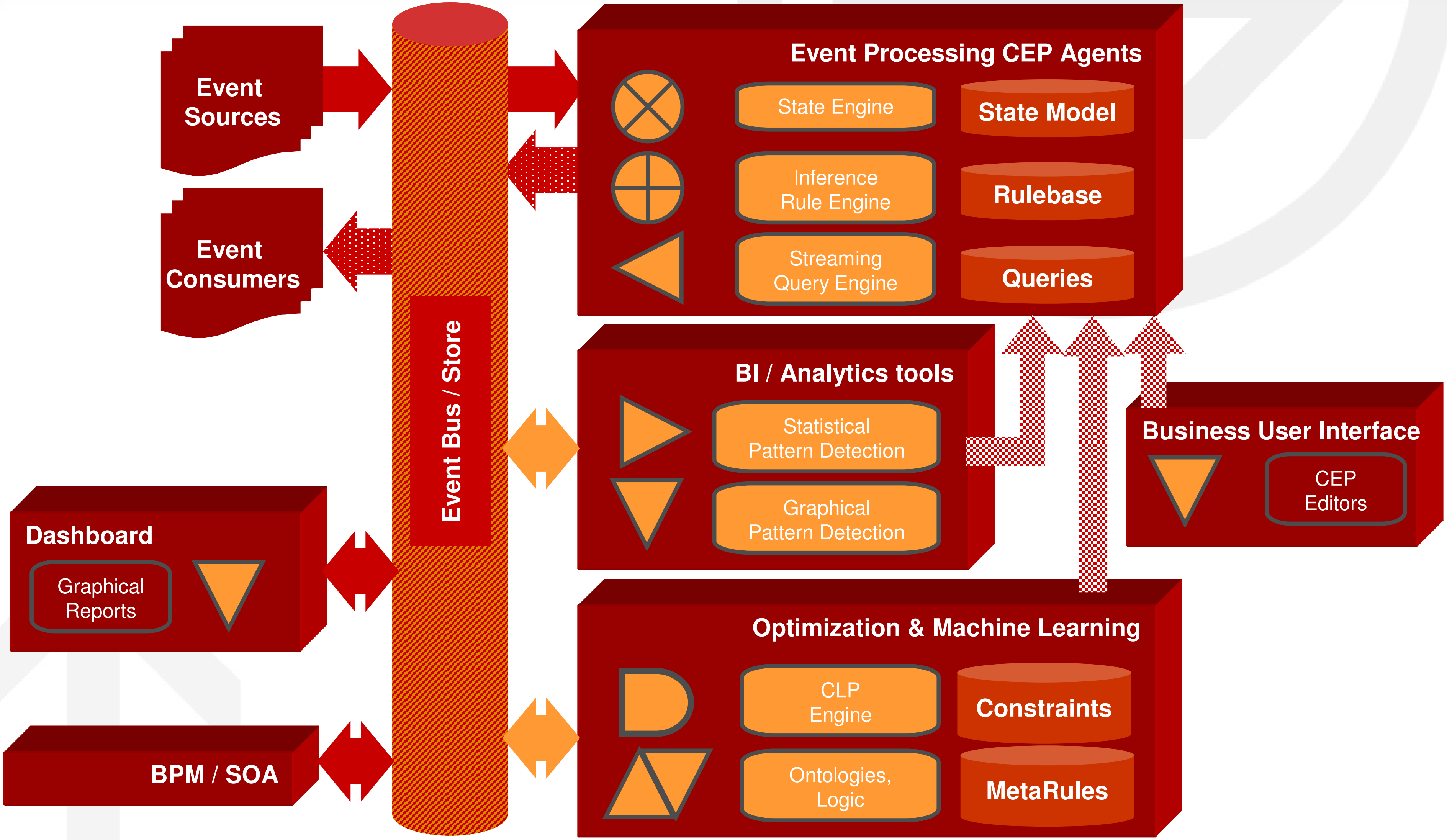
Agenda

- “Advanced” CEP

“Advanced” CEP defined in many ways

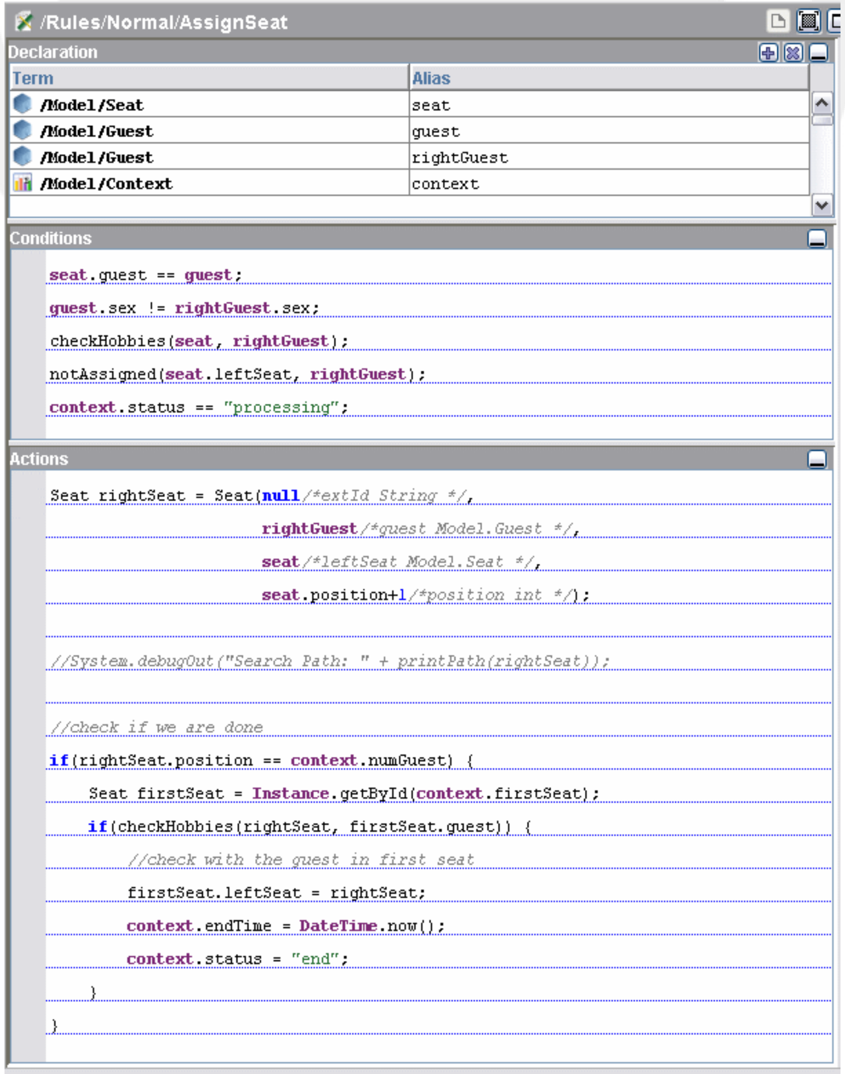
- **Intelligent CEP**
  - Adaptive
  - Learning
  - Logic
  - AI
- **Semantic CEP**
  - Ontologies + Logic
  - Text / language interpretation
- **Multiple CEP**
  - Including all types of data processing paradigm (transactional, CLP, inference, mathematical methods, …)

Advanced CEP Infrastructure



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”)



/Rules/Normal/AssignSeat

Declaration

Term	Alias
/Model/Seat	seat
/Model/Guest	guest
/Model/Guest	rightGuest
/Model/Context	context

Conditions

```
seat.guest == guest;
guest.sex != rightGuest.sex;
checkHobbies(seat, rightGuest);
notAssigned(seat.leftSeat, rightGuest);
context.status == "processing";
```

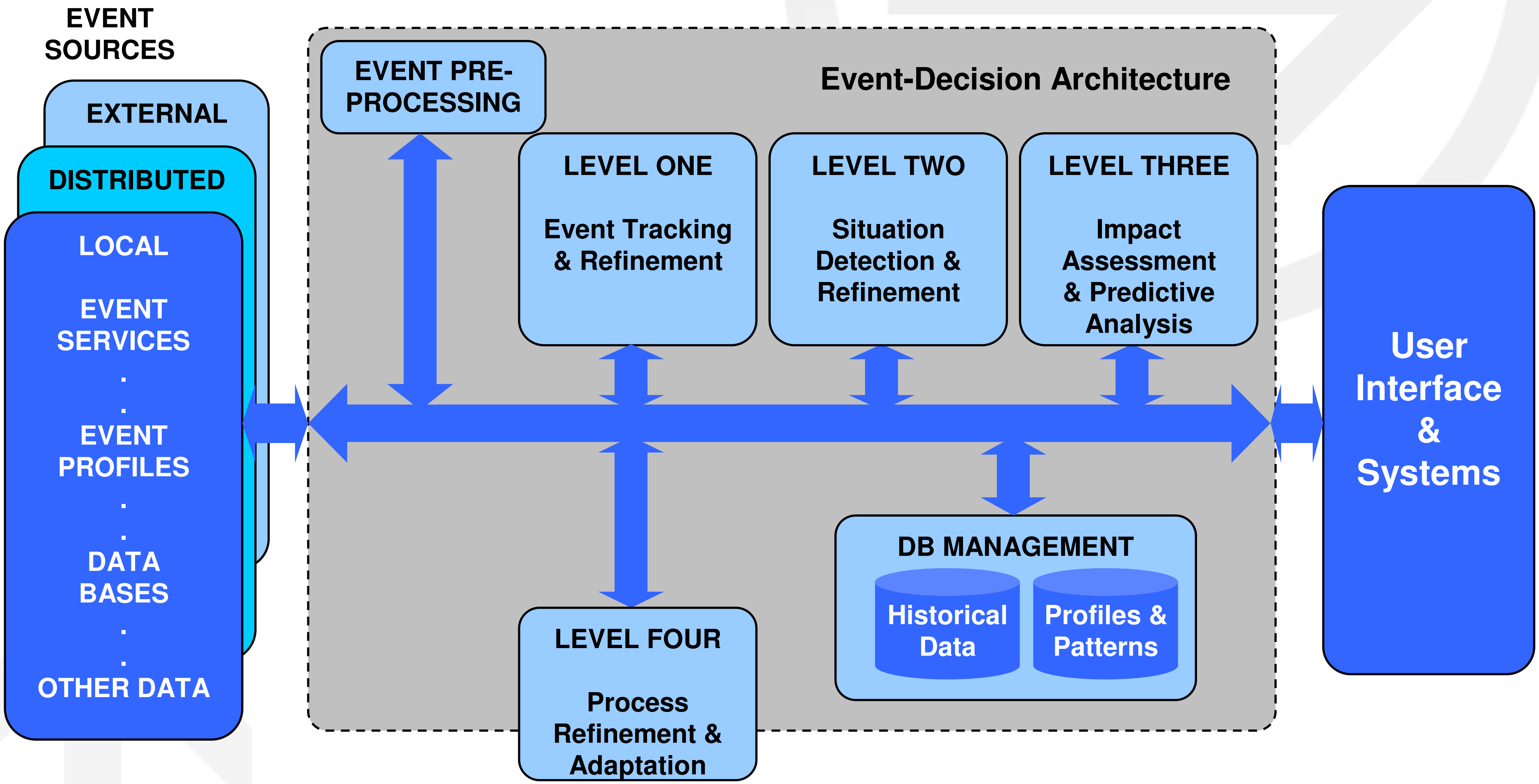
Actions

```
Seat rightSeat = Seat(null/*extId String */,
                      rightGuest/*guest Model.Guest */,
                      seat/*leftSeat Model.Seat */,
                      seat.position+1/*position int */);

//System.debugOut("Search Path: " + printPath(rightSeat));

//check if we are done
if(rightSeat.position == context.numGuest) {
    Seat firstSeat = Instance.getById(context.firstSeat);
    if(checkHobbies(rightSeat, firstSeat.guest)) {
        //check with the guest in first seat
        firstSeat.leftSeat = rightSeat;
        context.endTime = DateTime.now();
        context.status = "end";
    }
}
```

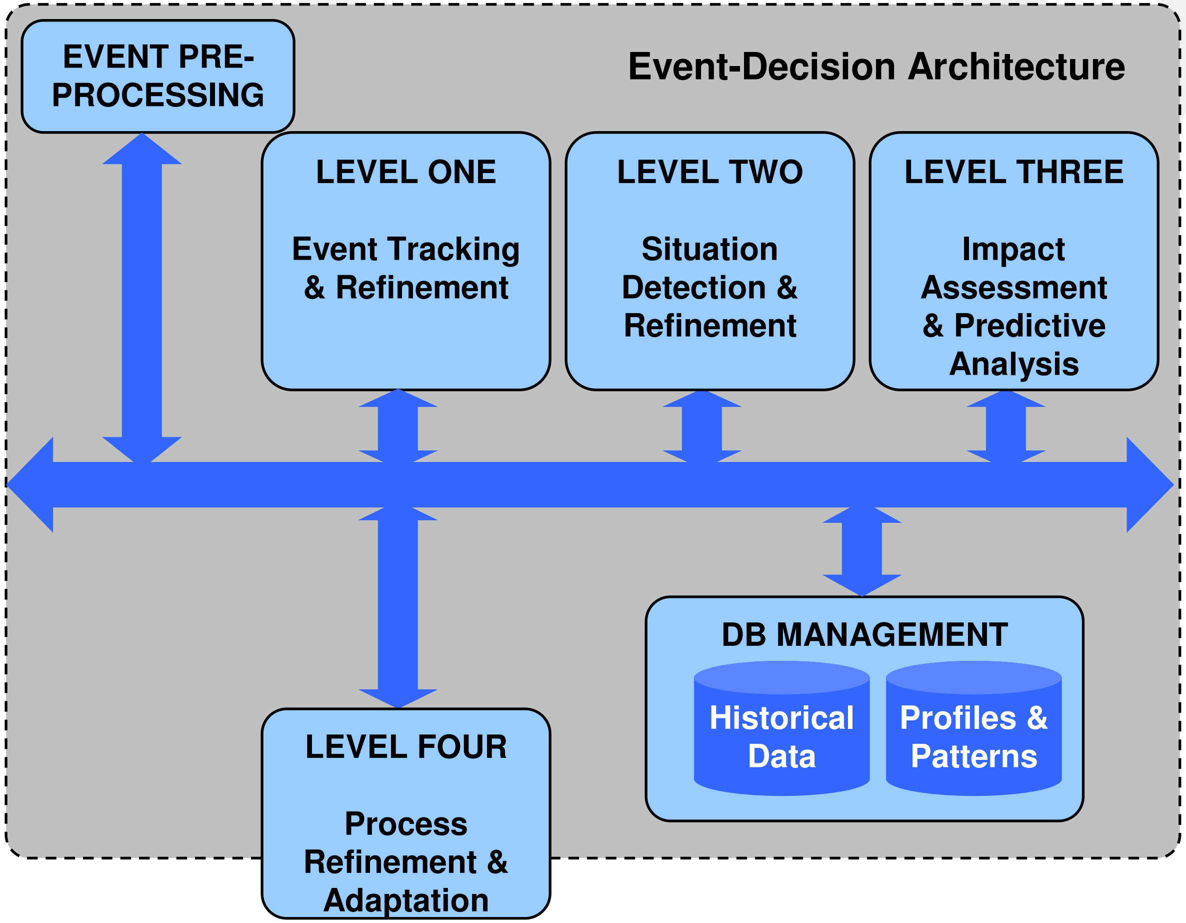
“Event-Decision” Architecture



-- Adapted from JDL
Steinberg, A., & Bowman, C., Handbook of Multisensor Data Fusion, CRC Press, 2001

Self-Modifying "Event-Decision" Rules

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

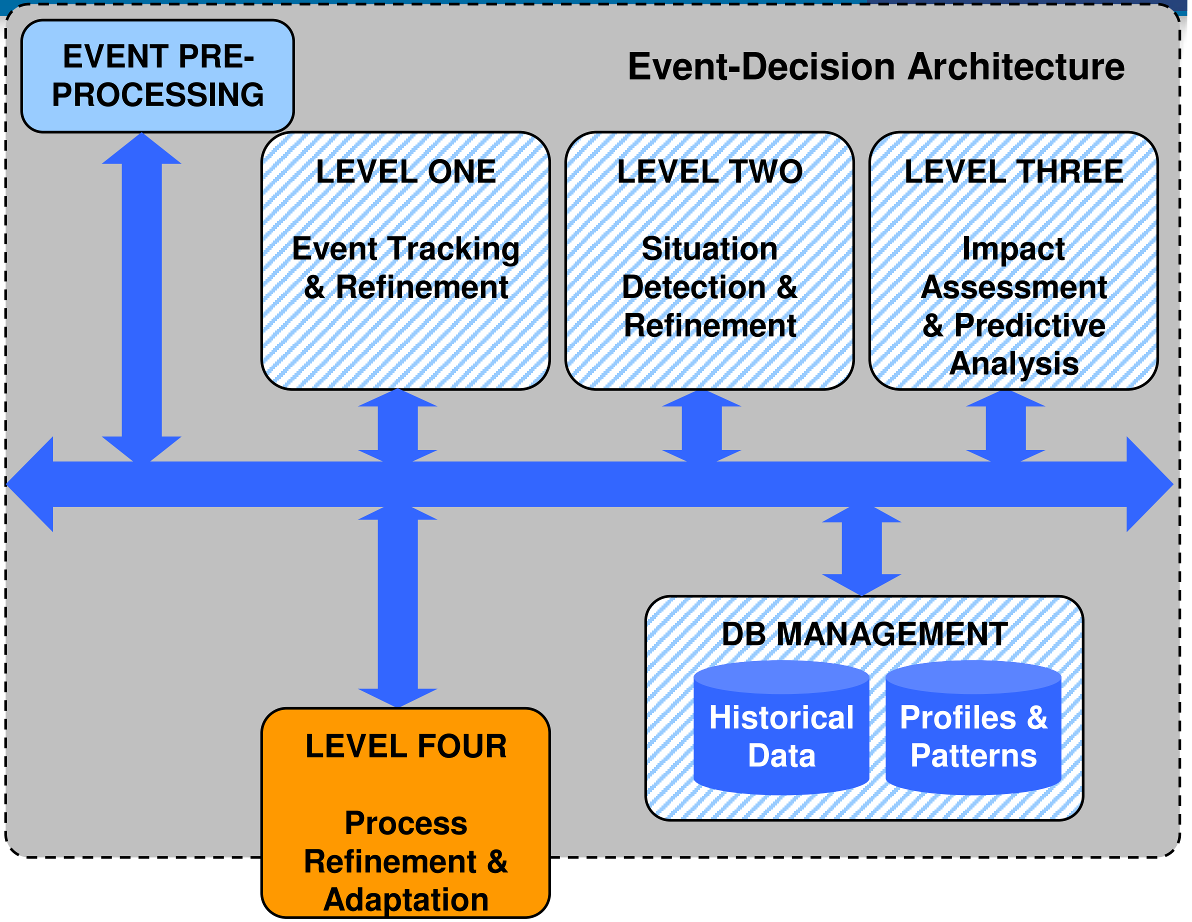

Event-Decision Architecture
EVENT PRE-PROCESSING
LEVEL ONE
Event Tracking & Refinement
LEVEL TWO
Situation Detection & Refinement
LEVEL THREE
Impact Assessment & Predictive Analysis
LEVEL FOUR
Process Refinement & Adaptation
DB MANAGEMENT
Historical Data
Profiles & Patterns

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
```


EVENT PRE-PROCESSING
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Situation Detection & Refinement
LEVEL THREE
Impact Assessment & Predictive Analysis
DB MANAGEMENT
Historical Data
Profiles & Patterns
LEVEL FOUR
Process Refinement & Adaptation

Updated by

```
If average loss increase
  for all products in Y > 2%
Then reduce Z by 5%
```

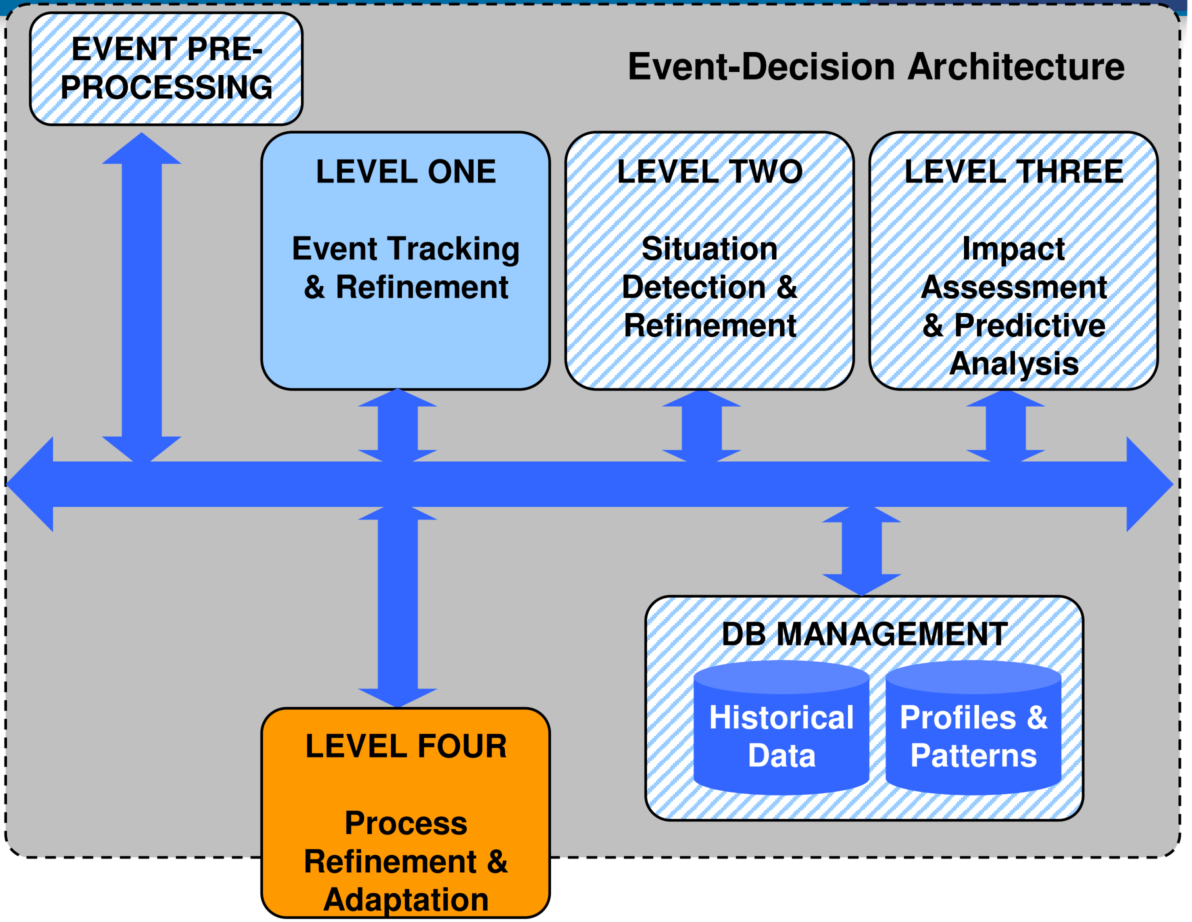
Event Tracking and Refinement Rules

```
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


EVENT PRE-PROCESSING
Event-Decision Architecture
LEVEL ONE
Event Tracking & Refinement
LEVEL TWO
Situation Detection & Refinement
LEVEL THREE
Impact Assessment & Predictive Analysis
DB MANAGEMENT
Historical Data
Profiles & Patterns
LEVEL FOUR
Process Refinement & Adaptation

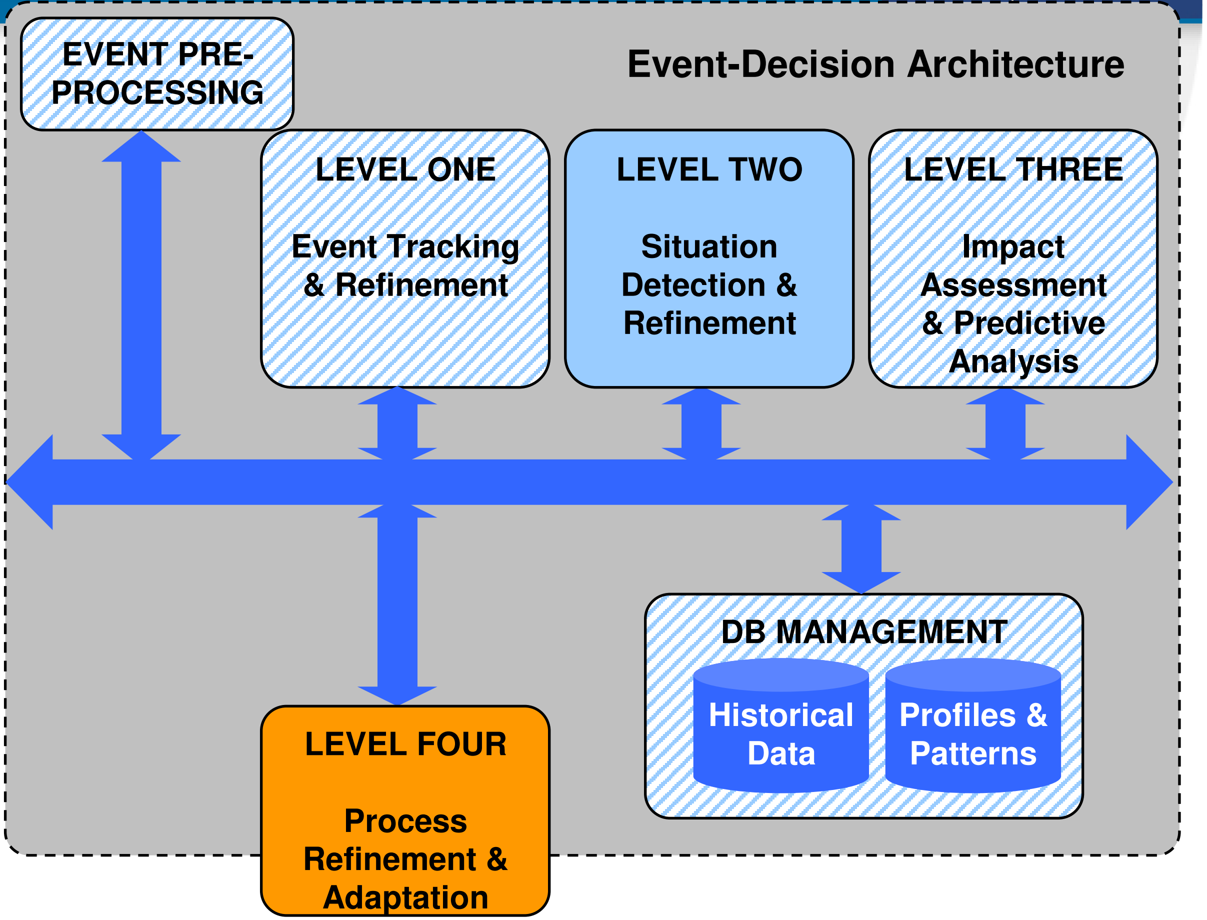
```
If clinical negative events for
  drug class X increase
Then reduce Z by 10ml
```

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
```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Updated by

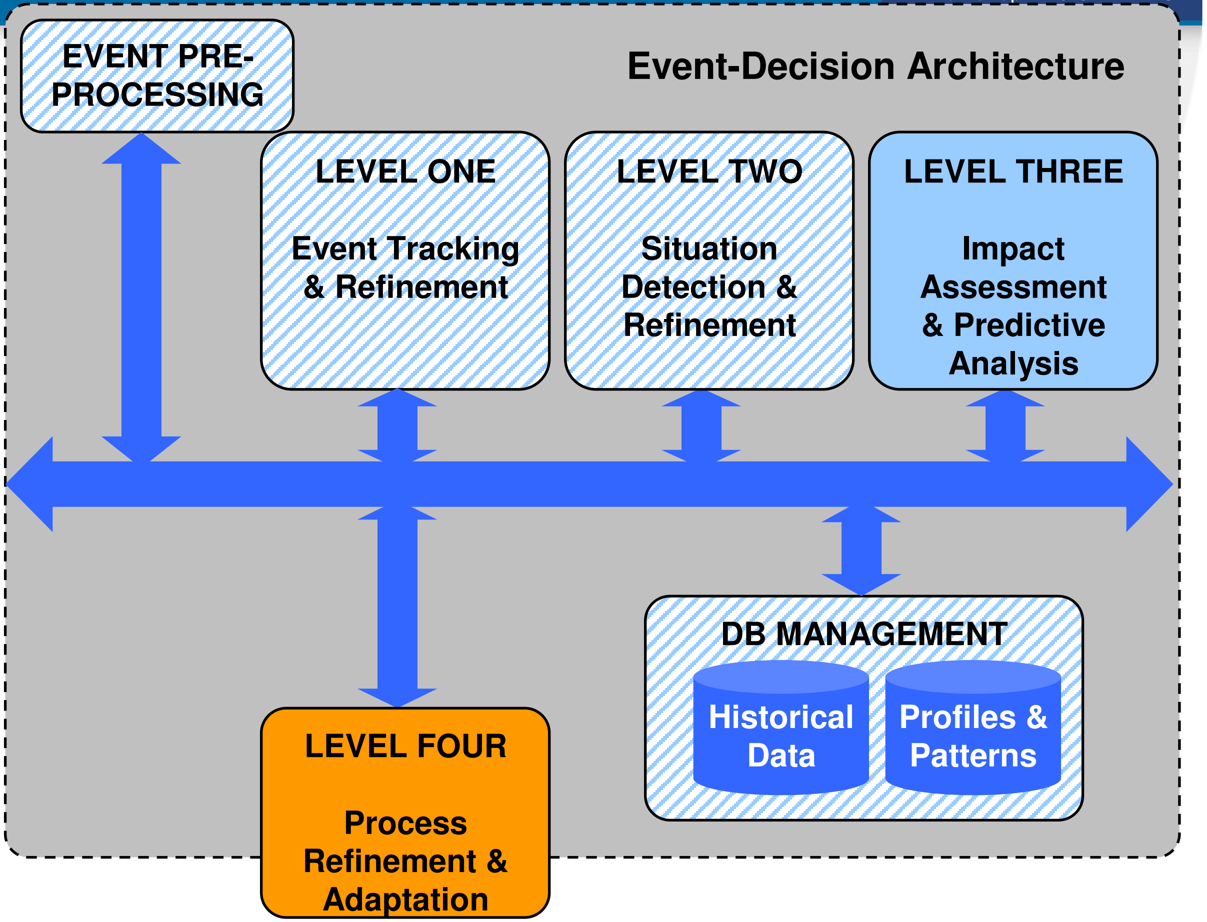
```
If flight NOT international
Then set lastBagTime to
  carrier’s min( DoorCloseTime)
```

Event Tracking and Refinement Rules

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

Becomes

```
If
  product.ShipDelay
  > contract.SLA
  MaxDelay –
  AllowedShipLag
Then
  warnLegal
```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Updated by

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

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**

Other sources for “advanced rules”

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

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

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

Predictive Analytics

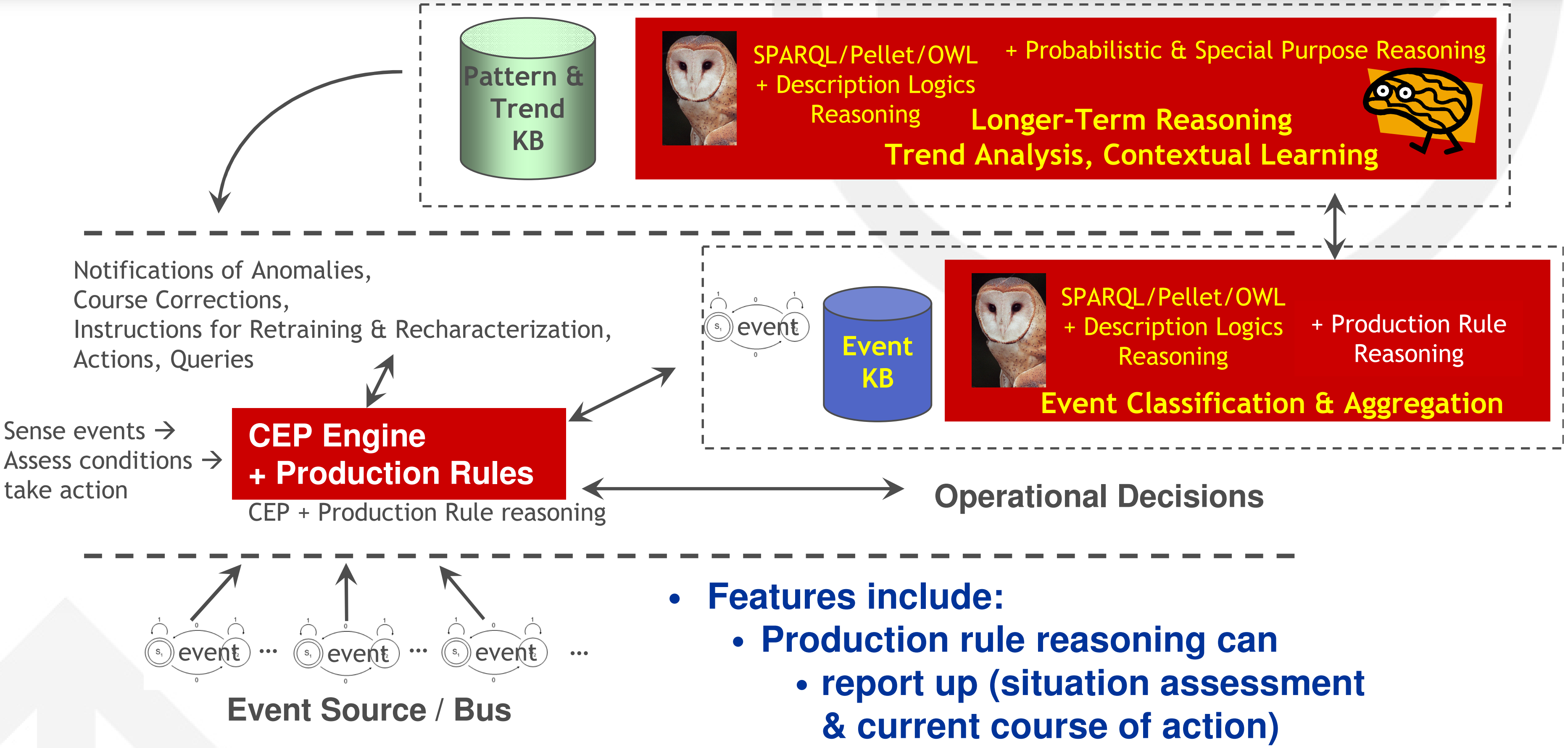
- **Analyze data to deduce segmentation breaks for tasks like customer classifications**
  - Eg: Which customers should be offered what interest rate to maximise profit?
- **Typically using specialist data mining tools**
  - Exports decision tree, rules etc in varieties of PMML
- **Overlaps with BI (eg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

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

Example: Semantic Technology to Refine CEP

Semantic Networking Event Monitoring Architecture



Pattern & Trend KB

SPARQL/Pellet/OWL
+ Description Logics Reasoning

+ Probabilistic & Special Purpose Reasoning

Longer-Term Reasoning
Trend Analysis, Contextual Learning

Notifications of Anomalies,
Course Corrections,
Instructions for Retraining & Recharacterization,
Actions, Queries

event

Event KB

SPARQL/Pellet/OWL
+ Description Logics
Reasoning

+ Production Rule Reasoning

Event Classification & Aggregation

Sense events →
Assess conditions →
take action

CEP Engine
+ Production Rules

CEP + Production Rule reasoning

Operational Decisions

event … event … event …

Event Source / Bus

- **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

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

Agenda

- The End

Agenda

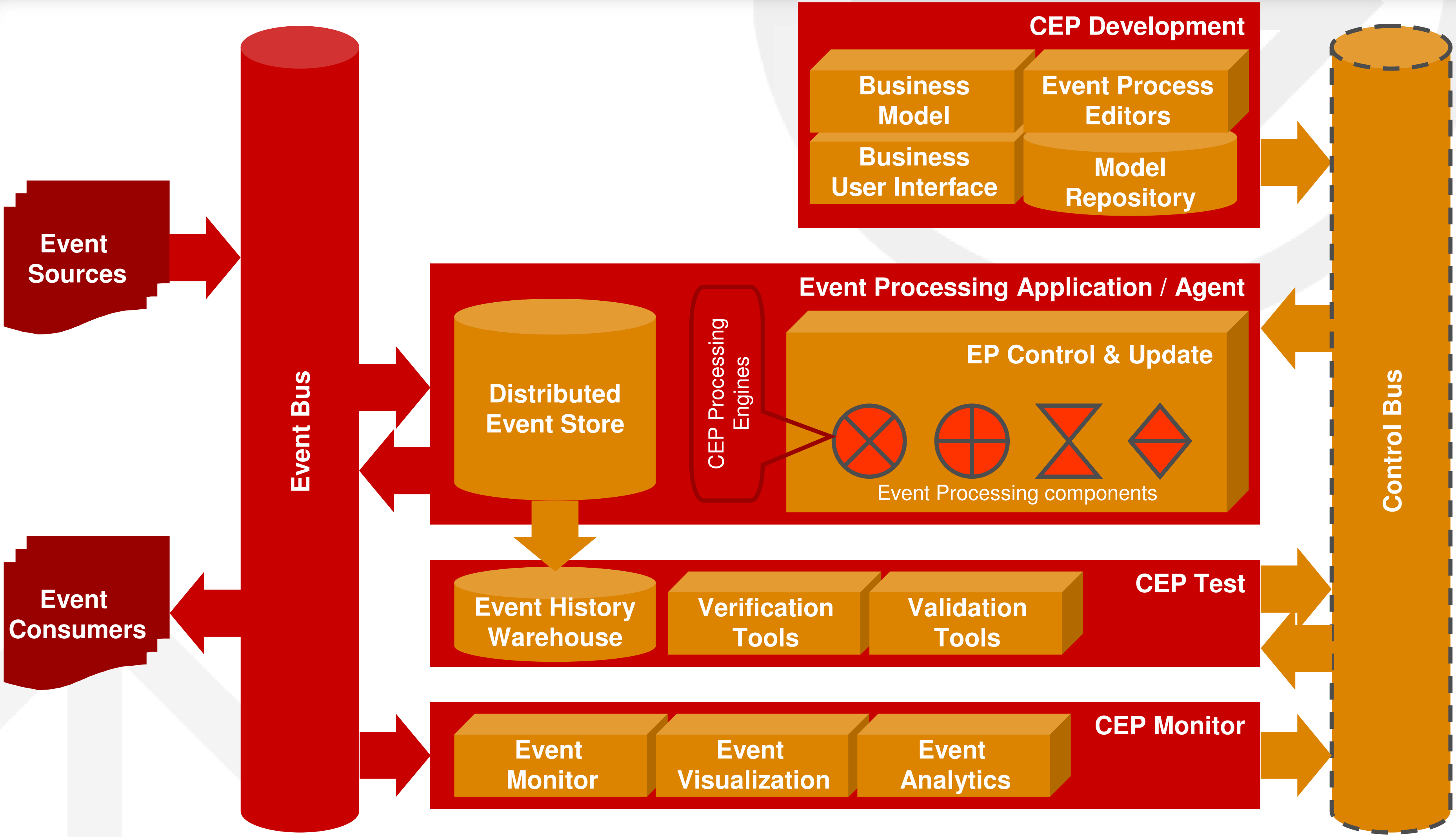
- Q & A

APPENDICES

A. Appendices & Back-up Information

Appendix: Generalized Architecture for CEP

OBJECT MANAGEMENT GROUP
workshop: DOC4RTES



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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)