Intelligent monitoring and real-time analytics for ATLAS TDAQ: a CEP-based solution

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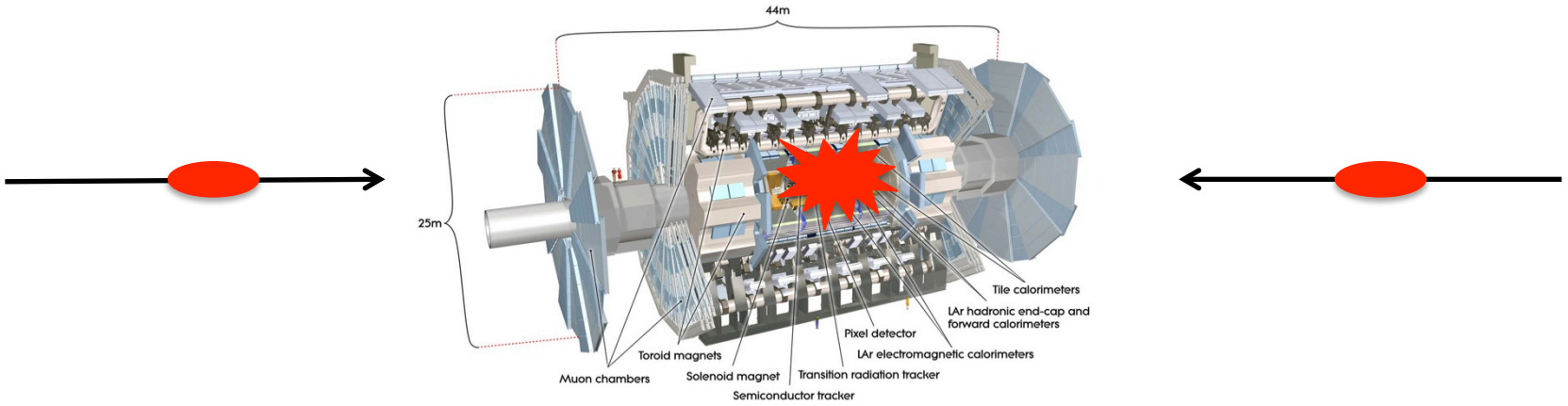
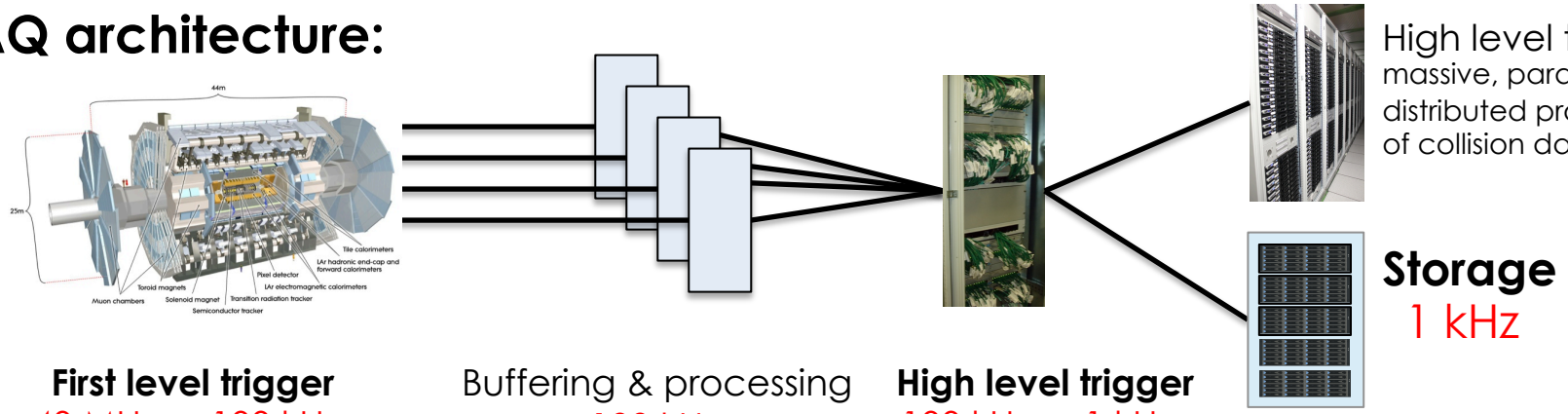
The ATLAS experiment



- Physics data are the asset of the experiment
  - when LHC delivers collisions, ATLAS must be ready to record them
  - every loss of good data reduces the physics potential of the experiment
- **Data-taking inefficiencies and problems must be spotted early and handled immediately**

Trigger and **DA**ta **A**cquisition system (TDAQ)

TDAQ architecture:



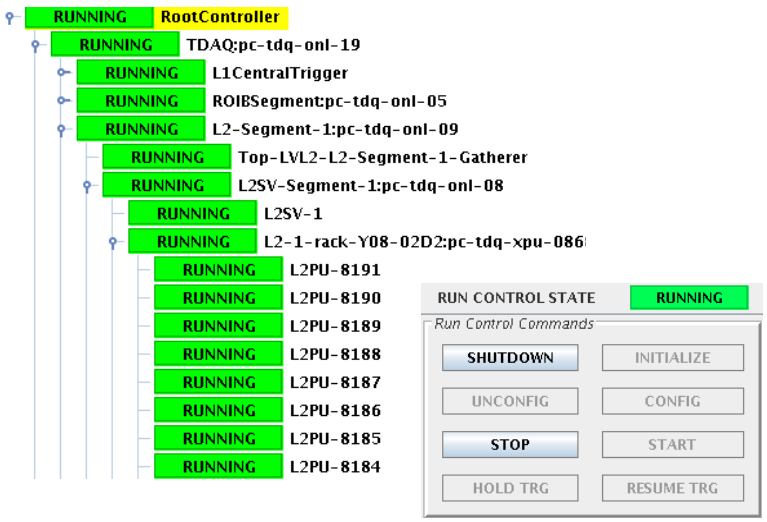
First level trigger
40 MHz -> 100 kHz

Buffering & processing
100 kHz

High level trigger
100 kHz -> 1 kHz

TDAQ control system:

- TDAQ control system is a hierarchical tree of components modeled around a finite state machine
- Service oriented system based on CORBA for inter-process communication
  - Distribute commands to perform tasks
  - Share information via publish/subscribe paradigm



Operational challenge

- ATLAS is a large and distributed collaboration
  - Operators rotate and are barely familiar with TDAQ tools
  - Each system has on-call service coverage by experts

- With increased LHC performance, data taking conditions have become more and more demanding
- **Effort to optimize reaction time to failures**
  - ➢ Automation of procedures
  - ➢ Automation of monitoring & error handling
  - ➢ Intelligent advice to operators

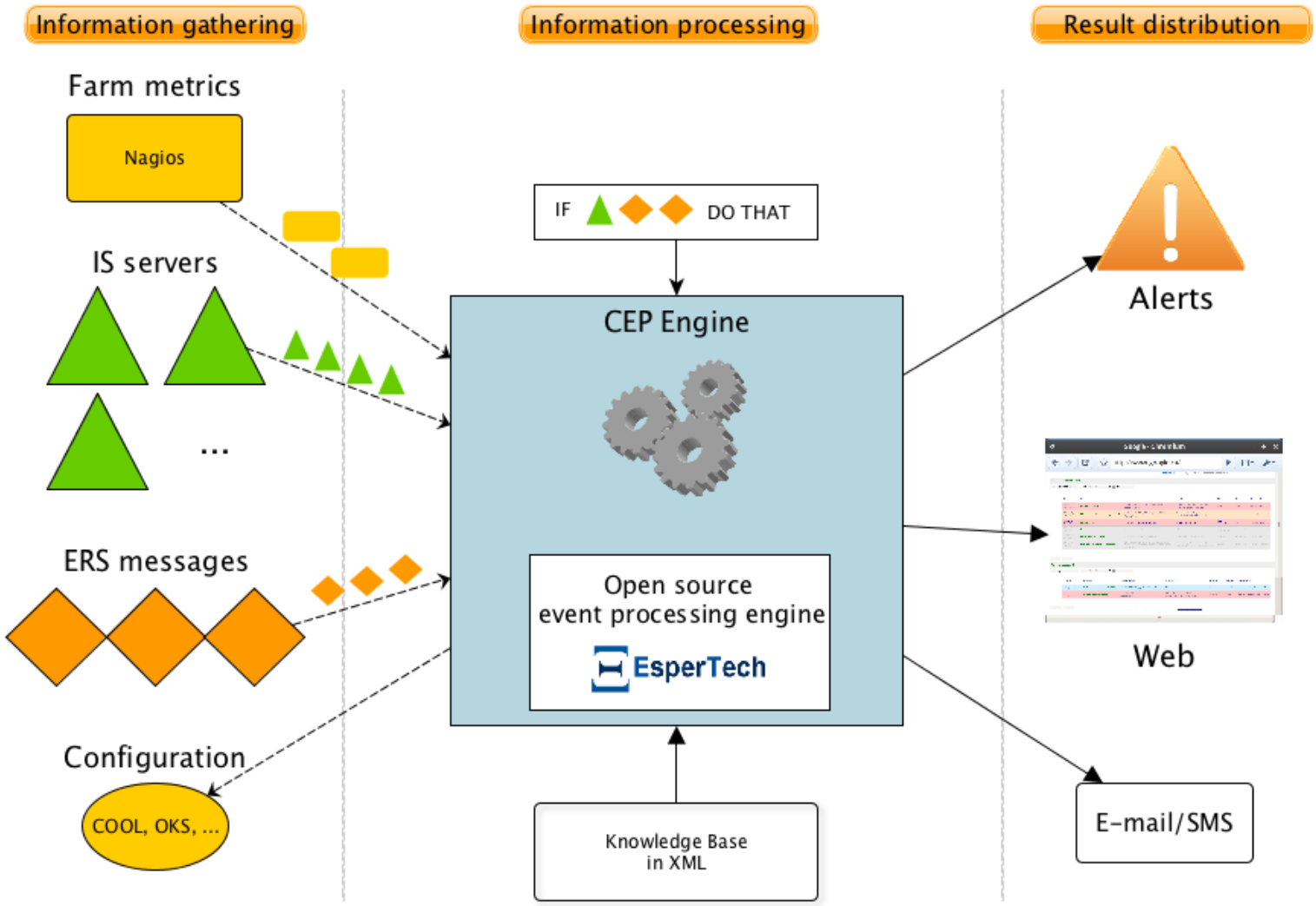
The challenge of intelligent monitoring

- TDAQ is a very large and heterogeneous system
  - Data scattered among different services and available in various formats
- **BUT** often data is only conclusive if correlated among the systems and services.
- **Need of central system which gathers the data, correlates it and is able to detect complex problems with minimal latency.**

Automation in ATLAS TDAQ

- Since early 2000's automated testing, error handling & procedures
  - Forward chaining expert system based on CLIPS
- In 2011 introduction of CEP engine for continuous monitoring and intelligent assistance to operators
  - **Shifter Assistant**
- In 2013 introduction of CEP engine for an active system
  - **CHIP**

Shifter Assistant



Shifter Assistant - example

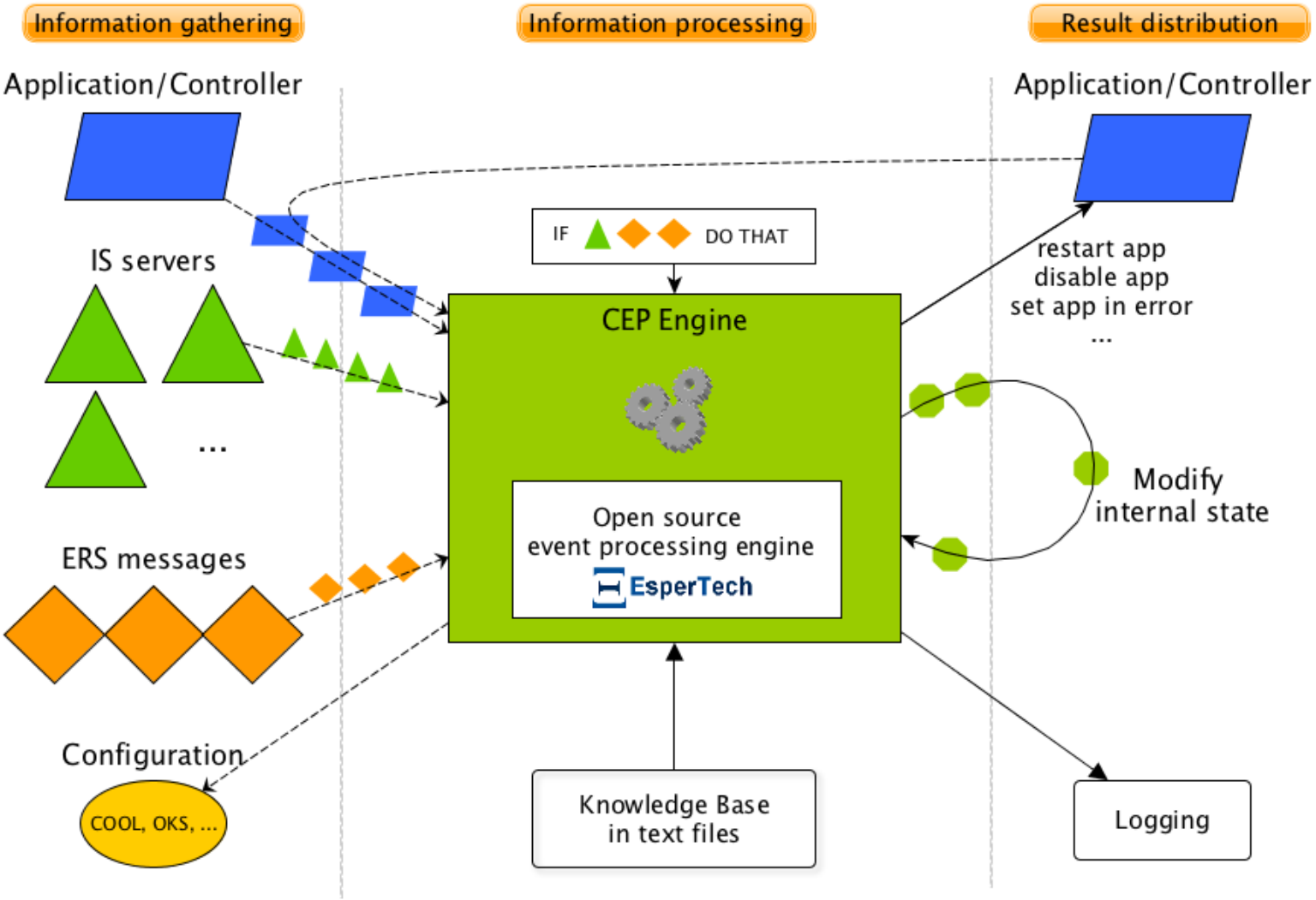
Example of directive in KB:

Directive name: EB_Network_Glitch	
EPL Query	**select machineName** as HostName **from Message**(messageID = 'SFI::DataFlowIssue', messageTxt regexp '.*Did not send SFI DataRequest').**win:time(20 sec).std:unique(machineName)** having **count(*) > 30** output first **every 3 minute**
Domain	AAL.TDAQ.Expert
Severity	WARNING
Message	possible Event Building network problem detected: many SFIs complained about network connectivity. There may be a glitch in one of the switches, or a ROS connectivity (bad NIC, hanging ROS application or a node reboot) problem.
Action	Problem detected, start recovery procedure.
Writer	jms

Going one step further ..

- In 2013, successful operation of Shifter Assistant led to the decision of using CEP also for automated decision making and actions on TDAQ system
- Use experience with intelligent monitoring to implement an active system
  - not only detect problems
  - try to handle and resolve them
- **CHIP**
  (**C**entral **H**int and **I**nformation **P**rocessor)

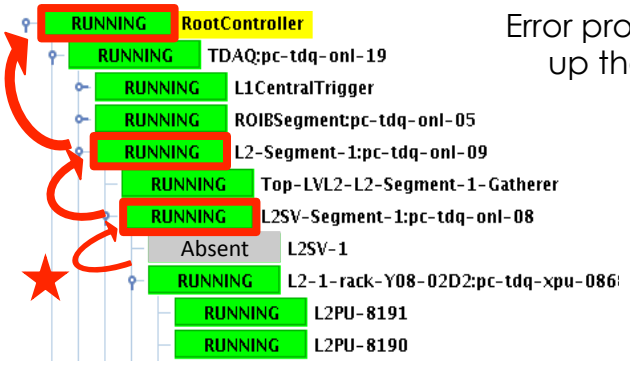
CHIP


Information gathering
Information processing
Result distribution
Application/Controller
Application/Controller
IF
DO THAT
IS servers
...
CEP Engine
restart app
disable app
set app in error
...
Modify
internal state
Open source
event processing engine
EsperTech
ERS messages
Configuration
COOL, OKS, ...
Knowledge Base
in text files
Logging

CHIP example – crashed application

Set error

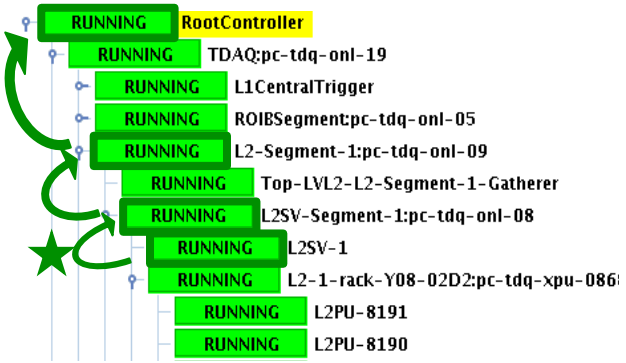
```
on RCApplication(name != 'RootController',
        application.status = STATUS.ABSENT,
        application.membership = MEMBERSHIP._IN) as
        application
insert into Problem(controller, application, type, state)
select application.controller,
        application.name,
        Problem$TYPE.APPLICATION_DEAD,
        Problem$STATUS._NEW;
```



Error propagates up the tree

Remove error

```
insert into Problem(controller, application, type, state)
select application.controller,
        application.name,
        Problem$TYPE.APPLICATION_DEAD,
        Problem$STATUS.RESOLVED
from pattern [ every (error=Problem(
        type=Problem$TYPE.APPLICATION_DEAD,
        state=Problem$STATUS.HANDLING)
        -> application = RCApplication(
        name=error.application,
        status = STATUS.UP,
        membership=MEMBERSHIP._IN))];
```



Summary and Outlook I

- Since 2011 ATLAS successfully employs CEP for intelligent monitoring in order to detect problems early and react fast
  - Shifter Assistant initially planned to only be used in DAQ domain, but later added directives for other systems as well
  - Shifter Assistant has 100 different directives and plays a central role in assisting the Control Room shifters
- Strong interest of sub-detector communities in common framework for intelligent monitoring
- Future plans with Shifter Assistant:
  - empower the experts to write problem detection rules for their systems on their own, since only they have the knowledge
  - provide experts with unit-testing templates which are an essential part of rule validation

Summary and Outlook II

- When developing an automated system targeting human operators, it is fundamental to have its functionalities accepted and understood from the early phase
  - for operators to trust it
  - for experts to be aware of the new capabilities
  - success of the tool strongly depends on expert's willingness to feed it
- Integration with notification services necessary in order to involve operators

Summary and Outlook III

- In 2013, good experience with intelligent monitoring led to the decision of using CEP also for automated decision making and actions on TDAQ system
- New tool **CHIP**
  - early stage of development but first tests were very successful
  - CHIP well on track to be ready for LHC Run 2
  - integrate more directives in an iterative process
- CEP-based tools have taken up a central role in monitoring and controlling the ATLAS TDAQ system