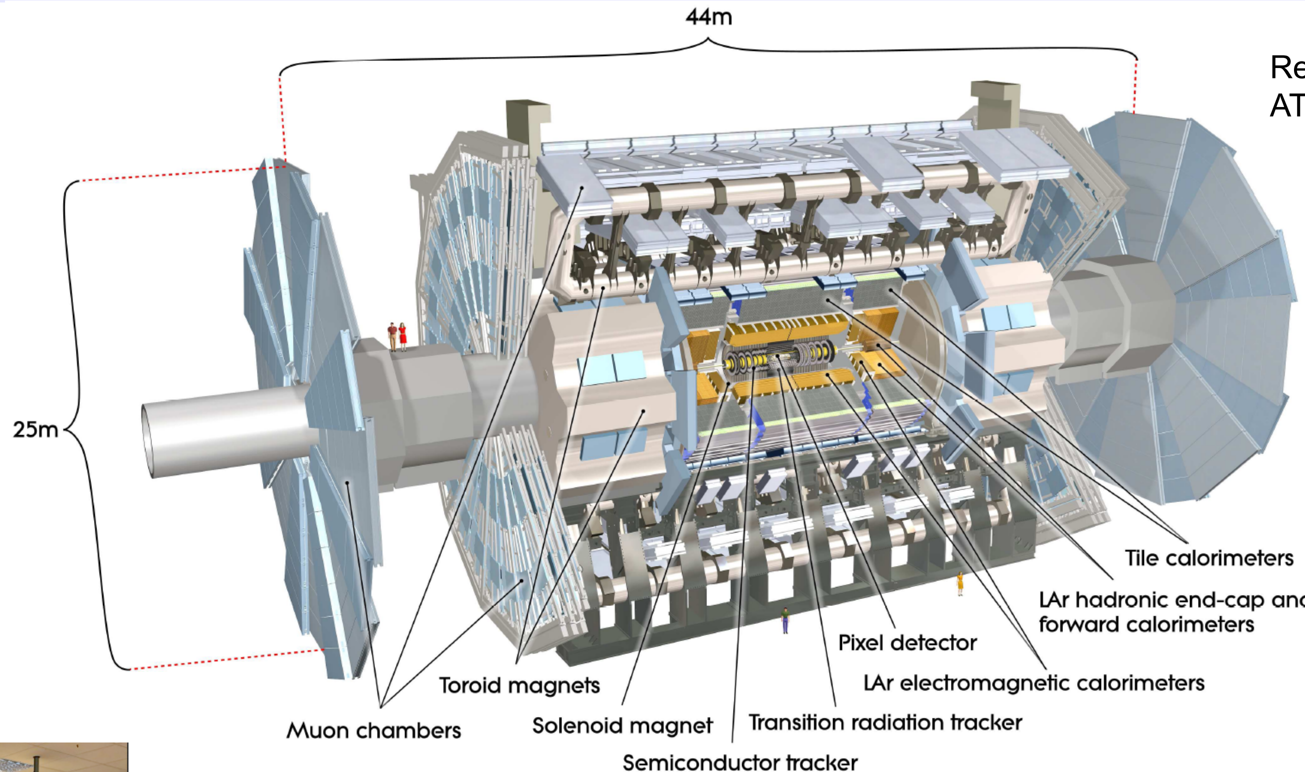
CHEP 2018
Sofia, Bulgaria

ATLAS TC Expert System

Ignacio Asensi, Carlos Solans, George Salukvadze, Andre Rummler, Kendall Reeves on behalf of the ATLAS Collaboration

ATLAS experiment



Representation of the ATLAS detector

Control room

- ATLAS is a general-purpose particle physics experiment at the LHC
- Its major components are
  - Magnet, Muon, Inner detector, Calorimeters
  - Many others like computing, Control and Safety systems
- Confident knowledge on many systems of the detector is critical for maintenance, upgrade operations control and monitoring

Expert System

- The ATLAS TC Expert System is a diagnostic tool of the experiment:
  - Technical Coordination is in charge of operations in the ATLAS infrastructure.
  - Increases the knowledge base of the experiment
  - Includes description of parts like gas systems, cooling and ventilation, electricity distribution and Detector Safety System
  - Document the behavior and interaction of different components
- Help understanding situations when time is critical and before interventions
- It is a simulator of events with a database back-end and a web interface front-end

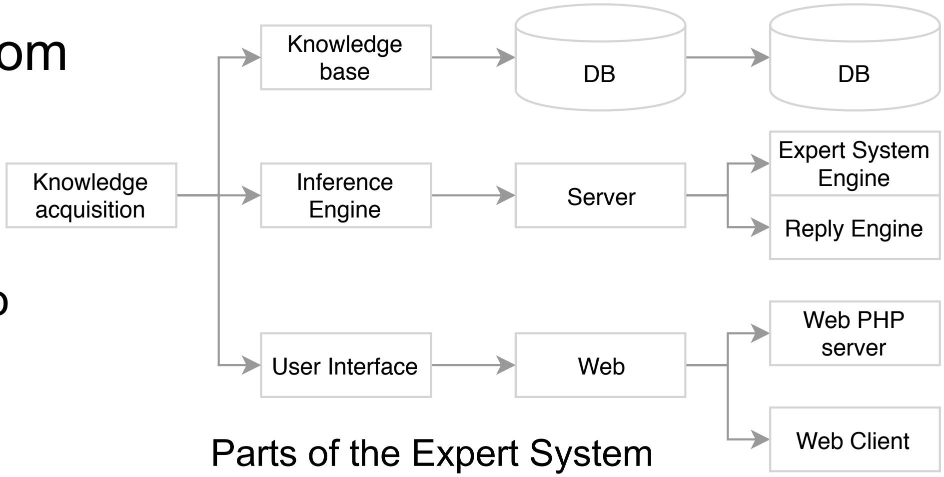
https://atlas-expert-system.web.cern.ch

Foresee what is going to happen
Explain why something is off

Compressors of the ID Evaporative Cooling System

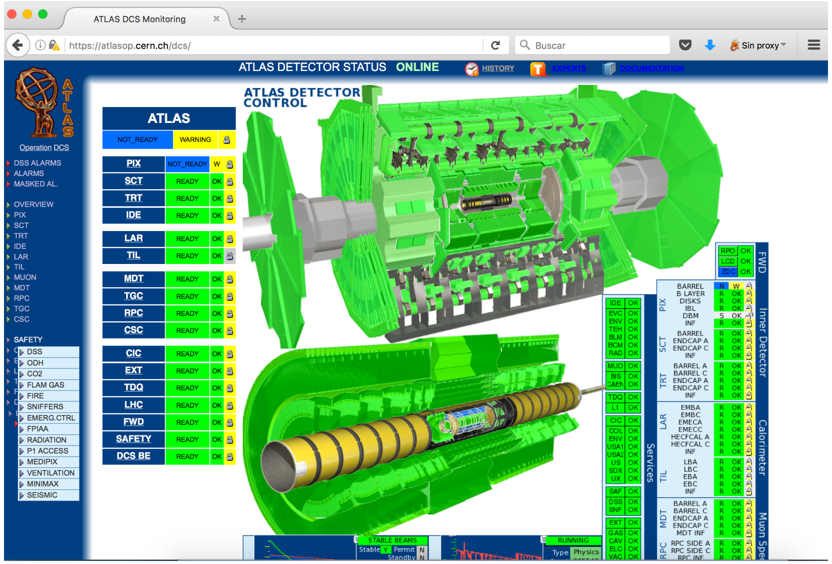
From people to knowledge base

- Starting from acquiring knowledge from many sources:
  - Technical documentation
  - Investigation
  - Meeting with Experts of each system to revise descriptions



Parts of the Expert System

- There is the design of:
  - Knowledge base
    - A database with the systems that constitute ATLAS
  - Inference engine
    - An engine that deducts the behavior of the systems and answers to the user input
  - User Interface
    - In accordance to experts advise and user needs

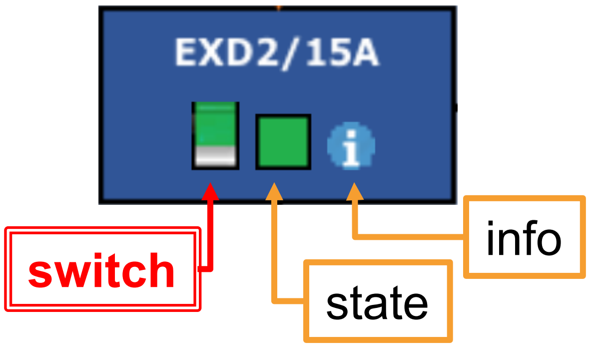


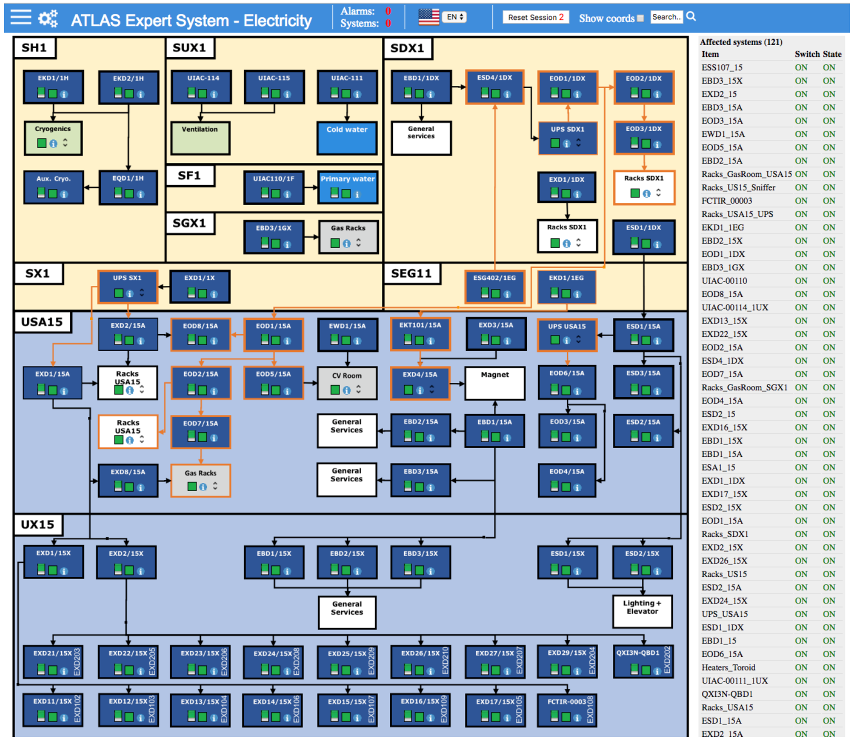
Screenshot of the ATLAS detector status in the Detector Control System (DCS)

Simulating ATLAS behavior

Using graphical interface

- Individual systems can be found by locations, types or groups
- Systems can be switched off and alarms be triggered
- Systems are represented as boxes with up to 3 icons (switch, state, info)
- When there is an interaction, the inference engine determines the consequences and displays the new scenario

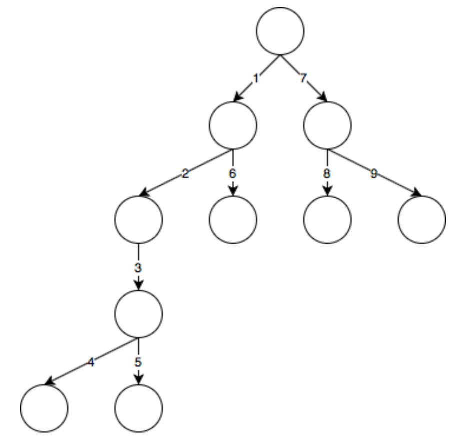




Deduction algorithm and relationships

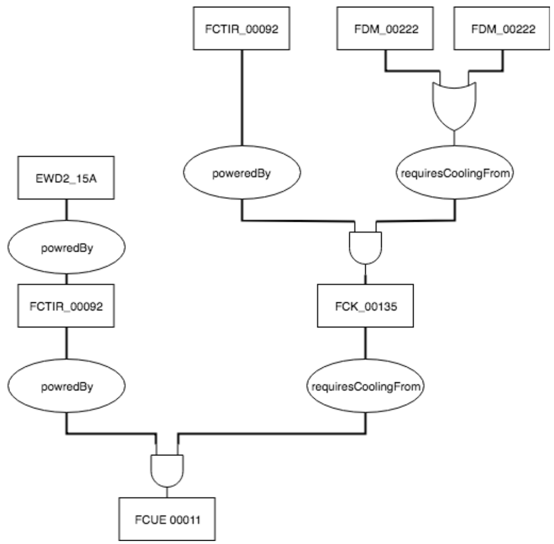
ATLAS individual systems are represented in the database as objects and relationships

- Relationships represent inputs and outputs
- In a system, each relationship is calculated as an independent node.
- Relationships are always combined in parallel
- Systems arranged in the same node can be in parallel or series
- In every simulation, the inference engine, using a deep-first algorithm, builds a fault tree for every system and deducts its state from its parents

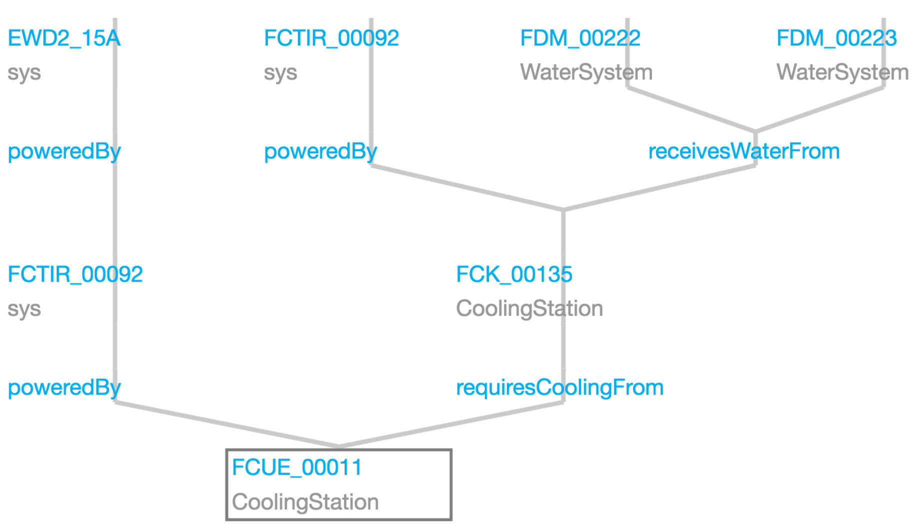


Search for children using Deep-first algorithm

Fault tree



Screenshot of visual representation of the tree of systems

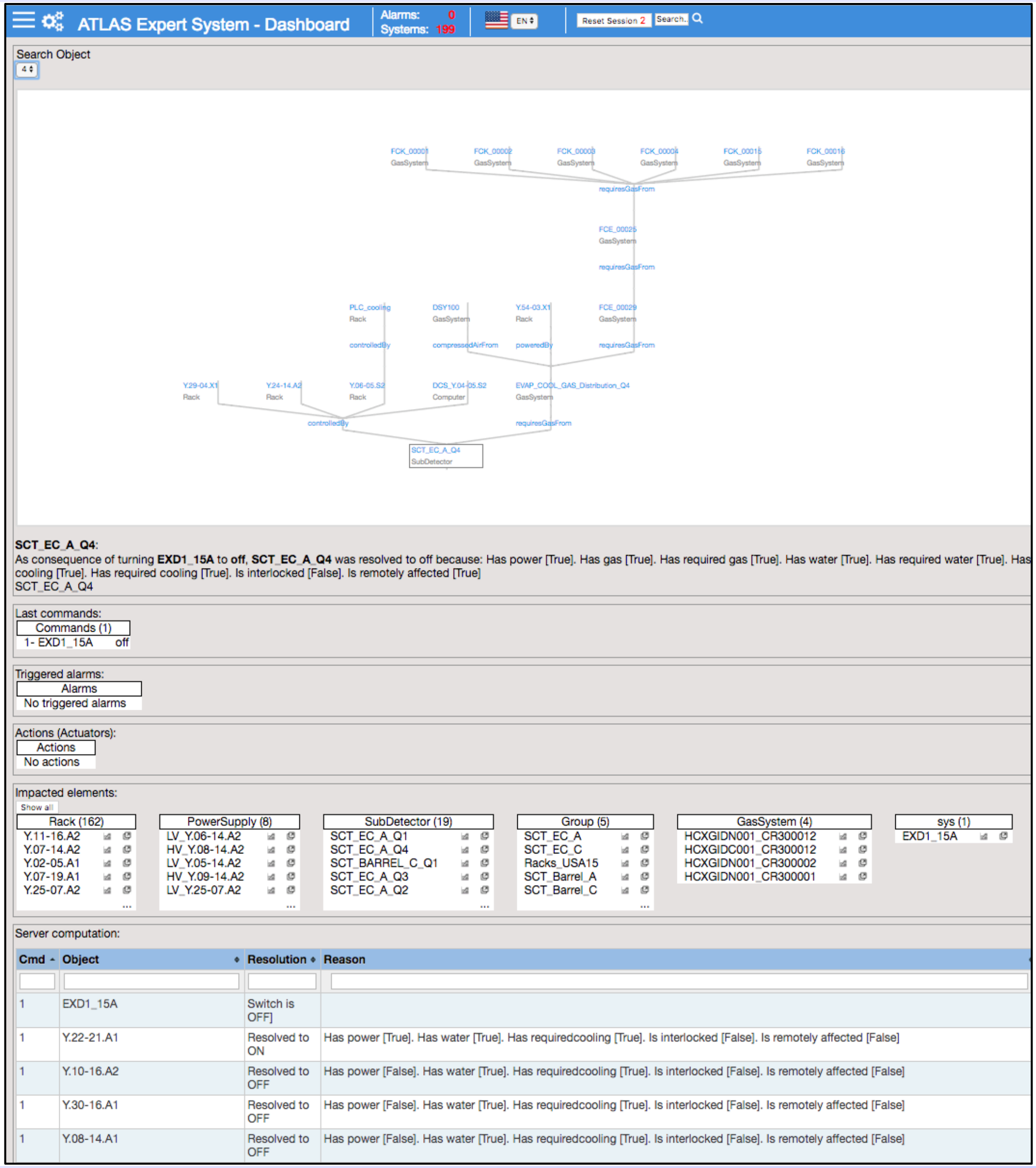


One visualization for each need

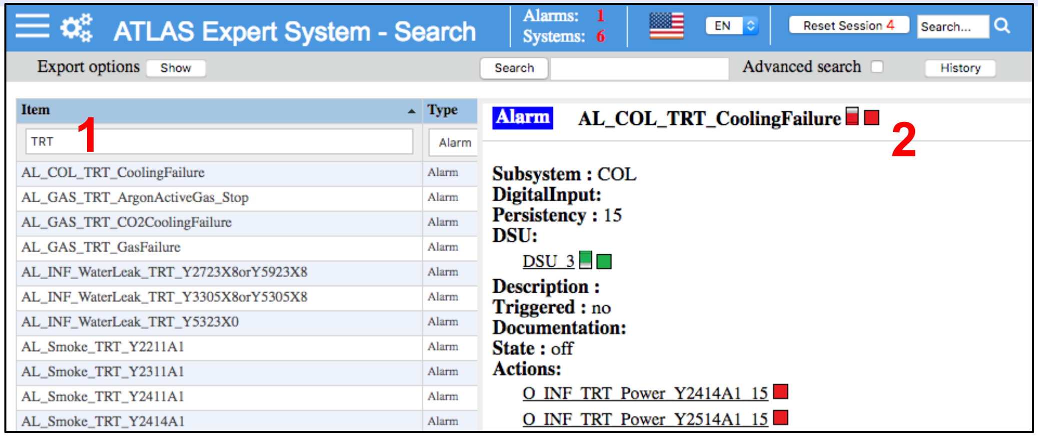
Helping users to understand complex systems using different levels and types of visualizations

- Navigation through objects via their relationships with detailed descriptions
- Presenting detailed status of the simulation
  - Report of actions taken by user and by ATLAS, affected systems, alarms…
- Fault tree visualization
  - Showing inheritance as a tree
- Explanation of deductions:
  - E.G.

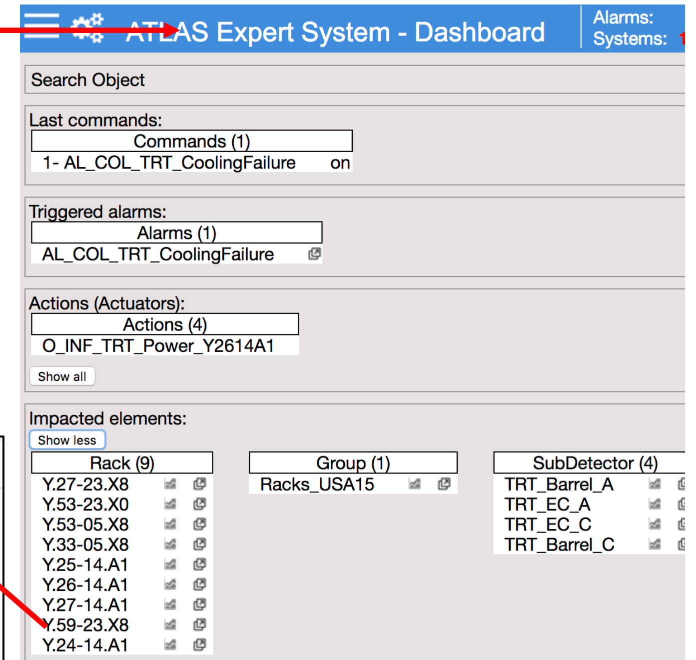
    System X was switched off because it was affected by the environmental alarm Y triggered by Z

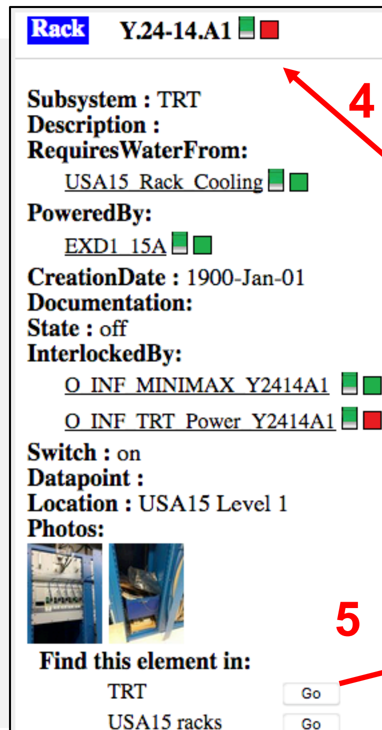


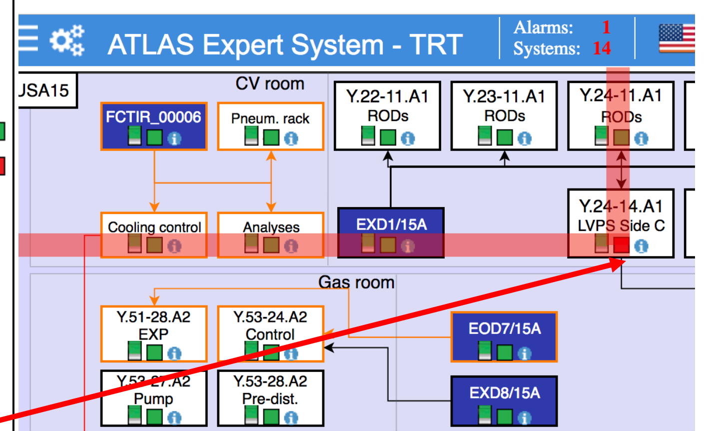
Simulation I - Consequences of triggering an alarm



3







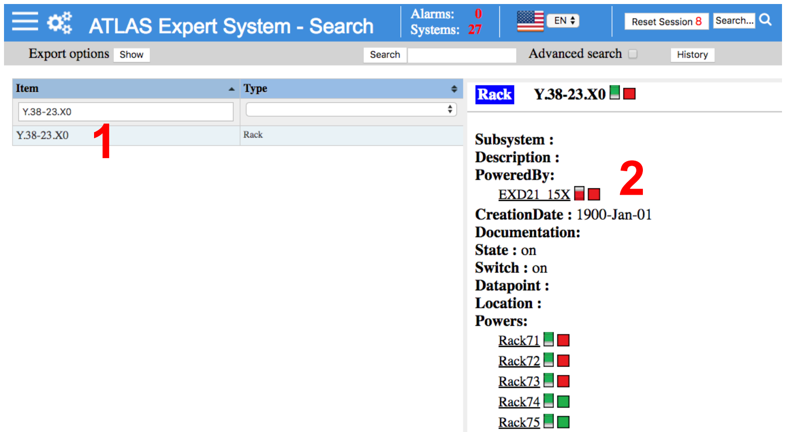
Situation: TRT team warns control room that an immediate intervention on TRT cooling is needed and they will probably trigger CoolingFailure alarm

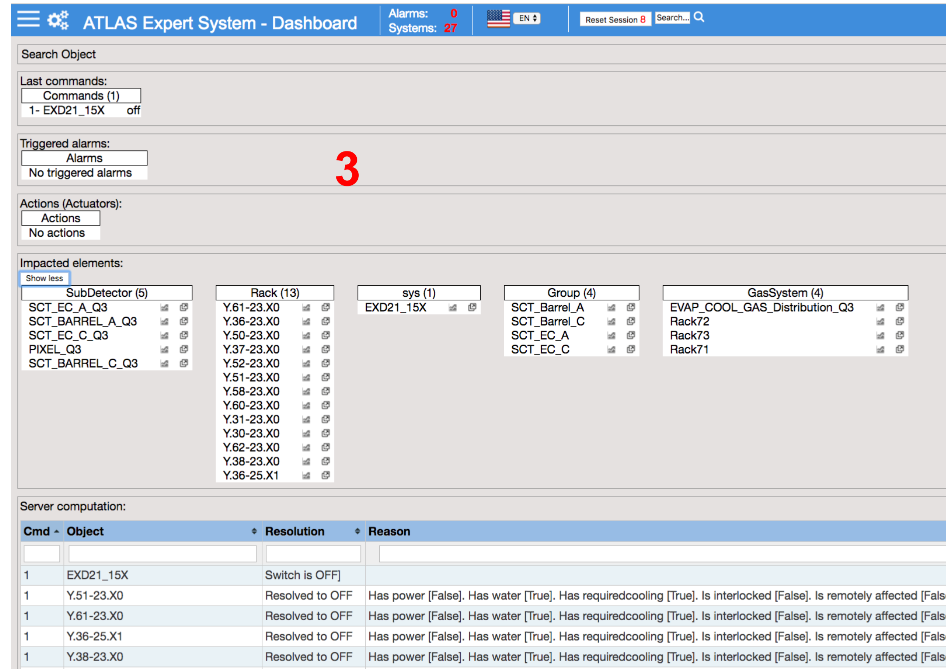
Simulation of scenario:

1. Search alarm
2. Trigger it
3. Check affected systems. Open an affected element in new tab
4. Look for the pages it appears and find it

Report affected groups

Simulation II - Intervention in a rack





Situation: Rack Y.38-23.X0 has to be switched off for a urgent intervention.

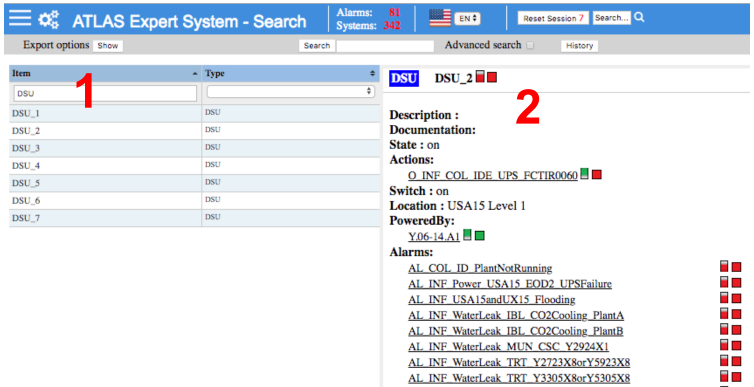
Simulation of scenario:

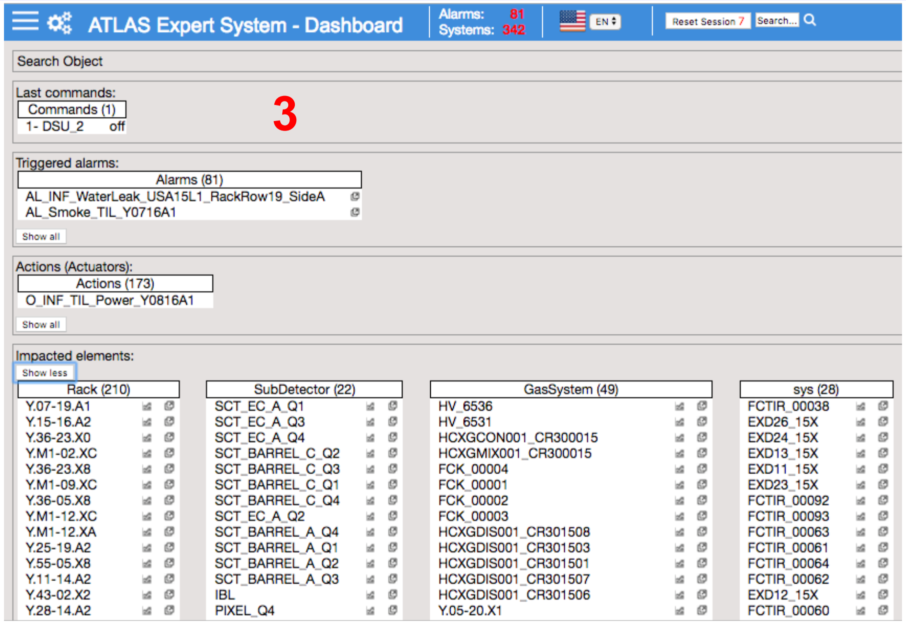
1. Search Y.38-23.X0
2. Switch it off its only power supply EXD21_15X
3. Check affected systems.

Important affected systems:

- Q3 of SCT and Pixel detectors are affected

Simulation III - Switching off DSU2





Situation: A Detector Safety Unit (DSU) needs to be switched off. Detail scenario of consequences has to be analyzed.

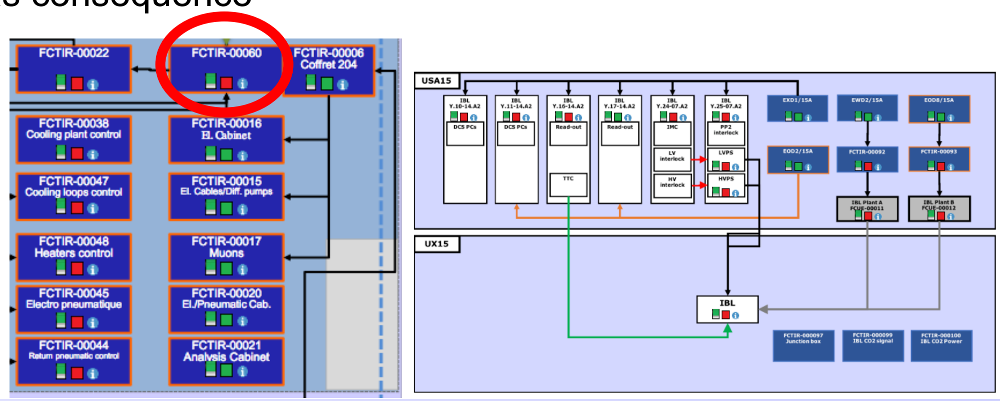
Simulation of scenario:

1. Search DSU2
2. Switch it off (see 81 triggered alarms in red)
3. Check affected systems.

Important affected systems:

- 22 subdetector systems affected
- 4 cooling stations
- 210 racks affected

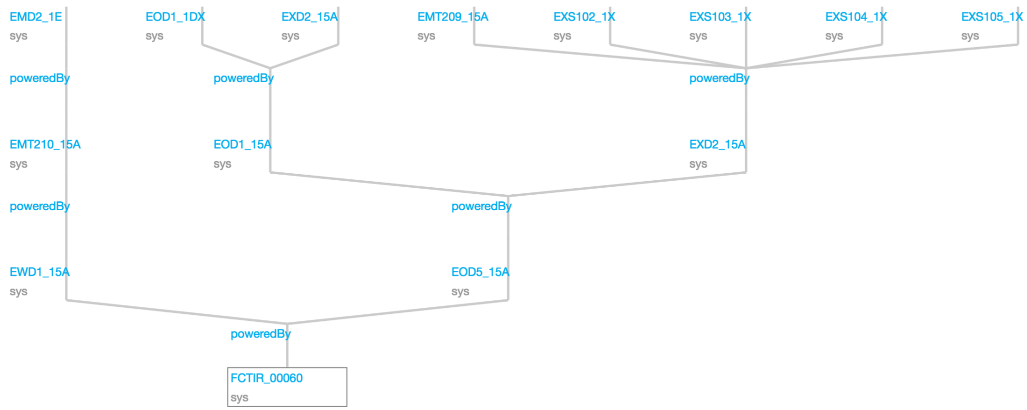
An error in the knowledge base produced a false scenario with FCTIR-00060 on. IBL was switched off unexpectedly as consequence



Risk analysis of ATLAS systems

Using the knowledge base and the fault tree we can make an estimation of the probability of failure for each system

- While we do not have a probability of success P_S for each system we assign one per type of system



Analysis on FCTIR-00060

$$P_S = 0.625307 = 0.9430^8$$

In a sample of 1762 samples with a mean of 96.2 FCTIR-00060 has P_s of 62.53 with a p-value of 3%

$$P_F = 0.374693 = (1 - 0.625307)$$

This system will have a probability of Failure of 37.46 % which is extremely high!

Combination of systems:

In parallel

$$P_s = 1 - \prod_{i=1}^{n} 1 - P(X_i)$$

In series

$$P_s = \prod_{i=1}^{n} P(X_i)$$

Probability of failure

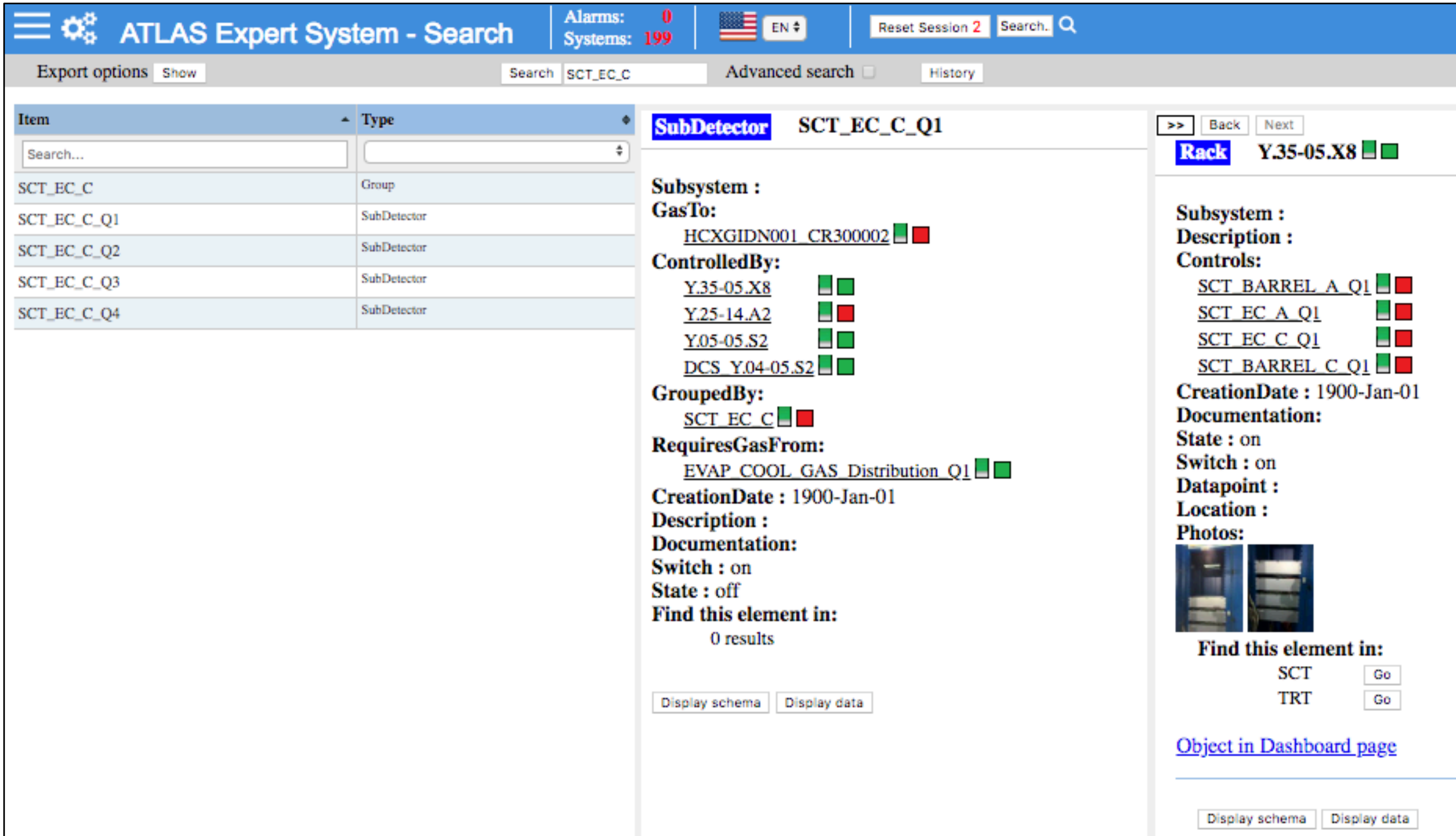
$$P_F = (1 - P_S)$$

Summary and status

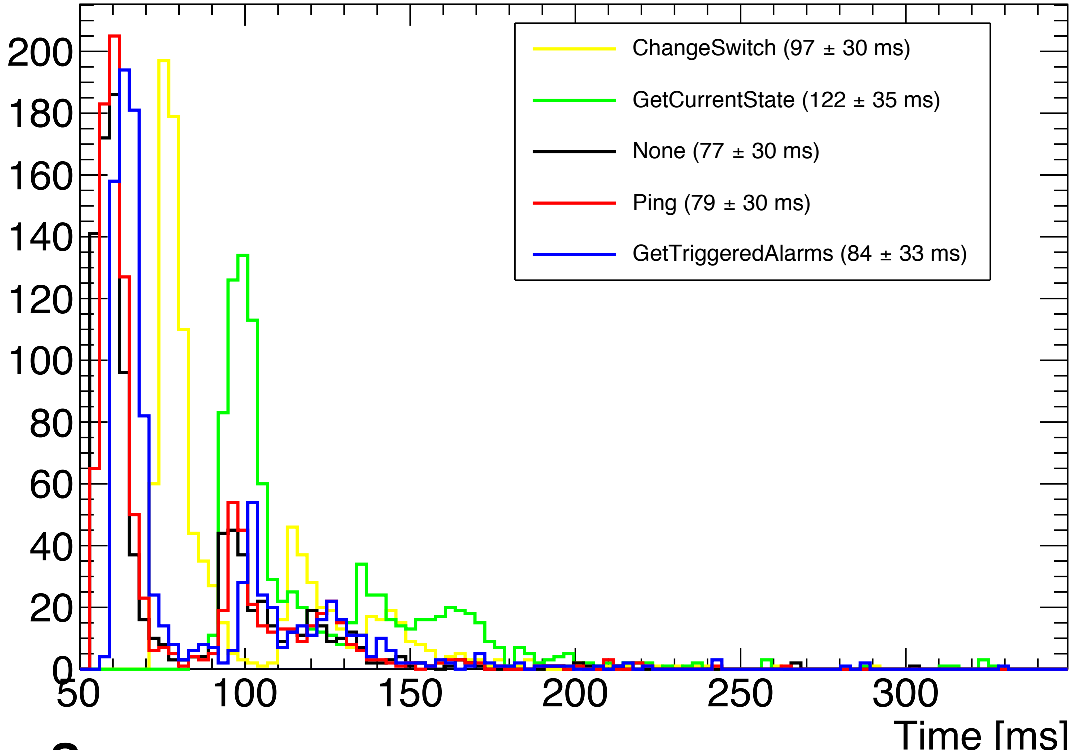
- The Expert System of the ATLAS expert system is a diagnostic tool for the maintenance of the experiment.
- It provides descriptions of critical systems like electricity, gas, sub-detectors, cryogenics, cooling and safety system.
- Descriptions are available graphic and text forms with different approaches depending on system being evaluated.
- It is able to simulate and predict the behavior of ATLAS in many scenarios and to explain its reasoning to a non-expert user.
- It is being used weekly in operations meetings to explain interventions and events of ATLAS.

Backup

Navigation through objects



Back-end



Database:

23 classes

3.3 Mb

3375 objects

Action	447
Alarm	522
Computer	2
CoolingLoop	26
CoolingProviderBase	0
CoolingReceiverBase	0
CoolingStation	11
DSU	7
DelayedAction	587
DigitalInput	41
GasSystem	161
Group	37
Heater	8
Magnet	11
PowerSupply	14
Rack	769
Session	1
SmokeCentral	0
SubDetector	47
VacuumPump	29
VentilationSystem	46
WaterSystem	169
sys	440

Server:

Shows good performance

$p(0.05) < 300ms$

Most Probable Value (MPV) for “get current state”, function that loads the simulation is ~100 ms