Understanding ATLAS infrastructure behaviour with an Expert System

VCHEP

18 May 2021

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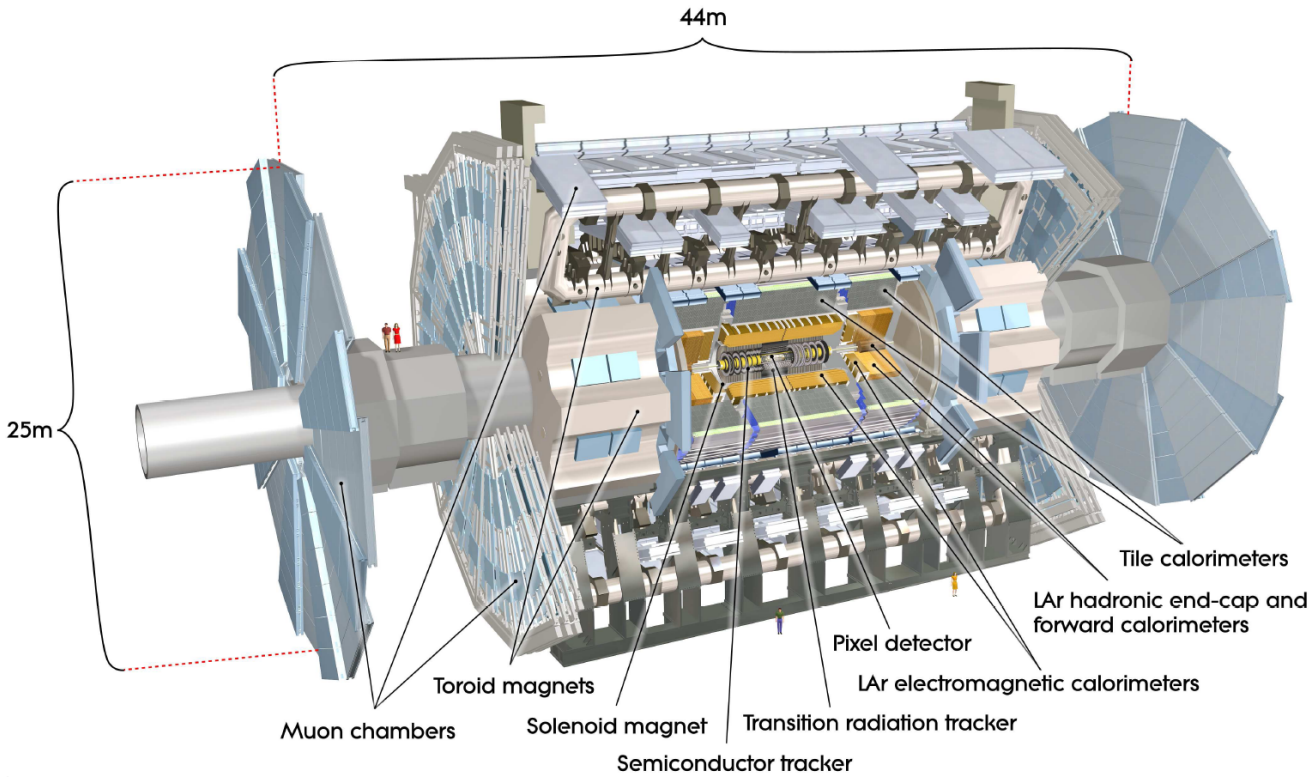
Introduction



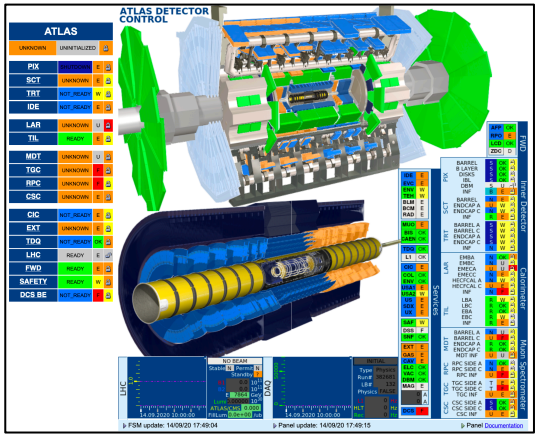
Representation of the ATLAS detector

Control room

- ATLAS is a general-purpose particle physics experiment at the LHC
- Its major components are
  - Magnets, Muon, Inner detector, Calorimeters
  - Detector control, safety systems, cooling stations, gas distribution...
- The Expert System provides reliable knowledge base for operations, maintenance and upgrade of the detector

What is an expert system

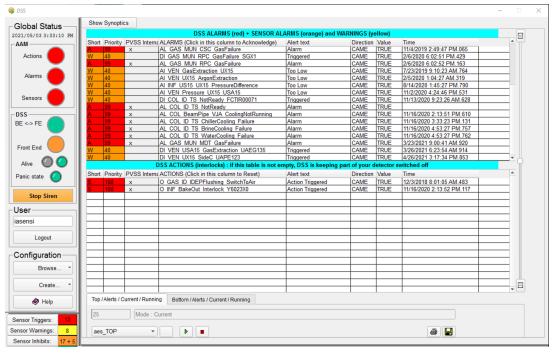
- Inference engine that provides **knowledge** and **reasoning** of experts
- Simulates the behavior of a complex system
- Explains causes and effects in a system
- Facilitates an easier sharing of knowledge



Monitoring panel of Detector Control System (DCS)

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

ATLAS Expert System welcome page

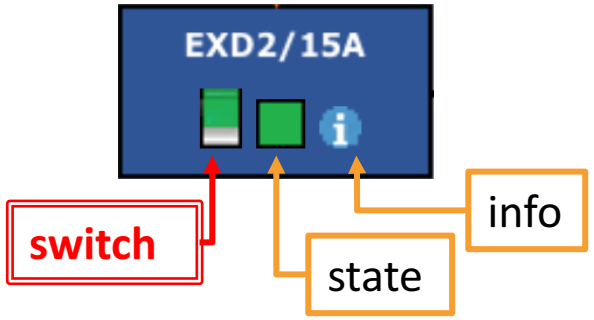


Monitoring panel of Detector Safety System (DSS)

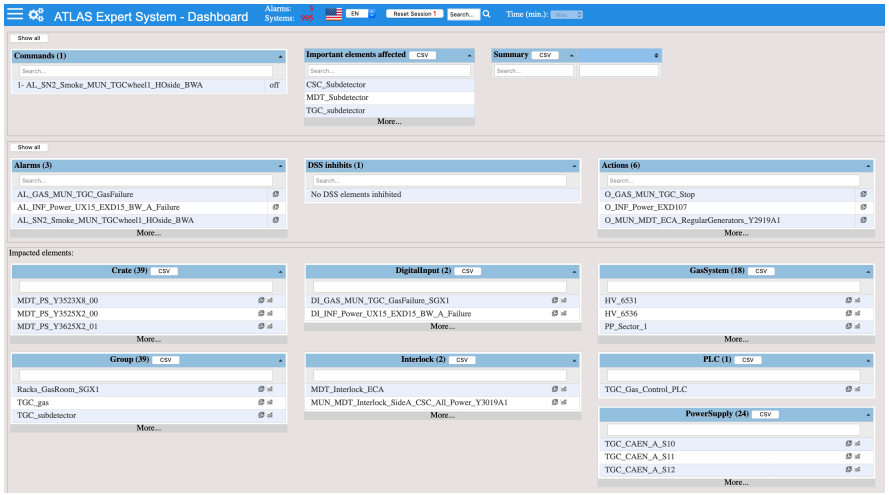
ATLAS Expert System

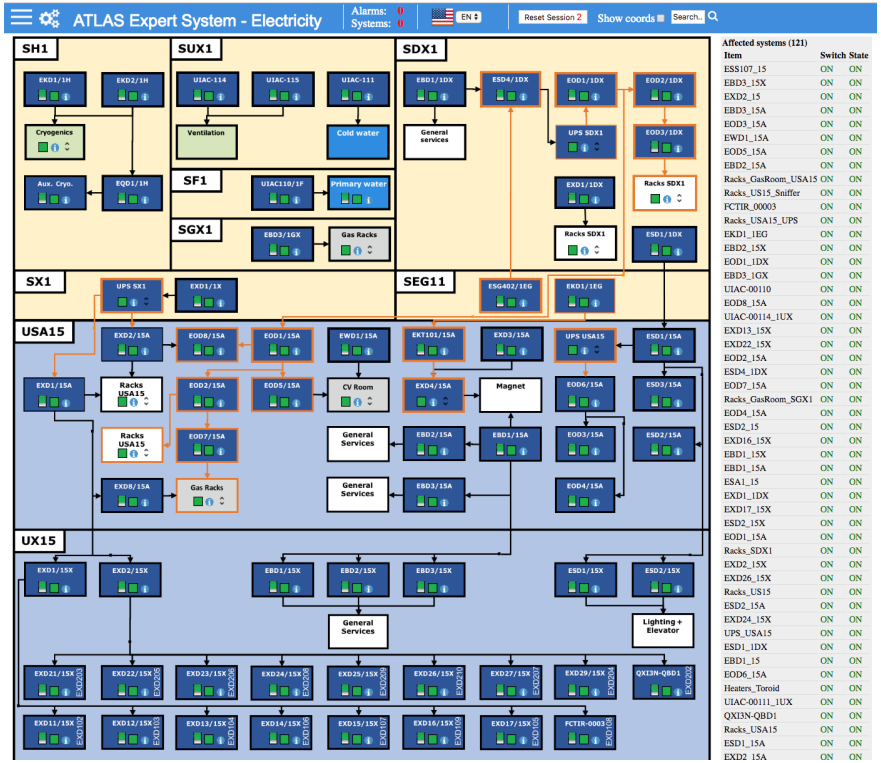
- **Simulate and describe** the behavior of ATLAS infrastructure
- **Plan interventions**, foresee possible unexpected outcomes
- Deep understanding of ongoing events
- **Event reporting**: Find information and see relationships between systems
- Easy access with a **web based** simulator user interface

Boxes represent systems



Detailed report of simulation is table organized

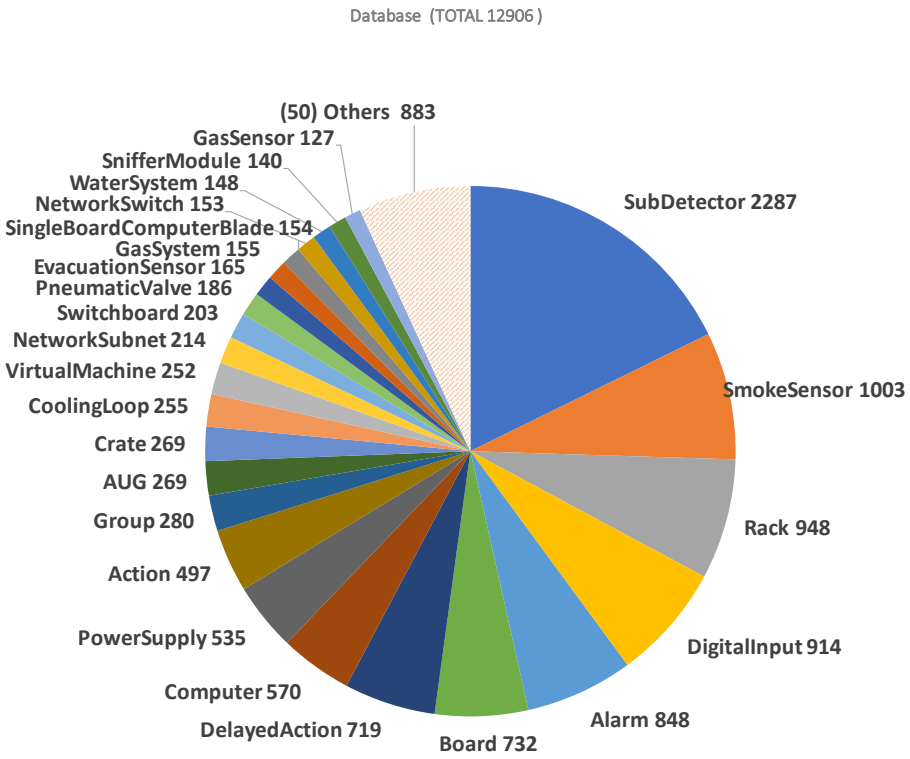


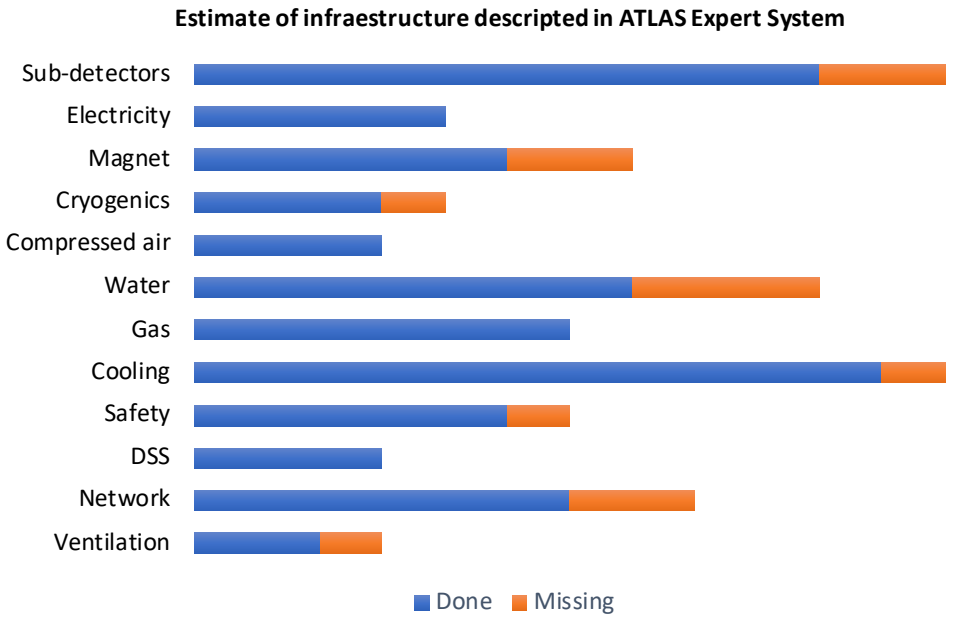


Following ATLAS upgrades

Recent descriptions

- **Simulate the network**
  - ATCN databases, clients, routers, switches and networks
  - Allow us to foresee impact during data taking periods
- **Improvements in descriptions** thanks to follow up of interventions during LS2
  - Test secours , switchboard interventions, AUG tests

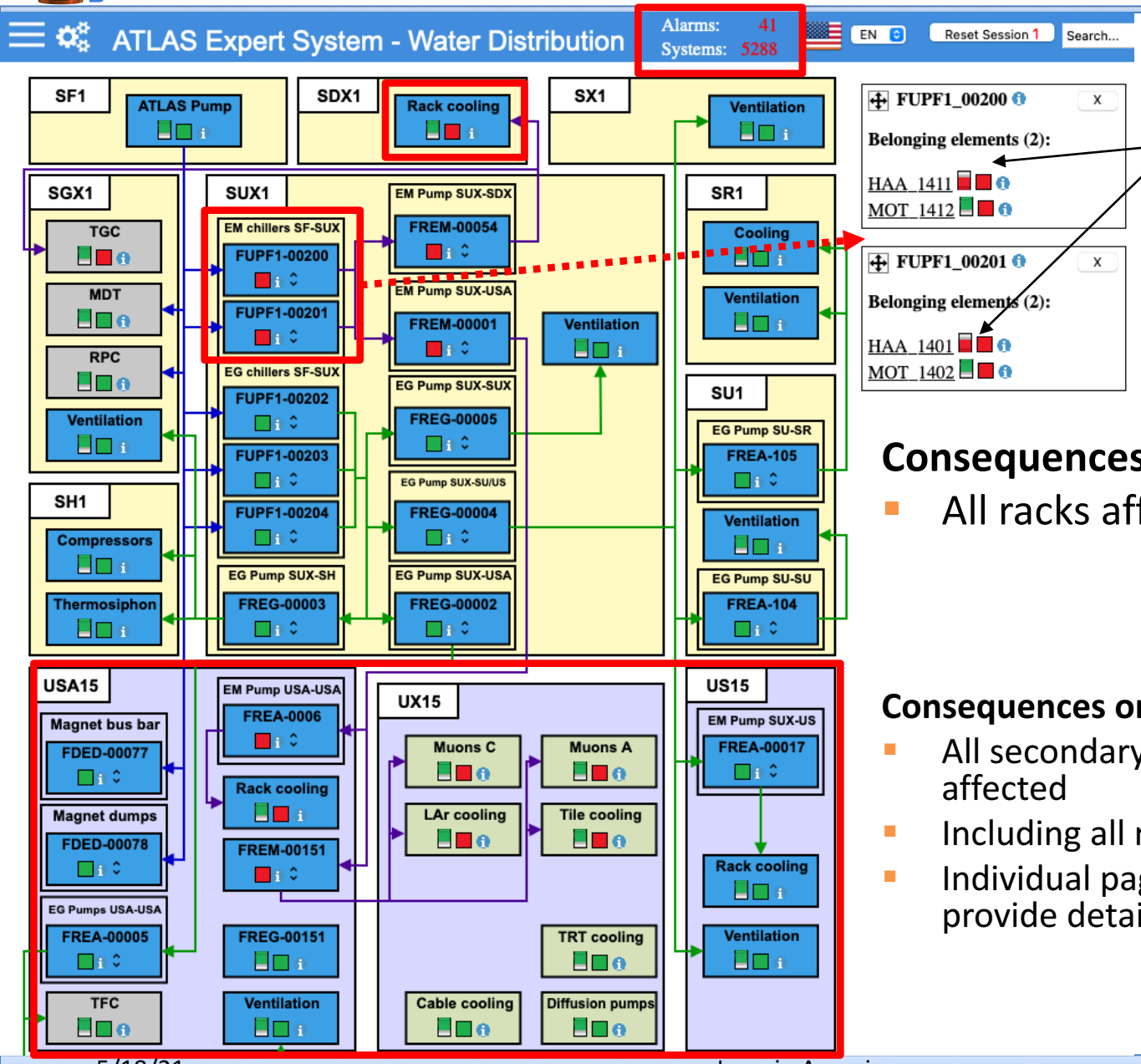




Recent updates during LS2

- Muon cooling stations
- NSW systems
- RPC distribution gas racks
- LAr racks

Simulation example – Annual maintenance water



Importance of mandatory annual interventions

Two main chillers on surface have to be stopped to maintain cooling underground

Consequences on surface

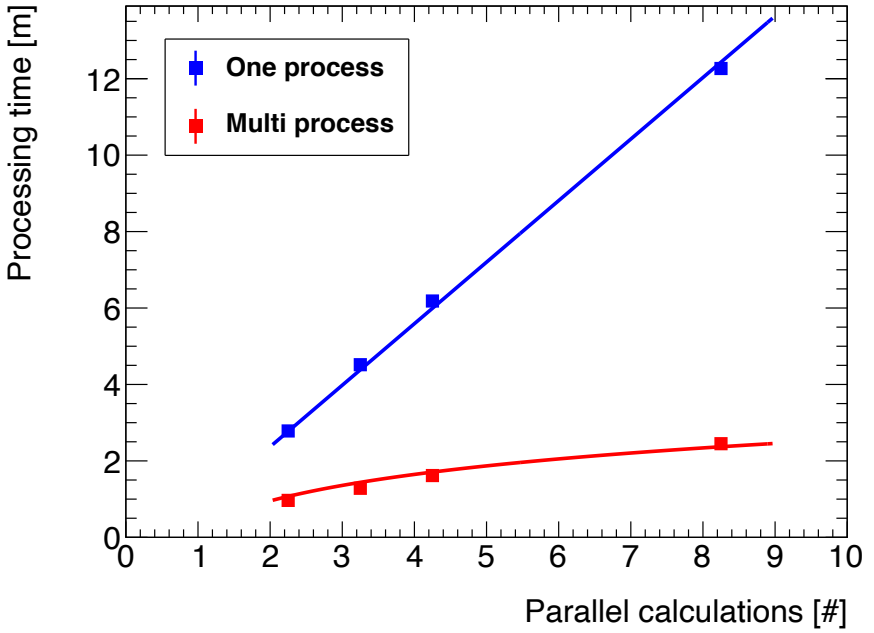
- All racks affected

Consequences on detector

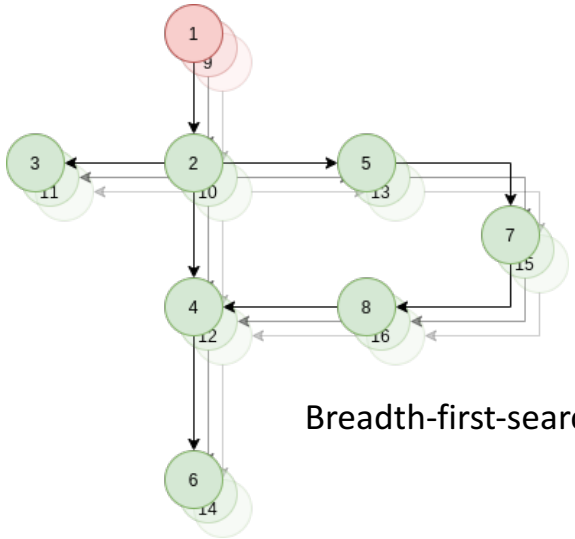
- All secondary cooling systems are affected
- Including all racks with water cooling
- Individual pages of secondary systems provide detailed lists of affected systems

Performance improvements

- Switched to NetworkX [1] to speed up searches
- Now using depth-first search for consequences and breadth first for parents
- New simulation convergence rules introduced:
  - The state of a node can change state during the simulation
  - The simulation is dynamic: one change requires several loops to run
  - Simulation is completed when the next loop does not change the state of any node in the tree



- Fewer loops, speed improvement of an order of magnitude
  - Code optimization
  - Circular dependencies detection and solution
  - Migration to multi-process engine
  - Iterate over edges in a breadth-first-search

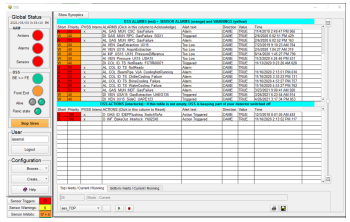


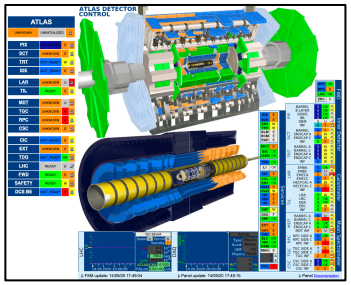
[1] https://networkx.org/

Most Probable Cause

- The Expert System can investigate the potential root cause for a scenario entered by the user
- Introduce list of affected systems
- Get list of most probable cause
- Two modes:
  - **Exhaustive**: all objects should be affected
  - **Non-exhaustive**: at least one object should be affected

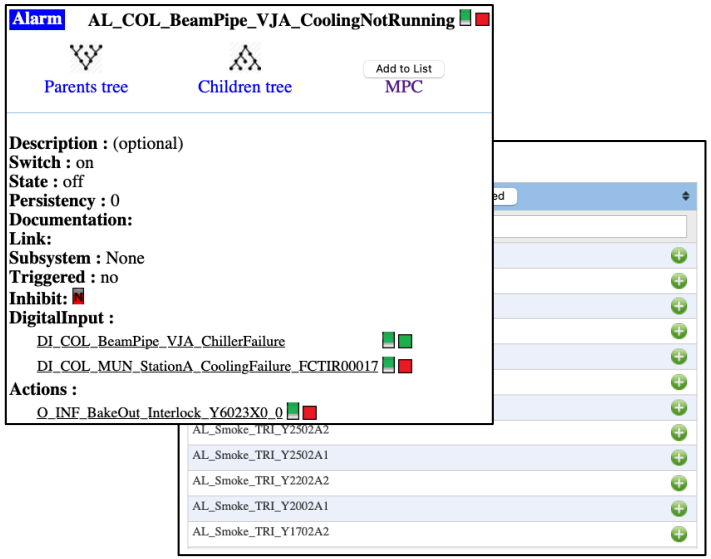
1. Check affected systems in detector control systems



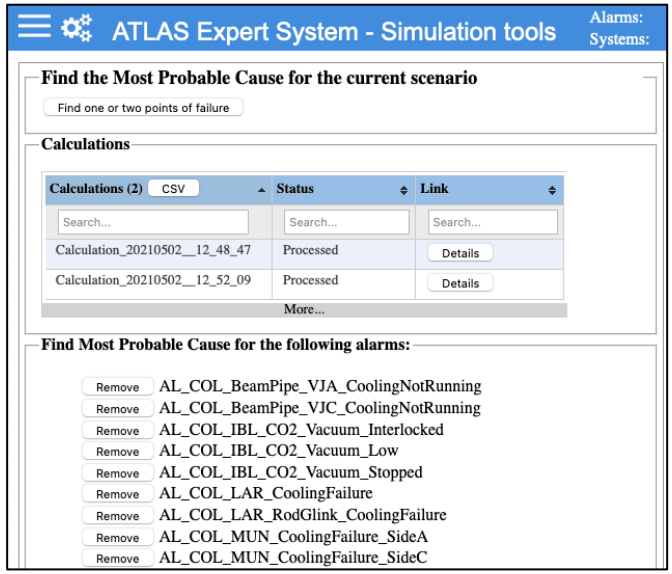


ATLAS Online monitoring tools

2. Search and add them to the MPC tool



3. Add to queue



Most Probable Cause

ATLAS Expert System - Simulation tools

Alarms:
Systems:

EN | Reset Session 1 | Search...

Name	Calculation_Water2_20210209__19_11_38
Type	MPC
Status	Processed
Date	2021-Feb-09
Affected	AL_COL_BeamPipe_VJA_CoolingNotRunning, AL_COL_BeamPipe_VJC_CoolingNotRunning, AL_COL_IBL_CO2_Vacuum_Interlocked, AL_COL_IBL_CO2_Vacuum_Low, AL_COL_IBL_CO2_Vacuum_Stopped, AL_COL_LAR_CoolingFailure, AL_COL_LAR_RodGlink_CoolingFailure, AL_COL_MUN_CoolingFailure_SideA, AL_COL_MUN_CoolingFailure_SideC, AL_COL_MUN_StationA_Loop10_Stopped, AL_COL_MUN_StationA_Loop11_Stopped, AL_COL_MUN_StationA_Loop12_Stopped, AL_COL_MUN_StationA_Loop13_Stopped, AL_COL_MUN_StationA_Loop14_Stopped, AL_COL_MUN_StationA_Loop15_Stopped, AL_COL_MUN_StationA_Loop1_Stopped, AL_COL_MUN_StationA_Loop2_Stopped, AL_COL_MUN_StationA_Loop3_Stopped, AL_COL_MUN_StationA_Loop4_Stopped, AL_COL_MUN_StationA_Loop5_Stopped, AL_COL_MUN_StationA_Loop6_Stopped, AL_COL_MUN_StationA_Loop7_Stopped, AL_COL_MUN_StationA_Loop8_Stopped, AL_COL_MUN_StationA_Loop9_Stopped, AL_COL_MUN_StationC_Loop10_Stopped, AL_COL_MUN_StationC_Loop11_Stopped, AL_COL_MUN_StationC_Loop12_Stopped, AL_COL_MUN_StationC_Loop13_Stopped, AL_COL_MUN_StationC_Loop1_Stopped, AL_COL_MUN_StationC_Loop2_Stopped, AL_COL_MUN_StationC_Loop3_Stopped, AL_COL_MUN_StationC_Loop4_Stopped, AL_COL_MUN_StationC_Loop5_Stopped, AL_COL_MUN_StationC_Loop6_Stopped, AL_COL_MUN_StationC_Loop7_Stopped, AL_COL_MUN_StationC_Loop8_Stopped, AL_COL_MUN_StationC_Loop9_Stopped, AL_COL_TIL_CoolingFailure, AL_CRY_LAR_FeedthroughTempLow, AL_INF_RackCoolingFailure_SDX1, AL_INF_RackCoolingFailure_USA15,
MPC	HAA_1401, HAA_1411,

5MW chiller units

- MPC of 41 alarms triggered in the Detector Safety System during annual water maintenance
- HAA_1401 and HAA_1411 succesfully identified

MPC performance

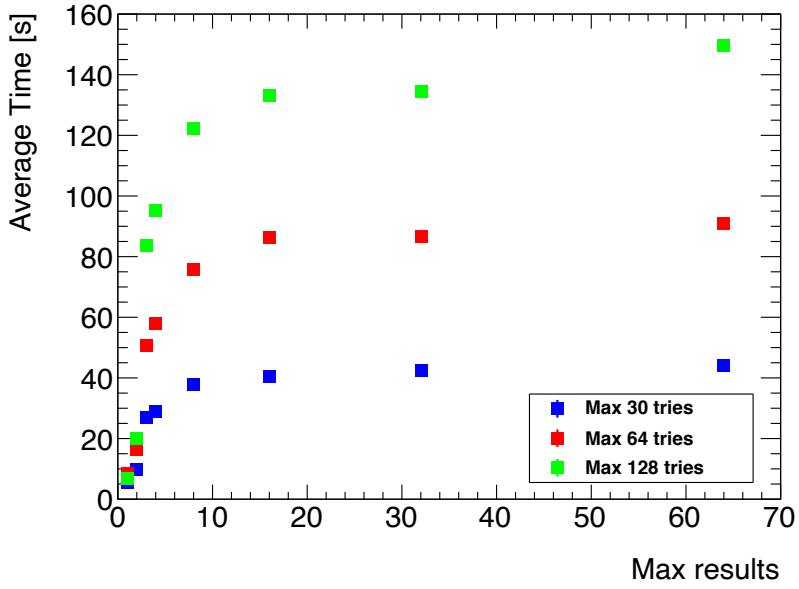
- The MPC algorithm uses two parameters.
  - Maximum **number of attempts** which is the number of parents that will be processed.
  - **Number of results** shown to the user.

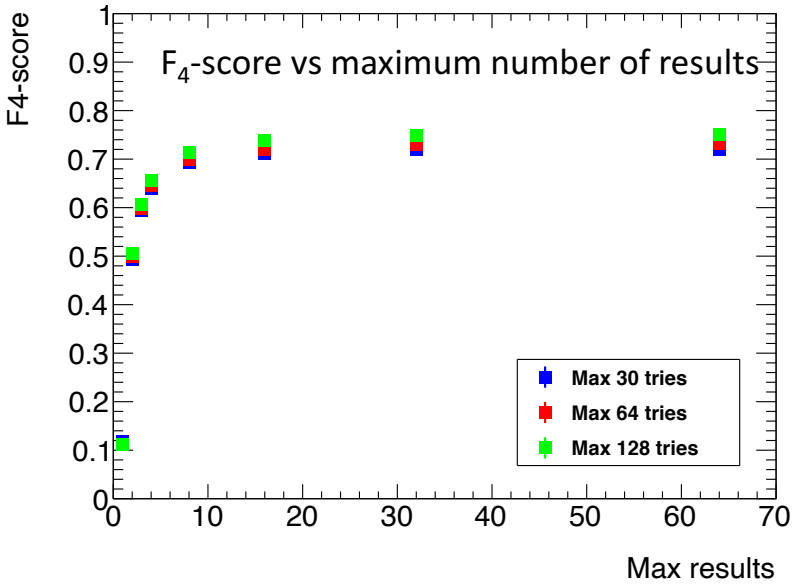
The F4-score is a measure for the quality of the results.

$$F_\beta = (1+\beta^2)\cdot\frac{\text{precision}\cdot\text{recall}}{(\beta^2\cdot\text{precision})+\text{recall}}$$

Increasing the maximum number of results would increase the processing time without significantly improving the quality of the results.
A number of **8 maximum results and 30 tries** has been established as the best parameter set for the algorithm in terms of time vs accuracy with an average time of 37 s and a F4-score of 0.7

Average processing time vs maximum number of results





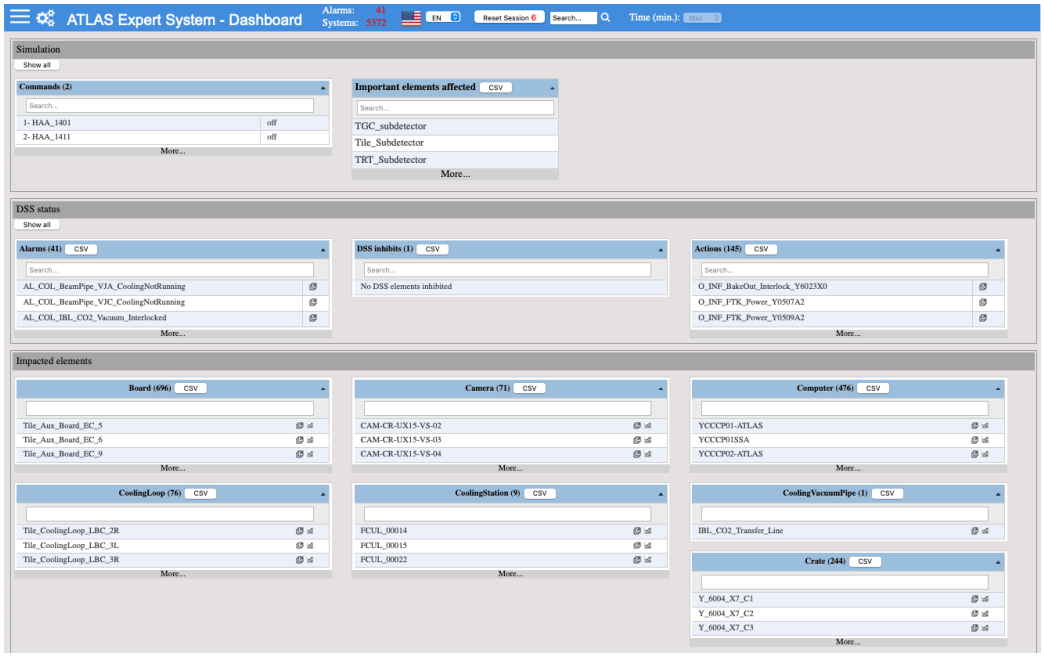
Summary and status

- The ATLAS Expert System by ATLAS Technical Coordination is a diagnostic tool for the maintenance of the experiment
- Description of critical systems like electricity, gas, detectors and others is reaching the desired granularity and it is kept updated constantly
- Simulations have been compared with actual intervention outcomes during LS2
- Now describing more than 12k objects
- The Expert System has been proven useful evaluating the impact of interventions
- It is possible to find the cause for the provided scenario
- Vast improvements in code execution speed and performance. Simulation time has been reduced

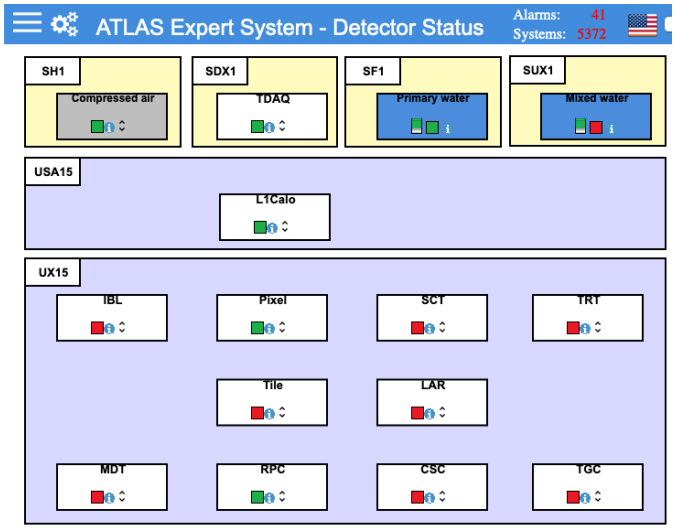
Thank you for your attention

Water maintenance simulation

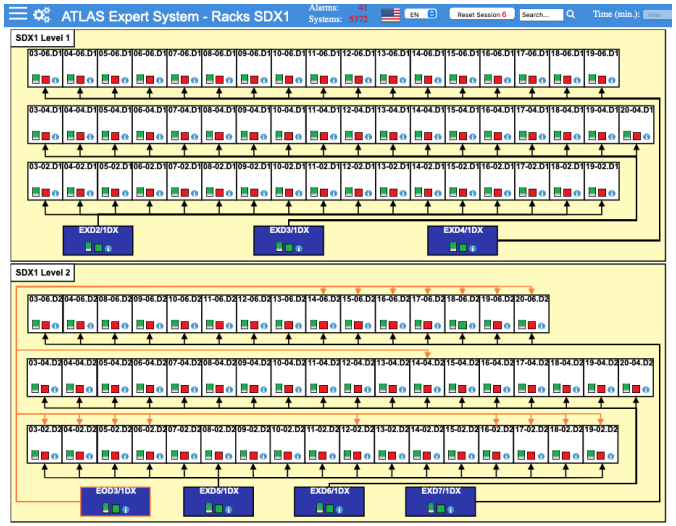
Detailed report of simulation



Status of the detector



Racks on surface are also affected



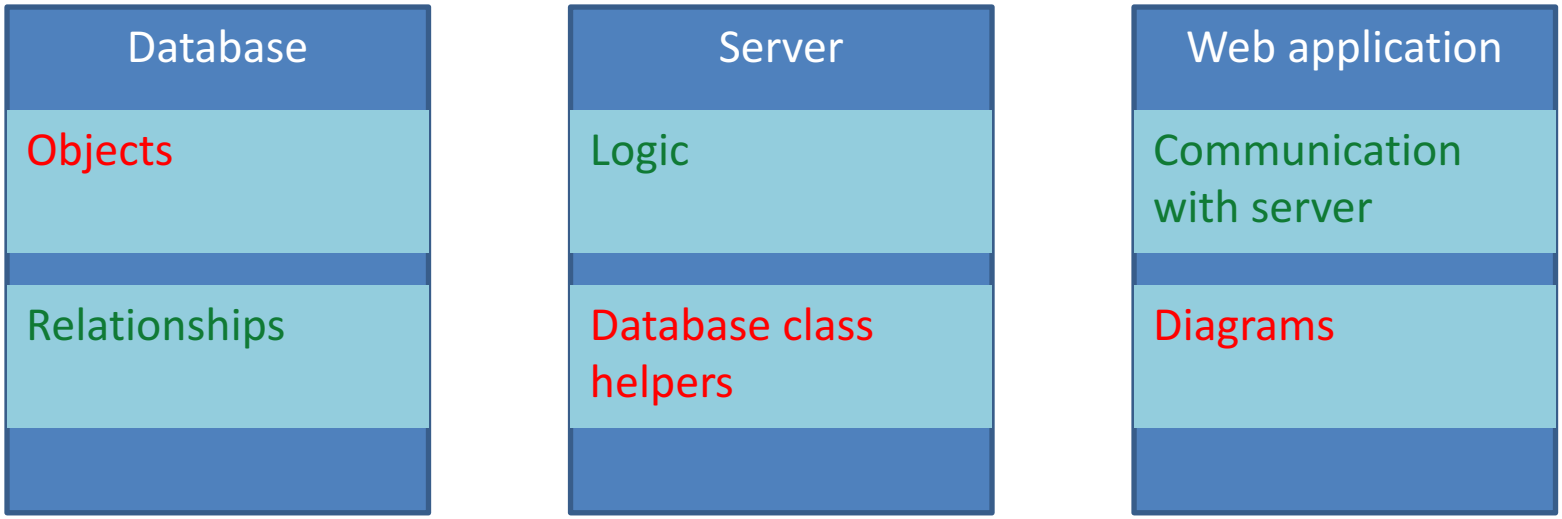
F4 score calculation

$$F_\beta = (1 + \beta^2) \cdot \frac{\text{precision} \cdot \text{recall}}{(\beta^2 \cdot \text{precision}) + \text{recall}}$$

Precision is the number of correctly identified positive results divided by the number of all positive results including those not identified correctly.

The **recall** is the number of correctly identified positive results divided by the number of all samples that should have been identified as positive

Expert System portability



Model

- Maintenance of simulation state
- Store and retrieve data

Controller

- Respond to user input
- Interpret user request with data from model

View

- User interaction
- Scenario rendering

General
ATLAS specific

	Done	Missing
Sub-detectors	IBL, Pix, SCT, TRT, LAR, Tile, MDT, RPC, TGC, CSC	L1Calo, interlocks
Electricity	Switchboards, repowering, coupling, UPS	Breakers
Magnet	VHS, LAR heaters, He flow (main, shield), ANRS, diff pumps	MCS, power distribution
Cryogenics	He flow (main, shield), ANRS	Control
Compressed air	Production, distribution, reservoirs	
Water	SF1, SUX1, USA15, US15, UX15, back-up chiller, SU1	Back-up US15, USA15
Gas	CSC, RPC, TGC, MDT, TRT, TFC	
Cooling	US15, USA15, UX15, Muon, TRT, Evap, Thermosyphon, IBL, Tile, LAR, Diff pumps	Cables
Safety	Light, elevator, sniffers, flammable gas, smoke, fireman boxes	CAN control
DSS	Inputs, alarms, actions	Check matrix
Network	Routers, switches, ATCN & TN clients, DHCP, NTP, NetApp	TN databases. "Big picture"
Ventilation	Units, controls	"Big picture"