

# CHEP 2018

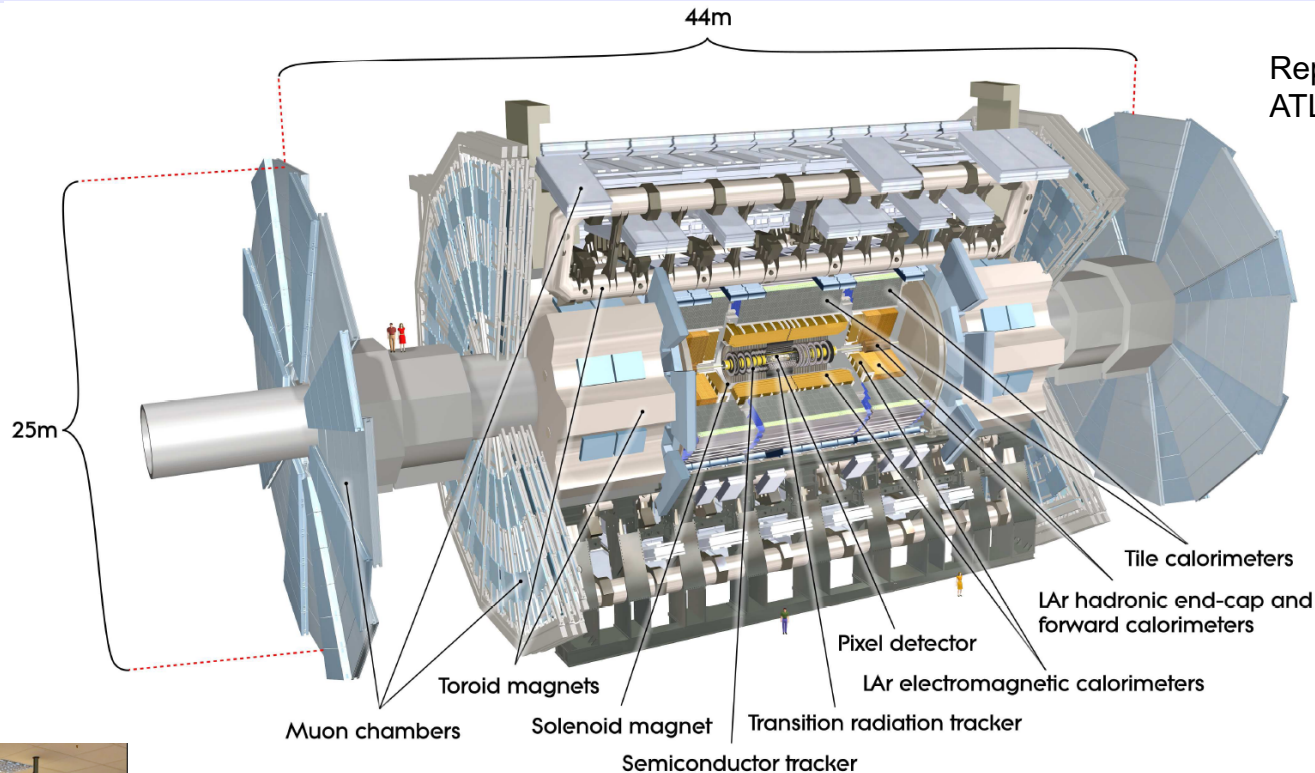
## Sofia, Bulgaria

### ATLAS TC Expert System



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Representation of the ATLAS detector

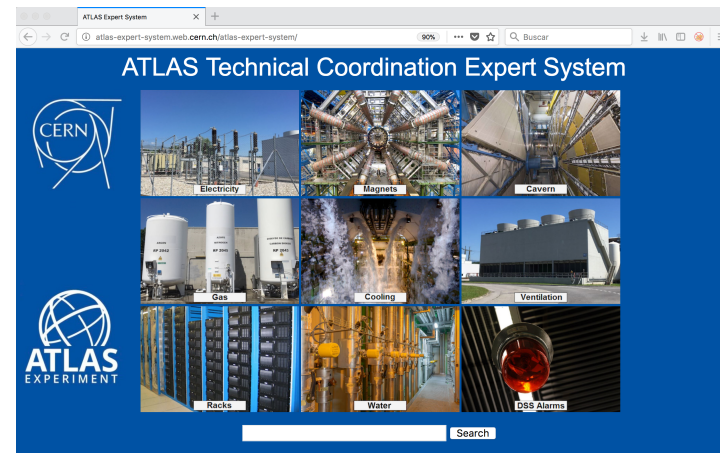


Control room

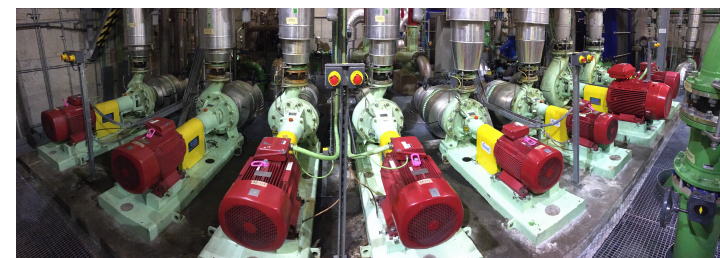
- ATLAS is a general-purpose particle physics experiment at the LHC
- Its major components are
  - Magnet, Muon, Inner detector, Calorimeters
  - Many others like computing, Control and Safety systems
- Confident knowledge on many systems of the detector is critical for maintenance, upgrade operations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

- 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>



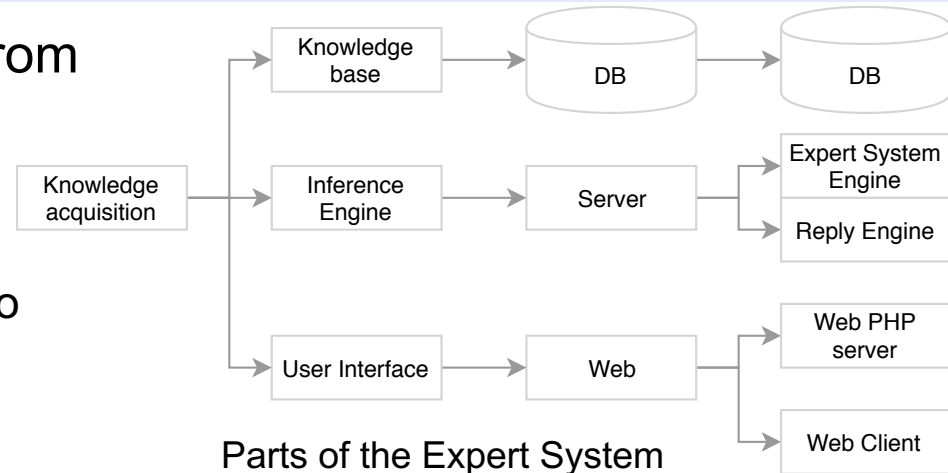
Foresee what is going to happen  
Explain why something is off



Compressors of the ID  
Evaporative Cooling System

- Starting from acquiring knowledge from many sources:

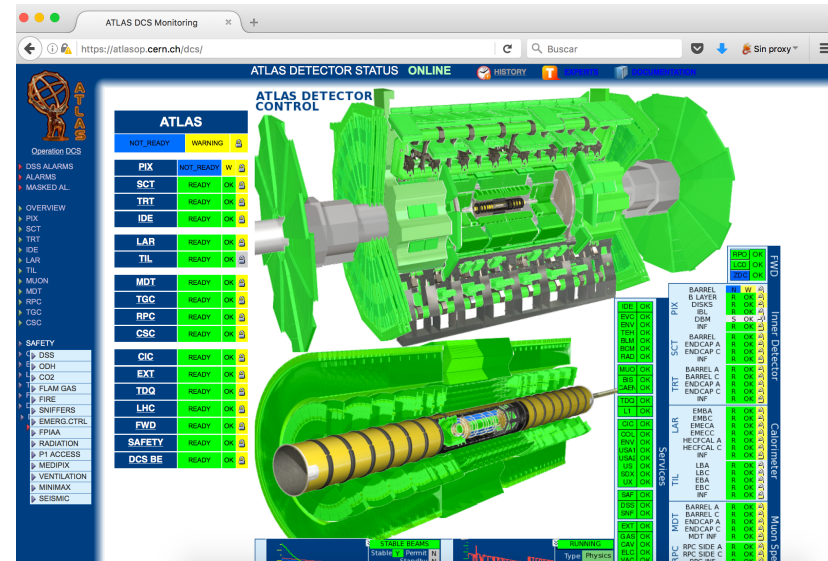
- Technical documentation
- Investigation
- Meeting with Experts of each system to revise descriptions



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 deduces the behavior of the systems and answers to the user input
- User Interface
  - In accordance to experts advise and user needs

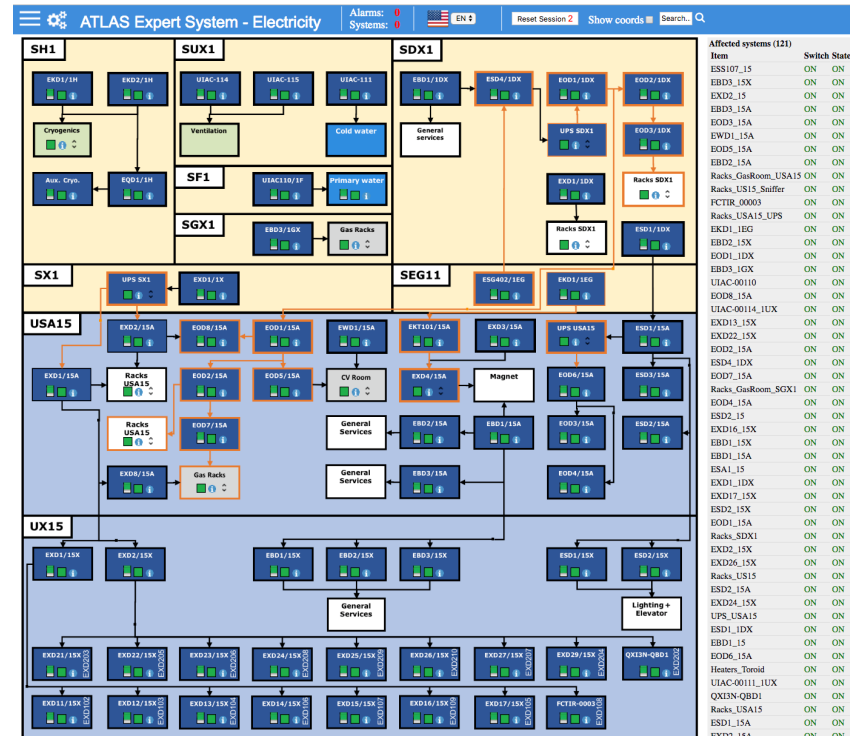
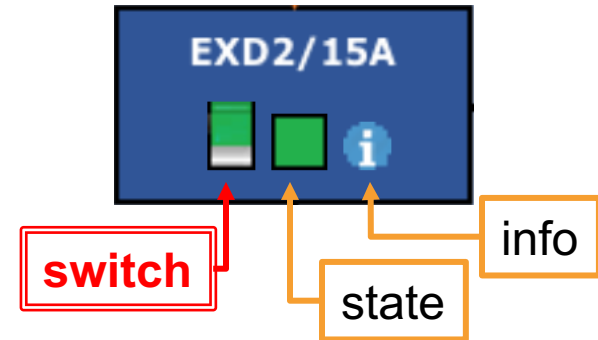


Screenshot of the ATLAS detector status in the Detector Control System (DCS)



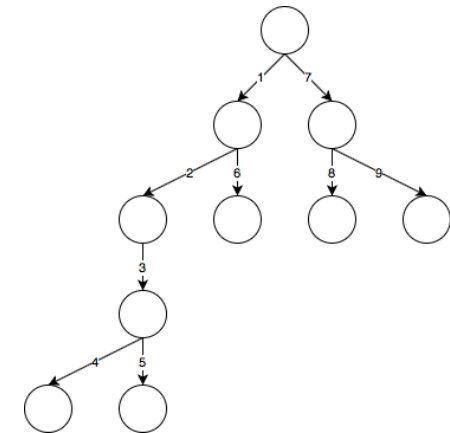
## Using graphical interface

- 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

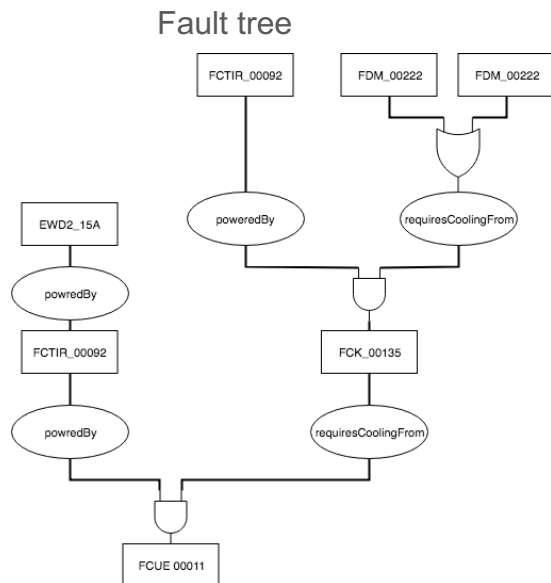


ATLAS individual systems are represented in the database as objects and relationships

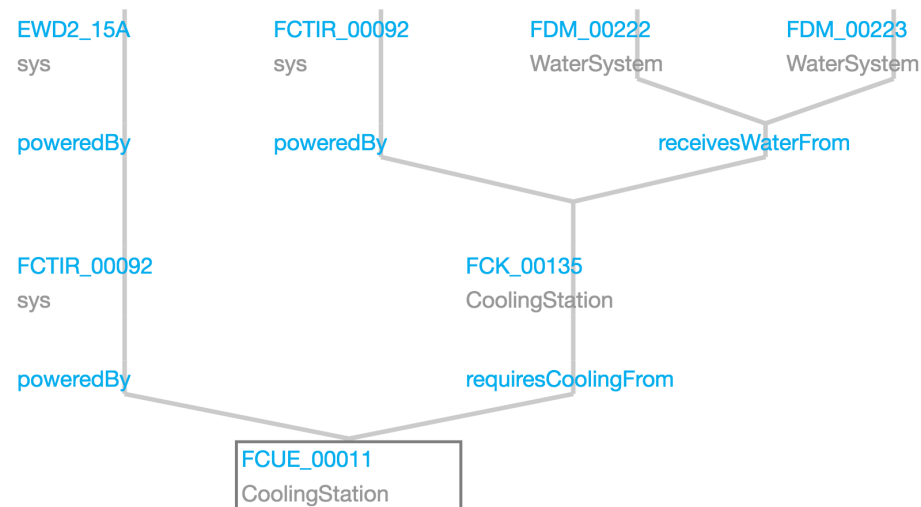
- Relationships represent inputs and outputs
- In a system, each relationship is calculated as an independent node.
- Relationships are always combined in parallel
- Systems arranged in the same node can be in parallel or series
- In every simulation, the inference engine, using a deep-first algorithm,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



Search for children using Deep-first algorithm



Screenshot of visual representation of the tree of systems



## 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*

ATLAS Expert System - Dashboard
Alarms: 0  
Systems: 199
EN1
Reset Session 2
Search

Search Object

**SCT\_EC\_A\_Q4:**  
 As consequence of turning EXD1\_15A to off, SCT\_EC\_A\_Q4 was resolved to off because: Has power [True]. Has gas [True]. Has required gas [True]. Has water [True]. Has required water [True]. Has cooling [True]. Has required cooling [True]. Is interlocked [False]. Is remotely affected [True]  
 SCT\_EC\_A\_Q4

Last commands:

Commands (1)

1- EXD1\_15A off

Triggered alarms:

Alarms

No triggered alarms

Actions (Actuators):

Actions

No actions

Impacted elements:

Rack (162)	PowerSupply (8)	SubDetector (19)	Group (5)	GasSystem (4)	sys (1)
Y.11-16.A2	LV_Y06-14.A2	SCT_EC_A_Q1	SCT_EC_A	HCXGIDN001_CR300012	EXD1_15A
Y.07-14.A2	HV_Y08-14.A2	SCT_EC_A_Q4	SCT_EC_C	HCXGIDC001_CR300012	
Y.02-05.A1	LV_Y05-14.A2	SCT_BARREL_C_Q1	Racks_USA15	HCXGIDN001_CR300002	
Y.07-19.A1	HV_Y09-14.A2	SCT_EC_A_Q3	SCT_Barrel_A	HCXGIDN001_CR300001	
Y.25-07.A2	LV_Y25-07.A2	SCT_EC_A_Q2	SCT_Barrel_C		

Server computation:

Cmd	Object	Resolution	Reason
1	EXD1_15A	Switch is OFF	
1	Y.22-21.A1	Resolved to ON	Has power [True]. Has water [True]. Has requiredcooling [True]. Is interlocked [False]. Is remotely affected [False]
1	Y.10-16.A2	Resolved to OFF	Has power [False]. Has water [True]. Has requiredcooling [True]. Is interlocked [False]. Is remotely affected [False]
1	Y.30-16.A1	Resolved to OFF	Has power [False]. Has water [True]. Has requiredcooling [True]. Is interlocked [False]. Is remotely affected [False]
1	Y.08-14.A1	Resolved to OFF	Has power [False]. Has water [True]. Has requiredcooling [True]. Is interlocked [False]. Is remotely affected [False]

ATLAS Expert System - Search

Alarms: 1  
Systems: 6

Export options Show Search Advanced search History

Item	Type
TRT	Alarm
AL_COL_TRT_CoolingFailure	Alarm
AL_GAS_TRT_ArgonActiveGas_Stop	Alarm
AL_GAS_TRT_CO2CoolingFailure	Alarm
AL_GAS_TRT_GasFailure	Alarm
AL_INF_WaterLeak_TRT_Y2723X8orY5923X8	Alarm
AL_INF_WaterLeak_TRT_Y3305X8orY5305X8	Alarm
AL_INF_WaterLeak_TRT_Y5323X0	Alarm
AL_Smoke_TRT_Y2211A1	Alarm
AL_Smoke_TRT_Y2311A1	Alarm
AL_Smoke_TRT_Y2411A1	Alarm
AL_Smoke_TRT_Y2414A1	Alarm

**Alarm** AL\_COL\_TRT\_CoolingFailure

Subsystem : COL  
DigitalInput:  
Persistence : 15  
DSU:  
DSU 3  
Description :  
Triggered : no  
Documentation:  
State : off  
Actions:  
O INF TRT Power Y2414A1 15  
O INF TRT Power Y2514A1 15

ATLAS Expert System - Dashboard

Alarms: Systems:

Search Object

Last commands:  
Commands (1)  
1- AL\_COL\_TRT\_CoolingFailure on

Triggered alarms:  
Alarms (1)  
AL\_COL\_TRT\_CoolingFailure

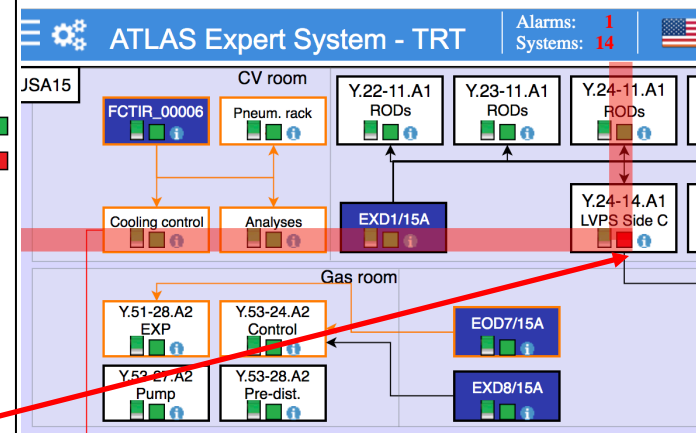
Actions (Actuators):  
Actions (4)  
O\_INF\_TRT\_Power\_Y2614A1  
Show all

Impacted elements:  
Show less

Rack (9)	Group (1)	SubDetector (4)
Y.27-23.X8	Racks_USA15	TRT_Barrel_A
Y.53-23.X0		TRT_EC_A
Y.53-05.X8		TRT_EC_C
Y.33-05.X8		TRT_Barrel_C
Y.25-14.A1		
Y.26-14.A1		
Y.27-14.A1		
Y.59-23.X8		
Y.24-14.A1		

Rack Y.24-14.A1

Subsystem : TRT  
Description :  
RequiresWaterFrom:  
USA15 Rack Cooling  
PoweredBy:  
EXD1 15A  
CreationDate : 1900-Jan-01  
Documentation:  
State : off  
InterlockedBy:  
O INF MINIMAX Y2414A1  
O INF TRT Power Y2414A1  
Switch : on  
Datapoint :  
Location : USA15 Level 1  
Photos:  
Find this element in:  
TRT  
USA15 racks



**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

ATLAS Expert System - Search

Alarms: 0 Systems: 27

EN

Reset Session B Search...

Export options Show Search Advanced search History

Item Type

Y.38-23.X0

Y.38-23.X0 **1** Rack

Rack Y.38-23.X0

Subsystem :  
Description :  
PoweredBy: EXD21\_15X **2**  
CreationDate : 1900-Jan-01  
Documentation:  
State : on  
Switch : on  
Datapoint :  
Location :  
Powers:  
Rack71  
Rack72  
Rack73  
Rack74  
Rack75

ATLAS Expert System - Dashboard

Alarms: 0 Systems: 27

EN

Reset Session B Search...

Search Object

Last commands:  
Commands (1)  
1- EXD21\_15X off

Triggered alarms:  
Alarms  
No triggered alarms **3**

Actions (Actuators):  
Actions  
No actions

Impacted elements:

SubDetector (5)	Rack (13)	sys (1)	Group (4)	GasSystem (4)
SCT_EC_A_Q3	Y.61-23.X0	EXD21_15X	SCT_Barrel_A	EVAP_COOL_GAS_Distribution_Q3
SCT_BARREL_A_Q3	Y.36-23.X0		SCT_Barrel_C	Rack72
SCT_EC_C_Q3	Y.50-23.X0		SCT_EC_A	Rack73
PIXEL_Q3	Y.37-23.X0		SCT_EC_C	Rack71
SCT_BARREL_C_Q3	Y.52-23.X0			
	Y.51-23.X0			
	Y.58-23.X0			
	Y.60-23.X0			
	Y.31-23.X0			
	Y.30-23.X0			
	Y.62-23.X0			
	Y.38-23.X0			
	Y.36-25.X1			

Server computation:

Cmd	Object	Resolution	Reason
1	EXD21_15X	Switch Is OFF]	
1	Y.51-23.X0	Resolved to OFF	Has power [False], Has water [True], Has requiredcooling [True], Is interlocked [False], Is remotely affected [False]
1	Y.61-23.X0	Resolved to OFF	Has power [False], Has water [True], Has requiredcooling [True], Is interlocked [False], Is remotely affected [False]
1	Y.36-25.X1	Resolved to OFF	Has power [False], Has water [True], Has requiredcooling [True], Is interlocked [False], Is remotely affected [False]
1	Y.38-23.X0	Resolved to OFF	Has power [False], Has water [True], Has requiredcooling [True], Is interlocked [False], Is remotely affected [False]

**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



ATLAS Expert System - Search

Alarms: 81 Systems: 312

Export options Show Search Advanced search History

Item 1 Type DSU

DSU\_1 DSU

DSU\_2 DSU

DSU\_3 DSU

DSU\_4 DSU

DSU\_5 DSU

DSU\_6 DSU

DSU\_7 DSU

Description : Documentation :

State : on

Actions: O\_INF\_COL\_IDE\_UPS\_FCTIR0060

Switch : on

Location : USA15 Level 1

PoweredBy: Y06-14-A1

Alarms:

- AL\_COL\_ID\_PlantNotRunning
- AL\_INF\_Power\_USA15\_EOD2\_UPSFailure
- AL\_INF\_USA15SandUX15\_Flooding
- AL\_INF\_WaterLeak\_IBL\_CO2Cooling\_PlantA
- AL\_INF\_WaterLeak\_IBL\_CO2Cooling\_PlantB
- AL\_INF\_WaterLeak\_MUN\_CSC\_Y2924X1
- AL\_INF\_WaterLeak\_TRT\_Y2723X8orY5923X8
- AL\_INF\_WaterLeak\_TRT\_Y3305X8orY3305X8

ATLAS Expert System - Dashboard

Alarms: 81 Systems: 342

Search Object

Last commands: Commands (1) 1- DSU\_2 off

Triggered alarms: Alarms (81)

- AL\_INF\_WaterLeak\_USA15L1\_RackRow19\_SideA
- AL\_Smoke\_TIL\_Y0716A1

Actions (Actuators): Actions (173)

- O\_INF\_TIL\_Power\_Y0816A1

Impacted elements:

Rack (210)	SubDetector (22)	GasSystem (49)	sys (28)
Y.07-19.A1	SCT_EC_A_Q1	HV_6536	FCTIR_00038
Y.15-16.A2	SCT_EC_A_Q3	HV_6531	EXD26_15X
Y.36-23.X0	SCT_EC_A_Q4	HXCGCON001_CR300015	EXD24_15X
Y.M1-02.XC	SCT_BARREL_C_Q2	HXCGMIX001_CR300015	EXD13_15X
Y.36-23.X8	SCT_BARREL_C_Q3	FCX_00004	EXD11_15X
Y.M1-09.XC	SCT_BARREL_C_Q1	FCX_00001	EXD23_15X
Y.36-05.X8	SCT_BARREL_C_Q4	FCX_00002	FCTIR_00092
Y.36-05.XC	SCT_EC_A_Q2	FCX_00003	FCTIR_00093
Y.M1-12.XA	SCT_BARREL_A_Q4	HXGDIS001_CR301508	FCTIR_00063
Y.25-19.A2	SCT_BARREL_A_Q1	HXGDIS001_CR301503	FCTIR_00061
Y.55-05.X8	SCT_BARREL_A_Q2	HXGDIS001_CR301501	FCTIR_00064
Y.11-14.A2	SCT_BARREL_A_Q3	HXGDIS001_CR301507	FCTIR_00062
Y.43-02.X2	IBL	HXGDIS001_CR301506	EXD12_15X
Y.28-14.A2	PIXEL_Q4	Y.05-20.X1	FCTIR_00060

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

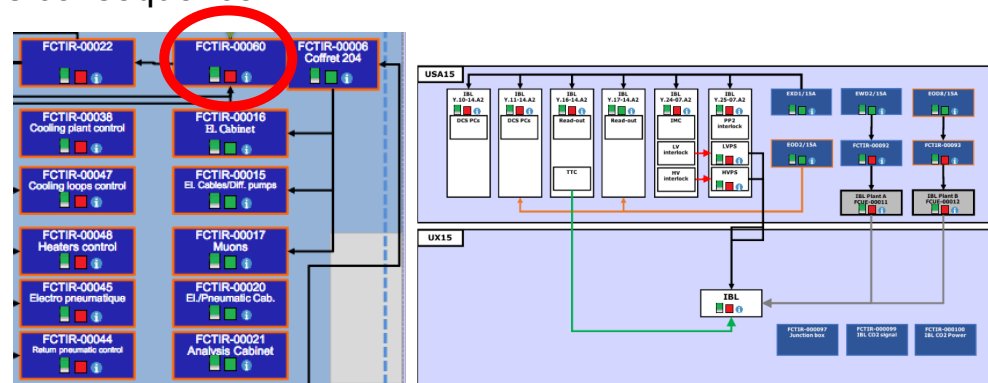
## Simulation of scenario:

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

## Important affected systems:

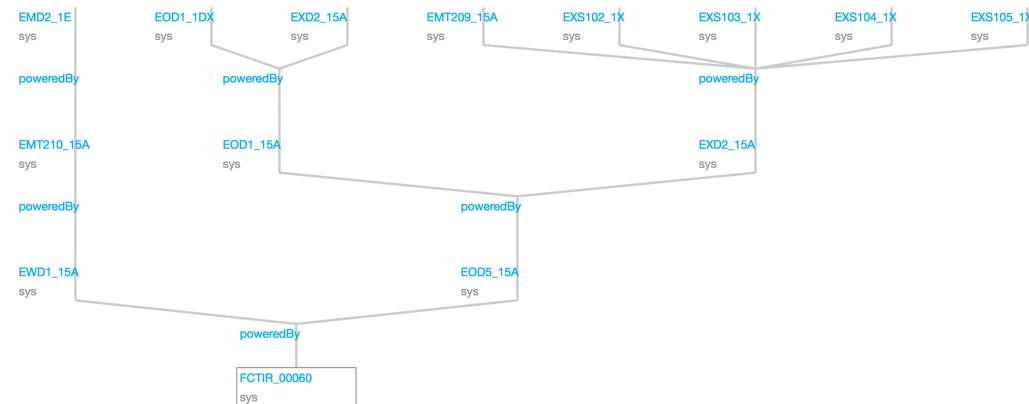
- 22 subdetector systems affected
- 4 cooling stations
- 210 racks affected

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



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



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

$$P_F = (1 - P_S)$$

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!

- 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

**ATLAS Expert System - Search**

 Alarms: 0  
 Systems: 199
 

 EN
 

 Reset Session 2 Search.

Export options 
Search 
Advanced search 
History

Item	Type
<input type="text" value="Search..."/>	<input type="text" value="Search..."/>
SCT_EC_C	Group
SCT_EC_C_Q1	SubDetector
SCT_EC_C_Q2	SubDetector
SCT_EC_C_Q3	SubDetector
SCT_EC_C_Q4	SubDetector

**SubDetector** SCT\_EC\_C\_Q1

**Subsystem :**  
**GasTo:**  
HCXGIDN001\_CR300002

**ControlledBy:**  
Y.35-05.X8    
Y.25-14.A2    
Y.05-05.S2    
DCS\_Y.04-05.S2

**GroupedBy:**  
SCT\_EC\_C

**RequiresGasFrom:**  
EVAP\_COOL\_GAS\_Distribution\_Q1

**CreationDate :** 1900-Jan-01  
**Description :**  
**Documentation:**  
**Switch :** on  
**State :** off  
**Find this element in:**  
 0 results

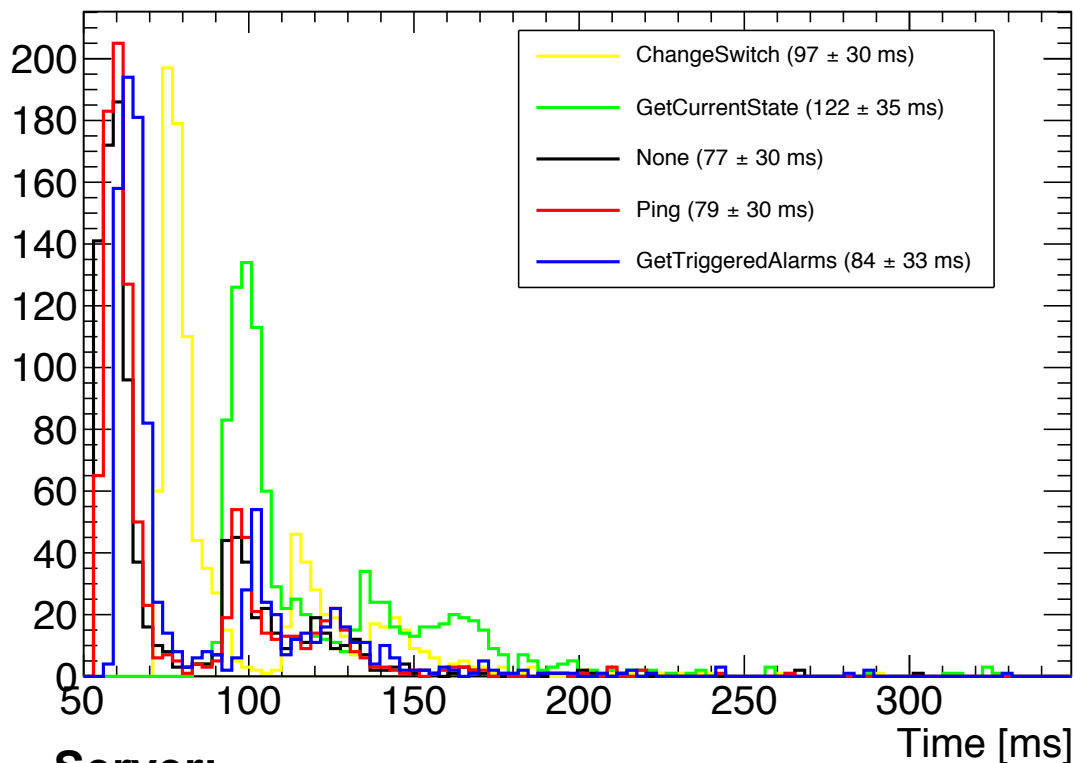
**Rack** Y.35-05.X8

**Subsystem :**  
**Description :**  
**Controls:**  
SCT\_BARREL\_A\_Q1    
SCT\_EC\_A\_Q1    
SCT\_EC\_C\_Q1    
SCT\_BARREL\_C\_Q1    
**CreationDate :** 1900-Jan-01  
**Documentation:**  
**State :** on  
**Switch :** on  
**Datapoint :**  
**Location :**  
**Photos:**

**Find this element in:**  
 SCT   
 TRT

[Object in Dashboard page](#)





## Server:

Shows good performance

$$p(0.05) < 300ms$$

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

**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