

CHEP 2018

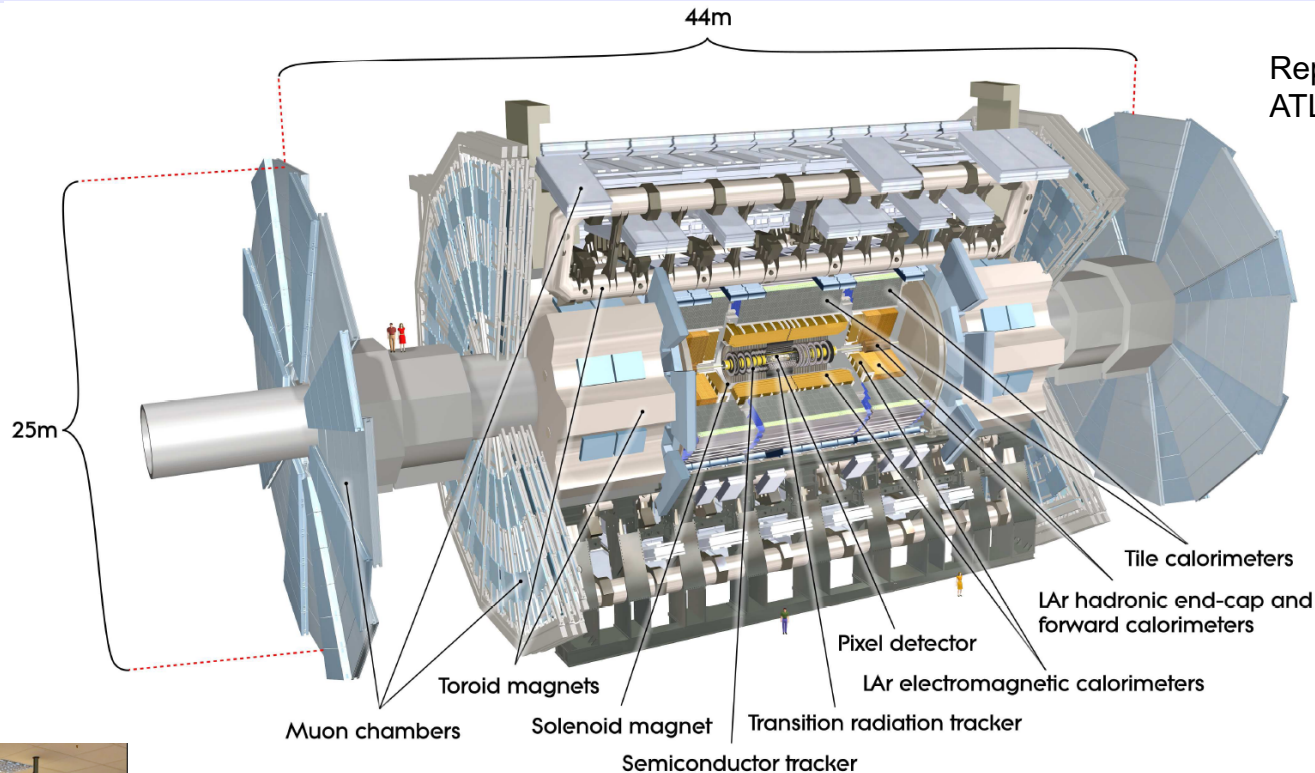
Sofia, Bulgaria

ATLAS TC Expert System



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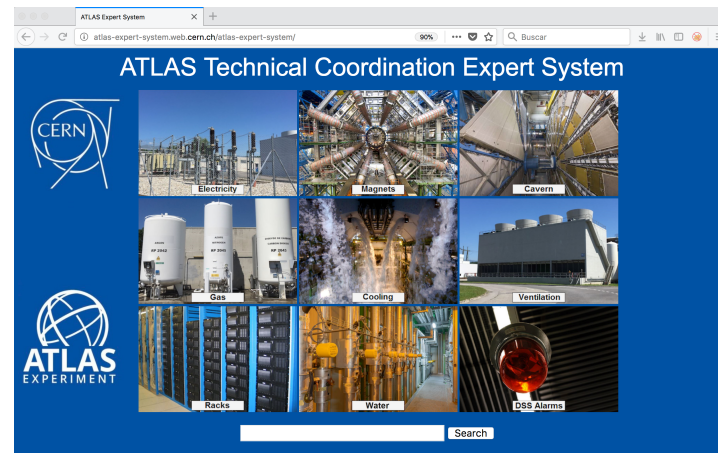
Representation of the ATLAS detector



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



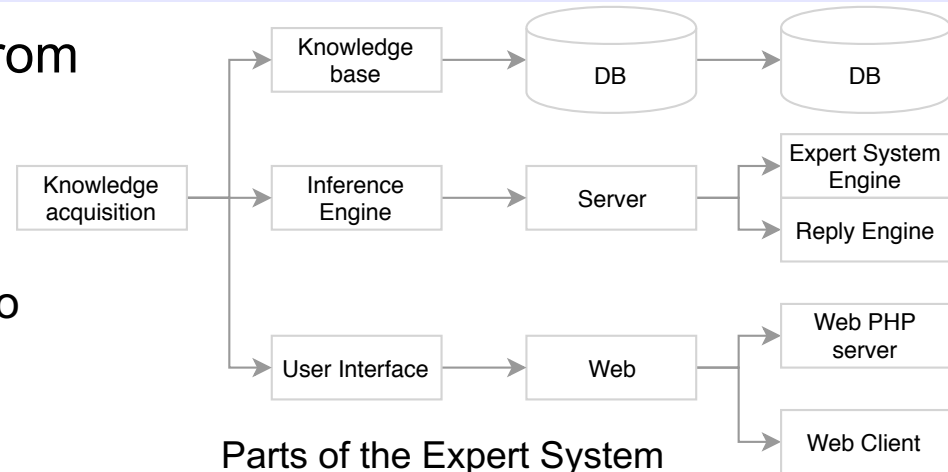
Foresee what is going to happen
Explain why something is off



Compressors of the ID
Evaporative Cooling System

- Starting from acquiring knowledge from many sources:

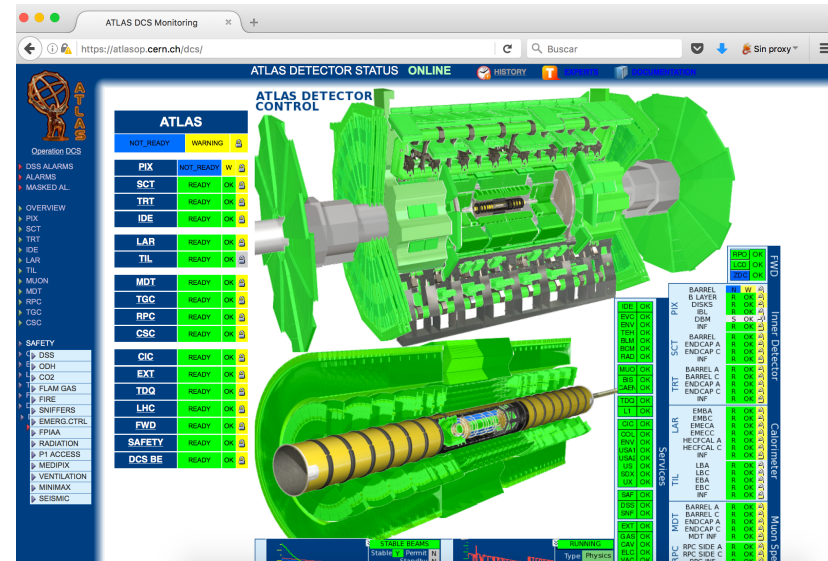
- Technical documentation
- Investigation
- Meeting with Experts of each system to revise descriptions



Parts of the Expert System

- There is the design of:

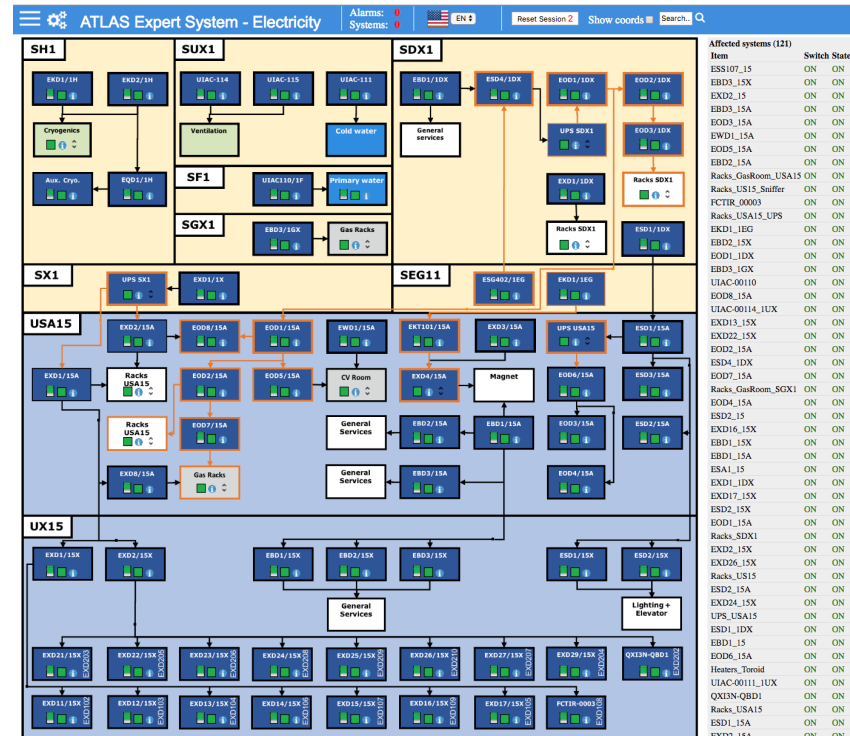
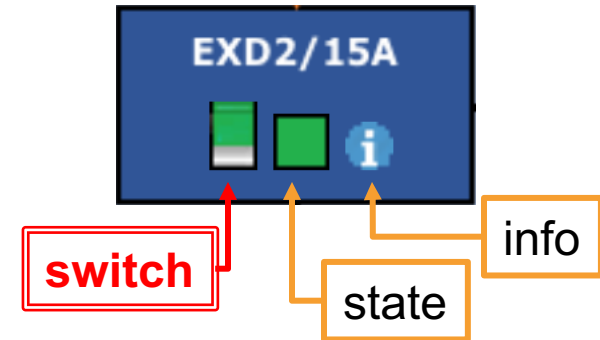
- Knowledge base
 - A database with the systems that constitute ATLAS
- Inference engine
 - An engine that deduces the behavior of the systems and answers to the user input
- User Interface
 - In accordance to experts advise and user needs



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

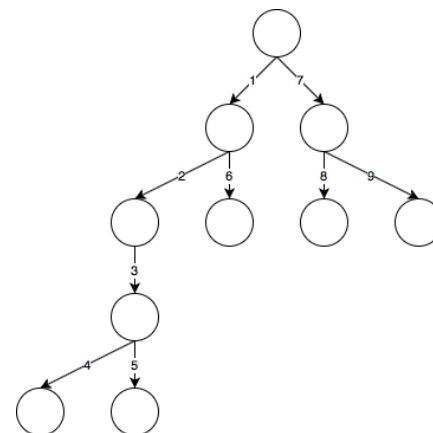
Using graphical interface

- 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

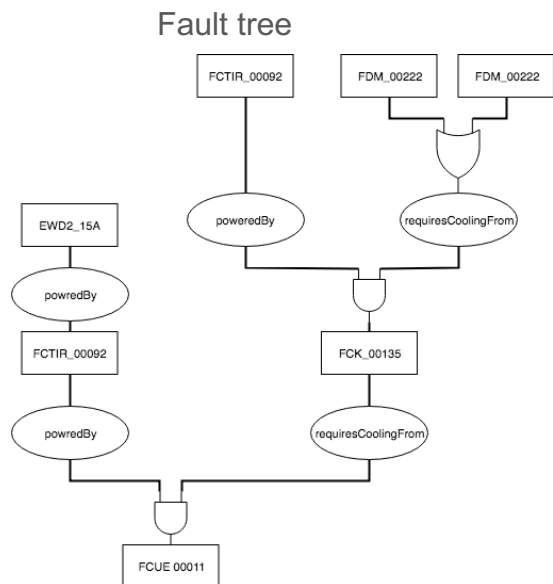


ATLAS individual systems are represented in the database as objects and relationships

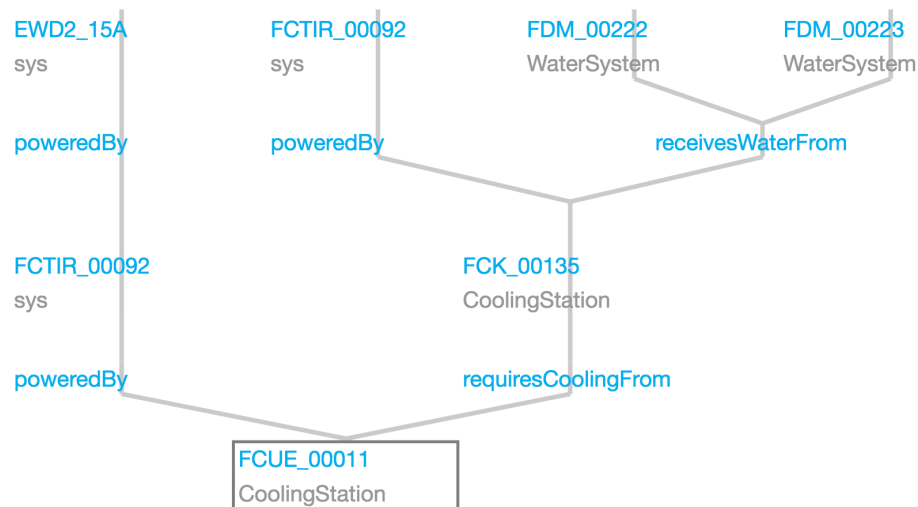
- Relationships represent inputs and outputs
- In a system, each relationship is calculated as an independent node.
- Relationships are always combined in parallel
- Systems arranged in the same node can be in parallel or series
- In every simulation, the inference engine, using a deep-first algorithm, 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:
 Persistency : 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: 1
Systems: 6

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

Impacted elements:
 Rack (9)
 Y.27-23.X8
 Y.53-23.X0
 Y.53-05.X8
 Y.33-05.X8
 Y.25-14.A1
 Y.26-14.A1
 Y.27-14.A1
 Y.59-23.X8
 Y.24-14.A1

Group (1)
 Racks_USA15

SubDetector (4)
 TRT_Barrel_A
 TRT_EC_A
 TRT_EC_C
 TRT_Barrel_C

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

Rack Y.24-14.A1

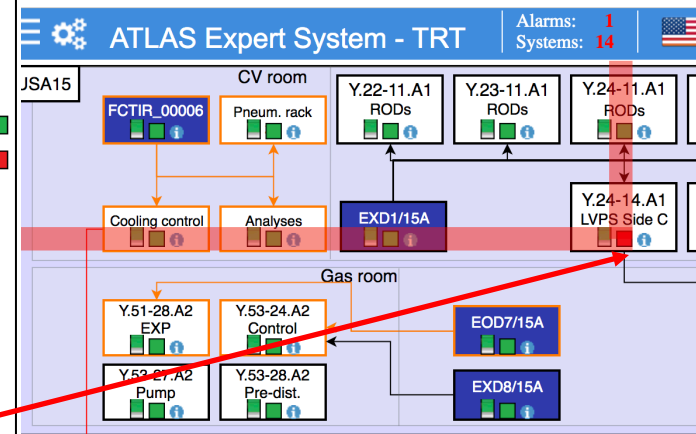
Subsystem : TRT
 Description :
 RequiresWaterFrom:
 USA15 Rack Cooling

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



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.

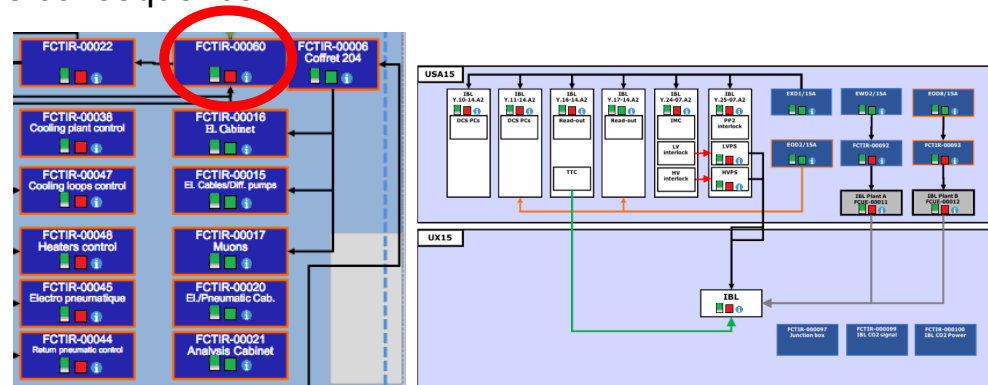
Simulation of scenario:

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

Important affected systems:

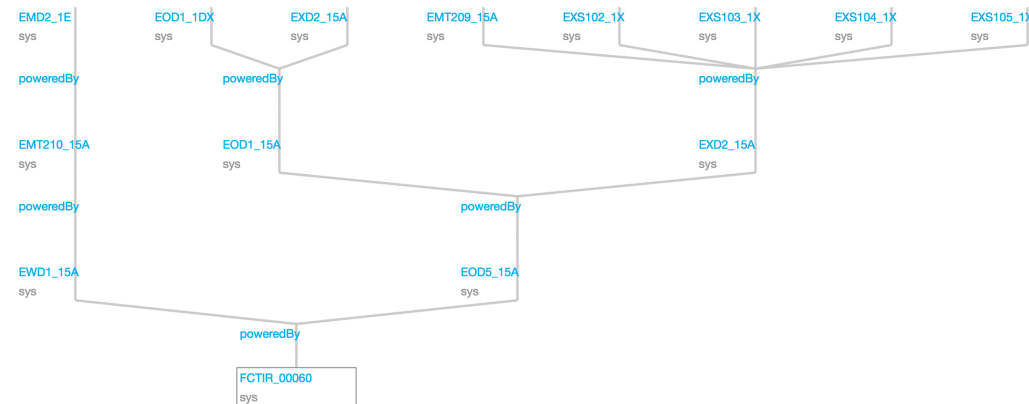
- 22 subdetector systems affected
- 4 cooling stations
- 210 racks affected

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

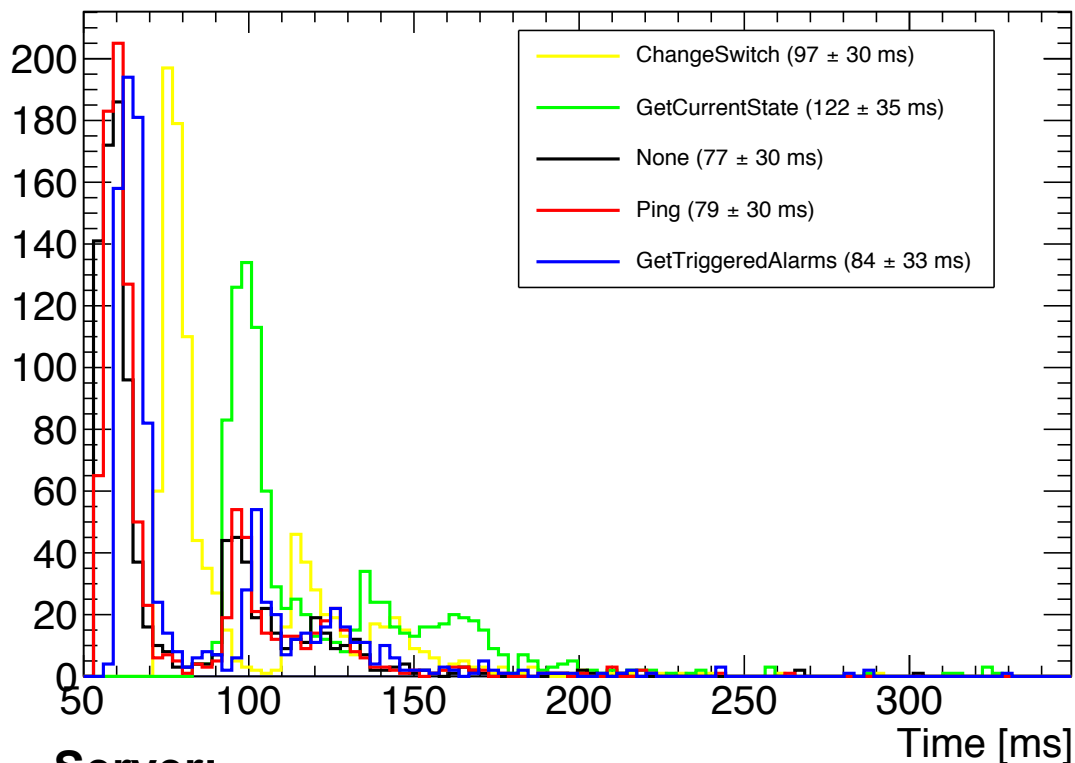
Subsystem :
Description :
Controls:
SCT_BARREL_A_Q1
SCT_EC_A_Q1
SCT_EC_C_Q1
SCT_BARREL_C_Q1

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 |