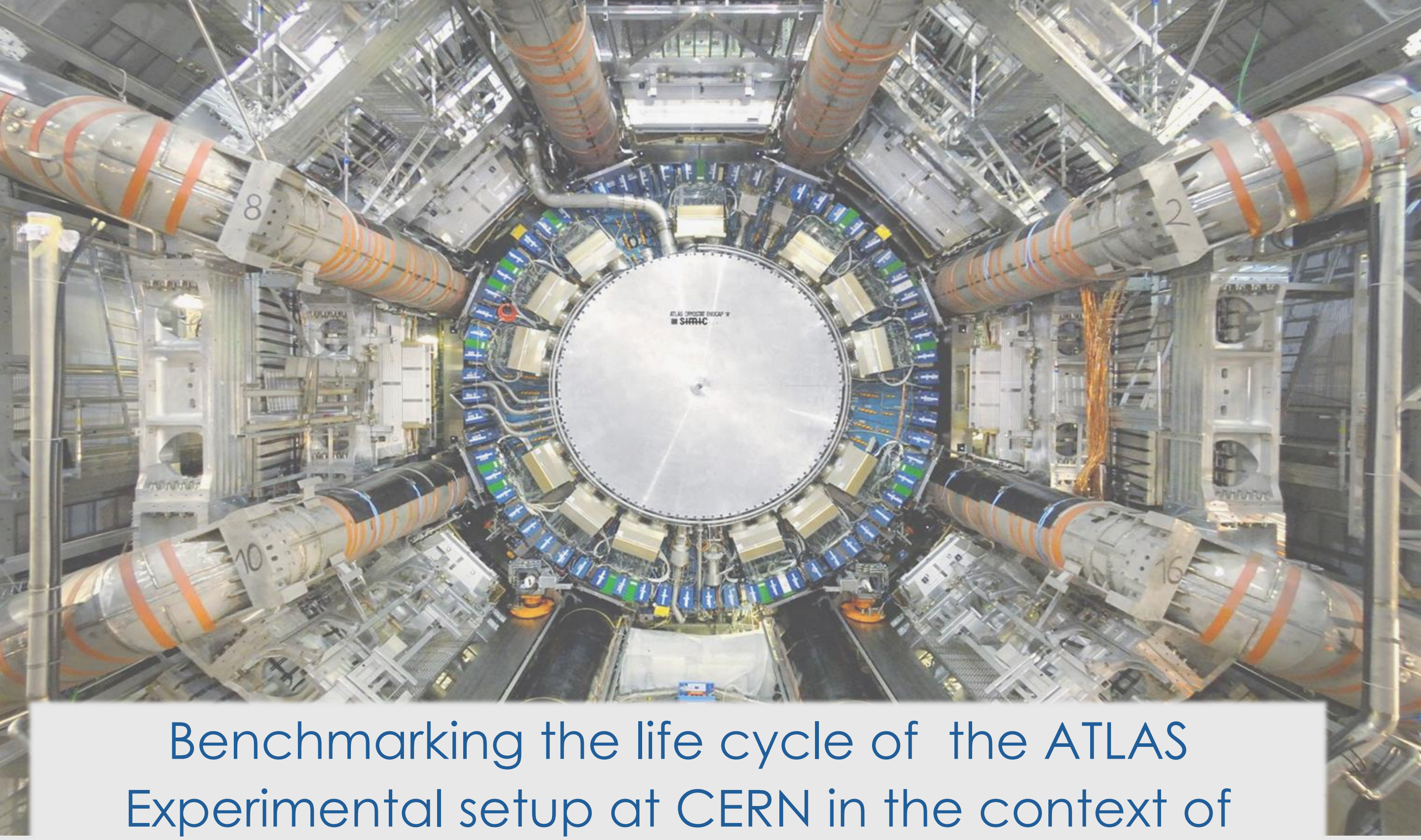

Benchmarking the life cycle of the ATLAS Experimental setup at CERN in the context of Automated Systems Composition

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Abstract

When discussing automation systems within experimental facilities systems that ensure stable operation, safety compliance, high-quality output, and optimal performance, it becomes essential to explore their life cycles. These life cycles consist of six stages: Specification, Design, Implementation, Testing, Integration, and Maintenance. In our investigation, we focus particularly on the initial two stages mentioning design and decomposition into subsystems. By formulating precise requirements, we aim to devise effective design solutions for the architecture of experimental facilities. This report underscores the critical role of system design decomposition within the context of the ATLAS Experiment.

Introduction

The ATLAS experiment at the Large Hadron Collider (LHC), located at CERN, aims to explore fundamental questions about the universe. To achieve this, the ATLAS collaboration relies on sophisticated automation systems, and their life cycles that ensure the smooth operation, data collection, and safety of the experiment. We are primarily interested in life cycles, completeness of design solutions at different stages, and discussing pre-design and design stages and needed requirements to achieve them.

Atlas Subsystems

Consists of Four main subsystems:

TDAQ	DSS	Online System	DCS
Responsible for selecting and storing interesting physics reactions from the plethora of data produced by the p-p collisions in the LHC. It filters vast amount of data to identify potentially significant events for further analysis	Has the mandate to put the detector in a safe state in case an abnormal situation arises which could be potentially dangerous for the detector	Responsible for all aspects of experimental and TDAQ operation and control during data-taking, and during testing and calibration run	Responsible for coherent and safe operation of Atlas detector, as well as the interface with external systems and services including LHC

1.TDAQ (Trigger and data acquisition system)

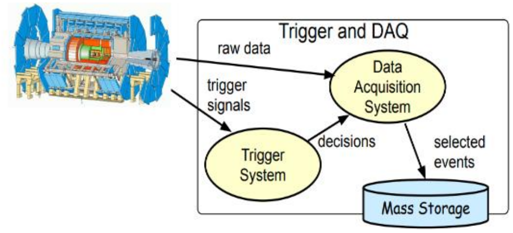

Figure 1

I. LVL1 Trigger: A hardware-based system that rapidly processes the raw data from the detector. This reduces the data rate from the initial 40 MHz frequency of the LHC to a more manageable level.

II. HLT: These are software-based systems that further scrutinize the events passed by the LVL-1 Trigger. They run complex algorithms to determine if an event should be kept for detailed analysis, further reducing the rate of stored events to several hundred Hz.

III. Data Acquisition: The selected events are then read out, formatted, and conveyed through the data-flow system. This system is responsible for the event building and saving the chosen events into mass storage for subsequent analysis.

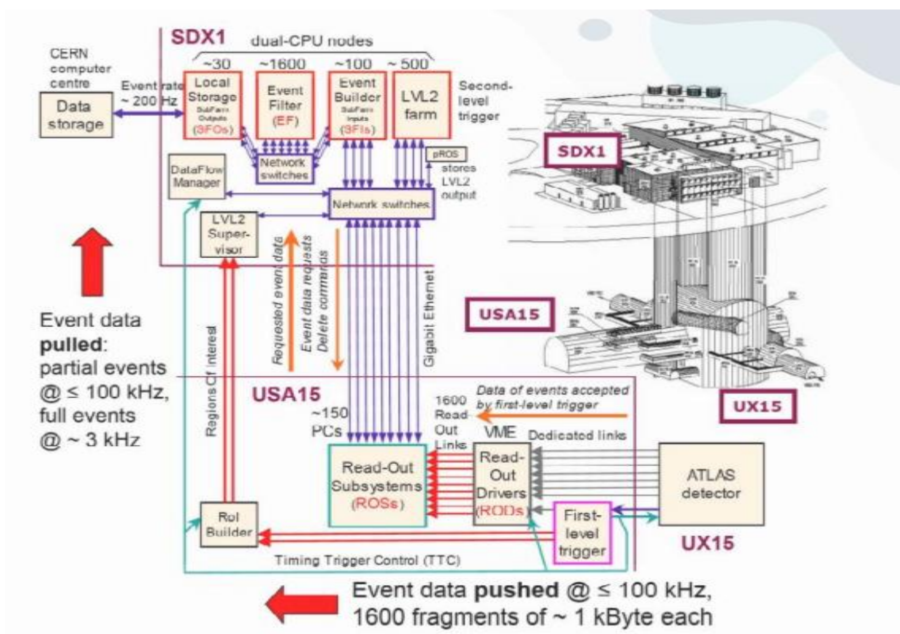

Figure 2. TDAQ overview

New Requirements

The Test Management and Diagnostics service was revised after the first data taking period of ATLAS. A set of new functional requirements were added:

• Experts shall be able to define the order in which tests should be executed for a component; the sequence may dynamically change based on the result of completed tests.

• Experts shall be able to define the order with which inter-related components shall be tested; the test sequence may change depending on the result obtained for the components.

• Experts shall be able to define what should be done upon failure of a test or a component to further diagnose the issue or recover.

All these requirements point towards an increased configurability of the system by ATLAS experts. The expert knowledge, like description of the testing behavior listed above, must be completely contained in the TDAQ configuration database, which can be populated and modified by the system experts using standard database editing tools.

An additional constraint was added, based on the evolution of other parts of the TDAQ system:

• The test management functionality should be provided in Java (in addition to C++), in order to be available for Java-based TDAQ applications like CHIP

2.DSS (Detector Safety System)

DSS works independently and hence complements the Detector Control System(mentioned later). It covers the cern alarm severity levels 1,2, and 3. Dedicated sensors detect safety hazards and are connected to the DSS I/O racks, which are located in each ATLAS counting room. Information from any of these sensors, which are distributed over all of ATLAS, can be combined into alarms which in turn can trigger actions on the detector to bring it in a safe state. This can be accompanied by informing people by SMS or e-mail, but no manual action is required. When the problem has been understood and solved, the operator can re-arm DSS and only then the equipment can be switched on again. The picture shows the main status display.

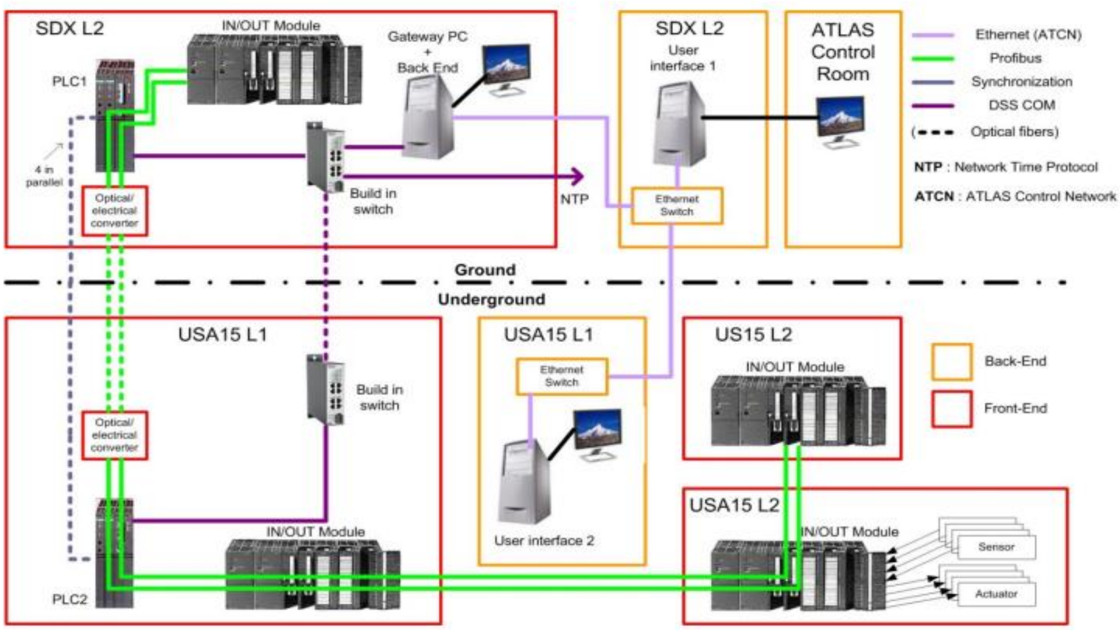

Figure 3. hardware layout in DSS

Digital sensors are implemented as an opto-isolated current loop, which has to be closed to signal normal conditions. Analogue sensors supply a standard 4 mA–20 mA signal. Most of the sensors connected to the ATLAS DSS are of the digital type, while a few analogue sensors provide temperature, flow, and pressure information of critical zones.

	Inputs	
DIGITAL	Cooling	13
	Cryogenics	4
	FG detection	20
	ODH detection	12
	Sniffers	164
	Rack smoke detection	276
	Ventilation	24
	Gas systems	5
	Environment smoke detection	64
	BCM	8
	ATLAS OFF button	1
	UPS power	2
	Magnets	4
ANALOGUE	4 to 20 mA	
	Ventilation	10
	PT100	
	Muon system	4
	TDAQ room	4
	TOTAL	615

	Outputs	
DIGITAL	Cooling	10
	Rack interlock	234
	Switchboard interlock	19
	Minimax	31
	Power supply interlock	44
	Magnet	4
	Gas	1
	TOTAL	343

Figure 4

3.Online Software System

The Online Software system is responsible for configuring, controlling, and monitoring the TDAQ system, but excludes any management, processing, or transportation of event data. It is a framework which provides the glue between the various elements of the DAQ, HLT and DCS systems, and defines interfaces to those elements. It also includes information-distribution services and access to configuration and other meta-data databases. An important part of the Online software is to provide the services that enable the TDAQ and detector systems to start up and shut down. It is also responsible for the synchronization of the entire system, and the supervision of processes. Verification and diagnostics facilities help with the early detection of problems.

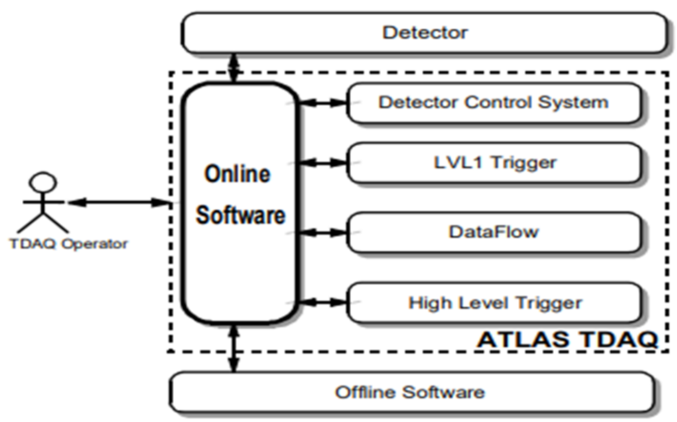

Figure 5

4.DCS (Detector Control System)

The DCS is the central nervous system of ATLAS. It ensures the safe and coherent operation of the entire experiment.

The experiment comprises nine specialized sub-detectors, each with distinct tasks and operational requirements. These sub-detectors must work seamlessly together.

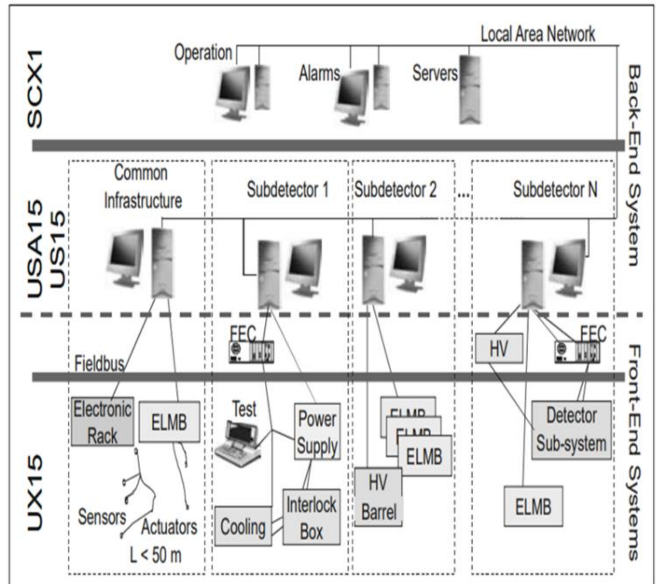

Figure 6

Key aspects of the DCS integration include:

- Back-end organization: Structuring the control system efficiently.
- Process model identification: Understanding the behavior of different components.
- Fault detection: Ensuring robustness and reliability.
- Synchronization with external systems: Coordinating with other experiment components.
- Automation of processes: Streamlining operations.
- Supervisory control: Overseeing the entire experiment.

It contains total >10^7parameters distributed over >140 LCS (rack servers)

System	Component	# Servers (# Appl.)	# Archived Parameters	Total # Parameters	# FSM Objects
Inner Detector	Pixel	11(12)	57k	1'086k	9.1k
	Silicon strips	11(11)	106k	1'265k	14.7k
	Transit. radiation	11(11)	69k	123k	13k
	Services	7(8)	16k	494k	3.7k
Calorimeters	Liquid Argon	13(13)	27k	910k	8.3k
	Tile	5(5)	51k	719k	2.4k
Muon Spectrometer	Drift tubes	29(29)	214k	3'229k	19.2k
	Cathode strip	2(2)	1.3k	109k	0.6k
	Resistive plate	7(7)	139k	1'597k	2.5k
	Thin gap	7(7)	81k	1'225k	10k
	Services	2(2)	0.7k	55k	0.04k
Forward detectors		4(4)	4.9k	194k	0.9k
Common Services	Counting rooms	7(7)	23k	568k	4.7k
	Trigger & DAQ	2(2)	11k	386k	1.3k
	External+safety	4(6)	8.0k	144k	0.4k
	Global services	9(13)	1.2k	222k	0.4k
Total		**131(139)**	**809k**	**12.3M**	**91.2k**

Figure 7

DCS Back-end Architecture

- In the top layer, there will be a Global Control Station (GCS) which oversees the overall operation of the detector. It provides high level monitoring and control of all sub-detectors, while data processing and command execution are handled at the lower levels. The(GCS) will be able to access all stations in the hierarchy.
- The Sub-detector Control Stations (SCSs) form the middle level of the hierarchy. Each sub-detector has its own station, and an additional one will exist to handle the Common Infrastructure Controls (CIC). The SCS allows the full local operation of the sub-detector by means of dedicated graphical interfaces. At this level in the hierarchy, the connection with the (DAQ) system takes place to ensure that detector operation and physics data taking are synchronized.
- The bottom level of the hierarchy is made up of the Local Control Stations (LCSs), which handle the low-level monitoring and control of instrumentation and services belonging to the sub-detector.

Sub-detector	Number of ROLs	Fragments size per ROL (byte) Low luminosity (2×10^{33} cm^{-2} s^{-1})	Design luminosity (1×10^{34} cm^{-2} s^{-1})
Pixels	120	200	500
SCT	92	300	1100
TRT	232	300	1200
E.m. calorimeter (LAr Barrel and EMEC)	724	752	752
FCAL	16	752	752
Hadron calorimeter	64 (Tilecal)	752	752
	24 (HEC)	752	752
Muon precision	192	800	800
Muon trigger (RPCs and TGCs)	48	380	380
CSC	32	200	200
LVL1	56	1200 (average)	1200 (average)
Total event size, raw (Mbyte)		1.0	1.3
Total event size, with headers (Mbyte)		1.2	1.5

Figure 8

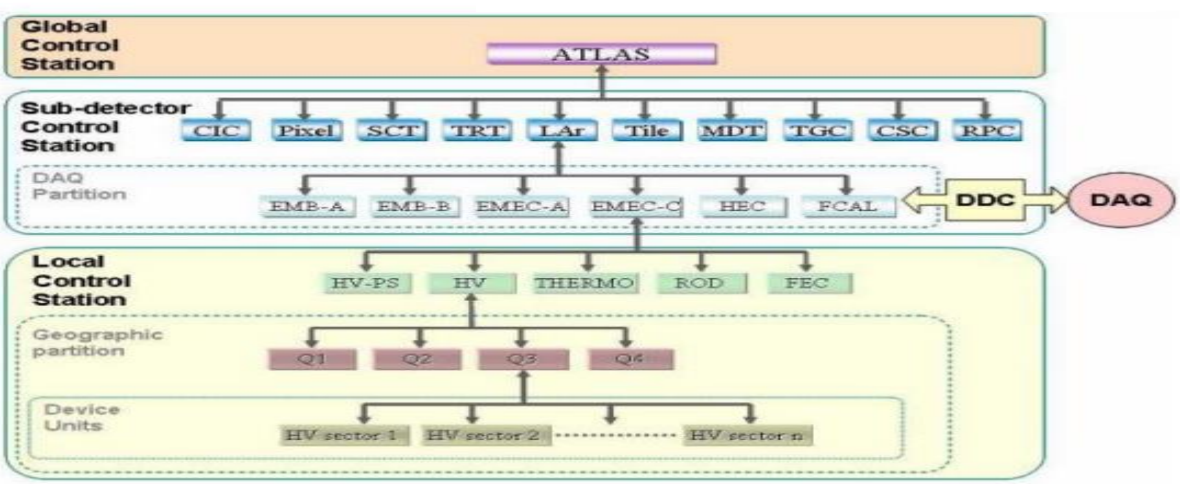

Figure 9

Requirements for DCS

1.Hardware Requirements:

- Specifies the necessary hardware components for the DCS.
- Includes details about memory, storage, and other critical components.

2.Functional Requirements:

- Describes the expected behavior and functionality of the DCS.
- Covers tasks such as transferring the detector to different operating states, monitoring parameters, and detecting deviations.

3.Operational Requirements:

- Outlines the operational aspects, including how the DCS interacts with other subsystems and technical infrastructure.
- Ensures seamless coordination across the experiment.

4.Modes and/or State Requirements:

- Defines the different modes or states in which the DCS must operate.
- Specifies how it transitions between these states.

5.Lifetime Requirements:

- Addresses the lifespan of the DCS components, considering factors like wear and tear.
- Ensures long-term reliability.

6.Monitoring of Non-Critical Components:

- Describes how non-critical components are monitored.
- Balances resource usage while maintaining system integrity.

References

- https://www.academia.edu/100912670/Test_Management_Framework_for_the_Data_Acquisition_of_the_ATLAS_Experiment
- ATLAS TDR CDR