2 Parameters

This chapter presents the parameters relevant to the HLT/DAQ system. These include the detector readout parameters and the trigger selection for the correct dimensioning of the dataflow system and for understanding the data volumes that will need to be stored. These are the subject of the first two sections. Many of the parameter values have been extracted from a static model of the system and depend on input parameters such as the LVL1 trigger rate. More details are given in Appendix A.

Other important parameters for the correct definition of the system are those coming from the monitoring and calibration requirements. These are discussed in the following two sections.

The last section is dedicated to the DCS parameters: the subdivision of the system in detector parts and the amount of configuration-data traffic in the case of start-up configuration and re-configuration of possible faulty elements.

2.1 Detector readout parameters

The ATLAS detector consists of three main detection systems: the Inner Detector, the Calorimeter System and the Muon Spectrometer. These systems are subdivided into sub-detectors.

The Inner Detector consists of three sub-detectors: Pixels, SCT and TRT [2-1], [2-2]. The Pixels sub-detector consists of semiconductor detectors with pixel readout. It is divided into two endcaps, an innermost barrel ‘B-layer’ and two outer barrel layers. All parts mentioned are divided into ϕ regions. The SCT sub-detector is built from silicon microstrip detectors. It is subdivided into two endcaps and a barrel part. The latter is subdivided into two regions, one for positive and the other for negative η. The TRT sub-detector is a tracking detector built from straw tubes and radiator, and features identification of highly-relativistic particles by means of the transition radiation generated.

The ATLAS Calorimeters consists of a LAr System and a Tilecal System. The LAr System consists of the barrel electromagnetic, the endcap electromagnetic, the endcap hadron, and the forward calorimeters, which use liquid argon as active medium [2-3]. The barrel and two extended-barrel hadron calorimeters, together forming the Tilecal System calorimeter, use plastic scintillator tiles, read out via optical fibres and photomultipliers, as active medium and iron as absorber [2-4].

The Muon Spectrometer is divided into a barrel part and two endcaps. The barrel consists of precision chambers based on Monitored Drift Tubes (MDTs), and trigger chambers based on Resistive Plate Chambers (RPCs). The two endcaps contain both MDTs and another type of trigger chamber: Thin Gap Chambers (TGCs). Furthermore at large pseudorapidities and close to the interaction point, Cathode Strip Chambers (CSCs) are used in the forward regions [2-5].

The LVL1 Trigger is another source of data for the DAQ system — it provides intermediate and final results from the trigger processing that should be recorded along with other event data [2-6].

The organization of the ATLAS detector read-out is specified in Table 2-1 in terms of the partitioning, of data sources (the RODs), of Read-Out Links (ROLs), and of Read-Out System (ROS) sub-systems, assuming that a maximum of 12 ROLs can be connected to a single ROS sub-system. These numbers are almost final, but tiny variations may be possible due to further developments in the ROD area. The information in the table is mainly based on information provided by the sub-detector groups during the Third ATLAS ROD Workshop held in Annecy in November 2002 [2-8]. The partitions used coincide with the TTC partitions described in [2-6]. Each ROD module, each ROD crate, and each ROS sub-system is associated with a single partition. Each partition can function independently.

In the following the official ATLAS coordinate system will be used, therefore the definitions of this system are briefly summarized [2-9].

The X axis is horizontal and points from the Interaction Point (IP) to the LHC ring centre. The Y axis is perpendicular to X and to Z.

The ϕ angle is measured from the polar X axis with positive values in the anti-clockwise direction. The pseudorapidity η is measured from the Y axis, positive towards Z-positive (side A).

A and C are the labels used to identify the two sides of any ATLAS component with respect to the pseudorapidity $\eta = 0$. They correspond to the convention of the two sides of the ATLAS cavern. If the Z axis is defined as the one along the beam direction, when looking from inside the LHC ring, the positive Z is in the left direction. The positive Z is identified as side A. The negative Z is in the right direction and is identified as side C.

Table 2-1 The distribution of the RODs and ROS sub-systems (assuming at maximum 12 ROLs per ROS sub-system) per detector per partition

Detector	Partition	RODs	ROD crates	ROLs	ROS subsystems	ROLs per ROS subsystem
Pixel Detector	B Layer	44	3	44	4	$3 \times 12 + 8$
	Disks	12	1	12	1	1×12
	Layer 1 + 2	38 + 26	4	38 + 26	6	$5 \times 12 + 4$
SCT	Barrel A	22	2	22	2	$1 \times 12 + 10$
	Barrel C	22	2	22	2	$1 \times 12 + 10$
	Endcap A	24	2	24	2	2×12
	Endcap C	24	2	24	2	2×12
TRT	Barrel A	32	3	32	3	$2 \times 12 + 8$
	Barrel C	32	3	32	3	$2 \times 12 + 8$
	Endcap A	84	7	84	7	7×12
	Endcap C	84	7	84	7	7×12

Table 2-1 The distribution of the RODs and ROS sub-systems (assuming at maximum 12 ROLs per ROS sub-system) per detector per partition

LAr	EMBarrel A	56	4	224	19	18 × 12 + 8
	EMBarrel C	56	4	224	19	18 × 12 + 8
	EMEC A	35	3	138	12	11 × 12 + 6
	EMEC C	35	3	138	12	11 × 12 + 6
	FCAL	4	1	16	2	1 × 12 + 4
	HEC	6	1	24	2	2 × 12
Tilecal	Barrel A	8	1	16	2	1 × 12+ 4
	Barrel C	8	1	16	2	1 × 12 + 4
	Ext Barrel A	8	1	16	2	1 × 12 + 4
	Ext Barrel C	8	1	16	2	1 × 12 + 4
MDT	Barrel A	48	4	48	4	4 × 12
	Barrel C	48	4	48	4	4 × 12
	Endcap A	48	4	48	4	4 × 12
	Endcap C	48	4	48	4	4 × 12
CSC	Endcap A	8 + 8	1	16	2	1 × 12 + 4
	Endcap C	8 + 8	1	16	2	1 × 12 + 4
RPC	Barrel A	16	1	16	2	1 × 12 + 4
	Barrel C	16	1	16	2	1 × 12 + 4
TGC	Endcap A	8	1	8	1	1 × 8
	Endcap C	8	1	8	1	1 × 8
LVL1 Muon Trigger	MIROD	1	1	1	5	4 × 12 + 8
LVL1 Calorimeter Trigger (RoI, CP, JEP and PP RODs belong to the same partition)	RoI	6	2	6		
	CP	4		16		
	JEP	4		16		
	PP	4	8	16		
	CTP	1	1	1		
Total	33	960	90	1600	144	

It is worth mentioning that the initial ATLAS detector will be missing some components due to the necessity of having a detector that is ready for the first LHC collisions in Spring 2007 and because of funding limitations. This staging scenario has an impact on the number of ROLs for some detectors. The Pixel sub-detector will initially be missing Layer 1 [2-2], the TRT sub-detector will initially not have the two end-cap C-wheels [2-1], and the CSC sub-detector will lack eight chambers per endcap [2-5]. In addition, for the LAr sub-detector the instrumentation of the RODs will be staged by using half of the DSP boards and re-arranging the ROD output to reduce by a factor two the number of ROLs [2-3]. This initial staging scenario is summarized in Table 2-2.

Table 2-2 Number of RODs and ROLs for the initial ATLAS detector

	Initial detector		Final detector	
Sub-detector	**Number of RODs**	**Number of ROLs**	**Number of RODs**	**Number of ROLs**
Pixel	82	82	120	120
SCT	92	92	92	92
TRT	192	192	232	232
LAr	192	382	192	764
Tilecal	32	64	32	64
MDT	192	192	192	192
CSC	16	16	32	32
RPC	32	32	32	32
TGC	16	16	16	16
LVL1	24	56	24	56

2.2 Trigger and Dataflow parameters

Table 2-3 presents an overview of typical values of data-transfer and request rates, and of data volumes for a LVL1 rate of 100 kHz at start-up and design luminosity (recall that the ATLAS architecture supports a LVL1 accept rate of 75 kHz, upgradeable to 100 kHz). Detailed simulation of the LVL1 trigger, with menu settings chosen to cover the ATLAS physics programme (see Chapter 4), shows that the expected accept rate at LHC start-up luminosity (2×10^{33} cm^{-2} s^{-1}) will be ~25 kHz (see Section 13.5), and that at design luminosity (1×10^{34} cm^{-2} s^{-1}) it will be ~40 kHz. Note that there are very large uncertainties on these rate estimates mainly due to uncertainties on the underlying cross-sections and the background conditions, but also from the model of the detector and the trigger used in the simulation. A simulation of the LVL2 trigger at start-up luminosity indicates a rejection factor of ~30 relative to LVL1 [2-7]. The numbers presented in the table are therefore estimates of the required design and performance capabilities of the system, and allow for a ‘safety factor’ of 4 in the LVL1 accept rate for start-up luminosity, and 2.5 at design luminosity.

The data needed for the LVL2 trigger and the type of processing performed by it, depend on the Regions of Interest (RoIs) supplied by the LVL1 trigger. Each of the four different types of RoI (‘muon’, ‘electron / gamma’, ‘jet’, and ‘hadron’) has its own characteristic type of processing. The processing consists of several steps and after each step a decision is taken on whether data from other sub-detectors within the RoI should be requested for further analysis. The data rates can be estimated with the help of information on the type, rate, sizes, and locations of the RoI, and on the mapping of the detector onto the ROLs. More details are provided in Appendix A.

Table 2-3 Typical values and rates for a 100 kHz LVL1 trigger rate

	Start-up Luminosity	Design luminosity
Average number of ROLs supplying data needed by LVL2, per LVL1 accept	17.9	16.2
Average number of groups of 12 ROLs supplying data needed by LVL2, per LVL1 accept	9.1	8.5
Maximum volume of data requested per ROL (Mbyte /s)	8.9	8.4
Maximum LVL2 request rate for data from a single ROL (kHz)	7.4	6.3
Maximum volume of data requested per group of 12 ROLs (Mbyte /s) [a]	70	68
Maximum LVL2 request rate per group of 12 ROLs (kHz)	21	19
Total bandwidth LVL2 traffic (Gbyte /s)	1.6	1.5
Event Building rate (kHz)	3.0	3.5
Total bandwidth traffic to Event Builder (Gbyte /s)	3.6	5.3

a. Fragments of the same event input via different ROLs are assumed to be requested by a single message and to be concatenated and output also as a single message.

The size of the HLT farms and the number of Sub-Farm Inputs (SFIs) have been estimated, assuming the use of 8 GHz dual-CPU PCs for LVL2 and EF processors, and 8 GHz single-CPU computer servers for the SFIs. At a LVL1 rate of 100 kHz, about 500 dual-CPU machines would be needed for LVL2. About 50–100 SFIs would be required, assuming an input bandwidth per SFI of ~70 Mbyte/s. For the Event Filter, approximately 1600 dual-CPU machines would be needed. More details on these estimates are provided in Appendix A, Chapter 13, and Chapter 14.

2.3 Monitoring requirements

Monitoring will be done locally, producing histograms to be transferred, and/or remotely therefore requiring the transfer of event fragments on a sampling basis. The concepts of sources and destinations of the monitoring traffic are introduced and a preliminary list is reported in Table 2-4. Investigations are under way to identify sources and destinations and the traffic generated.

The following sources of monitoring data can be identified:

- ROD crates (and LVL1 trigger crates)
- ROS
- SFI

- HLT processors (LVL2, EF).

Possible destinations are:

- Workstations, e.g. in the main Control Room (SCX1), dedicated to monitoring specific subsystems.
- Online monitoring farm (possibly a sub-set of the EF Farm), the location of which is not yet defined. It should be noted that results from the Online Monitoring farm will then be sent to the main Control Room.

More details on monitoring during data taking can be found in Chapter 7 and in Ref. [2-6].

Table 2-4 summarizes the present knowledge of the relations between the sources and the destinations for monitoring. This is based on a survey where detector and physics groups were asked to quantify their monitoring needs, details of which can be found in Ref. [2-8]. Some figures for the expected traffic generated by monitoring are still missing, but the ones quoted here should be considered as a reasonable upper limit. The situation of event fragments coming from the ROS needs to be clarified, while other pieces of information should travel on the Control network (i.e. standard TCP/IP on Fast or Gigabit Ethernet LAN).

Table 2-4 Monitoring sources and destinations

Source Destination	ROD/ROB	ROS	SFI	Trigger processors
Dedicated workstations	• event fragments (~5 Mbyte/s) • histograms, scalers, files, numbers from operational monitoring (several Gbyte once every hour)	• event fragments (some hundreds of Mbyte/s) • histograms (few Mbyte/s, surges of ~6 Gbyte every hour)	• histograms (some tens of Mbyte/s)	• histograms (some Mbyte/s)
Online Farm	• calibration data (Muons, size not yet fully decided	• if not done at SFI level (same load)	• events • calibration data (several tens of Mbyte once a day)	• rejected events (≤ 1% of the total bandwidth)

2.4 Calibration requirements

The calibrations of sub-detectors are another important source of data for the experiment. For each sub-detector and each type of calibration, the data may flow from the front-end electronics, through the RODs, to the ROD Crate Controller or to the same data flow elements used during the normal data taking, i.e. to the ROS and up to the Sub-Farm Output.

The data volumes involved for each sub-detector calibration, are still under study and it is difficult at this stage to make a complete evaluation. Nevertheless a few examples can be discussed.

The calibrations discussed in this section concerns the sub-detector electronics and reference systems. The in situ calibration of the detector with dedicated physics channels and cosmic rays are instead discussed in Chapter 4.

An example of sub-detector electronics calibration is the LAr charge injection. This calibration makes use of special calibration boards to inject a known charge in the electronics. The data can have a first treatment in the LAr RODs and in this case only the result of the calibration, a few calculated quantities and a few histograms, can be transferred to the storage via the ROD crate Processor. The amount of data produced has been estimated to be around 50 Mbyte. The time needed for a complete calibration is under study but it is approximately several minutes. There is a second mode of operation for this LAr calibration in which not only the results, but also the time-samples are sent to the RODs. In this case about 50 Gbyte of data are produced and a possible scenario for the data transfer is to send all the information through the ROLs to the storage as for the physics data.

Most of the calibrations require dedicated runs, but there are some that can be performed while taking data in physics mode, during the assigned LHC empty bunches (e.g. the Tilecal laser system). Other calibrations of sub-detector reference systems do not interact with DAQ and will make use of dedicated data-acquisition systems, e.g. the Tilecal radioactive-source system, the SCT and the MDT alignment systems [2-10].

2.5 DCS parameters

DCS deals with two categories of parameters: input parameters, which are used to set up both the DCS itself and the detector hardware, and output parameters, which are the values of the measurements and the status of the hardware of the experiment. For the first class, the ATLAS-wide configuration database (ConfDB) will be used, while parameters of the second class will be stored in the ATLAS conditions database (CondDB).

Two different types of set-up parameters are needed by DCS: static data, defining hardware and software of the DCS set-up, and variable data, describing the operation of the detector. The associated data volume is large because of the very many separate systems and the very high number of elements to be configured, of the order of 250 000. However, a high data-transfer rate is not required as the operations are not time-critical and will normally be performed during shutdown periods.

The variable data are used to configure the sub-detectors for the operation. Depending on the beam conditions of the LHC, different sets of operational parameters are needed for some parts of the detector. Also the different types of DAQ runs require different operational parameters. All these sets of dynamic configuration data are loaded at boot-up time into the relevant DCS station. This operation is therefore also not time-critical. During running of ATLAS, updates of subsets may be needed. Hence access to the ConfDB is required at all times and it is important to guarantee the consistency of the data between the database and the configuration of running sub-detector systems.

The output data of DCS are the measurements of the operational parameters of the detector and the infrastructure of the experiment, as well as the conditions and status of systems external to ATLAS (see Section 11.9), most notably the LHC accelerator. Much of these data are structured in very small entities; they essentially consist of the triplet definition, time, and value. The update frequency can be tuned individually and many quantities need only be stored when they change by more than a fixed amount. Nevertheless the total data volume is high and may reach 1 Gbyte per day. These data can be sent to the CondDB asynchronously, i.e. it can be held for small periods of time within DCS.

2.6 References

2-1 *ATLAS Inner Detector Technical Design Report*, CERN/LHCC 97-16 (1997)

2-2 *ATLAS Pixel Detector Technical Design Report*, CERN/LHCC 98-13 (1998)

2-3 *ATLAS Liquid Argon Calorimeter Technical Design Report*, CERN/LHCC 96-41 (1996)

2-4 *ATLAS Tile Calorimeter Technical Design Report*, CERN/LHCC 96-42 (1996)

2-5 *ATLAS Muon Spectrometer Technical Design Report*, CERN/LHCC 97-22 (1997)

2-6 *ATLAS First Level Trigger Technical Design Report*, CERN/LHCC 98-14 (1998)

2-7 *ATLAS HLT/DAQ/DCS Technical Proposal*, CERN/LHCC 2000-17 (1999)

2-8 *3rd ATLAS ROD Workshop,* http://wwwlapp.in2p3.fr/ROD2002/,
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2-9 *ATLAS Technical Co-ordination Technical Design Report*, CERN/LHCC 99-01 (1999)

2-10 *ATLAS Technical Co-ordination, Detector Interface Group, DIG Forums,*
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