University of California, Irvine (UCI)

The New ROD Complex

For the ATLAS CSC Electronics

Requirements

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Abstract

This document presents the requirements for the replacement of the current Cathode Strip Chamber (CSC) off-detector electronics, which encompass not only the readout electronics but also the hosting crates, power supplies, firmware, software, etc. This ensemble of elements is referred to as the ROD Complex and the new incarnation as the New ROD Complex (NRC). Broadly speaking, the sole requirement the ROD Complex must conform to is the following:

a) Upon receipt of a Level 1 Accept (L1A), the ROD Complex must retrieve the corresponding CSC chamber data and send the resulting feature extracted and formatted event to the Trigger and Data Acquisition (TDAQ) system.

The decomposition of this primary requirement into more detailed ones is given herein, as well as the requirements to interface the various systems the ROD Complex depends on.

Purpose of the document

The purpose of this document is to serve as the basis for the design and implementation of the CSC New ROD Complex.

Glossary, acronyms and abbreviations

ASM Amplifier-Shaper Module

CSC Cathode Strip Chamber

CTP Central Trigger Processor

DCS Detector Control System

L1A Level 1 Accept

LTP Local Trigger Processor

NRC New ROD Complex

ROD Read-Out Driver

ROL Read-Out Link

ROS	Read-Out Subsystem
SCA	Switched Capacitor Array
TDAQ	Trigger and Data Acquisition
TTC	Trigger, Timing and Control

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Document Control Sheet

Table 1 Document Control Sheet

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Document Status Sheet

Table 2 Document Status Sheet

Title:	The New ROD Complex Requirements		
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Version	**Issue**	**Date**	**Comment**
0.1	1	08/24/2012	First rough draft.
0.2	1	08/31/2012	Input from UCI.
0.3	1	09/04/2012	Input from SLAC.
0.4	1	09/17/2012	Update UR002. Add Figure 1.
0.5	1	09/18/2012	Update UR002 taking into account 2->4 samples.
0.6	1	09/20/2012	Input from the preparation meeting.
0.7	1	09/21/2012	Add UR003.
1.0	1	09/21/2012	First release for reviewers.

Chapter 1
Overview

1.1 Introduction

The ATLAS CSC system consists of 32 chambers grouped in 2 end-caps. Each chamber has four layers, each layer providing 192 precision coordinate channels in the direction of magnetic curvature and 48 transverse coordinate channels in the less critical non-bending direction.

The shaped pulses are sampled every 50 ns, and the analogue information is stored in CMOS Switched Capacitor Array (SCA) in the ASM-II. One ASM-II is designed to process 192 channels, that is, one precision layer or four transverse layers. Each channel is allocated 144 cells in the SCA, thus providing an effective pipeline depth of 288 bunch-crossings, larger than the trigger latency, which is estimated to reach 188 bunch crossings in the worst case scenario [1, 2, 3].

Each ASM-II board has 2 fiber-optic links to transmit chamber data. The downlink for one chamber includes 10 links grouped in a single 12 strand fibre-optic MPO cable. The uplink for one chamber requires 6 fibre-optic links, 5 for the timing and control of the ASM-II boards and 1 for the control of the pulser module. The uplinks for 2 chambers are bundled together into one 1 MPO cable.

Chapter 2
Requirements

2.1 Performance requirements

UR001 Level 1 trigger rate

The ROD Complex must handle average L1A rates of up to 100 KHz at the required data occupancy (UR002) without imposing a dead-time of more than 1%. A safety margin of 20% (120 KHz) would be desirable to accommodate new requirements in the ATLAS detector. The ROD Complex must also be able to absorb 'n' consecutive L1As as specified by the simple and complex dead-time [4].

Justification: required for operation in ATLAS combined runs.

UR002 Data occupancy

The ROD Complex must handle the expected data volume for the required trigger rate (UR001), which is specified as an average CSC event size of ~19 KBytes or ~0.6 KBytes per chamber.

Justification: The expected nominal luminosity during Phase 0 is $L = 1 \times 10^{34}$ cm^{-2} s^{-1}, with a maximum centre of mass energy of 14 TeV and a bunch spacing of 25 ns, which will yield a $\mu = 27$ [5]. However, the luminosity in Phase 0 might easily exceed the nominal one. Also, the data volume estimation presented below might be affected by switching from a bunch spacing of 50 ns to 25 ns. To have enough margin to account for these and other uncertainties, the luminosity and pile-up (μ) for Phase 1 will be considered instead. These are $L = 3 \times 10^{34}$ cm^{-2} s^{-1} and $\mu = 80$ [6].

Recording the average CSC event size and pile-up for each lumiblock in a run allows undestanding the relationship between these two parameters. Figure 1a shows the luminosity and pile-up for the fill associated to run number 208811, whilst Figure 1b shows the relationship between the CSC events size and the pile-up for that run[1]. The resulting first degree polynomial fit is given by Equation 1.

$$\text{Size (Kbytes)} = \mu * 0.089 + 2.232 \qquad \text{(Equ. 1)}$$

[1] Other runs have been studied with similar results: 208930, 208970...

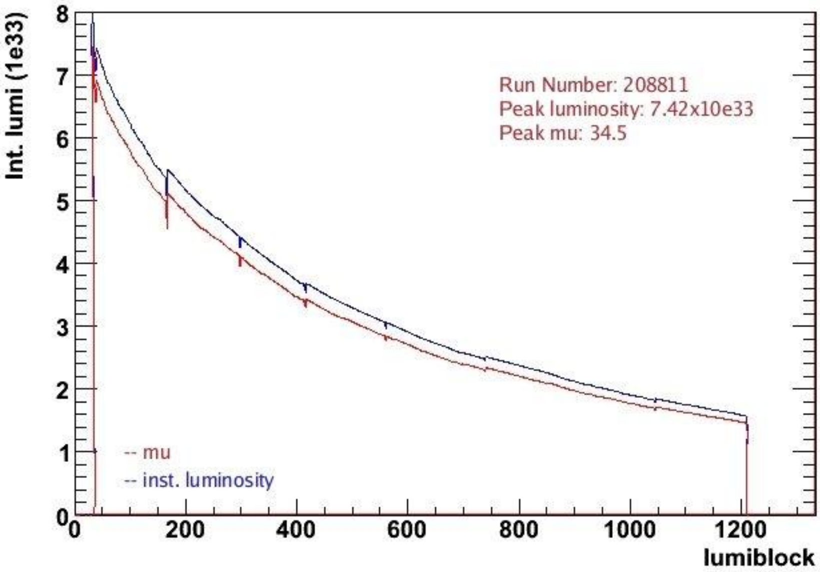

Figure 1a Instantaneous luminosity and μ for run number 208811.

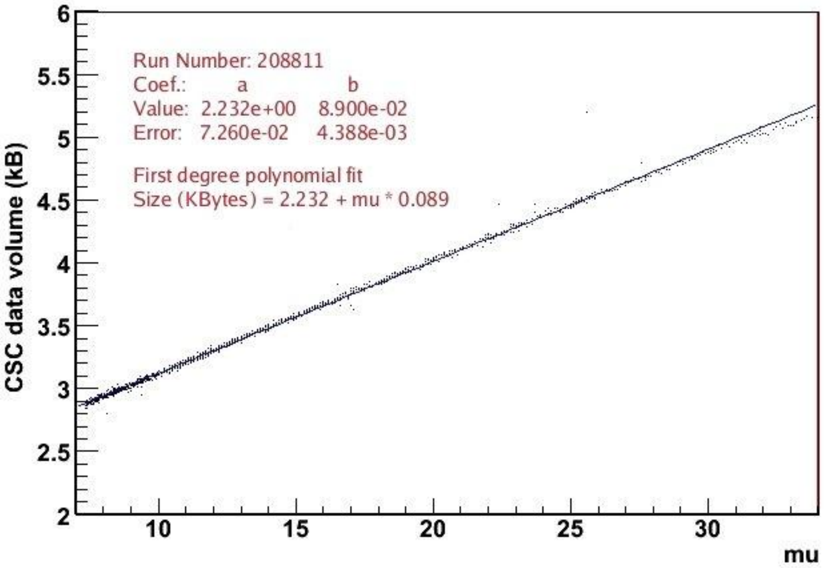

Figure 1b CSC event size vs. μ for run number 208811.

Note that currently the CSC readout is configured to transmit 2 samples even though 4 are retrieved from the on-detector electronics. This measure was taken to alleviate data volume and processing time in order to reduce the CSC dead-time. The New ROD Complex must, however, be able to transmit all 4 samples for physics data taking. Although the CSC event data includes ROS headers and trailers as well as CSC specific headers, a factor of 2 is applied to Equation 1 in the assumption that only sample data is considered. This provides an even larger safety margin. Equation 2 gives the final estimated relationship between the CSC event size and the pile-up.

$$\text{Size (Kbytes)} = 2 * (\mu * 0.178 + 4.464) \quad \text{(Equ. 2)}$$

Thus applying Equation 2 for a $\mu = 80$ yields an estimated average data volume for the CSC subsystem of 18.7 KBytes or 0.585 KBytes per chamber.

In addition, the ROD Complex must also be able to handle the largest CSC event without errors. Such events correspond to reading out all the channels from all the layers in all the chambers.

UR003 Robustness

The ROD Complex must operate robustly regardless of the inputs from external systems: L1A rate, data occupancy, corrupted data, TDAQ commands, etc.

Justification: external systems must not be able to make the ROD Complex fail and jeopardize data taking.

2.2 Requirements for the on-detector electronics interface

UR101 G-Link protocol

The ROD Complex must implement the G-Link protocol as determined by the on-detector electronics [7]. Consequently, the ROD Complex must establish fiber lock by sending fill frames, monitor the fiber lock status and re-establish lock whenever it is lost due to Single Event Upset (SEU) or other reasons such as loss of low voltage.

Justification: continuous operation of the on-detector electronics.

UR102 Fiber timing

The ROD Complex must lock all fibers with the same phase in order to provide constant timing.

Justification: operation of the existing on-detector electronics.

UR103 Control of the on-detector switched capacitor array

The ROD Complex must control the SCAs in the ASM-II boards by writing to the cells at the appropriate rate and reading the cells associated to a L1A [8, 9].

Justification: operation of the existing on-detector electronics.

UR104 SCA parameters

The number of samples for pedestal and calibration runs must be configurable from 2 to at least 8. The number of samples for runs dedicated to the study of the bipolar waveform must be configurable from 2 to at least 32. The sampling frequency must be configurable to 20 or 40 MHz. The latency must be adjustable.

Justification: operation of the existing on-detector electronics.

UR105 Pulser

The on-chamber pulser must be controlled and all functionality listed in the pulser documentation [10] has to be supported.

Justification: the pulser is used to verify the correct operation of the on-detector electronics and for calibration.

2.3 Requirements for the Local Trigger Processor interface

The Local Trigger Processor (LTP) provides the ROD Complex with all the signals necessary for timing and triggering. These signals include the bunch-crossing clock, L1A, the Bunch-Crossing Identification (BCID) and Reset (BCR), the Event Counter Identification (EVID) and Reset (ECR), the trigger-type, commands and data, including test and calibration pulses.

UR201 Timing Trigger and Control signals

The ROD Complex must receive and process the Trigger, Timing and Control (TTC) signals.

Justification: trigger information is essential to initiate the event data retrieval and to associate it with the right trigger information.

UR202 Re-synchronization

The ROD Complex must be able to re-synchronize with ATLAS when needed.

Justification: this is necessary for the TTC restart and stopless-recovery procedures.

UR203 Level-1 accept

Upon receipt of a L1A, the ROD Complex must retrieve the associated data from the on-detector electronics, perform feature extraction if need be, and output the resulting formatted event to the Read-Out Link (ROL).

Justification: this is the main purpose of the ROD Complex.

2.4 Requirements for the ROD-Busy module interface

UR301 Busy

The ROD Complex must provide a BUSY signal to the ROD-Busy module and assert it only when necessary (internal buffer nearly full) and under the constraints of UR001.

Support must be provided to perform stopless-removal at least at the end-cap level.

Justification: the busy signal is essential for L1A throttling.

2.5 Requirements for the Read-Out Subsystem

UR401 Readout Link output

The ROD Complex must output the event data resulting from a L1A to the S-link interface.

Justification: the output data must be received by the Read-Out Subsystem (ROS) for use by the TDAQ.

2.6 Data processing requirements

UR501 Data validation

The ROD Complex must ensure the validity of the event data in each stage of the data flow. Errors might be due to link lock losses, SCA errors, etc. If an anomalous condition is detected, the event must be marked as error as described in [11].

Justification: error detection is critical to guarantee data consistency and correctness.

UR502 Masking out layers

It must be possible to mask out specific layers for a given chamber.

Justification: to mask out layers that are known to be problematic and thus reduce the data occupancy.

UR503 Configurability

The ROD Complex must be capable of processing data differently depending on the purpose of the run.

Justification: different runs need dedicated processing, which might be optimized as required.

UR504 Feature extraction

The ROD Complex must be capable of feature extracting the raw data received during physics runs at rates of at least 100 KHz. A 20% margin (120 KHz) would be desirable to accommodate new requirements in the ATLAS detector.

Broadly speaking, the feature extraction algorithm consists of two steps: 1) threshold comparison and 2) wrong-time rejection (around a ~75 ns window). A more detailed explanation of this algorithm is given in [11].

Justification: data taking runs have well-known performance requirements.

UR505 Pedestal and calibration

The ROD Complex must be capable of processing event data for calibration and pedestal runs with at least 8 samples and trigger rates that provide sufficient calibration data during the available ATLAS calibration periods.

Justification: pedestal and calibration runs do not have high trigger rate constraints but require more samples than physics runs.

UR506 Bipolar wave form studies

The ROD Complex must be capable of processing data from runs dedicated to the study of the bipolar pulse generated by the pre-amplifier and shaper circuitry. Data must be sparsified as described in UR5041 but with a configurable number of samples of at least 30 and trigger rates that provide sufficient data during the available ATLAS calibration periods.

Justification: bipolar-wave studies do not have high trigger rate constraints but require more samples than physics runs.

UR507 Data output format

The CSC event data must conform to the format described in [11, 12].

Justification: the offline software and TDAQ system expect a well-defined event format.

2.7 Requirements imposed by the TDAQ online system

UR601 TDAQ state model

The ROD Complex must follow the TDAQ state model [13] and respond to state transitions.

Justification: compatibility with the TDAQ system.

UR602 Configuration database

Variables that parameterize the behaviour of the ROD Complex must be stored and retrieved from the TDAQ configuration database.

Justification: to be able to retrieve the ROD Complex configuration for a given run.

UR603 Error reporting

Errors that require an action from the shifter must be made public to the TDAQ Error Reporting Service (ERS).

Justification: shifters need to be informed to take the appropriate actions.

UR604 Histogramming

When histograms need to be made public, the Online Histogram Service (OHS) must be used.

Justification: shifters need to be informed to take the appropriate actions.

UR605 Information sharing

When information (rates, buffer occupancy, etc.) needs to be made public, the Information Service must be used.

Justification: shifters need to be informed to take the appropriate actions.

2.8 Requirements for the detector control system interface

The principal task of the Detector Control System (DCS) is to enable the coherent and safe operation of the detector and to serve as a homogeneous interface to all sub-detectors.

UR701 ROD Complex control

It must be possible to remotely power on/off the ROD Complex via the DCS interface.

Justification: access to USA15 is not always allowed. CSC must adhere to the ATLAS-wide usage of the DCS interface.

UR702 ROD Complex monitoring

To further satisfy UR701, it must be possible to remotely monitor the ROD Complex, (voltage, current, and temperature) via the DCS interface.

Justification: access to USA15 is not always allowed. CSC must adhere to the ATLAS-wide usage of the DCS interface.

2.9 Requirements for installation

UR801 Rack

The ROD Complex must adhere to the ATLAS-wide rack specifications in terms of crate mounting, power consumption, power dissipation, airflow direction for the cooling system, etc. Guidance can be found in [14].

Justification: installation of the ROD Complex in ATLAS USA15.

UR802 Networking

The ROD Complex must adhere to the ATLAS Technical and Control Network (ATCN) [15] specifications in terms of cabling, ports, bandwidth allocation, etc.

Justification: installation of the ROD Complex in ATLAS USA15.