Report of the Specifications Review of the ATLAS ITk Common Environmental Monitoring and Interlocking

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Prepared by:	Checked by:	Approved by:
M.Capeans (CERN)	Review Panel: M.Gonzalez (CERN) A.Grillo (USC) K.Lantzsch (U Bonn) P.Petagna (CERN) D.Robinson (U Cambridge) S.Schlenker (CERN) R.Teuscher (U Toronto) A.Cattai (CERN) Kevin Einsweiler (LBL) A.Affolder (USC) B.Gorini (CERN) S.McMahon (UKRI-STFC) P.Morettini (INFN e Universita Genova)	K.Einsweiler (LBL) F.Lanni (BNL) L.Pontecorvo (CERN)

Distribution: M.Aleksa, EB and TC members, management of the project, participants to the review.

Outline

1. Introduction

The Specifications Review (SPR) of ATLAS ITk Common Environmental Monitoring and Interlocking was held on February 1th 2019. The agenda is available in Appendix A and the review panel in Appendix B.

The ITk Common Environmental Monitoring system monitors all environmental parameters, such as temperature, humidity, radiation, of the so-called ITk volume composed on the Pixel system, Strips system and ITk Outer Volume. The ITk Common Interlock is a safety system for the Strip and Pixel detectors which protects both the detectors and personnel against any risks which may arise. It is a completely hardwired system which acts as a last line of defense for detector safety.

The goal of the SPR was to verify if complete written requirements and specifications exist for the Monitoring and Common Interlocking systems, and to evaluate if they are sufficiently accurate to develop the designs and proceed to manufacture prototypes that will be evaluated in Preliminary Design Reviews (PDR). The common specifications review facilitates getting the overview of all the needs and to check whether all areas of the ITk needing monitoring and interlocking are appropriately covered.

The review panel received in advance the following documents:

- ATLAS ITk Electronics Specification: ITk Environmental Monitoring System: Temperature
- ATLAS ITk Electronics Specification: ITk Environmental Monitoring System: Humidity
- ATLAS ITk Electronics Specification: ITk Environmental Monitoring System: Radiation
- ATLAS ITk Electronics Specification: ITk common Interlock System

During the review, the specifications were summarized in presentations which described the main requirements of the systems, type and number of sensors and information passed to software interlocks, and readout systems proposals. The presentations were often more design-oriented than discussing clear specifications and acceptance values on the basis of requirements given by the sub-detectors, and at times it was difficult to understand the boundaries between ITk-common and Pixel- and Strip-specific systems. However, the panel acknowledges the very substantial effort to produce a set of Specifications documents in short time, bearing in mind that first, some key related documentation (e.g. ATLAS DCS, Pixel services, ITk strip and pixel power supply systems) is still under preparation, and second, that the systems under review are interfacing with several sub-detectors, thus need several iterations and agreement rounds. The review panel thanks the teams for the effort invested in this review.

The panel observations, recommendations (R) and actions (A) are presented in section 2. Identified actions (A) will be actively monitored by the Review Office and should progress and be completed before the next planned reviews are held. The report ends with the final recommendation, which will be sent for approval to the ATLAS Upgrade and Technical Coordinators.

2. Observations and recommendations

2.1. ITk Common Environmental Monitoring

Environmental Monitoring systems will be installed not before 2024, however they will be needed as soon as large detector elements are assembled. Therefore the SPR is well-timed as the team has to quickly proceed to the design phase with a common agreement by clients (Strips and Pixels) on number, location and type of sensors, their services, and readout, operation modes, as well as on number of systems needed for the detectors test phase.

An detailed view on all external systems interfacing to the Monitoring would have been helpful (are additional pressure, flow, mechanical sensors going to be readout as well?), as well as the management of interfaces to ATLAS DCS and DSS.

Temperature monitoring

The temperature monitoring review was focused on sensors in the cooling pipes for the different regions of the Strips and Pixels, and sensors for atmospheric monitoring of Strip, Pixel and ITk Outer volumes. The specific Strip on-detector electronics and levels of control were presented in detail. This information was missing for the Pixel system.

> **(A1)** The Specs doc "ITk Environmental Monitoring System: Temperature" should be carefully reviewed to first, complete all sections (e.g. section 12), and second to present final numbers and specs (number and accuracy of sensors on pipes and atmosphere monitoring, input and output signals, etc.) compatible with clients' final requirements.
>
> (R) Individual sensor calibration is not excluded. A strategy how to handle the book-keeping in a reliable way would need to be specified.

Temperature sensor accuracy and precision were recently agreed by the ITk community (sensor stability of +/-0.5K and accuracy of +/-1K). ITk strongly prefers a two-wire readout solution, due to space and routing limitations, across the sub-systems.

> **(A2)** Need to close the loop between Pixels and Cooling group to agree on the impact of this decision, followed by an ECR of cooling system specs document.

Humidity monitoring

ITk humidity monitoring will be based on Fiber Long Period Grating (LPG) technology. This is an innovative sensor system that has been developed in recent years for Tracker applications. A first system, built with the first generation of Fiber Bragg grating sensors, has been installed and is successfully operated in the CMS tracker. R&D is ongoing for exploring new features, and a small system will be installed during the LS2 shutdown in ATLAS. A collaboration of experts is in place and covers all aspects of the technology.

The number of H-sensors in the ATLAS ITk was shown. 58 measurements points are foreseen (in each one at least T+RH must be measured), but probably not all will be connected to the readout for cost reasons. Studies must be performed on the maximum number of sensors that can be multiplexed on a single fibre. Studies for increasing the acquisition capacity with a new interrogator and/or with the introduction of optical switches are also to be started. Additionally, the panel calls attention to the significant R&D required to demonstrate compensation techniques for radiation sensitivity, in addition to the development of multiplexing.

The distribution of sensors per sub-system was presented, but a discrepancy of needs for the Pixel was noted (24 foreseen versus 32 requested).

> **(A3)** Agree on the final number of sensors, distribution and their precise location for Pixel, Strips and Outer Volume. Also, simulations of the diffusion of humidity against the dry gas flushing must be conducted, in order to guide the definition of the minimum number of measurement points absolutely needed.
>
> (R) The Beam Pipe volume monitoring needs should also be evaluated, and if any, be included in the Specs Document.

The experience operating this type of sensors in the harsh tracker environment is rather limited. Currently the information from fibers will be recorded for on-line monitoring and off-line diagnostic, but it has not been yet decided if the system acts on these values. In this respect it has to be noted that the derivation of the measured T-RH couple from the raw signals obtained from the optical interrogator requires some substantial SW processing: this is usually considered not in line with the standard recommendations for interlock signals.

> **(A4)** This calls for a specification on system reliability, and operational specs (e.g. during normal operation, action when out of range). An alternate chilled mirror system coupled to small metallic sniffing lines for second

humidity measurement in few critical points was recently proposed; the Specs document has to be updated if such a second system is pursued as well.

(A5) The document "ITk Environmental Monitoring System: Humidity" should be updated and all sections completed. In particular, for such novel technology, it is important to already present the QA programme (and QA acceptance values) that will be used to qualify the first prototypes.

Radiation monitoring

Radiation monitoring will be done with several types of dedicated sensors, the aim of these on-line measurements is to determine the proportionality of doses and fluences with integrated luminosity and compare with simulations of radiation background. The planned system is similar to the system currently running in the ATLAS ID. The technical specifications "ITk Environmental Monitoring System: Radiation" describes with enough detail the conceptual design, requirements and interfaces of the Radiation Monitor for the ITk. The presentation during the review also covered well the requirements and initial ideas for possible solutions.

(A6) The specs document should be updated with a better description of the sensors testing, providing acceptance values. The final position of sensors should be included and signed-off by the clients.

(R) The solution proposals were ELMB++ or custom made, probably depending on the final specs of the ELMB++. It is needed to agree on the latest deadline to take this decision for the worst case in terms of planning.

2.2. ITk Common Interlock System

The ITk common Interlock System concept is based on an existing interlock crate system in ATLAS. The modular design provides enough flexibility to account for unknowns such as number of channels, interlock signals and choice of power supplies. The technical specifications document describes with enough precision the system, interfaces and functional descriptions of sensors and each building block. There is some missing information, in particular about the interface to the LV and HV systems that will need to be followed closely.

(A7) This document is very relevant for the technical review process ahead (of designs, prototypes, pre-series), and it is essential for designers and prototype testing teams. It is therefore strongly recommended to complete the Specifications document with a summary table containing an unambiguous list of parameters and the corresponding acceptance criteria that will be used to validate and qualify designs against these specifications.

(A8) An overall understanding of the system operational modes, specs on acceptable system down time, etc., a list of failure scenarios against which protection is needed (since it affects the interlock logic) should be included. Also linked to system operation, monitoring of the disabled inputs (in case jumpers are used) or a regular testing strategy should be defined, as well as a transparent way (in general not creating spurious interlocks) to disable channels.

(A9) The document should clarify if/how to handle interlocks for the "opto power" (signals generated either by temperature sensors or DSS) and beam protection.

(A10) The current Specs document assumes that the monitoring, which is integrated in the interlock crates, is using ELMB2; however the decision to replace it by an ITk specific FPGA-based solution was presented. The specifications document should be updated accordingly.

(R) It is recommended to specify the firmware strategy; a common firmware for all subdetectors will make it simple to develop, and sub-detectors only have to provide their specific configuration of interlocks.

(R) Be aware that depending on how the interlocks between crates are implemented, they could break the general philosophy of the hardwired interlocks.

(R) The testing procedures that will be used to demonstrate that a fabricated component meets the specifications will be reviewed at the PDR, however it is useful to include in the Specifications some indications of the envisaged Quality Assurance programme, in order to demonstrate that the future designs will offer enough QC opportunities.

Despite few weaknesses of the Specs document, there is enough knowledge to move ahead to design phase in preparation of the PDR, currently foreseen for Summer 2019. The FDR could then be possible in Q4 2019 or Q1 2020.

(A11) Pixels and Strips should confirm that this schedule agrees with their plans, but first indications indicate that this matches well the Strips plans for 1 crate needed in SR1 for system tests in 2020, either a prototype or pre-production crate. Similarly, the total number of crates needed by Pixels and Strips needs to be cross-checked, now that 300 channels/crate are possible. It is important to confirm the number of crates needed and the expected delivery dates for systems to be used during commissioning and integration.

3. Panel recommendation

The review panel considers that the three Specification Documents serving as design base of the ITk Common Environmental Monitoring system need a significant revision. These documents should include the final number and location of all sensor types, with agreed requirements on accuracy and precision, services needs, and specifications for QA and operation. **The ITk Common Environmental Monitoring SPR is not passed.** A follow up review is recommended in about three months (~June 2019) to scrutinize the new version of each Specifications document.

The review panel considers that ITk Common Interlock System concept has been presented with enough detail and the system will benefit if proceeds to the design phase in preparation of the PDR, currently foreseen for Summer 2019. **The ITk common Interlock System SPR is passed**. Further work is however needed in the Technical Specification document, which should be updated and improved as described in section 2.2 of this Report, in about a month (April 2019).

For both systems, it is important to confirm the number of systems needed and the expected delivery dates for commissioning and integration of large detector elements.

These recommendations will be submitted for approval to the ATLAS Upgrade and Technical Coordinators.

4. Follow up

Following the ATLAS Review Strategy for Phase 2 (EDMS 1979229), the actions identified during the review will be followed up by the Review Office; tentative reporting mechanisms and dates will be agreed between the Review Office and the Activity Coordinators.

The file to track actions can be found at EDMS 2112552.

Appendix A: Review Agenda

Agenda in Indico: https://indico.cern.ch/event/781529/

- Introduction to the review process - Mar Capeans (CERN)
- Overview on the ITk interlock and monitoring systems - Susanne Kersten (Bergische Universitaet Wuppertal (DE))
- Overview on the strip specific temperature monitoring - Peter Phillips (Science and Technology Facilities Council STFC (GB))
- ITk common temperature environmental monitoring - David Magin Florez Rubio (Universidad Antonio Narino (CO))
- ITk Interlock system - Susanne Kersten (Bergische Universitaet Wuppertal (DE))
- ITk radiation monitoring - Igor Mandic (Jozef Stefan Institute (SI))
- ITk humidity monitoring- Simon Connell (University of Johannesburg (ZA))
- Restricted session for the Review Panel

Appendix B: Review Panel

- M.Gonzalez (CERN)
- A.Grillo (USC)
- K.Lantzsch (U Bonn)
- P.Petagna (CERN)
- D.Robinson (U Cambridge)
- S.Schlenker (CERN)
- R.Teuscher (U Toronto)
- Review office: A.Cattai (CERN) and M.Capeans (CERN) - *chair*
- Ex-officio: K.Einsweiller (LBL), B.Gorini (CERN), A.Affolder (USC), S.McMahon (UKRI-STFC), P.Morettini (INFN e Universita Genova)