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ATLAS Review Office and Review Strategy for Phase-II Detector Upgrades

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Abstract

This document describes the ATLAS Review Office mandate and the overall organization of reviews of components for the Phase-II detector upgrade projects.

1. Introduction

The ATLAS Review Office (RO) is an independent body embedded in the ATLAS Technical Coordination organization (TCn). The RO develops and organizes, in close collaboration with the ATLAS Upgrade Coordinator (UC) and the Upgrade Project Leaders (UPL) of the detector systems, technical reviews for the components of the upgrades following the ATLAS review strategy as defined in the ATLAS Upgrade Organization document [1]. The schedule and granularity of reviews has been tentatively defined in the Upgrade Technical Design Reports (TDR) of each of the systems; in certain cases, especially for subjects that touch several detectors or systems, the RO can suggest to hold specific additional reviews.

Currently the RO is run by two chairs covering two different areas:

- **electronics reviews** which cover custom ASICs, electronics boards, complete electronics systems, and firmware, and
- **detector and mechanics reviews** which cover a wide range of mechanical assemblies such as detectors and support structures.

Where appropriate, the RO chairs can arrange for a joint review to scrutinize at the same time the electrical and mechanical aspects of a given component. The RO chairs are appointed jointly by the Technical Coordinator (TC) and the Upgrade Coordinator.

For each review, the RO chair sets up a dedicated review panel comprising experts from ATLAS, from other experiments or departments, and from interfacing detector systems, adapted to the specific needs of each review. The Upgrade Project Leader and the Project Leader (PL) of the detector system of the component under review are ex-officio members of the review panel, as well as TC and UC (often represented by their deputies). The other RO chair has a standing invitation to attend.

The outcome of each review is summarized in a written report which flags problems and identifies follow-up actions. These reports are prepared by the review panel and approved by the UC and TC. The follow-up actions are tracked by the RO, including possible escalation to the Upgrade Steering Committee (USC) or the TC/UC.

This document merges and supersedes two earlier documents [2,3] on the ATLAS review strategy.

2. Requirements, Specifications, and Designs

Before getting to technical reviews, this section discusses the prerequisites of designs (and reviews thereof): requirements and specifications. The goal of these procedures is to ensure the quality of the detector and electronics components developed for the ATLAS Phase-II upgrade as well as to improve the efficiency of the development process and the design cycle.

With this in mind, these procedures promote the concept that designs are created to meet specifications and specifications are written to meet requirements. An important corollary to this theme is that the interfaces between components that make up a system are critical features of the design that must be understood and guaranteed to work by design. Therefore, the interface of each component is an important part of its specification in order to ensure that it will function properly in its intended application. Reliability is another feature of each component that must be considered at the time of design and not after the component is built, or even worse, after it is installed and operating. The issue of reliability then must be part of the specification of each component.

The first step in the process is to collect the requirements for the component to be designed. A set of high-level requirements for the detector system concerned might be available, as well as specific requirements for the detector, mechanics, and electronics aspects of the component. All these requirements must be fulfilled by the final component design.

In the second step, a specification is written for the component. In addition to individual component

specifications, assemblies of components must also have a specification. And finally, the interfaces between any pair of components in the assembly must be specified as well.[1]

For example, the powering of a detector may be made up of several components – AC-DC converters, DC-DC converters, etc. – as well as cables connecting them. There then should be a written specification for each component and each cable type. Furthermore, there must be a specification describing the entire power system, which will reference each of the individual component specifications, as well as specifications describing all the interfaces between pairs of components and between all cables and the components they connect to. For electronics boards with an FPGA, a separate firmware specification is required in addition to the hardware specification.

The specification for each component should be written and approved prior to the start of any serious design work on the component. This will make the design process much more efficient and minimize the need for re-design later. Since many components will be built in technologies new to ATLAS and some characteristics of those technologies, especially their level of radiation hardness, must be evaluated before a final approval of their use can be made, some component design, fabrication, and testing of test components can be done before formal component specifications are completed. Nonetheless, having a specification available during the technology evaluation can be very useful in directing the evaluation work and choosing the necessary qualification criteria for the technology. As soon as an architecture exists which will make use of certain components, specifications for those components should be written.

3. Reviews

The following sections present the standard sequence of technical reviews organized by the RO. Firmware designs will follow the same review process, with the expectation to have design reviews organized together with the hardware design reviews. Further ad-hoc reviews may be proposed by RO or TC/UC as the upgrade projects evolve, in order to provide additional scrutiny to support the upgrade projects toward a successful completion. Detailed lists of supporting material to be prepared for each review are available elsewhere [4].

The non-technical aspects, such as status, schedule, and resources of the upgrade projects are tracked by the projects themselves using tools provided by the Upgrade Project Office (UPO). In addition to the technical reviews organized by the RO, the UC and the USC organize periodical status reports and reviews, and the LHCC organizes annual reviews, all of which provide additional insight into the project status and progress but are outside the scope of this document.

The RO is an independent office in the sense that its assessments of the technical status and quality of the upgrade projects cannot and must not be influenced by any project management or schedule aspects. In turn, the RO does not interfere in the management of the upgrade projects – it merely provides advice and assistance to the UPL and UC/TC in order to help them manage the upgrade projects.

3.1. Specification Review

Once the specification for a component or a system has been written, it must be reviewed and approved by a Specification Review (SPR). An SPR verifies that complete written requirements and specifications for the components exist, and that the specifications are sufficient to develop the designs. An SPR should be held before the start of any serious design work.

A key component of the specification is the section on interfaces, detailing the quantitative charac-

1 In case of complex assemblies a systematic approach to specifying interfaces is advisable, e.g. by setting up an Assembly Breakdown Structure (ABS) – a structure, like a folder, in EDMS that is used to construct an Interface Control Matrix that maps interfaces internal and external to items in the ABS.

teristics of each interface. These must be checked for consistency with the components which will sit on the other side of each interface. The firmware specification should include the FPGA resources usage and power estimate, which are crucial to guide the FPGA selection in the hardware design.

The review should confirm that the specification details how the component will meet the requirements of the detector system which it will be a part of. It should also state what level of radiation the device needs to withstand. The required reliability level should also be addressed.

Sometimes, needed items in the specification may not be known before design work begins. For example the exact floor plan and size of a custom ASIC likely cannot be determined until some design is started. (However, if the ASIC dimensions are part of its requirements in order to fit into available space, then they cannot be left undefined.) Likewise, some reliability questions may not be answerable until a prototype is built and tested. Such items may be left open when the specification is first reviewed.

- **Prerequisites**:
  - Specification document, approved and released by the project.
- **Items to include**:
  - The requirements for the component, and a detailed description how the component will meet these requirements.
  - Interfaces to other components or systems, consistency with the components or systems on the other side of the interface.
  - Firmware functional block diagram, critical interfaces and parameters, e.g. link speed, protocol, data format and latency. FPGA resources usage and power estimate. Firmware source code management and release plan.
  - Expected level of radiation the component has to survive, including a discussion of the safety factors applicable.
  - Reliability considerations (consequences of failures, prior knowledge of expected reliability, measures to ensure reliability).
- **Outcome**:
  - If the review is passed, the Specification document is approved.

Instead of holding an ATLAS SPR organized by the RO, and with the agreement of RO chair and UC/TC, an internal Specification Review may be held by the project. In this case the internally reviewed and approved Specification document shall be submitted for final approval to the RO and UC/TC.

It is quite common that specifications need to be modified as the design process evolves. Such changes must be documented in a formal way, by releasing and approving an updated version of the Specification document after careful review by all interested parties. The Specification document should include a revision history.

Specification changes to a component already in production or in use must follow the same approval procedure but with considerably more care. If the component is in production, does the change require halting production and restarting from the beginning? If the component is already in use, does the change require replacement of the existing part? There could be large cost and schedule impacts to either scenario. Hopefully, such late changes are only needed to reflect new knowledge of how the component operates, without implying that it does not meet requirements and must be replaced. It will still be important to make the specification reflect how the part actually operates.

3.2. Preliminary Design Review

When a first complete design of the component is ready, a Preliminary Design Review (PDR) verifies that the design meets all aspects of the specifications, and that it is technically feasible. A PDR needs to be held before submission for fabrication or assembly of the first prototype of a component.

Under no circumstances will a PDR be held without an approved specification for the design to be reviewed. For new parts or circuits, simulations should be presented to demonstrate their feasibility. Test plans should be presented to show how the prototype devices will be tested to verify functionality that meets the specification. Measures proposed to ensure reliability should be addressed.

- **Prerequisites:**
  - Approved Specification document.
  - Design of the first full prototype of the component.
- **Items to include:**
  - A presentation of the design.
  - The project needs to demonstrate the technical feasibility of the design, so simulations or partial prototypes demonstrating feasibility for critical functions are important.
  - Firmware preliminary design addressing the main technical challenges, e.g. data flow and system clock speed demonstrated on the FPGA evaluation board. SEU mitigation strategy for FPGA exposed to radiation.
  - Complete test plans should be presented, including irradiation plans, showing how the prototypes will be tested to demonstrate functionality that meets the specifications.
  - Measures to ensure reliability of the component under review should be addressed.
- **Outcome:**
  - If the review is passed, the prototype design is cleared for submission for fabrication or assembly.

The submission of further prototypes does not usually require another review, unless there are very fundamental changes to the design or even to the concept of the component. In such cases, the intermediate review should focus on the aspects of the prototype that did not meet specifications, and the proposed changes for the next prototype.

3.3. Final Design Review

When it is believed that a design is final and ready for production, a Final Design Review (FDR) reviews all the available data from prototypes to determine how well the design, and the implementation of the design, meet the specifications. For components of a larger system, analysis and measurements demonstrating compatibility with external interfaces, consistent with specifications, are essential. An FDR needs to be held before submission of the final design for pre-production.

If there have been any changes in the design since the last prototypes produced, those changes must be looked at very carefully, hopefully with full simulations. By this time a fully developed Quality Control (QC) plan for production testing should be ready and exercised on some of the prototype components. If the component will operate in a radiation environment, then full irradiation data must also be reviewed. Whatever measures have been taken to ensure reliability should also be reviewed and a Quality Assurance (QA) plan to validate reliability of design and construction or manufacturing techniques should also be defined for review.

There are different levels of testing involved in the design and fabrication process. The most compre-

hensive tests are the ones performed between PDR and FDR to determine that the functionality of prototypes, and eventually the final prototype, meets the specifications. In contrast, QA and QC are two complementary approaches to assure and verify the quality of pre-production and production devices. QA is proactive, and comprises measures taken in optimizing and monitoring the production process to provide confidence that functioning and reliable components are produced. QC is reactive, and comprises acceptance tests performed on the produced components to identify faulty or unreliable ones. QC tests are normally less comprehensive than the prototype tests performed earlier, which (at least partially) were tests of the design, rather than of the prototype itself. QA may include producing dedicated test components and submitting them to tests that are more comprehensive than the QC tests, and may even be destructive. QA and QC refer to pre-production and production components, but the procedures have to be worked out and exercised already on prototypes.

- **Prerequisites:**
  - Final and approved Specification document.
  - Final prototypes built and successfully tested to demonstrate functionality that meets the specifications.
  - Final design of the component.
- **Items to include:**
  - A presentation of the final design, including draft production drawings (not ready for fabrication). If there have been any changes in the design since the last prototypes produced, those changes must be presented and reviewed very carefully.
  - All experience from tests of final prototypes as well as earlier ones, covering both performance and reliability aspects.
  - Integration of firmware blocks and test results on prototype boards. System integration plan and test results of major external firmware interfaces, e.g. readout link, clock recovery, and synchronization.
  - Full irradiation data.
  - Measures taken to ensure reliability, and a preliminary Quality Assurance (QA) plan to validate reliability of design and construction techniques should be presented.
  - The preliminary Quality Control (QC) plan for production testing, as well as the test infrastructure should be ready and should have been exercised on some of the prototype components.
  - Preliminary version of the production plan.
  - The preliminary procurement plan for pre-production and production, including the adjudication criteria and acceptance criteria. These should have been discussed with and cleared by the appropriate purchasing department or Funding Agency.
- **Outcome:**
  - If the review is passed, the final design is cleared for submission for pre-production fabrication or assembly with the selected supplier. The FDR thus gives green light for the first CORE expenditures. The number of pre-production components produced is usually small, but must be large enough to provide meaningful statistics.

3.4. Production Readiness Review

Unlike the previous reviews, the subjects of a Production Readiness Review (PRR) are the production technique and production process, not anymore the design of the component itself. If a firmware

PRR takes place after the corresponding hardware PRR, sufficient firmware development progress must be presented in the hardware PRR.

All the devices produced in the pre-production fabrication or build must be tested using the planned full QC test and the QA plan should be exercised at the planned sampling rate including any irradiation necessary for devices operating in a radiation environment. These results are then brought to the PRR for review. If the test results show acceptable yield to the QC testing and an acceptable level of passing the QA and irradiation tests, the design is cleared for full production.

It is a common mistake to confuse pre-production components with final prototypes, by deliberately implementing final changes to the design only after the FDR and thus abusing pre-production for prototyping. A definition of a pre-production component is that it should be so similar to the final production component that it could, if necessary, be installed in ATLAS. The main difference is, however, the purpose: a prototype is used to develop and test the component; in pre-production one develops and tests the production process.

- **Prerequisites:**
  - Components produced in the pre-production fabrication or assembly and tested using the full QC test procedure.
  - QA plan exercised at the planned sampling rate, including any irradiation necessary for components operating in a radiation environment.
- **Items to include:**
  - All experience from pre-production and from tests of pre-production components, fraction of items passing QA and QC tests.
  - Final production drawings, ready for fabrication. Any proposed minimal changes of the design after pre-production (which might be required as a consequence of production issues) should be very carefully reviewed.
  - System integration test results to validate external firmware interfaces and assess the readiness for commissioning and operation.
  - Fully developed production plan, as well as final QA and QC plans, describing procedures, material flow, work flow, and testing flow.
  - Procurement procedures for production, including the adjudication criteria and acceptance criteria, cleared by the appropriate purchasing department or Funding Agency.
- **Outcome:**
  - If the review is passed, the design is cleared for full production. The PRR qualifies the suppliers and the production sites that provided the pre-production components. The PRR thus gives green light for the bulk of CORE expenditures.

The PRR cannot be considered passed if significant changes are made to the fabrication or assembly process after pre-production; in this case, a new pre-production followed by a new PRR is required. In particular, if the supplier is changed between pre-production and production, a new round of pre-production with the final supplier is required.

If minimal design changes are made after the PRR as a result of interactions with the final supplier, these have to be brought to the attention of the RO. In case any significant changes have to be made to the design of the component after the PRR, a new FDR is required, followed by a new pre-production and a new PRR.

If the number of units to be produced is small, then the FDR and PRR can be merged, and the full number of units could be produced after this merged review is passed.

3.5. Design Reviews for Commercial Systems or Devices

For the case of purchase of a commercial device or system, for example a power supply, the writing and approval of a specification is still required. However, the design review process should be modified. There is no need for a PDR since no prototypes need to be built or tested. It is assumed that the persons responsible for this purchase have done their homework and found a commercial device that meets the specification. This may require purchasing a small number of units and testing them. When the specific device to purchase has been identified, there should be a Final Design Review, at which time the approved specification can be compared with the vendor's specification and the tests that have been performed on the device. If the FDR is passed, a pre-production quantity of the devices should be purchased such that the reproducibility of the manufacturer's quality and reliability can be measured. This quantity should be at least 10% of the full production quantity. This would be followed by a PRR to approve the full production quantity order. The PRR should include a review of the purchase contract with the vendor, which normally specifies acceptance procedures and how failed parts will be handled. If the number of units to purchase is small, then the FDR and PRR can be merged, and the full number of units could be purchased after this merged review is passed.

CERN has strict rules concerning the selection of vendors, as do other institutes. It is essential that the rules of the institute that is going to perform the purchasing be followed. These procedures, in particular the adjudication criteria, should be reviewed early in the procurement process but no later than at the time of the FDR. As the members of the FDR committee will be chosen mostly for their technical expertise and not their purchasing knowledge, the chair of the FDR committee should request confirmation that the procurement process has been approved by the appropriate purchasing department of the institute responsible for the procurement.

3.6. Further Reviews

If deemed useful, additional design and production reviews may be added to the sequence SPR–PDR–FDR–PRR. Intermediate Design Reviews (IDR) check the progress of the design between SPR and PDR, or between PDR and FDR, in particular if significant changes have been made to the design presented at the PDR. A Production Advancement Review (PAR) checks the progress of production after the PRR.

System Integration Reviews are required when a detector system consists of many different hardware, firmware, and software components that had previously been reviewed separately. Such reviews may address, for instance,

- the procedures, logistics, tools, manuals, material flow, and work flow for assembly and installation of hardware components into the detector system;
- the firmware and data acquisition software needed to commission and operate the trigger and readout electronics components of the system;
- the sensors, electronics, and software architecture of the detector control and monitoring system (DCS) and of the detector safety system (DSS).

The scope and granularity of System Integration Reviews are agreed upon by the RO chairs and the UPL, in consultation with UC/TC. These reviews must be scheduled early enough in the design process of each project such that any findings from the reviews can still be taken into account.

4. Organization

The organization of the review process comprises the review preparation, the review itself, and the review report and review follow-up.

4.1. Review Preparation

At least four weeks before the desired review date, the activity coordinators of the project, in agreement with their UPL, contact the RO to kick off the review preparation. At that time, an informal preparatory meeting between activity coordinators and one or both of the RO chairs is arranged to

- define the scope of the review,
- highlight critical areas,
- agree on a few options for the review date,
- discuss required documentation and the agenda, and
- identify potential candidates for the review panel.

The UPL and activity coordinators are encouraged to make first contact with the RO significantly earlier than four weeks in advance, in particular when there is some likelihood that the scope of the review might require discussion, or that additional work might be requested by the RO chair to be performed for presentation at the review. Similarly, if there are conditions that would cause severe consequences if the review were not passed (e.g. the risk of losing money due to funding constraints) it is advisable to minimize this risk by a timely and thorough preparation of the review. Under no circumstances can the consequences of not passing a review be expected to influence the outcome of a review.

Reviews are normally held at CERN, and video connection is provided. While in exceptional cases presentations can be made from remote, it is preferred that the speakers and in particular the activity coordinators and the reviewers attend in person.

The RO is in charge of creating the indico agenda page, booking the meeting room, recruiting the review panel members, and informing the ex-officio reviewers. The composition of the review panel is subject to approval by the UC. The activity coordinators are in charge of filling the indico agenda, identifying members of the project to make presentations, and inviting additional project members who should be present at the review meeting. For organizing the review and the agenda, the RO chair communicates with the review panel members and the activity coordinators. The activity coordinators communicate with the members of the project.

One week before the agreed review date the presentations and additional documentation are made available to the review panel on the indico agenda.

4.2. Review Meeting and Report

The review meeting starts with a reminder of the charge and the scope of the review by the RO chair, followed by an introductory presentation of the project by the activity coordinators. A presentation summarizing the responses of the project to the recommendations and actions from the previous review is also required.

The review meeting is chaired by the RO chair, who follows the agreed agenda, with ample time for discussion after each presentation. At the end of the review meeting, the review panel holds a closed session to exchange their general impressions and discuss the review outcome.

Using input and notes from the panel members, the RO chair drafts a written report which describes the content of the review, summarizes the presentations and the discussions, flags problems and points of concern, provides recommendations, and identifies follow-up actions. The panel members check and approve the report before it is submitted for final approval to TC and UC (who may delegate to their deputies). The UPL and PL of the project, being ex-officio members of the panel, should in this process bring up any concerns and objections in case they feel there are unfair assessments or factual errors in the draft report. In the interest of time, the RO chair and UC/TC should aim at re-

leasing the report as soon as can reasonably be achieved, no later than four weeks after the review. In order to assist the UPL and UC in their duties of reporting to the LHCC and other committees, the report should include a "quotable" paragraph summarizing the review outcome and the most relevant comments and action items from the panel.

After the final approval, the RO uploads the report in EDMS, creates a link in the indico agenda, and sends the report to the activity coordinates who forward it to the members of the project. The activity coordinators may request to schedule a meeting with the RO chair to discuss the review outcome, the content of the report, and possibly to clarify issues raised by the panel. The follow-up actions are discussed and reporting mechanisms agreed.

The RO chair gives regular reports in the USC meetings, summarizing the outcomes of reviews in the past reporting period.

4.3. Review Outcome and Follow-up

The review panel makes observations, gives recommendations, and defines action items. The members of the project under review are asked to take note of the observations. Recommendations are for their consideration, and the activity coordinators are asked to respond to recommendations stating whether they have decided to implement them, and to present their reasoning in case they have decided not to. Action items are requested to be implemented by the project, and the activity coordinators report to the RO chair once this is done.

Possible outcomes of reviews are:

- **Passed:** The reviewers were entirely satisfied with the material presented, and formulated only minor recommendations or action items, if any. Authorization is granted to begin the production of prototype, pre-series, or series components. The activity coordinators report on the actions and recommendations at the next review.[2]
- **Passed with recommendations:** The reviewers were satisfied with the material presented, but formulated relevant recommendations or action items. The authorization to proceed to the production of prototype, pre-series, or series components is not conditional upon any of them. The coordinators report on the actions and recommendations at the next review.
- **Conditionally passed with follow-up actions**: The reviewers were mostly satisfied with the material presented, but identified a number of areas where e.g. additional information is requested, further work is required, or choices have to be made. They formulated specific action items, with target dates, to address these issues. The authorization to proceed to the production of prototype, pre-series, or series components is conditional upon at least some of the action items; these are designated as *critical* action items. The RO chair keeps track of the critical action items (usually through a tracking file in EDMS), and depending on the scope and complexity of the issues the project may report back in writing, at an informal meeting, or at a formal follow-up review. The RO chair decides if and when actions can be closed, in consultation with other panel members from the review.
- **Not passed:** The reviewers were unsatisfied with the material presented, e.g. because of a lack of maturity and detail that was deemed inadequate for a review at that stage, or because they fundamentally questioned the viability of the concepts presented. A new full review at a later date is required.

Reviews that are **passed** or **passed with recommendations** are to be considered as "passed" on the date of the review for the purpose of reporting the status of milestones to USC and LHCC.

Reviews that are **conditionally passed with follow-up actions** are to be considered as "passed" on the date when authorization is given to proceed to prototype/pre-series/series production, i.e. when the last of the critical actions holding this up is closed.

2 In case of a PRR, the coordinators report on actions and recommendations either at the PAR, or in writing to the RO chair at their convenience.

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Resources

- Review reports (detectors & mechanics): https://edms.cern.ch/project/ATC-0699
- Review reports (electronics): https://edms.cern.ch/project/ATU-0000000029
- Review agendas (detectors & mechanics): https://indico.cern.ch/category/6988/
- Review agendas (electronics): https://indico.cern.ch/category/6924/

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