A.7 MTD Project QA Plans

A7.1. MTD Project Scope

The MIP Timing Detector (MDT) is a subsystem within the international CMS HL-LHC Upgrade Project. It consists of a thin layer of precision timing sensors just outside the tracking volume. Radiation tolerance and cost considerations led to different technologies in the barrel and endcap regions; the Barrel Timing Detector (BTL) uses small LYSO crystals read out by Silicon Photomultipliers (SiPMs) and the Endcap Timing Detector uses Low Gain Avalanche Detectors (LGAD), a specific type of silicon sensor. The BTL is integrated into the Tracker Support Tube, the mechanical support for the tracking system. The ETL is attached to the front face of the endcap calorimeter.

The MTD provides very precise time information for each particle traversing the detector, giving a time stamp for each track. Using this information, new event reconstruction algorithms have been developed to use four dimensions (space and time) rather than the traditional reconstruction in three-dimensional space only. This greatly reduces confusion in the event reconstruction due to “event pileup” (multiple pp interactions in each beam bunch crossing), and provides the equivalent performance at an average of 200 pileup events per crossing (the maximum anticipated for HL-LHC) as for the current-era detector with 3D reconstruction and 50 pileup events per crossing.

The U.S. MTD subproject is integrated with international CMS with respect to shared designs, procurements, and module production. Deliverables for the U.S. effort include modules for both BTL and ETL, the concentrator card for the BTL modules, and the readout ASIC for the ETL modules. The module is the basic self-contained subassembly of each detector. For BTL modules include crystals, SiPMs and readout electronics provided by international partners. Modules are then grouped with concentrator cards and mounted on a mechanical structure called a tray. For ETL, the modules consist of an LGAD sensor with the ASIC attached, read out by circuits provided by international partners and mounted on a mechanical plate.

The U.S. MTD WBS is:

- 402.8.1 Milestones
  - High level milestones (lower level milestones are within the other WBS elements)
- **402.8.2 Management**
  - Travel for Organizational Meetings and Misc. M&S
- **402.8.3 BTL**
  - 402.8.3.1 BTL LYSO Crystals
    - R&D to optimize crystal design
  - 402.8.3.2 BTL SiPMs
    - R&D to provide additional margin in radiation tolerance
    - Purchase of SiPMs, development of QC procedures, and QC on delivered parts
  - 402.8.3.3 BTL Concentrator Card

- Design and prototyping of the concentrator card. Procurement of boards, receipt of components from CERN, board assembly and QC.

- 402.8.3.4 BTL Assembly
  - Reception inspection of parts (crystals, SiPMs, concentrator cards and mechanics), assembly of modules and trays (mechanical structures of several modules), module QC and delivery of trays to CERN
- 402.8.3.5 BTL Integration and Commissioning
  - Participating at CERN on the QC aspects of installing and testing trays into the full detector.

- **402.8.4 ETL**
  - 402.8.4.1 ETL LGAD Sensors
    - R&D to qualify sensor performance
  - 402.8.4.2 ETL Front-end ASIC
    - Design and prototyping of the front-end ASIC. Purchase of production ASIC wafers. Qualification of the initial production wafers.
  - 402.8.4.3 BTL Assembly
    - Develop the assembly process using mechanical parts and demonstrate prototype module assembly. Reception testing of LGAD sensors, and hybrid readout circuits. Module assembly and QC. Delivery of modules to CERN.
  - 402.8.4.4 ETL Integration and Commissioning
    - Participating at CERN on the QC aspects of installing and testing modules into the full detector.

A7.2. MTD Project Organization

U.S. CMS MTD reports to the international CMS MTD Project Leader. The U.S. work is closely coordinated with the international project with respect to design validation, shared procurements organized through CERN to guarantee consistency, and fabrication in parallel. There are organization charts for CMS and U.S. CMS that define clear roles and responsibilities, as well as official channels for communication. Several U.S. team members fulfill roles in the CMS international organization.

The US MTD project planning and schedule are maintained independently from the CMS schedule, with deliverables to and from the U.S. project represented as external milestones. Key external interfaces are with CERN on procurements and deliveries of several module components. The U.S. shares module assembly with international partners, all of whom then deliver the assembled and testing modules to CERN.

Note: additional details can be added here once the international project has defined responsibilities in the TDR package.

The U.S. MTD project holds its own coordination meetings (currently two per week: one focusing on management and schedule and the other on technical issues). The U.S. L4 managers attend weekly international MTD meetings at which project planning and technical issues are discussed. Workshop meetings are held approximately four times a year during "CMS Weeks" for more extensive review and coordination.

Interfaces and decisions are handled at the international level because international and U.S. CMS share the same design for Modules. Design and fabrication plans, including Quality Assurance, are discussed and decided under the international CMS organization with participation from all countries. Participants at each level of the international CMS WBS, including U.S. project members, present, discuss and debate the current topic – design, fabrication plan, quality assurance level, prototyping result, etc. The decisions arising from these meetings, typically after several iterations, are presented at the CMS Week workshop meetings to be endorsed by the MTD management. Significant decisions are reported to the CMS Upgrade Coordinator who may call a review with outside experts. Similarly, decisions involving the U.S. scope are reported to the US HL-LHC Project Manager who may call a review.

reference here the change control document – should say that this is what we follow

QC procedures are approved by the international MTD QA Manager, including the final acceptance tests for modules delivered to CERN.

A7.3. Participating Institutions

The U.S. CMS MTD subproject leverages existing experience and expertise at participating institutes, see Table A8.3.1. The module assembly sites at Caltech, FNAL, Nebraska, and Virginia will each be qualified with prototype and preproduction parts. Site visits will be performed to ensure appropriate facilities and procedures are in place.

Institute	Interests (Coarse)
UCSB	ETL sensor & module R&D and construction
Caltech	BTL sensor & module R&D and construction, ETL sensor R&D
Fairfield	BTL sensor R&D
FNAL	ETL sensor & module R&D, FE ASIC, construction
Iowa	BTL sensor R&D, mechanics
Kansas	ETL sensor R&D
Kansas State	BTL readout electronics
Nebraska	ETL module R&D and construction
Northeastern	Backend electronics
Notre Dame	BTL sensor & SiPM R&D, backend electronics
Princeton	BTL sensor & module R&D, mechanics
Virginia	BTL sensor & module R&D and construction

Table A8.3.1 –Participating Institution Activities.

A7.4. Planned QA Activities

All QA aspects of the U.S. HL LHC CMS Detector Upgrade Project will be handled in accordance with the rules and procedures laid out in the Project-wide Quality Assurance Plan CMS-doc-13093. Detailed plans for QA/QC activities are found in the MTD QA Activities Spread Sheet (*QAP*, CMS-doc-13093, under *Other Documents*). The QA activities are linked to Technical Requirements established through the CMS review and approval process and recorded in the 402.8 MTD Requirements and Interface, CMS-doc-13337. While U.S. MTD is responsible for creating and following QA plans and processes for work at its sites, these plans must be consistent with international CMS QA plans and procedures. U.S. MTD L4 managers work with the assigned CMS MTD QA Manager on planning QA and validation of CMS requirements.

A7.3.1 Design Validation: Why is the section numbering like this in the template?

The verification activities include:

- Characterization of prototypes (often before and after irradiation). These tests will be used to qualify vendors and develop final specifications for production parts.
- Reception testing of parts delivered from vendors or international partners – including visual inspection and functional electrical testing. In some cases, sample parts will be tested per batch.
- Mechanical conformity measurement of assembled parts.
- Electrical function tests and characterization of assembled parts. This may include power and thermal cycling and data bit error rate measurement.
- All data is maintained in a standard database and electronic travelers are used to track progress for assembled parts.

The MTD conceptual design has been reviewed by the CERN LHCC (Reference Technical Proposal) to ensure that it will meet the scientific goals of the project. A Technical Design Report is currently being prepared and will again be reviewed by the LHCC with a more detailed description of the design. The US project Conceptual Design Report [reference] that is equivalent to the international TDR, but for the U.S. project scope, has been reviewed in a Technical Review [Reference]. These reviews to date have focused on the overall conceptual design and project plan.

Future reviews leading to the formal CMS Engineering Design Review (EDR) will include prototype validation (both components and assembly process), and QA/QC procedures. These reviews will be conducted by the international MTD project. The EDR will be held prior to final design approval and the start of the production phase of the project.

A7.3.2 Production Verification:

All components will be checked first by the vendor as part of the Quality Control specifications in the contract, with contracts written such that only satisfactory parts are paid for/delivered. Vendor QC will be cross checked by visual inspection and, where appropriate, functional testing, either of all parts or a sample from each batch delivered. Items which do not conform will be graded as such and segregated from conforming components, to be either discarded or used in dedicated tests/mock-ups where the lack of functionality does not affect the test.

Module production is coordinated by the CMS module group and the US activities are embedded into the work of this group. The CMS module group will approve the tooling and procedures to be used for assembly and publish the approved designs. The institutional sites where fabrication of components will take place will be required to follow the International CMS designs and procedures, which applies to all participants in MTD, independent of local institutional QA programs. To be approved for assembly of production modules, assembly centers will have to demonstrate to the CMS module group that they can meet the requirements by reliably by assembling five modules to specifications.

For U.S. production, subproject Leads will follow the process described in the U.S. CMS QAP to validate demonstrated capability for CMS designs and procedures after the prototyping campaign and to review/approve site QA plans. Site visits will occur before the start of production.

Continuous monitoring of the yield of recent fabrications will be performed throughout the production, with site follow-up visits by the U.S. L4 and/or L2 manager if the yield becomes unsatisfactory. Weekly reports of production throughput based on the standardized verification program will be used to judge progress as the production ensues. This will be the primary responsibility of the L4 manager, reporting results to the U.S. MTD L2 Manager.

In areas where the deliverable is part of the detector, acceptance tests of all components are planned to occur before integration into composite structures. These tests are carried out under the U.S. L4 for parts delivered to CERN. Reception testing of these parts, and of the assembled composite structures overseen by international MTD.

The QA Activities spreadsheet lists the entities responsible for performing the acceptance tests.

A7.5. Document/Record Storage:

Project designs, plans, and reports shared between the U.S., other CMS MTD stakeholders, and CERN engineering are maintained in the international organization, through the CERN Engineering Design Management System (EDMS), the CMS Document Database, or an online “e-space” built for collaborative work. These systems are meant to be the repository of the authoritative latest design and can have notification/approval mechanisms such that all stakeholders can be aware of and/or approve design changes. Implementation in EDMS is based on the 402.4 Endcap example and is ongoing.