Quality Assurance for Modules

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Outline

- What is Quality Assurance?
- An outline of a QA plan for Phase 2 Tracker Modules
- Example: A QA plan for 2S module assembly production
- Conclusions

What is Quality Assurance?

One formal definition of QA:

"a program for the systematic monitoring and evaluation of the various aspects of a project, service, or facility to ensure that standards of quality are being met." *(Miriam-Webster dictionary)*

Another: "refers to the systematic measurement, comparison with a standard, monitoring of processes and an associated feedback loop that confers error-prevention." *(Wikipedia)*

I'll redefine these as: "make a good plan covering design, fabrication, assembly, commissioning and operation of a silicon tracker module to ensure it meets its quality requirements."

What is Quality Assurance?

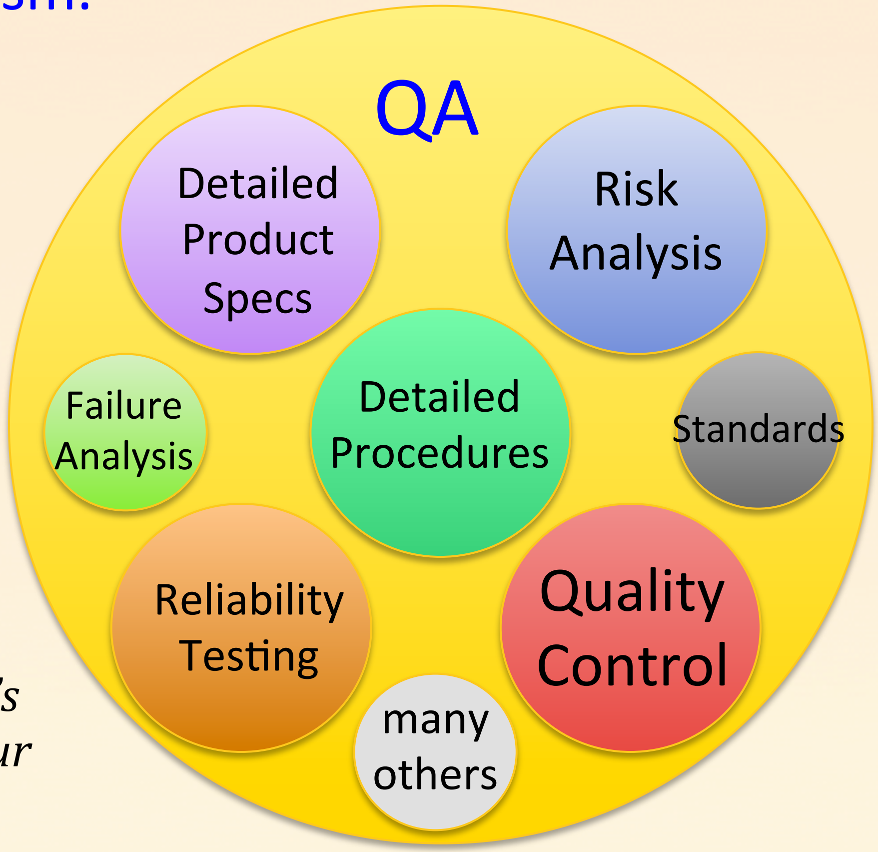
But a "good plan" means looking at each phase of the project and assessing risks and weak areas, then implementing quality checks at appropriate points. This is a pro-active approach.

Note that quality control (QC), on the other hand, is a re-active mechanism. So, QA≠QC, but QC should be an integral part of a QA plan.

The QA plan includes other steps taking place prior to, during, as well as after the production and construction phase.

Note also: QA ≠ ISO9000/9001

The ISO certification applies to the company's quality capabilities but not necessarily to your product made by that company.



What is Quality Assurance?

Finally, QA ≠ electrical testing (for modules or a detector system), this is a misconception I have seen quite often in CMS (and elsewhere). Although many electrical tests are a part of QC, some could be for qualification, for reliability studies, or as a part of failure analysis. So this means QC ≠ electrical testing, as well, since QC can also include visual inspection, mechanical testing, dimensional measurements, thermal tests, and many other tests and checks.

Another term that can be confused with QA is QM, or quality management. QM is a part of project management and looks at the implementation of QA and other quality related issues within a project. QA tends to be product oriented, which for us is usually a detector deliverable. If the product is the whole detector, then its QA will be a large part of the project QM. However, QM will be concerned with organisational structure, personnel, budget, training, and other aspects of the project that concern the quality. So, one can consider that QM is the highest level, with QA a part of QM, and QC a part of QA.

Outline for a QA plan for Modules

So, what would a QA plan for modules look like?

QA actions in magenta

These are all pre-production

- List the quality requirements for modules
- Define the module design, write the specifications
- List the module components and who produces them
- Determine the acceptance criteria for components
- Determine the non-conformity action procedures for components
- Define the module assembly procedure
- Decide where in the procedure QC will be needed
- Define the site requirements and the personnel qualification and training
- Determine the qualification criteria for the design and assembly (this will determine when you move from development to production) which should include dimensional measurements, mechanical tests, thermal tests, electrical tests, reliability tests, and tests after irradiation

Production

- Determine the acceptance criteria (similar list of measurements and tests) for the production modules
- Determine the non-conformity action procedures for module production
- Define the interaction with the database
- Determine the repair procedure

I am sure there are many others…

Outline for a QA plan for Modules

Some key points about the QA plan:

- Most of the QA plan applies to pre-production. The testing during this phase should be the most rigorous in order to ensure a high quality design and assembly procedure.
- Many parts of the plan will evolve with the development. Example: the module design may change and thus the specifications may need to change as a result.
- If the QA plan is sound and complete, the QC testing during production should reject very few modules.
- This QA plan does not mention specific tests. The full QA document should include these in the various places that QC is performed but the testing is only a part of QA. Electrical testing is therefore even a smaller part.

A QA plan for 2S module assembly production

Just the assembly process during production!

Assumption: The 2S module assembly production will follow the method using the assembly jigs designed and prototyped so far.

1. Have a complete set of technical requirements (=specification document) for the assembled module, not just electronic but mechanical and thermal.
2. Have a complete set of acceptance criteria for all components and tooling used in the assembly.
3. Make a written procedure for the assembly, including all steps to be taken from reception of components through to final acceptance tests.
4. An assembly site qualification criteria list should exist and the assembly site should conform to those requirements. This would cover the aspects of environmental conditions (temperature, humidity, ventilation), cleanliness (clean room quality), ESD protection, proper handling tools, work space requirements, inspection equipment, storage conditions, etc.
5. After an evaluation of the manpower required, define the training and testing requirements for the personnel, for each step in the assembly procedure requiring personnel.

A QA plan for 2S module assembly

6. The written procedure will require QC at various stages in the assembly. The QC may require specialised equipment and software, which must be specified and checked for compliance.
7. The assembly procedure should include the actions to be taken in the case of non-conformity. This should include the repair scenario and the actions in the case of a high failure rate.
8. A database (DB) should be defined and used to track the components and the assembly such that information on all components of a module can be easily found.
9. A module traveller document should be implemented which should include a checklist for all major assembly steps, including each QC step with the result (if appropriate). The date and person responsible should be noted for each entry. This information should be entered in the DB.
10. Each module should have an easy means of identification, usually a small self-adhesive barcode which also must be radiation hard.
11. Depending on the required reliability, either stress screening or sampling HALT (highly accelerated lifetime tests) tests should be performed to check that the module quality remains sufficient.

Draft procedure for 2S module assembly

(Draft) Procedure for 2S module assembly 15 March 2016

Equipment

Module parts (per module):

1) 2 Al-CF bridges
2) 1 Al-CF stump bridge
3) 2 2S sensors
4) 2 backplane polyimide (PI) circuits
5) 1 right and 1 left 2S readout hybrid
6) 1 service hybrid

Gluing jigs:

1) Backplane PI circuit gluing jig (not yet designed as circuit is not yet designed)
2) Sensor gluing jig with pins for bridge positioning, pin + bumpers for stump bridge positioning, 3 side wall blocks for sensor positioning, 2 spring loaded fingers for keeping sensor against walls. Vacuum holes for holding sensor flat on jig. This jig is designed to work for gluing both the top and bottom sensors. (exists and tested)
3) Glue transfer jig (exists and tested)
4) Hybrid gluing jig which uses pins for positioning the module via the bridge holes and spring loaded pads for keeping the hybrids in place. (exists, to be tested)

Glue: Low viscosity, room temperature cure, electronics grade epoxy glue such as Epo-tek 301. For some gluing steps, a high viscosity version may be preferable.

Bonding jig:

1) Bonding jig with vacuum support surface near edges of sensor close to wire bond pads. Will have an adjustable support bar to provide support under the readout hybrids as close as possible to the bonding areas. Has two pins to position module using the modules positioning holes in the bridge. The jig works for both top and bottom side bonding by flipping over the module. Can be used for repair work as the support areas do not interfere with already placed wire bonds. (exists and tested)

Encapsulant: Low viscosity, room or moderate temperature cure, electronics grade, flexible or slightly flexible, radiation hard encapsulant (Sylgard 186 should be OK for 2S modules).

Module carrier plate: alu frame-like plate which supports the 5 feet of the bridges and has threaded posts (for positioning) and long cylindrical nuts that can be screwed down to hold the module onto the plate. Should be able to be left in place for top-side and bottom-side encapsulation. (exists, mods in progress)

Encapsulation jig: A simple plate that can hold the module + module carrier in the air such that the side of the module facing down does not touch anything and the side facing up can be accessed by the encapsulation dispenser robot. This jig should be able to hold the module either top-side up or top-side down. (designed, to be fabricated)

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Other equipment for gluing steps:

Glue mixing equipment (scale, mixer, applicator, …)
Degassing (vacuum bell) device
Vacuum pump
ESD safe vacuum pens
HV power supply and test equipment for parylene coating conformity test
Optical measurement machine for checking top-bottom alignment
Inspection stereo-microscopes

Other equipment for bonding steps:

Aluminium wedge wire bonding machine with work table having locator pins for jigs
Vacuum pump
Pull test machine
Inspection stereo-microscopes
Assorted bond wire handling tools

Other equipment for encapsulation steps:

Encapsulation dispensing robot (X-Y-Z stage with dispensing equipment)
Mixing machine
Degassing (vacuum bell) device

Procedures:

Assumption: sensor edge cuts are good to better than 10 um

Procedure for backplane PI circuit gluing, bonding and encapsulation:

1) put top sensors on gluing jig in specified orientation and position into corner of jig
2) put glue stencil over sensor and apply glue to contact area defined by stencil
3) place top sensor PI circuit in slot in jig and put weight on top of glued area.
4) check that glue has filled gaps by seeing excess pushed out of gaps
5) repeat steps 1-4 for bottom sensors
6) wait for curing time, remove weights, test curing samples for proper polymerization
7) visual inspection
8) move sensor to bonding plate
9) add at least 10 wire bonds with length <1.5mm and height <200um
10) visual inspection
11) encapsulate by hand or with dispenser making sure no large bubbles trapped under wires
12) wait for curing time, test curing samples for proper polymerization
13) visual inspection
14) store in appropriate trays/boxes/envelopes

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Draft procedure for 2S module assembly

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Note: These can be assembled separately in large quantities and in advance of the rest of the assembly work.

Procedure for coating of Al-CF bridges:
1) apply Kapton tape to cooling contact surfaces of both large bridges and the stump bridge
2) send all bridges to company for parylene coating
3) On return from parylene coating, visual inspection
4) Test conformity of coating (thickness, HV standoff)

Note: These can be assembled separately and in advance of the rest of the assembly work.

Procedure for top sensor gluing:
1) place top sensor face down on jig with vac pen
2) engage springs for positioning
3) check (through microscope) that sensor edges are correctly pushed against the positioning stops
4) turn on vacuum to hold sensor in position
5) mix glue and de-gas
6) paint glue onto specified zones of the glue transfer jig
7) lower bridges onto transfer jig and then remove
8) put large bridges with glue side down onto sensor back plane using pins (for long bridges) or stops (for stump bridge) for positioning
9) lower weight plate onto bridges
10) wait for curing (probably 24h), check for polymerisation
11) clean transfer jig

Procedure for bottom sensor gluing:
1) release vacuum (if needed) and remove top sensor assembly from jig and set onto soft surface (paper/cloth) with sensor still facing down
2) place bottom sensor face down on jig with vac pen
3) engage springs for positioning
4) check (through microscope) that sensor edges are correctly pushed against the positioning stops
5) turn on vacuum to hold sensor in position
6) retract positioning springs
7) mix glue and de-gas
8) paint glue onto appropriate zones of the glue transfer jig
9) pick up top sensor assembly, flip over and lower onto transfer sheet then remove
10) place it on the bottom sensor carefully and guide into place using positioning toes but do not use pins
11) engage springs for positioning
12) lower weight plate on top sensor
13) check that sensor edges are correctly pushed against the positioning stops
14) wait for curing (probably 24h), check for polymerization
15) put on measuring device to check top to bottom sensor alignment accuracy

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Procedure for hybrid gluing (only true for 1.8mm version, additional steps for 4mm):
1) put sensor sandwich right side up on hybrid gluing jig using holes in bridges into jig pins for positioning
2) mix glue and de-gas
3) run glue dispensing program or paint/roll glue onto hybrid support surfaces
4) put a tiny spot of glue on top sensor for thermistor gluing
5) pick and place readout hybrids and service hybrid on bridges with vac pen
6) engage springs for positioning, check for correct positioning
7) put weight plates on hybrids using guide pins
8) carefully press thermistor on glue spot on top sensor to ensure good contact
9) wait for curing (probably 24h), check for polymerisation

Procedure for wire bonding:
1) connect the bias circuit, ground the service hybrid (but how do we ground the readout hybrids?)
2) move to bonding jig with top side up
3) adjust height of hybrid supports
4) bond all top side bonds (start with service hybrid to readout hybrid?)
5) visual inspection
6) flip over module on bonding jig
7) adjust height of sensor support and hybrid supports
8) bond all bottom side bonds
9) visual inspection
10) put module on module carrier
11) full electrical test (a complete separate written procedure should exist for performing this step)

Procedure for encapsulation of wire bonds:
1) put module + module carrier on encapsulation machine
2) mix encapsulant and de-gas
3) dispense encapsulant on top-side bonds
4) wait for curing, check for polymerisation
5) visual inspection
6) turn module + module carrier upside-down on encapsulation machine
7) repeat steps 2-5 above
8) fast electrical re-test

Note: as many (5-10) modules will likely be assembled in parallel, the mixed glue can be used for a group of modules if time allows. It is assumed the that assembly sequence will be followed step by step for all modules being assembled in parallel. This implied 5-10 jigs of each type.

At the end of each major assembly step, after each visual inspection and each electrical test, the module traveller should be signed and dated and the results noted if required.

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One can see that a complete procedure document allows one to determine best where the QC steps should occur.

Conclusions

- QA is a detailed plan for assuring the quality for any project and involves all project phases from design to operation.
- QA is applied in the same way to subsets of the project (whole tracker ➔TB2S➔ladder➔module➔hybrid➔CBC3)
- QA ≠ QC ≠ electrical testing (even for modules).
- A complete production planning is useful for defining the QA plan.
- A successful QA plan means the production was on schedule, within budget and met the quality requirements.