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**THE UNIVERSITY OF WISCONSIN**

WIPAC (Wisconsin Inst. for Particle Astrophysics Center)

**MADISON, WISCONSIN**

TITLE

# ICECUBE UPGRADE QUALITY PLAN

| ORIGINATOR | DATE | ENGINEER | DATE | DRAFTSPERSON | DATE |
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# IceCube Upgrade Quality Plan

University Of Wisconsin – WIPAC (Wisconsin Institute for Particle Astrophysics Center)
Madison, WI

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## 1.0 Purpose

The document describes the quality processes that are to be followed in the design, manufacture and deployment of the IceCube Upgrade Project. These processes are intended to be consistent with ISO 9001 elements for design, manufacturing, CAPA, training and document control.

## 2.0 Scope

This plan applies to all aspects of the IceCube Upgrade Project, including the Enhanced Hot Water Drill and IceCube instrumentation. This document applies the project team based at the University of Wisconsin-Madison, project collaborators and contractors involved in the design, development, manufacturing and deployment of IceCube Upgrade.

If a collaboration institution determines that it needs a quality plan for its tasks, the institution management shall ensure that their quality plan complies with this document. Discrepancies between this document and the local institution quality plan shall be justified in the local institution quality plan. Any unjustified discrepancies will default to the requirements of this document.

Other sites may have equivalent documents, describing similar processes to those contained herein. Those equivalent documents must still be compliant with those requirements contained herein.

## 3.0 References

**3.1** 9000-0002, IceCube Safety Manual

**3.2** 9000-0004, IceCube Configuration Management Process

**3.3** 9000-0005, IceCube Document Control Procedure

**3.4** 9000-0014, Systems Engineering Management Plan

**3.5** IceCube Project Execution Plan

## 4.0 Definitions

**4.1** **CAPA** – Corrective and preventive action. The term CAPA can be used for the process under which issues are corrected or for an individual issue report (including its evaluation and resolution).

**4.2** **Controlled Documents** – Documents that are under (or required to be under) formal document control.

**4.3** **Device** – In the context of this document, a device is any finished IceCube component, subsystem or system. It can include hardware or software.

**4.4** **DOM** – Digital Optical Module.

**4.5** **ECN** – Engineering Change Notice; the process by which document and design changes are revised, controlled and released.

**4.6** **EHWD** – Enhanced Hot Water Drill.

**4.7** **Employees or Staff** – For the purposes of this document, employees or staff are considered anyone working on the IceCube Upgrade Project who is an employee or contractor of one of the IceCube collaboration facilities.

**4.8** **HALT** – Highly Accelerated Life Testing.

**4.9** **HASS** – Highly Accelerated Stress Screening.

**4.10** **Labeling** – Any label affixed to or documentation accompanying the device which identifies, describes or provides instructions for using the device.

**4.11** **Product** – Same as device.

**4.12** **QA** – Quality Assurance.

**4.13** **ASC** - Antarctic Services Company. The company that manages United States operations at the South Pole station.

## 5.0 Responsibilities

**5.1** The Quality Assurance and Safety Manager for IceCube is responsible for the generation and updating of this document**.**

**5.2** The IceCube Project Director is responsible for ensuring the design, development, manufacturing and deployment of IceCube follows the processes described in this document.

**5.3** The IceCube Level 3 Managers are responsible for ensuring that the processes described in this document are completed appropriately.

## 6.0 Procedures

**6.1 Project Team** – The IceCube Project Team is a collaboration of global partners that have responsibilities for components of the project. The table below lists the collaboration facilities and their main areas of responsibility.

| Institution | Location | Responsibilities |
|---|---|---|
| | **NSF-Funded Institutions** | |
| UW-Madison | Madison, Wisconsin USA | WBS 1.1: Home institution of the Project Manager and Project Office; WBS 1.2; Hot Water Drill System, WBS 1.3.3 pDOM production; WBS 1.6.1.1: data acquisition firmware, WBS 1.3 electronics, WBS 1.4.4 CPT System |
| Michigan State University | East Lansing, Michigan USA | WBS 1.4.4: Communications power timing, WBS: 1.6.3, detector simulation |
| Penn State University | Happy Valley, Pennsylvania USA | WBS: 1.6.1; Data acquisition firmware, WBS: 1.3, electronics |
| University of Alabama | Tuscaloosa, Alabama USA | WBS: 1.5, Calibration coordination; commissioning |
| University of Maryland | College Park, Maryland USA | WBS: 1.6, Data filtering, software, IceCube integration |
| | **All Others (Non-NSF-Funded)** | |
| DESY – Zeuthen, Germany | Zeuthen, Germany | WBS: 1.3.1, mDOM production, data acquisition electronics, WBS: 1.4, cables |
| Universität Münster, Germany | Münster, Germany | WBS: 1.1.4, mDOM mechanical design |
| Tech. Univ. of Munich, Germany | Munich, Germany | WBS: 1.5, Precision Optical Calibration Module (POCAM) |
| Sungkyunkwan University, South Korea | Seoul, South Korea | WBS: 1.5.2.3, Camera system |
| Chiba University, Japan | Chiba, Japan | WBS: 1.3.2, Optical sensors, D-EGGs |
| Michigan State University (in-kind) | East Lansing, Michigan | WBS: 1.3.1, mDOM production |

**6.2 Design & Development** – The project design shall be managed and controlled via a process that ensures the system and subsystem designs meet the requirements of the project, including user needs and scientific objectives.

The design and development process is tailored for the needs of the project and defined in the Systems Engineering Management Plan. The schedule and allocation of resources for IceCube is described in the Project Execution Plan. The design process shall include the following (sections 6.2.1 to 6.2.10):

6.2.1 **Design Input** – The function, performance, physical requirements and interfaces shall be documented, reviewed and approved at the appropriate stages. The documentation and approval shall be completed per the process described in 9000-0004, IceCube Configuration Management Plan. Review of such documents will be via a formal requirements review.

6.2.1.1 **Requirements** – Requirements fully describe the system/subsystem such that if the system/subsystem were implemented only on the basis of the requirements, it would fully meet all the needs of the project. This is the "what" of the project. The requirements documents must fully specify the following:

6.2.1.2 **Specifications** – A specification describes how the design fulfills the stated requirements. Specifications are typically described in Design Documents or Design Specifications (i.e., DOM Main Board Design Specification).

6.2.1.3 **Compliance To Standards** – The requirements shall include or address with what standards or regulations the system or subsystem will comply. Examples of standards and standard organizations are:

- Occupational Safety and Health Administration (OSHA)
- National Electrical Code (NEC)
- National Fire Protection Association (NFPA)
- International Building Code (IBC)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- Institute of Electrical and Electronics Engineers (IEEE)
- Underwriters Laboratory (UL)

6.2.2 **Project Planning** – Planning for the IceCube Upgrade is divided into two tracks, Technical and Project Planning. Technical design activities are defined in the Systems Engineering Management Plan, and include system architecture, interfaces, generation of requirements and testing. Project Planning is described in the Project Execution Plan, and includes schedules, tasks and resource allocation.

The Project Execution Plan (PEP) shall be written and maintained to define the details of the project activities and the names of responsible individuals for major project activities. It shall include:

- Key personnel/resource allocation/responsibilities – Responsible engineer, project manager, and quality assurance representative for each system and subsystem.
- Major task schedules (and relationships of tasks)
- Major milestones
- Schedule for design reviews
- Development of safety, quality and test plans
- Major deliverables
- Configuration management – Individuals authorized to approve documents and changes.

6.2.3 **Design Reviews** – Reviews shall be conducted for the system, subsystem, and major components at the major milestones in the development process.

6.2.3.1 **Requirements Of Design Reviews**

6.2.3.1.1 They are planned in advance, scheduled and made known to facilitate participation. Design Reviews shall be identified in the PEP and on the project schedule, or specified by the Project Manager.

6.2.3.1.2 Design Reviews shall be attended by representatives of all functions concerned with the design and, wherever possible, include individuals not associated with the item being reviewed to provide an independent perspective. The PI, collaborators, and representatives of NSF and RPSC shall be invited as appropriate.

6.2.3.1.3 Design Reviews shall be documented.

- The Level 3 Lead for the topic being reviewed shall ensure the agenda is distributed prior to the review with a review package to participants. This will be sent to the reviewers at least a week before the review.

6.2.3.1.4 Minutes of the review shall identify the:

- Design being reviewed
- Date of review
- Major points of discussion
- Attendance (affiliation and e-mail address, if appropriate)
- Action items – List of action items, responsible parties and scheduled closure date

6.2.3.1.5 Action items shall be subsequently tracked until satisfactorily closed by the responsible Level 3 Lead.

6.2.3.1.6 Design Reviews are independent of project (cost and schedule) reviews. Project reviews are not technical in nature; they are merely "what have we completed" reviews.

6.2.3.2 **Types Of Reviews** – The following Reviews shall be conducted and additional reviews as needed should be held:

- **Preliminary Design Review (PDR)**

  When the initial design concept has been defined and the engineering studies between alternative approaches have been completed, a PDR is held to affirm the design approach before major investment is made in detail design work. The inputs to the review are the requirements and the preliminary design drawings, parts lists, and supporting documents. Requirements are reviewed at this time.

- **Final Design Review (FDR)**

  When the design is complete and before fabrication begins, the FDR is held to affirm the design is complete, correct, and satisfies requirements. In addition, the design is reviewed for manufacturability. The inputs to the FDR are the design documents (drawings, specifications, manufacturing plans, test plans, test procedures, etc.) in a form ready for formal sign-off for release.

- **Design Verification Test Review (DVTR)**

  When the fabrication and assembly is complete or nearly so and before the completed units are subjected to formal qualification or acceptance tests, the PTR is held to review the manufacturing records and the test plans to verify the readiness for test. Inputs to the PTR typically include the as built drawings, manufacturing records, in-process test data, traceability records, and the acceptance/ qualification test plans and procedures.

- **Pre-Production Review (PPR)**

  When a project plans to produce multiples of the same device, a PPR may be conducted instead of a PTR. The purpose of the PPR is to ensure that all items required to produce the devices are available in the quantities needed. These items include: availability of raw materials/components, test hardware/software, assembly/test documents, drawings, production forms, device process qualification complete, production quality processes ready and training complete.

  A PPR may be conducted at the beginning of each yearly production cycle to ensure process consistency between the production sites including assembly/test documents, record keeping, test equipment and materials.

- **Pre-Ship Review (PSR)**

  The PSR is held after the testing is complete or nearly so and before the item is packed for shipment. The review is held to review the test results, failures, non-conformances, repairs, the packing and shipping plans, post-delivery support plans, and all previous review action items to verify all issues are closed and the item is ready to ship.

6.2.4 **Verification and Validation** – Verification/validation plans and procedures shall be developed to ensure that IceCube systems, subsystems and their components have been adequately tested to ensure that the final devices function in compliance with their requirements and intended use. The types of verification and validation activities to be carried out for IceCube are described in the Systems Engineering Management Plan.

6.2.4.1 **Requirements Traceability** – Design traceability indicates that the design can be mapped from the project requirements through test procedures to passed test results. Secondarily, the requirements can be traced to the hazard analysis item that they mitigate (as applicable).

Each requirement (defined in the requirements document) shall be verified through inspection, test or analysis, or a combination of these methods. Each requirement shall be mapped to a verification activity via a verification requirements matrix or similar document. All requirements must be verified.

6.2.4.2 **Test Plans** – Test plans are higher level documents that describe the overall testing strategy for a particular system, subsystem or component, including the types of testing that need to be completed.

6.2.4.3 **Test Procedures** – Test procedures are the actual step-by-step protocols that are run to ensure the device meets its requirements. Test procedures can include inspection, confirmation and testing.

6.2.4.4 **Test Records** – Test records are defined in the test plan, shall be documented on data sheets and should include the following data:

- Identify what is being tested
- Identify the test method (i.e., procedure)
- Who conducted the tests and the date
- Acceptance criteria
- Test results
- Pass/fail status
- QA concurrence that the test has been satisfactorily completed

6.2.5 **Transition To Manufacturing** – The project shall have a mechanism to ensure that the design is accurately translated to manufacturing procedures, processes and documentation. This process is typically completed through a combination of testing the manufacturing processes to ensure they produce devices that meet specifications, manufacturing planning documents, assembly/test procedures, parts lists and training.

6.2.5.1 Where the same device is to be manufactured at multiple sites, design transfer must be the same for each site.

6.2.6 **Parts & Component Traceability** – Traceability for purposes of knowing where individual parts, components, and subsystems are at any given time, even after delivery and deployment, require a configuration identification list to be maintained. This is usually accomplished via a database that lists all critical items (unmaintainable after deployment) in the system and their

current location. Records therefore need to be maintained of the next higher assembly of all items.

6.2.7 **Instructional Materials (Manuals)** - During the development of IceCube, materials shall be developed to describe how the system is to be assembled, used and maintained. These materials may be generated in the form of manuals, guides, drawings, tables or presentations, and can be either hardcopy or electronic. Appropriate training regarding these documents shall be completed.

Examples of instructional materials that should be generated for the IceCube Upgrade are:

- South Pole Assembly & Test Instructions
- Seasonal Startup & Teardown Instructions
- Preventive Maintenance & Service Instructions
- User Instructions For EHWD
- User Instructions For IceCube Detector Array

Note: Manufacturing procedures are described in section 6.4.

## 6.3 Configuration Management

Configuration Management will be instituted on all hardware and software subsystems to ensure that the configuration of all product is traceable from production to its deployed location. Configuration Management shall be used to identify the features and functionality included in a specific version of hardware or software. For example, we may want to trace into which DOM a specific circuit board was installed, and in what string and position that DOM is located. Configuration Management includes controlling device design/documentation and assuring manufacturing records are sufficiently complete and accurate to answer questions such as:

- What modules have a particular manufacturing lot of a particular part?
- Where are they?
- What version of software is loaded on the DOM's in string 2?
- What functionality is in version 1.12 of DOM firmware X?
- When a particular board was tested, what was the performance of a particular parameter under a particular condition?

6.3.1 **Document Control** – Document Control shall be accomplished through processes described in 9000-0005, IceCube Document Control Procedure.

6.3.1.1 **Record Retention** – Records regarding design, manufacturing, deployment, training and corrective/preventive action for the IceCube Upgrade shall be retained for 5 years beyond the service life of IceCube (at a minimum, this is considered to be 15 years; 10 years deployment and data collection + 5 year retention period)

6.3.2 **Change Control (ECN)** – Change Control shall be accomplished through processes described in 9000-0004, IceCube Document Management Process. Changes to project design or manufacturing documentation shall undergo formal review and approval prior to release.

6.3.2.1 Changes shall be approved by the same functions that approved the original document or design.

6.3.2.2 Class 1-design changes shall be approved by (minimum list): Originator, Project Engineer, Project Manager, and Project QA.

6.3.2.3 Class 2 design changes shall be approved by (minimum list): Originator, Project Engineer, Level 3 Manager, and Project QA.

6.3.2.4 Except for the Originator, all approvers may specify a delegate to sign on their behalf.

6.3.3 **Parts Lists** – Parts lists shall be generated and controlled for all manufactured devices. The parts lists shall include all parts, materials and components needed to manufacture that device.

6.3.3.1 Parts list may be at different levels of components depending on the nature of the device. For example, the parts list for a circuit board may include the board itself, resistors, IC's, capacitors, relays, wires, connectors, etc. A parts list for a DOM may include the main board, flasher board, sphere, HV PMT base, μ-metal grid, cables, connectors, etc.

6.3.4 **Software Configuration Management** - A configuration management system is planned to ensure:

- Software releases are identified, controlled and available.
- Changes to identified software releases are controlled.
- Affected groups and individuals are informed of the status and content of software releases.

6.3.5 **Manufacturing Records (assembly/test records)** – Manufacturing records of devices designed by the collaboration shall indicate the configuration of the device being made (note: this requirement does not apply to off-the-shelf items designed outside of the collaboration). Records will typically consist of the data sheets (data sheets are defined in the test procedure) as filled out for the specific item being tested. The information shall include but not be limited to:

- Identity of the final device (name, model #, serial #)
- Identity of critical components (model #, serial #, batch #)
- Identity of software/firmware versions installed on the device
- Parts list with parts traceability information (mfg. lot, screening lot)
- Identity and revision of assembly/test document(s) used
- Identity of specific test equipment used, including serial # and calibration date, as appropriate
- Identity and revision of test software used, as appropriate
- Actual parameter measured (shown with test limits)
- All environmental test parameters (temperature, pressure, etc.)

- Signature of person(s) conducting assembly/test tasks and date
- Results of tests and pass/fail status of tests
- Final device approval/rejection
- Signature of independent, authorizing reviewer (see 6.4.6.1)

6.3.6 **Purchasing** – Each facility shall have a purchasing process that ensures all product received meets its specifications.

6.3.6.1 **Selection Of Vendors**

6.3.6.1.1 The evaluation and selection of vendors shall be according to defined criteria and shall be documented. These criteria shall be based in part on the vendor's ability to meet product specifications, previous experience, ability to meet the project schedule and the capability of their quality system.

6.3.6.1.2 Vendors should be reviewed yearly by the purchasing institution to ensure they are still suitable to supply product for IceCube. These reviews can be accomplished through a combination of:

- Review of inspection records of product received.
- Review of vendor's quality system (ISO) certification.
- Quality surveys.
- On-site quality audits.
- Other suitable means of determining the vendor is producing product suitable for IceCube.

6.3.6.2 **Approved Vendors** – Each purchasing institution shall maintain records of approved vendors for use by the IceCube collaboration team in selecting appropriate vendors.

6.3.6.3 **Common Product** – In the circumstances where the same product is used at multiple facilities, the Project Office shall determine:

- Which facility(ies) is responsible for vendor selection
- Whether the product should be purchased through one facility
- What facility is responsible for conducting the vendor review.

## 6.4 Manufacturing & Process Control

6.4.1 **Process Control** – Procedures shall be developed, documented, reviewed and verified to ensure that they produce a device that meets the project requirements and specifications.

6.4.1.1 **Documented Processes** – All processes and procedures for the assembly, test and burn-in of manufactured product shall be documented through the process described in 9000-0004, IceCube Configuration Management Plan.

6.4.1.1.1 These processes and procedures shall be written and verified to ensure they produce a device that meets specification; they shall also indicate the data that needs to be written on the manufacturing records.

6.4.1.1.2 All manufacturing facilities shall follow the same assembly, test and burn-in procedures to manufacture devices. Changes to these procedures can only be made through the formal change control process described below.

6.4.1.1.3 These procedures shall describe the test equipment that is required to successfully complete the task. Where multiple devices may be used to conduct a test, "or equivalent" may be used (i.e., Fluke 2112 DVM or equivalent).

6.4.1.1.4 The procedures shall note all applicable safety concerns.

6.4.1.1.5 The procedures shall note all applicable assembly precautions (i.e., ensure that you clean all cement from the connectors or wear ESD wrist-straps when installing boards).

6.4.1.1.6 The manufacturing staffs shall ensure that they are using the prescribed documentation.

6.4.1.2 **Production Processes** – Processes must be in place at the manufacturing facilities to ensure that the devices are manufactured to meet specifications. These processes shall ensure that:

- Correct assembly/test documentation is used, completed, reviewed and maintained (see 6.4.2, 6.4.3)
- Materials can be positively identified (through use of material bins or similar)

- Non-conforming material is identified and segregated from conforming material (see 6.4.7)
- The traveler (the copy of the manufacturing record accompanying the device) must be complete, up to date, and correct. Therefore, the assembler or inspector can identify what stage the device is in the assembly/test process (see 6.4.3)
- Control parameters are identified and recorded (temperature, pressure, humidity) (see 6.4.1.5)
- Specific test equipment is identified (see 6.4.2.5)

6.4.1.3 **Process Validation** – Any processes used in the manufacturing of devices that cannot be directly verified shall be validated to ensure that they produce the correct outcomes. Examples of process validation are:

- Control software functions properly
- Test software produces correct results
- Insulating gel sets to the proper consistency and density
- Evacuation process is capable of creating the vacuum required for the device

6.4.1.3.1 All validations shall be documented with the activity conducted, outcome, date of activity and individual approving the outcome.

6.4.1.3.2 Validated processes shall be monitored as appropriate for the activity in place.

6.4.1.3.3 Changes to validated processes shall require revalidation or justification why revalidation is not required.

6.4.1.4 **Production & Process Changes** – Production and process changes shall be completed through the Engineering Change Process described in 6.3.2, Change Control.

6.4.1.4.1 Changes shall be verified (and validated) as appropriate. Verification and validation shall be documented, and that documentation shall be attached to or referenced in the Engineering Change Notice.

6.4.1.4.2 Changes to product software shall be implemented through the Engineering Change Process.

6.4.1.4.3 Changes to test equipment and software shall be implemented through the Engineering Change Process.

6.4.1.5 **Facility & Environmental Control** – Where facility or environmental conditions may affect the quality of product, processes shall be instituted to ensure these conditions are controlled to the extent necessary to ensure product quality.

6.4.1.5.1 Controls shall be monitored periodically to ensure they are functioning appropriately.

6.4.1.5.2 These activities shall be documented.

6.4.1.6 **Personnel** – Manufacturing management shall ensure that all manufacturing personnel are adequately trained for the tasks they are to complete. This training shall include as appropriate:

6.4.1.6.1 Proper use of test equipment.

6.4.1.6.2 Assembly and test procedures, including maintaining the proper records.

6.4.1.6.3 Other manufacturing procedures, such as ESD control, wire crimping or rework.

6.4.1.6.4 Applicable quality processes, such as receiving inspection, non-conforming materials and process changes.

6.4.1.6.5 Facility requirements to ensure a safe, effective workplace, which can include cleanliness, chemical safety, and clean room/environmental chambers requirements.

6.4.2 **Assembly/Test Documents** – Documents shall be generated that give a detailed description of how the device is be assembled and tested to ensure that the final device meets its specifications.

6.4.2.1 Assembly/test documents are controlled documents.

6.4.2.2 Documents shall include, as appropriate, parts lists, schematics, assembly drawings and assembly/test instructions or references to other documents.

Note: Internal documents should not reference the revision level of other internal documents. The most current version is assumed unless otherwise stated. References to external documents (outside the collaboration) should reference the revision in affect or date (i.e., the memorandum of understanding that is effective on 1/2/03).

6.4.2.3 The assembly/test documents shall include any special processes or equipment needed to ensure the device meets its specifications.

6.4.2.4 Tests shall be traceable to specifications.

6.4.2.5 When specific test equipment is required to complete a task, the documents shall specify the type of equipment that is needed.

6.4.2.6 Assembly/test document shall specify the acceptance criteria for tests and critical assembly/test parameters (i.e., temperature and humidity).

6.4.2.7 The documents shall specify any labeling that needs to be placed on or with the device.

6.4.3 **Assembly/Test Records** – Records shall be maintained for the assembly/test of each device made. These records include manufacturing records, as-built parts lists, configuration identification lists, and traceability documentation.

6.4.3.1 **Assembly/Test Forms** shall be generated to identify the data that needs to be documented and the acceptance criteria for each test or critical parameter.

6.4.3.1.1 The data that needs to be documented in an assembly/test form is identified in 6.3.4, Manufacturing Records.

6.4.3.2 **Travelers** should accompany a particular device as it is being made. The purpose of a traveler is to note the status of the device in the manufacturing process, and describe issues or comments that may not be documented elsewhere. The traveler must clearly note the compliance status of the item: any failure or non-conformance must be clearly noted on the traveler and subsequent action (rework, retest, MRB action) must be included. Travelers may be incorporated into the assembly/test form.

6.4.4 **Identification & Physical Traceability**

6.4.4.1 Manufacturing operations shall establish and maintain procedures for identifying material, software, firmware and product during all stages of assembly, test, shipping and installation. These procedures should be the same for all manufacturing facilities.

6.4.4.2 Physical traceability (for the IceCube Upgrade) indicates that lots, revisions or serial numbers of particular components, software and firmware can be traced to the optical module in which they were installed and the position of that optical module in a particular string can be identified.

6.4.4.2.1 Design shall identify those components (i.e., circuit boards) that need to be serialized for traceability purposes.

6.4.4.2.2 Manufacturing shall ensure that those units are appropriately serialized and those serial numbers are appropriately recorded for traceability purposes.

6.4.4.2.3 Software and firmware shall be identified by their revision level.

6.4.5 **Calibration Of Test Equipment** – Each manufacturer shall have a process to ensure that equipment used in the inspection, testing and measuring of materials and product is:

- Suitable for its intended purpose,
- Produces valid results, and,
- Routinely calibrated.

6.4.5.1 This applies to all mechanical (i.e., calipers, gauges), electronic (i.e., DVM) and automated (i.e., test software) test equipment used in the manufacturing of IceCube devices.

6.4.5.2 Calibration shall be traceable to applicable national or international standards.

6.4.5.3 The calibration of a specific piece of test equipment shall be verified by comparison to a known article (i.e., gold standard) prior to each production shift in which it is used.

6.4.5.3.1 If the device does not pass this verification, it shall be removed from service, and tagged "for reference use only" or similar.

6.4.5.4 The period of calibration for mechanical and electronic test equipment shall be determined by the sensitivity of the tests being run and the nature of the test equipment. Typical calibration cycles are 6 months or 1 year for electronic equipment.

6.4.5.5 For automated test equipment not subject to routine calibration, the test equipment shall be initially tested to ensure that it produces the correct outcome or results (see section 6.4.1.3).

6.4.5.6 Records of calibrations shall be retained. Where test equipment was calibrated by a calibration facility, a certificate is appropriate.

6.4.5.7 Each calibrated test device shall bear a label identifying the equipment, stating the date of last calibration, the person performing that calibration and the date of the next calibration.

6.4.5.8 Test devices that do not pass calibration or do not have a current calibration shall not be used for measuring or testing purposes. These devices shall be:

- Used only for reference and shall be labeled "For Reference Use Only" (or similar wording), or,
- Removed from use and segregated from like test equipment to ensure they are not mistakenly used for testing and measuring purposes.

6.4.6 **Device Acceptance & Acceptance Status** – Upon completion of the assembly/test procedures, each manufacturer shall define and maintain a process to ensure that:

- All appropriate assembly/test procedures have been completed
- Test results meet the acceptance criteria (expected results) specified in the manufacturing documentation
- Pass/fail status of the device is explicitly noted in the records
- All applicable device, component and test equipment has been identified as specified in the manufacturing records
- The paperwork has appropriate signatures, initials and dates
- Ancillary paperwork is completed, such as deviations or non-conforming material reports
- Device identification has been applied to the device.

6.4.6.1 ***Final review and acceptance of the device shall be completed by someone independent of the manufacturing tasks, who has responsibility for the quality of the end-product device.***

6.4.7 **Non-Conforming Material** – The manufacturer shall have a system of segregating and identifying non-conforming material.

6.4.7.1 Non-conforming material shall not be used for production purposes unless the non-conforming issue has been remedied or a production deviation has been documented and approved.

6.4.7.2 Non-conforming material can be generated at any point during the manufacturing process, from receiving inspection to assembly/test to final packaging.

6.4.7.3 Non-conforming material shall be physically segregated from conforming material and tagged as non-conforming. Tagging of non-conforming material shall include:

6.4.7.3.1 Identification of the material.

6.4.7.3.2 Nature of the non-conformance.

6.4.7.3.3 Date determined non-conformant.

6.4.7.3.4 Person making determination.

6.4.7.3.5 Proposed dispensation of non-conforming material (scrap, rework, and return to vendor).

6.4.7.4 Non-conforming material shall be processed as follows:

6.4.7.4.1 Scrap.

6.4.7.4.2 Use as is.

6.4.7.4.3 Rework to bring item into full compliance with all requirements.

6.4.7.4.4 Return to vendor for rework or replacement.

6.4.7.4.5 Request customer approval

6.4.7.5 Non-conforming material shall be inaccessible to production personnel.

6.4.7.6 Each manufacturing site shall have a Materials Review Board (MRB) that reviews the dispensation of non-conforming materials at their site.

6.4.7.6.1 The MRB shall include representatives of engineering, management, and quality (and may include others as needed to make a proper determination).

6.4.7.6.2 Each facility MRB shall submit a report of its activities to Project Office QA for review weekly or as frequently as the MRB meets.

6.4.7.6.3 Levels of decision

6.4.7.6.3.1 Issues that would result in a Class 1 change (see 6.3.2 and 9000-0004, IceCube Configuration Management Process) shall be cleared through the Project Office prior to implementation.

6.4.7.6.3.2 Each facility shall have the authority to disposition non-conforming material that meets the definition of a Class 2 issue.

6.4.8 **Receiving Inspection** – Each manufacturing facility shall maintain procedures for accepting incoming product.

6.4.8.1 These procedures do not need to be the same between production facilities; however, the procedures must be able to verify that:

- The correct material and amount has been received.
- The material meets the quality acceptance criteria previously defined by the project.

6.4.8.2 If certificates of compliance (quality) are received with product, they shall be reviewed (for compliance to product specifications), approved and maintained.

6.4.8.3 Acceptance or rejection of product must be documented and maintained.

6.4.8.4 Material rejected at receiving inspection is considered non-conforming and dispositioned appropriately.

6.4.9 **Handling & Storage** – The handling and storage of materials, components and finished devices shall be defined by IceCube Systems Engineering during the development process. The production facilities are responsible for ensuring that the handling and storage requirements are met for the devices.

6.4.9.1 Where special handling or packing is required, a handling and packing instruction should be generated.

6.4.9.2 Special shipping or storage requirements shall be noted on the outside of the shipping containers.

6.4.9.2.1 The identification of the packed devices should be noted on the outside of the shipping containers.

6.4.9.3 In-process parts (materials and components) shall be handled and stored in a manner appropriate for the needs of the part.

6.4.9.3.1 In-process parts shall not be stored or handled in a manner that results in their deterioration.

6.4.9.3.2 Each in-process part shall be stored in a manner where it is readily identifiable and not confused with other parts.

6.4.9.3.3 Materials are not to be used beyond their stated useful lives.

### 6.4.10 **Internal Quality Audits**

6.4.10.1 In order to effectively gauge the Project Compliance Level with this plan, Internal Audits may be scheduled as necessary at the various sites that constitute the IceCube Upgrade Collaboration at the discretion of the Quality & Safety Manager.

**6.5 Corrective & Preventive Action (CAPA)** – The IceCube Upgrade Project shall have a mechanism to identify, evaluate and resolve quality issues that occur during the course of manufacturing, use and servicing. Corrective actions are those intended to correct conditions that have already occurred. Preventive action is intended to prevent future conditions.

6.5.1 **Ownership** – Ownership for the CAPA process is with the QA Manager at Project Office. Individual facilities may have their own CAPA or issue resolution process; however, the local facility processes must forward data to the Project Office to ensure that we are addressing the quality issues that are important to the project.

6.5.2 **Sources Of Reports** – The sources of CAPA issue reports may come from multiple sources and are noted in the table below.

| Report Source | Examples |
|---|---|
| Manufacturing | Incoming receiving failure<br>Non-conforming material reports<br>Assembly/test failures |
| Field Assembly | Assembly instructions incorrect<br>Missing components<br>DOM's broken upon arrival at Pole |
| Field Service/PM | Motor, drive, heater, pump failures<br>Warmup time excessively long prior to seasonal system startup |
| Use | Software crashes<br>False e-stop triggers<br>System sensors inaccurate<br>Procedural inefficiencies/inconsistencies<br>Use instructions incorrect or missing information |
| Safety | Fire hazards<br>Consumption of alcohol<br>Shock hazards<br>Assembler caught jacket in level wind of hose reel |

6.5.3 **Project Issue Reports** – Reports may be submitted as forms (i.e., non-conforming material reports), e-mail or verbally. Regardless of how they were communicated, all reports should contain the following data:

- Date issue discovered
- Name of reporter
- Site where issue was discovered
- Description of issue (including steps to recreate)
- How was issue resolved at site

- Was anyone hurt (if yes, describe nature of injury and treatment)

6.5.4 **Defect Tracking** – CAPA reports should be logged into the project defect tracking system or similar database for tracking purposes.

## 6.6 Training

IceCube project management shall assure that all employees have been properly trained to complete their assigned tasks in a safe, effective manner. All training shall be documented and records maintained in the Project Office (collaborators should send copies of training records to Project Office). Training materials may include:

- Document being trained on (i.e., user instructions, assembly procedures).
- Training documents (i.e., PowerPoint presentations) generated specifically for the training.
- Ancillary documents such as articles, white papers, lecture materials or abstracts.

6.6.1 **Safety** – All employees involved in potentially hazardous tasks shall receive and successfully complete training regarding safety for the tasks they plan to conduct. This includes potential safety risk, the potential hazard and safety measures taken to reduce the risk. Safety training applies to all aspects of IceCube, including manufacturing, development/design (i.e., testing) and deployment. Safety Training is covered in 9000-0002, IceCube Safety Manual.

6.6.2 **Process** – IceCube employees shall be trained on the quality processes that affect their job responsibilities. Such processes include development/design, manufacturing and document control.

6.6.3 **Assembly/Test** – Assembly instructions can be split into two groups: manufacturing and field.

6.6.3.1 **Manufacturing Training** – This applies to the assembly and test of the IceCube system and its associated components. As appropriate, staff completing these tasks shall be trained on proper assembly/test procedures, special assembly processes, equipment needed and material/components needed.

6.6.3.2 **Field Training** – This training applies to drill camp buildup at the South Pole, and includes assembly of main components (i.e., hose reel and tower), camp layout, interconnection of hoses/cables and drill testing.

6.6.4 **Service & Preventive Maintenance** - This training applies to the ongoing servicing activities at the South Pole after year one, and includes camp layout, camp warmup/startup, camp breakdown, ongoing maintenance of equipment and servicing of failing/failed equipment.

6.6.5 **Use** – This training includes how the system is to be operated, such as software, attaching drill heads, banding, moving equipment to the next hole location and DOM deployment.

6.6.5.1 Issue reporting is included in this category as well. Safety event reporting is included 9000-0002, IceCube Safety Manual. Issues of a non-safety nature also should be reported to the Project Office for review and remediation (see 6.5, CAPA).

## 7.0 Documents and Records

Over the life of the project, documents and records shall be maintained and delivered to the Project Office as evidence that the product was manufactured in compliance with the specifications and the processes described above have been followed.

The following documents and records shall be maintained per the retention period stated in section 6.3.1.1.

- Design requirements and specifications
- Project Execution Plan
- Design reviews – The following records of reviews shall be kept: the review materials, the agenda, the minutes, and a record of the closure of each action item.
- Test plans, procedures and results
- Plans – Quality, Safety and Systems Engineering
- Hazard analyses
- Engineering Change Notices
- Device specifications, including drawings, schematics, parts lists
- Manufacturing assembly/test procedures and results, travelers and manufacturing process documents, such as non-conforming material reports and incoming receiving forms
- Process validation results
- Calibration results
- CAPA reports
- User, Service and Preventive Maintenance Manuals
- Training forms

- ***Collect Signatures*** has completed on IceCube Upgrade Quality Plan.
- Collect Signatures on IceCube Upgrade Quality Plan has successfully completed. All participants have completed their tasks.
-
- Collect Signatures started by Mike Zernick on 3/16/2020 12:16 PM
  Comment:

  Signed by FARSHID FEYZI on 3/16/2020 1:14 PM
  Comment:

  Signed by Mike Zernick on 3/16/2020 1:29 PM