# Summary of electronics reliability studies

## KM3NeT_ELEC_2016_003-Electronics_Reliability_Summary

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**IFIC**

## Abstract

Summary of FIDES reliability analysis of KM3NeT electronics boards

## Recipients

The KM3NeT Collaboration

## Document Status

| Revision | Date | Comment | Reviewed by | Approved by |
|---|---|---|---|---|
| 3 | 11/06/2019 | Results updated | S. Colonges | |

## Revision History

| Revision | Date | Description |
|---|---|---|
| 3 | 11/06/2019 | Third version |
| 2 | 26/04/2016 | Second version (added remarks and conclusion) |
| 1 | 20/04/2016 | First version |
| Draft | 18/04/2016 | First draft |

### 1.1 Table of Contents

# 1. Documentation

## 1.1. Abbreviations

| Abbreviation | Description |
|---|---|
| DU | Detection Unit |
| DOM | Digital Optical Module |
| FIDES | (Latin: Trust) It is a guide allowing estimated reliability calculation for electronic c omponents and systems |
| FIT | Failure in Time |
| CLB | Central Logic Board |
| PB | Power Board |
| FMC | FMC connector expansion board for the DU Base |
| BPS | Base Power Supply board |

## 1.2. Reference Documents

| Abbreviation | Title | Reference |
|---|---|---|
| RD1 | KM3NeT TDR | KM3NeT_DS_TDR |
| RD2 | KM3NeT CRD | KM3NeT_DS_CDR |
| RD3 | | KM3NeT_ELEC_2015_001-REP_PBRelReport_V6 |
| RD4 | | KM3NeT_ELEC_2015_002-REP_CLBRelReport_V4 |
| RD5 | | KM3NeT_ELEC_2015_003-ELEC_BaseRelReportV3 |
| RD6 | | KM3NeT_ELEC_2015_004-REP_OCTOPUSRelReport_V4 |
| RD7 | | KM3NeT_ELEC_2015_005-REP_FMCRELREPORT |
| RD8 | | KM3NeT_ELEC_2015_006-REP_BPSRelReport |
| RD9 | | KM3NeT_REL_2015_007-REP_PS_12V_ICL-R1RelReport |
| RD10 | | KM3NeT_ELEC_2015_008-REP_PS12VR4RelReport |
| RD11 | | KM3NeT_REL_2015_009-REP_OMsupplyNIKHEFRelRepo rt |
| RD12 | Risk management report | KM3NeT Risk KM3NeT_DET_2014_003-Risk_Managemen t_Report.pdf |
| RD13 | | KM3NeT_QA_2014_016_Manufacturing_Audit_RoadMap |
| RD14 | KM3NET Overall RAMS an alysis | KM3NET_ELEC_2018_001_RAMS_Overall |

## 2. Introduction

In this document a summary is presented of the reliability studies performed on the KM3NeT electronics and power boards.
All such analyses have been performed using FIDES 2009 reliability handbook, comparing manufacturer data to FIDES evaluation when available.
Using the methodology FIDES, FIDES expert tool and Fides 2009 Excel template tool, it is possible to estimate the boards FIT (amount of failures per 109 hours).
Reliability evaluation is performed using FIDES Excel tools. The Fides guide is used as a reference in order to fill the FIDES excel table for the analysis. The FIDES is a guide structured in two main parts:
• A reliability prediction guide,
• A reliability process control and audit guide.

Excel tools help to evaluate the failure rate for boards, components and systems. These tools are built with the models and parameters presented in the FIDES guide.
To perform the analysis, we use FIDES expert tool 2009 version in order to use the latest prediction models.
The analysis has been performed for each component reference, considering the worst case when the conditions are not perfectly known. When we have multiple components for a single component reference, the worst-case condition (i.e., component with the higher stress) has been considered.

***The goal of the RAMS study is:***

- List the reliability related requirements
- List functional blocks and dependencies
- Evaluate failure rate probabilities
- Analyse failure modes, effects and criticality
- Identify weakness point in term of criticality
- Define reliability improvements in terms of design and processes
- Define test strategy and youth failure procedure elimination
- Identify Failure detection identification and recovery and maintenance strategy

Then this report will be spread into 7 sections:

1) Reliability requirements and life profile

2) Contributing factors

3) Product functional description

4) Products, functions and failure rate analysis

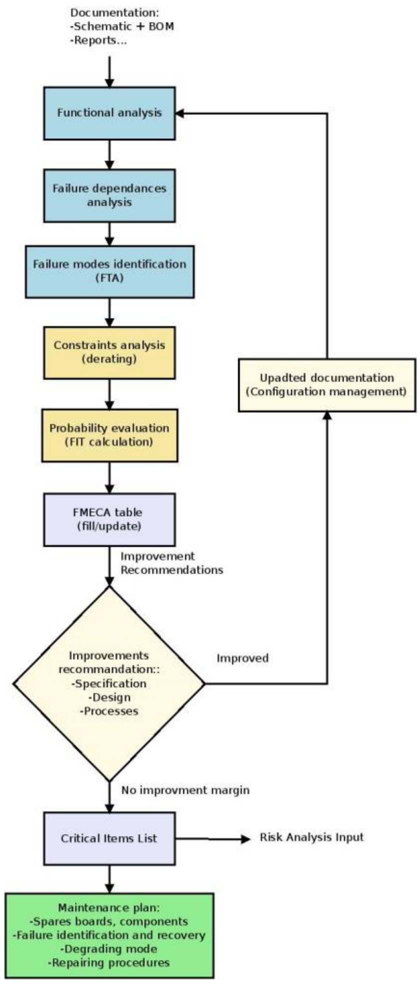
5) Failure modes and weakness points

6) Reliability improvements recommendations

7) Maintenance and failure detection, identification and recovery strategy

A short FIDES presentation is given in annex

**Reliability analysis process:**




## 3. Reliability requirements and life profile

**Lifetime :** 15 years for ARCA – 10 years for ORCA

**Environment :** 2500 meter deep for ORCA (250 bars pressure) / 3500 meter deep ARCA (350 bars pressure)

**2 environment are considered:**

- **Soft:** consider a good cooling (KM3NET_17°C life profile)
- **Warm:** cooling conditions not optimal is the case (KM3NET_17°C life profile)

**Soft LIFE PROFILE**

**Standard life profile**

| | | | Temperature | Temperature cycling | | | |
|---|---|---|---|---|---|---|---|
| Phase name | On / Off | Calendar time (hours) | Ambient temperature (°C) | Δt (°C) | Cycle duration (hours) | Number of cycles (/phase) | Maximum temperature during cycling (°C) |
| ON | ON | 8 759 h | 17,00 °C | 0,00 °C | 8 759 h | 1 | 17,00 °C |
| OFF | OFF | 1 h | 13,00 °C | 0,00 °C | 1 h | 1 | 13,00 °C |

**Warm LIFE PROFILE**

**Standard life profile**

| | | | Temperature | Temperature cycling | | | |
|---|---|---|---|---|---|---|---|
| Phase name | On / Off | Calendar time (hours) | Ambient temperature (°C) | Δt (°C) | Cycle duration (hours) | Number of cycles (/phase) | Maximum temperature during cycling (°C) |
| ON | ON | 8 759 h | 25,00 °C | 0,00 °C | 8 759 h | 1 | 25,00 °C |
| OFF | OFF | 1 h | 13,00 °C | 0,00 °C | 1 h | 1 | 13,00 °C |

We consider a really low vibration level, a good hermeticity and a humidity from 30 to 60% (the calculation is performed with 50%)

# 4. Contributing factors

See RD14

In the Fides method, the process impact is a multiplicating factor.

3 audits have been performed for this study:
- The application impact (Pi Application)
- Ruggedizing impact (Pi ruggedizing)
- Process impact (Pi process)

## 4.1. Pi Application

Different criteria are used to evaluate the severity of a usage phase in terms of exposure to overstresses. There are three levels per criterion. Evaluation of these levels provides a means of calculating the Пapplication parameter. The complete method is described in detail in the calculation sheets.

| Item | Description | On phase level | Off phase level |
|---|---|---|---|
| User type in the phase considered | Represents the capability to respect procedures, facing operational constraints. | 0: quality constraints (industrial) | 0: quality constraints (industrial) |
| User qualification level in the phase considered | Represents the level of control of the user or the worker regarding an operational context | 0: Highly qualified | 0: Highly qualified |
| System mobility | Represents contingencies related to possibilities of the system being moved | 0: Few contingencies (fixed or stable environment) | 0: Few contingencies (fixed or stable environment) |
| Product manipulation | Represents the possibility of false manipulations, shocks, drops, etc . | 0: Not manipulated | 0: Not manipulated |

| **Item** | **Description** | **On phase level** | **Off phase level** |
|---|---|---|---|
| Type of electrical network for the system | Represents the level of electrical disturbance expected on power supplies, signals and electrical lines: power on, switching, power supply, connection/disconnection | 1: Slightly disturbed network | 0: Undisturbed network (dedicated regulated power supply) |
| Product exposure to human activity | Represents exposure to contingencies related to human activity: shock, change in final use, etc. | 0: Uninhabitable zone | 0: Uninhabitable zone |
| Product exposure to machine disturbances | Represents contingencies related to operation of machines, engines, actuators: shock, overheating, electrical disturbances, pollutants, etc. | 1: Indirect exposure (product in compartment) | 1: Indirect exposure (product in compartment) |
| Product exposure to the weather | Represents exposure to rain, hail, frost, sandstorm, lightning, dust | 0: Null (home) | 0: Null (home) |

## 4.2. Pi ruggedizing

This factor allows evaluating the impact of applied recommendation in order to harden the product during the design and improve the reliability.

| **Detailled Π ruggedising** | | |
|---|---|---|
| **Recommendation** | **Weight** | **Level** |
| Check that environmental specifications are complete. | 4 | N3 - Recommendation is almost fully applied |
| Provide training and manage operation and maintenance for implementation and maintenance of the product | 7 | N3 - Recommendation is almost fully applied |
| Check that procedures specific to the product and rules specific to businesses are respected by an appropriate monitoring system | 7 | N3 - Recommendation is almost fully applied |
| Design dependable electrical protection devices | 4 | N3 - Recommendation is almost fully applied |
| Study and handle risks of the product under test being deteriorated by failures of its test or maintenance means. | 4 | N3 - Recommendation is almost fully applied |
| Identify and use appropriate prevention means of preventing reasonably predictable aggressions (related to the weather) | 4 | N3 - Recommendation is almost fully applied |
| Use appropriate prevention means to identify and handle reasonably predictable abnormal uses weather | 4 | N3 - Recommendation is almost fully applied |
| Include production, storage and maintenance environments in the product environment specifications | 4 | N3 - Recommendation is almost fully applied |
| Justify that environment specifications are respected | 4 | N3 - Recommendation is almost fully applied |
| Carry out a product improvement process (for example highly accelerated stress tests) so as to limit the product sensitivity to environmental constraints (disturbances, environments, overstress) | 7 | N3 - Recommendation is almost fully applied |
| Perform an analysis of failure cases that could result in failure propagation. | 4 | N3 - Recommendation is almost fully applied |
| Carry out a process analysis of implementation and maintenance operations | 4 | N3 - Recommendation is almost fully applied |
| Carry out a review of maintenance operations done by the final user and deal with his recommendations | 4 | N3 - Recommendation is almost fully applied |

| Detailled Π ruggedising | | |
|---|---|---|
| Write complete procedures for all product implementation and maintenance operations | 7 | N3 - Recommendation is almost fully applied |
| Respect a standard dealing with conducted and radiated electromagnetic disturbances. This is equally applicable to the product and the system into which it is integrated | 3 | N3 - Recommendation is almost fully applied |
| Respect a standard dealing with power supplies (standard that defines possible disturbances and possible EN2282 type variations). The standard must be respected both for electricity generation and for electricity consumption | 4 | N3 - Recommendation is almost fully applied |

### 4.3. Pi Process

The Π Process factor represents the quality and technical control over reliability in the product life cycle.

The evaluation method is based on the level of application of recommendations that apply to the entire life cycle. The product life cycle is broken down as follows with the specific impact of each phase in % on the reliability:

| PHASE | Phase contribution % |
|---|---|
| Specification | 8 |
| Design | 16 |
| Manufacturing of board or subassembly | 20 |
| Integration into equipment | 10 |
| Integration into the system | 10 |
| Operation and maintenance | 18 |
| Support Activities | 18 |
| Total: | 100 |

The variation range of the $\Pi_{Process}$ factor is from 1 (for the best process) to 8 (for the worst process). If $\Pi_{Process}$ is not evaluated, a default value of 4.0 is suggested. The use of the default value can reduce the precision of the final results.

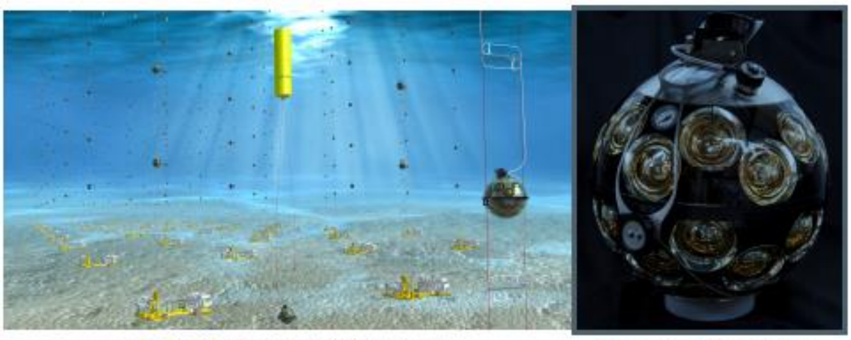
A process factor audit has been performed:

Pi Process result: 2

(see RD14, Process factor sheet)

# 5. Functional analysis:

ORCA will be a network of 115 Detection Unit line.
ARCA will be a network of 2 building blocks with 115 detection unit line each.
A detection unit is a line of 18 digital optical modules



(a) KM3NeT detector, artist impression. (b) Digital Optical Module.

**Figure 1: KM3NET artist view and DOM picture**

## 5.1. Shore station:

The shore station host the power station, and the data acquisition and control system.

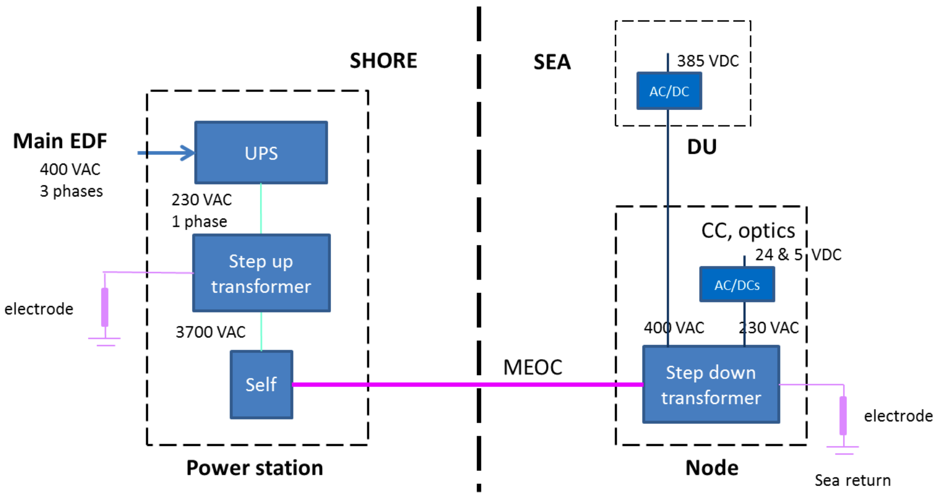



**Figure 2: Power feed**

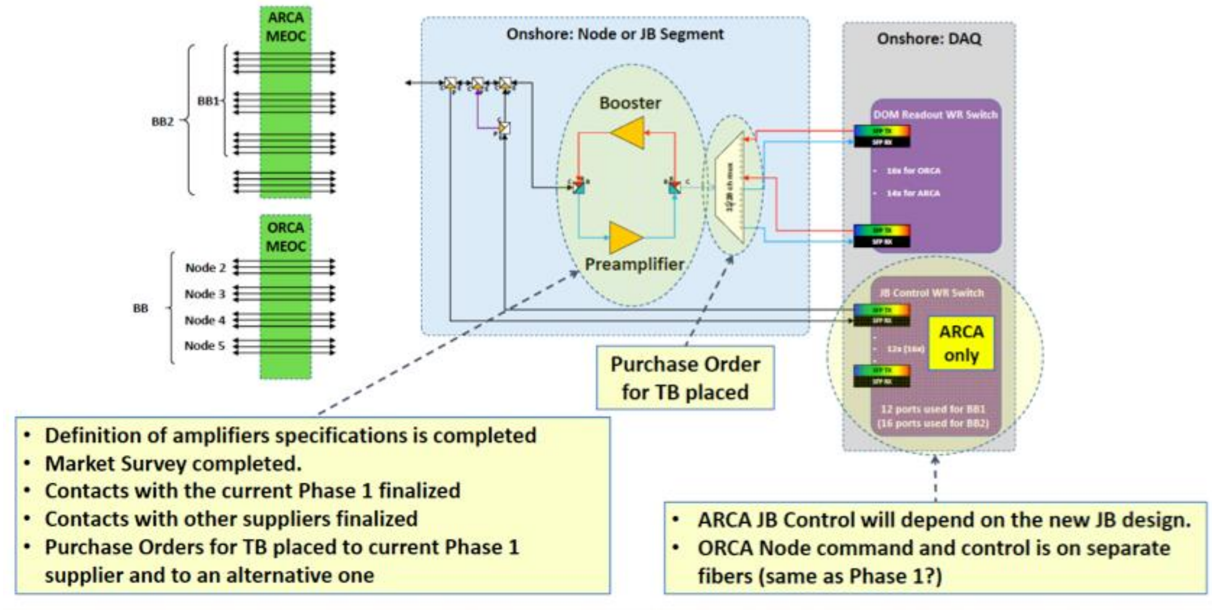



Figure 3: ORCA Onshore optical network

## 5.2. ORCA (French site) :

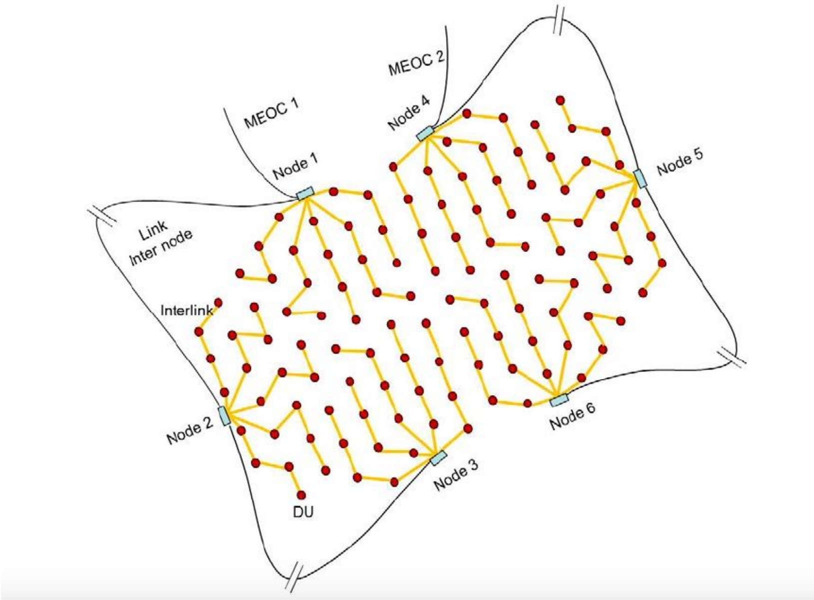



Figure 4: ORCA network

** Red point= Detection Units*

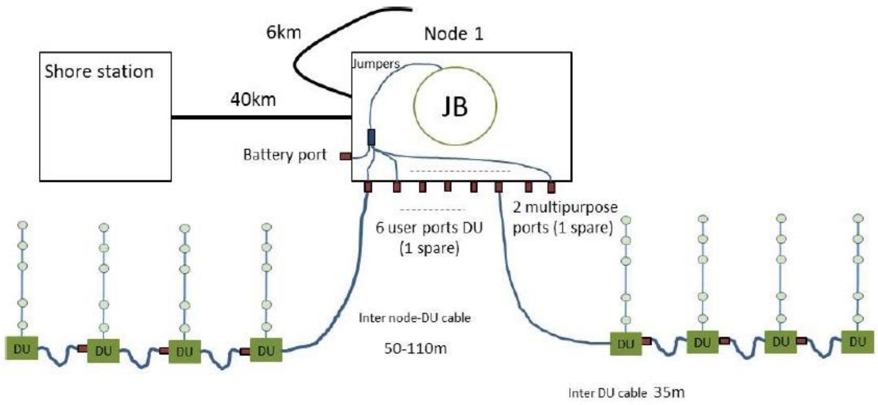



Figure 5: ORCA node principle

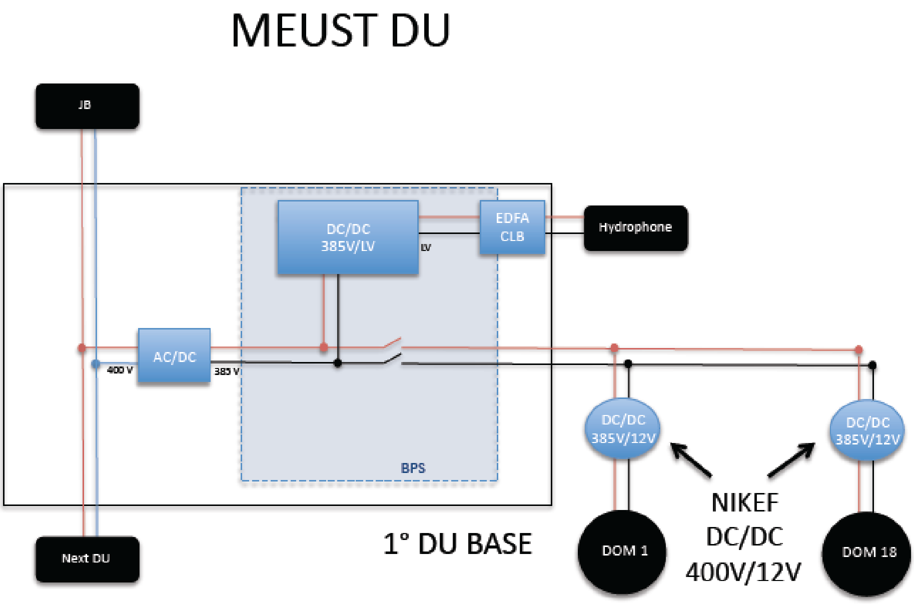



Figure 6: Detection Unit schematic

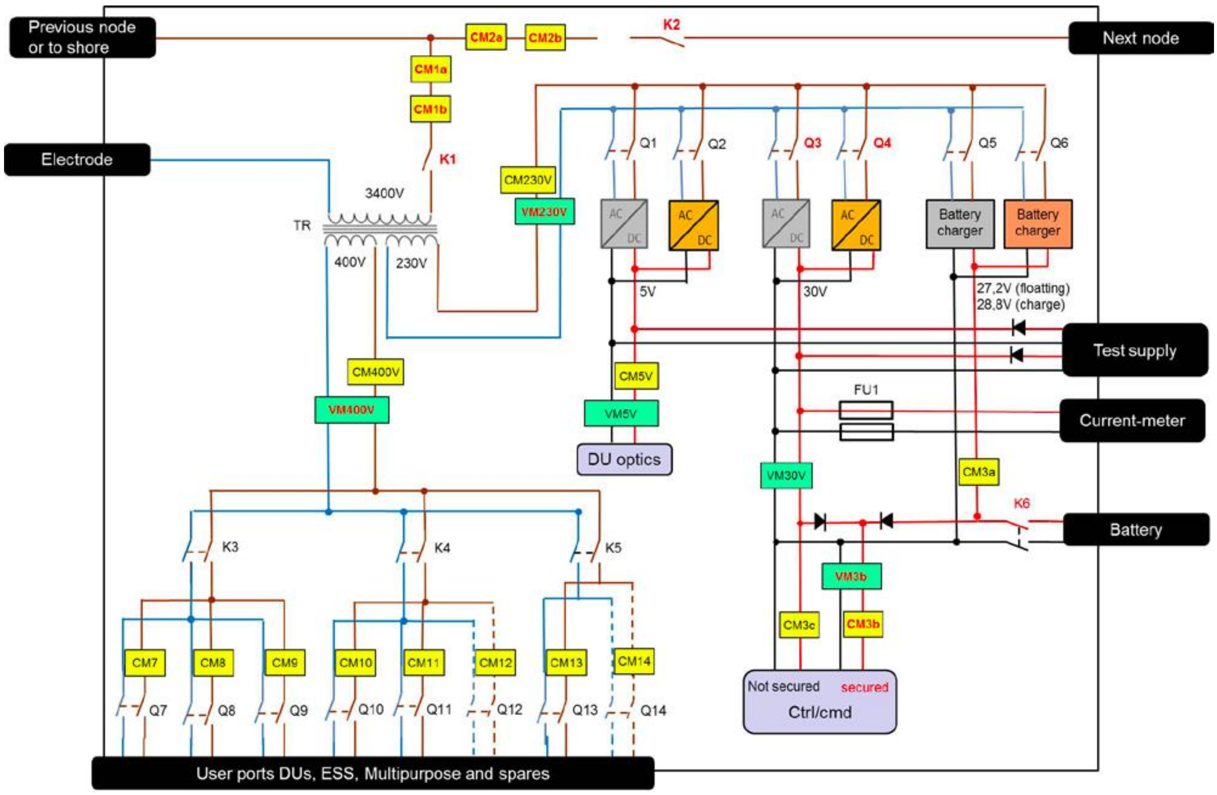



**Figure 7: ORCA node electrical distribution scheme**

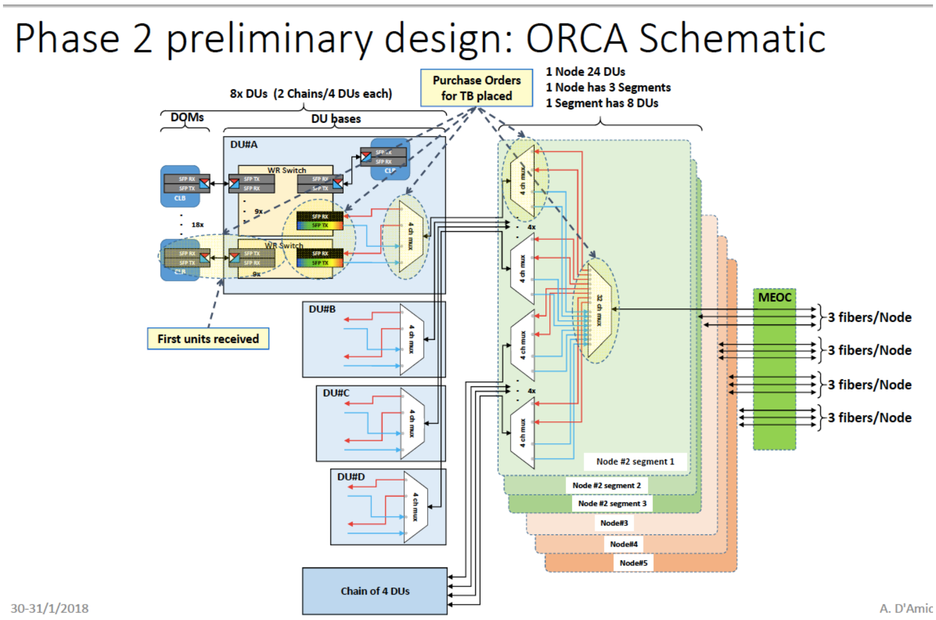



Figure 8: ORCA optical network

### 5.3. ARCA (Italian site):

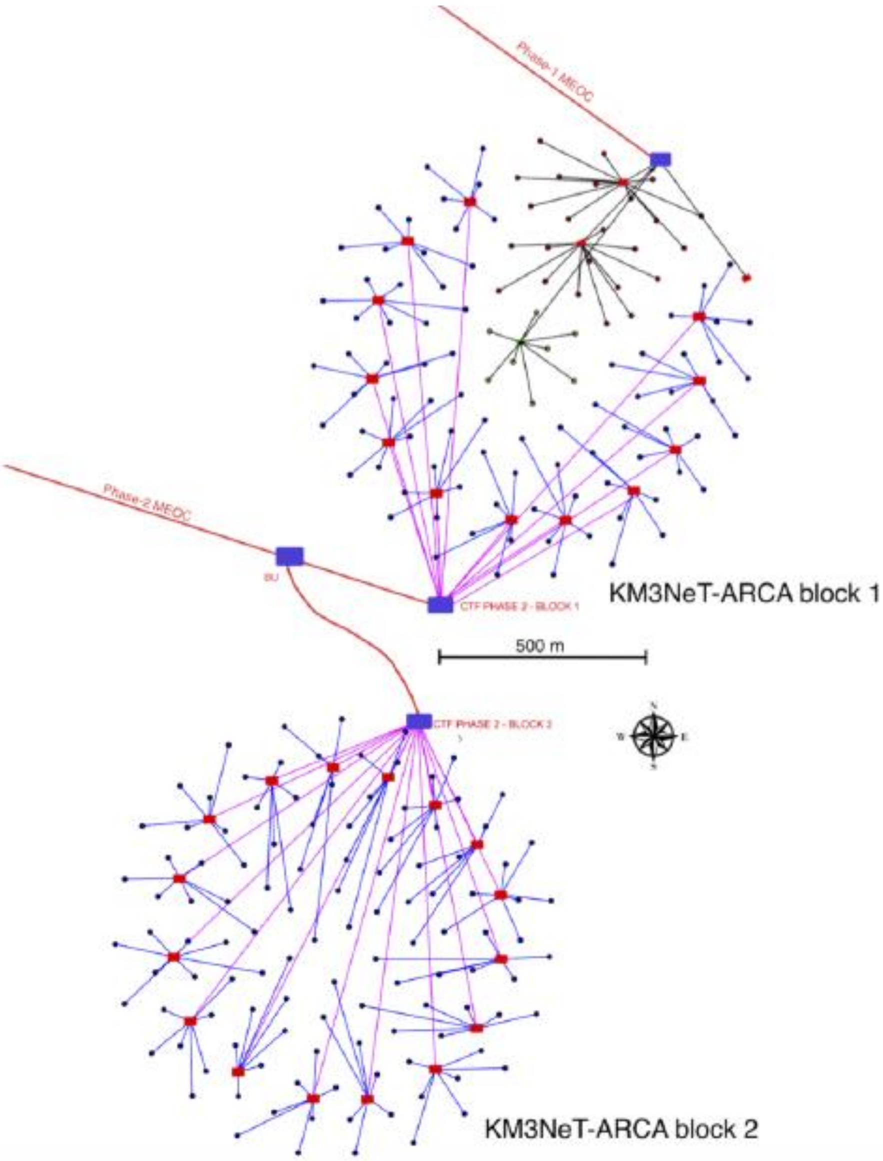



Figure 9: ARCA network

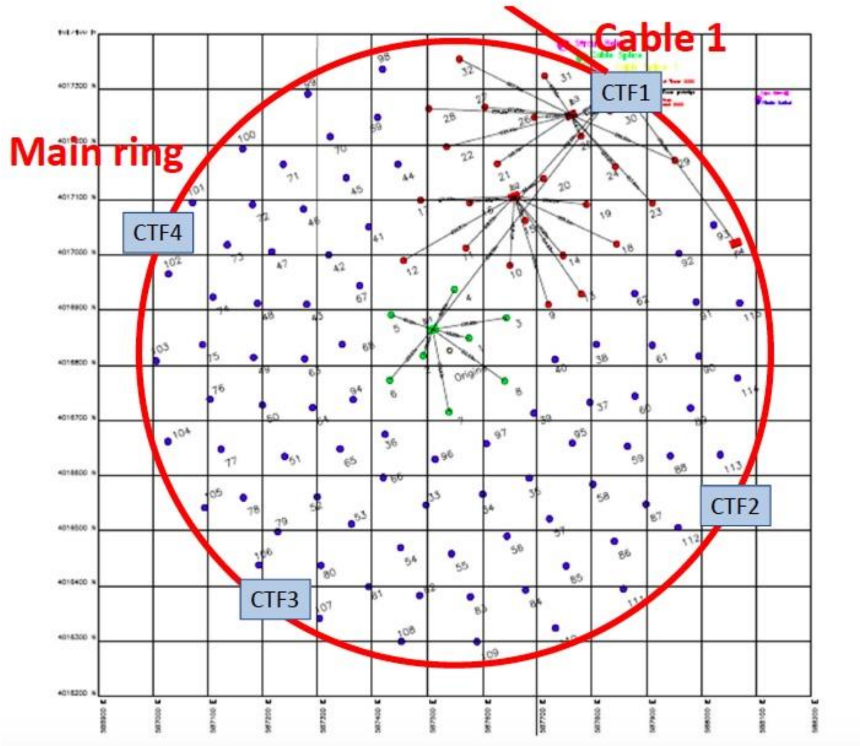



Figure 10: ARCA building block schematic

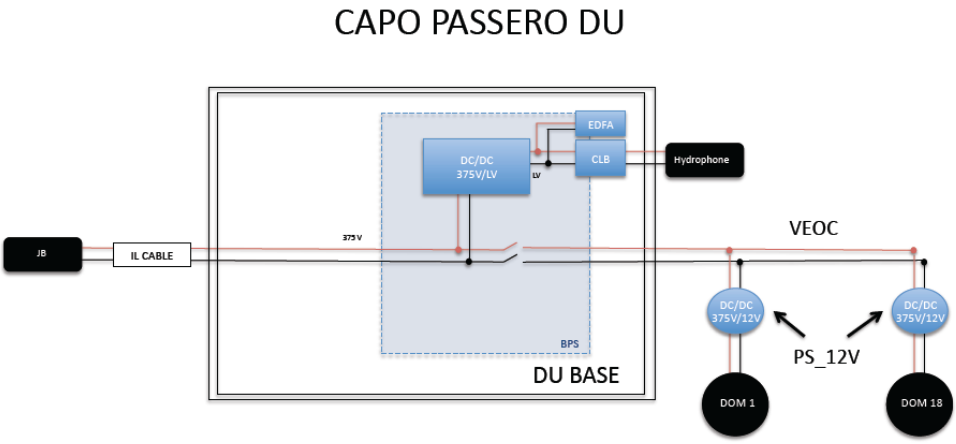



Figure 11: ARCA detection unit

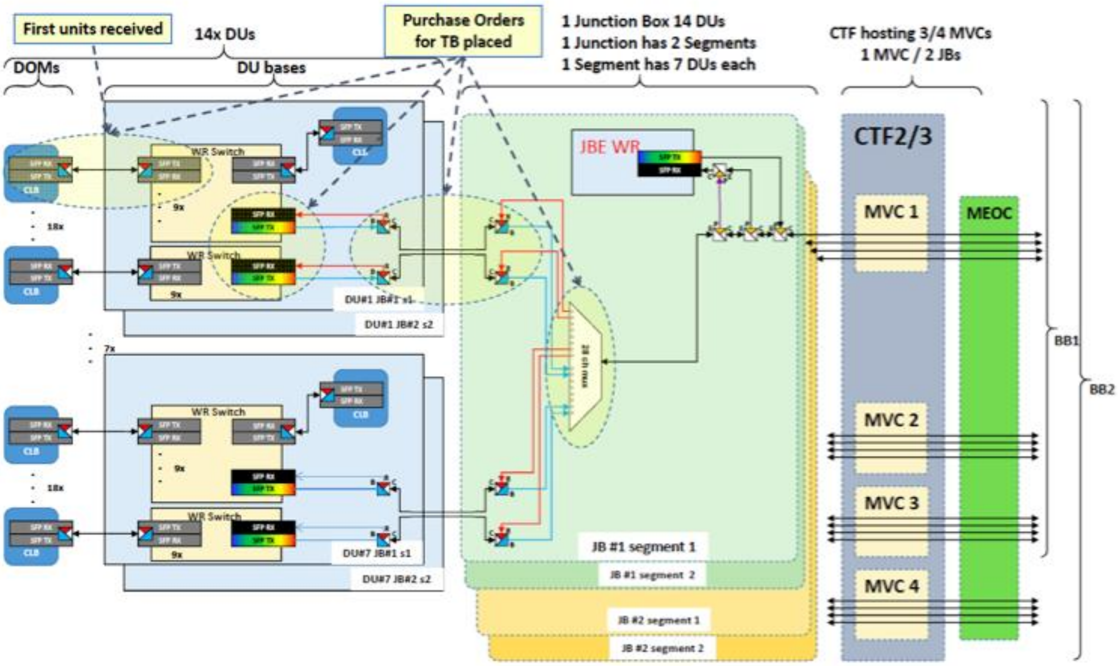
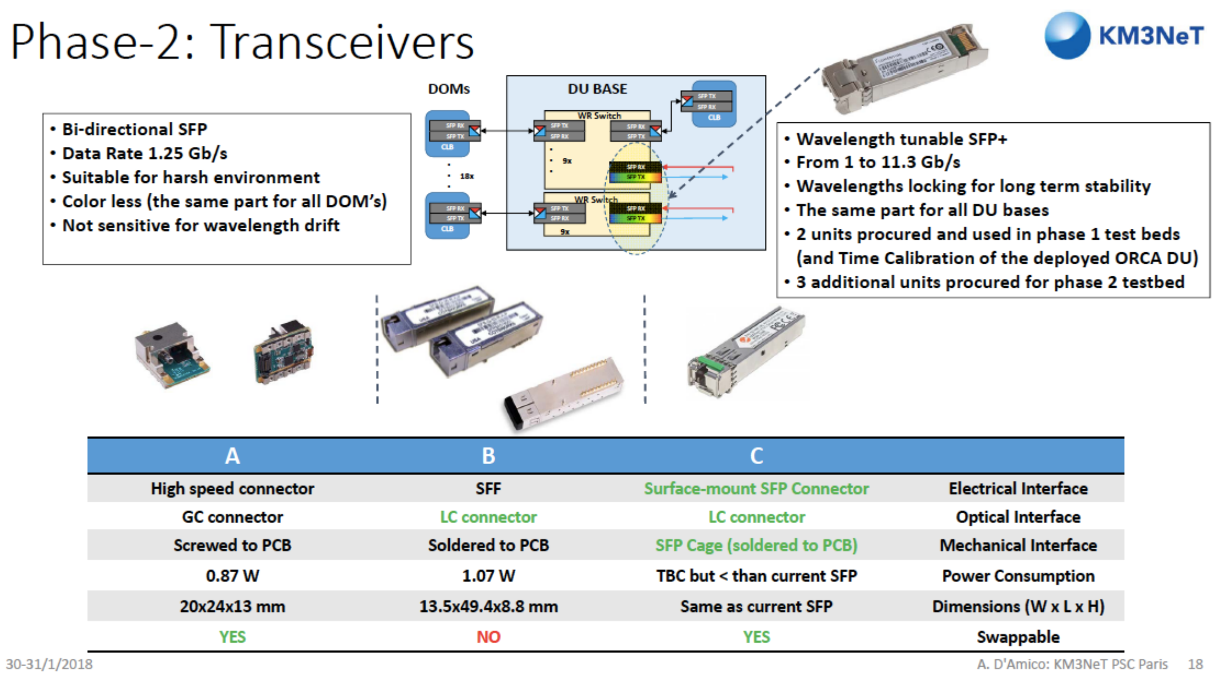



Figure 12: ARCA Optical network principle

### 5.4. Common ORCA / ARCA components:

### 5.4.1.DU base optical architecture:




| A | B | C | |
|---|---|---|---|
| High speed connector | SFF | Surface-mount SFP Connector | Electrical Interface |
| GC connector | LC connector | LC connector | Optical Interface |
| Screwed to PCB | Soldered to PCB | SFP Cage (soldered to PCB) | Mechanical Interface |
| 0.87 W | 1.07 W | TBC but < than current SFP | Power Consumption |
| 20x24x13 mm | 13.5x49.4x8.8 mm | Same as current SFP | Dimensions (W x L x H) |
| YES | NO | YES | Swappable |

Figure 13: DU base optics

### 5.4.2.DOM for ORCA and ARCA:

The DOM are the detector optical modules. There are 18 DOM per DU line.

For phase 2, the number total of DOM will be 2070 for ORCA and 4140 for ARCA.

Each DOM is composed by 31 photodetectors.

***For ORCA and ARCA, DOM are the same in term of architecture :***

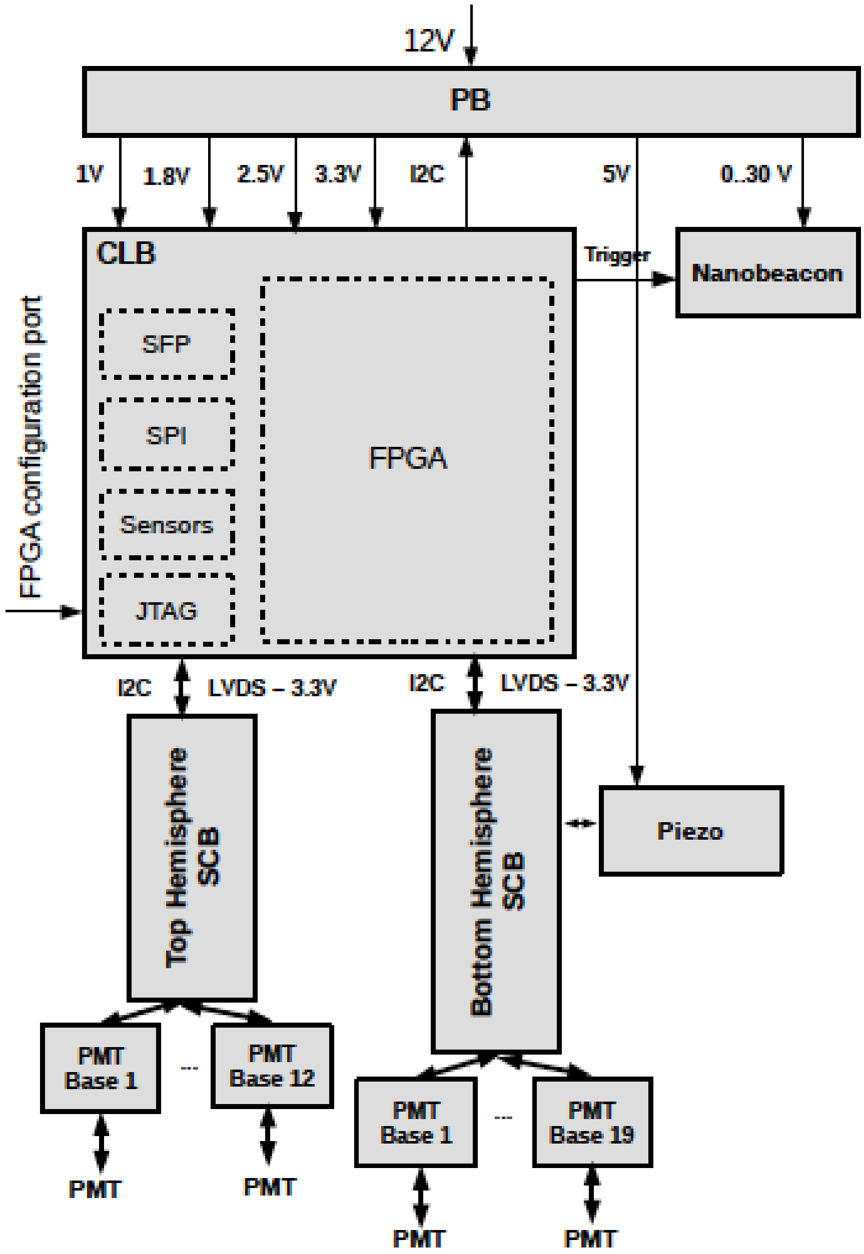



Figure 14: DOM functional schematic

### 5.5. Calibration unit:

The calibration unit will allow emitting acoustic wave towards all DOM, which will be detected by piezzo acoustic receiver. The signal analysis will permit to determine the exact position of each DOM in order to perform arrival direction muons particles analysis. A laser will permit to synchronise all detectors. Several instruments will permit to analyse water parameters useful for data analysis and sea science. A hydrophone allows measuring acoustic wave propagation on the DU foot to define the position of the line and DOM.

In order to calibrate the detectors, at least one calibration unit will be installed on the ORCA site and 5 on the ARCA site (because detectors spacing are different)

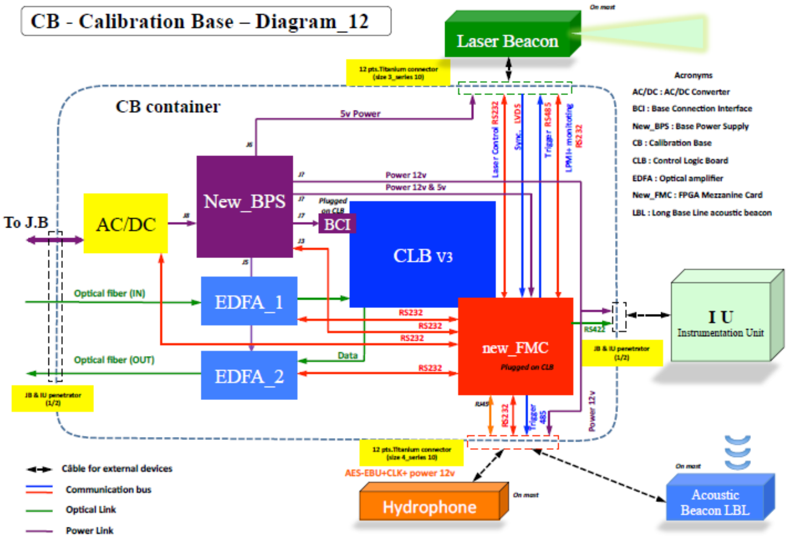



**Figure 15: Calibration unit functional schematic**

## 6. Failure occurrence analysis:

The main results obtained from the FIDES analysis of the KM3NeT electronics boards is presented in this chapter.
In the following table the FIT, the corresponding percentage of failure in 15 years and the numbers of PMTs affected by a single failure are shown for each board. It should be emphasized that the failures in such table refer to random failures of the boards during operation, i.e. not linked to infant mortality nor to end-of-lifetime failures; consequently the probabilities of such failures scale linearly with operation time. A plan for burn-in of the electronics and power boards has been set up in KM3NeT in order to remove infant mortality.
In a conservative approach, any kind of failure has been considered as a reason for failure of a complete board.
The results are shown bellow for each product level (from level 1 to level 4 when necessary).
Bellow are the main structures of the telescope:

| Product | Ref. Doc | Qty | FIT (unit) | % Failures in 10 years | % of the telescope affected | Comment |
|---|---|---|---|---|---|---|
| **1. On Shore** | **This doc** | 1 | | | Depend on the failure type (see lower levels) | FIT not evaluated – see FMECA |
| **2. Deep Sea Network** | **This doc** | 1 | | | Depend on the failure type (see lower levels) | Partially analysed. See FMECA for more info |
| **3. Detection Unit** | **This doc** | 120 ORCA 240 ARCA | | | 0,9% ORCA 0,45% ARCA (558 PMT affected if SPF). | |
| **4. Calibration Unit** | **This doc** | 2 ORCA 8 ARCA (TBC) | | | Performance degradation | Loss of calibration facility. |

Detail for On shore:

| BOARD | Ref. Doc. | Qty | FIT | Failures % / 10 years | Number of PMTs affected by single failure | Comments |
|---|---|---|---|---|---|---|
| 1.1 Shore station | This document | 1 | - | | | **The shore station host DAQ system** |
| 1.2 Power feed station | | 1 | - | | | **The power feed transform and deliver the energy neceesary for the deep sea network** |
| 1.3 On shore interconnection | | | - | | | **ON shore / Off shore interface** |

No FIT data evaluated for the On Shore as the system is accessible and could be repaired in case of failure.

**Recommendation:** Ask the MTBF of the delivered equipment's to the manufacturer, in order to select the best choice in term of reliability

**Detail for deep sea network:**

| BOARD | Ref. Doc. | Qty | FIT | Failures % / 10 years | Number of PMTs affected by single failure | Comments |
|---|---|---|---|---|---|---|
| 2.1 Link sea shore | This document | 2 ORCA<br>2 ARCA | NA | | | Include the 40 km MEOC cable |
| 2.2 Inter-node link | | 31 for ARCA<br>4 for ORCA | NA | | | JB link for ARCA, internode link for ORCA |
| 2.3 Junction box or Node | | 6 Node (ORCA)<br>31 JB (ARCA) | - | | | Distribute the HV AC or DC to 20 DU for ORCA node and to 7 DU for ARCA JB |
| 2.3.1 JB | | 1 ARCA | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| mechanics | | 1 ORCA | | | | |
| 2.3.2 JB container | | 1 ARCA<br>1 ORCA | | | | |
| 2.3.3 JB instrumentation | | ARCA<br>ORCA | | | | |
| 2.3.4 Power components | | ARCA<br>ORCA | | | | Breakers, contactors and battery system |
| 2.3.4 Control Command | | ARCA<br>ORCA | | | | Control circuit switching via ethernet |
| 2.3.6 Optical components | | ARCA<br>ORCA | | | | Optical amplifier and filter – optical connections with DU |
| 2.3.7 Connection | | ARCA<br>ORCA | | | | |
| 2.3.8 Cable | | ARCA | | | | |
| 2.3.9 JB subcontainer | | 1 ARCA | | | | Instruments assembly |

Detail on detection Unit:

| BOARD | Ref. Doc. | Qty | FIT | Failures % / 10 years | Number of PMTs affected by single failure | Comments |
|---|---|---|---|---|---|---|
| **3.1 Interlink Cable** | | | | | | |
| **3.2 DU base** | | | | | | |
| **3.2.1 Structure** | | | | | | |
| **3.2.2 Base container** | | | | | | |
| **3.2.2.1 Container** | | | | | | |
| **3.2.2.2 Optical components** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **3.2.2.3 Electronic co monents** | | | | | | |
| **3.2.2.3.3 Power conve rters** | | **1** | | | | **AC/DC for ORCA DC/DC for ARCA** |
| **3.2.2.3.6 FMC** | **RD7** | **1** | **72** | **1.0** | **-** | |
| **3.2.2.3.7 BPS** | **RD8** | | **517** | **4.4** | **558** | **Provide LV DU DC voltages – BPS V0-R1** |
| **3.2.2.4 Internal cablin g** | | | | | | |
| **3.2.3 Instruments** | | | | | | |
| **3.2.3.1 Hydrophone** | | | | | | |
| **3.2.3.2 LBL Beacon** | | | | | | |
| **3.3 VEOC** | | | | | | |
| **3.3.1 Cable** | | | | | | |
| **3.3.2 BoB** | | | | | | **Break out Box : convert 375V DC t o 24V DC** |
| **PSU_WIR_12V-R4** | **RD9** | | **289** | **2.5(**)** | **31** | |
| **PS_12V_ICL-R1** | **RD10** | | **210** | **1.8(**)** | **31** | |
| **OMSupplyv5** | **RD11** | | **202** | **1.8(**)** | **31** | |
| **3.4 Digital Optical Mo dule** | | | | | | |
| **3.4.3.5 PB** | **RD3** | | **1424** | **11.7%(*)** | **31** | |
| **3.4.3.2 CLB** | **RD4** | | **417** | **3.6** | **31** | |
| **3.4.3.1.2 Octopus Lar ge** | **RD6** | | **157** | **1.4** | **19** | |
| **3.4.3.1.1 Octopus Sho rt** | **RD6** | | **156** | **1.4** | **12** | |
| **3.4.2 PMT Unit** | | | | | | |
| **3.4.2.1 PMT** | | | **1** | | **1** | |
| **3.4.2.2 PMT Base** | **RD5** | | **1218** | **10.1** | **1** | |
| 3.4.3.3 Tiltmeter Board | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3.4.3.4 Compass Board | | | | | | |
| **3.4.3.6** *Acoustic Component* | | | | | | |
| **3.4.3.7** *Nano Beacon* | | | | | | |
| 3.4.4 Cables | | | | | | |
| 3.5 Top Buoy Storey | | | | | | |

Table 1. Summary of the outcome of the FIDES analysis of the KM3NeT electronics and power boards. (*) The percentage of failures in 10 years of the power-boards is expected to decrease to 8% if failures affecting only the calibration devices are not considered.

(**) The 350 bars oil pressure environment is not considered in the fides method.

Action: confirm that the reliability is not affected by high-pressure environment

Detail for Calibration Unit:

| BOARD | Ref. Doc. | Qty | FIT | Failures % / 10 years | Number of PMTs affected by single failure | Comments |
|---|---|---|---|---|---|---|
| 4.1 CU interconnection | This document | 1 | - | | | The shore station host DAQ system |
| 4.2 Calibration Base | | 1 | - | | | The power feed transform and deliver the energy neceesary for the deep sea network |
| 4.2.2 CB container | | | - | | | ON shore / Off shore interface |
| 4..2.2.5 BPS CB | | | | | | |
| 4.2.2.6 CLB | | | | | | Same as 3.4.3.2 but specific firmware |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4.2.2.7 BCI | | | | | | |
| 4.2.2.8 FMC | | | | | | |
| 4.2.2.10 SFP | | | | | | |
| 4.2.2.11 Splice canister | | | | | | |
| 4.2.2.12 Add and Drop | | | | | | |
| 4.2.2.13 Electrical wiring | | | | | | |
| 4.2.2.14 AC/DC | | **ORCA** | | | | |
| 4.2.2.15 EDFA | | | | | | |
| 4.2 Instrumentation Unit | | | | | | |
| 4.4 Laser beacon | | | | | | **Light pulse emitter** |
| 4.5 Hydrophone | | | | | | **Acoustic receiver** |
| 4.6 LBL beacon | | | | | | **Acoustic emitter** |
| | | | | | | |

## 7. Failure modes:

In this chapter, we describe the main failure modes identified in the FMECA (see RD xx) and impact on the system in term of PMT loose quantity.

An acceptability scale is defined:

Red : This is a not acceptable failure mode resulting in more than 30% loss of the telescope availability or high risk. A compensating provision should be proposed.

Orange : Action is necessary in order to reduce as much as possible the risk. Partial loss of performance between 5 and 30%

Green : Less tan 5% availability telescope loss of performance. No action foreseen.

A new acceptability is evaluated if the recommendation or compensating provision is applied.

No red tagged acceptability allowed.

| Product | Failure mode | RPN | Consequences | Compensating provision |
|---|---|---|---|---|
| 1. On Shore | Fire | 12 | Telescope loss | Fire prevention plan |
| | Power feed loss | | Telescope down | Evaluate years down time. Provide redundant power system |
| | Telescope Data processing loss | | No data processing | Provide redundancy |
| | ESS DAQ failure | | | |
| | Communication link | | | Redundancy |
| | | | | |
| **2. Deep Sea Network** | **MEOC LOSS** | | | Depend on the failure type (see lower levels) |
| **3. Detection Unit** | **This doc** | | | 558 if SPF. Depend on the failure type (see lower level) |
| **4. Calibration Unit** | **This doc** | | | |

## 2 Conclusion

Analysis have been performed on electronics boards excluding calibration base which is still under definition (for ORCA and ARCA). The study is planned to start as soon as all input data will be available

Note that an update of theses analysis is necessary as new versions are still under development ( CLB V3, BPS design update for calibration unit requirements, FMC...). A design review in order to check design rules applied for theses updates will be necessary.

A FMECA analysis is in progress in order to highlight most critical failures modes using probabili ty of occurrence calculated for each board. A prior interfaces analysis is currently in progress in order to identify all failure propagation path. Then it will be possible to take in account and focu s in priority on most critical failures

The reliability is strongly dependant to the process. A preliminary evaluation have been perform ed considering high reliability processes (not conservative approach) and design rules to be appl ied. Nevertheless, the next action is to perform a real audit on manufacturing and integration pro cesses.

A manufacturing matrix roadmap (draft version) written for KM3NET based on IPC standard. K M3NeT_QA_2014_016_Manufacturing_Audit_RoadMap (RD13) outline main recommandations fo r manufacturing audit

Commercial of the shelves (COTS) as ethernet and white rabbit switch and high voltage to low vo ltage power convertion (in nodes and detector unit bases) are not included in this study.

## 5. Fides short presentation

**FIDES short presentation:**

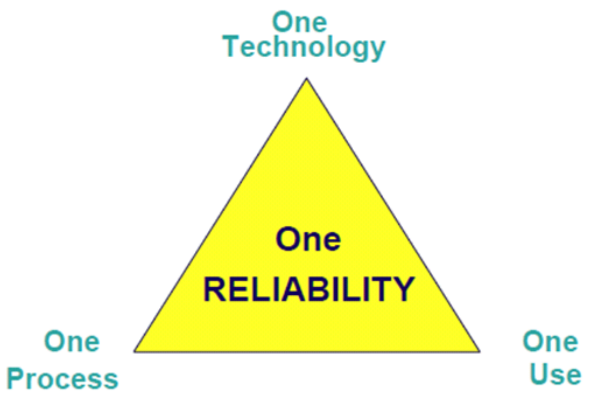



*Figure 1: FIDES method philosophy*

FIDES is not an acronym. FIDES is the Latin word for "faith" and is the root of the word "fidelity" and of the French word for reliability, "fiabilité".

The item failure rate is expressed in FIT (λ) i.e, number of failure per $10^9$ hours. The general for mula is:

$$\lambda = \left(\sum \text{Physical\_contributions}\right) \times \left(\Pi_{\text{Process\_contributions}}\right)$$

In practice this equation becomes:

$$\lambda = \lambda_{\text{Physical}} \cdot \Pi_{\text{PM}} \cdot \Pi_{\text{Process}}$$

Where:

• λ Physical represents the physical contribution.

• $\Pi_{PM}$ (PM standing for Part Manufacturing) represents the quality and technical control over ma nufacturing of the item.

• $\Pi_{Process}$ represents the quality and technical control over the development, manufacturing and u sage process for the product containing the item.

**Physical contribution is:**

$$\lambda_{\text{Physical}} = \left[\sum_{\text{Physical\_Contributions}} \left(\lambda_0 \cdot \Pi_{\text{acceleration}}\right)\right] \cdot \Pi_{\text{induced}}$$

Acceleration process is due to the environment (temperature, humidity, vibration, electrical):

| Stress | Physic of fialure law | Stress symbol | s = stress number | g Function | Acceleration factor |
|---|---|---|---|---|---|
| Thermal | Arrhenius | T | 1 | $g1 = \frac{1}{T}$ | $\exp\left[\frac{Ea}{Kb} \cdot \left(\frac{1}{T1} - \frac{1}{T2}\right)\right]$ |
| Thermal cycling | Norris-Lanzberg | T & ΔT | 2 | $g1 = \frac{1}{T}$ $\mathbf{g2} = \ln(\Delta T)$ | $\left(\frac{\Delta T2}{\Delta T1}\right)^m \cdot \exp\left(\frac{Ea}{Kb} \cdot \left(\frac{1}{T\max\_ref} - \frac{1}{T\max}\right)\right)$ |
| Humidity | Haldberg-Peck | RH | 2 | $g1 = \ln(RH)$ $\mathbf{g2} = \frac{1}{\mathbf{T}}$ | $\left(\frac{RH2}{RH1}\right)^p \cdot \exp\left(\frac{Ea}{Kb} \cdot \left(\frac{1}{T1} - \frac{1}{T2}\right)\right)$ |
| Vibration | Basquin | Grms | 1 | $g1 = \ln(Grms)$ | $\left(\frac{Grms\ 2}{Grms\ 1}\right)^b$ |
| Electrical | Eyring | T & V | 2 | $g1 = \ln(V)$ $\mathbf{g2} = \frac{1}{\mathbf{T}}$ | $\left(\frac{V2}{V1}\right)^n \cdot \exp\left(\frac{Ea}{Kb} \cdot \left(\frac{1}{T1} - \frac{1}{T2}\right)\right)$ |

$\Pi_{induced}$ represents the contribution of induced factors (also called overstress) inherent to an appl ication field. The induced factors considered are of mechanical (MOS), electrical (EOS) and ther mal (TOS) origin. The influence of the component placement inside the system, the application ( usage environment), the ruggedizing policy (product overstress taken into account in the produc t development) and the component overstress sensitivity are the parameters taken into account to evaluate the induced factor:

$$\Pi_{induce-i} = \left(\Pi_{placement-i} \times \Pi_{application-i} \times \Pi_{ruggedising}\right)^{0,511 \times Ln\left(C_{sensibility}\right)}$$

The factor take a value from 1 (best case) to 100. It's the reason why, for example, the usage of a component at its maximum rate decreases dramatically its reliability.

**The Part Manufacturing contribution is:**

$$\Pi_{PM} = e^{\delta_1 .(1-Part\_Grade)-\alpha_1}$$

$$Part\_Grade = \left[\frac{\left(QM_{manufacturer} + QA_{item} + RA_{component}\right) \times \varepsilon}{36}\right]$$

The evaluation method takes into account the manufacturer's quality assurance ($QM_{manufacturer}$) cr iteria, item quality assurance ($QA_{item}$) criteria and also the item purchaser's experience with his s upplier (ε). When not evaluated, the Part Manufacturing factor default value is 1.7 for active com ponents and 1.6 for other components and COTS boards.

**The $\Pi_{Process}$ is:**

the $\Pi_{Process}$ factor represents the quality and technical control over reliability in the product life c ycle. Its purpose is to globally evaluate the maturity of the designer and manufacturer on control over their reliability engineering process.

The evaluation method is based on the level of application of recommendations that apply to the entire life cycle. The product life cycle is broken down as follows:

1. Specification.
2. Design.

3. Board or subassembly manufacturing (manufacturing).
4. Integration into equipment (manufacturing).
5. Integration into system (manufacturing).
6. Operation and maintenance.
7. Support activities such as quality and human resources.

The recommendations are not intended to be exhaustive; they are more like a representative sa mple of good practice to improve the final reliability of products.

The variation range of the $\Pi_{Process}$ factor is from 1 (for the best process) to 8 (for the worst proce ss), with a suggested default value of 4.0 is suggested if $\Pi_{Process}$ is not evaluated.

The Audit to evaluate this factor has been done based on the PPM-DOM electronics using FIDES Mill V2004A - Process.xls tool. Main contributors and rules to be applied in order to obtain a real process factor conform to the evaluation.

High reliability process are considered for km3net. The evaluated value is 1,91. A more detalled audit (considering last updates) is suggested in order to be more confident about this value.

In terms of reliability for electronic systems, two strong needs must be managed:

To have realistic reliability prediction during the development of an electronic product

To be able to build-in the reliability of the electronic products (“design for reliability”), as done f or the electronics of KM3NeT, and not getting it only as a result.

FIDES Methodology is based on the physics of failures and supported by the analysis of test data, field returns and existing modelling.