Funded by
the European Union

Ref. Ares(2025)54716 - 06/01/2025

KM3NeT
INFRADEV-2

TOWARD FULL IMPLEMENTATION OF THE KM3NeT RESEARCH INFRASTRUCTURE

KM3NeT-INFRADEV2 – HORIZON – 101079679

FIDES analysis for all electronic boards

KM3NeT-INFRADEV2 GRANT AGREEMENT DELIVERABLE: D3.2

Document identifier:	KM3NeT-INFRADEV2-WP3-D3.2-v.final
Date:	31/12/2024
Work package:	WP3 - Accelerating Implementation
Lead partner:	CNRS
Document status:	FINAL
Dissemination level:	PUBLIC
Document link:	https://www.km3net.org/km3net-eu-projects/km3net-infradev2/infradev2-outputs/

ABSTRACT

This document presents the most updated results of the FIDES analysis of the electronic boards used in KM3NeT. The document seeks to study and enhance the reliability of components operating in the deep-sea environment where KM3NeT is deployed.

The FIDES methodology, tailored to electronic systems, offers a valuable estimate of the failure rates, accounting for the environmental stresses expected during the life cycle of the products (thermal, vibrational, etc.). By quantifying reliability and outlining failure modes, this analysis supports design optimization, ensuring the long-term performances required for the KM3NeT neutrino telescope.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Agency (REA). Neither the European Union nor the REA can be held responsible for them

1. COPYRIGHT NOTICE

2. DELIVERY SLIP

	Name	Partner and WP	Date
Author(s)	Stéphane Colonges Francesco Filippini Miles Lindsey Clark	CNRS, WP3 INFN, WP3 CNRS, WP3	14/11/2024
Reviewed by	KM3NeT Project Office KM3NeT TPM Marco Circella		20/12/2024 27/12/2024
Approved by	Paschal Coyle KM3NeT IB	CNRS, WP1	20/12/2024 31/12/2024

3. DOCUMENT LOG

Issue	Date	Comment	Author/Partner
1	13/05/2024	1st draft	WP3
2	09/12/2024	1st complete draft ready for review	WP3
3	20/12/2024	Reviewed by Marco Circella, Miles Lindsey Clark, Antonio D'Amico	KM3NeT Collaboration
4	31/12/2024	Final version	Victoria Ciarlet, CNRS

4. APPLICATION AREA

This document is a formal deliverable of the Grant Agreement of the project, applicable to all members of the KM3NeT-INFRADEV2 project, beneficiaries, and third parties, as well as its collaborating projects.

5. TABLE OF CONTENTS

6. TERMINOLOGY and ACRONYMS

ARCA	Astroparticle Research with Cosmics in the Abyss
BB	Building Block
BGA	Ball Grid Array
BM	Base Module
BOM	Bill Of Materials
BPC	Base Power Supplier Converter
BPD	Base Power Distribution
BPS	Base Power Supply
CB	Calibration Base
CLB	Central Logic Board
COTS	Components Off The Shelf
CTF	Cable Termination Frame
CU	Calibration Unit
DCR	Design Change Request
DOM	Digital Optical Module
DU	Detection Unit
DUL	DU Base Limiter
EDFA	Erbium-Doped Fiber Amplifier
FMC	FPGA Mezzanine Card
FMECA	Failure Mode, Effects and Criticality Analysis
GBP	Glenair BackPlane

HASS	Highly Accelerated Stress Screens
IMM	Inductive Modem Module
IB	Instrumentation Base
IU	Instrumentation Unit
JB	Junction Box
KM3NeT	Cubic Kilometre (km3) Neutrino Telescope
LBL Beacon	Long BaseLine Beacon
LF	Lead-Free
LVDS	Low-Voltage Differential Signaling
MDP	Manufacturing Data Package
MEOC	Main Electro-Optical Cable
MW	MicroWave
NCR	Non-Conformity Report
ORCA	Oscillation Research with Cosmics in the Abyss
OS	Over Stress. Mechanical, Electrical, Thermal OverStress: MOS, EOS, TOS.
PB	Power Board
PBS	Product Breakdown Structure
PCB	Printed Circuit Board
PM	Part Manufacturing
PMT	PhotoMultiplier Tube
PRR	Production Readiness Review
PSC	Project Steering Committee

QA/QC	Quality Assurance and Quality Control
RAMS	Reliability, Availability, Maintainability, and Safety
RF	Radio Frequency
SCB	Signal Collection Board
SFP transceiver	Small Form-Factor Pluggable transceiver
SPOF	Single Point Of Failure
SRS	Shipping Record Sheet
TDC	Time-to-Digital Converter
ToT	Time over Threshold
TDR	Technical Design Report
UPI	Unique Product Identifier
VEOC	Vertical Electro-Optical Cable
WP	Work Package
WRSCB	White Rabbit Switching Core Board
WWRS	Wet White Rabbit System

7. PROJECT SUMMARY

The Kilometre Cube Neutrino Telescope (KM3NeT) is a large Research Infrastructure comprising a network of deep-sea neutrino telescopes in the Mediterranean Sea with user ports for Earth and sea science instrumentation. During the EU-funded Design Study (2006-2010) and Preparatory Phase (2008-2012), a cost-effective technology was developed and the deep-sea sites for apparatus installation were selected. This led to the establishment of the KM3NeT Collaboration in 2013. This proposal constitutes a second INFRADEV project dedicated to KM3NeT in order to implement an efficient framework for the mass production of KM3NeT components, accelerate the completion of its construction, and provide a sustainable solution for the operation of the RI for at least ten years after completion. Following the appearance of KM3NeT on the 2016 ESFRI Roadmap and in line with the recommendations of the Assessment Expert Group, this project addresses the Coordination and Support Actions to prepare a legal entity for KM3NeT, accelerate its implementation, establish open access to the RI and its data and ensure its sustainability by implementing an environment-friendly operation mode and evaluating the Collaboration socio-economic impact.

8. EXECUTIVE SUMMARY

This document explains the reliability calculation methodology and applies its predictive power to electronic boards developed and integrated for the KM3NeT neutrino detector. The FIDES methodology, a reliability prediction model designed to estimate the failure probability of electronic boards, has been selected for that purpose.

The primary goals of the reliability prediction are to :

- Evaluate failure rate probabilities for each component and sub-assembly.
- Identify weak points in terms of criticality.
- Define reliability improvements in terms of design and processes.

The attempt to derive the predictive availability of the total detection apparatus across the lifetime of the detector is not addressed in this document, but in the KM3NeT RAMS report (an INFRADEV2 deliverable scheduled for the end of 2025).

9. INTRODUCTION

Reliability analysis is a discipline of system engineering that studies the ability of an equipment to function without failure. Several methodologies can be used to analyze the reliability of a subsystem, such as FIDES, MIL-HDBK-217F (Military Handbook 217), Telcordia SR-332, and many others.
The present document describes the methodology used to perform the reliability analysis of the electronic boards and components integrated into the KM3NeT detector, along with the results obtained for each product.

Noticeably, reliability analysis is an input for the RAMS activities. RAMS stands for "Reliability Availability, Maintainability, and Safety". The compiled availability of sub-assemblies up to the complete infrastructure is assessed in the RAMS report (an INFRADEV2 deliverable scheduled for the end of 2025).

In some cases, some single electronic elements are integrated inside multiple types of assemblies and are consequently subjected to multiple life profiles. For such cases, the failure rate evaluation is calculated for each applicable life profile.

The analysis has been performed for each component, considering the worst-case scenario when the conditions are not perfectly known, or for simplification when the same reference is used multiple times on a board. This approach is particularly critical when a component, such as a decoupling capacitor, is utilized across different voltage supply lines, where the most stringent operating conditions are applied to conduct a conservative predictive reliability assessment, providing a simplified yet robust evaluation of potential system reliability.

In this document, the complete bill of Materials (BOM) and schematics used for the reliability calculations of the various electronic boards are not shared due to copyright restrictions and the need to protect sensitive information.

10. DEFINITIONS

Hereby a set of definitions of key terminology as defined by the FIDES guide (2022) [1]:

Reliability
The ability of an entity to perform a required function under given conditions for a given length of time. Reliability is generally expressed quantitatively, through relevant characteristics. One of these characteristics, in certain applications, is that this ability is expressed in the form of a probability, also called “reliability”.

Failure mechanism
The chain of “cause-and-effect” relationships in a physical, chemical, or other process between the root cause of the failure and the failure mode.

Failure mode
One of the possible states entered by an entity when one of its required functions fails.

System
A set of equipment capable of performing or supporting an operational role. A complete system comprises all the equipment, hardware, software, services, and personnel necessary for it to be able to function self-sufficiently in its environment of use. Examples: cars, aircraft, microcomputers.

Subsystem
A set of equipment capable of performing an operational function of a system. A subsystem is a major subdivision of a system, and is often called a “system”.
Examples: the ABS of a car; and the GPS of an aircraft.

Assembly
An assembly refers to a collection of electronic components and/or sub-assemblies put together in a single enclosure to perform a specific function. It often includes both mechanical and electrical parts; Each assembly encloses two types of components: custom components designed and manufactured for KM3NeT, and commercial components, with the custom products being primarily electronic boards specifically developed for the project, and commercial components potentially including off-the-shelf electronic boards used in various configurations;

Subassembly
A term referring to an item or assembled group of items capable of performing one of the functions of a piece of equipment. Examples: circuit board of a computer; hard drive.
Subassembly is a smaller, independent part of an assembly that is built separately. It may contain its own set of components and can often be tested independently before integration.

Electronic component
A term referring to an element designed to be assembled with others to perform one or more electronic functions. Examples: transistors, resistors. This definition also covers printed circuit boards (PCBs).

Product
Refers to the assembled entity of which the reliability is being analyzed. Generally a piece of equipment.

11. FAILURE RATE ANALYSIS METHOD AND ASSOCIATED PARAMETERS

11.1. Method

Failure rate estimations have been performed mainly by following the FIDES 2022 reliability handbook [1], or by comparing or using manufacturer reliability data to FIDES evaluations when these were available. In such a specific case, the information concerning the source of the data is also reported.

The FIDES methodology is a reliability modeling approach developed as part of a European industry initiative, led by stakeholders from high-reliability sectors such as aerospace, military, space, and automotive industries. The FIDES guide and the associated FIDES "Expertool" calculation tool are freely available on the fides-reliability.org website providing the creation of a user account (an example of the software interface is reported in Figure 1). The FIDES expert tool utilizes the formulas and recommendations from the FIDES reference guide to calculate the reliability of components based on the constraints and stresses applied to them.

Figure 1: *FIDES Expert tool.*

FIDES is not an acronym but derives from the Latin word for "faith," which is also the root of "fidelity" and the French term for reliability, "fiabilité": the underlying philosophy can be summarized as shown in Figure 2. In the FIDES methodology, a base failure rate is calculated for each component. This rate is then adjusted using various multiplication factors that account for processes throughout the product lifecycle and design robustness [1].

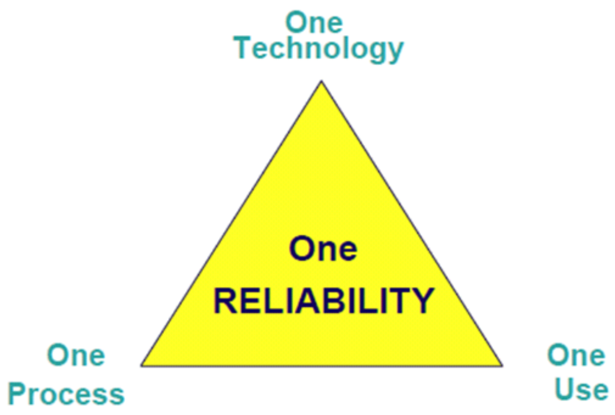


Figure 2: *philosophy of the FIDES methodology.*

A schematic representation of the reliability analysis process adopted for the analysis of this document, showing the sources of the inputs needed for the analysis, is illustrated in Figure 3:

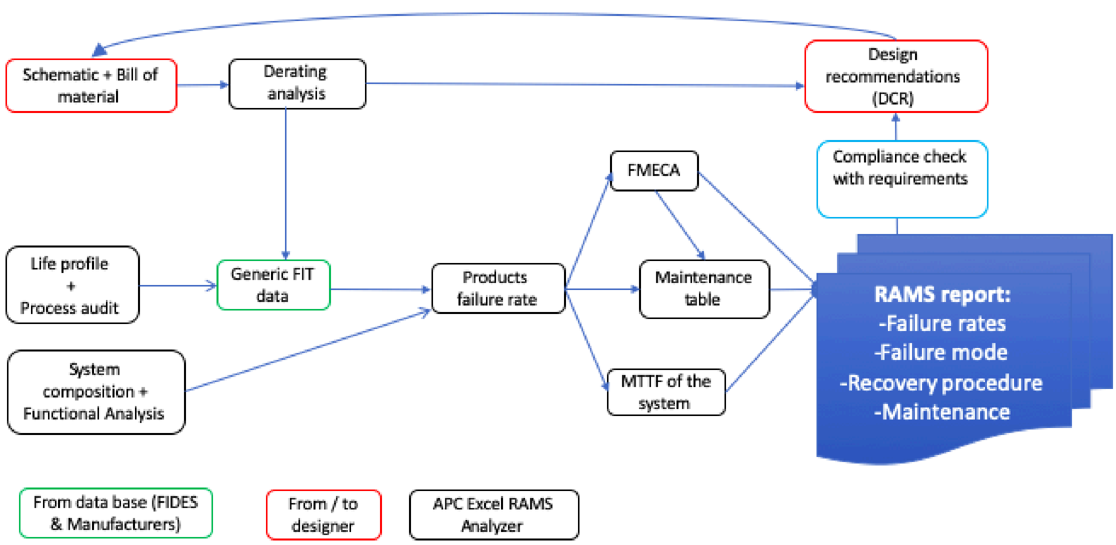


Figure 3: reliability analysis process.

For each electronic board, the input data for this process are the BOM and the schematics. Based on this information, a derating analysis is performed to calculate the constraints (such as voltage, power, temperature, etc.) applied to each component.

The FIDES expert tool is then used to calculate the FIT rate for each component under different stress conditions. These reliability models are subsequently integrated into a custom-developed Excel tool [2], specifically designed for this project yet adaptable for analyzing a wide range of infrastructures or complex systems. A schematic diagram of the Excel tool analysis principle is reported in Figure 4.

This Excel tool enables the consolidation of reliability data, whether sourced from the FIDES methodology or directly from manufacturers, for each component of the boards and assemblies. It facilitates the calculation of the overall reliability of each product or function, factoring in redundancies and the product hierarchy.

Additionally, inside this tool, a sheet conforming to the audit section of the FIDES guide allows to calculate the impact of process quality on the FIT rates. The tool also includes an FMECA (Failure Mode, Effects, and Criticality Analysis) module that automatically displays the criticality of each failure mode based on the reliability calculations. Finally, the tool provides the necessary information to evaluate the maintenance requirements. With its reporting capabilities, the data presented in this report has been extracted from the Excel tool.

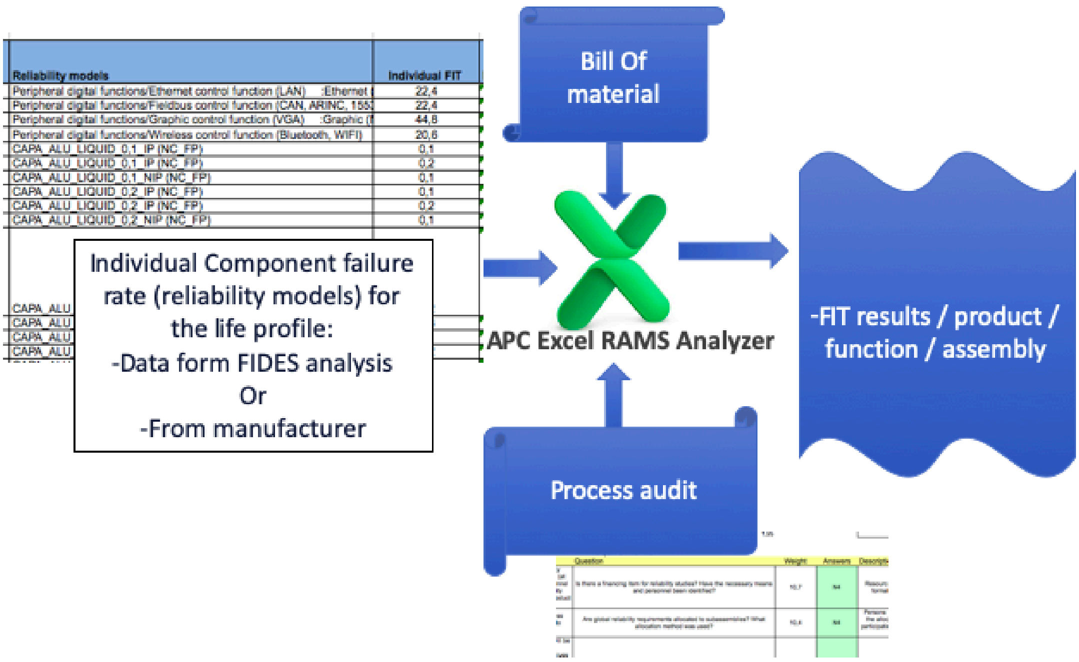


Figure 4: Excel tool reliability analysis principle.

The analysis of the overall availability of the infrastructure and assemblies, failure modes, manufacturing, integration, qualification, and validation processes to optimize the availability of our infrastructure are all covered in the RAMS report, based on the data collected and presented in the present report. Furthermore, assessing reliability data collected during the integration and operation phases will enable us to compare it with our predicted performance and propose strategies to improve reliability.

11.2. Failure In Time (FIT)

In this analysis, the parameter λ, representing the **FIT** rate, is used as the key metric to estimate the reliability of electronic boards. It expresses the likelihood of failure per unit of time, or equivalently the number of failures in one billion hours (10^9 hours) of operation for a device.

The **Mean Time To Failure** (MTTF) or the **Mean Time Between Failures** (MTBF) can also be derived through the FIT parameter as follows:

$$MTTF\ (or\ MTBF) = 1/\lambda$$

and represents the average time between failures for a non-repairable system (*MTTF*) or repairable system (*MTBF*).
The probability for a product to work without failure for a period of time *t* (in hours) is calculated using the following formula:

$$R(t) = e^{-\lambda t}$$

where *R(t)* is expressed in %. Here, a product failure is defined as either a loss of functionality or a degradation of its performance.

The probability of failure over a period t is then derived using the following formula:

$$F(t) = 1 - R(t) = 1 - e^{-\lambda t}$$

The failure rate calculation does not account for the contribution of youth failures. These failures are considered removed by the quality of the design, the production, and by an adequate stress screening procedure.
In Figure 5, a graphical representation of the typical failure rate curve is reported, describing the main phases of the failure rate of a product, component, or system over its lifecycle.

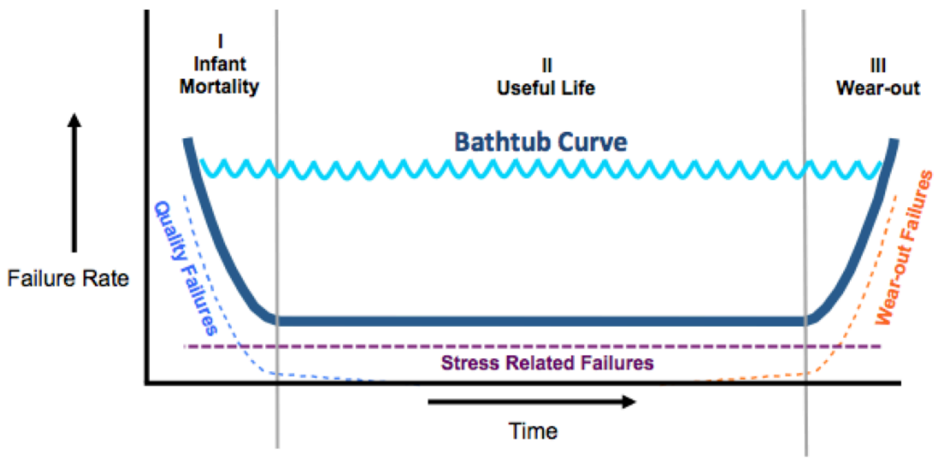


Figure 5: bathtub curve - typical failure rate curve over the product lifetime.

The FIDES general reliability model for an item is based on the following equation :

$$\lambda = \left(\sum Physical\ contributions \right) \times \left(\prod Process\ contributions \right)$$

$\sum Physical\ contributions$ is an additive term, representing the physical and technological factors that contribute to reliability.

In practice, this equation becomes:

$$\lambda = \lambda_{Physical} \times \prod PM \times \prod Process$$

where $\lambda_{Physical}$ represents the physical factors, that could be factorized as follows:

$$\lambda_{Physical} = \left[\sum_{Physical\ contributions} \left(\lambda_0 \times \prod acceleration \right) \right] \times \prod induced$$

with

- ***λ_0*** being the base failure rate.
- ***Π acceleration***: acceleration factors due to the environment (temperature, humidity, vibration, electrical).
- ***Π induced*** the contribution of induced factors, also called overstress, specific to each field of application.

Detailed definitions of these various contributing factors are given in the following chapters.

11.3. Contributing factors

11.3.1. Π acceleration

The FIDES method considers several acceleration factors for reliability analysis:

Temperature: the acceleration factor follows the Arrhenius model, relating failure rate to operating temperature.

Electrical Stress: high electric fields can induce dielectric breakdown, modeled using an exponential relationship. The electrical stress effect is added as the working voltage/rated voltage ratio to the Arrhenius model.

Temperature Cycling: the acceleration factor follows the Norris-Landzberg equation. Cyclic temperature changes can cause thermal expansion mismatch and fatigue, typically using a power law model.

Humidity: humidity stress can increase corrosion, ion migration, and other failure mechanisms. The acceleration effect is described by Peck's equation.

Vibration: mechanical stresses from vibration can lead to fatigue failures, as described by the Basquin equation.

Chemical: chemical stresses are modeled qualitatively since there is no physical model for this type of stress. In some models, the chemical stress becomes an acceleration factor of other physical stresses (salinity, pollution, hermetic or non-hermetic enclosure, geographic areas like urban, industrial, coastal, or continental,etc.).

For more details about acceleration equations, refer to the FIDES guide.

11.3.2. Π induced

The term ***Π induced*** in the equation above represents the contribution of induced factors, also called overstress, specific to each field of application. The nature of the over stress could be mechanical, electrical, or thermal. Specifically, the **placement** of the component inside the system, the **application** and its environment, the **ruggedizing** policy (product overstress during the product development) and the component **overstress** sensitivity are among the key parameters taken into account in the evaluation of this term (more details later in the paragraph). The factor takes a value from 1 (best case) to 100. Different criteria are used to evaluate the severity of a usage phase in terms of exposure to overstresses (*Π application* parameter), as explained in the table below.

$$\Pi_{induced\,,\,i} = (\Pi_{placement,\,i} \times \Pi_{application,\,i} \times \Pi_{ruggedizing,\,i})^{0.511 \times ln(e^{Csensitivity})}$$

The index *i* denotes the phase considered.
The *Csensitivity* factor considers the relative sensitivities to EOS (Electrical OverStress), TOS (Thermal OverStress) and MOS (Mechanical OverStress) of product families to the different types of overstress.

$$Csensitivity = \alpha \times EOS + \beta \times MOS + \gamma \times TOS \, with \, \alpha = 77,5\%, \, \beta = 22,5\%, \, \gamma = 5\%$$

The Π placement factor :

Placement factor must be assigned according to the electronic function served by the component, and not according to the nature or technology of the component itself.
The values of the Placement parameter therefore differ depending on the type of function (digital, low-level analog, or power analog) and whether or not this component interfaces with the board's external electrical environment

The Π application factor :

The *Π application* parameter is evaluated using the Expertool software by scoring a series of criteria. Each criterion can have three levels: low (favorable), medium (moderate), or high level (unfavorable situation), corresponding to a particular impact on the overstresses. The calculation of this factor impact is performed by the FIDES Expertool and the result impacts the components' failure rate.

In the scope of KM3NeT, only two usage phases are identified: ON (most of the time), and OFF (few days per year).

The table below presents the scoring for each criterion applied to KM3NeT:

Item	Description	ON phase level	OFF phase level
User type in the phase considered.	Represents the capability to respect procedures, when facing operational constraints.	**0, low level**	**0, low level**
User qualification level in the phase considered.	Represents the level of control of the user or the worker regarding an operational context.	**0, low level**	**0, low level**
System mobility.	Represents contingencies related to the possibility of the system being moved.	**0, low level**	**0, low level**
Product manipulation.	Represents the possibility of false manipulations, shocks, and drops.	**0, low level**	**0, low 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, medium level**	**0, low level**

Item	Description	ON phase level	OFF phase level
Product exposure to human activity.	Represents exposure to contingencies related to human activity: shock, change in final use, etc.	**0, low level**	**0, low level**
Product exposure to machine disturbances.	Represents contingencies related to the operation of machines, engines, and actuators: shock, overheating, electrical disturbances, pollutants, etc.	**1, medium level**	**0, low level**
Product exposure to the weather.	Represents exposure to rain, hail, frost, sandstorms, lightning, and dust.	**0, low level**	**0, low level**

Table 1: usage severity impact criterion.

The Π ruggedizing factor :

The *Π ruggedizing* factor evaluates the impact of the application of recommendations defined in the FIDES guide to harden the product during its design phase and therefore improve its reliability. The calculation of this factor is also performed by the FIDES Expertool. Its result impacts the components' failure rate.

To do this, the fides tool provides a list of questions that can be used to conduct an audit in order to assess the value of this factor. The answers and the justifications provided by the audit are used to determine a level of compliance with each recommendation (levels from N1 to N4):
N1 = Recommendation not applied. Definite risks concerning reliability.
N2 = Recommendation only partially applied. Potential risks about reliability.
N3 = Recommendation generally applied. Few risks concerning reliability.
N4 = Recommendation is fully applied. Reliability is under control.

The audit results for KM3NeT are listed in the table below:

Recommendation	Level
Check that environmental specifications are complete.	N3 - Recommendation is almost fully applied.
Provide training and manage operation and maintenance for implementation and maintenance of the product.	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.	N3 - Recommendation is almost fully applied.
Design dependable electrical protection devices.	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.	N3 - Recommendation is almost fully applied.
Identify and use appropriate prevention means of preventing reasonably predictable aggressions (related to the weather).	N4 - Recommendation is fully applied.
Use appropriate prevention means to identify and handle reasonably predictable abnormal uses of weather.	N4 - Recommendation is fully applied.

Recommendation	Level
Include production, storage, and maintenance environments in the product environment specifications.	N3 - Recommendation is almost fully applied.
Justify that environment specifications are respected.	N4 - Recommendation is fully applied.
Carry out a product improvement process (for example highly accelerated stress tests) to limit the product sensitivity to environmental constraints (disturbances, environments, overstress).	N4 - Recommendation is fully applied.
Perform an analysis of failure cases that could result in failure propagation.	N4 - Recommendation is fully applied.
Carry out a process analysis of implementation and maintenance operations.	N3 - Recommendation is almost fully applied.
Carry out a review of maintenance operations done by the final user and deal with his recommendations.	N3 - Recommendation is almost fully applied.
Write complete procedures for all product implementation and maintenance operations.	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.	N3 - Recommendation is almost fully applied.
Respect a standard dealing with power supplies (a standard that defines possible disturbances and possible EN2282-type variations). The standard must be respected both for electricity generation and for electricity consumption.	N3 - Recommendation is almost fully applied.

Table 2: product hardening recommendations.

11.3.3. Π part manufacturing

Reminder :

$$\lambda = \lambda_{Physical} \times \prod PM \times \prod Process$$

The **term Π_{PM}** accounts for the quality and technique used to manufacture an item.
Generally, it can be expressed through the formula:

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

where:

$$Part\_Grade = [\frac{(QA_{manufacturer} + QA_{Item} + RA_{component}) \times \epsilon}{36}]$$

The assessment method exploited for the computation of this term depends on the nature of the item considered, i.e. electronic component, board assembly, or subassembly. Nevertheless, it takes into account the manufacturer's quality assurance criteria (*QAManufacturer*), the quality assurance of the item (*QAItem*), and also, where applicable, the buyer's experience with the supplier. Moreover, ϵ represents correlating factors that determine the impact of the Part Manufacturing (PM) on the item's reliability and also normalizes the overall result to the required range.

For active components, the PM factor evaluation principle also includes qualification tests and periodic reliability monitoring tests, both on the package and on the active part. These data can be mainly found in reliability reports and audit results. The PM factor ranges from 0.5 (supplier superior to state of the art) to 2 (worst case). If the PM factor is not evaluated, a default value of 1.7 is proposed for active components and 1.6 for other components, such as Component Off The Shelf (COTS) boards and the various subassemblies. See FIDES GUIDES 2022 [1], chapter 1.9.

Active components	**1.6**
Other components (including COTS and subassemblies)	**1.7**

11.3.4. Π process

Reminder :

$$\lambda = \lambda_{Physical} \times \prod PM \times \prod Process$$

The *Π Process* term represents the quality and technical control over the development, manufacturing, and usage process for the product containing the item. The purpose of this term is to assess the overall maturity and effectiveness of designer's and manufacturer's control over their reliability engineering processes. To do this, we perform an audit.

The FIDES process audit is a method for evaluating the quality of processes related to the specification, design, manufacturing, assembly, maintenance, and operation of an electronic product. It aims to assess the control of processes impacting the product's reliability. The FIDES guide provides questions for each phase, scored according to four levels:

- **N1**: Uncontrolled process (absence of procedure or implementation);
- **N2**: Partial control (procedures exist but are poorly applied);
- **N3**: Well-controlled process (procedures are systematically applied);
- **N4**: Optimal control (best practices with a continuous improvement approach).

The evaluation is based on measuring how accurately recommendations are applied throughout the entire product lifecycle. These recommendations are not meant to be exhaustive but they represent a sample of best practices to enhance the final reliability of the products. A formula provided in the FIDES guide allows us to calculate the global ***Π Process factor value*** from the audit answers. The reader can refer to the FIDES guide for the full description of the *Π Process* factor calculation.

The variation range of the ***Π Process* factor spans from 1 (the best process) to 8 (the worst process)**, The product life cycle is broken down as shown in the table below, with the specific impact on the ***Π Process*** of each phase reported in %:

Phase	**Phase contribution (%)**
Definition/specification	8
Design	16

Phase	Phase contribution (%)
Manufacturing (board sub-assembly)	20
Integration into the equipment (assembly)	10
Integration into the system	10
Operation and maintenance	18
Support activities	18
Total	**100**

Table 3: product phase breakdown and relative percentage contribution.

A *Π process* factor evaluation was performed for KM3NeT by conducting an audit including 267 questions. A tool to calculate the process factor has been developed and full audit answers can also be found in Annex 1: Process audit.

Π Process calculated: 1,97

A further margin on the calculated value has been taken into account, therefore considering a Π *Process* value for KM3NeT analyses as:

Π process for KM3NeT calculations	2

A value of 2 in the Π *Process* corresponds to a system with very high reliability, featuring nearly optimal processes but slightly below the excellence, represented by a value of 1.
This means:

- Processes are very well-defined and generally applied consistently.
- Reliability practices incorporate advanced tools such as FMECA analysis, rigorous testing, and quality control loops.
- Some room for improvement remains, but it is usually minor (e.g. marginal optimizations or non-critical weaknesses).
- This level reflects a system close to the state-of-the-art in its field, with extremely high performance reliability, capable of meeting demanding requirements (e.g. in aerospace or critical systems).
- Such a system will have a very low Lambda base (failure rate), reflecting a minimal risk of failure.

11.3.5. Additional factors

Two additional process factors could be also taken into account :

- the ***Π process* RF/HF factor** concerns the control over the life cycle of a radio frequency (RF) or microwave (MW) product reliability. The final numerical value depends on the specific model adopted but generally can vary between 0.5 and 4. In case the data are unknown, a default value of 2.2 is applied. This factor is complementary to the *Π process* factor, which can be independently applied to microwave and radiofrequency products.
  Refer to FIDES Guide 2022 [1], "RF and MW process factor" chapter page 201.

Π process RF/HF	**2.2**

- the ***Π* LF factor** ("LF" standing for Lead-Free) takes into account the producer's expertise in the design and manufacturing of lead-free electronic assemblies. The factor is equal to 1 as long as series manufacturing is performed based on the "mastered" tin-lead process. Indeed, the lead-free process is now standard for all manufacturers.

Π LF Lead-free process factor	**1**

11.4. Manufacturer data

If available, manufacturer data for a specific temperature are used. In order to compare such data with other FIDES calculations, the FIT value has been adjusted using acceleration laws like the Arrhenius or the Norris-Landzberg equation.
Below the **Arrhenius** law commonly used in reliability studies is reported:

$$FIT_{recalculated} = FIT_{manufacturer} \times e^{\left(\frac{Ea}{k} \times \left(\frac{1}{Tmanufacturer} - \frac{1}{Trecalculated}\right)\right)}$$

where k is the Boltzmann constant : 8.617×10^{-5} eV/K. The activation energy (*Ea*) is a crucial parameter for characterizing the stability and reliability of electronic components. It represents the energy barrier that electrons must cross to participate in a given process (conduction, generation, recombination, etc.).
Passive components (resistors, capacitors, inductors) generally undergo thermal degradation mechanisms, such as ion migration, oxidation or loss of dielectric properties.
Active components (diodes, transistors, integrated circuits) are mainly affected by mechanisms such as dopant diffusion, interface degradation or electromigration. Mechanical mechanisms include material fatigue, cracking, or delamination (printed circuit boards) in welds and substrates.

Typical values for activation energy (*Ea*):

Component type	Typical Activation Energy (*Ea*)
Passive components	0,3 to 0,6 eV
Mechanical components (including printed circuit boards and passives opticals components)	0,4 to 0,6 eV
Active components (Integrated circuit)	0,5 to 0,9 eV
Discrete components (transistors…)	0,7 to 1,2 eV
Commercial components (passive and active components mixed in an equipment)	0,4 to 0,7 eV

Important note: the values given above are indications (there is no precise and accurate reference), and may vary significantly depending on the technology used, materials, operating conditions and other factors. An extension of the Arrhenius law, the **Norris-Landzberg** law, is an empirical equation used to predict the lifetime of solder joints under thermal fatigue conditions. It models the effect of temperature variations and the frequency of thermal cycles on solder joint reliability.
However, the temperature is stable in the deep sea and it is not needed to apply this law to adapt values given by the manufacturers to KM3NeT life profile.

11.5. Life profile

The product life profile, accounting for example for the operating time, the number of ON/OFF cycles, and the environmental conditions (temperature, humidity, vibration, shocks, and chemical pollution) deeply affects the final product reliability. A careful definition of the life profile of various assemblies inside the KM3NeT detectors is derived through an analysis of data obtained from post-mortem investigation, operation of deployed devices, such as Detection Unit (DU), Base Modules (BM), Digital Optical Modules (DOMs), Junction Boxes (JB), in addition to temperature tests performed in climatic chambers.

The high level life profile required for products deployed in the underwater environment of theKM3NeT detectors is defined as follow:

- **Lifetime:** at least 10 years of operation after KM3NeT completion;
- **Environment:** 2500 m deep for ORCA (250 bars of pressure) and 3500 m deep for ARCA (350 bars of pressure).

The final life profiles differ depending on the assembly considered: the component failure rate should then be evaluated by taking into account the enclosure temperature of the container in which the product is integrated. Specifically, power dissipation, mechanical frame, and thermal dissipation heavily impact the final temperature reached inside the mechanical container. Within the electronic enclosures used for the KM3NeT detector, the final temperature can greatly vary depending on the dissipation medium (oil for the nodes, air for DU BMs, DOMs, and calibration instruments) and the mechanical frame adopted. In the table below, various life profiles taken into account for failure rate calculations are summarized, per assembly (more details are given in [3]):

Assembly type and phase					Temperature and cycling					Humidity	Mechanical
Life Profile name	Assembly type	Phase name	On/ Off	Calendar time (hours)	Ambient temperature (°C)	Δt (°C)	Cycle duration (hours)	Number of cycles	Maximum temperature during cycling	Relative humidity (%)	Random vibrations (GRMS)
IU_13°C	Instrumentation Unit or Cable and deep sea network	ON	ON	8 472 h	13,00 °C	0 °C	706 h	12	13,00 °C	40	0,01 Grms
		OFF	OFF	288 h	13,00 °C	0 °C	24 h	12	13,00 °C	55	0,01 Grms
DU Base	DU Base	ON	ON	8 472 h	20,00 °C	0 °C	706 h	12	20,00 °C	40	0,01 Grms
		OFF	OFF	288 h	13,00 °C	0 °C	24 h	12	13,00 °C	55	0,01 Grms
DU_WRS	DU Base with White Rabbit Switch	ON	ON	8 472 h	24,00 °C	0 °C	706 h	12	24,00 °C	40	0,01 Grms
		OFF	OFF	288 h	13,00 °C	0 °C	24 h	12	13,00 °C	55	0,01 Grms
Node	Junction Box (nodes) and CTF	ON	ON	8 472 h	25,00 °C	0 °C	706 h	12	25,00 °C	40	0,01 Grms
		OFF	OFF	288 h	13,00 °C	0 °C	24 h	12	13,00 °C	55	0,01 Grms
DOM	DOM	ON	ON	8 472 h	17,00 °C	0 °C	706 h	24	17,00 °C	40	0,01 Grms
		OFF	OFF	288 h	13,00 °C	0 °C	24 h	24	13,00 °C	55	0,01 Grms

Table 4: summary of different life profiles considered for the failure rate calculations.

11.6. Failure rate aggregation

The global failure rate for a product, subassembly, or assembly, can be obtained as the sum of each component's failure rate.

A reliability diagram, like the ones reported in Figure 6, 7 or 8, can be used when necessary to evaluate the system failure probability.

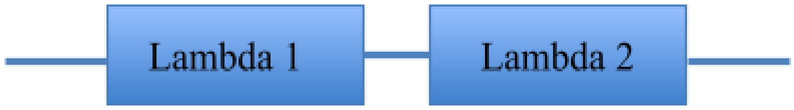


Figure 6: reliability block diagram for the series case.

In the series case, the total success probability *R(t)* for the product to work without failure for a time duration *t* is therefore the product of a single subassembly's success probabilities:

$$R(t) = R_1(t) \times R_2(t) \times ... \times R_n(t)$$

where the individual success probability of the *i*-th element is expressed as in the equation in chap. 11.2.

In the case of redundant blocks, two main distinctions can be made:

- **HOT (or Active) redundant system:** backup components are fully active and operational in parallel with the primary system. For example, all the units are powered on, but only "*n*" over the total are needed to make the system work;

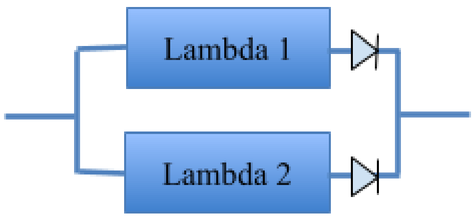


Figure 7: hot redundancy block diagram.

- **COLD (or standby) redundant system:** backup components are not powered on or actively operating until the primary component fails. This means that backup components do not accumulate operating hours or they have lower random failure risk when inactive. Therefore their failure rate may be lower than the primary component. Nevertheless, calculating the reliability of a cold redundant system is more complex compared to hot redundancy, and it can also require complex simulation methods such as Monte Carlo analysis. In fact, the failure rate of the switch-over system itself, including the monitoring system (the mechanism that detects the primary failure and induces the transition to the backup component) should be taken into account. This adds another potential point of failure. Furthermore, the powered-off state of cold/standby components often reduces failure rates. However, this is not the case for specific components which may experience higher failure rates when inactive due to factors such as humidity, and whisker growth.

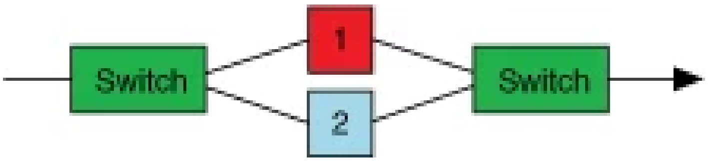


Figure 8: Cold redundancy block diagram.

For KM3NeT, only **the hot (or active) redundancy** scheme is considered for the FIT calculation as a good approximation, since this was mainly selected for KM3NeT due to its robustness and simplicity. Furthermore, FIDES takes into account only random failure rates.
Few cold redundancies are implemented in the ARCA and ORCA nodes. The real impact of cold redundancies will be examined in the system-level RAMS report, once detailed information on the reliability of the switching systems, controlling the redundancy.

For hot redundancy, the success probability $R(t)$ is expressed through the following formula:

$$R(t)_{redundant} = 1 - F(t) = 1 - (F_1(t) \times F_2(t) \times \ldots \times F_n(t))$$

which is not anymore a simple exponential form. Therefore if redundancies are present in the design of a product, single-element failure rates cannot be simply combined to obtain the overall system failure rate. However, the MTTF of such systems can be evaluated.

Following MIL-HDBK-338, for n active parallel elements, each of which has the same constant failure rate λ, the product success probability can be derived as follows:

$$R(t) = 1 - F_{tot}(t) = 1 - (F_1(t) \times F_2(t) \times \ldots \times F_n(t)) = 1 - (1 - e^{-\lambda \times t})^n$$

12. PRODUCT BREAKDOWN STRUCTURE

The KM3NeT neutrino telescope comprises a deep-sea research infrastructure currently under deployment in the abyss of the Mediterranean Sea, and composed of two detectors positioned at two different locations but sharing the same construction technology:

- **Astroparticle Research with Cosmics in the Abyss (ARCA)**, located 100 km away from Capo Passero, the southern tip of Sicily, Italy, at a depth of 3500 m. It will be mainly dedicated to high-energy neutrino astrophysics.

- **Oscillation Research with Cosmics in the Abyss (ORCA)**, situated 40 km offshore the coast near Toulon, France at a depth of about 2450 m, that has been optimized for the study of atmospheric neutrino oscillations.

The principle (as shown in figure 9) at the basis of the two telescopes is the detection of Cherenkov photons induced by relativistic charged particles that originate from neutrino interactions with the detector surroundings. A 3-D array of DOMs is dedicated to detecting the Cherenkov photons, allowing the reconstruction of the trajectory and the energy of the incoming particles. The DOM is the active element of the detector and consists of a 17-inch diameter pressure-resistant glass sphere housing 31 3-inch photomultiplier tubes (PMTs) together with the front-end and readout electronics. Eighteen DOMs, mounted on a vertical structure, form a DU, otherwise referred to as a "strings", which stands on the sea bottom. Each DU is anchored (DU foot) to the seabed and kept taut through a buoy at its top. At the base of each DU, a BM supplies power to the line and enables the transmission of data and commands between the DOMs and the shore station.

Electro-optical cables, connecting the shore station and the submarine infrastructure, with a length of 40 km in ORCA and 100 km in ARCA allows data transmission and powering.

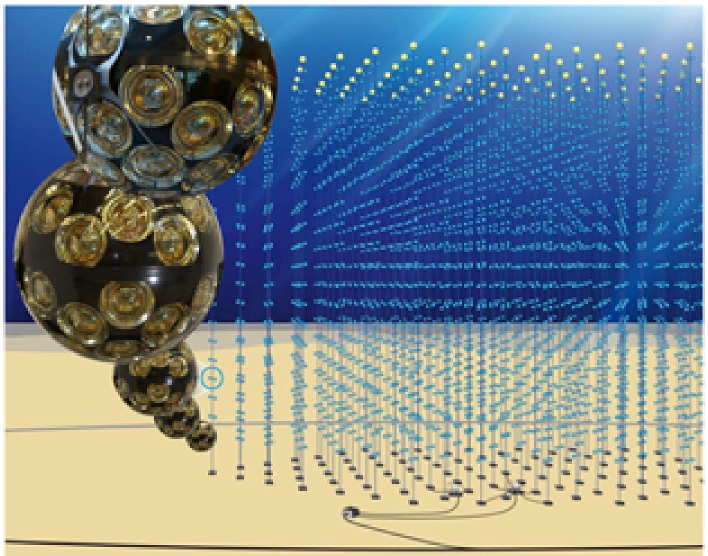


Figure 9: KM3NET artist view

115 DUs will be deployed for the KM3NeT/ORCA infrastructure and 230 DUs for the KM3NeT/ARCA one.

Two technologies have been developed for the data acquisition and time synchronization:

- **Broadcast, at the early stage:** hybrid timing system and data communication exploiting a customized White Rabbit architecture and protocol. It implies an asymmetric connection topology: a single downlink channel from the shore station broadcasting slow control commands to all the DOMs with one direct uplink per DOM transferring the collected data to the onshore resources. The maintenance of this solution is not easy because a customized firmware is needed both in the White Rabbit Switch and in the Central Logic Board (CLB) hosted inside the DOM.
  This solution is implemented in the first 32 deployed DUs for KM3NeT/ARCA and for KM3NeT/ORCA.
  Optical amplifiers are necessary for this architecture, hosted in the DU BMs, but commercial products, initially selected for this purpose, became obsolete.

Due to the above-mentioned limitations and due to constraints in the number of optical fibers available in commercial electro-optical cables, a new system for data transmission and read-out has been developed in recent years.

- **Wet White Rabbit System (namely WWRS)**: based on standard White Rabbit architecture developed at CERN. Communication and data transmission require only two fibers per DU. Nevertheless, the cost is higher and since two White Rabbit switches are hosted in the BMs, more electronics are needed in the off-shore infrastructure, impacting the final reliability. The full Wet White Rabbit-based architecture was selected to address the performance limitations of the broadcast system, resolve the obsolescence of optical amplifiers (EDFAs), and simplify maintenance by ensuring full compatibility with the White Rabbit standard developed by CERN. The increased reliability cost (due to additional electronics) is compensated by the implementation of redundancies. For ORCA, the decision to select the Wet White Rabbit architecture for the remaining 63 DUs is still under discussion (decision planned beginning 2025).

For what concerns the seabed infrastructures:

- **KM3NeT/ORCA:** all 115 DUs are connected to the shore station via 5 nodes, namely Junction Boxes (JB). All the nodes are connected in a loop via inter-node cables. Two MEOCs (Main Electro-Optical Cable), one at each side of the loop, ensure the link with the shore station.
  The footprint of the KM3NeT/ORCA detector, with the elements and connection scheme just described is reported in Figure 10. Each node, allowing the conversion from 3400 VAC to 400 VAC, will provide up to 5 interlink outputs, each of them in turn connected to 4 DUs, in a daisy chain. The mean spacing between DUs is 20 m, with 9 m spacing between each DOM. The DUs are about 200 m high. In the final configuration, 52 Broadcast DUs are planned to be produced. Currently, a discussion is ongoing (by the end of 2024) to decide whether the WWRS solution will be selected for the next 63 DU lines.

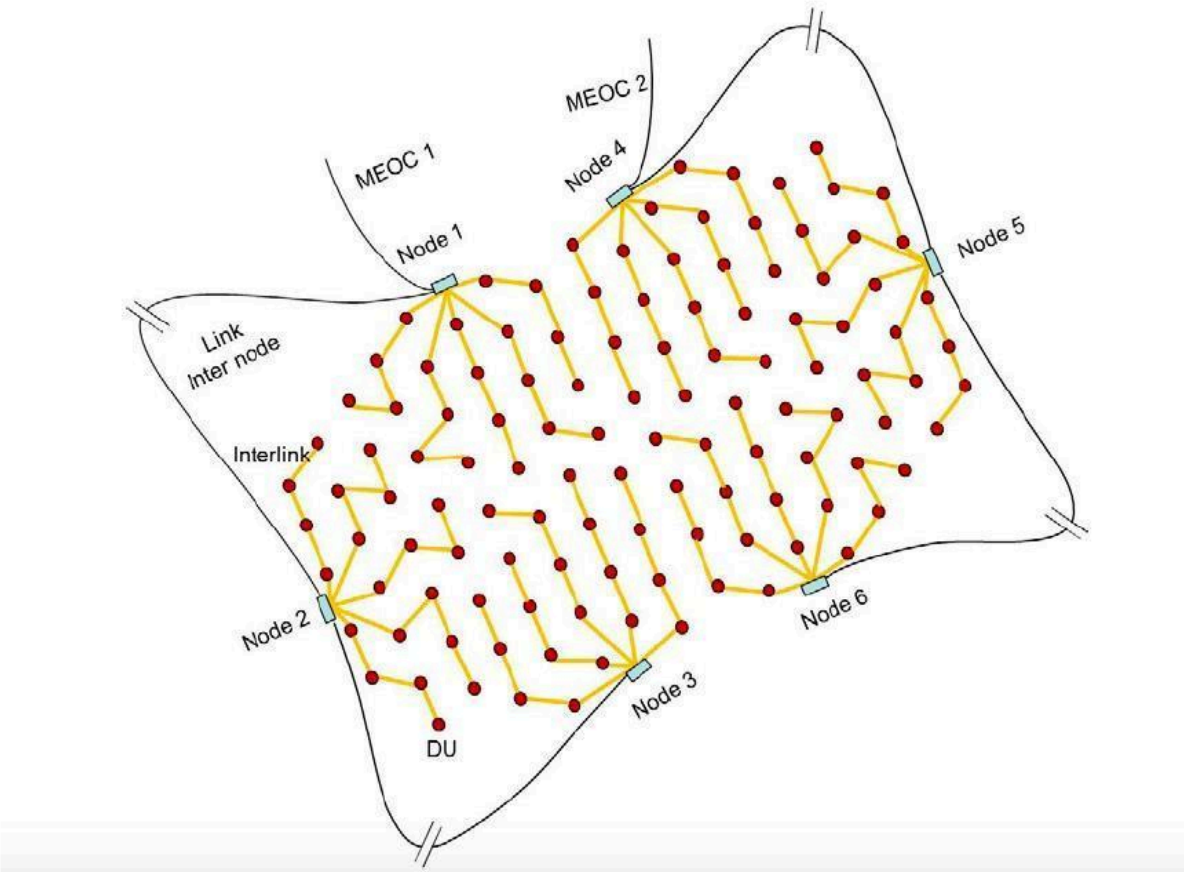


Figure 10: KM3NeT/ORCA footprint and seabed network infrastructure.

- **KM3NeT/ARCA:** 2 building blocks (BB) of 115 DUs each are connected to the onshore station via Junction Boxes (1 JB hosts from 8 to 14 DUs connected). Two MEOCs ensure the connection between the onshore station and the Junction Boxes via several Cable Termination Frame (CTF), allowing for the conversion of the medium DC voltage (6500 V) to low DC voltage (400 V). The footprint of the KM3NeT/ARCA detector is reported in Figure 11.
  The mean horizontal spacing between DUs is 95 m, with 36 m spacing between each DOM. The DUs are about 700 m in height.
  As of today, 32 Broadcast DUs and the first 3 WWRS DUs have been deployed. The next 198 DUs will adopt the WWRS solution.

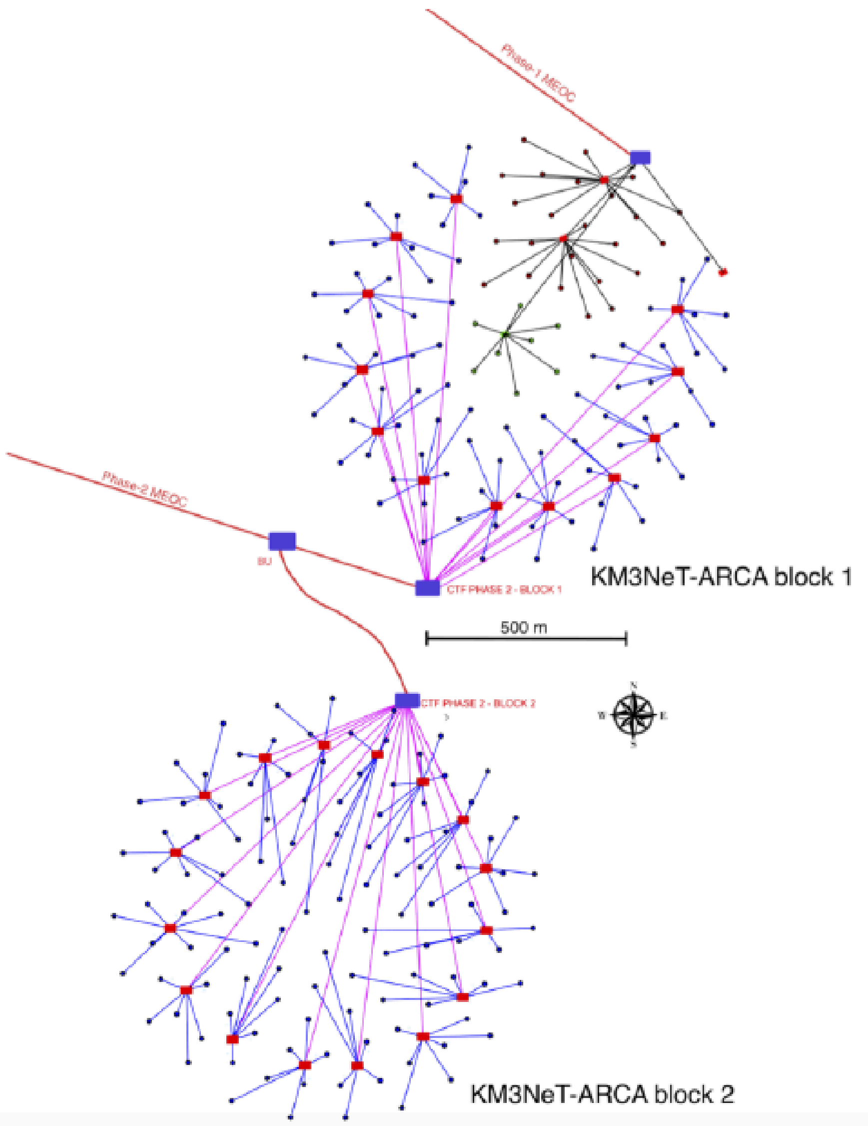


Figure 11: KM3NeT/ARCA footprint and seabed network infrastructure.

13. LIST OF CUSTOM BOARDS ANALYZED WITH THE FIDES METHOD

The table below contains the summary results of the FIT calculation, evaluated for each sub-assembly. More details and associated calculations are presented in the next chapters for each item listed:

PBS	Item name	Variant	Life profile for estimates	FIT	Analysis Chapter
3.2.2.3.2	DU Base Current Limiter (DUL) Board	IT: V1B	DU Base	54	DUL
3.2.2.3.2	DU Base Current Limiter (DUL) Board	IT: V1B	WWRS DU Base	40	DUL
3.2.2.3.3	AC/DC ORCA	D0 and B0 (mother and daughter board)	DU Base	455	AC/DC converter ORCA
3.2.2.3.3	AC/DC ORCA	FR: TIMERV5	DU Base	327	AC/DC converter ORCA
3.2.2.3.6	FPGA Mezzanine Card (FMC) Expansion Board	V3_CU	DU Base	55	FMC
3.2.2.3.6	FPGA Mezzanine Card (FMC) Expansion Board	V4	DU Base	66	FMC V4
3.2.2.3.7	BPS Board	BPS CU V01-R1	DU Base	267	BPS for Broadcast and Calibration unit
3.2.2.3.7	BPS Board	FR: V03-R2 IT: V03-R1	DU Base	211	BPS for Broadcast and Calibration unit
3.2.2.3.8	BCI Interconnecting Board	Default	DU Base	9	BCI
3.2.2.3.9	CLB same product as 3.4.3.2	V2.2.1	DU Base	195	CLB V2.2.1
3.2.2.3.9	CLB same product as 3.4.3.2	V4	WWRS DU Base	256	CLB V4
3.2.2.3.10	BPC - Base Power Supply Converter	V02-R1	WWRS DU Base	78	BPC
3.2.2.3.11	BPD - Base Power Distribution	V02-R1	WWRS DU Base	283	BPD
3.2.2.3.12	WRSCB: White Rabbit Switching Core Board	V02-R1	WWRS DU Base	583 / 276 (redundancy)	WWR SCB
3.2.2.3.13	GBP: Glenair BackPlane	V04-R1	WWRS DU Base	2695 / 382 (redundancy)	WWR GBP
3.2.2.3.13	WRSBP: SFP Backplane	TBD. Finisar solution	WWRS DU Base	1514 / 356 (redundancy)	WRSFPB
3.2.3.1	Hydrophone. Same product as 4.5		DU Base	170	Hydrophone
3.3.1.2.2	DC/DC Converter	FR	DOM	56	PS 12V ORCA
3.3.1.2.2	DC/DC Converter	IT: EF-R1	DOM	135	PS 12V ARCA

PBS	Item name	Variant	Life profile for estimates	FIT	Analysis Chapter
3.4.2.2	PMT Base	HAMA-R12199	DOM	105	PMT Base
3.4.3.1.1	Short SCB (Octopus short)	V3 / V4	DOM	92	Short SCB
3.4.3.1.2	Long SCB (Octopus long)	V3 / V4	DOM	94	Long SCB
3.4.3.2	Central Logic Board (CLB)	V2.2.1	DOM	186	CLB V2.2.1
3.4.3.2	Central Logic Board (CLB)	V4 /V5	DOM	232	CLBV4
3.4.3.2	Central Logic Board (CLB)	V6	DOM	232	Design in validation. Same FIT as CLB V5
3.4.3.4	Compass Board	LSM303	DOM	6,43	
3.4.3.5	Power Conversion Board	V2-3	DOM	697	PBV2.3
3.4.3.5	Power Conversion Board	V3 / V4	DOM	464	PBV4
3.4.3.6	Acoustic Component		DOM	149	Piezo
3.4.3.7	Nano Beacon pulser		DOM	4,4	LED Pulser
4.2.2.8	FMC	V3-CU	DU Base	55	FMC
4.4.5	LPMI+ board	V02	DU Base	96	LPMI
4.4.7	Laser driver board		DU Base	282	Laser driver
4.3.2.4.2	Power and comm interface board (BCI)	FR / IT	DU Base	9	BCI
4.6	RAPS LBL Beacon	MSMTIGI / MSMTIGIW	DU Base	122	LBL Beacon
4.3.2.4	4.3.2.4 IU Base container Instrumentation Unit interface	IU base container	DU Base	66	IU Base container

14. RELIABILITY ANALYSIS OF ELECTRONIC BOARDS

14.1. Introduction

In this chapter, the failure rates for the designed electronic boards and products are calculated. Noticeably, these results are necessary inputs for assembly calculations in the next chapter.

Below is the standardized template format used throughout the document for reporting the analysis results of each product.

14.2. Generic template report for custom products or boards

14.2.1. Description

PBS - Product or component name	PBS Id + Component name
Function:	Product function
Last change date - Version	Last analysis update - on dd/mm/yyyy
Comments	Comments Name of the designer - Work package responsible
Life profile	Indicates the life profile taken into account for the reliability estimates
Reference documents	Schematic, technical design reports, bill of material reference and version…

Functional description:

Describes the functions of the products, along with functional schemes and photos.

Product hierarchy:

Identifies where the product is or will be integrated and its global quantity:

	Product	Product quantity integrated inside the upper-level assembly
Integrated inside		
Integrated inside		
Integrated inside		
Integrated inside		

14.2.2. Failure rate

The predictive reliability calculation is presented below, reporting for each product the FIT value, its reliability and the risk of failure as a function of time. Furthermore, a series of detailed tables show the distribution of failure probabilities by component type, highlighting as well the components that are most likely to contribute to product failure.

Product Failure rate	Value	Unit
Function FIT		$/10^9$ hours
MTTF (Hours)		hours
MTTF (years)		years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)	Expected failing product per complete detector
1	8760			
2	17520			
5	43800			
10	87600			
15	131400			
20	175200			

Contribution by component type:

Lists of the total FIT for the product per component type, for example:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]		
Connectors [ECCO]		
Discrete semiconductors [ECDS]		
Integrated Circuits [ECIC]		
Light Emitting Diode (LED) [ECLE]		
Magnetic Components: Inductors and Transformers [ECIN]		
Optocouplers [ECOP]		
Piezoelectric components: Oscillators and Quartz [ECPZ]		
Printed circuit board (PCB) [ECPC]		
Resistors [ECRE]		
Switches [ECSW]		
Total		

** Where acronyms for component types have the following format [ECXX] : [Electronic Component + abbreviation for the component type]. For example [ECCC]: Electronic Component Ceramic Capacitors.*

Highest component contributors:

Lists the 10 to 20 highest component failure rates.

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT

14.2.3. Conclusion and recommendations

This paragraph indicates if critical points have been found and delivers recommendations to improve reliability, when it is considered possible.

14.3. CLBv2.2.1

14.3.1. Description

Functional description:

The Central Logic Board (CLB) is the main electronic board in the readout chain of KM3NeT. It has the task of digitizing all the events detected by the photomultiplier tubes inside the DOM. This board also configures all the subsystems it hosts and drives the various sensors, integrated on the same CLB PCB, for the position and orientation calibration, i.e. tiltmeter, compass, and temperature sensor. The main component of the CLB is a Kintex FPGA, where are implemented the firmware and software deputed to the time synchronization and communication with the on-shore switching network. In order to synchronize DOMs and BMs in KM3NeT, the CLB integrates the White Rabbit protocol capable of providing a 1 ns time resolution.

The CLBV2.2.1 are integrated into all the DOMs, BMs of the Broadcast DUs. The CLB monitors housekeeping parameters in the base module and also controls the ON/OFF switching of the DU line. It also drives and records data from hydrophones and LBL beacon emitters.

The CLB V2.2.1 is also used inside the Calibration Unit (CU) base container, referred in the text also as Calibration Base (CB). For a detailed description of CLB structure and functionalities see [4].

The CLB board was originally designed for the DOM and later on adapted for the BM to control and steer electronic boards dedicated to powering on DOMs within a string, i.e. the BPS and the AC/DC converter in ORCA, to amplify optical signals through the communication with commercial optical amplifiers, i.e. EDFA, and with instruments (hydrophone, LBL emitter and laser beacon).

Figure 12: the Central Logic Board.

PBS - Product or component name	3.4.3.2 - CLB V2.2.1 DOM
Function:	**Controller board :** DOM: Digitization of the events and DOM control
Last change date - Version	Last analysis update - on 28/08/2024
Comments	Responsibles : Diego Real – David Calvo (IFIC)
Life profile	DOM
Reference documents	Last analysis update - on 28/08/2024 Documents/schematics: Refer to KM3NeT_ELEC_2020_001-CIDL for the documents list. Refer to DOM electronic technical design report : 1. TDR_electronic 2. KM3NeT_ELEC_PRR_CLB_2014_005_Schematics (June 25th, 2014) 3. KM3NeT_ELEC_PRR_CLB_2014_006_Bill_of_Material (June 30th, 2014)

Broadcast DOM product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.2 - Central Logic Board (CLB)	1
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	32 ARCA / 52 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	576 ARCA / 936 ORCA

PBS - Product or component name	3.2.2.3.9 / 4.2.2.6 - CLB V2.2.1 DU base (Broadcast)
Function:	**The Central Logic Board :** CLB Variant 2.2.1 developed for KM3NeT phase 1 (Broadcast). Inside DU base (PBS 3.2.2.3.9): Control DU base switch ON/OFF, EDFA, and instruments. Inside CB (PBS 4.2.2.6): Control Calibration Base (CB) instrument, and BPS switch ON/OFF.
Last change date - Version	CLB V2.2.1 - Last analysis update - on 28/08/2024
Comments	Responsibles : Diego Real – David Calvo (IFIC)
Life profile	DU base

Reference documents	Last analysis update - on 28/08/2024 Documents/schematics: Refer to KM3NeT_ELEC_2020_001-CIDL for the documents list. Refer to DOM electronic technical design report : 4. TDR_electronic 5. KM3NeT_ELEC_PRR_CLB_2014_005_Schematics (June 25th, 2014) 6. KM3NeT_ELEC_PRR_CLB_2014_006_Bill_of_Material (June 30th, 2014)

Broadcast BM product hierarchy:

CLB Variant 2.2.1 developed for the KM3NeT Broadcast scenario. Inside DU base: control DU base switch ON/OFF, EDFA, and instruments.

	Product	**Product quantity integrated inside the upper-level assembly**
	3.2.2.3.9 – CLB V2.2.1	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Container	32 ARCA / 52 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	32 ARCA / 52 ORCA

CB product hierarchy:

Inside the calibration base: control the instruments, and the BPS switch ON/OFF.

	Product	**Product quantity integrated inside the upper-level assembly**
	4.2.2.6 CLB V2.2.1 - CB	1
Integrated inside	4.2.2 Base Container	1
Integrated inside	4.2 CALIBRATION BASE(CB)	1
Integrated inside	4 - Calibration Unit	2 ARCA/ 1 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	2 ARCA / 1 ORCA

14.3.2. Failure rate

CLB V2.2.1 broadcast DOM failure rate :

Description: calculation for the broadcast DOM life profile.

Product Failure rate	Value	Unit
Function FIT	185,65	/10^9 hours
MTTF (Hours)	5386500	hours
MTTF (years)	615	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,84	0,16
2	17520	99,68	0,32
5	43800	99,19	0,81
10	87600	98,39	1,61
15	131400	97,59	2,41
20	175200	96,80	3,20

Contribution by component types:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	64	111
Connectors [ECCO]	40	15
Discrete semiconductors [ECDS]	1	5
Integrated Circuits [ECIC]	14	21
Light Emitting Diode (LED) [ECLE]	0	1
Magnetic Components: Inductors and Transformers [ECIN]	4	15
Optocouplers [ECOP]	0	1
Piezoelectric components: Oscillators and Quartz [ECPZ]	62	4
Printed circuit board (PCB) [ECPC]	1	1
Resistors [ECRE]	0	57
Switches [ECSW]	0	0
Total	**186**	**231**

Highest component contributors :

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
CLBV2: Euroquartz 10.000 MHZ XO53050UITA	X1,X2	19,23	2	38,46
CLBV2: 22 µF Murata GRM31CR61E226KE15L - 1206 - 35 V	C43,C44,C45,C46,C47,C48,C49,C53,C60,C61,C63,C64,C81,C82,C85,C90,C91,C93,C143,C153	1,60	20	32,07
CLBV2: 100 µF JMK316BJ107ML-T Taiyo Yuden - 1206 -10 V	C32,C33,C34,C35,C36,C37,C38,C39,C40	1,60	9	14,43
CLBV2: 25 MHz Mercury Electronics VM53S3-25.000-2.5/-30+75	U9	11,64	1	11,64
CLBV2: 20 MHz IQD Frequency Products CFPV-45 (Farnell 1674677)	U5	11,64	1	11,64
CLBV2: Samtec ASP-134486-01	J34	9,27	1	9,27
CLBV2: Molex 75433-2104	J11, J12	4,45	2	8,89
CLBV2: 100 nf ref GCC0603KRX7R9BB104 - 50 V - Tageo/Phycomp	C2,C56,C57,C58,C59,C68, C69,C72,C76,C78,C83,C84,C86,C89,C92,C94,C95,C96,C97,C105,C107,C108,C110,C116,C124,C125,C129,C130, C141,C142,C144,C145,C146,C148	0,36	24	8,66
CLBV2: SAMTEC MPT_08_630_03_L_V	J1, J3	3,14	2	6,29
CLBV2: Xilinx XC7K160T-2FBG676C	U1	5,20	1	5,20
CLBV2: 4,7 µF TDK C1005X5R0J475M - 0402 - 10 V	C11,C12,C13,C14,C16,C17,C18,C19,C20,C21,C23,C24,C25,C26,C27,C28,C29,C30,C31,C42,C52	0,20	21	4,21
CLBV2: BLM21PG221SN1	L1,L2,L3,L4,L5,L6,L7,L9,L10,L12,L13,L18,L19	0,27	13	3,56

CLB V2.2.1 Broadcast DU BM or CB failure rate (same life profile):

Description: calculation for the Broadcast DU base module life profile.

Product Failure rate	Value	Unit
Function FIT	195,27	/10^9 hours
MTTF (Hours)	5121227	hours
MTTF (years)	585	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,83	0,17
2	17520	99,66	0,34
5	43800	99,15	0,85
10	87600	98,30	1,70
15	131400	97,47	2,53
20	175200	96,64	3,36

Contribution by component types:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	67	111
Connectors [ECCO]	41	15
Discrete semiconductors [ECDS]	1	5
Integrated Circuits [ECIC]	19	21
Light Emitting Diode (LED) [ECLE]	0	1
Magnetic Components: Inductors and Transformers [ECIN]	4	15
Optocouplers [ECOP]	0	1
Piezoelectric components: Oscillators and Quartz [ECPZ]	62	4
Printed circuit board (PCB) [ECPC]	1	1
Resistors [ECRE]	0	57
Switches [ECSW]	0	0
Total	**195**	**231**

Highest component contributors :

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
CLBV2: Euroquartz 10.000 MHZ XO53050UITA	X1,X2	19,23	2	38,46
CLBV2: 22 µF Murata GRM31CR61E226KE15L - 1206 - 35 V	C43,C44,C45,C46,C47,C48,C49,C53,C60,C61,C63,C64,C81,C82,C85,C90,C91,C93,C143,C153	1,67	20	33,41
CLBV2: 100 µF JMK316BJ107ML-T Taiyo Yuden - 1206 -10 V	C32,C33,C34,C35,C36,C37,C38,C39,C40	1,67	9	15,03
CLBV2: 25 MHz Mercury Electronics VM53S3-25.000-2.5/-30+75	U9	11,64	1	11,64
CLBV2: 20 MHz IQD Frequency Products CFPV-45 (Farnell 1674677)	U5	11,64	1	11,64
CLBV2: Samtec ASP-134486-01	J34	9,71	1	9,71
CLBV2: Molex 75433-2104	J11, J12	4,65	2	9,29
CLBV2: 100 nf ref GCC0603KRX7R9BB104 - 50 V - Tageo/Phycomp	C2,C56,C57,C58,C59,C68, C69,C72,C76,C78,C83,C84,C86,C89,C92,C94,C95,C96,C97,C105,C107,C108,C110,C116,C124,C125,C129,C130,C141,C142,C144,C145,C146,C148	0,38	24	9,02
CLBV2: Xilinx XC7K160T-2FBG676C	U1	6,68	1	6,68
CLBV2: SAMTEC MPT_08_630_03_L_V	J1, J3	3,29	2	6,57
CLBV2: 4,7 µF TDK C1005X5R0J475M - 0402 - 10 V	C11,C12,C13,C14,C16,C17,C18,C19,C20,C21,C23,C24,C25,C26,C27,C28,C29,C30,C31,C42,C52	0,21	21	4,39
CLBV2: BLM21PG221SN1	L1,L2,L3,L4,L5,L6,L7,L9,L10,L12,L13,L18,L19	0,29	13	3,79
CLBV2: 10 µF CL10A106MP8NNNC - 0603 - 10 V		1,67	2	3,34
MPTC_01_24_01_630_03_L_V	J4	3,29	1	3,29
CLBV2: Tyco 281274-1	J35	3,29	1	3,29
CLBV2: Molex 75331-0444	J13, J14	1,47	2	2,94

14.3.3. Conclusion and recommendations

No critical point has been identified on CLB V2.2.1. The component showing the highest FIT value is the oscillator. Noticeably, it represents a key element for timing accuracy and synchronization of the board. Hence, some improvements specific to capacitors were taken into account during the development phase of the next variant, CLB V4.

This board also integrates press-fit connectors and Ball Grid Array (BGA) components: special care should be taken during assembly in order to control the soldering quality for the BGA and to apply constraint limitations during press-fit connector insertion. Specific actions and improvements for these processes have been evaluated and will be reported in the RAMS report.

For CLBV2.2.1 only one flash memory stores the firmware. A separate flash for the firmware and data is recommended.

14.4. CLBv4

14.4.1. Description

Functional description:
The CLB V4 is designed to be integrated into the Wet White Rabbit switch base container for DU BMs and into WWRS DOMs.

A specific life profile, namely DU_WR, has been considered for the reliability analysis of CLBV4 integrated in the base container since higher temperatures, compared to the Broadcast counterpart, have been measured, mainly due to the electronic dissipation induced by the introduction of Wet White Rabbit switches.

The main element of the CLB is a Kintex-7 FPGA which implements the acquisition, communication, and synchronization systems of the DOM. The control of all the systems is done through two embedded microcontrollers inside the FPGA, the LatticeMico32 (LM32). Furthermore, an automatic reconfiguration system has been developed for the CLB, capable of storing up to four different firmware and software images, allowing the remote replacement of FPGA images. Several communication interfaces, such as the GPIO, I2C, or UART are exploited for communication with sensors.
Among the several improvements adopted for CLB version 4, there is an additional flash memory to separate data from firmware storage.

The Printed Circuit Board (PCB) of the CLB comprises 12 layers: 6 layers for the signal, 2 for the power supply planes and 4 for the grounding. Special care should be taken to respect signal integrity. The PMT differential lines have been routed with a relative delay lower than 100 ps. The delay between the clock signals is lower than 20 ps. Thanks to the efficiency of the FPGA, the consumption of the CLB is lower than 6 W.

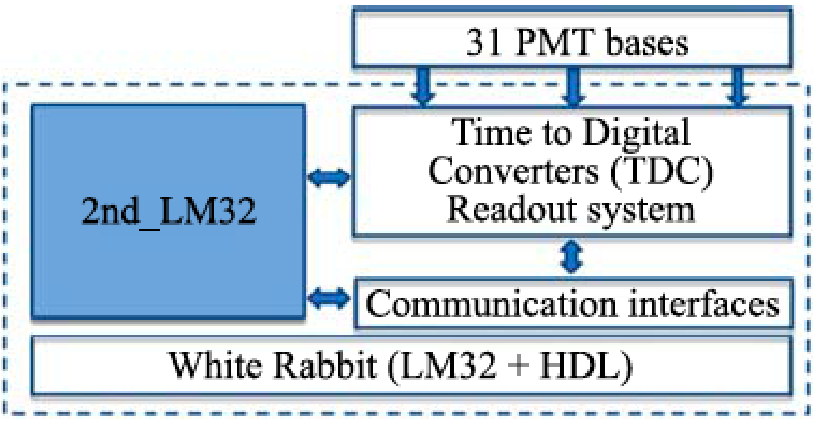


Figure 13: CLB Firmware simplified block diagram.

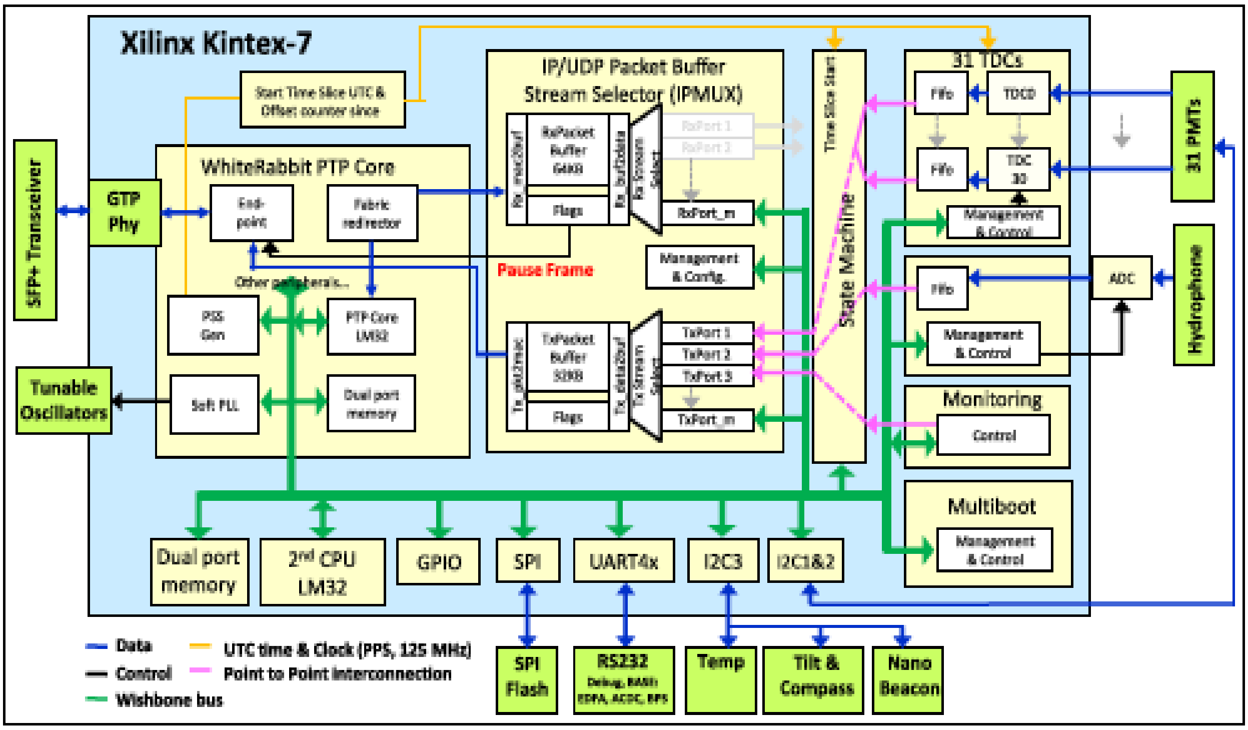


Figure 14: CLB block diagram.

Product:	3.4.3.2.V4 - Central Logic Board (CLB)
Function:	Control DOM electronic
Product version	V4
Responsible	David Calvo (IFIC), Diego real (IFIC) Fernando Carreo (IFIC) Reviewers : P. JANSWEIJER (NIKHEF) / G. PELLEGRINI (INFN) / P. MUSICO (INFN1)
Life profile	DOM
Reference documents	V4 – schematic CLBV4_4 – Last change 17/01/2020 Failure rate Analysis reviewed on March 22nd, 2022 by S.Colonges Based on the Analysis performed by Luis Gutierrez-CLB_Fidesanalysis.pdf from IFIC (27 November 2019).

DOM product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.2 - Central Logic Board (CLB)	1
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	198 ARCA / 63 ORCA
	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	3564 ARCA / 1134 ORCA

Product:	3.2.2.3.9V4 - Central Logic Board (CLB)
Function:	Control DU base switch ON/OFF and instruments
Product version	V4
Responsible	David Calvo (IFIC), Diego real (IFIC) Fernando Carreo (IFIC) Reviewers : P. JANSWEIJER (NIKHEF) / G. PELLEGRINI (INFN) / P. MUSICO (INFN1)
Life profile	DU WRS
Reference documents	V4 – schematic CLBV4_4 – Last change 17/01/2020 Failure rate Analysis reviewed on March 22nd, 2022 by S.Colonges Based on the Analysis performed by Luis Gutierrez-CLB_Fidesanalysis.pdf from IFIC (27 November 2019).

BM product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.9 – CLB V4	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Container	198 ARCA / 63 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	198 ARCA / 63 ORCA

14.4.2. Failure rate

CLB V4 for WWR DU BM life profile:

Description: calculation for the WWR DU base life profile.

Product Failure rate	Value	Unit
Function FIT (/10^9 hours)	256,22	/10^9 hours
MTTF (Hours)	3902964	hours
MTTF (years)	446	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,78	0,22
2	17520	99,55	0,45
5	43800	98,88	1,12
10	87600	97,78	2,22
15	131400	96,69	3,31
20	175200	95,61	4,39

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	39,19	181
Connectors [ECCO]	66,51	14
Discrete semiconductors [ECDS]	1,39	7
Integrated Circuits [ECIC]	50,48	31
Magnetic Components: Inductors and Transformers [ECIN]	10,41	33
Piezoelectric components: Oscillators and Quartz [ECPZ]	85,00	6
Printed circuit board (PCB) [ECPC]	0,82	1
Resistors [ECRE]	0,09	108
Switches [ECSW]	1,80	2
Tantalum capacitors [ECTC]	0,51	6
Total	**256,22**	**389**

Highest component contributors:

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
XO53_10 MHZ	X1; X2	19,23	2	38,46
XO53050UITA - OSCILADOR, 25 MHZ	U5; U64	11,64	2	23,27
OSCILADOR, 125 MHZ	U52; U53	11,64	2	23,27
GLENAIR FTLF1318* connector	U13	18,38	1	18,38
CON754332104 Molex	J11; J12	5,81	2	11,62
Samtec ASP-134486-01	J34	10,32	1	10,32
LT1962-3.3*	U39;U49;U50;U51	2,37	4	9,47
xilinx XC7K160TFBG676	U1	9,26	1	9,26
100 µF EMK325ABJ107MM-T - 16 V-capa cer	C32;C33;C34;C35;C36;C37;C38;C39;C40;C161	0,74	10	7,43
100 µF EMK325ABJ107MM-T	C32;C33;C34;C35;C36;C37;C38;C39;C40;C161	0,74	10	7,43

CLB V4 for DOM life profile:

Description: calculation for the DOM life profile.

Product Failure rate	Value	Unit
Function FIT (/10^9 hours)	232,48	/10^9 hours
MTTF (Hours)	4301481	hours
MTTF (years)	491	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,80	0,20
2	17520	99,59	0,41
5	43800	98,99	1,01
10	87600	97,98	2,02
15	131400	96,99	3,01
20	175200	96,01	3,99

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	35,66	181
Connectors [ECCO]	59,94	14
Discrete semiconductors [ECDS]	0,74	7
Integrated Circuits [ECIC]	39,16	31
Magnetic Components: Inductors and Transformers [ECIN]	9,04	33
Piezoelectric components: Oscillators and Quartz [ECPZ]	85,00	6
Printed circuit board (PCB) [ECPC]	0,61	1
Resistors [ECRE]	0,08	108
Switches [ECSW]	1,80	2
Tantalum capacitors [ECTC]	0,45	6
Total	**232,48**	**389**

Highest component contributors:

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
XO53_10 MHZ	X1; X2	19,23	2	38,46
XO53050UITA - OSCILADOR, 25 MHZ	U5; U64	11,64	2	23,27
OSCILADOR, 125 MHZ	U52; U53	11,64	2	23,27
xilinx XC7K160TFBG676	U1	17,39	1	17,39
GLENAIR FTLF1318*	U13	16,57	1	16,57
CON754332104 Molex	J11; J12	5,24	2	10,48
Samtec ASP-134486-01	J34	9,27	1	9,27
100 µF EMK325ABJ107MM-T - 16 V-capa cer	C32;C33;C34;C35;C36;C37;C38;C39;C40;C161	0,68	10	6,76
100 µF EMK325ABJ107MM-T	C32;C33;C34;C35;C36;C37;C38;C39;C40;C161	0,68	10	6,76
SAM13131CT-ND CONN RCPT	J35	5,24	1	5,24

14.4.3. Conclusion and recommendations

The main differences between CLB V2 and V4 in terms of reliability are due to the adoption of a new compass module and to the integration of additional flash memory in the V4 design. Furthermore, higher derating has been applied on capacitors when possible. However, since White Rabbit switches contained in the WWRS DUs require more FPGA resources, the reliability of the CLB FPGA has been estimated using a temperature rise of 50°C with respect to the ambient temperature, instead of 35°C measured, to consider the worst case scenario (for example an implemented firmware with higher consumption and dissipation).

Two other variants are currently under validation from the KM3NeT collaboration:

- CLB V5: new Octopus connector ⇒ Molex connectors (75433-2104) replaced by SAMTEC connectors (HDTM-4-08-1-S-VT-0-1 and HPTS4);
- CLB V6: Glainer transceiver interface replaced by a SFP cage interface (Finisar SFP selected).

As the pin number is the same, there is no significant impact on the reliability estimates, and CLB V4 estimates can be applied for V5 and V6 variants.

14.5. Optical transceiver

14.5.1. Description

Functional description:

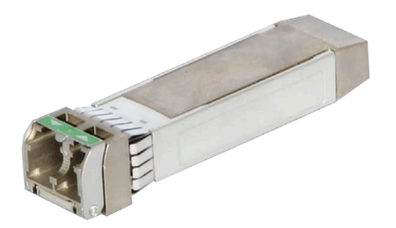
Optical transceivers are small, self-contained and off-the-shelf electronic devices that have a transmitter and receiver pair. They work by receiving light pulses through an optical fiber cable and converting them into electrical signals. All the data communication through the KM3NET deep-sea network is performed through optical fibers both in the Broadcast (Phase 1) and in the Wet White Rabbit scenario (see Chapter 12 for more details). They could be SFP module (small Form-Factor Pluggable, tunable or not) or PCB module (Glenair transceiver). The choice of the transceiver has evolved along the detector design to take into account their availability (long-term delivery), their cost, and also their reliability.

The table below lists the different references of optical transceivers used for KM3NET:

Transceiver reference	Integrated with	Description
SFP OE solutions RDP12SZX-SxxC/H GbE SFP DWDM Transceiver (80 km)	CLB V2.2.1 (DOM Broadcast, DU base to shore station communication). Glenair Backplane and CLB V4, V5, V6 for DU base.	1.25 Gbps - 80 km. Allows long-distance optical communication from DU Base to the shore station.
Lumentum SFP TRS70xxFxCPA000-x	CLB V2.2.1 (DOM Broadcast, DU base to shore station communication). Glenair Backplane and CLB V4, V5, V6 for DU Base.	80 km - up to 10 Gb - Tunable SFP - 0 Gb. Allow to select the optical channel (tunable).
Glenair transceiver	CLB V4 and V5 (inside WR DOM), Glenair Backplane (DU Base White Rabbit Switch for communication between DU base and the 18 DOM of the DU line).	Glenair 057-0231 is derived from 050-341, which is a ruggedized harsh environment PCB Mount Transceiver with electrical and optical functionality equivalent to SFP transceivers but with a mechanical design that is suited to the harsh temperature and vibration environments found in Military, Aerospace, Railway. 1 Gb / 10 km maximum - 1270 / 1330 nm.
Finisar FTLX2072D3xx	CLB V6 (inside DOM), SFP Backplane (DOM to Backplane communication).	SFP+ Low cost, high reliability, available for purchase SFP module. 10 Gb / 10 km max.

14.5.2. Failure rate

The OE solutions SFP for DU BM life profile :

PBS - Product or component name	3.2.2.2.6 - SFP Transceiver CLB base / Broadcast
Function:	Optical communication between the shore station and DU BM Broadcast CLB
Last change date - Version	7/04/2019
Comments	Value from the manufacturer for the DU Base broadcast life profile
Reference documents	Data from the manufacturer: Calculated life statistic report - OE Solutions for SFP+ Reference : 190807_Calculated_Life_Statistics_Report_(1.25Gbps_DWDM_SFP+) 

Product Failure rate	Value	Unit
Unit FIT	96,40	/10^9 hours
MTTF (Hours)	10373444	hours
MTTF (years)	1184	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,92	0,08
2	17520	99,83	0,17
5	43800	99,58	0,42
10	87600	99,16	0,84
15	131400	98,74	1,26
20	175200	98,33	1,67

OE solution SFP FIT for DOM life profile :

PBS - Product or component name	3.4.3.2.3 - Optical line terminator/Broadcast
Function:	Optical communication between DOM CLB Broadcast and shore station
Last change date - Version	7/04/2019
Comments	Value from the manufacturer for DOM Broadcast life profile
Reference documents	Data from the manufacturer: Calculated life statistic report - OE Solutions for SFP. Reference: 190807_Calculated_Life_Statistics_Report_(1.25Gbps_DWDM_SFP+) - Calculated FIT Rate based on GR-468 and Accelerated Aging Test Data 

Product Failure rate	Value	Unit
Unit FIT	63,80	/10^9 hours
MTTF (Hours)	15673981	hours
MTTF (years)	1789	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,94	0,06
2	17520	99,89	0,11
5	43800	99,72	0,28
10	87600	99,44	0,56
15	131400	99,17	0,83
20	175200	98,89	1,11

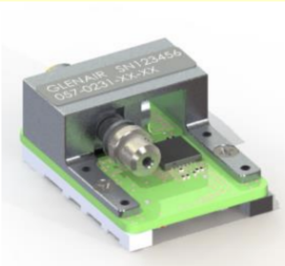
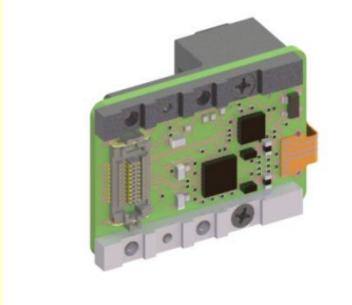
Lumentum TSFP FIT for DOM life profile :

PBS - Product or component name	3.4.3.2.3 - Optical line terminator/Broadcast
Function:	Optical communication between DOM CLB Broadcast and shore station
Last change date - Version	14/03/14
Comments	Value from the manufacturer for DOM Broadcast life profile
Reference documents	Data from the manufacturer: Calculated life statistic report - Lumentum **Reference :** Lumentum_22061690_REV_00_TSFP_Plus_GEN_II_FIT_Estimate.pdf 

Product Failure rate	Value	Unit
Unit FIT	197	$/10^9$ hours
MTTF (Hours)	5076142	hours
MTTF (years)	579	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,83	0,17
2	17520	99,66	0,34
5	43800	99,14	0,86
10	87600	98,29	1,71
15	131400	97,44	2,56
20	175200	96,61	3,39

Glenair for DOM life profile :

PBS - Product or component name	**3.4.3.2.3 - Optical line terminator**
Function:	Optical communication between DOM CLB at 20°C and shore station
Last change date - Version	9/11/2021
Comments	Value from the manufacturer for DOM life profile: for transceiver integrated into a DOM
Reference documents	Data from the manufacturer : 217Plus 20C 30%H 0.5G 057-0231 MTBF  

Product Failure rate	**Value**	**Unit**
Unit FIT	92,80	/10^9 hours
MTTF (Hours)	10775978	hours
MTTF (years)	1230	years

Mission (year)	**Duration (hours)**	**Reliability (%)**	**Unit failure risk (%)**
1	8760	99,92	0,08
2	17520	99,84	0,16
5	43800	99,59	0,41
10	87600	99,19	0,81
15	131400	98,79	1,21
20	175200	98,39	1,61

Glenair for WWRS DU BM life profile:

PBS - Product or component name	3.4.3.2.3 - Optical line terminator
Function:	Optical communication between DOM CLB at 25°C and shore station
Last change date - Version	09/11/2021
Comments	Value from the manufacturer for DU Base WRS life profile
Reference documents	Data from the manufacturer : 217Plus 25C 30%H 0.5G 057-0231 MTBF

Product Failure rate	Value	Unit
Unit FIT	126,69	/10^9 hours
MTTF (Hours)	7893283	hours
MTTF (years)	901	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,89	0,11
2	17520	99,78	0,22
5	43800	99,45	0,55
10	87600	98,90	1,10
15	131400	98,35	1,65
20	175200	97,80	2,20

Note: values have been calculated assuming the worst-case scenario. Using FIDES part count the evaluation is a FIT of 69 for 20 years for DOM life profile.

Finisar:

For the WWR scenario (CLB V6, and SFP backplane), the SFP Finisar solution has been selected.

PBS - Product or component name	3.4.3.2.3 - Optical line terminator
Function:	Optical communication between DOM CLB and shore station
Last change date - Version	13/09/2024
Comments	Value from manufacturer at 40°C
Reference documents	Data from the manufacturer: SR-332 - Calculation temperature not explained in the FINISAR MTBF report. Assumed to be worst case at 40°C. Pi Factor KM3NET applied for worst-case consideration 

Product Failure rate	Value	Unit
Unit FIT	52,50	$/10^9$ hours
MTTF (Hours)	19047619	hours
MTTF (years)	2174	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,95	0,05
2	17520	99,91	0,09
5	43800	99,77	0,23
10	87600	99,54	0,46
15	131400	99,31	0,69
20	175200	99,08	0,92

14.5.3. Conclusion and recommendations

Special attention has been given to the selection of SFP transceivers. While Glenair transceivers demonstrate good reliability, the manufacturer does not provide guarantees for long-term commercial availability. Additionally, their power consumption and cost are higher compared to the Finisar SFP transceivers, whose manufacturer claims better performance both in terms of reliability and energy efficiency.

14.6. EDFA

14.6.1. Description

Functional description:

The EDFA is a high-power Erbium-Doped Fiber Amplifier for optical signal amplification.

PBS - Product or component name	3.2.2.2.2 - Optical Amplifier
Function:	Optical amplifier hosted in the DU Base or in the node
Last change date - Version	30/07/2018
Comments	This reference is no longer available. All modules have been purchased for KM3NeT broadcast. New reference is under study in December 2024.
Reference documents	Data from the manufacturer (calculated at 40°C): FIT_rate_analysis_offshore_type_L_M_E_C_France-3.pdf EDFA 2018 FIT rate analysis type N and P 

Product hierarchy:

EDFAs are commercial components integrated into several KM3NeT assemblies for Broadcast architecture:

- Nodes (ORCA and ARCA).
- DU base modules (ORCA and ARCA).
- Calibration base (ORCA and ARCA).

14.6.2. Failure rate

The EDFA FIT values are given by the manufacturer at 40°C. Thanks to the Arrhenius law these values have been derived at the reference temperature of 20°C.
However, for an EDFA component the activation energy determination is complex as it is an assembly composed of different types of components.
Generally, for this type of complex optical components, the recommended activation energy (*Ea*) is in the range of 0.5 to 0.7 eV, which typically covers:

1. Active components and lasers (Er^{3+} doped lasers): ~0.6-0.7 eV (up to 1 or 1.2 eV for transistors).
2. Passive electronic components: ~0.3-0.6 eV.
3. Passive optical components (fibers, connectors, thermo-mechanical effects): ~0.4-0.5 eV.

A recommended median value would be 0.5 which offers a reasonable approximation for the entire EDFA architecture. Values for each EDFA type are:

Component designation	**Unit FIT at 40°C (manufacturer data)**	**Recalculated Unit FIT at 25°C**	**Recalculated Unit FIT at 20°C**
EAU-160-C3-W-10-E, type E	453	178	128
EAU-100-C3-W-20-L, Type L	447	176	126
EAU-30-C3-W-15-M, Type M	447	176	126
EAU-100-C3-20-C, Type C	398	157	112
EAU-100-C3-W-20-N, Type N	476	187	134
EAU-30-C3-W-20-P, Type P	476	187	134

In summary :

Product Failure rate	**Value**	**Unit**
Unit FIT	128 to 134 depending on the EDFA type for BM 157 to 187 for Nodes	$/10^9$ hours
MTTF (Hours)	8 928 571 to 7 462 687 for BM 6 369 427 to 5 347 594 for nodes	hours
MTTF (years)	1 019 to 852 for BM 727 to 610 for nodes	years

Note: the Arrhenius law has been applied in order to calculate the FIT at 20°C for the worst case FIT EDFA model.

For the worst-case scenario for the node (FIT=187), the following time dependency was calculated:

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,84	0,16
2	17520	99,67	0,33
5	43800	99,18	0,82
10	87600	98,38	1,62
15	131400	97,57	2,43
20	175200	96,78	3,22

For the worst-case scenario for the base module (FIT=134), the following time dependency was calculated:

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,88	0,12
2	17520	99,77	0,23
5	43800	99,41	0,59
10	87600	98,83	1,17
15	131400	98,25	1,75
20	175200	97,68	2,32

14.6.3. Conclusion and recommendations

The estimates above consider EDFA electronics component random failure rate. It excludes the failure rate related to data retention of the flash memory embedded in the EDFA.
EDFAs are commercial components, only provided by IPG photonics for the form factor needed inside base modules. This component is now obsolete, and no longer available on the market. This is one of the reasons why KM3NeT introduced for ARCA a new standard White Rabbit architecture after the 32 first DUs of the detector construction, which does not require EDFAs and minimizes their number for the ARCA JBs. IPG photonics is committed to supply the limited number of EDFAs which are needed to complete the construction of ARCA and ORCA. The decision regarding ORCA is still pending: either select and approve a new EDFA manufacturer and reference or develop the next-generation Wet White Rabbit architecture. At the time we write this report, "BKTEL", an alternative EDFA manufacturer with a suitable form factor, has been identified. Analysis and verification are planned to be performed before June 2025.

14.7. Power Board (PB) v2.3

14.7.1. Description

Functional description:

The Power conversion Board (PB) inside the DOM is dedicated to deriving all different client voltage levels from the 12 V input voltage. Specifically, it produces six regulated power rails: 1 V, 1.8 V, 2.5 V, 3.3 V, 3.3 V-PMT, and 5 V to power various electronic modules within the DOM. It also provides voltages (from 0 to 30 V, 5 mA) programmable via an I2C interface to power the Nanobeacon module. The PB is coupled with the CLB through three board-to-board connectors (see the black connectors in the figure below). Apart from the power rails, the PB has additional connections for I2C communication as well as remote sense and diagnostic signals.

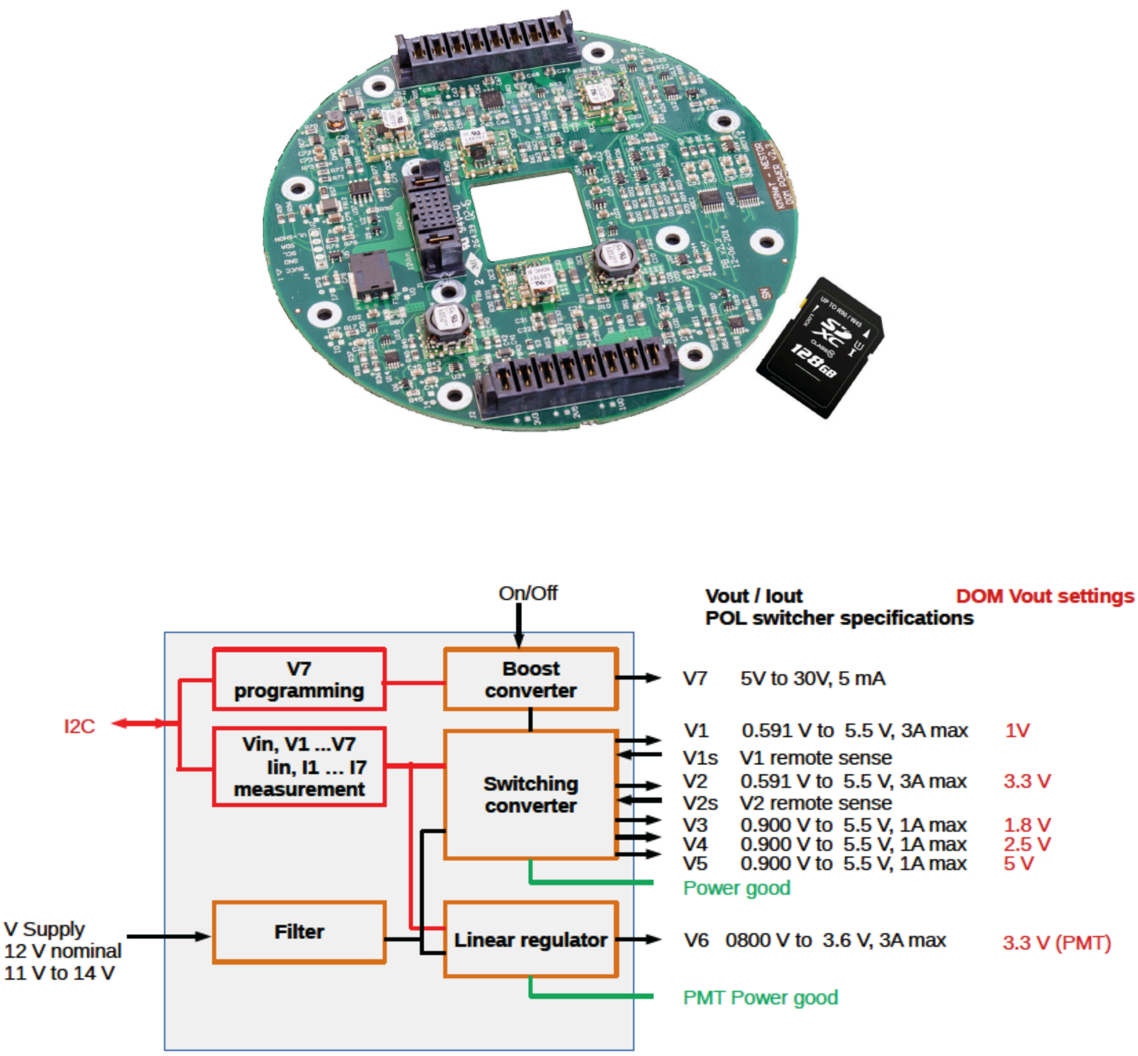


Figure 15: Power Conversion Board (top) and Power board block diagram (bottom).

Product:	**3.4.3.5 - PB V2.3**
Function:	Convert Power conversion board: 12 V DC into useful voltage for the DOM
PBS number	3.4.3.5
Product version	V2.3
Responsible	David Calvo (IFIC), Diego real (IFIC) Fernando Carreo (IFIC)
Life profile	DOM
Reference documents	Schematic : KM3NeT_ELEC_PRR_PB_2014_005_Schematics (16/06/2014) BOM: 01_DOMPWR_v2.2 01DOMPWR_v2.1_BlockDiagram DOM Power Supply Board – Product Readiness Review Analysis performed using Pedro_Mora_Gómez assumptions : "Trabajo de Fin de Grado-6 : ANÁLISIS DE FIABILIDAD ELECTRÓNICA DE LAS TARJETAS PBV2 Y PBV4 CON EL MÉTODO FIDES - September 2020"

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.5 - Power Board	1
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	32 ARCA / 52 ORCA (*)
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	576 ARCA / 936 ORCA (*)

*a final decision for WWRS solution should be taken beginning 2025, affecting the overall number of integrated PBv2.3 into the ORCA detector.

14.7.2. Failure rate

The PB V2.3 are integrated into the 32 ARCA Broadcast DUs and into the 52 ORCA (to be confirmed beginning 2025) Broadcast DUs.

PB V2.3 failure rate probability for DOM life profile:

Product Failure rate	Value	Unit
Function FIT	696,67	$/10^9$ hours
MTTF (Hours)	1435395	hours
MTTF (years)	164	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,39	0,61
2	17520	98,79	1,21
5	43800	96,99	3,01
10	87600	94,08	5,92
15	131400	91,25	8,75
20	175200	88,51	11,49

Contribution by component types:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	502	6
Ceramic capacitors [ECCC]	138	77
Connectors [ECCO]	9	4
Discrete semiconductors [ECDS]	4	2
Integrated Circuits [ECIC]	38	34
Magnetic Components: Inductors and Transformers [ECIN]	3	17
Printed circuit board (PCB) [FCPB]	2	1
Resistors [ECRE]	0	91
Total	**697**	**232**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
DC/DC POL Converter 12 Vin 0.9-5.5 Vout 1 A 5 W Neg Polarity	OKL-T/1-W12N-C	DC6, DC5, DC3	80,59	3	241,77
		DC2	80,59	1	80,59
DC/DC POL Converter 12 Vin 0.591-5.5 Vout 3 A 15 W Neg Polarity	OKL-T/3-W12N-C	DC1	99,36	1	99,36
		DC4	80,59	1	80,59
X5R 6.3 V 0805 22 uF 20%, TC 15%, -55/+85°C	22uF	C68, C67, C46, C43,C42, C41, C33, C32, C31, C23, C22, C21, C19, C18, C16, C15, C9, C8	3,13	18	56,35
X5R 25 V 0805 10 uF 10%, -55/+85°C	10uF 25V	C71, C65, C64, C63, C61, C60, C53, C52, C51, C50, C40, C30, C20, C11, C10, C4, C3, C2	3,13	18	56,35
X5R 6.3 V 0805 10 uF 20%, TC 15%, -55/+85°C	10uF 6.3V	C98, C96, C93, C91, C12	3,13	5	15,65
Current sense amp, 50 V/V ±1%, 2.7-26 V, 0.04 V/us, 14 kHz, 35 uV	INA213AIDCK	U36, U35, U34, U33, U32, U31, U30	1,25	7	8,75
Vref, +3.3 V, tol 0.05% 1.65 mV, acc 10 ppm/C, 0/+70°C SOT-23	LT6656ACS6-3.3#TRMP BF	VREF1	5,82	1	5,82
DC/DC CONV, 85 mA, Boost, TSOT23-8	LT3464ETS8	DC7	5,82	1	5,82

14.7.3. Conclusion and recommendations

DC/DC converters and capacitors are the major contributors to the board failure rate. Recommendations have been provided to the designer to improve capacitor derating, even though the value assumed in this analysis represents the worst-case scenario. The analysis of this board has been performed thanks to the contribution of the IFIC Valencia institute in Spain.

The FIDES analysis does not consider the mechanical weak points of connectors.

Connector reliability and locking should be carefully checked especially during integration processes. Special attention must be taken to the test procedure and test reports to check the conformity of the PB with the requirements. ElectroMagnetic Interference and ElectroMagnetic Compatibility tests are highly suggested to check the PB induced noise on other systems, shielding inductors if necessary. Mechanical weaknesses have been detected on the DC1 to DC7 modules and inductors soldering. In fact, small mechanical chocks can induce unsoldering, therefore using potting or glue to protect these “components” is highly recommended.

Changes related to derating aspects have been applied for the design of the following version of the power board (PBv4).

Degraded mode:
Some failure modes are not critical for the DOM but degrade its nominal functionality. For example, the supply failures of Piezo, Nano Beacon, or calibration devices are not critical. Therefore, the FIT contribution of these components can be removed from the overall computation, only if the failure has no propagation effect: if a component is short-circuited, the failure could be propagated to the whole system in case no fuses are implemented. For sub-systems powered by DC-DC converters, there is no risk of failure propagation: an overcurrent protection is implemented on these components. UTE C80-810 RDF2000 data handbook -failure repartition is not covered in the Fides handbook- collects generic information about components failure modes in order to analyse the effects. However, in the most relevant cases, degraded modes will be evaluated in the system-level FMECA analysis in the RAMS report.

14.8. Power Board (PB) v4

14.8.1. Description

Functional description:

See the functional description given in the PBv2.3 section above.

PBS - Product or component name	3.4.3.5 - PB V4 DOM
Function:	Convert Power conversion board: 12 V DC into useful voltage for the DOM
Last change date - Version	28/8/2024
Comments	Responsibles : David Calvo (IFIC), Diego real (IFIC) Fernando Carreo (IFIC) DOM life profile
Reference documents	KM3NeT_ELEC_MRR_2021_Schematic_PBv4 KM3NeT_ELEC_MRR_2021_PBV4_BOM_Mass "Pedro_Mora_Gómez Trabajo de Fin de Grado-6 : ANÁLISIS DE FIABILIDAD ELECTRÓNICA DE LAS TARJETAS PBV2 Y PBV4 CON EL MÉTODO FIDES September 2020" The Power Board of the KM3NeT Digital Optical Module: Design, Upgrade, and Production https://www.mdpi.com/2079-9292/13/11/2044

Product hierarchy for DOM:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.5 V4 - Power Board	1
Integrated inside	3.4.3.5 - Power Board	1
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	63 ORCA / 198 ARCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	1134 ORCA / 3564 ARCA

PBS - Product or component name	3.4.3.5 - PB V4 DOM (installed inside DU WRS)
Function:	Convert Power conversion board: 12 V DC into useful voltage for the DOM
Last change date - Version	28/8/2024
Comments	Responsibles : David Calvo (IFIC), Diego real (IFIC) Fernando Carreo (IFIC) DU WRS Life profile
Reference documents	KM3NeT_ELEC_MRR_2021_Schematic_PBv4 KM3NeT_ELEC_MRR_2021_PBV4_BOM_Mass "Pedro_Mora_Gómez Trabajo de Fin de Grado-6 : ANÁLISIS DE FIABILIDAD ELECTRÓNICA DE LAS TARJETAS PBV2 Y PBV4 CON EL MÉTODO FIDES September 2020" The Power Board of the KM3NeT Digital Optical Module: Design, Upgrade, and Production https://www.mdpi.com/2079-9292/13/11/2044

Product hierarchy for DU WWR:

	Product	Product quantity integrated inside the upper-level assembly
Integrated inside	**3.4.3.5 V4 - Power Board**	1
Integrated inside	3.2.2 - Base Container	198 ARCA / 63 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	198 ARCA / 63 ORCA

14.8.2. Failure rate

PB V4 for DOM life profile:

Description: calculation for DOM life profile.

Product Failure rate	Value	Unit
Function FIT	464,54	/10^9 hours
MTTF (Hours)	2152664	hours
MTTF (years)	246	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,59	0,41
2	17520	99,19	0,81
5	43800	97,99	2,01
10	87600	96,01	3,99
15	131400	94,08	5,92
20	175200	92,18	7,82

Contribution by component type:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	360	4
Ceramic capacitors [ECCC]	26	80
Connectors [ECCO]	8	4
Discrete semiconductors [ECDS]	4	2
Fuses [ECFU]	1	1
Integrated Circuits [ECIC]	63	35
Magnetic Components: Inductors and Transformers [ECIN]	3	17
Resistors [ECRE]	0	80
Total	**465**	**223**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
OKL-T/3-W12N-C		DC1,DC4	99,36	2	198,73
OKL-T/1-W12N-C		DC2,DC6	80,59	2	161,18
MAX17542GATB+		DC5	8,86	1	8,86
INA213AIDCK	current sense	U30,U31,U32,U33,U34,U35,U36	1,25	7	8,75
GRM21BR61H106ME43L	10 uF 50 V	C02, C03,C10,C11,C20,C40,C50,C60, C64,C75,C100	0,68	11	7,44
LT6656ACS6-3.3#TRMPBF	VREF 3.3 V	VREF1	5,82	1	5,82
LT3464ETS8		DC7	5,82	1	5,82
LP2981AIM5-5.0	LDO 5.0 V	VR1	5,82	1	5,82
LP2981AIM5-3.3	LDO 3.3 V	VR4	5,82	1	5,82
MCP606T-I/OT	opAmp	U4,U5,U7,U8,U9,U10	0,83	6	5,00

In the table above the worst-case scenario has been considered. The LED beacon and 5 V supply for piezo are of secondary importance: their failures will not affect physics data but simply degrade the nominal DOM functionality. This impact is not yet precisely calculated, however a quick estimate leads to FIT values 0.5% lower over 20 years.

PB V4 for WWR BM life profile:

Description: calculation for WWR base module life profile.

The power board V4 will also be integrated into WWR DU BMs in order to supply the corresponding CLB V4. In this specific container, CLB V4 is also used to supply and control Long BaseLine (LBL) emitters and to steer the two boards dedicated to the powering of the DOMs within the same string, namely the Base Power supplier Converter (BPC) and the Base Power Distribution (BPD) boards.
The failure of this assembly will result in a degradation of the system performance but physics data will still be available.

Product Failure rate	Value	Unit
Unit FIT	682,09	/10^9 hours
MTTF (Hours)	1466089	hours
MTTF (years)	167	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,40	0,60
2	17520	98,81	1,19
5	43800	97,06	2,94
10	87600	94,20	5,80
15	131400	91,43	8,57
20	175200	88,74	11,26

Contribution by component type:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	524	4
Ceramic capacitors [ECCC]	28	80
Connectors [ECCO]	9	4
Discrete semiconductors [ECDS]	7	2
Fuses [ECFU]	1	1
Integrated Circuits [ECIC]	109	33
Magnetic Components: Inductors and Transformers [ECIN]	4	17
Resistors [ECRE]	0	80
Total	**682**	**221**

Highest component contributors:

Component designation	***Value or version***	***Refdes***	**Unit FIT**	**Quantity**	**Total FIT**
OKL-T/3-W12N-C		DC1,DC4	144,65	2	289,30
OKL-T/1-W12N-C		DC2,DC6	117,32	2	234,64
INA213AIDCK	current sense	U30,U31,U32,U33,U34,U35,U36	2,37	7	16,57
MAX17542GATB+		DC5	15,52	1	15,52
LT6656ACS6-3.3#TRMPBF	VREF 3.3 V	VREF1	10,20	1	10,20
LT3464ETS8		DC7	10,20	1	10,20
LP2981AIM5-5.0	LDO 5.0 V	VR1	10,20	1	10,20
LP2981AIM5-3.3	LDO 3.3 V	VR4	10,20	1	10,20
MCP606T-I/OT	opAmp	U4,U5,U7,U8,U9,U10	1,58	6	9,47
GRM21BR61H106ME43L	10 uF 50 V	C02, C03,C10,C11, C20,C40,C50, C60,C64,C75, C100	0,74	11	8,18

14.8.3. Conclusion and recommendations

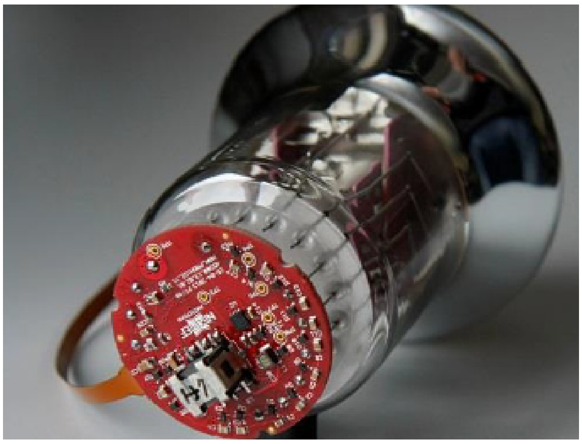
Between PBV2 and PBV4, capacitor deratings have been improved, and the FIT has been lowered down.

14.9. PMT Unit

14.9.1. Description

Functional description:

The PMT unit is referred to here as PMT and PMT base board. The base board is designed to generate the High Voltage (HV) required for the correct functioning of the PMTs and to ensure the digitization of the PMT signal. Before the digitization, the PMT signal is amplified through a pre-amplifier integrated into the PMT base itself.
The PMT base incorporates also a comparator, which generates a logical high signal when the PMT output is over the comparator threshold set through the I2C protocol. The duration of the primary signal, called "Time over Threshold" (ToT) provided by the PMT base is accurately measured by CLB Time-to-Digital Converters (TDCs). The 31 PMT base boards are connected to the SCB via a flexible PCB. The HV, which is remotely configurable through I2C from 800 to 1400 V, is independently generated in each PMT base: this allows for the tuning of the gain of individual PMTs to equalize cross-PMT photon response.



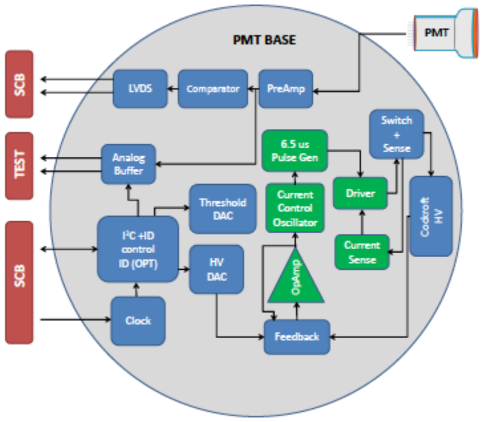


Figure 16: PMT tube with base(left) and PMT base block diagram (right).

Product:	**3.4.2 - PMT Unit**
Function:	Convert electrons into charge. Polarize PMT
PBS number	3.4.2
Product version	16/04/2013 - HAM PROMISE 2 - V1
Responsible	Julio Acostar (Nikhef)
Life profile	DOM
Reference documents	Schematic: HAM_promis2_V1 BOM: Bom_list HAM_PROMiS2_V1 KM3NeT_PP_2010_003-WPFL_Low_power_PMT_HV-base_TWEPP2010_Proceedings-P._Timmer Asic CoCo: Datasheet_CoCo_v2 Asic Promis: Datasheet_PROMiS_v2

Product hierarchy for PMT Base:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.2.2 - PMT Base	1
Integrated inside	3.4.2 - PMT Unit	31
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	230 ARCA / 115 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	128340 ARCA / 64170 ORCA

Product hierarchy for PMT:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.2.3 - PMT	1
Integrated inside	3.4.2 - PMT Unit	31
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	230 ARCA / 115 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	128340 ARCA / 64170 ORCA

14.9.2. Failure rate

Failure rate probability for the PMT Unit (PMT + PMT base board).

Product Failure rate	Value	Unit
Function FIT	105,15	/10^9 hours
MTTF (Hours)	9509883	hours
MTTF (years)	1086	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,91	0,09
2	17520	99,82	0,18
5	43800	99,54	0,46
10	87600	99,08	0,92
15	131400	98,63	1,37
20	175200	98,17	1,83

Contribution by component type:

Component type	Total FIT	Quantity
ASIC [ECAS]	4	2
Ceramic capacitors [ECCC]	75	42
Connectors [ECCO]	2	1
Discrete semiconductors [ECDS]	0	15
Magnetic Components: Inductors and Transformers [ECIN]	1	7
Optical detector (PMT)	23	1
Resistors [ECRE]	0	14
Total	**105**	**83**

Highest component contributors:

Component designation	Unit FIT	Quantity	Total FIT
PMT	23,00	1	23,00
0805 X7R 22 nF 200V(C1,C2,C3,C4,C5,C6,C7,C8 CAPC2012X145L_special)	1,67	13	21,71
1206 X7R 100 nF 200 V (C20,C21,C22,C23,C24,C25,C26 CAPC3216X190L_special)	1,60	13	20,84
0805 X7R 47 nF 200 V (C10,C12,C16,C28 CAPC2012X145L_special)	3,13	4	12,53
0603 X5R 10 uF 6 V (C29,C30,C33,C39 CAPC1608X90N)	3,13	4	12,53
0402 X5R 100 nF (C36,C43 CAPC1005X55N)	3,13	2	6,26
PROMIS_V2	2,08	1	2,08
Coco_V2	2,08	1	2,08
CON smd ver F 2x5p 0.8 mm (J1 SEM-105-02-03.0-H-D-WT_et)	1,54	1	1,54
0603 X5R 1 uF - 6.3 V (C34 CAPC1608X90N)	0,98	1	0,98

About the PMT :

Hamamatsu R14374-02 has been selected for the KM3NeT experiment. The estimated average KM3NeT PMT anode current is in the order of 10 nA.

The reliability data were retrieved from the manufacturer (Hamamatsu) through an answer to Pasquale Migliozzi (KM3NeT PMT responsible), dated 30/04/2020:

"We are afraid we cannot estimate the MTTF at the average anode output current of 10 nA because we don't have enough data.
Judging from Hamamatsu life test data with the initial average anode output current of 100 µA for R14374, the estimated MTTF (extrapolated from test data) for the tube is 2,019,000 h (= about 230 years) at the average anode current of 100 nA and 172,000 h (= about 20 years) at the average anode output current of 10 uA. However, in the case of such a long time, it is necessary to study the MTTF for the materials themselves. (We don't have suitable data to estimate the MTTF for the materials). Therefore, we are not sure if the MTTF of about 230 years at an average anode output current of 100 nA is surely correct. "

Hamamatsu confirmed that the MTTF for the PMT at the average anode output current of 10 nA is much longer than 20 years. In consequence, this ageing effect could also be considered negligible for KM3NET. In other words, no wear-out period needs to be considered for KM3NET PMTs. Then, we propose to consider, for reliability estimates only random failure rates risk. According to the 217Plus reliability prediction methodology and to the available literature "Multi-anode photomultiplier tube reliability assessment for JEM Euso Space mission" [5], the estimation was 23,34 failures / 1000000000 hours.

The detailed computations extracted from the same article are reported in the tables below:

Condition	Value
Integrated Circuit, Plastic Encapsulated	PMT
Year of Manufacture	2010
Growth constant (β)	0.293
Duty Cycle	20%
Cycling Rate	5840
Activation Energy Operating (Eaop)	0.8
Activation Energy nonoperating (Eanonop)	0.3
Ambient temperature, operating in °C (TAO)	26°C
Ambient temperature, non operating in °C (TAE)	15°C
Duty Cycle Operating (DC1op)	0.72
Duty Cycle non Operating (DC1nonop)	0.28
Default temperature rise ($TR_{default}$) in °C	25°C
Delta Temperature (DT_1) in °C	26.5°C
Cycling Rate (CR_1)	482.46

Failure Rate Multiplier (FRM)	Symbol	Result
Reliability Growth FRM	π_G	6.867×10^{-3}
Base failure rate, Operating	λ_{OB}	8×10^{-6}
FRM for Duty Cycle Operating	π_{DCO}	0.27
FRM for Temperature Operating	π_{TO}	12.18
Base failure rate, Environmental	λ_{EB}	1.997×10^{-3}
FRM, Duty Cycle, Non operating	π_{DCN}	1.11
FRM for Temperature environment	π_{RHT}	0
Base failure rate, Temp Cycling	λ_{TCB}	8.9×10^{-5}
FRM, Cycling Rate	π_{CR}	12.10
FRM,Delta Temperature	π_{DT}	3.405
Base failure rate, Solder Joint	λ_{SJB}	4.850×10^{-3}
FRM, Solder Joint Delta Temp	π_{SJDT}	0.635
Failure rate Electrical Overstress	λ_{EOS}	1.562×10^{-3}
	Failure Rate = 2.334×10^{-2} F/10^6h	

Figure 17: PMT EUSO Hamamatsu Photomultiplier random failure rate evaluation

The KM3NET PMT life cycle is softer than the one considered for EUSO. However, a FIT of 23 was assumed in the calculations as the worst-case scenario, the random failure rate evaluated by EUSO.

14.9.3. Conclusion and recommendations

The failure rate probability for the PMT Unit is low. No critical component has been found. The biggest contributors are PMTs and capacitors mainly due to the high voltage applied. Unfortunately, it is not easy to improve capacitor derating due to the density of the board. In fact, the ones with the highest FIT values are those with the lowest derating (40% and 50%).
For example, the high contribution of the 100 nF -1206 capacitor is mainly due to the applied voltage of 115 V, since the maximum value allowed is 200 V.
Ceramic capacitor models have been reviewed in the 2022 FIDES guide edition and have been applied for the calculations above. Indeed the previous 2009 edition was based on the experience gathered with the early multilayer ceramic capacitors which showed problems in layer separation. Ceramic capacitor technology improved greatly in recent times. Another way to increase the reliability is to apply better deratings by increasing the case capacitor size. Unfortunately, the drawback is a bigger capacitor case that is not compatible with the limited space available on the base board. For more details, see the original report: KM3NeT_REL_2015_003_REP_BaseRelReport.

14.10. Octopus board - Signal Collection Board (SCB)

14.10.1. Description

Functional description :

All 31 PMT bases generate Low-Voltage Differential Signaling (LVDS) signals that are collected on a set of hub boards, called “Signal Collection Board” (SCB) or “Octopus”. The main function of the SCB is to transfer signals from the PMT base to the TDCs embedded in the CLB. The SCB also transfers the I2C command signals from the CLB to the PMT bases, to monitor and control the PMTs. Each DOM comprises two SCBs, one large and one small, collecting signals respectively from the 19 PMTs in the lower DOM hemisphere and 12 PMTs in the upper hemisphere of the DOM. There are also current limiter switches to protect the CLB against a short circuit occurring in a PMT base.

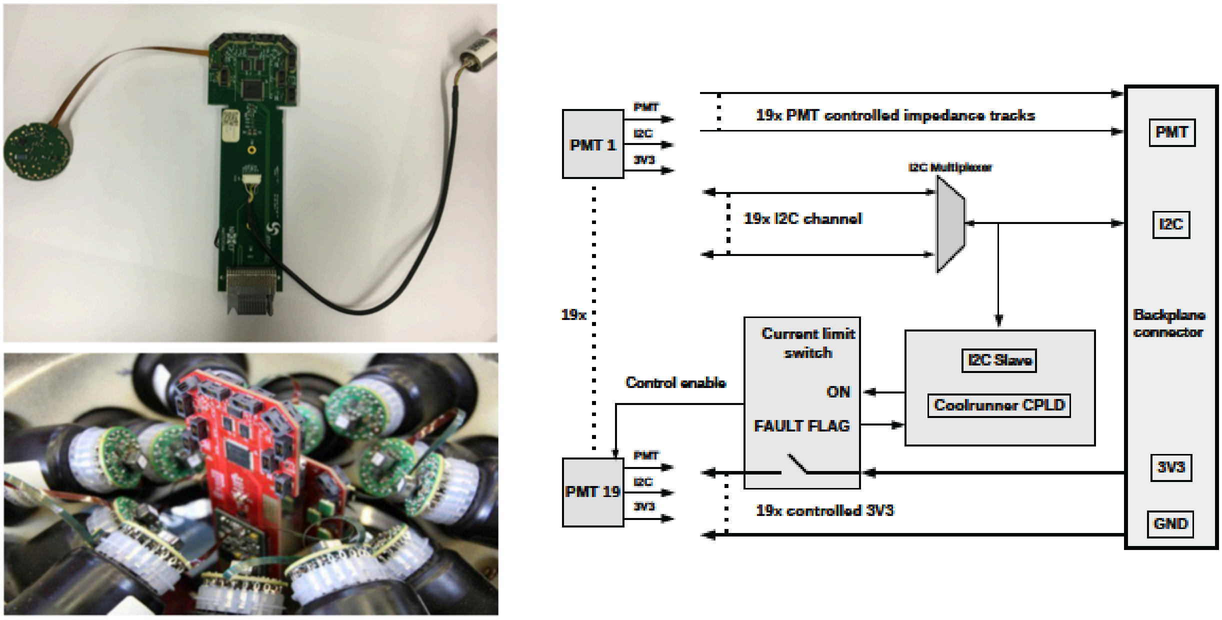


Figure 18: OCTOPUS board (SCB) with PMTs base and piezo sensor connected (top left), OCTOPUS board integrated into the lower DOM hemisphere (bottom left), and SCB block diagram (right).

Product:	3.4.3.1 - Signal Collection Board (SCB) - Octopus board
Function:	Collect signals from PMT bases and transmit them to CLB. Transmit control signal to PMT bases. Small Octopus collects 12 PMT signals Large Octopus collects 19 PMT signals
Product version	V3 - 01/07/2010
Responsible	NIKHEF - KVI
Life profile	DOM
Reference documents	-KM3NeT_ELEC_PRR_OCTOPUS_2014_011_Short_Octopus_Schematics - KM3NeT_ELEC_PRR_OCTOPUS_2014_012_Short_Octopus_Bill_Of_Material - KM3NeT_ELEC_PRR_OCTOPUS_2014_006_Large_Octopus_Schematics - KM3NeT_ELEC_PRR_OCTOPUS_2014_007_Large_Octopus_Bill_Of_Material -KM3NeT_ELEC_2024_008_OCTOPUS_CPLD_Octopussystemtop_vhd

Product hierarchy :

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.1 - Signal Collection Board (SCB) - Octopus board	1 large + 1 small
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	115 ORCA / 230 ARCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	2070 ORCA / 4140 ARCA

14.10.2. Failure rate

For SCB small :

Product Failure rate	Value	Unit
Function FIT	91,84	$/10^9$ hours
MTTF (Hours)	10888731	hours
MTTF (years)	1243	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,92	0,08
2	17520	99,84	0,16
5	43800	99,60	0,40
10	87600	99,20	0,80
15	131400	98,80	1,20
20	175200	98,40	1,60

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	7	81
Connectors [ECCO]	37	23
Integrated Circuits [ECIC]	48	24
Printed circuit board (PCB) [ECPC]	0	1
Resistors [ECRE]	1	55
Total	**92**	**184**

Highest component contributors :

Component designation	Unit FIT	Quantity	Total FIT
OCTOPUS SMALL: FPF2002 (U1_0,U1_1,U1_2,U1_3,U1_4,U1_5,U1_6,U1_7,U1_8,U1_9,U1_10,U1_11,U1_12,U1_13,U1_14,U1_15,U1_16,U1_17,U1_18)	1,69	19	32,17
OCTOPUS SMALL: Male 2 x 5p 0.8 mm (J1_0,J1_1,J1_2,J1_3,J1_4,J1_5,J1_6,J1_7,J1_8,J1_9,J1_10,J1_11,J1_12,J1_13,J1_14,J1_15,J1_16,J1_17,J1_18,J1_19)	1,47	20	29,32
OCTOPUS SMALL: PCA9548 (U2,U3,U4)	4,65	3	13,96
OCTOPUS SMALL: 75876-0040 (J99)	4,40	1	4,40
OCTOPUS SMALL: MLCC 0402 X7R 100 nF (C1_0,C1_1,C1_2,C1_3,C1_4,C1_5,C1_6,C1_7,C1_8,C1_9,C1_10,C1_11,C1_12,C1_13,C1_14,C1_15,C1_16,C1_17,C1_18,C2_0,C2_1,C2_2,C2_3,C2_4,C2_5,C2_6,C2_7,C2_8,C2_9,C2_10,C2_11,C2_12,C2_13,C2_14,C2_15,C2_16,C2_17,C2_18,C22,C44)	0,11	40	4,28
OCTOPUS SMALL: MLCC 0402 X7R 22 nF (C1-C10,C19-C25,C29,C32)	0,11	17	1,82
OCTOPUS SMALL: J3_19 Male 1 x 5p 2.00 mm TMM-105-01-G-S-SM Samtec	1,47	1	1,47
OCTOPUS SMALL: J2_19 Male 2 x 5p 2.00 mm TMM-105-01-G-D-SM Samtec	1,47	1	1,47
OCTOPUS SMALL: XC2C128 (U5)	1,37	1	1,37
OCTOPUS SMALL: Rsmd 0402 1K R11,R12_0,R12_1,R12_2,R12_3,R12_4,R12_5,R12_6,R12_7,R12_8,R12_9,R12_10,R12_11,R12_12,R12_13,R12_14	0,03	16	0,45

For SCB large :

Product Failure rate	Value	Unit
Function FIT	94,25	$/10^9$ hours
MTTF (Hours)	10609592	hours
MTTF (years)	1211	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,92	0,08
2	17520	99,84	0,16
5	43800	99,59	0,41
10	87600	99,18	0,82
15	131400	98,77	1,23
20	175200	98,36	1,64

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	9	81
Connectors [ECCO]	37	23
Integrated Circuits [ECIC]	48	24
Printed circuit board (PCB) [ECPC]	0	1
Resistors [ECRE]	1	70
Total	**94**	**199**

Highest component contributors :

Component designation	Unit FIT	Quantity	Total FIT
OCTOPUS LARGE: FPF2002 (U1_0,U1_1,U1_2,U1_3,U1_4,U1_5,U1_6,U1_7,U1_8,U1_9,U1_10,U1_11,U1_12,U1_13,U1_14, U1_15,U1_16,U1_17,U1_18)	1,69	19	32,17
OCTOPUS LARGE: Male 2 x 5p 0.8 mm (J1_0,J1_1,J1_2,J1_3,J1_4,J1_5,J1_6,J1_7,J1_8,J1_9,J1_10,J1_11,J1_12,J1_13,J1_14,J1_15,J1_16 ,J1_17,J1_18,J1_19)	1,47	20	29,32
OCTOPUS LARGE: PCA9548 (U2,U3,U4)	4,65	3	13,96
OCTOPUS LARGE: 75876-0040 (J99)	4,40	1	4,40
OCTOPUS LARGE: MLCC 0402 X7R 100 nF (C1_0,C1_1,C1_2,C1_3,C1_4,C1_5,C1_6,C1_7,C1_8,C1_9,C1_10,C1_11,C1_12,C1_13,C1_14,C1_1 5,C1_16,C1_17,C1_18,C2_0,C2_1,C2_2,C2_3,C2_4,C2_5,C2_6,C2_7,C2_8,C2_9,C2_10,C2_11,C2_ 12,C2_13,C2_14,C2_15,C2_16,C2_17,C2_18,C22,C44) - 16V	0,11	40	4,28
OCTOPUS LARGE: MLCC 0402 X7R 22 nF (C1-C10,C19-C25,C29,C32)	0,20	17	3,41
OCTOPUS LARGE: J3_19 Male 1 x 5p 2.00 mm TMM-105-01-G-S-SM Samtec	1,47	1	1,47
OCTOPUS LARGE: J2_19 Male 2 x 5p 2.00 mm TMM-105-01-G-D-SM Samtec	1,47	1	1,47
OCTOPUS LARGE: XC2C128 (U5)	1,37	1	1,37
OCTOPUS LARGE: MLCC 1210 X5R 47 uF 10 V (C15)	0,68	1	0,68

14.10.3. Conclusion and recommendations

No critical component was found, the failure rate is acceptable, and derating rules are respected.
The PMT connectors must be correctly glued to avoid mechanical constraints, which are not taken into account in this analysis. The Octopus V4 differs from the V3 by the change of the SAMTEC connector, which became obsolete and was replaced by the MOLEX connector. No new calculation is necessary as there is no impact on the FIT.

14.11. FMC V3

14.11.1. Description

Functional description:

The main goal of the FMC_MEZZANINE board is the conversion of the output signal from the CLB, via an FMC connector (LVDS signal, according to the ANSI/VITA 57.1 standard), into different standard input signals, specifically:

- RS232 for the AC/DC, EDFA and PB.
- Ethernet for the hydrophone.
- RS485 for the acoustic and laser beacons.

The FMC_MEZZANINE board is an FR4, six-layer board, whose size is 69 x 57 mm^2.
It hosts a JTAG connector and an I2C to access the CLB programming chains.

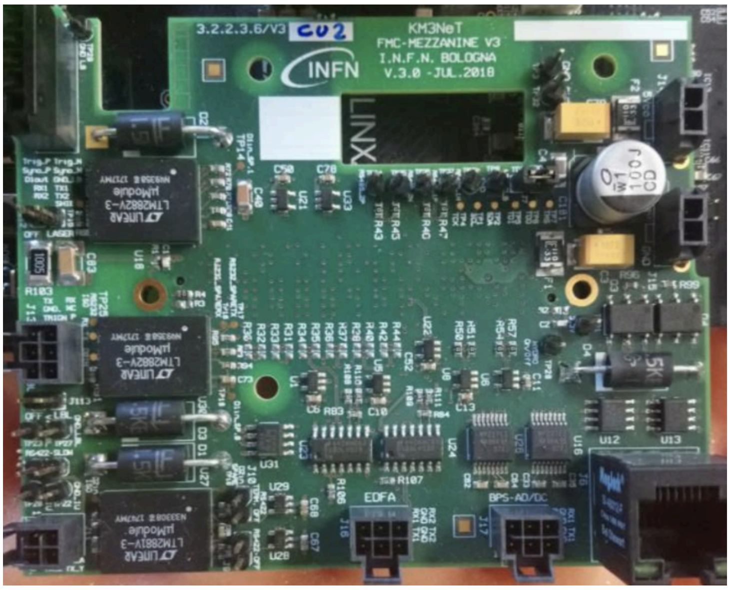


Figure 19: FMC V3 board.

This board is integrated inside the broadcast DU BM or CU:

Product:	3.2.2.3.6 - FPGA Mezzanine Card
Function:	3.2.2.3.6 FPGA Mezzanine Card (FMC) Expansion Board: FMC DU provides an interface between CLB and its peripheral 4.2.2.8 Interface CLB with instrument (Transceivers) or 3.2.2.3.6 FMC V3_CU. FMC CB provides an interface between CLB and its peripheral and instrumentation
Product version	V3_CU and V3_DU
Responsible	INFN - Giuliano Pellegrini
Life profile	DU Base
Reference documents	FMC_mezzanine.pdf July 02, 2014

Product hierarchy for DU BM:

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.6 - FPGA Mezzanine Card	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3.2 - Detection Unit Foot	1
Integrated inside	3 - Detection Unit	52 ORCA / 32 ARCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	84

This board is also integrated inside the CU base:

Product hierarchy for CU base:

	Product	Product quantity integrated inside the upper-level assembly
	4.2.2.8 FMC	1
Integrated inside	4.2.2 Base Container	1
Integrated inside	4.2 CALIBRATION BASE(CB)	1
Integrated inside	4 - Calibration Unit	1 ORCA / 2 ARCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	3

14.11.2. Failure rate

Design is almost the same between FMC CU and FMC DU. Then the FIT evaluation is similar.

Product Failure rate	Value	Unit
Function FIT	55,58	/10^9 hours
MTTF (Hours)	17992920	hours
MTTF (years)	2054	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,95	0,05
2	17520	99,90	0,10
5	43800	99,76	0,24
10	87600	99,51	0,49
15	131400	99,27	0,73
20	175200	99,03	0,97

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	7	49
Connectors [ECCO]	23	14
Discrete semiconductors [ECDS]	0	2
Fuses [ECFU]	2	2
Integrated Circuits [ECIC]	20	26
Optocouplers [ECOP]	1	2
Printed circuit board (PCB) [ECPC]	0	1
Resistors [ECRE]	0	59
Tantalum capacitors [ECTC]	1	2
Total	**56**	**190**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
ASP-134488-01	CONN_FMC_VITA57.1	J1	17,32	1	17,32
CC0603KPX7R9BB104	100 nF / 0,1 / 50 V	C5,C6,C7,C8,C9,C10,C11,C12,C13,C17,C18,C19,C20,C31,C32,C33,C34,C35,C50,C51,C52,C55,C58,C59,C60,C61,C62,C63,C64,C67,C68,C74,C77,C78,C80,C82	0,17	36	6,05
SN65LVDS1DBV	SN65LVDS1	U1,U5,U6,U20,U22,U28,U32	0,66	7	4,63
LTM2882CV-3	LTM2882CV-3	U18,U30	2,04	2	4,08
SN75HVD10D	SN75HVD10	U12,U13	1,92	2	3,84

Component designation	Value or version	Refdes	Unit FIT	Quantity	Total FIT
SN65LVDT2DBV	SN65LVDT2	U2,U3,U7,U4,U8,U21,U25,U29,U33	0,31	9	2,76
LTM2881CV-3	LTM2881CV-3	U27	2,04	1	2,04
826629-2	HDR_1X2	J7,J9,J10,J18,J112, J113	0,33	6	1,97
SN65HVD10DG4	SN65HVD10DG4	U31	1,92	1	1,92
Resettable Fuses		F1,F2	0,90	2	1,80

14.11.3. Conclusion and recommendations

No critical components were found. This board is a simple interface with a low FIT rate.

14.12. FMC V4

14.12.1. Description

Functional description:

The functional description for FMC v4 is similar to the one given in the paragraph above, for FMC v3. However, the development of this newer version makes the board compatible with its integration in the WWR base container, allowing communication between the CLBv4 and the BPC+BPD.

PBS - Product or component name	3.2.2.3.6 FPGA Mezzanine Card (FMC) Expansion Board/V4
Function:	FMC V4 DU provides an interface between CLB and BPC+BPD for WWR DU
Last change date - Version	21/11/2024
Comments	Board modification in progress due to components obsolescence - To be reviewed
Life profile	DU_WRS
Reference documents	- KM3NeT_ELEC_2023_019_FMCV4_Schematic - KM3NeT_ELEC_2023_018_FMCv4_Bill_Of_Material

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.6 - FPGA Mezzanine Card	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3.2 - Detection Unit Foot	1
Integrated inside	3 - Detection Unit	83 ORCA / 198 ARCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	281

14.12.2. Failure rate

Design is almost the same between FMC CU and FMC DU. Then the FIT evaluation is similar.

Product Failure rate	Value	Unit
Function FIT	66,32	$/10^9$ hours
MTTF (Hours)	15077747	hours
MTTF (years)	1721	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,94	0,06
2	17520	99,88	0,12
5	43800	99,71	0,29
10	87600	99,42	0,58
15	131400	99,13	0,87
20	175200	98,84	1,16

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	7,90	49
Connectors [ECCO]	24,69	14
Discrete semiconductors [ECDS]	0,32	2
Fuses [ECFU]	1,95	2
Integrated Circuits [ECIC]	28,30	26
Optocouplers [ECOP]	1,01	2
Printed circuit board (PCB) [ECPC]	0,74	1
Resistors [ECRE]	0,05	59
Tantalum capacitors [ECTC]	1,36	2
Total	**66,32**	**190**

Highest component contributors :

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
ASP-134488-01	CONN_FMC_VITA57.1	J1	18,38	1	18,38
SN65LVDS1DBV	SN65LVDS1	U1,U5,U6,U20,U22,U28,U32	0,92	7	6,46
CC0603KPX7R9BB104	100 nF / 0,1 / 50 V	C5,C6,C7,C8,C9,C10,C11,C12,C13,C17,C18,C19,C20,C31,C32,C33,C34,C35,C50,C51,C52,C55,C58,C59,C60,C61,C62,C63,C64,C67,C68,C74,C77,C78,C80,C82	0,18	36	6,38
LTM2882CV-3	LTM2882CV-3	U18,U30	2,92	2	5,85
SN75HVD10D	SN75HVD10	U12,U13	2,61	2	5,22
SN65LVDT2DBV	SN65LVDT2	U2,U3,U7,U4,U8,U21,U25,U29,U33	0,44	9	3,93
LTM2881CV-3	LTM2881CV-3	U27	2,92	1	2,92
SN65HVD10DG4	SN65HVD10DG4	U31	2,61	1	2,61
826629-2	HDR_1X2	J7,J9,J10,J18,J112, J113	0,35	6	2,09
Resettable Fuses		F1,F2	0,97	2	1,95

14.12.3. Conclusion and recommendations

No critical point was found.

14.13. Base module Power Supply (BPS) for Broadcast and calibration unit

14.13.1. Description

Functional description:

The BPS board is designed to power the electronic devices connected to the Broadcast DU base container, such as the hydrophone and the LBL beacon. It also controls the DU power line (375 VDC) in order to switch ON and OFF all the 18 DOMs.

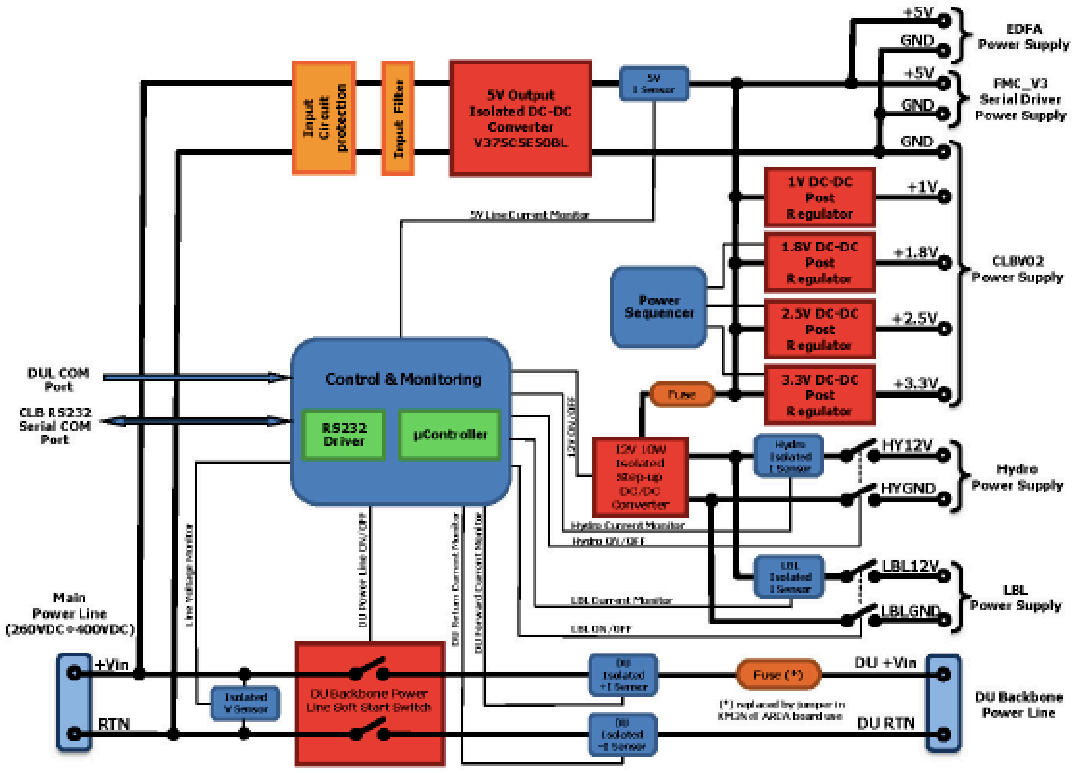


Figure 20: BPS DU block diagram.

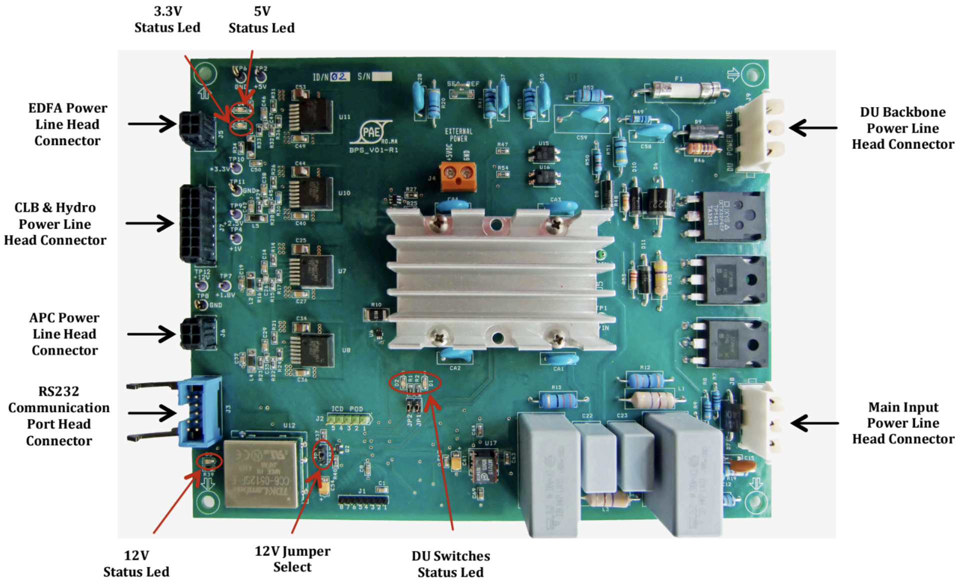


Figure 21: BPS DU board.

The BPS V03-R02 is the Broadcast BM power supply board:

Product:	**3.2.2.3.7 - BPS Board DU base**
Function:	Provide DU base instruments supply voltages and distribute 375/400 VDC
PBS number	3.2.2.3.7
Product version	V03-R02 - Analysis updated on April 6th, 2021
Responsible	R. Masullo (PAE), R. Cocimano (INFN), C.A. Nicolau (INFN), A.Orlando (INFN)
Life profile	DU base
Reference documents	- KM3NeT_POWER_2020_012_BPS_V03-R2 Schematics_v1 (November 29th, 2019) - KM3NeT_POWER_2020_014_Bill Of Materials_BPS_V03-R2_ Part_Number_v1 - KM3NeT_POWER_2020_045_BPS_BOARD_V03-R1 & R2_v1DU

Product hierarchy for DU BM:

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.7 - BPS Board	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3.2 - Detection Unit Foot	1
Integrated inside	3 - Detection Unit	32 ARCA / 52 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	32 ARCA / 52 ORCA

BPS board is integrated inside the CU base:

The design has been specifically modified for the calibration unit.

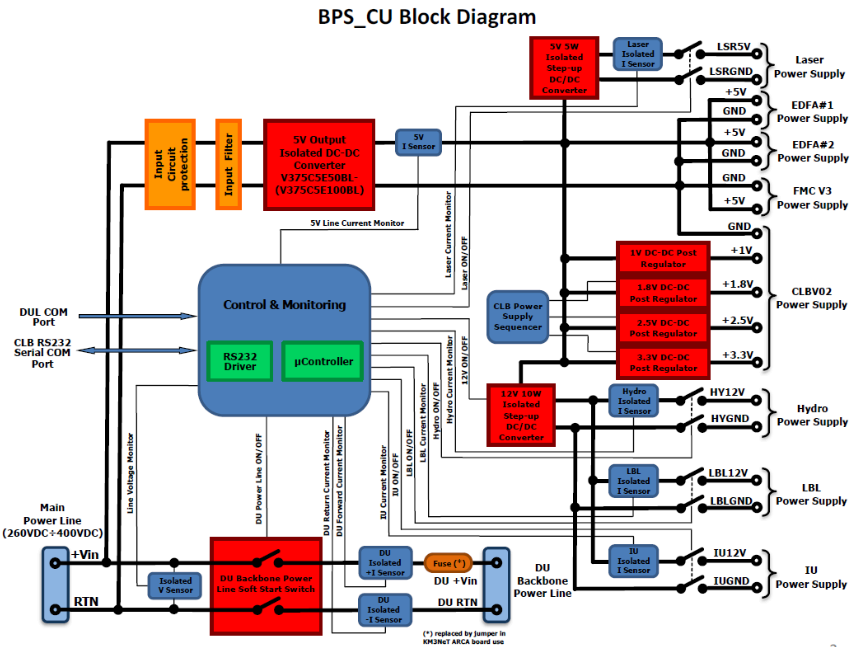


Figure 22: BPS CU Block diagram.

Product:	**4.2.2.5 BPS CB**
Function:	CB powering
Product version	V01-R1 - November 15th, 2019
Responsible	Rocco Masullo <Rocco.Masullo@roma1.infn.it>
Life profile	DU base
Reference documents	- KM3NeT_POWER_2020_015_BPS_CU_V01-R1 - KM3NeT_POWER_2020_019_BPS_CU_V01-R1 November 15th, 2019

Product hierarchy for CU base:

	Product	**Product quantity integrated inside the upper-level assembly**
	4.2.2.5 BPS CB	1
Integrated inside	4.2.2 Base Container	1
Integrated inside	4.2 CALIBRATION BASE (CB)	1
Integrated inside	4 - Calibration Unit	2
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	2

14.13.2. Failure rate

BPS DU Broadcast failure rate :

Product Failure rate	Value	Unit
Function FIT	210,81	/10^9 hours
MTTF (Hours)	4743688	hours
MTTF (years)	542	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,82	0,18
2	17520	99,63	0,37
5	43800	99,08	0,92
10	87600	98,17	1,83
15	131400	97,27	2,73
20	175200	96,37	3,63

Subassemblies/functions contribution:

For the BPS the loss of a hydrophone or LBL emitter power supply will have only a marginal impact on the calibration performance since there are also LBL emitters and hydrophones in neighboring DUs (ie. redundancy). Hence, it was decided to split the analysis into:

- BPS main functions: DU line powering including the control of the board itself allows to command solid states switches and EDFA supply;
- BPS auxiliary supplies: LBL and hydrophone power supply (12 V). The loss of this section should not propagate to the DU line.

Sub-function or component	FIT
3.2.2.3.7.1 - BPS main functions/ORCA/Broadcast	151
3.2.2.3.7.2 - BPS auxiliary supplies/ORCA/Broadcast	60

Contribution by component type:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	84	2
Ceramic capacitors [ECCC]	54	46
Connectors [ECCO]	16	15
Discrete semiconductors [ECDS]	6	23

Component type	Total FIT	Quantity
Fuses [ECFU]	0	7
Integrated Circuits [ECIC]	29	27
Light Emitting Diode (LED) [ECLE]	0	1
Magnetic Components: Inductors and Transformers [ECIN]	0	6
Optocouplers [ECOP]	1	1
Piezoelectric components: Oscillators and Quartz [ECPZ]	2	1
Printed circuit board (PCB) [ECPC]	0	1
Resistors [ECRE]	0	84
Tantalum capacitors [ECTC]	18	5
Total	**211**	**219**

Highest component contributors :

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
375 V Input Micro Family DC-DC Converter Module		U5	48,50	1	48,50
Isolated Board Mount DC-DC Converter CC-E Series,10 W, 12 V, 800 mA - CC-10-0512SF-E		U12	35,07	1	35,07
Multilayer Ceramic Capacitor, RDE Series, 0.47 µF ±10%, 450 V, Radial Leaded Through Hole BPS: RDED72W474K5B1C13B 470 nF (C12)	470nF	C12	13,36	1	13,36
Polypropylene Film Capacitor, MKP3384 X2 Series, 330 nF ±20% 630 V, Radial Leaded Through Hole BPS: BFC233920334 330 nF (C22,C23)	330 nF - 630V	C22, C23	4,92	2	9,84
Polypropylene Film Capacitor MKP339 X2 Series, 2.2 uF ±20% 630 V, Radial Leaded Through Hole BPS: BFC233920225 2.2 uF (C20,C21)	2.2µF - 630V	C20, C21	4,92	2	9,84
Solid Tantalum Surface Mount Capacitors, TR3 Series, Case 7361, 100 uF ±10% 25 V	100µF-25V	C55	9,82	1	9,82
Tantalum Polymer Capacitor, T510 Series, 220 µF, ±10%,16 V, 0.025 Ω, Case 7343-43		C24,C33,C43,C52	2,12	4	8,49
Wire-To-Board Connector, 3 mm, 4 Contacts, Header, Micro-Fit 3.0 43045 Series, Verical Header, 2 Rows		J5,J7, J8, J9	1,47	4	5,88
Tiny Low Power Precision Operational Amplifier CMOS Input RRIO		U17,U18,U20	1,65	3	4,95
Wire-To-Board Connector, Micro-Fit 3.0 Vertical Header, 3.00 mm Pitch, Single Row, 2 Circuits, with PCB Polarizing Peg, Tin, Through Hole		J11, J13, J4	1,47	3	4,41

BPS CU failure rate :

Product Failure rate	Value	Unit
Unit FIT	267,25	/10^9 hours
MTTF (Hours)	3741828	hours
MTTF (years)	427	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,77	0,23
2	17520	99,53	0,47
5	43800	98,84	1,16
10	87600	97,69	2,31
15	131400	96,55	3,45
20	175200	95,43	4,57

Subassemblies/functions contribution: the BPS CU has not been divided into sub-functions for this analysis.

Contribution by component type:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	119	3
ALUMINIUM CAPACITOR [ECAC]	6	4
Ceramic capacitors [ECCC]	26	82
Connectors [ECCO]	20	18
Discrete semiconductors [ECDS]	7	25
Fuses [ECFU]	0	8
Integrated Circuits [ECIC]	45	34
Light Emitting Diode (LED) [ECLE]	0	1
Magnetic Components: Inductors and Transformers [ECIN]	0	6
Optocouplers [ECOP]	1	1
Piezoelectric components: Oscillators and Quartz [ECPZ]	2	1
Printed circuit board (PCB) [ECPC]	0	1
Resistors [ECRE]	0	76
Tantalum capacitors [ECTC]	40	8
Total	**267,253**	**268**

Highest component contributors :

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
Isolated Board Mount DC-DC Converter CC-E Series,10 W, 12 V, 800 mA - CC-10-0512SF-E	U33, U12	35,07	2	35,07
375 V Input Micro Family DC-DC Converter Module	U5	48,50	1	48,50
Solid Tantalum Surface Mount Capacitors, TR3 Series, Case 7361, 100 uF ±10% 25 V	C55,C59	9,82	2	19,64
MOSFET Relay, 60 V, 1.25 A, 0.5 Ω, SPST-NO, SMD SOP 4	U25,U26,U28,U29, U31,U32,U34,U35	1,65	8	13,20
Polymer Surface Mount Chip Capacitor, T59 Series, 470 uF ±20% 16 V, Case 7343-43	C11	9,82	1	9,82
Wire-To-Board Connector, Micro-Fit 3.0 Vertical Header, 3.00mm Pitch, Single Row, 2 Circuits, with PCB Polarizing Peg, Tin, Through Hole	J11, J13, J4, J12, J14, J15	1,47	6	8,82
Tantalum Polymer Capacitor, T510 Series, 220 µF, ±10%,16 V, 0.025 Ω, Case 7343-43	C24,C33,C43,C52	2,12	4	8,49
Tiny Low Power Precision Operational Amplifier CMOS Input RRIO	U20,U21,U22,U23,U24	1,65	5	8,25
Wire-To-Board Connector, 3 mm, 4 Contacts, Header, Micro-Fit 3.0 43045 Series, Verical Header, 2 Rows	J5,J6, J7, J8, J9	1,47	5	7,35
Multilayer Ceramic Capacitor, C Series, 22 uF, ±10%, X5R, 16 V, SMD 1210	C25, C34, C43, C53	1,06	4	4,25

14.13.3. Conclusion and recommendations

The BPS DU is a critical component for the whole DU line. The most impacting failure could be the loss of the 375 VDC supply line, causing the loss of all 18 DOMs connected. In case of overconsumption, a current protection is implemented to avoid failure propagation.

The BPS CU FIT is higher than the one of the BPS DU due to the presence of additional DC-DC converters implemented in the board to supply all the instruments, including the Laser Beacon and the Instrumentation Line modem.

14.14. Base module power converter for WWR DU BM - BPC

14.14.1. Description

Functional description:

For the WWR DU BM, the power supply has been split into 3 boards, namely BPC, BPD, and DUL to add redundancies and allow better temperature dissipation. The goal was to improve the reliability and handle the consumption increase due to the presence of two WWR switches in the DU base. In this section, the BPC failure mode will be evaluated.

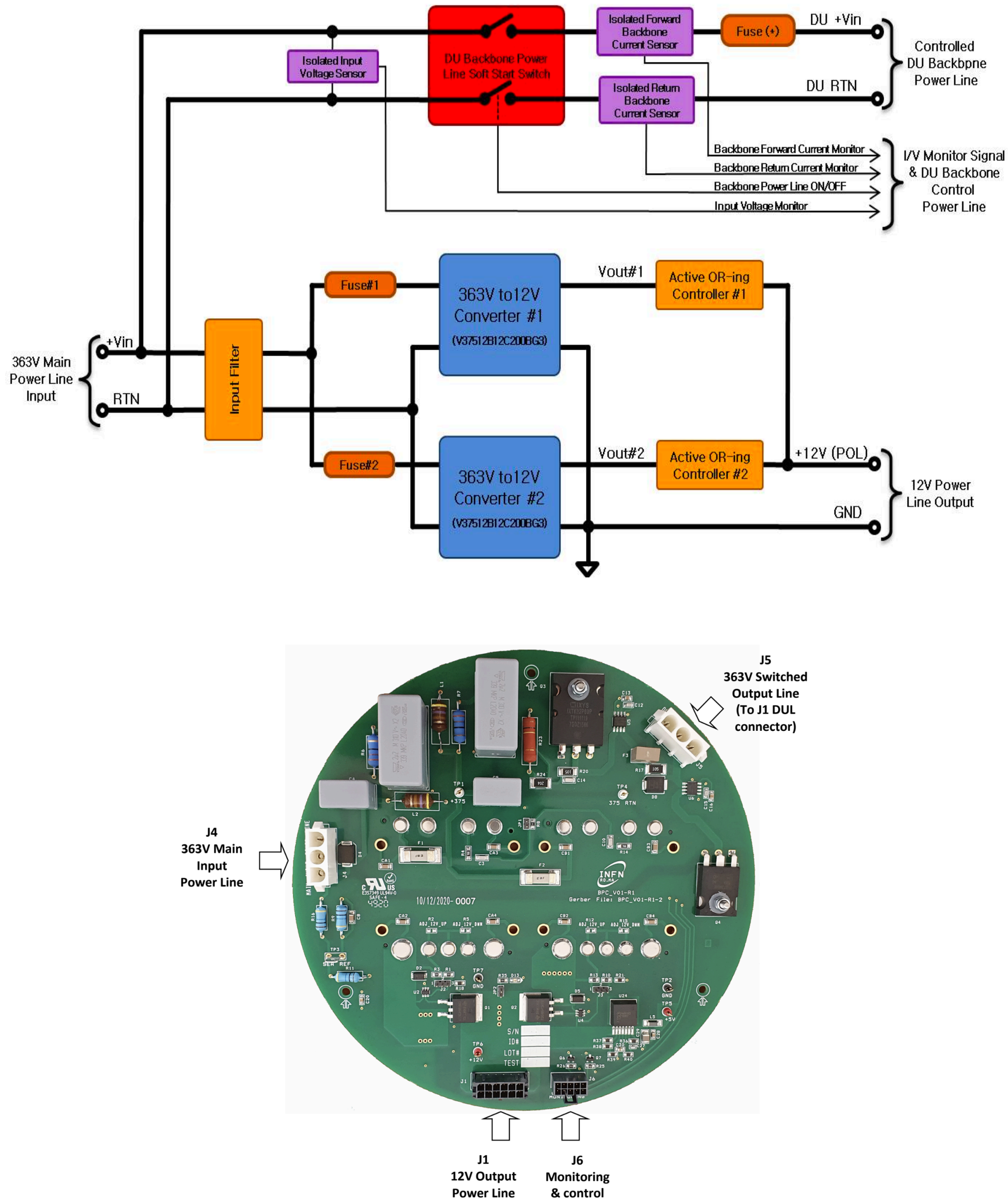


Figure 23: BPC functional block diagram (top) and BPC board picture (bottom).

PBS - Product or component name	3.2.2.3.10 - BPC/WWRS
Function:	BPC - Base Power Supply Converter
Last change date - Version	V02-R1 - from December 2021 data
Comments	BPC_V02-R1 board is designed to convert the 363 VDC main voltage into the voltage of 12 VDC to feed the electronic devices hosted in the DU base. The board is equipped with switches to power on and off the DU backbone lines.
Reference documents	- KM3NeT_POWER_2021_007 - WWRS ARCA DU base BPC, BPD, DUL connectors and cabling_V02 -BPC_V02-R1 Bill of Materials P-N -BPC_V02-R1 SCHEMATIC - 15/12/2021 -KM3NeT_Power_2021_014_BPC V02-R1_Technical Design Report_V01 -List of changes from BPC_V01 to BPC_V02

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.10 - BPC	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3.2 - Detection Unit Foot	1
Integrated inside	3 - Detection Unit	198 ARCA / 63 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	198 ARCA / 63 ORCA

14.14.2. Failure rate

Product Failure rate	Value	Unit
Unit FIT	77,77	$/10^9$ hours
MTTF (Hours)	12857829	hours
MTTF (years)	1468	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,93	0,07
2	17520	99,86	0,14
5	43800	99,66	0,34
10	87600	99,32	0,68
15	131400	98,98	1,02
20	175200	98,65	1,35

Sub-function or component	FIT
3.2.2.3.10 - BPC-Non-redondant-functions/WWRS/Component	54
3.2.2.3.10 - BPC-redondant-functions/WWRS/Component	24

Contribution by component type:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	24	2
ALluminium capacitor [ECAC]	24	5
Ceramic capacitors [ECCC]	3	32
Connectors [ECCO]	10	8
DC/DC converter	0	1
Discrete semiconductors [ECDS]	7	19
Fuses [ECFU]	0	3
Integrated Circuits [ECIC]	5	5
Light Emitting Diode (LED) [ECLE]	0	1
Magnetic Components: Inductors and Transformers [ECIN]	0	5
Optocouplers [ECOP]	4	2
Printed circuit board (PCB) [ECPC]	1	1
Resistors [ECRE]	0	40
Total	**77,77**	**133**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
DC-DC Converter Module, Output Voltage 12 V, Military Grade, 200 W, Pin Style G: Long RoHS, Baseplate Through-hole	V375B12M200BG3	U1,U3 (Be careful one redundant)	381,34	2	23,89 (because of redundancy)
Polypropylene Film Capacitor, MKP3384 X2 Series, 330 nF ±20% 630 V, Radial Leaded Through Hole	330nF	C4,C5	5,74	2	11,47
Polypropylene Film Capacitor MKP339 X2 Series, 2.2 uF ±20% 630 V, Radial Leaded Through Hole	2.2uF	C6,C7	5,74	2	11,47
Wire-To-Board Connector, Universal MATE-N-LOK Series, Header, UL94V-0, 3WAY 6.35 mm, Vertical, Through Hole	CON3	J4,J5	2,21	2	4,41
Optoisolator Photovoltaic Output 3750 V rms 1 Channel 6-SO, 4 Lead	TLX9906	U8,U9	2,12	2	4,23
Tiny Low Power Precision Operational Amplifier CMOS Input RRIO	LMP7701MF	U10	2,37	1	2,37
Automotive high-impedance, 2 V input, basic isolated amplifier for voltage sensing	AMC1211	U12	2,37	1	2,37
Wire-To-Board Connector, 3 mm, 12 Contacts, Header, Micro-Fit 3.0 43045 Series, Verical Header, 2 Rows	MOLEX_MICRO-FIT12	J1	2,21	1	2,21
Zener Diode 100 V ±5% 5 W, Surface Mount DO-214AA (SMB)	SMBJ5378B	D7,D10	0,87	2	1,74
Quick-Fit Male Terminal, PCB Solder, Straigth, 4.8 x 0.8 mm	SEA_REF	TP3	1,56	1	1,56

14.14.3. Conclusion and recommendations

The BPC is a critical component of the WWR DU line. As in the case of the BPS for the Broadcast DU line, the most impacting failure is the loss of the 375 VDC line supply. In case of overconsumption, a current protection is implemented to avoid failure propagation.

The highest contributors are the Vicor DC/DC converters. The power consumption on the 12 V is higher (200 W) with respect to the Broadcast design. Redundancies implemented (DC-DC converters modules) have a great effect on the BPC reliability improvement.

14.15. Base module power converter for the WWRS DU BM - BPD

14.15.1. Description

Functional description:

The WWRS DU BM Power Supply has been split into 3 boards, namely the BPC, the BPD, and the DUL in order to add redundancies and allow better temperature dissipation. The goal was to improve the reliability and handle the consumption increase due to the presence of two WWR switches in the DU base. In this section, the BPD failure mode will be evaluated. The Base Power Distribution Board allows for the conversion of the 12 V DC power supply into useful voltages necessary to supply and switch ON/OFF BM electronics and instruments.

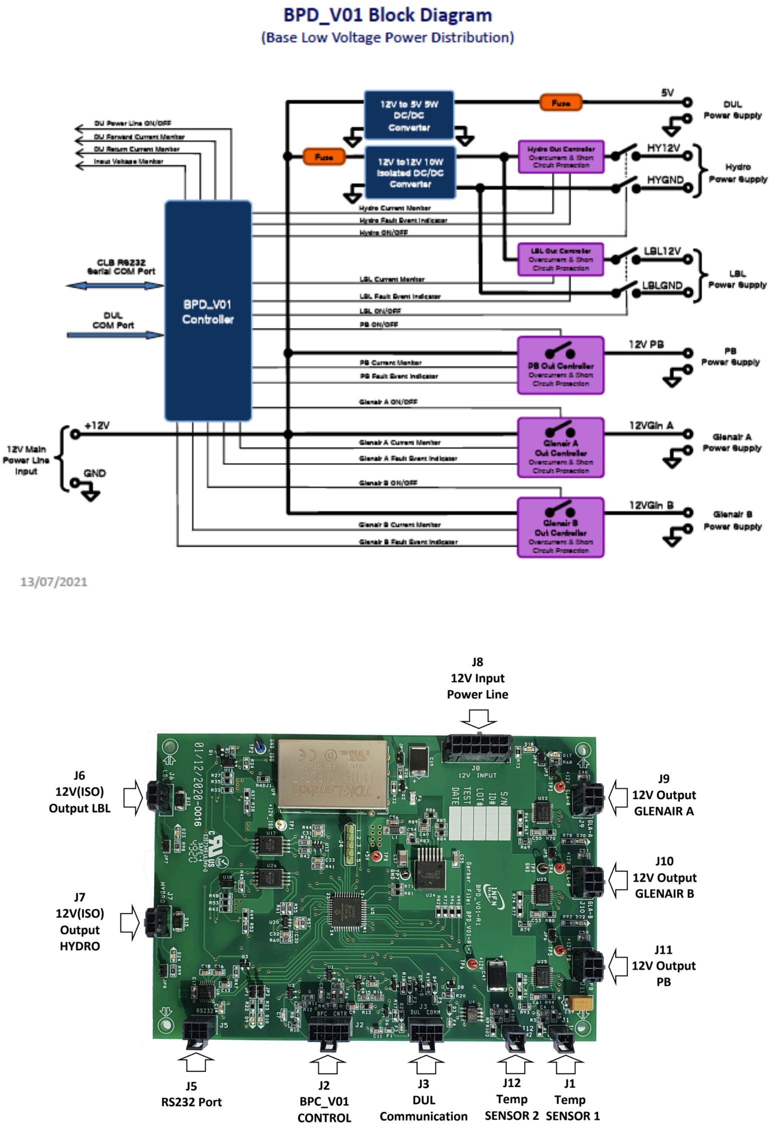


Figure 24: BPD functional block diagram (top) and BPD board picture (bottom).

PBS - Product or component name	3.2.2.3.11 - BPD/WWRS
Function:	Base Power Distribution
Last change date - Version	V03-R2 - Analysis updated on April 6th, 2021
Comments	The BPD's main functions are to distribute the 12 V DC input voltage to the internal DU base electronic loads and external instrumentations, to switch on /off to all the DU base power lines, to monitor voltages, currents, and temperatures in the DU base, to protect the DU base power lines from overcurrent and short circuit and to host the microcontroller that manages the communication with the CLB through a serial port.
Reference documents	- KM3NeT_POWER_2021_015_BPD V02-R1_Technical Design Report_V01 - KM3NeT_POWER_2021_007 - WWRS ARCA DU base BPC, BPD, DUL connectors and cabling_V02 --BPD_V02-R1 SCHEMATIC -BPD_V02-R1 Bill of Materials P-N

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.11 - BPD/WWRS	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3.2 - Detection Unit Foot	1
Integrated inside	3 - Detection Unit	198 ARCA / 63 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	198 ARCA / 63 ORCA

14.15.2. Failure rate

Product Failure rate	Value	Unit
Unit FIT	282,79	$/10^9$ hours
MTTF (Hours)	3536237	hours
MTTF (years)	404	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,75	0,25
2	17520	99,51	0,49
5	43800	98,77	1,23
10	87600	97,55	2,45
15	131400	96,35	3,65
20	175200	95,17	4,83

Contribution by component type:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	101	1
Ceramic capacitors [ECCC]	15	47
Connectors [ECCO]	19	12
Discrete semiconductors [ECDS]	4	18
Fuses [ECFU]	4	6
Integrated Circuits [ECIC]	99	15
Magnetic Components: Inductors and Transformers [FCIN]	0	1
Optocouplers [ECOP]	13	6
Resistors [ECRE]	0	99
Tantalum capacitors [ECTC]	27	5
Total	**283**	**236**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
Isolated Board Mount DC-DC Converter CC-E Series,10 W, 12 Vin 12 Vout, 800 mA	CC-10-1212SF-E	U9	101,28	1	101,28
4.5 V-60 V, 31 mΩ, 0.6-6 A eFuse with Adjustable Overcurrent Limiting, HTSSOP Package	TPS16630	U22,U23,U25	15,52	3	46,56
4.5 V to 60 V, 1 A Current Limiter with OV, UV, and Reverse Protection, 12-pin (3 mm x 3 mm) TDFN-EP package	MAX17608	U10,U16	15,52	2	31,04
Molded Tantalum Polymer Capacitor 47 uF 35 V 20% EE Case 7343 55 mΩ @ 100 kHz	47uF	C25,C36,C49,C52,C59	5,45	5	27,23
Tiny Low Power Precision Operational Amplifier CMOS Input RRIO	LMP7701MF	U1,U2,U3	2,37	3	7,10
Tiny Low Power Precision Operational Amplifier CMOS Input RRIO	LMP7701MF	U13,U20	2,37	2	4,73
MOSFET Relay, 100 V, 32.2 A, 70 mΩ, SPST-NO, SMD SOP 6	AQV255G3S	U7,U12,U15,U19	2,12	4	8,47
Molded Tantalum Polymer Capacitor 150 uF 30 V 20%, Case7343, 75 mΩ @ 100 kHz	150uF	C19,C22,C47	1,76	3	5,29
Automotive high-impedance, 2 V input, basic isolated amplifier for voltage sensing	AMC1211	U17,U26	2,37	2	4,73
Wire-To-Board Connector, 3 mm, 4 Contacts, Header, Micro-Fit 3.0 43045 Series, Verical Header, 2 Rows	MOLEX_MICRO-FIT4	J9,J10,J11	1,56	3	4,68
Optoisolator Transistor Output 2500 Vrms, 1 Channel, 4-Mini-Flat	PS2913-1	U11,U18	2,12	2	4,23

14.15.3. Conclusion and recommendations

The highest contributor is the 12 V DC/DC 10 W converter: it represents 35% of the overall BPD FIT. Nevertheless, this component is used to supply the LBL emitter, therefore is not a critical component, and neither a single-point of failure.

14.16. BCI

14.16.1. Description

Functional description:

The BCI board is a passive board, with 4 connectors designed to provide the electrical interface between the BPS and the CLB.

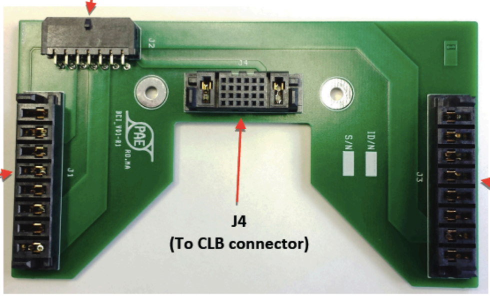


Figure 25: BCI board. Red arrows highlight the connected board (CLB and BPS).

Product:	**3.2.2.3.8 / 4.2.2.7 - BCI Interconnecting Board**
Function:	Power interface between BPS board and CLB in the base container. Allows to supply CLB
PBS number	3.2.2.3.8 / 4.2.2.7
Product version	V02-R1
Responsible	Prodeggi e apparati elettronici (PAE)
Life profile	DU base
Reference documents	KM3NeT_POWER_2020_026_BCI_V02 Board layout_dimentions_schematics_v1

Product hierarchy:

	Product	**Product quantity integrated inside the upper-level assembly**
	3.2.2.3.8 - BCI Interconnecting Board	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3 - Detection Unit	115 ORCA /230 ARCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	115 ORCA / 230 ARCA

14.16.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	9	/10^9 hours
MTTF (Hours)	120278601	hours
MTTF (years)	13730	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,99	0,01
2	17520	99,99	0,01
5	43800	99,96	0,04
10	87600	99,93	0,07
15	131400	99,89	0,11
20	175200	99,85	0,15

Contribution by component type:

Component type	Total FIT	Quantity
Connectors [ECCO]	8	4
Printed circuit board (PCB) [ECPC]	0	1
Total	**9**	**5**

Highest component contributors:

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
10-pin power connector	J4	1,56	2	3,12
14-pin power connector	J1 and J3	2,21	1	2,21
24-pin power connector	J2	3,49	1	3,49
PCB	BCI PCB	0,02	1	0,02
Total		**7,27**	**5**	**8,83**

14.16.3. Conclusion and recommendations

The BCI is a small interconnection board with a low risk due to its low failure rate.

14.17. DU base Limiter (DUL)

14.17.1. Description

Functional description :

The DU base Limiter (DUL) board provides protection against overcurrent and short circuits occurring on the Vertical Electro-Optical Cable (VEOC) side. It exploits a set of signals that the BPS uses to perform fast detection of over-current conditions. This board is only implemented for the KM3NeT/ARCA detector.
The DUL board has not been implemented for ORCA since the short protection system is different. Specifically, there is a fuse at the input of the converter and a fuse at the output of the BPS: this design choice was motivated by the presence of a fuse in the converter originally designed before the BPS.
In ARCA instead, an e-fuse is implemented at the input of the converter. In the base module, the short circuit protection is implemented with the use of the DUL board that limits the current (fast short circuit protection - about 50 µs) and the BPS (BPS for Broadcast or BPC+BPD for WWRS) that reads the current and opens the switch (slow short circuit protection - about 1 ms with the DUL, 35 ms without the DUL).

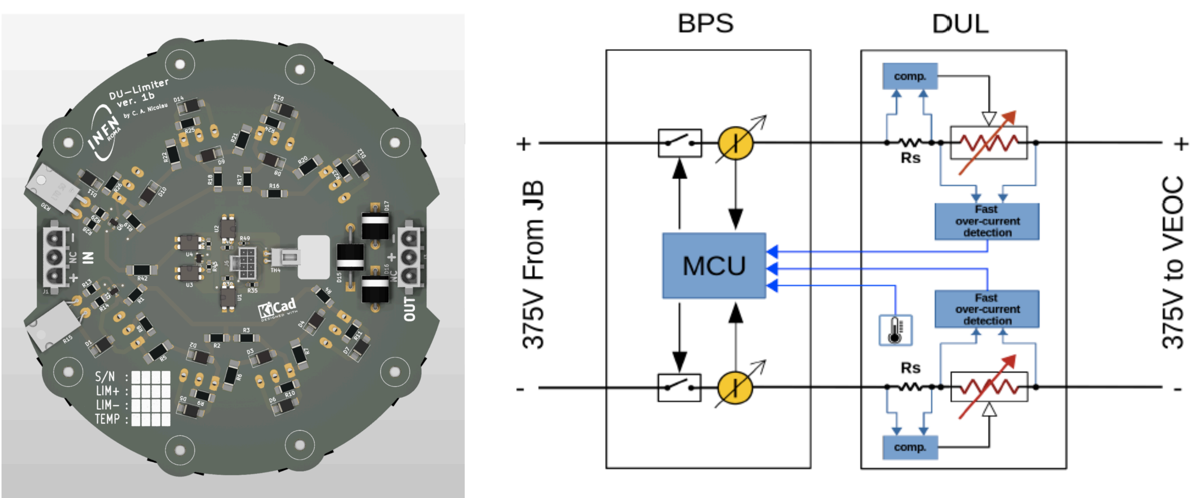


Figure 26: layout DUL sketch (left) and DUL block diagram (right).

Product:	3.2.2.3.2 - DU Base Current Limiter /ARCA
Function:	BPS Current limiter for ARCA: Protect DU base, protect against overcurrent on DOM
PBS number	3.2.2.3.2
Product version and latest analysis update	20/12/2015 - V1
Responsible	Carlo A.Nicolau - INFN Roma
Life profile	DU base
Reference documents	-DUL schematics - 2017-12-20 -DUL components -KM3NeT_POWER_2019_086 -ARCA DUL board description_V01

Product hierarchy :

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.2 - DU Base Current Limiter	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3.2 - Detection Unit Foot	1
Integrated inside	3 - Detection Unit	230
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	230

14.17.2. Failure rate

FIT for WWR life profile:

Product Failure rate	Value	Unit
Function FIT	53,74	$/10^9$ hours
MTTF (Hours)	18609183	hours
MTTF (years)	2124	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,95	0,05
2	17520	99,91	0,09
5	43800	99,76	0,24
10	87600	99,53	0,47
15	131400	99,30	0,70
20	175200	99,06	0,94

Contribution by component type:

Component type	Total FIT	Quantity
Connectors [ECCO]	5	2
Discrete semiconductors [ECDS]	48	31
Printed circuit board (PCB) [ECPC]	1	1
Resistors [ECRE]	0	47
Total	**54**	**87**

Highest component contributors :

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
Zener Diode	12 V and 91 V	D7, D6, D5, D14, D13, D12, D1, D9, D8, D4, D3, D2, D10	19,19	14	19,19
Power MOSFET P-Channel	IXTK32P60P	Q5, Q4, Q3, Q2	13,22	4	13,22
Power MOSFET N-Channel	FDL100N50F	Q9, Q8, Q7, Q10	13,22	4	13,22
Connector	NanoFit 02X04, VEOC, VIN	J6, J3, J1	5,20	3	5,20
Small Signal Fast Switching Diode	LL4148	D21, D20, D17, D18	0,89	4	0,89
DUL PCB		DUL PCB	0,73	1	0,73
Rectifier diode	P600M	D17, D16, D15	0,67	3	0,67
500 V NPN Transistor	FMMT459	Q6	0,29	1	0,29
400 V PNP Transistor	FMMT558	Q1	0,29	1	0,29
Thick Film High Voltage Chip Resistors			0,01	16	0,01

FIT for Broadcast life profile:

Product Failure rate	Value	Unit
Unit FIT	39,75	$/10^9$ hours
MTTF (Hours)	25159835	hours
MTTF (years)	2872	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,97	0,03
2	17520	99,93	0,07
5	43800	99,83	0,17
10	87600	99,65	0,35
15	131400	99,48	0,52
20	175200	99,31	0,69

Contribution by component type:

Component type	Total FIT	Quantity
Connectors [ECCO]	5	2
Discrete semiconductors [ECDS]	34	31
Printed circuit board (PCB) [ECPC]	0	1
Resistors [ECRE]	0	47
Total	**40**	**87**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
Zener Diode	12 V and 91 V	D7, D6, D5, D14, D13, D12, D1, D9, D8, D4, D3, D2, D10	13,37	14	13,37
Power MOSFET P-Channel	IXTK32P60P	Q5, Q4, Q3, Q2	9,72	4	9,72
Power MOSFET N-Channel	FDL100N50F	Q9, Q8, Q7, Q10	9,72	4	9,72
Connector	NanoFit 02 X 04, VEOC, VIN	J6, J3, J1	4,90	3	4,90
Small Signal Fast Switching Diode	LL4148	D21, D20, D17, D18	0,63	4	0,63
DUL PCB		DUL PCB	0,49	1	0,49
Rectifier diode	P600M	D17, D16, D15	0,47	3	0,47
500 V NPN Transistor	FMMT459	Q6	0,20	1	0,20
400 V PNP Transistor	FMMT558	Q1	0,20	1	0,20
Thick Film High Voltage Chip Resistors			0,01	16	0,01

14.17.3. Conclusion and recommendations

No critical components were found, even though the worst-case scenario has been analyzed. All the failures will not affect the global system's reliability.

14.18. AC/DC converter ORCA

14.18.1. Description

Functional description:

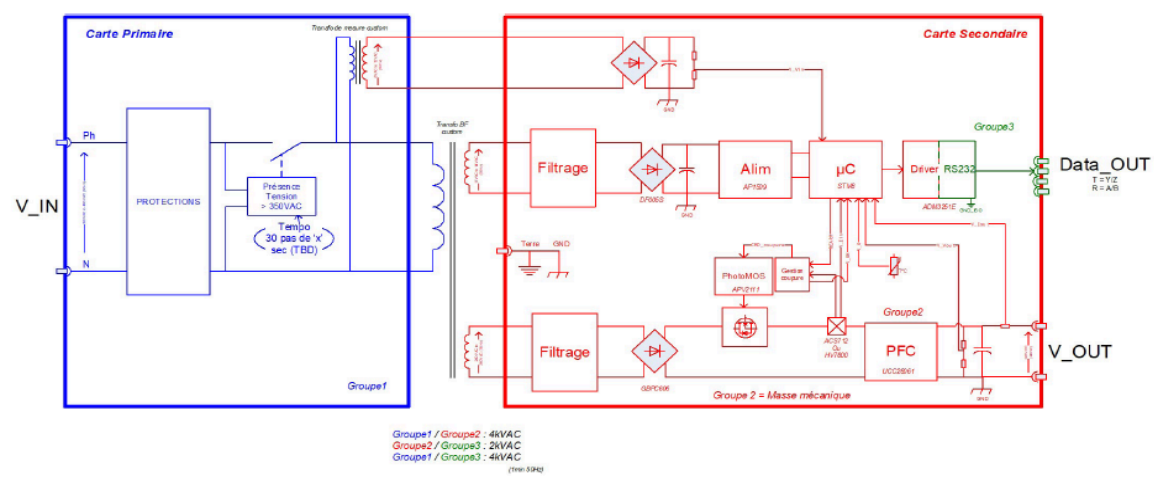


Figure 27: AC/DC block diagram.

The reliability analysis reported here concerns the latest version of the AC/DC design, with improvements on the component ratings, and issues found along the production.

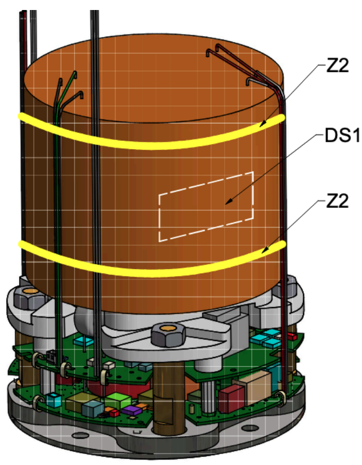


Figure 28: AC/DC assembly.

Product version 3.2.2.3.3.1/FR:TIMER/version 1 to 4 (32 units batch):

<table>
<tr><th>PBS - Product or component name</th><th>3.2.2.3.3.1 AC/DC Converter/FR:TIMER/DU_Base and 4.2.2.14 for Calibration Base</th></tr>
<tr><td>Function:</td><td>AC/DC converter 400 VAC-385 VDC</td></tr>
<tr><td>Last change date - Version</td><td>14/11/2024 (updated LM2594 values)</td></tr>
<tr><td>Comments</td><td>S.Theraube CPPM designer
Stress screening (mail S.Theraube 25/07/2022) :
12 thermal cycles are performed.
o Maximum temperatures: 60°C; Minimum temperatures: 5°C
o Temperature rise and fall rates: 10°C per minute.
o High and low plateaus were maintained for 96 minutes.
The AC/DC converter is powered at the supply voltage of 400 V RMS and loaded at 160 W (useful power for KM3NeT).
o The AC/DC converter is turned off for 10 minutes at each plateau (at the end of the high plateau and at the beginning of the low plateau to limit condensation effects in the oven).

-Board assembly: EOLANE
-PCB: SAFE-PCB
IPC level :
Référentiel de brasage : IPC A610 classe 2
Référentiel PCB : IPC A600 classe 2
Référentiel de câblage : IPC A620 classe 2
Mail Philippe BRICHET <philippe.brichet@eolane.com> - 31/08/2022</td></tr>
<tr><td>Reference documents</td><td>Based on Eolane reliability report BRE-AF-190375-SDF-01 - Ed A - 14/10/2019
KM3NeT_POWER_2019_081-Plan_cablage_carte_fille_ACDC_CNR19001_ORCA_EOLANE
New analysis 07/10/2021:
-Carte fille : Plan P947221 - B0 - 08/06/2020 - BOM E947220 - B0- 08/06/20
-Carte mère : Plan P947211 - D0 - 08/06/20 - BOM E947210 - D0 - 08/06/20
<table>
<tr><th>#</th><th>Référence</th><th>Titre</th></tr>
<tr><td>[DR 1]</td><td>P947221 – Vers.: A2</td><td>Alim AC-DC 240W (Carte fille) – Schéma de Principe</td></tr>
<tr><td>[DR 2]</td><td>P947211 – Vers.: C1</td><td>Alim AC-DC 240W (Carte Mère) – Schéma de Principe</td></tr>
<tr><td>[DR 3]</td><td>E947210 – Vers : A0</td><td>Alim AC-DC 240W (Carte Mère) – Nomenclature + Taux de charge</td></tr>
<tr><td>[DR 4]</td><td>E947220 – Vers : A0</td><td>Alim AC-DC 240W (Carte Fille) – Nomenclature + Taux de charge</td></tr>
</table>
</td></tr>
</table>

Product version 3.2.2.3.3.1/FR:TIMER/version 5 (20 units batch) :

Note: version 5 is an updated 240 W AC/DC with a new components rating.

PBS - Product or component name	3.2.2.3.3.2 AC/DC Converter/FR: TIMER_v5/ACDC
Function:	AC DC converter 400 VAC/400 VDC - New design
Last change date - Version	14/11/2024
Comments	Based on Eolane's reliability report H2P solutions 13/06/2024 and analysis review by S.Colonges. New 20 boards batch -Board assembly: EOLANE -PCB: CIPSA IPC level : Référentiel de brasage : IPC A610 classe 3 Référentiel PCB : IPC A600 classe 3 Référentiel de câblage : IPC A620 classe 2 Manuel Ley et Maxime Renier - New design 06/2024
Reference documents	-Plan_cablage_carte_fille_ACDC_CNR19001_ORCA_EOLANE -Analyse de fiabilité prédictive FIDES CNRS EOLANE 2.0 (june 2024) -Daughter board : E947220_B1_nomenclature_carte_fille070624 P947221 - C0 - Schéma carte fille -Mother Board : E947210_E0_nomenclature_carte_mère_070624 P947211 - E2 - Schéma carte mère

BM product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.3.3 - Power Converter	1
Integrated inside	3.2.2.3 - Base container electronic	1
Integrated inside	3.2.2 - Base Module	1
Integrated inside	3.2 - Detection Unit Foot	1
Integrated inside	3 - Detection Unit	115
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	115

CU product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	4.2.2.14 AC/DC	1
Integrated inside	4.2.2 Base Container	1
Integrated inside	4.2 CALIBRATION BASE(CB)	1
Integrated inside	4 - Calibration Unit	1
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	1

14.18.2. Failure rate

Product version 3.2.2.3.3.1/FR:TIMER/version 1 to 4:

Product Failure rate	Value	Unit
Unit FIT	454,78	$/10^9$ hours
MTTF (Hours)	2198855	hours
MTTF (years)	251	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,60	0,40
2	17520	99,21	0,79
5	43800	98,03	1,97
10	87600	96,09	3,91
15	131400	94,20	5,80
20	175200	92,34	7,66

Contribution by component type:

Component type	Total FIT	Quantity
Transformer	100,80	92
Aluminium capacitor [ECAC]	21,97	2
Ceramic capacitors [ECCC]	100,88	83
Connectors [ECCO]	4,41	3
Discrete semiconductors [ECDS]	66,98	18
Discrete semiconductors [PCDS]	0,22	1
Eolane	12,00	5

Component type	Total FIT	Quantity
Fuses [ECFU]	1,20	2
Integrated Circuits [ECIC]	109,14	12
Magnetic Components: Inductors and Transformers [ECIN]	0,48	6
OMSEMI	5,80	4
Optocouplers [ECOP]	2,38	3
Piezoelectric components: Oscillators and Quartz [PCPZ]	0,78	1
Resistors [ECRE]	0,10	121
Resistors [PCRE]	0,62	4
Switches [FCSW]	27,02	2
Total	**454,78**	**359**

Highest component contributors :

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
TRANSFORMER 400 VAC/10.06 VAC 50 Hz	T1	100,80	1	100,80
LM2594	U1	51,23	1	51,23
LM2594	U2	35,71	1	35,71
Diode Bridge 600 V	D5	51,49	1	51,49
150 uF 450 VDC 20% 105°C	C16	10,99	1	10,99
150 uF 450 VDC 20% 105°C	C15	10,99	1	10,99
39 nF X7R 500 V 20% (X2Y)*	C19	13,36	1	13,36
39 nF X7R 500 V 20% (X2Y)*	C18	3,26	1	3,26
39 nF X7R 500 V 20% (X2Y)*	C17	3,26	1	3,26
COND CER CMS	C17	0,00	1	0,00

Conclusion about version 1 to 4 and additional comments :

The highest contributors are the transformer, LM2594 and D5 mainly due to the current flowing through them and the subsequent temperature elevation. However, no critical component has been found.
EOLANE has also conducted a Fides analysis for the version 4 (BRE-AF-190375-SDF-01 performed by Studia company). Nevertheless, the results presented above have been processed by Stéphane Colonges because Studia assumptions were much more conservative with a Π *Process* of 4, resulting to an overestimates of the FIT.

Product version 3.2.2.3.3.1/FR:TIMER/version 5 :

Product Failure rate	Value	Unit
Function FIT	326,96	/10^9 hours
MTTF (Hours)	3058480	hours
MTTF (years)	349	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,72	0,28
2	17520	99,43	0,57
5	43800	98,58	1,42
10	87600	97,19	2,81
15	131400	95,81	4,19
20	175200	94,45	5,55

Detail per subassemblies:

Subassembly	Components quantity	FIT	MTBF hours
Motherboard	185	206,03	4853662
Daughter board	75	20,12	49682800
Transformer BF 320 W	1	100,8	9920635
Total	**261**	**326,96**	**3058478**

Contribution by component type for the ACDC Motherboard + Daughter Board + Transformer:

Component type	Total FIT	Quantity
Aluminium capacitor [ECAC]	33	3
Ceramic capacitors [ECCC]	65,35	73
Connectors [ECCO]	5,88	4
Discrete semiconductors [ECDS]	7,06	19
Eolane	10,6	3
Fuses [ECFU]	1,20	2
Integrated Circuits [ECIC]	22,215	10
Integrated Circuits [ECIC]	73,5	2
Magnetic Components: Inductors and Transformers [ECIN]	0,48	6
Magnetic Components: Inductors and Transformers [ECIN]	100,8	1

Component type	Total FIT	Quantity
OMSEMI	2,9	2
Optocouplers [ECOP]	2,38	3
Resistors [ECRE]	0,094	118
Total	**326,96**	**261**

Highest component contributors for the daughter board:

Component designation	*Value or version*	*Refdes*	Quantity	Total FIT
COND CER CMS	2.2 uF X7R 10 V 10%	C6	1	3,26
TRIAC CMS	T1635T-8G	Q1	1	2,51
COND POLYPRO MET	220 nF PP 760 VAC X1 20%	C13	1	1,87
AMPLI OP CMS	AD8602	U5	1	1,65
CONNECTOR 2 PINS	2PTS	J1	1	1,47
REGULATOR LDO CMS	5 V	U3	1	1,34
DIODE ZENER CMS	6 V	D3	1	0,96
PHOTO TRIAC CMS	MOC3083M	U7	1	0,79
FUSE CMS	2 A 600 VAC	F1	1	0,60
FUSE CMS	2 A 600 VAC	F2	1	0,60

Highest component contributors for Motherboard + Transformer:

Component designation	*Value or version*	*Refdes*	Quantity	Total FIT
TRANSFORMER BF 320W	400 VAC/10.06 VAC 50 Hz	T1	1	100,8
CONVERTER DC-DC	LM2594	U1	1	43,3
CONVERTER DC-DC	LM2594	U2	1	30,2
COND CHIM RAD	150 uF 450 VDC 20% 105°C	C15	1	15,64
COND CHIM RAD	150 uF 450 VDC 20% 105°C	C16	1	15,64
COND CHIM CMS 105°C	100 uF 6.3 V 105°C 20%	C4	1	13,36
MICRO CMS	STM8S207K6T6	U7	1	11,30
COND CER CMS	47 nF 630 V X7R 10%	C56	1	5,64

Component designation	*Value or version*	*Refdes*	Quantity	Total FIT
DIOD TRANSIL	600 V 3 A	D7	1	5
DIOD TRANSIL	600 V 3 A	D9	1	5
COND CHIM CMS 105°C	47 uF 50 V 105°C 20%	C1	1	3,26

Analysis :

With respect to the previous version, the D5 diode bridge is no longer the highest contributor, since new ratings have been applied. A current threshold below 3 A was assumed in this analysis (for version 4, it was assumed above 3 A) and a temperature elevation below 23°C instead of 34°C. In these conditions, the D5 FIT becomes negligible, since now it is 50 times lower than the previous analysis with a value of 1.3. LM2594 are now the highest contributors (values communicated by H2P solutions for Eolane).

The FIT value has been also calculated by H2P solutions for Eolane ("Analyze de fiabilité prédictive Rapport MTBF Fides 2009 Produit Alimentation 240W Eolane V2.0 - 13/06/2024 - H2P solutions"). Results were higher than our calculation shown above because they considered FIDES 2009 models for ceramic capacitors, while in our study the most recent FIDES 2022 models were used. Moreover, H2P solutions applied a more detailed life profile reported for completeness in the figure below but without significant changes in the results. Nevertheless the FIT for the transformer (100,8) used in our analysis comes from the H2P solutions company analysis.

14.18.3. Conclusion and recommendations

There are no critical components for this AC/DC converter.
The most impacting components are the transformer and LM2594 DC/DC converters.

The following improvements based on the experimental results gathered have been implemented when transiting from AC/DC Version 4 to Version 5:

- **Improvement following EN 61000-4-5 (resistance to shock waves)**
  - Filtering of the overcurrent detection function on the motherboard.

- **Improvement following EN 55011 (conducted emissions)**
  - Removal of the 'pi' filter on the motherboard (U11, C21, C22). Addition of a 0 Ω jumper in parallel without removing the filter footprints.

Furthermore, obsolete components have been replaced.

For the daughter board:

Risk - Lifecycle	Part Status	Description	Reference Designator	Part	MFR	Proposal
High	Discontinued	Rectifier Diode, Schottky, 1 Phase, 1 Element, 1A, 60V V(RRM)	D4	SS16	VISHAY	SS16T3G
High	Discontinued	Board Connector, 2 Contact(s), 1 Row(s), Male, Straight, Solder Terminal	J1	B2B-PH-K-S	JST	B2B-PH-K-S (LF)(SN)(PP)

For the motherboard:

Risk - Lifecycle	Part Status	Description	Reference Designator	Part	MFR	Proposal
High	Discontinued	Board Connector, 2 Contact(s), 1 Row(s), Male, Straight, Solder Terminal	J2	B2B-PH-K-S	JST	B2B-PH-K-S (LF)(SN)(PP)
High	Discontinued	Board Connector, 3 Contact(s), 1 Row(s), Male, Straight, Solder Terminal	J4	B3B-PH-K-S	JST	B3B-PH-K-S (LF)(SN)(PP)
High	Discontinued	Power Field-Effect Transistor, 11A I(D), 500V, 0.52ohm, 1-Element, N-Channel, Silicon, Metal-oxide Semiconductor FET, TO-220AB	Q2, Q1	IRFB11N50A	VISHAY	SiHP12N50C-E3
High	Discontinued	NTC Thermistor, 100000ohm, Surface Mount	R25	B57371V2104J 60	EPCOS	B57371V2104J060
High	Unknown	Self	L4	CTX16-17769-R	COOPER BUSSMANN	Validé par Rutronic

Figure 29: Replaced components

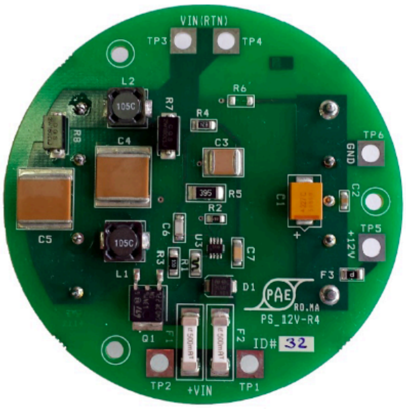
Moreover C17, C18, and C19 footprints have been removed.

14.19. PS_12V ARCA

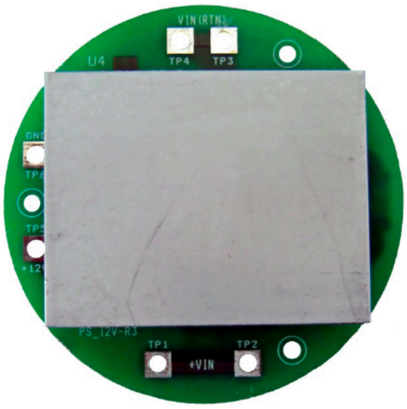
14.19.1. Description

Functional description :

The PS_12V is a board developed to supply 12 VDC to the DOM. It is hosted in a plastic container located along the DU vertical cable, and it is designed to work in an oil bath at pressures up to 350 bar. The output of the device is regulated and remains constant at 12 V (within a few tens of millivolts and low noise) for load changes from 0 to 10 W. The efficiency is up to 80% for an input ranging from 200 VDC to 400 VDC (75% for 400 VDC input).
The board provides an output ramp-up to limit the inrush current and fuses are used for overcurrent protection.



PS_12V top view



PS_12V-R4 bottom view

Figure 30: DC/DC 12 Volts for ARCA.

Product:	**3.3.1.2.2.2 - OM12V IT+ e-fuse**
Function:	Convert 375V DC into 12 VDC for DOM supply + PS12V_IT VEOC overcurrent protection
PBS number	3.3.1.2.2.2 + 3.3.1.2.2.3
Product version	14/06/2015
Responsible	Progetti & Apparetti Electtronici (PAE) - Roma
Life profile	DOM
Reference documents	- Schematic : PS_12V_ICL-R1 (14/06/2015) - Bill Of Materials PS_NKF-R4-1(Burn-in-tests).pdf - KM3NET BPS & PS_12V description & user manual_2015_001

Product hierarchy :

	Product	Product quantity integrated inside the upper-level assembly
	3.3.1.2.2.2 - OM12V IT	1
Integrated inside	3.3.1.2.2 - DC/DC Converter	1
Integrated inside	3.3.1.2.2 - DOM DC/DC	1
Integrated inside	3.3.1.2 - Break Out Box (BOB)	18
Integrated inside	3.3.1 - Cable	1
Integrated inside	3.3 - Vertical Electro-Optical Cable (VEOC)	1
Integrated inside	3 - Detection Unit	230
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	4140

14.19.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	135,05	$/10^9$ hours
MTTF (Hours)	7404720	hours
MTTF (years)	845	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,88	0,12
2	17520	99,76	0,24
5	43800	99,41	0,59
10	87600	98,82	1,18
15	131400	98,24	1,76
20	175200	97,66	2,34

Contribution by component type:

Component type	Total FIT	Quantity
AC/DC and DC/DC voltage converters [VSAD]	113,49	1
Ceramic capacitors [ECCC]	17,50	7
Discrete semiconductors [ECDS]	2,12	5
Fuses [ECFU]	0,85	1
Magnetic Components: Inductors and Transformers [ECIN]	0,06	2
Printed circuit board (PCB) [ECPC]	0,01	1
Resistors [ECRE]	0,01	13
Total	**134,04**	**37**

Highest component contributors:

Component designation	***Value or version***	***Refdes***	**Unit FIT**	**Quantity**	**Total FIT**
Half Brick 375 V to 12 V 25 W DC-DC Converter		U4	113,49	1	113,49
Multilayer Ceramic Capacitor, CKG Series, 680 nF ±20% X7R 630 V, SMD/SMT 2220	680nF	C4-C5	5,41	2	10,82
Solid Tantalum Surface Mount Capacitors, TR3 Series, Case 7361, 100 uF ±10% 25 V	100µF	C1	4,72	1	4,72
Multilayer Ceramic Capacitor, ArcShield V Series, 10 nF ±10% X7R, 500 V, SMD/SMT 0805	10nF	C3	0,86	1	0,86
SinglFuse SF-1206S Series 0.8 A SMD 1206		F1	0,85	1	0,85
Zener Diode, 4.7 V 200 mW ±2% SMD SOD-323F		D5	0,72	1	0,72
Zener Diode 7.5 V 1 W SMD SOD-128		D7	0,72	1	0,72
Low-Voltage Adjustable Precision Shunt Regulator, 2.495 V to 36 V 1%, SMD SOT23-3		U5	0,66	1	0,66
Multilayer Ceramic Capacitor, SMD Auto C0G Series, 680 pF ±5% COG, 100 V, SMD/SMT 0805	680pF	C10	0,54	1	0,54
Multilayer Ceramic Capacitor, AEC-Q200 C Series, 0.1 uF, ±10%, X7R, 50 V, SMD 0805	100nF	C2	0,54	1	0,54

14.19.3. Conclusion and recommendations

No critical point was found.
However, the PS 12 V converter is integrated in an equi-pressure enclosure filled with oil and subject to a pressure of 350 bar. The FIDES method does not directly take into account very specific environments such as high-pressure oil immersion, since the models at its basis are designed for ‘classic land’ or military environments (vibration, extreme temperatures, thermal cycles, etc.).
This means that specific failures due to pressure or oil-component interaction will not be correctly estimated.

Recommendations :

- Experimental validation: carry out tests under real or simulated conditions (pressure + oil) in order to identify specific failure modes and adjust theoretical estimates from FIDES. These tests should be performed with the units powered on in order to monitor their performances during the pressure test. It is also advised to carry out mechanical and thermal fatigue tests under pressure to assess potential damages (housings, connectors, solder joints).
- Material analysis: check the chemical and mechanical compatibility of the components and the board with high-pressure oil. Choose encapsulated or reinforced components.
- Complement FIDES analysis with specific tools or methodologies for severe environments, such as MIL-STD standards or probabilistic approaches (Reliability of Mechanical Structures).

Qualification and validation procedures performed on the product have also a great effect on reliability improvements. In particular, Highly Accelerated Stress Screens (HASS) have been performed by the KM3NeT Collaboration in order to exclude ‘youth failure’, and the results will be analysed in the RAMS report.

14.20. PS_12V ORCA

14.20.1. Description

Functional description :

- Deliver 12 V DC to the DOM: 325-400 VDC / 12 VDC – 18 W power converter.
- Tested up to 600 bar.
- Efficiency > 93% (low power dissipation).
- Overcurrent protection.
- Soft start (limit inrush current at power up).
- Galvanic isolation.

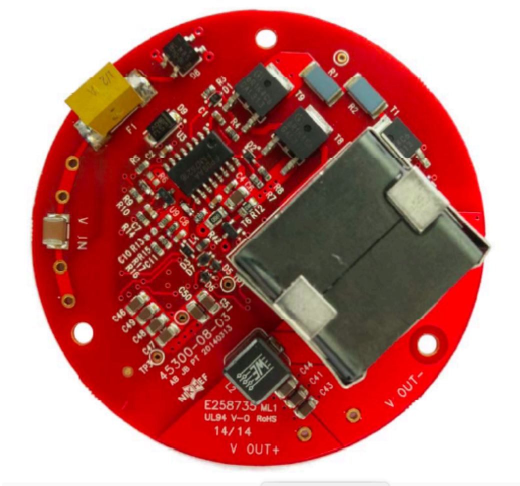


Figure 31: DC/DC 12 Volts for ORCA.

Product:	**3.3.1.2.2.1 - NIKHEF OM12V**
Function:	Convert 375 V DC into 12 V DC for DOM supply
Product version	15-11-2017
Responsible	Nikhef - Julio Acosta
Life profile	DOM
Reference documents	- Schematic: OM_400v_600bar_DCDC_v5.4 (2017-11-15) - BOM: OM_400v_600bar_DCDC_v5.4.xls - Components placement: 45300.08.14.0_PCA.PDF - Datasheet_OM_Supply - Transformator voor de KM3NeT OM Supply

Product hierarchy :

	Product	Product quantity integrated inside the upper-level assembly
	3.3.1.2.2.1 - NIKHEF OM12V	1
Integrated inside	3.3.1.2.2 - DC/DC Converter	1
Integrated inside	3.3.1.2.2 - DOM DC/DC	1
Integrated inside	3.3.1.2 - Break Out Box (BOB)	18
Integrated inside	3.3.1 - Cable	1
Integrated inside	3.3 - Vertical Electro-Optical Cable (VEOC)	1
Integrated inside	3 - Detection Unit	115
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	2070

14.20.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	55,68	$/10^9$ hours
MTTF (Hours)	17959446	hours
MTTF (years)	2050	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,95	0,05
2	17520	99,90	0,10
5	43800	99,76	0,24
10	87600	99,51	0,49
15	131400	99,27	0,73
20	175200	99,03	0,97

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	47,76	45
Discrete semiconductors [ECDS]	1,58	27
Fuses [ECFU]	0,05	1
Integrated Circuits [ECIC]	6,12	9
Magnetic Components: Inductors and Transformers [ECIN]	0,02	4
Printed circuit board (PCB) [ECPC]	0,14	1
Resistors [ECRE]	0,02	38
Total	**55,68**	**125**

Highest component contributors:

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
Total for OM12V_NIKHEF : TMK316BJ106KL-T C smd 1206 X5R 10 uF 25 V	C6,C20,C21,C22,C26,C32,C33,C34,C35,C36,C37,C38,C39,C40, C41,C43,C44,C45,C46,C47,C48,C49,C50,C51	1,02	24	24,47
Total for OM12V_NIKHEF : 0603ZD105KAT2A MLCC 0603 X7R 1 uF - 10 V	C28, C52, C53	3,13	3	9,39
Total for OM12V_NIKHEF : CC1812JKNPOCBN152 CAP1812_1n5_1000 V	C16,C17	2,42	2	4,83
Total for OM12V_NIKHEF : 2220AC124KAZ1A C smd 2220 X7R 120n 1kV	C10, C18	1,60	2	3,21
Total for OM12V_NIKHEF : CC0603KRX7R9BB104 MLCC 0603 X7R 100 nF - 50 V	C1,C4,C5,C24,C27, C29, C42	0,36	7	2,53
Total for OM12V_NIKHEF : LMC7211AIM5	U2,U4,U15	0,65	3	1,95
Total for OM12V_NIKHEF : 1812AC153KAT1A CAP1812_15n_1000 V	C9	1,60	1	1,60
Total for OM12V_NIKHEF : BVC61C	U8	0,79	1	0,79
Total for OM12V_NIKHEF : BCV62C	U7	0,79	1	0,79
Total for OM12V_NIKHEF : 06035C473KAT2A - 50 V	C7,C11	0,36	2	0,72

14.20.3. Conclusion and recommendations

No critical point was found. However, this component is integrated in an equi-pressure enclosure filled with oil and subject to a pressure of 350 bar. The FIDES method does not directly take into account very specific environments such as high-pressure oil immersion and specific failures due to pressure or oil-component interaction will not be correctly estimated.
The same recommendations reported in the conclusion section of the PS_12V for ARCA are applicable for this assembly.

14.21. LPMI

14.21.1. Description

Functional description :

The LPMI board has the function to control the Laser Beacon battery charge and send commands to the laser controller.

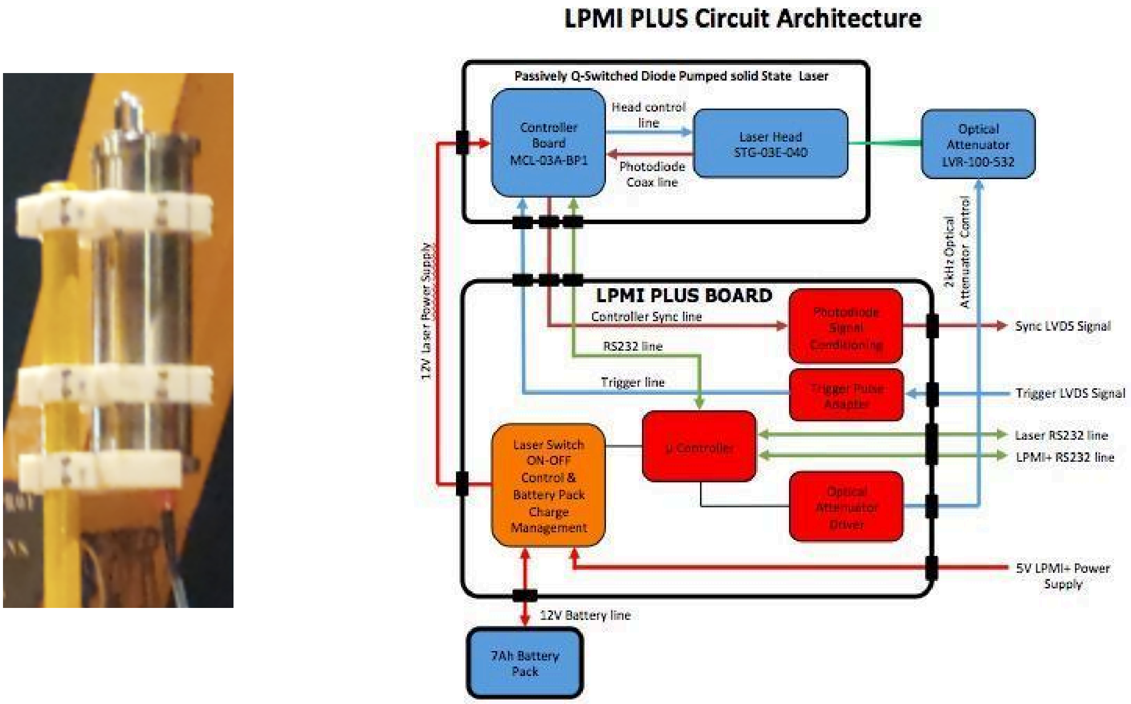


Figure 32: Laser beacon image, mounted on the specific support in DU anchor (left), and LPMI functional architecture scheme (right).

Product:	**4.4.5.1 LPMI+ board**
Function:	Control the laser battery charge and send commands to the laser controller. The laser Beacon is an instrument both ORCA and ARCA use for calibration tasks (time synchronization).
Product version	SCHEMATIC_LPMI-PLUS-V01R02_Updated Version 8.12.2017 Bill of Materials LPMI-PLUS-V01R02
Responsible	Rocco Masullo <rocco.masullo@tiscali.it>
Life profile	DU base
Reference documents	SCHEMATIC_LPMI-PLUS-V01R02_Updated Version 8.12.2017 Bill of Materials LPMI-PLUS-V01R02

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	4.4.5.1 LPMI+ board	1
Integrated inside	4.4.5 LPMI Board Assembly	1
Integrated inside	4,4 Laser beacon	1
Integrated inside	4 - Calibration Unit	1
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	1

14.21.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	96,01	/10^9 hours
MTTF (Hours)	10415915	hours
MTTF (years)	1189	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,92	0,08
2	17520	99,83	0,17
5	43800	99,58	0,42
10	87600	99,16	0,84
15	131400	98,75	1,25
20	175200	98,33	1,67

Subassemblies/functions contribution:

Component	FIT
4.4.5.1.1 Laser beacon controller	17,54
4.4.5.1.2 Laser Sync and Trigger	15,73
4.4.5.1.3 Optical attenuator driver	35,73
4.4.5.1.4 Battery charger	26,98
4.4.5.1.5 LPMI PCB and Common Functions	0,04

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	5,87	39
Connectors [ECCO]	7,20	14
Discrete semiconductors [ECDS]	0,45	6
Fuses [ECFU]	0,14	1
Integrated Circuits [ECIC]	36,36	16
Magnetic Components: Inductors and Transformers [ECIN]	0,05	1
Piezoelectric components: Oscillators and Quartz [ECPZ]	2,33	1
Printed circuit board (PCB) [ECPC]	0,04	1
Resistors [ECRE]	0,04	45
Tantalum capacitors [ECTC]	43,52	6
Total	**96,01**	**148**

Highest component contributors :

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
Tantalum Capacitor - Solid SMD 10 uF ±10%, ESR 0,9 Ω, 25 VDC, 125°C, package 6032-28	10 uF 25 V	C31,C33	9,82	2	19,64
650 kHz /1.3 MHz Step-Up PWM, Adjustable DC-DC Switching Converters	ADP1613ARMZ-R7	U2	11,30	1	11,30
Tantalum Capacitor - Solid SMD 47 uF ±10%, ESR 0.9 Ω, 25 VDC, 125°C, package 7343-31	47 uF 25 V	C29	9,82	1	9,82
Tantalum Capacitor - Solid SMD 35volts 22 uF 10%, 125°C, package 7343-31	22 uF 35 V	C43	9,82	1	9,82
LDO Voltage Regulators 3.3 V 1% 500 mA Low Noise	MIC5209-3.3YS	U10	7,43	1	7,43
1.2 V to 37 V adjustable voltage regulators	LM217	U1	7,43	1	7,43
Tantalum Capacitor - Solid SMD 47 uF ±10%, ESR 0.3 Ω, 16 VDC, 125°C, package 6032-28	47 uF 16 V	C26,C28	2,12	2	4,24
		C41	0,00	1	0,00
Tiny Low Power Operational Amplifier with Rail-to-Rail LMC7101	LMC7101AIM5	U4,U6,U7	1,10	3	3,30
CRYSTAL 3.6864 MHz, ±30 ppm, HC-49-S	3.6864 MHz	Y1	2,33	1	2,33
Multilayer Ceramic Capacitor MLCC 0805 50 V 0.1 uF X7R 10%	100 nF	C30,C32,C34	0,57	3	1,70
Multilayer Ceramic Capacitor MLCC 0805 50 V 0.1 uF X7R 10%	100 nF	C15,C16,C17,C18,C19,C20,C23,C24,C25,C27	0,02	10	0,21
Multilayer Ceramic Capacitor MLCC 0805 50 V 0.1 uF X7R 10%	100 nF	C36,C37,C38,C42,C44,C45	0,02	6	0,13
Multilayer Ceramic Capacitor MLCC 0805 50 V 0.1 uF X7R 10%	100 nF	C35	0,02	1	0,02

The battery lifetime has not been included in the table above.

Guidelines for the correct management of the battery charge:

- limit the number of charge and discharge cycling (for KM3NeT only one cycle per week).
- avoid battery over-charged.
- implement a protection against deep discharge.
- protect against over-consumption: LPMI current is limited to 2,5 A.

The first two lasers have been equipped with Ni-MH batteries (NEXcell HTD x 10 - 12 V Nominal voltage).
The Ni-MH technology offers an operational life of 10–15 years (reference sciencedirect.com). Nevertheless, the manufacturer's warranty lasts for 5 years, with the constraint that the battery charging profile recommended by the manufacturer must be respected: the battery should be charged at least one time every 3 months.

Further reference can be found at:
- Nickel Metal Hydride 7 Ah (RS-777-0387) NEXcell HTDx10;
- charger_appman-NIMH: handbook and application manual.

The next lasers to be installed will be equipped with LIFEPO4 power battery (Lithium Iron Phosphate-ECO-WORTHY 12 V 8 Ah LiFePO4 Lithium Battery). Generally, this type of battery can sustain between 2000 and 5000 cycles (or more) with a depth of discharge of 80%, which translates to a lifespan of 5 to 10 years. However, due to the small number of charge cycles performed in our case, this type of battery could last for over 20 years. With the FIDES method, Nickel and Lithium batteries are considered at the same level (same category) in terms of failure rate probability.

FIDES evaluation for battery FIT:

Component	FIT
Battery	3618,28

14.21.3. Conclusion and recommendations

The battery is the weakest component connected to the LPMI.
The LPMI controls only the charging current with a 100 mA limitation to perform a slow charge (up to 80 hours). The battery should be charged at least one time every 3 months.
The ON/OFF charge control is performed by the CLB firmware.

14.22. Laser module

The laser module is a Team photonics STG-03 E model with the following characteristics:

- wavelength: 532 nm.
- Ultra short pulses down to 350 ns.
- Up to 4 kHz frequency.

As per manufacturer information about reliability, a sealed package ensures an incredibly long lifetime even in harsh industrial environments.

A laser lifetime is generally between 10000 and 50000 hours for continuous operation. In KM3NeT the laser beacon is used only 15 minutes per week, therefore the risk associated to a laser failure is negligible.

Figure 33: Laser module.

14.23. Laser Drive Controller board (LDC)

14.23.1. Description

Functional description :

The LDC board controls the laser photodiode.

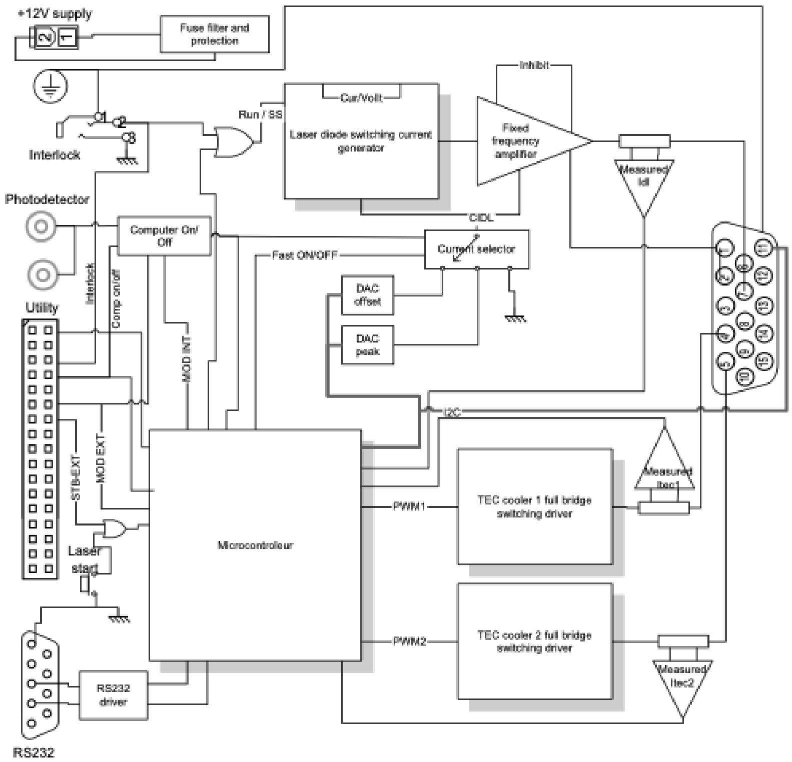


Figure 34: LDC board synoptic.

Product:	4.4.7 Laser Driver board
Function:	Control the laser photodiode
PBS number	4.4.7
Product version	22/07/2022 latest analysis updates
Responsible	Teem Photonics France
Life profile	DU base
Reference documents	- ELDRI3A-HN - 45000574 rev001 schematic - December 23, 2008 - 45000575-010 BOM Product : ref: LDC-MLC-03A-BP1

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	4.4.7 Laser Driver Board	1
Integrated inside	4,4 Laser beacon	1
Integrated inside	4 - Calibration Unit	1
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	1

14.23.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	282,93	$/10^9$ hours
MTTF (Hours)	3534391	hours
MTTF (years)	403	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,75	0,25
2	17520	99,51	0,49
5	43800	98,77	1,23
10	87600	97,55	2,45
15	131400	96,35	3,65
20	175200	95,16	4,84

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	194,09	88
Connectors [ECCO]	13,36	6
Discrete semiconductors [ECDS]	29,68	39
Fuses [HMFU]	0,27	2
Integrated Circuits [ECIC]	21,61	22
Light Emitting Diode (LED) [HMLE]	4,82	6
Magnetic Components: Inductors and Transformers [ECIN]	5,77	19
Resistors [ECRE]	0,09	113
Switches [ECSW]	13,24	1
Total	**282,93**	**318**

Highest component contributors :

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
capacitor CMS 1210 80% -20% Y5V 16 V -30°C to +85°C 10 uF - Rating : 0,8	C58 C79 C90-92	13,36	4	53,45
capacitor CMS 1210 80% -20% Y5V 16 V -30°C to +85°C 10 uF - Rating : 0,6	C79	5,64	1	5,64
capacitor CMS 1210 80% -20% Y5V 16 V -30°C to +85°C 10uF - Rating : 0,3	C94	0,70	1	0,70
capacitor CMS 1210 80% -20% Y5V 16 V -30°C to +85°C 10 uF - Rating : 0,1	C23-24 C29 C31	0,03	4	0,10
capacitor CMS 0603 10% X7R 25 V -55 to +125°C 10 nF	C13 C33 C45-55 C62-63 C72-74 C100 C101	1,74	20	34,80
capacitor CMS Alu Electrolytique 470 uF ±20% 16 V -55 to +105°C	C20 C88	13,36	2	26,73
capacitor CMS 0603 10% X7R 16V -55 to +125°C 100 nF	C1-7 C9 C11-12 C14 C16 C19 C26-27 C32 C35 C38 C40-41 C60 C64-71 C77-78 C83-87 C93 C97	0,57	38	21,53
capacitor CMS Tantale Faible ESR ±10% 16 V -55 to 125°C 100 uF - Rating : 0,8	C89	13,36	1	13,36
capacitor CMS Tantale Faible ESR ±10% 16 V -55 to 125°C 100 uF - Rating : 0,4	C21 C59	1,67	3	5,01
capacitor CMS 1206 10% X7R 6.3 V -55 to +125°C 10 uF - Rating : 0,8	C75	13,36	1	13,36
capacitor CMS 1206 10% X7R 6.3V -55 to +125°C 10 uF - Rating : 0,5	C44 C75	3,26	1	3,26
switch button Touches CI 6 x 6 vertical series STTSKHH RoHS	J12	13,24	1	13,24
Transistor CMS MOSFET dual SO8 Canal N 6 A FDS6982NL	Q2-4 Q14-15	2,51	5	12,56
capacitor CMS 1206 10% X7R 25 V -55 to +125°C 1 uF	C15 C56 C76 C80-82	1,67	6	10,02
Diode CMS Zener BZX84C5V1_NL SOT23	D13-22 D27-29 D33 D36 D37	0,60	16	9,61

14.23.3. Conclusion and recommendations

C58 C79 and C90-92, namely 10 µF decoupling capacitors, appear to be the highest contributors. Assuming the continuous operation of the apparatus, and according to the board analysis above, the resulting FIT value is high. However, the LDC board will be powered off most of the time (we estimate to operate only two calibration runs every week). Therefore, the real FIT value for the highest contributor capacitors will be divided by a factor of 10.

14.24. ORCA instrumentation unit

14.24.1. Description

Functional description:

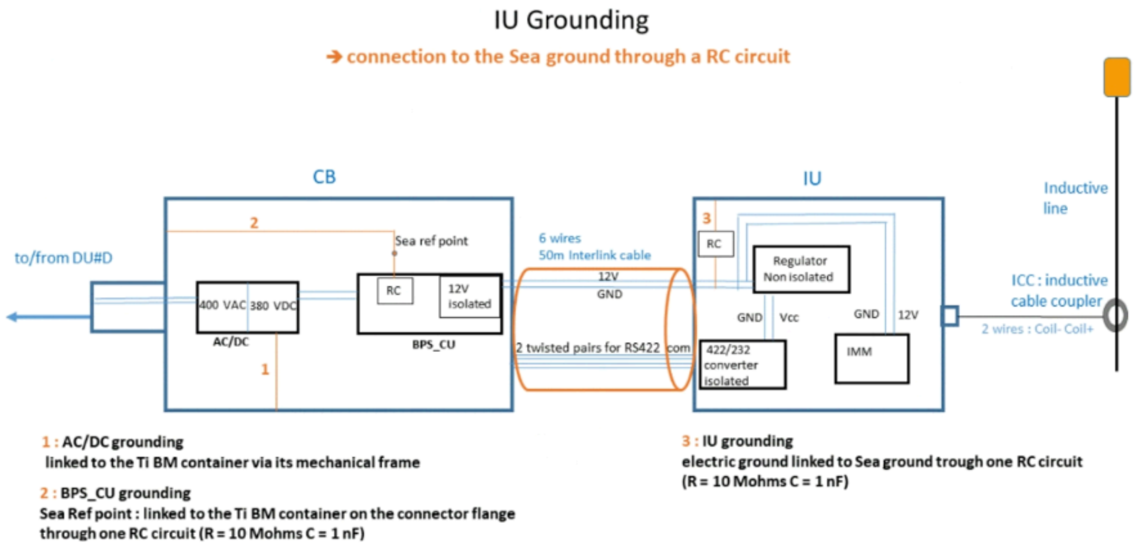
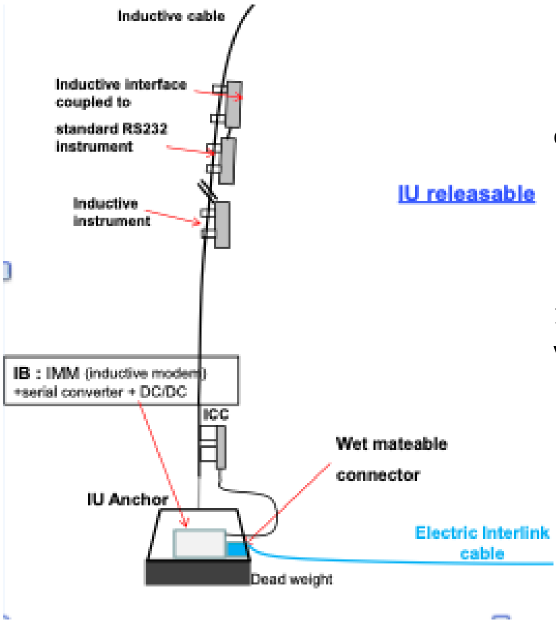


Figure 35: Instrumentation Unit interfaces.

The Instrumentation Unit (IU) linked to the Calibration Base (CB) is composed of:

- A base module integrated into the IU anchor, hosting:
  - An inductive modem to communicate with instruments through an inductive cable.
  - A regulator to supply the IU base electronics.
  - An RS422 driver to communicate with the CB.
- The inductive cable holds the instruments and transmits their signal. The inductive cable hosts several oceanographic instruments:
  - 3 “CTD” probes measuring conductivity, temperature, and depth for calculating the speed of sound and performing environmental monitoring.
  - 3 sound velocimeters allowing direct measurement of sound velocity.
  - 3 current meters for measuring the marine current along the 3 axes.
  - 7 instruments to interface with cables.
  - 1 Instrumentation Base (IB) interfaced with the inductive cable with an Inductive Cable Coupler (ICC).

For non-inductive instruments (already purchased for the ANTARES experiment), an SBE44 underwater inductive modem allows to integrate the current meter or other instruments thanks to a standard serial interface.



Note about instruments:

- Aquadopp Nortek inductive IM6000M
- Aquadopp Nortek non-inductive 3000M coupled to UIMM (seabird) 5 V or 12 V – 50 Wh
- Buoy

Consumption: 0.1 W;
18 months for 1 acquisition every 10 minutes;
For KM3NeT ORCA the setting is: one acquisition every 15 to 30 minutes. Batteries will survive more than 2 years.

Figure 36: ORCA Instrumentation Unit principle.

The base module IU (or anchor):

The IU base contains an electronic board equipped with a 12 V to 5 V regulator designed to power the RS422 driver (MAX232) with low power consumption (8 mA). Additionally, it houses the SBE 44 Inductive Modem Module (IMM), which combines low power consumption with high reliability.

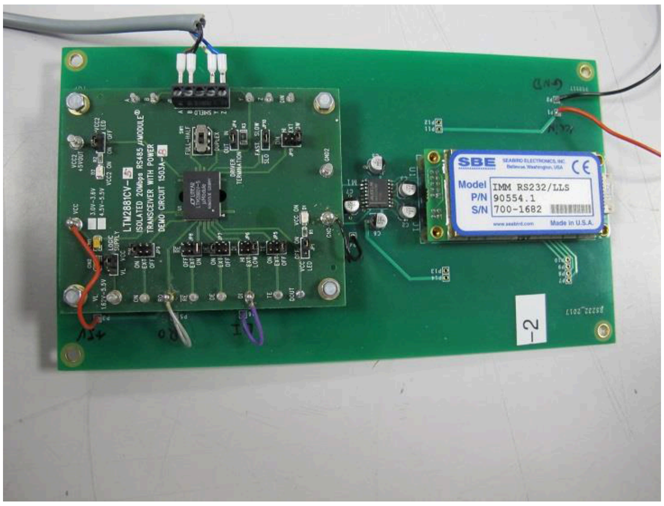


Figure 37: IU Base container electronic board.

Figure 38: Seabird Inductive Modem Module (RS422 standard).

Product:	**4.3 Instrumentation Unit (IU)**
Function:	Collect subsea science data
PBS number	4.3
Product version	21/03/2020
Responsible	Pascale Keller (CPPM)
Life profile	DU base (for the IU base) and IU 13°C for the instruments (low consumption power dissipation)
Reference documents	V5 - Definition Document – ORCA Instrumentation Unit (KM3NeT_CALIB_2019_017) CPPM, Marseille

PBS - Product or component name	**4.3.2.4 IU Base container/ORCA**
Function:	Supply RS22 driver and Inductive Module Modem (IMM)
Last change date - Version	17/04/2018
Comments	
Life profile	DU Base
Reference documents	- Schema_carte_IU-01022018 - BOM-17042018

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	4.3 Instrumentation Unit (IU)	
Integrated inside	4 - Calibration Unit	1
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	1

The instrumentation line will be recovered every 2 years for instrument battery replacement and recalibration of some of the probes.

14.24.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	65,78	$/10^9$ hours
MTTF (Hours)	15201298	hours
MTTF (years)	1735	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,94	0,06
2	17520	99,88	0,12
5	43800	99,71	0,29
10	87600	99,43	0,57
15	131400	99,14	0,86
20	175200	98,85	1,15

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	33,43	10
Connectors [ECCO]	4,90	2
Discrete semiconductors [ECDS]	1,12	1
Integrated Circuits [ECIC]	1,34	1
Printed circuit board (PCB) [ECPC]	0,00	1
Seabird instruments	25,00	1
Total	**65,78**	**30**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
IMM Seabird		IMM	25,00	1	25,00
CPOL-4.7U, T35X28S20V	4.7 uF	C1,C4	8,50	2	17,00
CPOL-10U, T35X28S10V	10 uF	C2,C3, C5-C7	3,26	5	16,31
CON4P_CPPM-SILW RA	?	J1	2,45	1	2,45
CON10P_CPPM-COU DE_M	?	U1	2,45	1	2,45
MAX232-C	?	M1	1,34	1	1,34
7805_H	?	M2	1,12	1	1,12
CAPA-100N, C1206S100V10%	100 n	C8-C10	0,04	3	0,12
IU electronic PCB		PCB_IU	0,00	1	0,00
PASCON-183	?	P1-P14	0,00	14	0,00
Total			**44,16**	**30**	**65,78**

For the instruments mounted on the inductive line (data from manufacturers):

Components	FIT (/10^9 hours)	Qty
inductive interface SeaBird UIMM	28538,81	2
CTD Seabird inductive : SBE 37-IMP	14269,41	1
SV miniSVS Valeport non inductive (coupled to SBE44)	2623,36	1
CTD Seabird non inductive : SBE 37SMP-IDO (O2 measurement) (coupled to SBE44)	0,00	1
Aquadopp Nortek non inductive : Aquadopp 3000 m (coupled to UIMM)	0,00	2
Aquadopp Nortek inductive : Aquadopp IM 6000 m	0,00	1
CTD Seabird non inductive : SBE 37-SMP (coupled to SBE44)	0,00	1

The high FIT value for the various instruments installed on the instrumentation unit is mainly affected by batteries powering the instruments themselves.

14.24.3. Conclusion and recommendations

No critical components were found.

14.25. Nano Beacon emitter

14.25.1. Description

Functional description:

The Nano Beacon, a small LED flasher, has been developed and integrated inside each DOM.

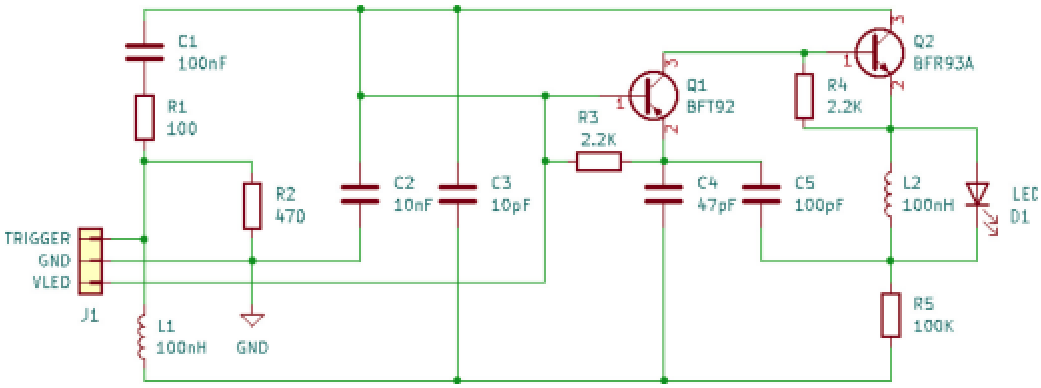


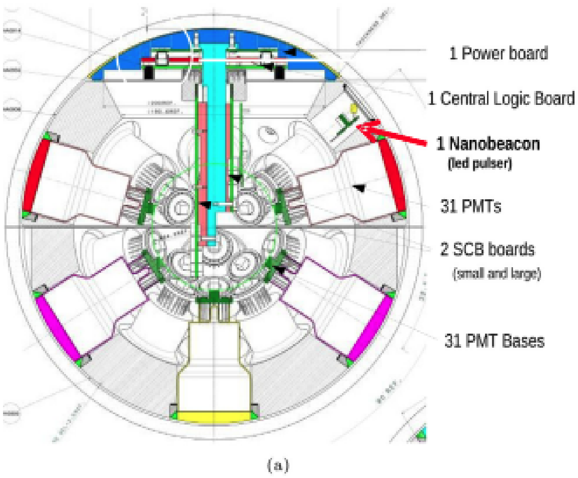
Fig. 3. Electronics schematics of the Nanobeacon pulser.

Figure 39: Nano Beacon electronics.

PBS - Product or component name	3.4.3.7 - Nano Beacon
Function:	Generate light signal for inter-DOM calibration and synchronization
Last change date - Version	
Comments	
Reference documents	KM3NeT_CALIB_2009_01-Nanobeacon_Jonthan Perkin_v1 nanobeaconemitter0722

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.7 - Nano Beacon	1
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	230 ARCA / 115 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	230 ARCA / 115 ORCA



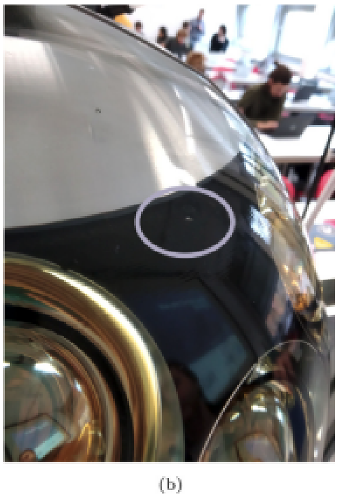


Figure 40: Nano Beacon DOM integration.

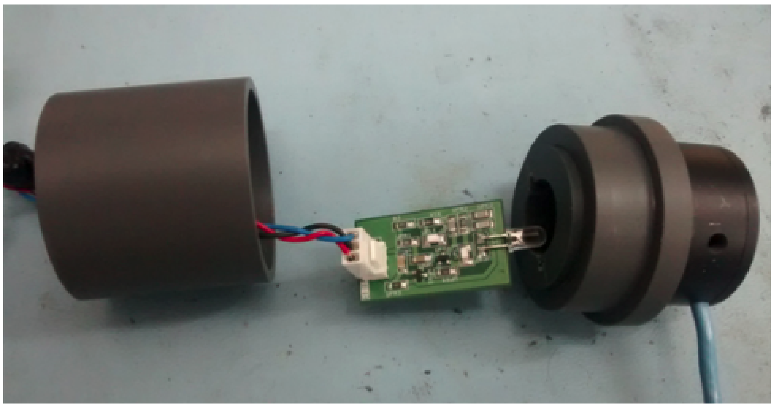


Figure 41: Nano Beacon assembly.

14.25.2. Failure rate

Product Failure rate	Value	Unit
Unit FIT	4,43	/10^9 hours
MTTF (Hours)	225494292	hours
MTTF (years)	>150	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	100,00	0,00
2	17520	99,99	0,01
5	43800	99,98	0,02
10	87600	99,96	0,04
15	131400	99,94	0,06
20	175200	99,92	0,08

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	1,80	5
Connectors [ECCO]	1,41	1
Discrete semiconductors [PCDS]	0,34	2
Light Emitting Diode (LED) [ECLE]	0,34	1
Magnetic Components: Inductors and Transformers [ECIN]	0,55	2
Total	**4,43**	**17**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
Male 3 pin	Male 3 pin	Connector	1,41	1	1,41
100 nH	100 nH	UpL1, UpL2	0,27	1	0,54
47 pF	47 pF	UpC2	0,36	1	0,36
10pF	10pF	UpC4	0,36	1	0,36
100 pF	100 pF	UpC3	0,36	1	0,36
100 nF	100 nF	UpC1	0,36	1	0,36
10 nF	10 nF	C1	0,36	1	0,36
LED 470 nm. HLMP-CB1A-XY0DD	LED 470 nm. HLMP-CB1A-XY0DD	UpD1	0,34	1	0,34
BFT92	BFT92	UpQ2	0,17	1	0,17
BFR93A	BFR93A	UpQ1	0,17	1	0,17

14.25.3. Conclusion and recommendations

The Nano Beacon is not a critical component since, even with a partial number of working DOMs within a DU, it is still possible to calibrate the DOM orientation (ie. redundancy).

14.26. DOM Piezo

14.26.1. Description

Functional description:

Piezo sensors are used in order to perform the spatial localization of the DOMs during data acquisition, thanks to the triangulation of various acoustic signals emitted by long baseline acoustic beacons. This component is not critical since not all the piezo signals from all DOMs within a line are needed to determine their exact position. This component has been developed by AST-X company.

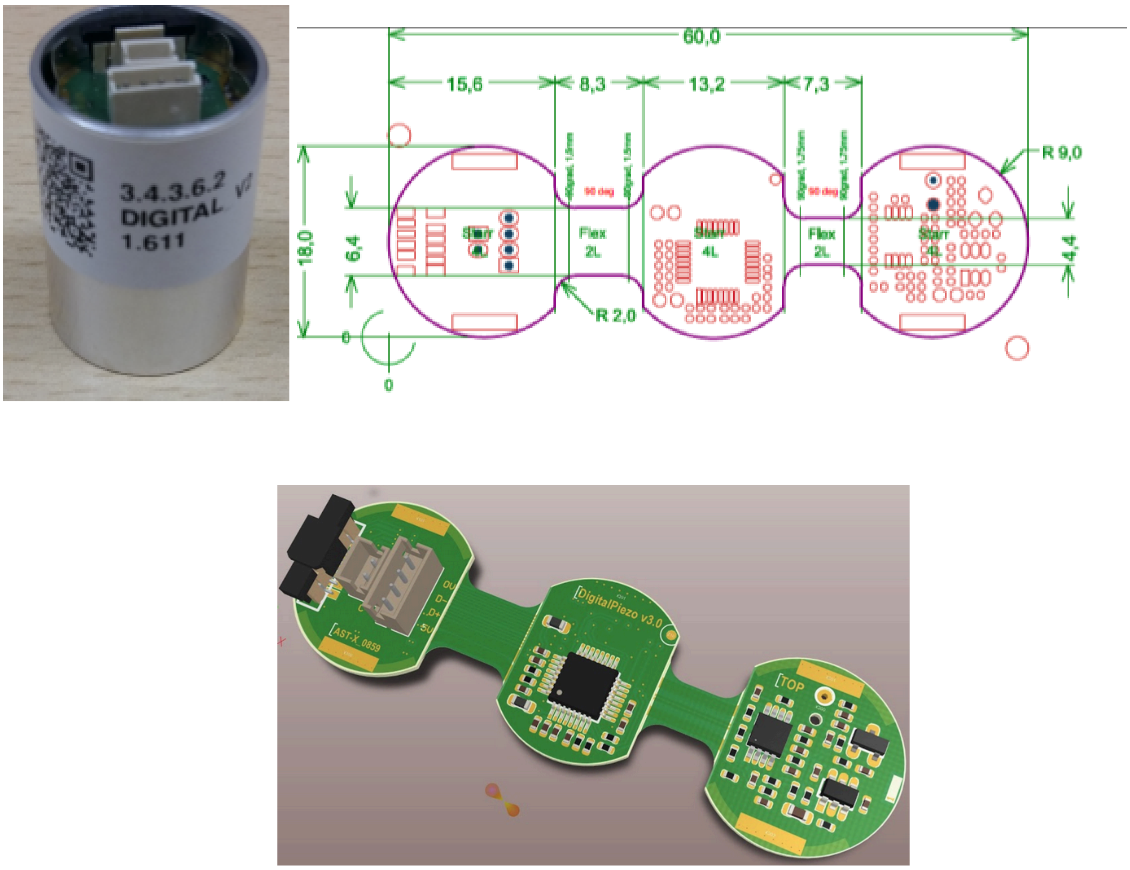


Figure 42: DOM acoustic beacon / Piezo assembly.

PBS - Product or component name	3.4.3.6 - Acoustic components (Piezo)
Function:	Detect acoustic waves for DOM positioning
Last change date - Version	21/10/2019
Comments	Piezo sensor for DOM developed by AST-X. AGE Scientific has proposed also a V4 design to replace the FPGA shortage (not validated)
Life profile	See component level
Reference documents	- Digital Piezo V3 v4.0 (AST-X_0871) SCD+PCB - KM3NET_CALIB_2023_014_Piezo_Bill_Of_Material

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.6 - Acoustic components (Piezo)	1
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	230 ARCA / 115 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	230 ARCA / 115 ORCA

14.26.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	149,00	$/10^9$ hours
MTTF (Hours)	6711384	hours
MTTF (years)	766	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,87	0,13
2	17520	99,74	0,26
5	43800	99,35	0,65
10	87600	98,70	1,30
15	131400	98,06	1,94
20	175200	97,42	2,58

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	111,32	39
Connectors [ECCO]	7,03	3
Discrete semiconductors [ECDS]	1,76	2
Discrete semiconductors [FCDS]	1,49	1
Integrated Circuits [ECIC]	1,77	4
Magnetic Components: Inductors and Transformers [FCIN]	0,67	5
Piezoelectric components: Oscillators and Quartz [ECPZ]	23,27	2
Printed circuit board (PCB) [FCPB]	1,67	1
Resistors [ECRE]	0,03	39
Total	**149,00**	**102**

Highest component contributors :

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
Capacitor Ceramic X5R, 20% -55...+85°C	X5R 10 uF 10 V 0402	C100, C101, C104, C201, C300, C301	3,13	6	18,79
Capacitor Ceramic X5R, 10% -55...+85°C	X5R 47 uF 6.3 V 0805	C106, C217, C313	12,83	3	38,48
Capacitor Ceramic X5R, 10% -55...+85°C	X5R 1 uF 10 V 0402	C204, C205, C206, C207, C208, C211, C216, C303, C306	3,13	9	28,18
Capacitor Ceramic X5R, 10% -55...+85°C	X5R 220 nF 10 V 0402	C304, C309	1,67	2	3,34
Capacitor Ceramic X7R, 10% -55...+125°C	X7R 100 nF 16 V 0402	C102, C105, C200, C202, C209, C210, C212, C213, C214, C215, C302, C305, C307	1,60	13	20,84
Capacitor Ceramic X7R, 10% -55...+125°C	X7R 1 uF 16 V 0603	C310	1,60	1	1,60
Piezo 17,9 x 12,0 (DxL)	PIEZO	PZ300	11,64	1	11,64
IC Clock Osc, 50ppm 3V3 MEMS	SiT8008B 24.576 MHz 3.2x2.5	IC101	11,64	1	11,64
Connector Rectangular RM 2.00 Male, 5-pos Single Row 180°, Shrouded	WR-FPC 08 V RM0.50	J102	2,34	1	2,34
Connector Rectangular RM 1.50 Male, 4-pos Single Row 180°, Shrouded	WR-WTB 1x04 V RM1.50	J100	2,34	1	2,34
Connector Rectangular RM 1.50 Male, 2-pos Single Row 180°, Shrouded	WR-WTB 1x02 V RM1.50	J101	2,34	1	2,34
PCB-Symbol, Fiducial for SMD Placement	Z_PCB_Fiducial	PCB	1,67	1	1,67
Transistor JFET N-Ch, 15V 50mA 35mS, Low Noise	2SK3557 SOT23	T300	1,49	1	1,49

14.26.3. Conclusion and recommendations

47 µF decoupling capacitors come out to be the highest contributors. The application of recommendations is not always possible since this is a complex board with flexible PCB and highly integrated. Nevertheless, the FIT rate of this component is not critical for the system availability.

14.27. Compass board

14.27.1. Description

Functional description:

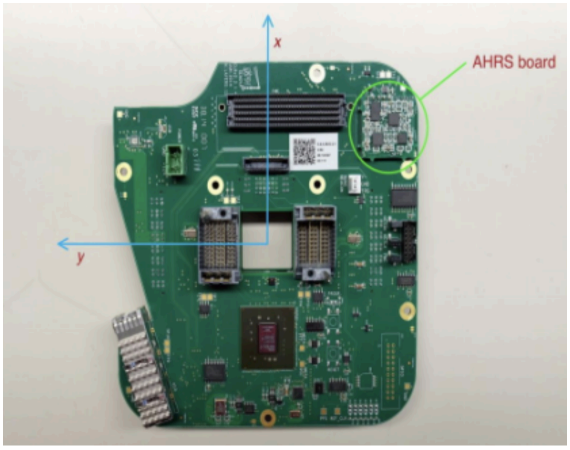
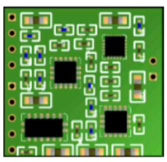


Figure 43: compass board (AHRS) mounted on the CLB.

Compass models in ARCA and ORCA detectors	
AHRS-LNS	**LSM303**
	
LIS3LV02DL 3D accelerometer and HMC5843 3D magnetometer in separated chips.	3D accelerometer and 3D magnetometer sensor integrated in a single custom chip.

	Accelerometer	Magnetometer		Accelerometer	Magnetometer
Range	±2 g	±4 gauss	Range	±2 g	±2 gauss
Resolution	<1 mg	<7 mgauss	Resolution	N/A	<2 mgauss

Figure 44: summary of the main features for the 2 types of compass boards integrated in KM3NeT.

PBS - Product or component name	3.4.3.4. compass board LSM303 or AHRS
Function:	DOM orientation measurement
Last change date - Version	
Comments	
Life profile	DOM
Reference documents	

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	3.4.3.4. compass board LSM303 or AHRS	1
Integrated inside	3.4.3 - DOM Electronics	1
Integrated inside	3.4 - Digital Optical Module (DOM)	18
Integrated inside	3 - Detection Unit	230 ARCA / 115 ORCA
Integrated inside	0 - KM3NET	1
	Total lower level quantity inside higher level assembly:	4140 ARCA / 2070 ORCA

14.27.2. Failure rate

Product Failure rate	Value	Unit
Function FIT	6,42	/10^9 hours
MTTF (Hours)	155850623	hours
MTTF (years)	>150	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,99	0,01
2	17520	99,99	0,01
5	43800	99,97	0,03
10	87600	99,94	0,06
15	131400	99,92	0,08
20	175200	99,89	0,11

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	0,65	4
Connectors [ECCO]	4,22	3
Integrated Circuits [ECIC]	1,25	1
Magnetic Components: Inductors and Transformers [ECIN]	0,29	1
Printed circuit board (PCB) [ECPC]	0,01	1
Resistors [ECRE]	0,00	2
Total	**6,42**	**12**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
HTSW-105-05-T-S		J2	1,41	1	1,41
HTSW-104-05-T-S		J1	1,41	1	1,41
HTSW-102-05-T-S		J3	1,41	1	1,41
LSM303D		U1	1,25	1	1,25
C0805C475K3PAC	4.7 uF	C2	0,30	1	0,30
C0805C106K4PAC	10 uF	C1	0,30	1	0,30
MMZ1608B601C		L1	0,29	1	0,29
22_22_58_0_1_5_6_54	220 nF	C3	0,03	1	0,03
22_22_58_0_1_5_6_49	100 nF /50 V	C4	0,02	1	0,02
CompassV1_PCB		CompassV1_ PCB	0,01	1	0,01
MC_0.063W_0603_1%_10K	10K	R1,R2	0,00	2	0,00
Total			**6,42**	**12**	**6,42**

14.27.3. Conclusion and recommendations

The compass board is not a critical component since, even with a partial number of working DOMs within a DU, it is possible to calibrate the DOMs orientations in the DU.

14.28. Hydrophone

14.28.1. Description

Functional description:

The hydrophone is an acoustic wave receiver installed on the DU base anchor or on the calibration base anchor. Inside the KM3NeT detector, it is used to calibrate piezo sensors mounted on DOMs and to derive their exact position.

Figure 45: Hydrophone assembly.

PBS - Product or component name	4.5 Hydrophone/Broadcast
Function:	Acoustic waves receiver: installed on the DU base anchor or the Calibration Base anchor, the hydrophone is used for calibrating piezo sensors on DOMs and for detecting their exact position. It also allows us to perform sea science, i.e. detecting sea animals.
Last change date - Version	September 2018
Comments	Non-disclosure agreement. No additional details will be given on the design. Design data limited diffusion. Designed and manufactured by Colmar company in Italy. Hydrophones are not single-point failures.
Life profile	DU base
Reference documents	- Lista Parti DIGITALIDROPHONE V3.2 Hydrophone schematic: -Digital hydrophone -Digital Hydrone A/D converter -Digital hydrophone CPU -Digital Hydrophone I/F -Digital Hydrophone Power -Digital hydrophone SPDIF

14.28.2. Failure rate

Product Failure rate	Value	Unit
Unit FIT	169,62	$/10^9$ hours
MTTF (Hours)	5895472	hours
MTTF (years)	673	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,85	0,15
2	17520	99,70	0,30
5	43800	99,26	0,74
10	87600	98,53	1,47
15	131400	97,80	2,20
20	175200	97,07	2,93

Contribution by component type:

Component type	Total FIT	Quantity
Aluminium capacitors [ECAC]	6,84	17
Ceramic capacitors [ECCC]	129,41	68
Coilcraft	21,10	2
Discrete semiconductors [ECDS]	0,08	1
Integrated Circuits [ECIC]	8,58	8
Light Emitting Diode (LED) [ECLE]	0,16	2
Magnetic Components: Inductors and Transformers [ECIN]	1,44	10
Printed circuit board (PCB) [FCPB]	1,92	1
Resistors [ECRE]	0,10	83
Total	**169,62**	**195**

Highest component contributors :

Component designation	*Value or version*	Unit FIT	Quantity	Total FIT
Multilayer Ceramic Capacitors MLCC - SMD/SMT 0402 6.3 V 10 uF X5R 20%	10 uF 6.3 V	8,50	10	84,99
Multilayer Ceramic Capacitors MLCC - SMD/SMT 47 uF 6.3 V X5R 10%	47 uF 6.3 V	8,50	3	25,50
Audio Transformers / Signal Transformers 3T:6T Impd 75:75	PT203	10,55	2	21,10
Aluminium Electrolytic Capacitors - SMD 47 uF 16 V	47 uF 16 V	0,40	13	5,23
Multilayer Ceramic Capacitors MLCC - SMD/SMT 0402 0.1 uF 16volts X7R 10%	100 nF 16 V	0,17	29	4,87

The piezo element itself is not included in this calculation since it is a specific component developed by a private company (Colmar) and no reliability models are available.
A non-disclosure agreement does not allow us to communicate more details.

14.28.3. Conclusion and recommendations

Some reliability improvements have been identified and listed below:

- Improve capacitors derating.
- Improve manufacturing and validation quality control. Results about anomalies found during hydrophone integration or operation will be presented in the RAMS report.

14.29. LBL emitter

14.29.1. Description

Functional description:

The RASP LBL acoustic beacons are devices used in the frame of the underwater positioning systems. They are commonly used in subsea exploration, and remotely operated vehicle (ROV) operations to determine precise locations underwater. The RASP (Remote Acoustic Sensor Platform) beacon serves as a key element of the Long Baseline (LBL) system, acting as a fixed or mobile reference point that emits or receives acoustic signals.

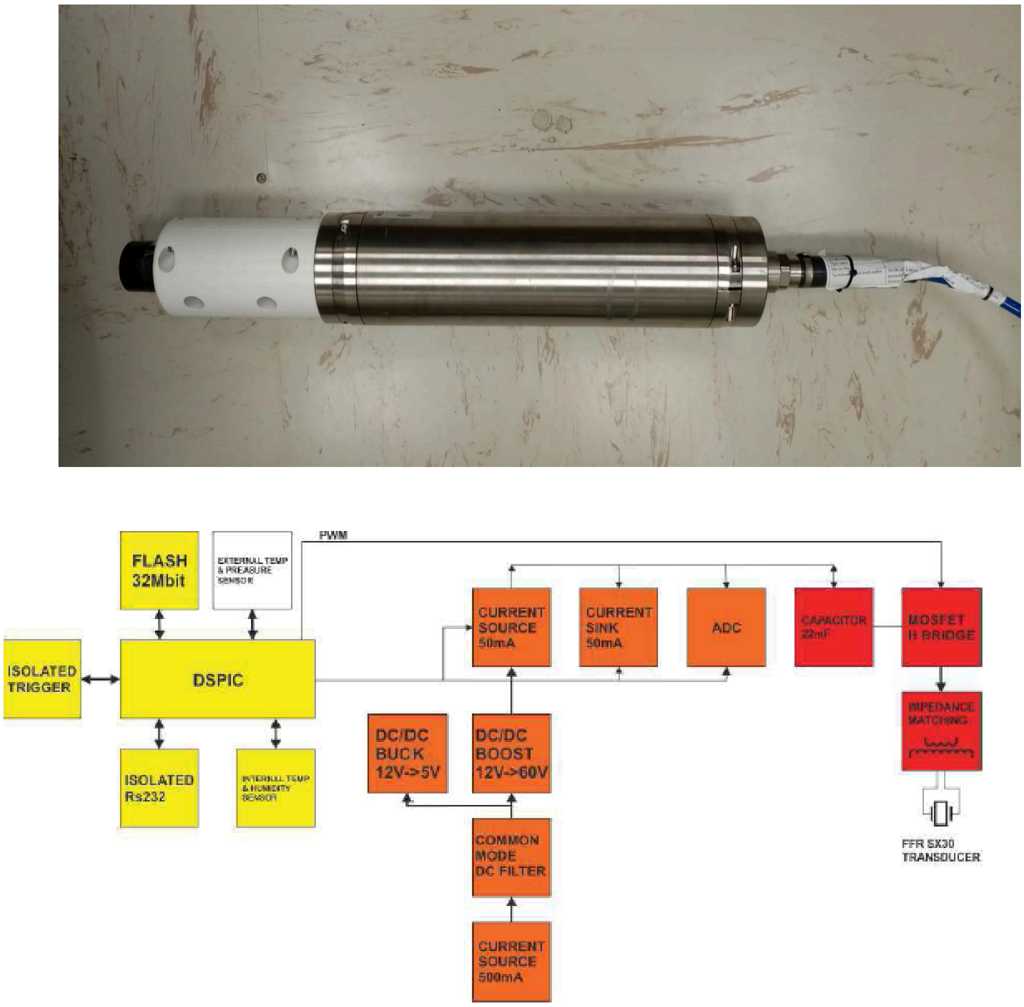


Figure 46: LBL beacon assembly (top) and LBL emitter functional schematic (bottom).

PBS - Product or component name	4.6 RAPS LBL Beacon
Function:	Acoustic Beacon: it emits acoustic waves for the positioning system
Last change date - Version	July 2017
Comments	
Life profile	See component level
Reference documents	Acoustic beacon software and electronic : Trigger Receiver Supply Schematic Esquematico DSPIC Board Diagram

14.29.2. Failure rate

Product Failure rate	Value	Unit
Unit FIT	121,93	/10^9 hours
MTTF (Hours)	8201480	hours
MTTF (years)	936	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,89	0,11
2	17520	99,79	0,21
5	43800	99,47	0,53
10	87600	98,94	1,06
15	131400	98,41	1,59
20	175200	97,89	2,11

Contribution by component type:

Component type	Total FIT	Quantity
Aluminum capacitor [FCAC]	2,21	1
Ceramic capacitors [ECCC]	38,62	49
Connectors [ECCO]	8,65	10
COTS Board	10,28	1
Discrete semiconductors [ECDS]	28,56	23
Integrated Circuits [ECIC]	8,20	11
Magnetic Components: Inductors and Transformers [ECIN]	0,72	5
Magnetic Components: Inductors and Transformers [FCIN]	0,49	2
Optocouplers [ECOP]	3,49	2
Piezoelectric components: Oscillators and Quartz [ECPZ]	1,05	2
Resistors [ECRE]	0,02	31
Tantalum capacitors [ECTC]	19,64	2
Total	**121,93**	**177**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
GRM32ER72A225KA35L	2,2 uF 100 V	C7 C8 C9 C18 C19 C20 C26 C27 C31 C32	3,26	10	32,62
	2,2 uF 100 V 60 V CERAMIC	C4,C5,C6,C7,C8,C9,C10,C11	0,21	8	1,67
TR3E227K016C0100	220 uF 16 V 12 V TANTALUM	C2,C14	9,82	2	19,64
ADUM1250ARZ		IC3	10,28	1	10,28
AUIRF540ZS	Transistors	Q1 Q2 Q3 Q4	2,51	4	10,05
FQD5P10TM	3,6 A 25 W 100 V 12 V MOSFET P Working idmax=500 mA	Q5 Q3	2,51	2	5,02
BSS63LT1G	100 mA 225 mW 100 V 12 V BJT PNP Working icmax=0,1 mA	Q6, Q4	2,51	2	5,02
VOM617A-7X001T		OP1,OP2	1,74	2	3,49
Connector		SUPPLY/RS232/SYNC	1,47	1	1,47
PBSS8110T	1 A 300 mW 100 V 60 V BJT NPN Working icmax=0,2 mA	Q2	2,51	1	2,51
IRLR110PBF	4,3 A 25 W 100 V 60 V MOSFET N Working Idmax=33 mA	Q1	2,51	1	2,51

14.29.3. Conclusion and recommendations

The most critical component is the flash memory due to its 20-year data retention capacity, as stated by the manufacturer. A possible mitigation of the problem may be remote memory reprogramming, although the technical implementation of such a solution is still under investigation.
Additionally, special care has been taken during component derating, since up to 60 V are generated on this board.

14.30. Broadcast DU base optical components

14.30.1. Description

Functional description:

Optical components allow for communication between on-shore infrastructure and DOMs. In the Broadcast scenario, a single optical fiber transmits information from the on-shore switching infrastructure to the DOMs, via base modules. The acquired data are then sent back on-shore via a dedicated optical fiber for each DOM.

The main optical components for the Broadcast design are:

- The EDFA: an optical amplifier/repeater, supplied with 12 V by the BPS and controlled by the CLB (see a dedicated section earlier in this document for more details).
- The Add&Drop filter: a system designed for multiplexing and routing ("add and drop") optical signal wavelengths from multiple fibers onto a single fiber.
- The optical fibers to transmit light signals.
- The optical splitters: systems dedicated to split an optical signal into multiple channels.
- The optical interleaver: device to expand the number of channels per fiber.

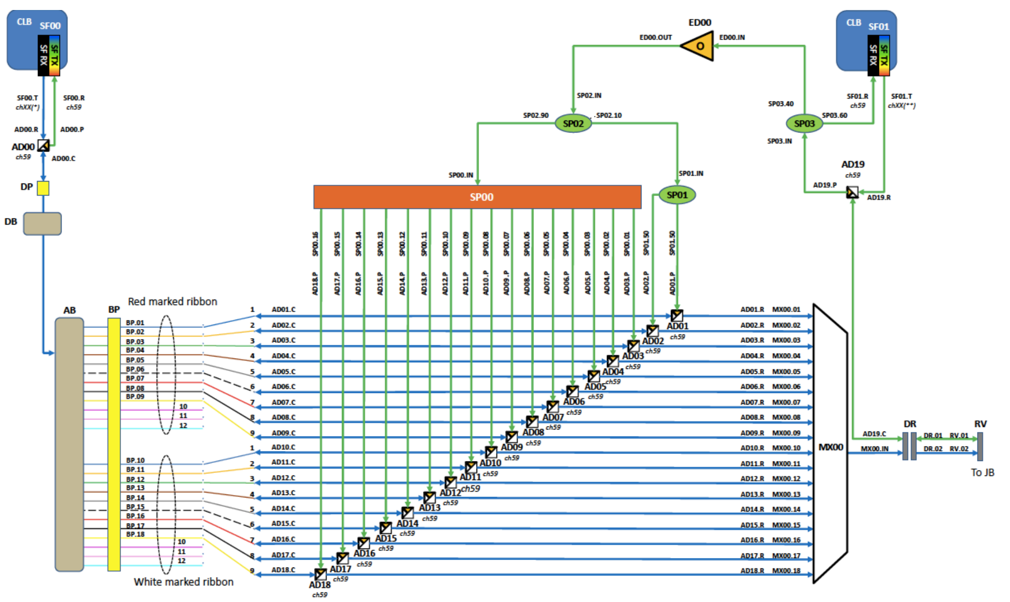


Figure 47: Broadcast DU base optic system schematic.

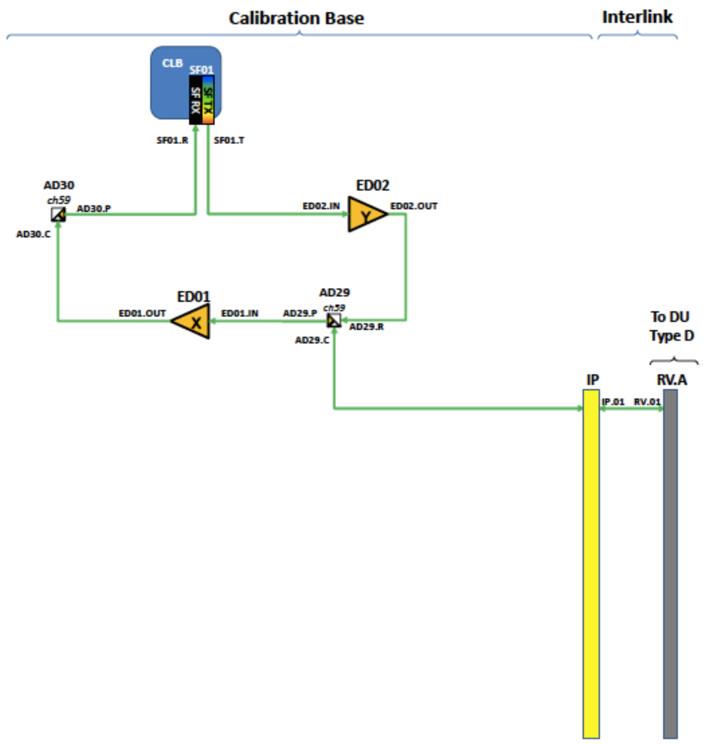


Figure 48: CU base optic system schematic.

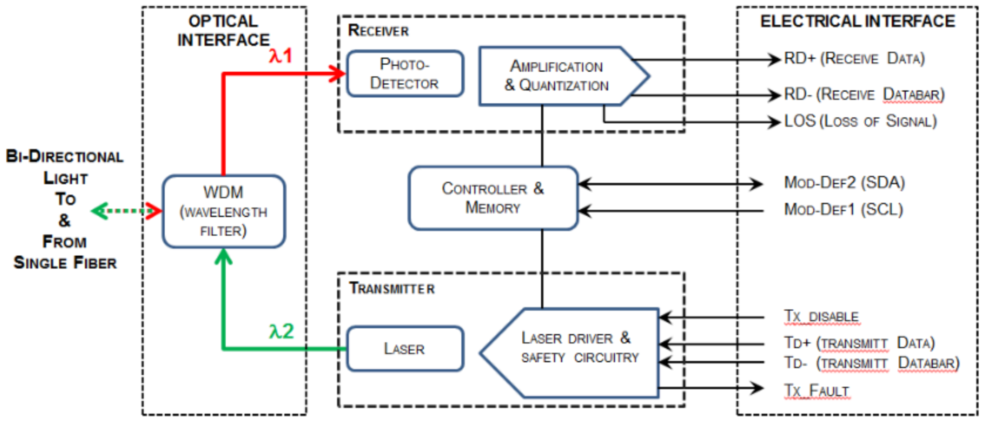


Figure 49: TSFP block diagram.

Product:	3.2.2.2 - Optical Component/Broadcast
Function:	3.2.2.2 - Optical Component
PBS number	3.2.2.2
Product version	P1 : Phase 1
Responsible	Antonio D'Amico
Life profile	DU base
Reference documents	See DET/Optical/registered documents for information : https://drive.google.com/drive/folders/0B6CcXapUNLNLc1hDek1VNTRXemM?usp=sharing

Product hierarchy :

	Product	Product quantity integrated inside the upper-level assembly
	3.2.2.2 - Optical Component	1
Integrated inside	3.2.2 - Base Container	52 ORCA / 32 ARCA
	Total lower level quantity inside higher level assembly:	52/32

14.30.2. DU base module optical components failure rate

Product Failure rate	Value	Unit
Function FIT	402,00	$/10^9$ hours
MTTF (Hours)	2487562	hours
MTTF (years)	284	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,65	0,35
2	17520	99,30	0,70
5	43800	98,25	1,75
10	87600	96,54	3,46
15	131400	94,85	5,15
20	175200	93,20	6,80

Contribution by component type:

Only the highest contributor components have been considered for this analysis. Pure optical components, like fibers (0,228 FIT/km), Add&Drops and splitters have a really low failure rate thanks to their high-quality, as documented in several papers. In fact, these optical technologies have been specifically developed for Large Area Optical Network communication, with equipment installed up to 8000 m deep on the sea bed.

Highest component contributors:

Components	Total FIT	Quantity
Optical fiber	1,0	1
Splitter	1,0	3
Add&Drop	1,0	20
Penetrators	1,0	2
IPG Photonics (EDFA)	220	1,00
SFP+	182	1,00

14.30.3. Calibration Unit base optical components failure rate

Product Failure rate	Value	Unit
Function FIT	622	$/10^9$ hours
MTTF (Hours)	1607717	hours
MTTF (years)	184	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,46	0,54
2	17520	98,92	1,08
5	43800	97,31	2,69
10	87600	94,70	5,30
15	131400	92,15	7,85
20	175200	89,68	10,32

Highest component contributors:

Components	Total FIT	Quantity
Optical fiber	1,0	1
Splitter	1,0	3
Add&Drop	1,0	20
Penetrators	1,0	2
EDFA IPG Photonics	440	2,00
SFP transceiver	182	1,00

14.30.4. Conclusion and recommendations

The highest component contributors to the failure rate probability of the DU optical system are mainly EDFAs and SFPs (dedicated sections have been reported earlier in this document for specific FIT calculations). Since no redundancy is implemented, EDFA or SFP failures will result in the loss of communication with all the DOMs within a DU.

14.31. Wet White Rabbit switch

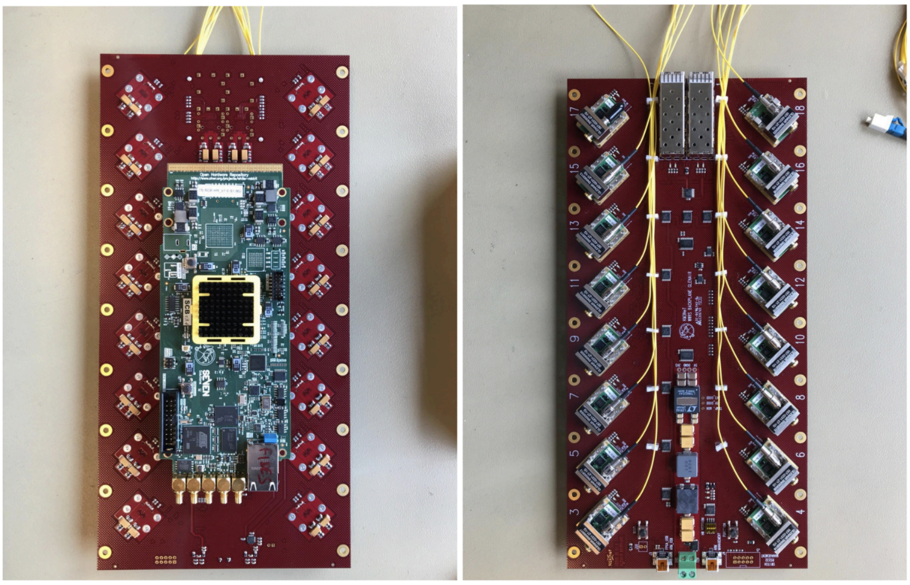
14.31.1. Description

Functional description:

Wet White Rabbit switches are the core of the WWRS data acquisition system developed for the KM3NeT detector. A dedicated life profile has been defined on the basis of the measurements performed on the ARCA WWRS DU base prototype, which emerged in 13°C cooled water in order to simulate the thermal environment of the detector.

Each WWR switch consists of two boards:

- The Glenair Backplane (GBP) hosts the Glenair transceivers, needed to insure the communication with each DOM.
- The SCB processor board of the WWRS.
  Glenair and SFP transceivers are single boards plugged individually on the GBP for optical/electrical interface.



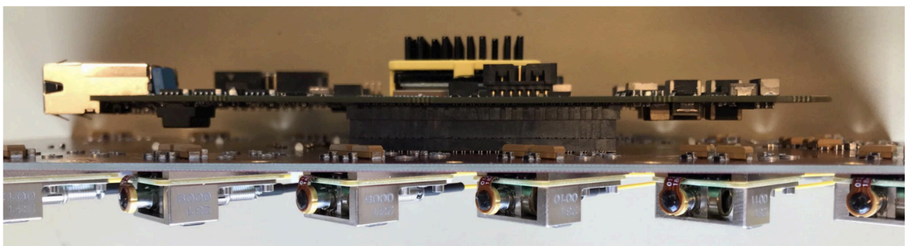


Figure 50: view of the SCB board (top left), of the Glanair backplane (top right), and side view of the coupling of SCB and backplane (bottom).

Every DU in the Wet White Rabbit configuration comprises 2 WWR switches (WWRS-A and WWRS-B), integrated inside the base container. Comparing the number of DOMs within a string to the total number of available ports on each switch (16 ports dedicated to communication with the DOMs over a total of 18), each switch can provide 12 redundant and 3 non-redundant channels to communicate with DOMs through the VEOC. An additional port is exploited as an interlink between the two switches and activated only in case of failure of one of the two.
The WWRS optical block diagram is reported below:

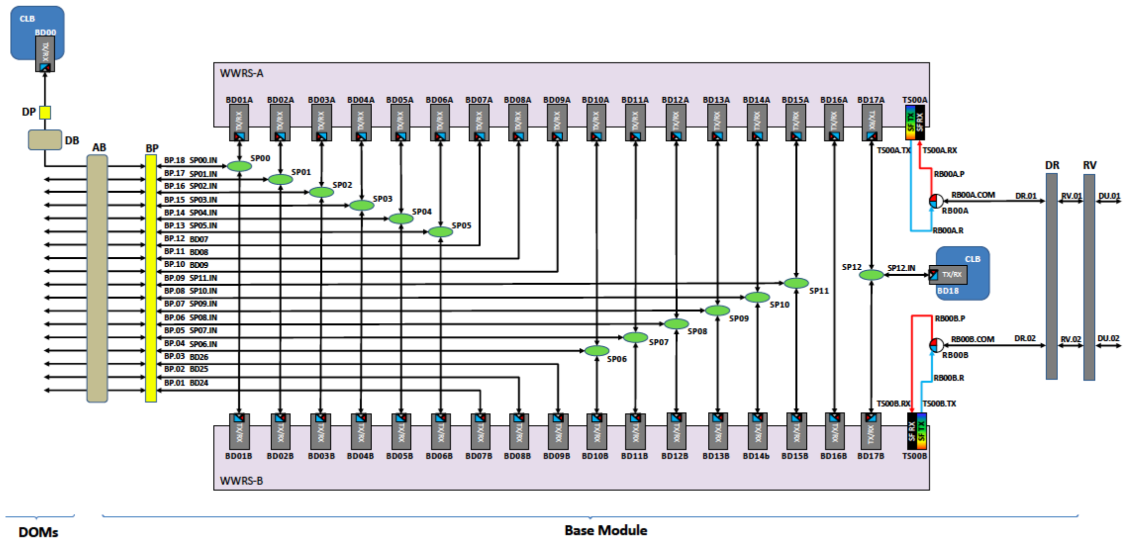


Figure 51: DU Base WWRS architecture with 2 switches.

The failure of one or several DOMs can be the result of a combination of different sub-component failures due to redundancies and the ability to route data through a single switch:

- 1 DOM lost: losing one of the 6 non-redundant channels or losing one redundant channel and optical splitter failure for redundant SFP.
- 3 DOMs can be lost due to the failure of a single WWRS.
- all DOMs lost since the 2 WWRS are in failure at the same time.

Transceivers providing communication between the Wet White Rabbit Switches and the DOMs are short range Glenair transceivers for the Glenair Backplane variant (V04-R1), or Finisar SFP transceivers for the SFP variant (V01-SFP-BP).

Product:	Wet White Rabbit switch
Function:	Wet White Rabbit switch is the communication and clock synchronization system developed for WWRS phase of the project and hosted in the DU Base. This new development is fully based on the White Rabbit protocol developed at CERN. The goal is to meet the required performances, increase system maintainability and also, the replacement of EFDA modules.
Product version	WWRS
Responsible	J-W Schmelling - A.Diaz - D.Real
Life profile	WWRS DU base (DU_WRS)
Reference documents	

Product hierarchy:

	Product	Product quantity integrated inside the upper-level assembly
	Wet White Rabbit (WWRS)	1
Integrated inside	3.2.2.3 Electronic Component/WWRS (ARCA/ORCA)	1
Integrated inside	3.2.2 - Base Module/WWRS	1
Integrated inside	3.2 - Detection Unit Foot/WWRS	1
Integrated inside	3 - Detection Unit/WWRS	63 ORCA / 198 ARCA

3.2.2.3.12 WRSCB: White Rabbit Switching Core Board

PBS - Product or component name	3.2.2.3.12 WRSCB: White Rabbit Switching Core Board
Function:	White Rabbit control board
Last change date - Version	18/06/2014
Comments	Seven solution / IFIC design. DU WRS life profile.
Reference documents	- SCB_Schematics_V3_4-1 - SCB_White_Rabbit_BOM

Quantity: 2 WRSCB every DU, 1 for each WWR switch.

3.2.2.3.13 - WRS Backplane/GBP Variant

PBS - Product or component name	3.2.2.3.13 - WRS Backplane/GBP
Function:	Provide optical to electrical interface and communicate with SCB for test purposes.
Last change date - Version	19/11/2024 for reliability analysis Jan-Willem Schmelling <janwillem.schmelling@nikhef.nl> and Diego Real IFIC 17/12/2021
Comments	Glenair Backplane is the WWR switch backplane using Glenair transceivers. 60 Glenair Backplanes were produced in November 2024. A new version using an SFP transceiver is under development and evaluation (see below).
Life profile	DU_WRS
Reference documents	- 45300.26.02.2: schematic - Updated: 2021-03-09 - GBP45300.26.02.2.BOM.XLS - 45300.26.02.2_PCA - 45300.26.01.2_PCB_incl._layer_stackup - GlenAir BackPlane v3 Technical Design Report KM3NeT_ELEC_PRR_GBP_v3_2022_002_TDR

Quantity: 2 GBP backplanes every DU, 1 for each WWR Switch.

3.2.2.3.13 - WRS Backplane/SFPvariant

PBS - Product or component name	3.2.2.3.13 - WRS Backplane/SFPvariant
Function:	WRS Backplane with SFP Finisar transceiver
Last change date - Version	19/11/2024 for reliability analysis
Comments	A new variant of the SFP backplane has been proposed with Finisar SFP due to an announcement from Glenair of their product obsolescence, cost, and reliability data.
Life profile	DU_WRS
Reference documents	- miniBackplane_SFP_V3_3-1 - SCB_White_Rabbit_BOM

14.31.2. Failure rate

Two different FIT results are reported for each sub-component of the Wet White Rabbit switch: the first represents the total sum of the failure rates while the second provides the FIT value once accounted by the effect of redundancies.
The failure rate analysis also takes into account the optical transceivers for the backplanes. Details of the sub-component's contribution are presented below.

14.31.2.1. WRSCB failure rate

Product Failure rate	Value	Unit
Unit FIT (for a single SCB board)	582,88	/10^9 hours
MTTF (Hours)	1715622	hours
MTTF (years)	196	years
FIT considering redundancies	**276,39**	**units**

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)	Failure risk considering redundancies
1	8760	99,49	0,51	**0,24**
2	17520	98,98	1,02	**0,48**
5	43800	97,48	2,52	**1,20**
10	87600	95,02	4,98	**2,39**
15	131400	92,63	7,37	**3,57**
20	175200	90,29	9,71	**4,73**

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	200,88	320
Connectors [FCCO]	11,26	11
Discrete semiconductors [ECDS]	9,21	10
Discrete semiconductors [PCDS]	0,94	3
Integrated Circuits [ECIC]	239,09	35
Magnetic Components: Inductors and Transformers [ECIN]	6,08	20
Magnetic Components: Inductors and Transformers [FCIN]	0,26	1
Piezoelectric components: Oscillators and Quartz [ECPZ]	58,18	5
Resistors [ECRE]	0,22	197
Switches [FCSW]	14,21	2
Tantalum capacitors [ECTC]	42,55	4
Total	**582,88**	**616**

Highest component contributors:

Component designation	Value or version	Refdes	Unit FIT	Quantity	Total FIT
AP7173-SPG-13	1.5 A Low Dropout Linear Regulator	IC32, IC34, IC35, IC39, IC48	31,35	5	156,75
4,7 uF ±10% 10 V X5R Capacitor		C10, C23, C68, C71, C72, C74, C84, C91, C92, C93, C94, C95, C96, C218, C238, C246, C255, C256, C264, C267, C273, C274, C275, C276, C277, C284, C287, C303, C304, C312, C318, C322, C323	1,76	33	58,14
10 uF ±20% 6,3 V X5R Capacitor		C35, C36, C42, C46, C47, C55, C140, C144, C151, C155, C156, C161, C167, C175, C203, C211	3,44	16	55,06
22 uF ±20% 6,3 V X5R Capacitor		C1, C2, C3, C4, C75, C76, C85, C86, C247, C263, C266, C268, C269, C270, C271, C283, C292, C294, C295, C296, C297, C300, C301, C302, C311, C429, C430, C431, C432	1,76	29	51,09
220 uF ±20% 10 V 18mΩ Tantalum Capacitor		C249, C258, C280, C307	10,64	4	42,55
XC6VLX240T-1FFG1156C	Virtex-6 LXT Platform FPGA, 600 User I/Os, 20 GTXs, 1156-Ball FFBGA, Speed Grade 1, Commercial Grade	IC33	29,44	1	29,44
FNETHE025	Differential Data and Clock D-Type Flip-Flop	IC22, IC40	11,64	2	23,27
LAN8720A-CP	RMII Ethernet Transceiver with Auto MIDIX	IC41	15,52	1	15,52
FSM6JSMA	Push button	S1, S2	7,11	2	14,21
100 nF ±10% 16 V X7R Capacitor		C5, C6, C7, C8, C9, C11, C12, C13, C14, C15, C16, C17, C18, C24, C25, C26, C29, C30, C31, C33, C34, C37, C38, C40, C41, C44, C45, C52, C56, C57, C59, C60, C100, C141, C142, C143, C146, C148, C159, C160, C162, C169, C171, C172, C173, C174, C176, C177, C178, C180, C181, C183, C184, C186, C187, C191, C192, C193, C194, C201, C207, C208, C209, C210, C212, C213, C215, C216, C217, C219, C220, C221, C222, C223, C224, C225, C226, C227, C228, C229, C230, C231, C232, C233, C234, C240, C241, C242, C243, C244, C253, C261, C285, C286, C293, C298, C299, C309, C316, C317, C319, C320, C321, C324, C325, C326, C422	0,12	111	13,04
VM53S3-25.000-2.5/-30+75	VCTCXO 25 MHz Oscillator	IC4	11,64	1	11,64
ABS09-32.768 kHz-T	Crystal Oscillator 32768 Hz 12,5 pF	X1	11,64	1	11,64
7M-12.000MAAJ-T	SMD Crystal 7M Series 18 pF 30 ppm	X2	11,64	1	11,64
IRF9910Pbf	Dual N-Channel 20 V 10 A MOSFET Logic Level Gate, 9.3 mΩat 12 A	T2, T3, T4, T5	2,37	4	9,47

Component designation	Value or version	Refdes	Unit FIT	Quantity	Total FIT
1 uF ±10% 16 V X5R Capacitor		C61, C235, C236, C237, C250, C251, C252, C272, C281, C315	0,74	10	7,43
TMP100	I2C temperature sensor	IC17, IC18, IC19, IC20	1,58	4	6,31
22 uF ±10% 16 V X5R Capacitor		C239, C248, C254, C257, C278, C279, C305, C306	0,74	8	5,95
220 uF ±20% 6,3 V 9mΩ Tantalum Capacitor		C259, C260, C288, C289, C290, C291, C427, C428	0,74	8	5,95
High Speed Switching Diode	TS4148RZ	D1,D2,D3,D4	1,44	4	5,75
AD5662BRJZ	NanoDAC 16 Bits, SPI, 2.7 V to 5.5 V, 250 uA, Rail-to-Rail Output	IC5, IC8	2,37	2	4,73

14.31.2.2. Switch Backplane (SBP) failure rate

14.31.2.2.1. WRS Backplane/GBP Variant failure rate

The sum of all components :

Product Failure rate	Value	Unit
Unit FIT	2694,78	$/10^9$ hours
MTTF (Hours)	371087	hours
MTTF (years)	42	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	97,67	2,33
2	17520	95,39	4,61
5	43800	88,87	11,13
10	87600	78,97	21,03
15	131400	70,18	29,82
20	175200	62,37	37,63

Mean failure rate per DU communication channel, with redundancies (2 SBP):

Product Failure rate	Value	Unit
Unit FIT	381,89	$/10^9$ hours
MTTF (Hours)	2618589	hours
MTTF (years)	299	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,67	**0,33**
2	17520	99,33	**0,67**
5	43800	98,34	**1,66**

10	87600	96,71	**3,29**
15	131400	95,11	**4,89**
20	175200	93,53	**6,47**

Contribution by component type:

Component type	Total FIT	Quantity
Ceramic capacitors [ECCC]	27,16	119
Connectors [ECCO]	47,46	27
Connectors [FCCO]	41,69	68
Discrete semiconductors [ECDS]	9,72	7
Integrated Circuits [ECIC]	140,24	17
IPG Photonics	182,00	1
Light Emitting Diode (LED) [ECLE]	7,22	38
Magnetic Components: Inductors and Transformers [ECIN]	24,61	78
Optical transceivers	2 153,78	17
Resistors [ECRE]	0,15	175
Switches [ECSW]	0,92	1
Switches [FCSW]	14,21	2
Tantalum capacitors [ECTC]	45,63	40
Total	**2 694,78**	**651**

Highest component contributors:

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
Mini SFP High reliability - PCB Mount Single Fiber BIDI Transceiver, 1 Gbps, 10 km, SMF, 3.3 V	PCB Mount Single Fiber BIDI Transceiver, 1 Gbps, 10 km, SMF, 3.3 V	GLENAIR modules	380,08	17	2153,78 (considering redundancies)
SFP+ Long range transceiver			182,00	1	182,00
PCA9548		U17,U18	7,64	2	15,29
	I/O port, I2C-bus and SMBus, 8-bit, low-voltage, low power with interrupt	U6,U7,U8,U9,U10,U11,U19,U20,U21,U20	7,64	10	76,43
LTM4620AIV#PBF (LGA144S127P12X12)	Module, dual 13 A or single 26 A output switching mode DC/DC power supply	U2	47,70	1	47,70
Elco, Tant., 100 uF/25 V. TAJ series		C70,C71,C72,C73	10,64	4	42,55
Threaded PCB-Mount fastener, #0-80 UNF-2B Thread	2p straight THT Locking header (approximative model…)	17_MP2,17_MP3,17_MP4,17_MP5,18_MP2,18_MP3,18_MP4,18_MP5,19_MP2,19_MP3,19_MP4,19_MP5,20_MP2,20_MP3,20_MP4,20_MP5,21_MP2,21_MP3,21_MP4,21_MP5,22_MP2,22_MP3,22_MP4,22_MP5,23_MP2,23_MP3,23_M	0,61	68	41,69

Component designation	*Value or version*	*Refdes*	Unit FIT	Quantity	Total FIT
		P4,23_MP5,24_MP2,24_MP3,24_MP4,24_MP5,25_MP2,25_MP3,25_MP4,25_MP5,26_MP2,26_MP3,26_MP4,26_MP5,27_MP2,27_MP3,27_MP4,27_MP5,28_MP2,28_MP3,28_MP4,28_MP5,29_MP2,29_MP3,29_MP4,29_MP5,30_MP2,30_MP3,30_MP4,30_MP5,31_MP2,31_MP3,31_MP4,31_MP5,32_MP2,32_MP3,32_MP4,32_MP5,48_MP2,48_MP3,48_MP4,48_MP5			
Glenair connector Samtec		17_J1,18_J1,19_J1,20_J1,21_J1,22_J1,23_J1,24_J1,25_J1,26_J1,27_J1,28_J1,29_J1,30_J1,31_J1,32_J1,48_J1	1,56	15	23,39
		for single channel	1,56	1	1,56
		for clb communication	1,56	2	0,00
SWITCH_TYCO_FSMJSMA,SWITCH_TYCO_FSMJSMA	Tactile Switch, 6x6mm, Surface Mount, 12 V, 50 mA	S2,S3	7,11	2	14,21
SMD MCC 35 V 22 uF X5R 20%	General purpose MLCC 1210 X5R 22 uF 35 V	C76,C77,C78,C79	1,76	8	14,10
Ferrite Bead 0805 220 Ω 2 A max DC0.05 Ω (for power lines)	Ferrite Bead 0805 220 Ohm 2 A max DC0.05 Ω (for power lines)	LB1,LB2,LB3,LB4,LB5,LB6,LB9,LB10,LB13,LB14,LB17,LB18,LB21,LB22,LB23,LB24,LB25,LB26,LB27,LB28,LB29,LB30,LB31,LB32,LB33,LB34,LB35,LB36,LB37,LB38,LB39,LB40,LB41,LB42,LB43,LB44,LB45,LB46,LB47,LB48	0,32	40	12,62
SMD inductor power 1uH 900 mA, 0805	SMD inductor power 1 uH 900 mA, 0805	L3,L4,L7,L8,L11,L12,L15,L16,L19,L20,L21,L22,L23,L24,L25,L26,L27,L28,L29,L30,L31,L32,L33,L34,L35,L36,L37,L38,L39,L40,L41,L42,L43,L44,L45,L46	0,32	36	11,36
SAMTEC_QTS-048-02-L-D-DP-A,SAMTEC_QTS-048-02-L-D-DP-A	Differential Pairs HS Terminal	J1,J2	3,68	2	7,35
MOLEX_54819-5,MOLEX_54819-5	USB, 1x5 pins, 0.8 mm pitch, SMT, Right Angled, series mini-B receptacle,	J3,J4	3,68	2	7,35
X5R 1 uF - 10 V	General purpose multilayer ceramic smd X5R 1 uF - 10 V	C66,C67,C68,C69	1,84	4	7,34

14.31.2.2.2. WRS Backplane/SFP Variant failure rate

The sum of all components :

Product Failure rate	Value	Unit
Unit FIT	1514,15	$/10^9$ hours
MTTF (Hours)	660436	hours
MTTF (years)	75	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	98,68	1,32
2	17520	97,38	2,62
5	43800	93,58	6,42
10	87600	87,58	12,42
15	131400	81,96	18,04
20	175200	76,70	23,30

Mean failure rate per DU communication channel, with redundancies (2 SBP):

Product Failure rate	Value	Unit
Unit FIT	356,21	/10^9 hours
MTTF (Hours)	2807342	hours
MTTF (years)	320	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,69	0,31
2	17520	99,38	0,62
5	43800	98,45	1,55
10	87600	96,93	3,07
15	131400	95,43	4,57
20	175200	93,95	6,05

Contribution by component type:

Component type	Total FIT	Quantity
Undefined	10,00	26
Ceramic capacitors [ECCC]	19,36	113
Connectors [ECCO]	154,40	42
Discrete semiconductors [ECDS]	9,72	7
Integrated Circuits [ECIC]	155,11	17
IPG Photonics	182,00	1
Light Emitting Diode (LED) [ECLE]	7,22	38
Magnetic Components: Inductors and Transformers [ECIN]	24,61	78
Optical_repeater	945,36	18
Resistors [ECRE]	0,21	243
Switches [ECSW]	2,75	3
Tantalum capacitors [ECTC]	3,42	40
Total	**1 514,15**	**626**

Highest component contributors :

Component designation	*Refdes*	Unit FIT	Quantity	Total FIT
Mini SFP High reliability - PCB Mount Single Fiber BIDI Transceiver, 1 Gbps, 10 km, SMF, 3.3 V	FTLX2x	157,56	17	892,84 (considering redundancies)
SFP+ Long range transceiver		182,00	1	182,00
PCA9554BPW	U1,U2,U4,U5,U6,U7,U9,U10,U13,U16	7,64	10	76,43
2007198-2	PORT-01MP1,PORT-02MP1,PORT-03MP1,PORT-04MP1, PORT-05MP1,PORT-06MP1,PORT-07MP1,PORT-08MP1, PORT-09MP1,PORT-10MP1,PORT-11MP1,PORT-12MP1, PORT-13MP1,PORT-14MP1,PORT-15MP1,PORT-16MP1, PORT-17MP1,PORT-18MP1	3,68	18	66,17
1888247-1	PORT-01J1,PORT-02J1,PORT-03J1,PORT-04J1,PORT-05J1 ,PORT-06J1,PORT-07J1,PORT-08J1,PORT-09J1,PORT-10J 1,PORT-11J1,PORT-12J1,PORT-13J1,PORT-14J1,PORT-15 J1,PORT-16J1,PORT-17J1,PORT-18J1	3,68	18	66,17
	Finisar	52,52	1	52,52
LTM4620AIV#PBF	U17	47,70	1	47,70
PCA9548APW	U3,U8	7,64	2	15,29
PCA9517ADP	U11,U14	7,64	2	15,29
BLM21PG221SN1D	LB1,LB2,LB3,LB4,LB5,LB6,LB7,LB8,LB9,LB10,LB11,LB12, LB13,LB14,LB15,LB16,LB17,LB18,LB19,LB20,LB21,LB22, LB23,LB24,LB25,LB26,LB27,LB28,LB29,LB30,LB31,LB32, LB33,LB34,LB35,LB36,LB37,LB38,LB39,LB40	0,32	40	12,62
Coil - LLQNA201212T1R0M - 1 uH	L1,L2,L3,L4,L5,L6,L7,L8,L9,L10,L11,L12,L13,L14,L15,L16, L17,L18,L19,L20,L21,L22,L23,L24,L25,L26,L27,L28,L29,L 30,L31,L32,L33,L34,L35,L38	0,32	36	11,36
WRS SFP PCB	PCB	10,00	1	10,00
QTS-048-03-L-D-DP-A	J2,J3	3,68	2	7,35
502237-0517	J4,J5	3,68	2	7,35
Capacitor 0603ZD105KAT2A - 1 uF	C106,C109,C147,C150	1,84	4	7,34
Capacitor MSASG32MSB5226MPNA01 22 uF	C125,C126,C136,C137	1,76	4	7,05

14.31.3. Conclusion and recommendations

Despite the increase in the number of electronic boards in the WWRS scenario compared to the Broadcast one, the use of redundancies significantly improves the final reliability. Furthermore, in the development of the backplane, the use of SFP Finisar transceivers for the new variant allows to further decrease the final failure rate probability and the costs.

15. CONNECTORS

The major contribution to the electrical and optical connector failure rate comes from youth failures due to non-conformances during assembly. High-level quality controls and tests during this production phase allow to significantly reduce the risk. In KM3NeT, connectors and interlink cables are further tested under pressure and titanium checks are performed using fluorescence X devices. The risk of failure is also minimized thanks to the limited number of mating and unmating cycles. Based on experimental feedback available online, each mating/unmating cycle increases the risk of failure by approximately 5%. This is particularly relevant as these connectors are designed for underwater mating. The main causes of connector failure are:

- Seal failure, flooding.
- Contact resistance.
- Mechanism jamming.

The risk of failure increases with the depth and the environmental conditions (sea water, current, etc.).

An attempt to calculate the failure rate of circular connectors has been carried out through FIDES, although this methodology is not designed for wet underwater mate connectors.
The calculated FIT value is between 0.4 and 0.6.

This result can be compared to manufacturer data available online:

- MacArtney manufacturer, same types of wet mate connectors used in KM3NET https://www.macartney.com/media/10597/data-sheet_rollingseal-4-optical-connector-rs4.pdf

- Fujitsu manufacturer, repeater installed in the deep sea up to 8000 m depth https://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol44-2/paper03.pdf

On the basis of these references, a FIT equal to 20 is a reasonable value to consider for the RAMS analysis, with no significant difference in the number of optical and electrical pins considered.

Below is a detailed list of connector manufacturers used within KM3NET:

- **ODI** (Ocean Design Inc.) is part of Teledyne connectivity, focusing on underwater and subsea connectivity solutions.
- **Seacon,** a part of Teledyne Marine which offers a wide range of marine products, including underwater connectors and sensors. Teledyne Marine's products are also used in challenging subsea conditions.
- **GISMA,** a company specialized in underwater and subsea connector technology.
- **MacArtney Group** is an independent company that provides underwater technology solutions, including subsea connectors and systems.

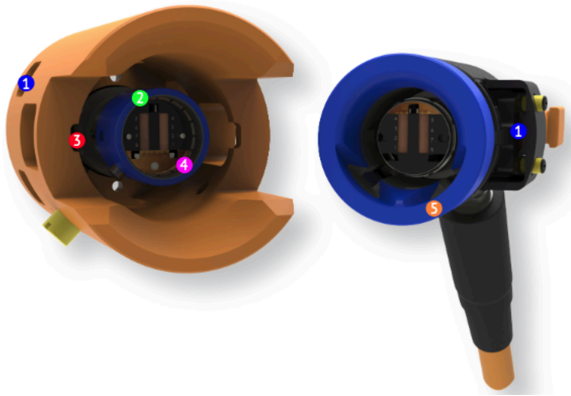


Figure 52: Example of wet mate connector (picture from Teledyne Marine).

Wet Mate connectors :

Product Failure rate	Value	Unit
Function FIT	20	/10^9 hours
MTTF (Hours)	2487562	hours
MTTF (years)	284	years

Mission (year)	Duration (hours)	Reliability (%)	Unit failure risk (%)
1	8760	99,98	0,02
2	17520	99,96	0,04
5	43800	99,91	0,09
10	87600	99,82	0,18
15	131400	99,74	0,26
20	175200	99,65	0,35

16. CABLES

16.1. Description

In ORCA and ARCA there are mainly 4 types of cables:

- MEOC:
    - 42 km AC cable, 3400 V for ORCA (max rating 15 kV) - providing 36 single mode fibers and power.
    - 86 km DC cable, 6500 V for ARCA.
- Interlink cables connecting the CTF to the nodes in ARCA or linking nodes in ORCA, with lengths of up to 600 m.
- Interlink cables between nodes and DUs for ARCA and ORCA, with a maximum length of 300 m.
- Inter-DU cables for ORCA: mean length of 70 m with a maximum of 110 m.
- VEOC cables 400 VDC + optical fibers: 200 m long for ORCA and 700 m for ARCA.

16.2. Failure rate

The reliability analysis of submarine cables is based on the following references:

- ICPC (International Cable Protection Committee) database: https://www.iscpc.org/.
- TeleGeography report on the state of submarine cables: https://www2.telegeography.com/submarine-cable-map.
- IEEE (Institute of Electrical and Electronics Engineers) studies: https://ieeexplore.ieee.org/.

When analyzing submarine cable data, it appears that on average around 100-150 submarine cable failures occur globally every year. The causes of the failures are divided into subcategories, as described in the following table. The FIT and MTBF values were calculated assuming a cable length of 1000 km:

Failure Cause	Percentage (%)	FIT	MTBF (years)
Fishing (fad damages)	45	25714	2-3
Ship anchors	15	12557	5-7
Natural phenomena (earthquakes)	8	6849	10-12
Abrasion/Wear	7	3973	15-20
Component failures	5	3726	20-25
Other human activities (ROV, waste dumping, military…)	20	16811	4-5

The total FIT value obtained by adding all the components in the table is 69630 per 1000 km. Considering instead only the random failure rate components -specifically, abrasion and random component failure- gives a FIT value of 7699 per 1000 km.

In the literature a reference value of 0.1 failure / years / 1000 km is given, meaning an MTBF of 10 years for 1000 km.

The risk of cable damage should then be computed accordingly to the different KM3NeT cable types:

- MEOC (3.4 kV ORCA AC, 6.5 kV ARCA + optical fibers);
- Interlink with DU : 400 VDC for ARCA (90 m to 400 m), 400 VAC for ORCA + Optical fiber (40 m to 105 m);
- VEOC (200 m for ARCA, 700 m for ORCA) ⇒ fishing Fad risk ⇒ weak cable filled with oil - 400 VDC + Fiber.

Hereby the base calculation parameters taken into account for this analysis:

- Base FIT: 69630 per 1000 km.

- DC Voltage Factor: 0.85 (compared to AC).

- Low Voltage Factor (< 1000 V): 0.9.

- Shallow Water Factor (< 500 m): 1.2.

From this set of data, the FIT values obtained for ORCA and ARCA are:

Cable type	FIT
AC 40 km	2785,2
DC 100 km (worst case including interlink to CTF)	5918,55
Inter-DU ORCA (mean 70 m length)	4,39
Interlink ARCA (mean 170 m length)	9
VEOC cables ORCA (200 m)	10,65
VEOC cables ARCA (700 m)	37,29

Some key observations can then be derived:

1. The longest cable (100 km) has the highest absolute failure rate although the best per-km reliability.
2. The 300 m long cable in shallow water shows a higher failure rate per km due to higher external risks.
3. Low voltage cables show slightly better reliability due to the reduced electrical stress.
4. AC cable shows a slightly higher failure rate than an equivalent DC cable.

16.3. Conclusion and recommendations

The highest risk for underwater mate connectors is water infiltration.
Quality checks during manufacturing, tests and mechanical stresses during deployment would also drastically reduce the risk of youth failure.

17. ORCA NODE COMPONENTS

Reliability data for the node have been collected by the MEUST team for ORCA and presented inside the Technical Design Report of the MEUST/NUMerEnv power system for the KM3NeT-Fr infrastructure KM3NeT_POWER_2016_003. Hereby an extract:

"The MEUST infrastructure must operate without maintenance for at least 15 years at a depth of 2500 m in an aggressive deep-sea environment. Meeting these requirements involves a high level of reliability. Main focus is made on the product reliability, traceability and documentation. Industrial components with high reliability were chosen when possible and we avoided the use of electrolytic capacitors as much as possible, especially for critical items, and when necessary the best quality was used. In addition we benefit from the experience of ANTARES, solutions and components were re-used when possible. Table 19 gives the reliability data from manufacturers. It has to be noted that for contactor and breakers only numbers of switching data are available because for such common industrial products this is the key parameter and most of the time MTBF is not available."

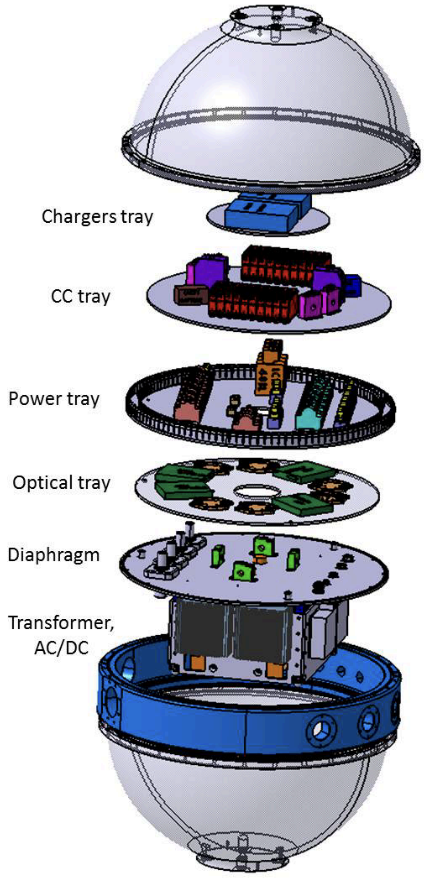


Figure 53: Junction box components view

Item	label	Quantity		Supplier	Reference	MTBF (h)	Nb of switching
		use	redundancy				
Power							
Contactor HV	K1,K2	2	0	Schneider electric	LC1D1150046BD		8000000
Coil				Schneider electric	LX4D8BD		8000000
attachment module				Schneider electric	LA6DK20B		500000
auxiliary contact				Schneider electric	LAD8N11		3000000
free wheel diode				ST micoelectronics	STTH1212D		
Contactor DUs	K3,K4	2	0	Schneider electric	LC1DT40BL		30000000
attachment module				Schneider electric	LAD6K10B		500000
free wheel diode				ST micoelectronics	STTH1212D		
Contactor multipurpose	K5	1	0	Schneider electric	LC1DT32BL		30000000
attachment module				Schneider electric	LAD6K10B		500000
free wheel diode				ST micoelectronics	STTH1212D		
Beaker user port	Q7 à Q14	8	0	ABB	S202P-K4		20000
Motor control unit				ABB	S2C-CM2/3		20000
Breaker AC/DC	Q1 à Q4	4	2	ABB	S202P-D4		20000
Motor control unit		4	2	ABB	S2C-CM2/3		20000
breaker battery charger	Q5,Q6	2	1	ABB	S202P-D4		20000
Motor control unit		2	1	ABB	S2C-CM2/3		20000
Battery relay	K6	1	0	Panasonic	ST2-DC24-F		100000
HV contactor relay		4	0	OMRON	G8P-1A2T-F		100000
AC/DC 30V		2	1	FEAS	STN11524	380000	
AC/DC 5V		2	1	FEAS	STN8005	380000	
battery charger		2	1	MASCOT	2043		
Battery		1	0	Deep sea & light	SB-24/40		
Control/command							
Ethernet Switch (with SFP)	SW1, SW2	2	1	Microsens	MS650869D	400000	
Digital output module	DOx	6	3	MOXA	E1211	221000	
Digital input module	DIx	4	2	MOXA	E1210	671000	
Analog input module	AIx	6	3	MOXA	E1240	474000	
Thermocouple Module	TCx	2	1	MOXA	E1262	631000	
serial link module	SLx	2		MOXA	IA5450AI	262000	
RS232-TTL converter		1	0	CPPM			

18. ARCA CTF and NODE COMPONENTS

ARCA nodes are developed and integrated by external companies under non-disclosure agreements. No details of the components are available. The availability summary will be presented in the RAMS report.

19. GENERAL CONCLUSION

This reliability analysis offers a comprehensive review of all electronic boards and equipment used in the detector subassemblies. The information presented in this report will be utilized in the RAMS analysis to assess the availability of the various sub systems within the KM3NeT infrastructure. Furthermore, it serves as a reference point for comparing real system failure rates observed during operation.

The calculations in this report stem from multiple iterations, integrating designer recommendations aimed at enhancing reliability, such as improved derating measures. Special attention was also given to controlling the production processes of electronic components and subassemblies, as production quality plays a critical role in ensuring product reliability.

These studies helped identify the most significant contributions from each sub-assembly. Notably, no critical sub-assemblies were detected. Among the components analyzed, power boards exhibit the highest probability of failure, which aligns with their function in energy dissipation.

This analysis establishes a robust foundation for assessing the reliability of the telescope's electronic systems and will play a key role in guiding future enhancements.

20. Bibliography

[1] FIDES Guide 2022, website
https://www.fides-reliability.org/en/system/files/guides/FIDES_Guide_2022_Edition_A_%28July%202023%29.pdf

[2] KM3NeT_ELEC_2018_001_RAMS_Overall: Spreadsheet tool developed in order to perform RAMS analysis.
https://docs.google.com/spreadsheets/d/1EG18i6YX5nLaDra5EQNSKpa2tUyZkZ2K/edit?gid=1542329588#gid=1542329588
The diffusion of this document is limited.

[3] "KM3NET Life Profile for electronic boards reliability analysis", internal KM3NeT document, https://docs.google.com/document/d/1-ypM4srFyupqqGLPxz7zHNTqawHtMXnF/edit

[4] "The Central Logic Board for the KM3NeT detector: Design and production",
https://www.sciencedirect.com/science/article/abs/pii/S0168900215012553

[5]"Multi Anode Photomultiplier Tube Reliability Assessment for the JEM-EUSO Space Mission", https://arxiv.org/pdf/1501.05908

Annex 1 : Process audit

See paragraph 11.3.4. Π process

Below the details of the audit performed to evaluate the process factor for KM3NeT are reported:

N°	Recommendation	Question	Weight	Answers	Description	Rating
	Requirements					
1	Financing is assigned to the project's reliability manager. This is the subject of a separate item (at accounting level) in project management. Personnel and means necessary for carrying out Reliability studies satisfactorily are made available to the product reliability manager	Is there a financing item for reliability studies? Have the necessary means and personnel been identified?	10,7	N3	Resources allocated to reliability studies are identified at project management level and are formalised in a validated plan.	21,4
2	The operating dependability (reliability) business participates in the allocation of requirements to subassemblies.	Are global reliability requirements allocated to subassemblies? What allocation method was used?	10,4	N3	Persons responsible for reliability engineering have defined (or have participated in defining) the allocation of reliability requirements to subassemblies. Validated documents certify this participation.	20,8
26	Describe the environment in which the product will be stored, transported, used and maintained. Describe average and maximum quantitative values for the following characteristics: Temperature, Humidity Shocks Vibrations, Pressure Penetration/abrasion, Ambient light, Mounting position, Weather (wind, rain, snow), Operators' qualification level.		12,4	N4	The product environment is known perfectly (applicable parameters defined in the recommendation are known). A document lists all these parameters.	37,2
28	Define precisely what will be considered as a product failure (possibilities of acceptable degraded modes)	Is there a description and characterisation of the environment in which the product will be stored, transported, used and maintained?	10,3	N3	The manufacturer has produced the description of the product failure and (or) the list of feared events, and (or) product degraded modes with formal validation by the customer	20,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
29	Define the method of demonstrating the product reliability (this method must be accepted by the customer). Clearly describe the method selected to demonstrate that the product is conforming with the specified reliability, particularly taking account of the real life profile, treatment of the early life period, the confidence level used for measurement (e.g. > high limit at 60%), failures due to reliability. For example, this can include classes C, E, F, V1 in the following classification of the origin of technical events. C: Random failure of a component / E: Incomplete study (or defective design) / F: Manufacturing outside standard (or production defect) / M: Manipulation too severe (or failure to respect the user and maintenance documentation) / O: Special check (check correct operation) / P: Preventive maintenance / R: Application of a retrofit / S: Consequence of another failure (or secondary failure) / V: Aging of equipment (1 Unexpected wear, 2 life limits exceeded) / X: Use outside specifications / Y: Abnormal technical events (or unconfirmed anomaly) / ?: Undetermined origin or cause. Measurement method: e.g. No. of hours of flight / No. of failures with determined causes. In general, conformity with a requirement can be verified by one of the following four methods depending on its nature: · Inspection (I): Visual or dimensional verification of product constituents. The verification is based on human senses (view, touch) or uses simple measurement and manipulation methods. No stimulus is necessary. Passive means such as a measuring tape, microscope, gauge etc. can be used. · Analysis (A) : Verification based on analytic proofs obtained by calculation, without any intervention on product constituents. The techniques used are modelling, simulation and prediction. E.g. predicted reliability calculation. · Demonstration (D) : Verification of observable characteristics on product constituents while functioning, without the use of physical measurements. Examples: demonstration of a start sequence, functioning of a safety sequence, functioning of a built-in test device, etc. · Test (T) : Verification of measurable characteristics, directly or indirectly accessible. Standard or specific test equipment is usually required. E.g. measurement of operational reliability.	How is it planned to demonstrate the product reliability?	9,8	N4	The method of demonstrating the product reliability is defined perfectly in the call for bids or the contract (in accordance with the content of the recommendation).	29,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
31	Define the life profile for the product (breakdown into operational scenarios for which reliability performances are expected). Give successive phases for use of the product (environment/phase duration pair). The description shall cover at least the following phases: Storage (non-functioning, protected environment, small temperature variation, controlled humidity, etc.), Non-functioning (the product possibly being in its operational environment), Operational functioning (e.g. in flight, taxiing, navigation, etc.).	Is the usage profile of the product for which reliability performances are expected defined?	9,9	N4	The life profile provided in the specification (contract) satisfies the recommendation or was defined completely by the manufacturer and formally validated by the customer.	29,7
40	The following essential elements must be taken into account in formulating the requirement for a reliability specification: - Quantitative formulation of the reliability requirement, - Complete description of the environment in which the system will be stored, transported, used and maintained, - Life profile of the product for which Reliability performances are expected, - Clear identification of the type of time measurement (Hours of operation, Hours of flight, cycles, etc), - Clear definition of what forms a failure, - Clear description of the method selected to demonstrate that the system is confirming with the specified reliability, - Associate penalties with a failure to satisfy reliability requirements.	What is the context associated with product reliability requirements?	8,1	N3	Complete identification of customer reliability requirements as requested in the recommendation.	16,2
53	Make use of feedback from operations obtained from similar products used in similar environments so as to achieve a good level of confidence in maintenance of reliability performances. Feedback from operations is also used to calibrate or check predictive reliability methods. These studies require a large amount of time to collect operational data and precise recording of anomalies encountered. Input data comprise - records of observed anomalies, - conditions for use of the product (life profile, operational environment, usage duration), - analysis of the cause of the failure (that may or may not be due to the manufacturer). Output data comprise: Operational reliability that may be extrapolated for different environments and life profiles by models output from the system engineering.	Is feedback from operations used to maintain a good level of confidence in achieving reliability performances?	8,5	N3	The manufacturer's feedback from operations is used and formalised in a document. This feedback from operations does not precisely correspond to the technologies currently used. There is a validation or adjustment of predicted reliability methods.	17

N°	Recommendation	Question	Weight	Answers	Description	Rating
54	Use reliability engineering to optimize product architecture, design choices. Give reliability engineering authority if a reliability performance is not reached	Are the reliability criteria taken into account in the architecture of the products, and design, industrialisation and support choices?	12,6	N4	Reliability engineering contributes to the design and has the authority to make decisions if a reliability objective is not achieved. This is certified in documents. The company's baseline describes this participation. A reliability engineering guide like the FIDES Guide is applied	37,8
57	At least one of the following three types of specifications (or an equivalent) must be used for the specification of reliability performances (that must be quantitative): The MTBF or the failure rate is a definition adapted to reparable systems with a long life and / or for which the life of missions is short relative to their MTBF. The validity of the assumed constant failure rate in time sometimes needs to be proven. The probability of survival for a defined time period. For example, this specification is used when a high reliability level is required throughout the mission duration. The probability of success independent of time for single use devices. It can also be used for devices with cyclic use. These quantitative values shall be specified either as average values (design objectives) or minimum acceptable values below which the customer finds that the system is completely unsatisfactory with regard to his operational requirements. The objective type (design objective or minimum acceptable) shall be specified explicitly.	Is the reliability requirement expressed quantitatively?	8,2	N3	The specification contains one of the three types of performance specification (as defined in the recommendation). Some elements about the quantification are covered in non formalised assumptions.	16,4
62	Formally identify requirements and critical factors related to reliability. The risk management procedure will use this information. Mark and manage these risks. Existence of an action plan.	Have technical risks affecting reliability been identified?	12,4	N3	An initial analysis of risks related to obtaining reliability performances has been made. This is formalised, but risk management is not maintained in the long term: cooperation is set up between the equipment manufacturer and the system engineer to evaluate risks related to the product environment.	24,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
64	Identify the type of time measurement for reliability performances (Hours of operation, Hours of flight, cycles, etc).	Has a type of time measurement (Hours of operation, Hours of flight, number of cycles, etc.) been identified for reliability performances?	6,6	N4	The type of time measurement is fully defined in the call for bids (or the contract).	19,8
65	Customer requirements must be identified, documented and traced with respect to input documents.	Have customer requirements been identified, documented and traced?	7,3	N4	Customer requirements related to reliability are identified and listed in a document and kept up to date (successive versions if justified) with their revision index, there is traceability of changes to these requirements (justification and record in a document).	21,9
103	Reliability requirements must be negotiated to take account of the state-of-the-art of technology and to optimise the cost-performance of the product design and Reliability studies. For an initial objective requested by the customer, a study by the project manager will evaluate the cost of achieving Reliability performances and propose alternatives so as to optimise the cost of achieving Reliability performances. The results of the negotiations will be integrated into the final offer submitted to the customer.	s the state-of-the-art of technology taken into account, and is the cost-performance of the product design optimised during negotiations of reliability requirements with the customer?	10,7	N3	Negotiations with the customer leading to optimisation of costs / performances in achieving Reliability performances.	21,4
106	Organise a design review. Check that reliability requirements are respected. This review defines: - reliability allocations - conditions for use (life profile)	Has a design review been organised in which Reliability aspects are dealt with?	10,3	N4	Organisation of a design review in which reliability aspects are dealt with completely by persons who are reliability specialists. A procedure or plan imposes this review.	30,9
107	Organise a requirements review, check that all reliability requirements are identified and that the customer and the supplier understand each other. It must be possible to validate, achieve and verify these requirements (conformity means).	Has a requirements review been organised dealing with reliability aspects?	10,3	N3	An informal requirements review has been set up (or is planned depending on progress with the project). Persons responsible for reliability engineering were called upon to participate in the document review or validation, and records of this participation are available.	20,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
117	The maintenance policy requested by the customer should be taken into account in this activity to maintain product reliability in the long term.	How is the product maintenance policy (requested by the customer) taken into account?	5,8	N3	The maintenance policy is defined taking account of reliability aspects (identification and monitoring of critical elements).	11,6
122	A Reliability plan has been written, or there is a Development Plan that fully describes reliability aspects	Has a Reliability Plan been written for the product?	7,6	N4	The reliability plan has been written and validated by the project. This document is updated throughout the project as a function of events that might make it change.	22,8
	Design					
6	Obtain technical data for subassemblies in order to develop the production test.	Are technical data for subassemblies available for development of the production test?	7,8	N4	Existing data are complete, validated and useable for all subassemblies	23,4
7	Procedures related to corrective actions include: - Effective processing of customer complaints and product nonconformity reports, - The search for the causes of nonconformity related to the product, the process and the quality system, and recording the results of this search, - Determining corrective actions necessary to eliminate the causes of nonconformity, - Application of all means to measure the effectiveness of the corrective action.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	6,7	N4	Procedures related to corrective actions include: Effective processing of customer complaints and nonconformity reports on the product, The search for causes of nonconformity related to the product, the process and the quality system and recording the results of this search, Determination of corrective actions necessary to eliminate the causes of the nonconformity, Application of control means to assure that the corrective action is implemented and that it produces the expected effect.	20,1

N°	Recommendation	Question	Weight	Answers	Description	Rating
8	Procedures related to preventive actions include: - The use of appropriate information sources such a processes and operations affecting the product quality, waivers, audit results, quality records, maintenance reports and customer complaints, so as to detect, analyse and eliminate the potential causes of nonconformities, - Determination of appropriate steps to deal with any problem requiring preventive action, - Triggering of preventive actions and the application of control means to make sure that they produce the expected effect, - Assurance that relative information about actions implemented is submitted to the management review.	Do procedures related to preventive actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of preventive actions and application of control means? - A management review of corrective actions?	6,8	N3	Procedures for preventive actions do exist and are almost complete with regard to the mentioned criteria (there are possible minor non-conformities in the application or satisfaction of criteria)	13,6
16	Make sure that a person responsible for logistics support, industrialisation, purchasing, development and RAMS is involved at every step. Make sure that the baseline used allows simultaneous engineering. The contractor's organisation is based on permanent specialists of the function.	Is the point of view of the different disciplines involved in engineering taken into account?	16,7	N3	Procedures for preventive actions do exist and are almost complete with regard to the mentioned criteria (there are possible minor non-conformities in the application or satisfaction of criteria)	33,4
34	Set up training courses so that the person is in full control of the test means, standards and interpretation of measurements: planned training and monitoring of skills	What measures have been taken so that the person concerned is qualified for the test means, measurements and relevant standards?	5,8	N3	Training followed individually.	11,6
36	Make sure that all data justifying the need are available and are validated in a preliminary reliability study document. A directive imposes that this document is written.	Is there a list of justification elements?	8	N3	There is a formalised and identified document in the justification file, which assures that all requirements are satisfied.	16
38	Have a means of recording know how and technical standards through business procedures (information recording the designer's know how: guidelines, checklist, process, operating methods, etc.). Manage and monitor these procedures as a function of changes to techniques.	Is there any management of business procedures?	13,8	N3	Existence of managed and validated procedures.	27,6
39	Make sure that the skills required for an activity are assigned by name in a regularly reviewed skills table and periodically verify that training is appropriate for the activities.	Is there any management of skills?	24,5	N2	There is a skills table but this table is not monitored in training.	24,5

N°	Recommendation	Question	Weight	Answers	Description	Rating
44	Make sure that there is a list of business recommendations on manipulation and storage operations at the user, for use by Logistics Support. This collection must be enriched by feedback from operations.	Is there a collection of business recommendations for manipulation and storage operations at the customer?	7,7	N3	There is a formalised collection of recommendations but it is not necessarily applicable to the project (not referenced to the project) and is not validated. Feedback from operations formalised in a base that is not managed and is not much used in design.	15,4
48	Produce and maintain a preferred components list taking account of reduced reliability characteristics.	Is there a preferred components list?	8	N2	There is non formalised preferred components list, that has not been validated, and only contains technical characteristics.	8
50	Make sure that there is a methodology to: gather technical events, update, operation. Recording feedback from operations, with the objective of improving the reliability of future designs. Make sure that feedback from operations is actually used by designers; existence of a usage methodology.	Has feedback from operations been used to improve future designs?	24,2	N4	Methodology updated, useable and used.	72,6
51	Make sure that there is centralised management of reliability evaluation studies to reuse previous calculations with stresses: clearly identified basic assumptions, data extractable and reusable by design businesses	Is there a database recording reliability evaluation studies?	10,6	N4	There is a centralised database with a formal and updated enrichment process.	31,8
52	Make sure that the traceability and justification for the design are done with the objective of controlling definitions and changes. Existence of a methodology to allow access to this information within the design office.	Is there a database on the history and definition justifications?	7,8	N3	Formal definition of knowledge and the history of the justification of definitions in a database, but with no procedures for updating and management of configuration monitoring.	15,6
54	Use reliability engineering to optimise product architecture, design choices. Give reliability engineering authority if a reliability performance is not reached	Are the reliability criteria taken into account in the architecture of the products, and design, industrialisation and support choices?	12,6	N4	Reliability engineering contributes to the design and has the authority to make decisions if a reliability objective is not achieved. This is certified in documents. The company's baseline describes this participation. A reliability engineering	37,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
					guide like the FIDES Guide is applied	
61	List and implement protection means to avoid reducing the reliability of the subassembly.	Have means of protecting subassemblies during some production activities been identified and implemented?	7,3	N4	Protection means are identified following a periodic analysis of observed anomalies and their application is verified.	21,9
62	Formally identify requirements and critical factors related to reliability. The risk management procedure will use this information. Mark and manage these risks. Existence of an action plan.	Have technical risks affecting the reliability been identified?	21	N3	An initial analysis of risks related to obtaining reliability performances has been made. This is formalised, but risk management is not maintained in the long term: cooperation is set up between the equipment manufacturer and the system engineer to evaluate risks related to the product environment.	42
83	Make sure that the test coverage is maximum and is based on the specification. Justification of the coverage in a document.	Is there assurance that the test coverage is maximum, and that it is based on the specification? Is there a justification document?	6	N3	The test coverage is evaluated and some actions are done to maximise performance. The performance justification is formalised.	12
86	Implement design verifications: these procedures must be based on proof reading, approval circuit and reviews with the objective of making sure that the orientation actions, and elements chosen are correct.	Are there any design verification procedures?	27,1	N4	There are formal verification procedures that are periodically revised, including peer reviews.	81,3
87	Make sure that the maintenance concept is formalised and validated by the customer. Example of documents to be presented in response to requirements of the concept: integrated logistics support plan, logistics supportability file.	Is there a maintenance concept?	5,4	N4	Support requirements formalised: maintenance concept . There is a project organisation at the manufacturer to satisfy customer requirements in the form of a logistics support plan . Support requirements are taken into account at the design stage, they are broken down into subassemblies, justified and validated in a supportability file.	16,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
					Elements in the support system (documents, training, spare parts batches, tools and test means, etc.) are available and are consistent and validated .	
106	Organise a design review. Check that reliability requirements are respected. This review defines: - reliability allocations - conditions for use (life profile)	Has a design review been organised in which Reliability aspects are dealt with?	12,1	N4	Organisation of a design review in which reliability aspects are dealt with completely by persons who are reliability specialists. A procedure or plan imposes this review.	36,3
123	Make sure that adjustments to the baseline are specified in the management plan. Make sure that skills are committed on the project in the management plan and that there is a planning.	Is there a reliability management plan in which key skills (specialists) are identified?	17,7	N4	There is a complete management plan specifying any adjustments to the baseline. There is planning describing tasks to be accomplished and the precise and validated organisation set up; there is a good match with the company workload plan.	53,1
124	Make sure that there is an acceptance procedure and that it is relevant. The acceptance procedure is written from a definition file and a test oriented manufacturing file describing adjacent cases, presenting a functional description, inputs/outputs, and key manufacturing points.	Is there an acceptance procedure for production tests?	7,8	N4	The acceptance procedure is adapted to the product (proof of traceability of its application to the product and its configuration) and is validated.	23,4
130	Make sure that there is a project documentation to correctly evaluate the reliability.	Is there any analysis documentation for evaluating the reliability?	7,5	N4	The definition file contains up-to-date and validated studies.	22,5
131	Make sure that there is a design methodology obliging designers to apply rules aimed at improving reliability. Make sure that it is checked that rules are applied.	Are there any design rules to adapt the choice of a component for a given reliability?	12,7	N4	There are formalised, updated and validated rules.	38,1
132	Make sure that the developer includes test operation stresses specified by the test manager in the product definition. There is a precise test methodology.	Are test points defined and are recommendations for production tests applied?	6	N4	Production managers participate in the definition of the production test. There is a validated compilation of recommendations specifically describing the manner in which the tests are carried	18

N°	Recommendation	Question	Weight	Answers	Description	Rating
					out, and there is proof that the recommendations are applied.	
133	Make sure that there is a product / process qualification procedure for manufacturing processes.	Is there a qualification procedure for products and manufacturing process?	7,2	N4	The company reference documentation imposes a product / process qualification procedure.	21,6
134	Make sure that suppliers are qualified and follow up the following aspects: sustainability, quality monitoring.	Is there a product/supplier qualification procedure?	7,6	N4	The company baseline requires that suppliers should be qualified based on the reliability (and / or the manufacturing quality) criterion, this qualification is effective and is based on formal activities (interview with suppliers, analysis of previous services, audits, ISO certification).	22,8
135	Make sure that there is a qualification procedure so as to evaluate risks related to the use of the new technology component (for example by extrapolation of use in a similar environment).	Are new components qualified before they are used?	7,2	N4	There is a managed procedure that monitors technological change and validated by competent technical services.	21,6
137	Make sure that the predicted reliability calculation is made using a recognised tool associated with the selected calculation methodology	Is there a tool for formally calculating the reliability? Is there a formal choice of the reliability compilation (FIDES, adjusted MIL-HDBK-217, proprietary feedback from operations or other method)?	7,7	N4	Selection and validation of methods and tools used for predicted reliability calculations	23,1
147	Make a compromise between the complexity of built-in tests and the reliability of components used for the operational functions, in order to achieve an effective test coverage ratio. Request a justification document on the subject.	Are choices related to test coverage documented?	10,2	N3	There is a specified objective limiting the impact of built-in test devices on reliability. There is an a posteriori verification that this objective is achieved.	20,4
150	Use of validated and recognised modelling means (particularly electrical, thermal, mechanical models). Demonstrate that tools are monitored and updated.	Are validated and recognised modelling means used?	13,8	N3	Modelling means are recognised, validated and monitored but no one is assigned to management of tools.	27,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
	Manufacturing of board or sub-assemblies					
5	The product final test and particularly the coverage level achieved by this test must be studied and defined with respect to the product. Specification and Design. This test must check the product according to procedures in the System Testability Manual: - Appropriate treatment in case of a nonconformity, - Recording and saving results for monitoring of tests.	Is there a final product test? Are nonconforming test results treated: at the product, at the process? Are test results recorded?	6,6	N4	Final product tests are regularly reviewed, even after specification and design. The purpose is to increase the predefined test coverage. Documents describe the procedure to be adopted. These were validated by an authority independent from the operating entity.	19,8
7	Procedures related to corrective actions include: - Effective processing of customer complaints and product nonconformity reports, - The search for the causes of nonconformity related to the product, the process and the quality system, and recording the results of this search, - Determining corrective actions necessary to eliminate the causes of nonconformity, - Application of all means to measure the effectiveness of the corrective action.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	15,4	N4	Procedures related to corrective actions include: Effective processing of customer complaints and nonconformity reports on the product, The search for causes of nonconformity related to the product, the process and the quality system and recording the results of this search, Determination of corrective actions necessary to eliminate the causes of the nonconformity, Application of control means to assure that the corrective action is implemented and that it produces the expected effect.	46,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
8	Procedures related to preventive actions include: - The use of appropriate information sources such a processes and operations affecting the product quality, waivers, audit results, quality records, maintenance reports and customer complaints, so as to detect, analyse and eliminate the potential causes of nonconformities, - Determination of appropriate steps to deal with any problem requiring preventive action, - Triggering of preventive actions and the application of control means to make sure that they produce the expected effect, - Assurance that relative information about actions implemented is submitted to the management review.	Do procedures related to preventive actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of preventive actions and application of control means? - A management review of corrective actions?	15,6	N4	Procedures for preventive actions do exist, they are formalised and are complete with regard to the mentioned criteria	46,8
17	The subassembly varnishing activity, that must result in immunity to a number of stresses that can reduce the reliability of the subassembly, must be carried out with a permanent inspection particularly dealing with monitoring of the main parameters that are: - The humidity rate, - The temperature, - The quality of varnish constituents, - The thickness of the varnish deposit. The varnish viscosity must also be checked at least daily.	Are inspection parameters monitored during the varnishing activity?	9,9	N4	The varnishing activity is monitored by supervision of a number of mentioned parameters at the stipulated frequency. These parameters are monitored and derived from a critical analysis of the varnishing activity regarding the reliability of the subassembly. This criticality plan was generated and then validated (parameters monitored and implemented) by an independent authority.	29,7
18	Maintenance procedures related to corrective actions in production must include: - Effective processing of complaints and subassembly nonconformity reports, - The search for causes of nonconformity related to the process and recording of the results of this search, - Determination of corrective actions necessary to eliminate causes of nonconformity, - Application of control means to assure that the corrective action is implemented and that it produces the required effect.	Does corrective maintenance take place as soon as an anomaly appears on production means or produced subassemblies?	6,9	N4	Real maintenance procedures related to corrective actions are implemented, a formal corrective maintenance procedure is applied for them and has been validated by an authority independent from the operating entity.	20,7

N°	Recommendation	Question	Weight	Answers	Description	Rating
19	Based on the defined preventive maintenance plan and after its production, a correction is made by: redefining production means references, replacement of consumables, replacement of worn and therefore potentially defective parts (probes and inspection tools).	Is preventive maintenance planned to correct drifts to production means parameters?	4	N4	Real maintenance procedures are implemented for preventive actions, there is a formal preventive maintenance plan for them and it has been validated by an authority independent from the operating entity.	12
21	This verification is less complicated than a planned preventive maintenance action, and should be done by the user of the means (it forms part of the operator's training). Its purpose is to make sure that the operation will be done correctly and that it will provide the expected result (using the right loaded software or a correct configuration). The frequency of the verifications (to be defined) may be systematic before each use or after a defined number of uses of the means.	Is there a periodic verification of programming means so that the software loading operation is done correctly?	4,1	N4	Strict planning of verifications has been studied, this planning is respected and a written document has been produced verifying all points (and way this was done). This document was produced taking account of the entire software loading process and was validated by an authority independent from the operating entity.	12,3
22	This filter assures that the final test that forms the final verification milestone is carried out by a competent person and particularly a person whose skills are monitored to assure that the most recent requirements are taken into consideration. The audit assures that the operator reviews control over procedures and critical points, to achieve perfect confidence in execution of the final test.	Are the skills of final test operators systematically audited?	4,1	N4	An audit is done to monitor the skills of operators performing the final product test and this audit follows an identified formal definition, This audit has been validated by an authority independent from the operating entity.	12,3
23	It is important to perform the minimum number of manipulations of subassemblies during the production phase to limit risks of mechanical shocks and other overstresses. Furthermore, the automation of manipulations between activities during the entire production provides a means of eliminating a large number of failures caused by human intervention. This recommendation remains applicable to very small series	Are production and manipulation of subassemblies automated?	6,5	N4	Manipulations of subassemblies are automated. The level of automation was studied in a feasibility and result study. The whole procedure is formalised, and has been validated by an authority independent from the operating entity.	19,5

N°	Recommendation	Question	Weight	Answers	Description	Rating
25	It is essential to specifically monitor and maintain (by updating) references coordinates, batch numbers, etc.) loaded in production tools, for the automation of tasks and for reliable execution of activities.	Are data loaded in programmable production means managed?	2,8	N4	A check and maintenance of data programmed in production means are done, in accordance with an identified formal definition (document, inspection procedure, update procedure). All documents have been validated by an authority independent from the operating entity.	8,4
33	Delegation of the general inspection assures objectivity making it possible to better filter any errors that could have occurred during processes used for varnishing of subassemblies and critical for reliability. Filling in the follower sheet enables traceability of all operations and actions that occurred during this varnishing.	Is the subassembly varnishing inspection done by someone other than the varnishing operator?	4,4	N4	A person other than the varnishing operator makes a general inspection of this operation. This inspection is done according to a formalised procedure described in a document that has been validated by an authority independent from the operating entity.	13,2
37	The particular subassembly drying task within the varnishing activity requires know-how by the operator, who therefore needs to be experienced if it is required to avoid overstressing subassemblies. Reduced reliability due to an excessively high temperature, an excessively long application or imperfect drying, can cause serious degradations in the remainder of the process.	Is the subassembly drying activity after varnishing carried out by experienced personnel?	5,6	N4	Operators drying the subassembly are experienced. Their experience is based on similar drying activities. This experience is proven in formal documents validated by an independent authority.	16,8
41	Operators must be provided with a workstation datasheet or any other information means describing actions to be carried out and different instructions and protocols to be followed.	Are the instructions (protocol and particular instructions to be respected) given to operators?	7,4	N4	Instructions related to the activity to be performed do exist and are formalised in documents (workstation sheets, protocols, etc.). They are given to each operator responsible for carrying out an activity. These documents have been validated by an authority independent from the operating entity.	22,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
42	Take readings of temperature profiles for each program used with the soldering means to precisely determine levels that were applied (amplitude and duration so as to verify that values remain within the required range during execution of the activity).	Are there any records of temperature profiles for each program used for the soldering means?	6,9	N4	Readings are used to precisely know levels applied on subassemblies. They are done according to a predefined formal definition (document indicating the protocol, frequency, etc.), and these documents have been validated by an authority independent from the operating entity.	20,7
43	The description of actions to be carried out during application of a production tool on a subassembly must be sufficiently explicit to not allow interpretation by the operator that would result in accidental use of inappropriate means. It must be assured that the reliability of subassemblies will not be reduced by the use of an unsuitable tool.	How is it assured that production means are adapted to elements to be produced?	7,2	N4	Each production means is accompanied by a description of a set of parameters to be verified before use on a subassembly. This description is sufficiently explicit so that the identified means match the subassembly. All parameters to be verified are formalised in a document that has been validated by an authority independent from the operating entity.	21,6
46	Recording on an Anomaly datasheet type document facilitates monitoring of different malfunctions. This anomaly datasheet is one of the main documents used to implement preventive and/or corrective maintenance actions. The assembly contributes to traceability for management of nonconformities (products and means).	How are technical events or anomaly reports recorded?	7,6	N4	Every production problem, regardless of its nature, is identified and recorded in a document provided for this purpose and following a predefined formal format. The complete system and more particularly the way in which information is recorded for reuse during preventive and corrective maintenance, has been validated by an authority independent from the operating entity.	22,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
60	The different subassemblies are made and integrated starting from planned tasks that may correspond to simultaneous activities. Priorities have to be managed, so that only a minimum number of subassemblies needs to be stored (any time taken in routing production will require storage and additional manipulations of subassemblies), thus limiting ways in which the reliability of elements might be reduced.	How are priorities managed as a function of end of file dates?	3,1	N4	A genuine priority management is set up as a function of end of file dates. This planning is based on formal documents that have been validated by an authority independent from the operating entity.	9,3
61	List and implement protection means to avoid reducing the reliability of the subassembly.	Have means of protecting subassemblies during some production activities been identified and implemented?	7,3	N4	Protection means are identified following a periodic analysis of observed anomalies and their application is verified.	21,9
77	A clear statement of persons authorised to approve process changes must be available. These changes requiring acceptance by the customer must be identified before they are applied. Any change affecting processes, production equipment, tools and programs, must be documented and must lead to a procedure to control its application. Make sure that results of process changes produce the required effect and that the changes have not reduce the product quality.	How are changes to manufacturing processes controlled?	13,9	N4	Process changes are recorded, persons authorised to approve changes to production processes are clearly named. Changes requiring acceptance by the customer are identified before application. Any change affecting processes, production equipment, tools and programs is described in a document and a procedure must be produced to control its application. Systematic checks are carried out to assure that the results of changes to processes produce the required effect and that these changes have not modified the product quality.	41,7
84	Measure the bath contamination by sampling (frequency to be defined) so as not to exceed the allowable pollutant content during this activity. Excess content of pollutant will increase the risks of reducing the reliability of the solder.	Is contamination of solder baths measured by sampling (so as not to exceed the pollutant content during this activity)?	5,8	N4	The content of contaminating pollutant in the solder bath is measured. These measurements are made following an identified protocol and frequency. All these points to be respected are described in a document that has been validated by an	17,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
					authority independent from the operating entity.	
88	Set up self-checking to filter human errors that could reduce the reliability of the subassembly	Is a self checking system applied to filter human errors (that could reduce reliability of the subassembly)?	5,3	N4	Self-checking is done at the end of the activity. This is done in accordance with a protocol that was validated by an authority independent from the operating entity. This protocol is formalised in a document .	15,9
89	It must be impossible for reliability to be reduced due to nonconformity of soldering (missing, excess or offset) during electronic component transfer activities. Indicators (deposited quantity, appearance after transfer, etc.) must be identified and they must be monitored (operator check, etc) to detect all causes of reduced reliability of subassemblies.	Are there any indicators to verify that a good solder is obtained when components are transferred?	6	N4	There are indicators to assure that a good solder has been achieved. These are based on a document giving their information level and the protocol to be followed. Furthermore, these documents have been validated by an authority independent from the operating entity .	18
90	Setting up periodic store inventories prevents the use of any elements that do not satisfy expiration criteria; correct name or identification, correct geographic location during storage).	Are checks made to assure that stock inventories are defined and respected	5,5	N4	Periodic inventories are made. If the date of an inventory is not respected, a reminder is systematically issued until a new inventory has been validated. Documents formally define actions to be done and the different monitoring forms to be updated. It was validated by an authority independent from the operating entity.	16,5
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	26	N4	Protection against ESD is described in validated procedures and follow-up checks are made on these procedures.	78

N°	Recommendation	Question	Weight	Answers	Description	Rating
92	A number of production means parameters are provided by test tools (probes, sensors, detectors, etc.). These test tools need to be monitored periodically (frequency to be defined) to assure that the measurements made are reliable. The delta between the stress actually applied by the production means and the measurement made of this stress must be minimal and perfectly measurable.	Are there any periodic verifications used to monitor tools used for inspection of production means?	4,9	N4	Tools and instruments used for inspection of production means are periodically checked. These verifications (frequency and procedures) are formalised in documents and they have been validated by an authority independent from the operating entity.	14,7
93	Set up suitable protections if necessary to avoid degrading subassemblies during this activity. The purpose of these protections is to isolate part of the subassembly, and it must be possible to verify that they were effective after the activity is complete (tests, measurements).	Are there any appropriate protections to avoid degrading subassemblies while cleaning?	6	N4	A number of protections are set up during the subassembly cleaning activity. Protections and appropriate procedures to be followed are formalised in one or several documents as a function of types of subassembly, and these documents have been validated by an authority independent from the operating entity.	18
94	Set up a self-test of testers in order to detect any anomalies. It must be impossible to perform a test if the self-test is not conclusive or unless there is a traced waiver (authorisation to execute the test provided that the follower sheet is marked and signed and cannot be separated from the subassembly) accompanying the subassembly thus tested.	Are there any self-tests of test tools in order to detect any anomalies before use on the subassembly ?	5,1	N4	A self-test is carried out on the testers. This self test is described in documents used to determine the degree of effectiveness and the procedure. These documents have been validated by an authority independent from the operating entity.	15,3
95	This cross check filters nonconformities before the subassembly is continued in the production process. The final inspection activity is the last level for identification of errors that could reduce the reliability of the subassembly caused by unreliable varnishing.	Is there a cross-check to optimise the final inspection of varnishing of subassemblies?	5,6	N4	A cross-check is done during the final inspection of the subassembly varnishing activity. The effectiveness of this method has been measured and the procedure and the scope of the inspection are formally described in validated documents.	16,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
96	A so-called conformity check must be identified and must occur before every final entry of items into storage. Check on reception that there is no non-conforming element that could potentially reduce reliability during the remainder of the process.	Is there a conformity check when putting into stock in stores with the exclusion of non-conforming items?	6	N4	A real check on conformity of items is made before putting in stock in stores. This conformity check is formally described (parameters, special points, etc.) through a set of documents. The relevance of the information in these documents and the manner in which they are broken down has been validated by an authority independent from the operating entity.	18
97	Use of the statistical process control by making SPC (Statistical Process Control) cards verifies that some activities carried out at precise moments in the production phase take place correctly. The SPC is used for activities for which the risk (statistical) of having a nonconformity that reduces the reliability of the subassembly is highest.	is there an SPC (Statistical Process Control) for the production process?	4,5	N4	There is a means of inspecting the production process by SPC card. This statistical check is formalised and its efficiency for the process to be checked is known. The complete system has been validated by an authority independent from the operating entity.	13,5
98	The special feature of the varnishing activity requires a precise description of the protocol and parallel actions to be followed to assure that it is done reliably.	Is there a detailed description of the varnishing protocol?	5,8	N4	The different actions to be carried out and the operations to be followed to varnish the subassembly are described in a document formally setting down the protocol to be respected. This document has also been validated by an authority independent from the operating entity.	17,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
99	Accidental use of out-of-date consumables can have a negative influence on quality and consequently reliability, a number of suitable methods must be set up for preservation, identification and withdrawal of the products concerned if necessary. Systematically reading labels before use to identify each product used and to obtain all information about expiration, reduces risks of using a product that would reduce reliability.	Is there a label for identification and withdrawal of out-of-date consumables?	6,4	N4	Consumables are correctly identified by labelling. All information necessary for this identification is formally described in documents, and these documents have been validated by an authority independent from the operating entity.	19,2
100	This involves monitoring of test execution indicators to take immediate action with: - a definition of envelope curves, outside which it can be deemed that there is no anomaly, - an alarm as soon as an anomaly is detected, - suspension of the current activity to avoid stressing the subassembly, - compulsory action and correction of the anomaly before the activity can be resumed and continued.	Is there a real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears?	4,7	N4	There is real time processing of test monitoring indicators. Documents formally describe the way in which these indicators are processed. These documents have been validated by an authority independent from the operating entity.	14,1
101	This maintenance by metrological monitoring of production tool parameters must make it possible to eliminate the risk of degrading the reliability of an element by aggression of the subassembly (overstress). The use of parameters that are not precisely consistent with specified parameters (temperature too low, etc.) would make it impossible to ensure that the operation is reliable.	Is there preventive maintenance by metrological monitoring?	5,9	N4	Real metrological monitoring is recorded in the preventive maintenance plan that is applied. One or several documents formally define these actions, and this preventive maintenance plan has been validated by an organisation independent from the operating entity.	17,7
102	The activity must be done under the permanent control of a number of fundamental parameters and it must be possible to determine if the subassembly was overstressed or affected by a malfunction during this activity.	Is a method used for checking drifts and malfunctions (by probes and other monitoring systems), and to validate or allow the operation of drying ovens?	6,1	N4	The operator makes a real check on drifts and malfunction indicators . Documents are used as a reference to authorise the operation of drying ovens. These documents have been validated by an authority independent from the operating entity.	18,3
112	Have high and low safety systems tied to inspection and monitoring means (systematically stop the cycle and have a technician carry out an analysis before restarting)	Are high and low safety systems provided tied to inspection and monitoring means	5,7	N4	There are high and low safety systems on inspection and monitoring means. They are formally	17,1

N°	Recommendation	Question	Weight	Answers	Description	Rating
		(systematically stop the cycle and analysis by a technician before restarting)?			identified in a document specific to each means. Furthermore, these documents and stop procedures have been validated by an authority independent from the operating entity.	
115	Possess a plan for qualification of a method of removing the masking varnishes used so as to avoid reducing the reliability of the subassembly. Risks of the penetration of humidity affecting the reliability of the subassembly are strong if the operator does not take some precautions.	Is there a qualification plan of the method of removing masking varnishes used so as not to reduce reliability of the subassembly?	6,5	N4	Operators apply a qualification plan for the method of removing masking varnishes after varnishing of subassemblies. This plan is formally defined through specific documents that have been validated by an authority independent from the operating entity.	19,5
120	Include an inspection step (even visual) to assure that the masking varnish is placed correctly before varnishing.	Is there an inspection step (even visual) to assure that the masking varnish placement activity takes place correctly before varnishing?	6,5	N4	An inspection step specific to the placement of masking varnish is done. This particular inspection is described in a correctly formalised procedure. These documents have been validated by an independent authority.	19,5
121	Provide preventive maintenance (by the use of a plan describing a maintenance strategy) to detect an anomaly, if there is one, before use on the subassembly. This maintenance must be described in a maintenance plan describing intervals, parameters to be verified, critical levels, margins, etc.	Is there a preventive maintenance to detect an anomaly, if there is one, before a production means is used on a subassembly?	4,7	N4	Preventive maintenance does exist on production means. This maintenance is broken down in a documented maintenance plan that has been validated by an authority independent from the operating entity.	14,1
125	Wait for the time necessary to reach thermal equilibrium between each transfer phase to avoid overstressing the subassembly. A procedure must specify this need and describe the method.	Is a rest time between each silk screen printing operation respected to avoid overstressing the subassembly?	6,4	N4	A document explicitly describes times and actions to be respected for the transfer of components. Furthermore, this document has been validated by an authority independent from the operating entity.	19,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
126	All preventive and corrective maintenance operations for keeping production means and tools in condition, must be described in a plan revised periodically so as to prevent the use of any tool for which parameters have changed (drifts, etc.) and that could thus cause damage (physical deformations of component connections) during placement operations.	Have plans for maintenance of production means been revised and made more robust to eliminate any possibility of degradation to component connections?	6,7	N4	Documentation describes points to be revised and to be made more robust regarding the maintenance of production means. The frequency of these revisions and all actions aimed at reducing possibilities of degradation due to parameter drifts have been validated by an authority independent from the operating entity.	20,1
127	Make sure that varnish preparation (dosing) is controlled by a qualified procedure and measurements used for checking before use.	Is the preparation (dosing) of varnish controlled by a qualified procedure and test measurements?	5,9	N4	The preparation of the varnish is controlled by making checks on a number of points. These points and the procedure to be followed are formalised in a document that has been validated by an independent authority.	17,7
128	Make sure that the operators are well informed about final test activities and study how to update their skills in real time.	Is there a procedure for assuring that operators are well informed and are studies done to determine how to update their skills in real time?	4,4	N4	Operators are informed about particular activities and their skills are updated occasionally according to needs. These actions are described in documents describing details of actions to be followed and these documents have been validated by an authority independent from the operating entity.	13,2
129	Make sure that the final inspection of the varnishing is effective by strict application of the inspection procedure. This final inspection must verify that the subassembly has passed each elementary step and its associated inspection (check the various validations of documents attached to the subassembly), respecting a formalised procedure.	Is it assured that the inspection on the final varnishing quality is effective, by strictly applying the inspection procedure	5,2	N4	The final inspection of varnishing activities is made by reviewing a number of points considered to be critical. The different actions to be carried out are described in a documented procedure. This document has also been validated by an authority independent from the operating entity.	15,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
136	Make sure that the person who will perform the task knows the procedure for implementing the means at a production workstation.	Is it checked that the procedure for implementing the means is known?	5,1	N4	There is a procedure explicitly describing implementation of production means at the workstation. This is formalised in a manner that obliges the operator to become familiar with it before implementing the means (visual warning when starting up the means, etc). This formal definition has also been validated by an authority independent from the operating entity.	15,3
138	Make sure that the right software is loaded and more particularly that it is the most recent version to be used in the subassembly. This identification information must also be traced in the remainder of the process.	Is it checked that the right software is loaded, and that its version is identified?	6,7	N4	Every time that software is loaded, the operator is informed of the software version to be used. An identifier of the version to be used is provided after the operation A cross verification is formalised.	20,1
139	Make sure that maintenance is done on production means and that this maintenance is followed, particularly to take account of the most recent nonconformities.	Is a check carried out to assure that means are maintained and that this maintenance is followed?	5,9	N4	Real maintenance of the production means has been set up. It is monitored based on a plan describing all compulsory application points and the frequency of the different actions. Furthermore, these documents have been validated by an authority independent from the operating entity.	17,7
140	Make sure that the operator has received training (qualification), appropriate for the activity.	Is it checked that the operator has received training (qualification), appropriate for the activity?	8,5	N4	There is a verification to assure that the operator required to perform the identified task has actually previously received appropriate training. This verification follows a formal procedure for a complete review of the different points. The procedure has been validated by an	25,5

N°	Recommendation	Question	Weight	Answers	Description	Rating
					authority independent from the operating entity.	
141	All overstresses must be detectable and quantified (instant of occurrence stress level relative to required parameters). It must be possible to display this detection in real time and not only after the activity, so that action can be taken during the application thus reducing the overstress on the subassembly and therefore limiting its degradation.	Are means secured (drying oven T°) through direct monitoring by probes and recordings, to prevent overstresses?	6,6	N4	There are monitoring systems or other indicators to determine that parameters to be applied by means on subassemblies are respected. Documents formally define the coverage level and setting up of these direct monitoring systems. The monitoring plan thus produced has been validated by an authority independent from the operating entity.	19,8
144	It is important that the person responsible for this activity should be informed so as to reduce anomalies caused by human error (in this case visual inspection) not detected during the inspection, so as to minimise the risk due to human error or the failure to detect an anomaly.	Are personnel made aware about a visual verification of subassemblies after placement and before remelting?	5,9	N4	The operator does make a verification that the placement activity before remelting took place correctly. This verification is done in accordance with a procedure (from mentioning a simple visual inspection to the description of points to be systematically verified). Furthermore, this procedure has been validated by an authority independent from the operating entity.	17,7
145	Increase operators awareness about the verification of the quality of soldering flux deposit. Since this operation requires a special verification after it has been done, placement of an electronic barcode reading as verification phase must enable good monitoring of this inspection and the subassembly follower sheet must include a check that it has been done.	Are operators made aware of the need to verify the quality of soldering flux deposit (implementation of a verification action that must appear in the subassembly follower sheet)?	5,9	N4	The operator checks that the activity for the soldering flux deposit (quantity, appearance, etc.) took place correctly. This verification is done in accordance with a procedure enabling traceability (for example barcode reading of the manufacturing follower sheet). Furthermore, these verification means and their placement have	17,7

N°	Recommendation	Question	Weight	Answers	Description	Rating
					been validated by an authority independent from the operating entity.	
153	Use measurements for verification of purchased products such as: examination of the required documentation, inspection and audit at the purchase source, examination of products on delivery.	Is the conformity of purchased products checked?	8,6	N4	Conformity of purchased products is verified by examination of products on delivery, by examination of the required documentation and by inspection and audit of the purchase source.	25,8
154	Perform an inspection action (barcode reading, reading the S/N) to verify that the right product is available before starting the test.	Is an inspection action (barcode reading, reading the S/N) performed to verify that the right product is available before starting the test?	6,1	N4	The identification of the product to be tested is systematically verified. This is based on a documented procedure indicating the procedure to be followed (barcode reading of an identifier, etc.). This verification method has been validated by an authority independent from the operating entity.	18,3
155	Check that the test coverage during and after burn-in is formalised correctly.	Is it checked that the test coverage for burn-in is formalised correctly?	5,2	N4	The test coverage rate during burn-in is verified. A document describes changes requiring a verification and the procedure to be implemented. This entire document has been validated by an authority independent from the operating entity.	15,6
	Equipement integration					
5	The product final test and particularly the coverage level achieved by this test must be studied and defined with respect to the product. Specification and Design. This test must check the product according to procedures in the System Testability Manual: - Appropriate treatment in case of a nonconformity, - Recording and saving results for monitoring of tests.	Is there a final product test? Are nonconforming test results treated: at the product, at the process? Are test results recorded?	6,6	N4	Final product tests are regularly reviewed, even after specification and design. The purpose is to increase the predefined test coverage. Documents describe the procedure to be adopted. These were validated by an authority independent from the operating entity.	19,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
7	Procedures related to corrective actions include: - Effective processing of customer complaints and product nonconformity reports, - The search for the causes of nonconformity related to the product, the process and the quality system, and recording the results of this search, - Determining corrective actions necessary to eliminate the causes of nonconformity, - Application of all means to measure the effectiveness of the corrective action.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	15,4	N4	Procedures related to corrective actions include: Effective processing of customer complaints and nonconformity reports on the product, The search for causes of nonconformity related to the product, the process and the quality system and recording the results of this search, Determination of corrective actions necessary to eliminate the causes of the nonconformity, Application of control means to assure that the corrective action is implemented and that it produces the expected effect.	46,2
8	Procedures related to preventive actions include: - The use of appropriate information sources such a processes and operations affecting the product quality, waivers, audit results, quality records, maintenance reports and customer complaints, so as to detect, analyse and eliminate the potential causes of nonconformities, - Determination of appropriate steps to deal with any problem requiring preventive action, - Triggering of preventive actions and the application of control means to make sure that they produce the expected effect, - Assurance that relative information about actions implemented is submitted to the management review.	Do procedures related to preventive actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of preventive actions and application of control means? - A management review of corrective actions?	15,6	N3	Procedures for preventive actions do exist and are almost complete with regard to the mentioned criteria (there are possible minor nonconformities in the application or satisfaction of criteria)	31,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
9	When traceability is required, the system implemented must make it possible of: - maintaining the product identification throughout the life cycle, - knowing the history (definition file + changes) and the final use (deliveries, scrap) of all products manufactured from the same batch of raw material or from the same manufacturing batch, - finding the identity of elements making up an assembly and the higher assembly, - finding the sequential documentation on production (manufacturing, assembly, inspection) of a given product (e.g. configuration follower sheet including recording of actual operations and observed anomalies). The traceability system must be capable of determining the product configuration ready for delivery, including variations between the real state and the agreed state.	How is product traceability achieved?	16,5	N3	Traceability is used to identify and know the product history (Definition file + changes), However it is not sufficient to know the documentation associated with its life cycle (e.g. no configuration follower sheet containing records of operations carried out and anomalies observed).	33
10	Wrapping, packaging and marking processes must be controlled to assure conformity with specified requirements. Define a list of equipment for which packaging is necessary. Suggest a method of managing special packaging by product (dates, modes, duration). Periodically check the quality of packaging. Use appropriate packaging specific to the products.	Does the supplier control wrapping, packaging and marking processes to assure conformity with the specified requirements? Is there a list of equipment requiring packaging?	12,3	N3	Special product packaging is provided, and documentation is associated with it No specific inspection of the packaging.	24,6
11	Designated storage areas or premises must be used to prevent damage or deterioration of the product. Appropriate measures are taken to allow reception in these areas and shipment from them. The state of the product in stock must be evaluated at appropriate intervals to detect any deterioration. Manage and control atmospheres in storage. Tailor positioning in storage. Manage periodic actions to maintain product characteristics in storage (powering on).	Are there any designated storage areas or premises? Are they used to prevent damage or deterioration of the product? Are appropriate measures taken to enable reception and shipping in these areas?	10,8	N2	Product storage areas are not specific, the storage environment is controlled and adapted to the stored products.	10,8
12	The supplier shall take measures to protect the product quality after inspections and final tests. When specified in the contract, this protection is extended to include delivery for final use. The supplier makes sure that the accompanying documentation for the product as specified at the order is present at the time of the delivery, and that it is protected against loss and damage.	Does the supplier take steps to maintain the product quality after the inspections and final tests? When specified in the contract, are these steps extended to include delivery for final use?	17,5	N3	Product quality protections are used during delivery to the customer. The supplier does check that accompanying documents are present, but does not protect them against loss and deterioration.	35

N°	Recommendation	Question	Weight	Answers	Description	Rating
13	During the phase, the product must be inspected and tests must be carried out in accordance with the quality plan and/or written procedures. The product must remain blocked until the required inspections and tests are terminated, or until the necessary reports have been received and verified.	Is there any risk that a product that has not satisfied inspections and tests specified during one phase will go on to the next phase without corrective action?	7,2	N3	Inspections are carried out during the phase and are formalised in the form of written procedures or a quality plan. These inspections and test are not always complete.	14,4
14	Perform all final inspections and tests in accordance with the quality plan and/or written procedures. The quality plan and/or procedures for final inspections and tests must require that all specified inspections and tests, including those defined for product reception, are carried out and that the results are conforming with requirements. Before shipment, make sure that: All activities specified in the quality plan and/or written procedures have been satisfactory accomplished, The associated data and documentation are available and accepted.	Have all final inspections and tests been carried out in accordance with the quality plan and/or written procedures?	7,9	N3	Final inspections and tests are carried out, They are described in strict procedures or in a quality plan. Application of these inspections and tests is not verified and validated.	15,8
15	Make sure that the incoming product is not used or implemented until it has been inspected or until its conformity with specified requirements has been verified in another way. The check on conformity with specified requirements must be made in accordance with the quality plan and/or written procedures. Inspections carried out in the premises of subcontractors and proofs of conformity provided must be taken into account to determine the importance and nature of inspections to be carried out on reception. When the incoming product is released before it has been verified for reasons of urgency, it must be identified and this release shall be recorded.	Are appropriate inspections and tests carried out on incoming products before use?	6,7	N4	Conformity with specified requirements is verified in accordance with a quality plan and/or written procedures. Inspections carried out in subcontractor premises and proofs of conformity supplied are taken into account to determine the importance and nature of inspections to be carried out on reception. When the entering product is released before it has been verified for reasons of urgency, it is identified and this release is recorded.	20,1

N°	Recommendation	Question	Weight	Answers	Description	Rating
18	Maintenance procedures related to corrective actions in production must include: - Effective processing of complaints and subassembly nonconformity reports, - The search for causes of nonconformity related to the process and recording of the results ofthis search, - Determination of corrective actions necessary to eliminate causes of nonconformity, - Application of control means to assure that the corrective action is implemented and that it produces the required effect.	Does corrective maintenance take place as soon as an anomaly appears on production means or produced subassemblies?	6,9	N3	Real maintenance procedures related to corrective actions are implemented, a formal corrective maintenance procedure is applied for them but it has not been validated by an authority independent from the operating entity.	13,8
19	Based on the defined preventive maintenance plan and after its production, a correction is made by: redefining production means references, replacement of consumables, replacement of worn and therefore potentially defective parts (probes and inspection tools).	Is preventive maintenance planned to correct drifts to production means parameters?	4	N3	Real maintenance procedures are implemented for preventive actions, there is a formal preventive maintenance plan for them but it has not been validated by an authority independent from the operating entity.	8
21	This verification is less complicated than a planned preventive maintenance action, and should be done by the user of the means (it forms part of the operator's training). Its purpose is to make sure that the operation will be done correctly and that it will provide the expected result (using the right loaded software or a correct configuration). The frequency of the verifications (to be defined) may be systematic before each use or after a defined number of uses of the means.	Is there a periodic verification of programming means so that the software loading operation is done correctly?	4,1	N3	Planning of verifications has been studied, this planning is respected and a written document has been produced verifying all points (and way this was done).	8,2
22	This filter assures that the final test that forms the final verification milestone is carried out by a competent person and particularly a person whose skills are monitored to assure that the most recent requirements are taken into consideration. The audit assures that the operator reviews control over procedures and critical points, to achieve perfect confidence in execution of the final test.	Are the skills of final test operators systematically audited?	4,1	N3	An audit is done to monitor the skills of operators performing the final product test and this audit follows an identified formal definition, although it has not been validated by an authority independent from the operating entity.	8,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
23	It is important to perform the minimum number of manipulations of subassemblies during the production phase to limit risks of mechanical shocks and other overstresses. Furthermore, the automation of manipulations between activities during the entire production provides a means of eliminating a large number of failures caused by human intervention. This recommendation remains applicable to very small series	Are production and manipulation of subassemblies automated?	6,5	N2	A number of manipulations of subassemblies has been automated.	6,5
25	It is essential to specifically monitor and maintain (by updating) references coordinates, batch numbers, etc.) loaded in production tools, for the automation of tasks and for reliable execution of activities.	Are data loaded in programmable production means managed?	2,8	N3	A check and maintenance of data programmed in production means are done, in accordance with an identified formal definition (document, inspection procedure, update procedure).	5,6
30	The description of the accepted nonconformity or repairs made is recorded to indicate the real condition of the product. Written procedures are kept up to date defining at least: The process for classification of nonconformities and control over the use of nonconforming components in finished products, The formal authorisation process and the application field for personnel authorising the use of replacement materials and/or nonconforming products (waiver procedures), The process for control of scrapped parts.	Is the description of the accepted nonconformity or of the repairs performed recorded to indicate the product's real condition?	10,3	N3	The description of the accepted nonconformity or the repairs made is recorded to indicate the real condition of the product. Written procedures define the process for classification of nonconformities and control over the use of nonconforming components in finished products. The process for authorisation of personnel to use replacement materials and/or nonconforming products is not formalised.	20,6
32	Product inspection and test procedures must specify resources (men, means), methods to be implemented, acceptance criteria and methods of recording the results. These procedures must also define the training and if necessary require operators' qualification.	Are means necessary for inspections and tests of the product defined?	11,6	N3	Product inspection or test procedures are specified. Acceptance methods and criteria are described. Results are not recorded and used for feedback from operations. Procedures also describe training and qualification of operators.	23,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
35	Purchasing documents must include the following when applicable: The type, category and any other precise identification, the title or any other formal identification and the applicable edition of specifications, drawings, requirements for processes, inspection instructions and other relevant technical data, the title, identifier and edition of the quality system standard to be applied, purchasing document reviewed and approved before distribution to assure that they are capable of satisfying the requirements. Documented procurement requirements must include the following when applicable: Tests, examinations, inspections and acceptance conditions imposed by the customer, and any relevant instructions or requirements, requirements related to specimens (production method, number, storage conditions) for inspections, investigations or audits, requirements related to notification of anomalies, changes to the definition and approval of their processing. Suppliers must be notified about customer requirements.	Are there any documents for performing incoming inspection on supplies?	8,8	N3	Purchasing documents include a precise identification, the applicable edition of specifications, drawings, requirements in terms of process, inspection instructions and other relevant technical data, the title, identifier and edition of the quality system standard to be applied, purchasing documents reviewed and approved before distribution, to assure that they satisfy the requirements.	17,6
41	Operators must be provided with a workstation datasheet or any other information means describing actions to be carried out and different instructions and protocols to be followed.	Are the instructions (protocol and particular instructions to be respected) given to operators?	7,4	N3	Instructions related to the activity to be performed do exist and are formalised in documents (workstation sheets, protocols, etc.). They are given to each operator responsible for carrying out an activity. These documents have not been validated by an authority independent from the operating entity.	14,8
43	The description of actions to be carried out during application of a production tool on a subassembly must be sufficiently explicit to not allow interpretation by the operator that would result in accidental use of inappropriate means. It must be assured that the reliability of subassemblies will not be reduced by the use of an unsuitable tool.	How is it assured that production means are adapted to elements to be produced?	7,2	N3	Each production means is accompanied by a description of a set of parameters to be verified before use on a subassembly. These are formally identified in a document that has not been validated by an authority independent from the operating entity.	14,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
46	Recording on an Anomaly datasheet type document facilitates monitoring of different malfunctions. This anomaly datasheet is one of the main documents used to implement preventive and/or corrective maintenance actions. The assembly contributes to traceability for management of nonconformities (products and means).	How are technical events or anomaly reports recorded?	7,6	N4	Every production problem, regardless of its nature, is identified and recorded in a document provided for this purpose and following a predefined formal format. The complete system and more particularly the way in which information is recorded for reuse during preventive and corrective maintenance, has been validated by an authority independent from the operating entity.	22,8
47	Produce written procedures to assure that the purchased product is conforming with the specified requirements. Define the terms and conditions for procurement and the responsibilities of all persons concerned. Check that procedures are applied.	Are there any written procedures for assuring that products are conforming with specified requirements?	10,6	N4	Procedures specific to the product are defined in a validated plan to assure conformity of the purchased product. Procurement conditions and the responsibilities of persons doing the work are described. Proofs that these procedures have been evaluated exist.	31,8
49	The responsibility for examination and the decision to process the nonconforming product must be defined. Written procedures must describe processing of nonconformities. These procedures must predict that the nonconforming product can be: reworked to satisfy the specified requirements, accepted by waiver with or without repair. declassified for other applications, rejected or scrapped. If required by the contract, the proposal for use or repair of the nonconforming product may be submitted to the customer. The repaired and/or reworked product is inspected once again in accordance with the requirements in the quality plan and/or written procedures.	Has the responsibility for the examination and the decision to process the nonconforming product been defined?	13,6	N3	The nonconforming product is examined and described according to written procedures, but they do not allow for product modifications or acceptance without modification.	27,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
60	The different subassemblies are made and integrated starting from planned tasks that may correspond to simultaneous activities. Priorities have to be managed, so that only a minimum number of subassemblies needs to be stored (any time taken in routing production will require storage and additional manipulations of subassemblies), thus limiting ways in which the reliability of elements might be reduced.	How are priorities managed as a function of end of file dates?	3,1	N3	A genuine priority management is set up as a function of end of file dates. This planning is based on formal documents that have not been validated by an authority independent from the operating entity.	6,2
61	List and implement protection means to avoid reducing the reliability of the subassembly.	Have means of protecting subassemblies during some production activities been identified and implemented?	7,3	N3	Protection means are identified and their application is verified.	14,6
66	Requirements for qualification of process operations including equipment and associated personnel, must be specified.	Are means concerning special processes identified?	13,1	N3	Process operation qualification requirements, including associated equipment and personnel, are specified.	26,2
67	Special processes must be done by qualified operators and/or are continuously monitored, with control over process parameters to assure conformity with requirements.	Are human resources concerning special processes managed?	11,7	N3	Special processes are done by qualified operators, or they are continuously monitored.	23,4
70	Written inspection and test procedures have to be produced and kept up to date, to verify that specified requirements for the product are respected.	How is the product inspection and test documentation controlled?	9,3	N3	The documentation includes a program and a test report containing information about the test itself, and also all results with a list of anomalies remaining at the end of the test.	18,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
71	Store and keep product and process documentation available in the workshop. Make a list of the documentation regularly. Periodically update the documentation. Train an entity among workshop personnel in the management of technical documentation. Have technical documentation for products. Have a documentation specific to the inspection and maintenance tests. Associate this product technical documentation with implementation processes. When documents are provided, analyse the validity of this product documentation. Be in possession of process control documentation. Specify technical documentation for each process. Provide this technical documentation and make it useable. Have a documentation specific to the inspection and tests .	Is documentation well controlled? Does it take account of all equipment changes?	12,2	N3	Documentation specific to products and processes does exist, it is updated periodically in a planned manner, the validity of the documents used is not analysed.	24,4
73	Inspection, measurement and test equipment is used to assure that the measurement uncertainty is known and is compatible with the required measurement aptitude. Test software or comparison references used as inspection means are verified before they are put into service to demonstrate that they are capable of checking that the product is acceptable.	What steps are taken to control how inspection, measurement and test equipment is compatible with needs?	9,6	N3	Inspection, measurement and test equipment is used in such a manner that the measurement uncertainty is known and is compatible with the required measurement aptitude. There is no verification of inspection equipment before it is put into service.	19,2
74	Handling, preservation and storage of inspection and measurement equipment assures that precision and usability are maintained. Inspection, measurement and test equipment, including the test benches and test software, are protected against manipulations that would invalidate calibration settings.	How is the environment of inspection, measurement and test equipment controlled?	7,9	N3	Product storage areas are specific. The storage environment is controlled and adapted to the stored products. Storage positions are individually defined. Periodic actions are carried out to maintain product characteristics.	15,8
75	When the working environment is important for product quality, appropriate limits must be specified, controlled and verified (layout of the workshop, ergonomy of the workstation, etc).	How is the working environment controlled?	9,6	N3	Workstations are specific to equipment. The working environment is controlled and verified.	19,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
77	A clear statement of persons authorised to approve process changes must be available. These changes requiring acceptance by the customer must be identified before they are applied. Any change affecting processes, production equipment, tools and programs, must be documented and must lead to a procedure to control its application. Make sure that results of process changes produce the required effect and that the changes have not reduce the product quality.	How are changes to manufacturing processes controlled?	13,9	N3	Process changes are recorded, persons authorised to approve changes to production processes are clearly named. Changes requiring acceptance by the customer are identified before application. Any change affecting processes, production equipment, tools and programs is described in a document and a procedure must be produced to control its application. However, there is no systematic check that the results of changes to processes produce the required effect and that these changes have not modified the product quality.	27,8
78	Product handling methods and means are provided to prevent damage or deterioration to the product and include: - transport procedures, - handling methods specific to each product.	Are handling and transport methods defined?	8,8	N3	Handling methods specific to the product are written down, specific means are provided to prevent any deterioration during manipulations. There is no verification about their application.	17,6
79	Make sure that written procedures describe the following activities, for all production means, tools and programs: validation before use, maintenance, periodic inspection according to written procedures.	How are production equipment, tools and programs for numerical control machine controlled?	10,5	N3	The periodic inspection of means and tools is submitted for validation, formal procedures identify periodic inspections to be carried out.	21

N°	Recommendation	Question	Weight	Answers	Description	Rating
80	A procedure is necessary to take account of specific requirements for the following at the different production steps, if applicable in accordance with the manufacturer's recommendations and/or applicable regulations: - cleaning, - prevention, detection and removal of foreign bodies, - handling adapted to sensitive products, - marking and labelling, including safety marking, - control of shelf life and stock rotation, - dangerous equipment Produce special management procedures for perishables. Eliminate all products that have passed their useful life and unidentified products. Suggest criteria for evaluating and analysing the quality of storage conditions. List and analyse failures related to lack of quality in storage.	How are handling, storage, packaging, preservation, and delivery controlled?	6,5	N3	Handling, storage, packaging, preservation and delivery conditions are coded, there are procedures specific to each product.	13
81	Further description When special processes are used (processes for which results cannot be fully verified a posteriori by an inspection or test of the product, and for which the consequences of deficiencies in application will not appear until this product is used, for example gluing, soldering: The special processes to be implemented must be identified. The supplier verifies that all parameters of special processes (for example materials, personnel, procedures and software) produce satisfactory results. The supplier identifies and documents significant operations and process parameters to be controlled. Any modification to these operations and parameters must be described in a proposal justifying this modification and guaranteeing that it does not introduce any harmful effect on the result of the process. The supplier must verify special processes by making one or several typical parts under the conditions defined for the phase. Special processes or subcontracted processes must be qualified before use. The supplier must keep qualified special processes up to date.	How are special processes controlled?	14,4	N3	Special processes are identified. The parameters for these processes (materials, personnel, procedures and software) are evaluated. Significant operations and parameters of the process to be controlled in production have been identified and documented. Any modification to these operations and parameters will be described in a proposal justifying this modification and guaranteeing that it does not introduce any harmful effect on the result of the process. Special processes have not been verified by making one or several typical parts under defined conditions.	28,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
82	Further description When they have an influence on the quality and reliability of the product, services and supplies such as water, compressed air, electricity and chemicals used must be controlled and verified regularly to make sure that their effect on the process is constant.	How are services and fluids in the working environment controlled?	10,1	N3	Services and supplies such as water, compressed air, electricity and chemicals are controlled and verified periodically to make sure that their effect on the process is constant.	20,2
88	Set up self-checking to filter human errors that could reduce the reliability of the subassembly	Is a self checking system applied to filter human errors (that could reduce reliability of the subassembly)?	5,3	N3	Self-checking is done at the end of the activity. This is done in accordance with a predefined protocol formalised in a document.	10,6
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	26	N3	There are validated procedures for protection against ESD defining practices recognised as protecting the subassemblies.	52
92	A number of production means parameters are provided by test tools (probes, sensors, detectors, etc.). These test tools need to be monitored periodically (frequency to be defined) to assure that the measurements made are reliable. The delta between the stress actually applied by the production means and the measurement made of this stress must be minimal and perfectly measurable.	Are there any periodic verifications used to monitor tools used for inspection of production means?	4,9	N3	Tools and instruments used for inspection of production means are periodically checked. These verifications (frequency and procedures) are formalised in documents, but there is no validation of these documents by an authority independent from the operating entity.	9,8
94	Set up a self-test of testers in order to detect any anomalies. It must be impossible to perform a test if the self-test is not conclusive or unless there is a traced waiver (authorisation to execute the test provided that the follower sheet is marked and signed and cannot be separated from the subassembly) accompanying the subassembly thus tested.	Are there any self-tests of test tools in order to detect any anomalies before use on the subassembly ?	5,1	N3	A self-test is carried out on the testers. This self test is described in documents used to determine the degree of effectiveness and the procedure. But these documents have not been validated by an authority independent from the operating entity.	10,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
99	Accidental use of out-of-date consumables can have a negative influence on quality and consequently reliability, a number of suitable methods must be set up for preservation, identification and withdrawal of the products concerned if necessary. Systematically reading labels before use to identify each product used and to obtain all information about expiration, reduces risks of using a product that would reduce reliability.	Is there a label for identification and withdrawal of out-of-date consumables?	6,4	N3	Consumables are correctly identified by labelling. All information necessary for this identification is formally described in documents, but these documents have not been validated by an authority independent from the operating entity.	12,8
100	This involves monitoring of test execution indicators to take immediate action with: - a definition of envelope curves, outside which it can be deemed that there is no anomaly, - an alarm as soon as an anomaly is detected, - suspension of the current activity to avoid stressing the subassembly, - compulsory action and correction of the anomaly before the activity can be resumed and continued.	Is there a real time processing of test monitoring indicators so as to not to degrade the subassembly as soon as an anomaly appears?	4,7	N3	There is real time processing of test monitoring indicators. Documents formally describe the way in which these indicators are processed. However, these data have not been validated by an authority independent from the operating entity.	9,4
113	Records must be produced and kept to provide proof that the product has been subjected to inspections and/or tests in accordance with defined criteria. Records must be sufficient to identify the person who performed the inspections and released the product. Test records must indicate measured values when they are required by the specification or the acceptance plan. If specified, the supplier must demonstrate the qualification of the product.	Are records produced and kept to prove that the product has been inspected and/or tested in accordance with defined criteria? Are the records sufficient to identify the person who made the checks?	5,3	N3	Records of inspections and tests are produced and are kept and can be used to identify the source of the inspection (persons, machine).	10,6
114	The inspection file must contain: criteria for acceptance and refusal, a sequential list of inspection and test operations to be done, inspection result record documents, a list of specific and non-specific inspection instruments, the documents associated with specific inspection instruments for their design, production, validation, management, use and maintenance .	Is there an inspection file containing acceptance criteria, the sequential list of inspection and test operations, inspection result record documents, list of specific and non-specific inspection instruments?	5,7	N4	The inspection file contains: the definition of acceptance or refusal criteria, the sequential list of inspection and test operations to be carried out, Inspection result record documents, the list of specific and non-specific inspection instruments, and documents associated with specific inspection instruments for their design, production,	17,1

N°	Recommendation	Question	Weight	Answers	Description	Rating
					validation, management, use, and maintenance.	
116	Nonconformity documents must specify: the product identification, the description of the nonconformity, the cause of the nonconformity, actions taken to prevent recurrence of the nonconformity, reworking or repairs if necessary, check of characteristics affected by the reworking or repairs, the final decision.	Is there any documentation specific to the nonconformity?	11,1	N4	Nonconformity documents specify the product identification, the description of the nonconformity and the cause of the nonconformity. Actions are formalised to prevent recurrence of the nonconformity, reworking or repairs if necessary and checking of characteristics affected by the reworking or repairs.	33,3
121	Provide preventive maintenance (by the use of a plan describing a maintenance strategy) to detect an anomaly, if there is one, before use on the subassembly. This maintenance must be described in a maintenance plan describing intervals, parameters to be verified, critical levels, margins, etc.	Is there a preventive maintenance to detect an anomaly, if there is one, before a production means is used on a subassembly?	4,7	N3	Preventive maintenance does exist on production means. This maintenance is broken down in a documented maintenance plan. Not all of this plan has been validated.	9,4
136	Make sure that the person who will perform the task knows the procedure for implementing the means at a production workstation.	Is it checked that the procedure for implementing the means is known?	5,1	N3	There is a procedure explicitly describing implementation of production means at the workstation. This is formalised in a manner that obliges the operator to be familiar with it before implementing the means (visual warning when starting up the means, etc).	10,2
138	Make sure that the right software is loaded and more particularly that it is the most recent version to be used in the subassembly. This identification information must also be traced in the remainder of the process.	Is it checked that the right software is loaded, and that its version is identified?	6,7	N3	Every time that software is loaded, the operator is informed of the software version to be used. An identifier of the version to be used is provided after the operation.	13,4
139	Make sure that maintenance is done on production means and that this maintenance is followed, particularly to take account of the most recent nonconformities.	Is a check carried out to assure that means are maintained and that this maintenance is followed?	5,9	N3	Real maintenance of the production means has been set up. It is monitored based on a plan describing all compulsory application points and the	11,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
					frequency of the different actions.	
140	Make sure that the operator has received training (qualification), appropriate for the activity.	Is it checked that the operator has received training (qualification), appropriate for the activity?	8,5	N3	There is a verification to assure that the operator required to perform the identified task has actually previously received appropriate training. This verification follows a formal procedure for a complete review of the different points.	17
153	Use measurements for verification of purchased products such as: examination of the required documentation, inspection and audit at the purchase source, examination of products on delivery.	Is the conformity of purchased products checked?	8,6	N3	Conformity of purchased products is verified by examination of products on delivery and by examination of the required documentation.	17,2
	System integration					
umé	Recommendation	Question	Weight	Answers	Description	Rating
7	Procedures related to corrective actions include: - Effective processing of customer complaints and product nonconformity reports, - The search for the causes of nonconformity related to the product, the process and the quality system, and recording the results of this search, - Determining corrective actions necessary to eliminate the causes of nonconformity, - Application of all means to measure the effectiveness of the corrective action.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	15,4	N3	Procedures related to corrective actions include at least: Effective processing of customer complaints and nonconformity reports on the product, The search for causes of nonconformity related to the product, the process and the quality system and recording the results of this search, Determination of corrective actions necessary to eliminate the causes of the nonconformity, These procedures do not define the application of control means to assure that the corrective action is implemented and that it produces the expected effect.	30,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
8	Procedures related to preventive actions include: - The use of appropriate information sources such a processes and operations affecting the product quality, waivers, audit results, quality records, maintenance reports and customer complaints, so as to detect, analyse and eliminate the potential causes of nonconformities, - Determination of appropriate steps to deal with any problem requiring preventive action, - Triggering of preventive actions and the application of control means to make sure that they produce the expected effect, - Assurance that relative information about actions implemented is submitted to the management review.	Do procedures related to preventive actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of preventive actions and application of control means? - A management review of corrective actions?	15,6	N3	Procedures for preventive actions do exist and are almost complete with regard to the mentioned criteria (there are possible minor nonconformities in the application or satisfaction of criteria)	31,2
9	When traceability is required, the system implemented must make it possible of: - maintaining the product identification throughout the life cycle, - knowing the history (definition file + changes) and the final use (deliveries, scrap) of all products manufactured from the same batch of raw material or from the same manufacturing batch, - finding the identity of elements making up an assembly and the higher assembly, - finding the sequential documentation on production (manufacturing, assembly, inspection) of a given product (e.g. configuration follower sheet including recording of actual operations and observed anomalies). The traceability system must be capable of determining the product configuration ready for delivery, including variations between the real state and the agreed state.	How is product traceability achieved?	16,5	N3	Traceability is used to identify and know the product history (Definition file + changes), However it is not sufficient to know the documentation associated with its life cycle (e.g. no configuration follower sheet containing records of operations carried out and anomalies observed).	33
10	Wrapping, packaging and marking processes must be controlled to assure conformity with specified requirements. Define a list of equipment for which packaging is necessary. Suggest a method of managing special packaging by product (dates, modes, duration). Periodically check the quality of packaging. Use appropriate packaging specific to the products.	Does the supplier control wrapping, packaging and marking processes to assure conformity with the specified requirements? Is there a list of equipment requiring packaging?	12,3	N3	Special product packaging is provided, and documentation is associated with it No specific inspection of the packaging.	24,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
11	Designated storage areas or premises must be used to prevent damage or deterioration of the product. Appropriate measures are taken to allow reception in these areas and shipment from them. The state of the product in stock must be evaluated at appropriate intervals to detect any deterioration. Manage and control atmospheres in storage. Tailor positioning in storage. Manage periodic actions to maintain product characteristics in storage (powering on).	Are there any designated storage areas or premises? Are they used to prevent damage or deterioration of the product? Are appropriate measures taken to enable reception and shipping in these areas?	10,8	N3	Product storage areas are specific. The storage environment is controlled and adapted to the stored products. Storage positions are individually defined. Periodic actions are carried out to maintain product characteristics.	21,6
12	The supplier shall take measures to protect the product quality after inspections and final tests. When specified in the contract, this protection is extended to include delivery for final use. The supplier makes sure that the accompanying documentation for the product as specified at the order is present at the time of the delivery, and that it is protected against loss and damage.	Does the supplier take steps to maintain the product quality after the inspections and final tests? When specified in the contract, are these steps extended to include delivery for final use?	17,5	N4	The supplier takes measures to protect the product quality during delivery for its final use. He assures that the accompanying documentation for the product is present as specified at the time of the order, and that the documentation is protected against loss and deterioration.	52,5
13	During the phase, the product must be inspected and tests must be carried out in accordance with the quality plan and/or written procedures. The product must remain blocked until the required inspections and tests are terminated, or until the necessary reports have been received and verified.	Is there any risk that a product that has not satisfied inspections and tests specified during one phase will go on to the next phase without corrective action?	7,2	N4	Inspections are carried out during the phase and are formalised in the form of written procedures or a quality plan. These inspections and tests are complete.	21,6
14	Perform all final inspections and tests in accordance with the quality plan and/or written procedures. The quality plan and/or procedures for final inspections and tests must require that all specified inspections and tests, including those defined for product reception, are carried out and that the results are conforming with requirements. Before shipment, make sure that: All activities specified in the quality plan and/or written procedures have been satisfactory accomplished, The associated data and documentation are available and accepted.	Have all final inspections and tests been carried out in accordance with the quality plan and/or written procedures?	7,9	N4	Final inspections and tests are carried out in accordance with the quality plan and/or written procedures. The quality plan and/or procedures for final inspections and tests require that all specified inspections and tests, including those specified for product reception or during its manufacturing, are done and that the results are conforming with the requirements. It is checked before shipment that: All activities specified in the quality plan and/or in written procedures	23,7

N°	Recommendation	Question	Weight	Answers	Description	Rating
					have been satisfactorily accomplished Data and the associated documentation are available (follower sheet type document that records the configuration, operations carried out and observed anomalies) and accepted.	
15	Make sure that the incoming product is not used or implemented until it has been inspected or until its conformity with specified requirements has been verified in another way. The check on conformity with specified requirements must be made in accordance with the quality plan and/or written procedures. Inspections carried out in the premises of subcontractors and proofs of conformity provided must be taken into account to determine the importance and nature of inspections to be carried out on reception. When the incoming product is released before it has been verified for reasons of urgency, it must be identified and this release shall be recorded.	Are appropriate inspections and tests carried out on incoming products before use?	6,7	N4	Conformity with specified requirements is verified in accordance with a quality plan and/or written procedures. Inspections carried out in subcontractor premises and proofs of conformity supplied are taken into account to determine the importance and nature of inspections to be carried out on reception. When the entering product is released before it has been verified for reasons of urgency, it is identified and this release is recorded.	20,1
30	The description of the accepted nonconformity or repairs made is recorded to indicate the real condition of the product. Written procedures are kept up to date defining at least: The process for classification of nonconformities and control over the use of nonconforming components in finished products, The formal authorisation process and the application field for personnel authorising the use of replacement materials and/or nonconforming products (waiver procedures), The process for control of scrapped parts.	Is the description of the accepted nonconformity or of the repairs performed recorded to indicate the product's real condition?	10,3	N3	The description of the accepted nonconformity or the repairs made is recorded to indicate the real condition of the product. Written procedures define the process for classification of nonconformities and control over the use of nonconforming components in finished products. The process for authorisation of personnel to use replacement materials and/or nonconforming	20,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
					products is not formalised.	
32	Product inspection and test procedures must specify resources (men, means), methods to be implemented, acceptance criteria and methods of recording the results. These procedures must also define the training and if necessary require operators' qualification.	Are means necessary for inspections and tests of the product defined?	11,6	N3	Product inspection or test procedures are specified. Acceptance methods and criteria are described. Results are not recorded and used for feedback from operations. Procedures also describe training and qualification of operators.	23,2
35	Purchasing documents must include the following when applicable: The type, category and any other precise identification, the title or any other formal identification and the applicable edition of specifications, drawings, requirements for processes, inspection Instructions and other relevant technical data, the title, identifier, and edition of the quality system standard to be applied, purchasing document reviewed and approved before distribution to assure that they are capable of satisfying the requirements. Documented procurement requirements must include the following when applicable: Tests, examinations, inspections and acceptance conditions imposed by the customer, and any relevant instructions or requirements, requirements related to specimens (production method, number, storage conditions) for inspections, investigations or audits, requirements related to notification of anomalies, changes to the definition and approval of their processing. Suppliers must be notified about customer requirements.	Are there any documents for performing incoming inspection on supplies?	8,8	N4	Purchasing documents include a precise identification, the applicable edition of specifications, drawings, requirements in terms of process, inspection instructions and other relevant technical data, the title, identifier and edition of the quality system standard to be applied, purchasing documents reviewed and approved before distribution, to assure that they satisfy the requirements. Documented procurement requirements also include: Tests, examinations, inspections and customer acceptance conditions and any relevant instruction or requirements, requirements related to specimens (production method, number, storage conditions) for inspections, investigations or audits, requirements related to notification of anomalies, changes to the definition and approval of their processing	26,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
					The customer's requirements are forwarded to suppliers.	
47	Produce written procedures to assure that the purchased product is conforming with the specified requirements. Define the terms and conditions for procurement and the responsibilities of all persons concerned. Check that procedures are applied.	Are there any written procedures for assuring that products are conforming with specified requirements?	10,6	N3	Procedures specific to the product are defined in a validated plan to assure conformity of the purchased product. Procurement conditions and the responsibilities of persons doing the work are not described.	21,2
49	The responsibility for examination and the decision to process the nonconforming product must be defined. Written procedures must describe processing of nonconformities. These procedures must predict that the nonconforming product can be: reworked to satisfy the specified requirements, accepted by waiver with or without repair. declassified for other applications, rejected or scrapped. If required by the contract, the proposal for use or repair of the nonconforming product may be submitted to the customer. The repaired and/or reworked product is inspected once again in accordance with the requirements in the quality plan and/or written procedures.	Has the responsibility for the examination and the decision to process the nonconforming product been defined?	13,6	N4	The nonconforming product is examined and described according to written procedures. These specify that the product may be: Reworked to satisfy specified requirements. Accepted by waiver with or without repair. Declassified for other applications. Rejected or scrapped. If required by the contract, the proposal for use or repair of the non-conforming product is submitted to the customer. The repaired and/or reworked product is once again inspected in accordance with the requirements in the quality plan and/or the written procedures.	40,8
66	Requirements for qualification of process operations including equipment and associated personnel, must be specified.	Are means concerning special processes identified?	13,1	N4	Process operation qualification requirements, including associated equipment and personnel, are specified. Documents identifying these requirements are regularly updated.	39,3
67	Special processes must be done by qualified operators and/or are continuously monitored, with control over process parameters to assure conformity with requirements.	Are human resources concerning special processes managed?	11,7	N3	Special processes are done by qualified operators, or they are continuously monitored.	23,4
70	Written inspection and test procedures have to be produced and kept up to date, to verify that specified requirements for the product are respected.	How is the product inspection and test	9,3	N4	The documentation includes the test program, the test	27,9

N°	Recommendation	Question	Weight	Answers	Description	Rating
		documentation controlled?			report, specifications for test means, and the definition of test means.	
71	Store and keep product and process documentation available in the workshop. Make a list of the documentation regularly. Periodically update the documentation. Train an entity among workshop personnel in the management of technical documentation. Have technical documentation for products. Have a documentation specific to the inspection and maintenance tests. Associate this product technical documentation with implementation processes. When documents are provided, analyse the validity of this product documentation. Be in possession of process control documentation. Specify technical documentation for each process. Provide this technical documentation and make it useable. Have a documentation specific to the inspection and tests .	Is documentation well controlled? Does it take account of all equipment changes?	12,2	N4	Documentation specific to products and processes does exist, it is updated periodically in a planned manner, the validity of the documents used is analysed. Precise procedures are applied for storage and preservation of the documentation.	36,6
73	Inspection, measurement and test equipment is used to assure that the measurement uncertainty is known and is compatible with the required measurement aptitude. Test software or comparison references used as inspection means are verified before they are put into service to demonstrate that they are capable of checking that the product is acceptable.	What steps are taken to control how inspection, measurement and test equipment is compatible with needs?	9,6	N4	Inspection, measurement and test equipment is used in such a manner that the measurement uncertainty is known and is compatible with the required measurement aptitude. Test software or comparison references used as inspection means are verified before they are put into service to demonstrate that they are capable of checking if the product is acceptable. Systematic verification before use is industrially impossible but the use of a metrological procedure (Validation period and definition of the class of equipment in the test procedure), the class is defined in advance.	28,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
74	Handling, preservation and storage of inspection and measurement equipment assures that precision and usability are maintained. Inspection, measurement and test equipment, including the test benches and test software, are protected against manipulations that would invalidate calibration settings.	How is the environment of inspection, measurement and test equipment controlled?	7,9	N3	Inspection, measurement and test equipment is protected against aggression that could damage it, it is also protected against manipulations that would invalidate calibration settings. Handling, preservation and storage of inspection equipment are not defined by strict procedures.	15,8
75	When the working environment is important for product quality, appropriate limits must be specified, controlled and verified (layout of the workshop, ergonomy of the workstation, etc).	How is the working environment controlled?	9,6	N3	Workstations are specific to equipment. The working environment is controlled and verified.	19,2
77	A clear statement of persons authorised to approve process changes must be available. These changes requiring acceptance by the customer must be identified before they are applied. Any change affecting processes, production equipment, tools and programs, must be documented and must lead to a procedure to control its application. Make sure that results of process changes produce the required effect and that the changes have not reduce the product quality.	How are changes to manufacturing processes controlled?	13,9	N4	Process changes are recorded, persons authorised to approve changes to production processes are clearly named. Changes requiring acceptance by the customer are identified before application. Any change affecting processes, production equipment, tools and programs is described in a document and a procedure must be produced to control its application. Systematic checks are carried out to assure that the results of changes to processes produce the required effect and that these changes have not modified the product quality.	41,7
78	Product handling methods and means are provided to prevent damage or deterioration to the product and include: - transport procedures, - handling methods specific to each product.	Are handling and transport methods defined?	8,8	N4	Product manipulation procedures are specifically defined, and associated means prevent any deterioration to the product during manipulations. It is	26,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
					verified that these methods are applied.	
79	Make sure that written procedures describe the following activities, for all production means, tools and programs: validation before use, maintenance, periodic inspection according to written procedures.	How are production equipment, tools and programs for numerical control machine controlled?	10,5	N3	The periodic inspection of means and tools is submitted for validation, formal procedures identify periodic inspections to be carried out.	21
80	A procedure is necessary to take account of specific requirements for the following at the different production steps, if applicable in accordance with the manufacturer's recommendations and/or applicable regulations: - cleaning, - prevention, detection and removal of foreign bodies, - handling adapted to sensitive products, - marking and labelling, including safety marking, - control of shelf life and stock rotation, - dangerous equipment Produce special management procedures for perishables. Eliminate all products that have passed their useful life and unidentified products. Suggest criteria for evaluating and analysing the quality of storage conditions. List and analyse failures related to lack of quality in storage.	How are handling, storage, packaging, preservation, and delivery controlled?	6,5	N3	Handling, storage, packaging, preservation and delivery conditions are coded, there are procedures specific to each product.	13

N°	Recommendation	Question	Weight	Answers	Description	Rating
81	Further description When special processes are used (processes for which results cannot be fully verified a posteriori by an inspection or test of the product, and for which the consequences of deficiencies in application will not appear until this product is used, for example gluing, soldering: The special processes to be implemented must be identified. The supplier verifies that all parameters of special processes (for example materials, personnel, procedures and software) produce satisfactory results. The supplier identifies and documents significant operations and process parameters to be controlled. Any modification to these operations and parameters must be described in a proposal justifying this modification and guaranteeing that it does not introduce any harmful effect on the result of the process. The supplier must verify special processes by making one or several typical parts under the conditions defined for the phase. Special processes or subcontracted processes must be qualified before use. The supplier must keep qualified special processes up to date.	How are special processes controlled?	14,4	N2	Special processes are identified. The parameters for these processes (materials, personnel, procedures and software) are evaluated. These processes are not documented, or not defined by strict procedures.	14,4
82	Further description When they have an influence on the quality and reliability of the product, services and supplies such as water, compressed air, electricity and chemicals used must be controlled and verified regularly to make sure that their effect on the process is constant.	How are services and fluids in the working environment controlled?	10,1	N3	Services and supplies such as water, compressed air, electricity and chemicals are controlled and verified periodically to make sure that their effect on the process is constant.	20,2
88	Set up self-checking to filter human errors that could reduce the reliability of the subassembly	Is a self checking system applied to filter human errors (that could reduce reliability of the subassembly)?	5,3	N2	Self-checking is done at the end of the activity. However, it is not described in any formal document .	5,3
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	18,4	N3	There are validated procedures for protection against ESD defining practices recognised as protecting the subassemblies.	36,8

N°	Recommendation	Question	Weight	Answers	Description	Rating
99	Accidental use of out-of-date consumables can have a negative influence on quality and consequently reliability, a number of suitable methods must be set up for preservation, identification and withdrawal of the products concerned if necessary. Systematically reading labels before use to identify each product used and to obtain all information about expiration, reduces risks of using a product that would reduce reliability.	Is there a label for identification and withdrawal of out-of-date consumables?	6,4	N3	Consumables are correctly identified by labelling. All information necessary for this identification is formally described in documents, but these documents have not been validated by an authority independent from the operating entity.	12,8
113	Records must be produced and kept to provide proof that the product has been subjected to inspections and/or tests in accordance with defined criteria. Records must be sufficient to identify the person who performed the inspections and released the product. Test records must indicate measured values when they are required by the specification or the acceptance plan. If specified, the supplier must demonstrate the qualification of the product.	Are records produced and kept to prove that the product has been inspected and/or tested in accordance with defined criteria? Are the records sufficient to identify the person who made the checks?	5,3	N4	Records prove that inspections and/or tests have been carried out on the product in accordance with defined criteria. The records are sufficient to identify the person who carried out the inspections and authorised release of the product. Test records indicate measured values when they are required by the specification or the acceptance plan.	15,9
114	The inspection file must contain: criteria for acceptance and refusal, a sequential list of inspection and test operations to be done, inspection result record documents, a list of specific and non-specific inspection instruments, the documents associated with specific inspection instruments for their design, production, validation, management, use and maintenance .	Is there an inspection file containing acceptance criteria, the sequential list of inspection and test operations, inspection result record documents, list of specific and non-specific inspection instruments?	5,7	N4	The inspection file contains: the definition of acceptance or refusal criteria, the sequential list of inspection and test operations to be carried out, Inspection result record documents, the list of specific and non-specific inspection instruments, and documents associated with specific inspection instruments for their design, production, validation, management, use, and maintenance.	17,1

N°	Recommendation	Question	Weight	Answers	Description	Rating
116	Nonconformity documents must specify: the product identification, the description of the nonconformity, the cause of the nonconformity, actions taken to prevent recurrence of the nonconformity, reworking or repairs if necessary, check of characteristics affected by the reworking or repairs, the final decision.	Is there any documentation specific to the nonconformity?	11,1	N4	Nonconformity documents specify the product identification, the description of the nonconformity and the cause of the nonconformity. Actions are formalised to prevent recurrence of the nonconformity, reworking or repairs if necessary and checking of characteristics affected by the reworking or repairs.	33,3
136	Make sure that the person who will perform the task knows the procedure for implementing the means at a production workstation.	Is it checked that the procedure for implementing the means is known?	5,1	N3	There is a procedure explicitly describing implementation of production means at the workstation. This is formalised in a manner that obliges the operator to be familiar with it before implementing the means (visual warning when starting up the means, etc).	10,2
138	Make sure that the right software is loaded and more particularly that it is the most recent version to be used in the subassembly. This identification information must also be traced in the remainder of the process.	Is it checked that the right software is loaded, and that its version is identified?	6,7	N3	Every time that software is loaded, the operator is informed of the software version to be used. An identifier of the version to be used is provided after the operation.	13,4
153	Use measurements for verification of purchased products such as: examination of the required documentation, inspection and audit at the purchase source, examination of products on delivery.	Is the conformity of purchased products checked?	8,6	N3	Conformity of purchased products is verified by examination of products on delivery and by examination of the required documentation.	17,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
	Operation and maintenance					
7	Procedures related to corrective actions include: - Effective processing of customer complaints and product nonconformity reports, - The search for the causes of nonconformity related to the product, the process and the quality system, and recording the results of this search, - Determining corrective actions necessary to eliminate the causes of nonconformity, - Application of all means to measure the effectiveness of the corrective action.	What process is used to collect technical events, to produce anomaly reports and measure increases in reliability? How are equipment changes managed?	17,5	N3	Procedures related to corrective actions include at least: Effective processing of customer complaints and nonconformity reports on the product, The search for causes of nonconformity related to the product, the process and the quality system and recording the results of this search, Determination of corrective actions necessary to eliminate the causes of the nonconformity, These procedures do not define the application of control means to assure that the corrective action is implemented and that it produces the expected effect.	35
8	Procedures related to preventive actions include: - The use of appropriate information sources such a processes and operations affecting the product quality, waivers, audit results, quality records, maintenance reports and customer complaints, so as to detect, analyse and eliminate the potential causes of nonconformities, - Determination of appropriate steps to deal with any problem requiring preventive action, - Triggering of preventive actions and the application of control means to make sure that they produce the expected effect, - Assurance that relative information about actions implemented is submitted to the management review.	Do procedures related to preventive actions include: - The use of appropriate information sources? - Determination of appropriate steps? - Triggering of preventive actions and application of control means? - A management review of corrective actions?	17,7	N3	Procedures for preventive actions do exist and are almost complete with regard to the mentioned criteria (there are possible minor nonconformities in the application or satisfaction of criteria)	35,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
9	When traceability is required, the system implemented must make it possible of: - maintaining the product identification throughout the life cycle, - knowing the history (definition file + changes) and the final use (deliveries, scrap) of all products manufactured from the same batch of raw material or from the same manufacturing batch, - finding the identity of elements making up an assembly and the higher assembly, - finding the sequential documentation on production (manufacturing, assembly, inspection) of a given product (e.g. configuration follower sheet including recording of actual operations and observed anomalies). The traceability system must be capable of determining the product configuration ready for delivery, including variations between the real state and the agreed state.	How is product traceability achieved?	9,2	N3	Traceability is used to identify and know the product history (Definition file + changes), However it is not sufficient to know the documentation associated with its life cycle (e.g. no configuration follower sheet containing records of operations carried out and anomalies observed).	18,4
10	Wrapping, packaging and marking processes must be controlled to assure conformity with specified requirements. Define a list of equipment for which packaging is necessary. Suggest a method of managing special packaging by product (dates, modes, duration). Periodically check the quality of packaging. Use appropriate packaging specific to the products.	Does the supplier control wrapping, packaging and marking processes to assure conformity with the specified requirements? Is there a list of equipment requiring packaging?	13,8	N4	Special product packaging is provided, and documentation is associated with it. A specific regular inspection of the packaging is made A procedure regularly checks that periodic inspections are applied.	41,4
11	Designated storage areas or premises must be used to prevent damage or deterioration of the product. Appropriate measures are taken to allow reception in these areas and shipment from them. The state of the product in stock must be evaluated at appropriate intervals to detect any deterioration. Manage and control atmospheres in storage. Tailor positioning in storage. Manage periodic actions to maintain product characteristics in storage (powering on).	Are there any designated storage areas or premises? Are they used to prevent damage or deterioration of the product? Are appropriate measures taken to enable reception and shipping in these areas?	15,6	N2	Product storage areas are not specific, the storage environment is controlled and adapted to the stored products.	15,6
13	During the phase, the product must be inspected and tests must be carried out in accordance with the quality plan and/or written procedures. The product must remain blocked until the required inspections and tests are terminated, or until the necessary reports have been received and verified.	Is there any risk that a product that has not satisfied inspections and tests specified during one phase will go on to the next phase without corrective action?	11,2	N4	Inspections are carried out during the phase and are formalised in the form of written procedures or a quality plan. These inspections and tests are complete.	33,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
14	Perform all final inspections and tests in accordance with the quality plan and/or written procedures. The quality plan and/or procedures for final inspections and tests must require that all specified inspections and tests, including those defined for product reception, are carried out and that the results are conforming with requirements. Before shipment, make sure that: All activities specified in the quality plan and/or written procedures have been satisfactory accomplished, The associated data and documentation are available and accepted.	Have all final inspections and tests been carried out in accordance with the quality plan and/or written procedures?	10,4	N4	Final inspections and tests are carried out in accordance with the quality plan and/or written procedures. The quality plan and/or procedures for final inspections and tests require that all specified inspections and tests, including those specified for product reception or during its manufacturing, are done and that the results are conforming with the requirements. It is checked before shipment that: All activities specified in the quality plan and/or in written procedures have been satisfactorily accomplished Data and the associated documentation are available (follower sheet type document that records the configuration, operations carried out and observed anomalies) and accepted.	31,2
20	A policy is applied aimed at identifying, evaluating and managing potential risks associated with nonconformities, non only on products but also on all design, planning, manufacturing, assembly, inspection processes, etc. This policy must take account of potential risks associated with human factors.	Is a policy applied aimed at identifying, evaluating and managing potential risks associated with nonconformities, on products and also on all design, planning, manufacturing, assembly and inspection processes, etc?	16,3	N3	There is a policy aimed at identifying, evaluating and managing potential risks associated with nonconformities, not only on products but also on all design, planning, manufacturing, assembly, inspection processes, etc. This policy does not take account of potential risks associated with human factors.	32,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
30	The description of the accepted nonconformity or repairs made is recorded to indicate the real condition of the product. Written procedures are kept up to date defining at least: The process for classification of nonconformities and control over the use of nonconforming components in finished products, The formal authorisation process and the application field for personnel authorising the use of replacement materials and/or nonconforming products (waiver procedures), The process for control of scrapped parts.	Is the description of the accepted nonconformity or of the repairs performed recorded to indicate the product's real condition?	12,8	N4	The description of the accepted nonconformity or the repairs made is recorded to indicate the real condition of the product. Written procedures are kept up to date defining: The process for classification of nonconformities and control over the use of nonconforming components in finished products. The formal process for authorisation and the application field for personnel authorising the use of replacement materials and/or nonconforming products. The process for control over scrapped parts.	38,4
32	Product inspection and test procedures must specify resources (men, means), methods to be implemented, acceptance criteria and methods of recording the results. These procedures must also define the training and if necessary require operators' qualification.	Are means necessary for inspections and tests of the product defined?	14,3	N3	Product inspection or test procedures are specified. Acceptance methods and criteria are described. Results are not recorded and used for feedback from operations. Procedures also describe training and qualification of operators.	28,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
35	Purchasing documents must include the following when applicable: The type, category and any other precise identification, the title or any other formal identification and the applicable edition of specifications, drawings, requirements for processes, inspection Instructions and other relevant technical data, the title, identifier, and edition of the quality system standard to be applied, purchasing document reviewed and approved before distribution to assure that they are capable of satisfying the requirements. Documented procurement requirements must include the following when applicable: Tests, examinations, inspections and acceptance conditions imposed by the customer, and any relevant instructions or requirements, requirements related to specimens (production method, number, storage conditions) for inspections, investigations or audits, requirements related to notification of anomalies, changes to the definition and approval of their processing. Suppliers must be notified about customer requirements.	Are there any documents for performing incoming inspection on supplies?	9,9	N3	Purchasing documents include a precise identification, the applicable edition of specifications, drawings, requirements in terms of process, inspection instructions and other relevant technical data, the title, identifier and edition of the quality system standard to be applied, purchasing documents reviewed and approved before distribution, to assure that they satisfy the requirements.	19,8
47	Produce written procedures to assure that the purchased product is conforming with the specified requirements. Define the terms and conditions for procurement and the responsibilities of all persons concerned. Check that procedures are applied.	Are there any written procedures for assuring that products are conforming with specified requirements?	6,8	N3	Procedures specific to the product are defined in a validated plan to assure conformity of the purchased product. Procurement conditions and the responsibilities of persons doing the work are not described.	13,6
63	Records concerning processes, products and personnel are kept up to date.	Is there any documentation for special processes? Is this documentation kept up to date?	12,2	N3	Records are provided for processes, products and personnel associated with special processes, but these procedures are not updated.	24,4
66	Requirements for qualification of process operations including equipment and associated personnel, must be specified.	Are means concerning special processes identified?	13,1	N3	Process operation qualification requirements, including associated equipment and personnel, are specified.	26,2
67	Special processes must be done by qualified operators and/or are continuously monitored, with control over process parameters to assure conformity with requirements.	Are human resources concerning special processes managed?	13,7	N3	Special processes are done by qualified operators, or they are continuously monitored.	27,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
71	Store and keep product and process documentation available in the workshop. Make a list of the documentation regularly. Periodically update the documentation. Train an entity among workshop personnel in the management of technical documentation. Have technical documentation for products. Have a documentation specific to the inspection and maintenance tests. Associate this product technical documentation with implementation processes. When documents are provided, analyse the validity of this product documentation. Be in possession of process control documentation. Specify technical documentation for each process. Provide this technical documentation and make it useable. Have a documentation specific to the inspection and tests .	Is documentation well controlled? Does it take account of all equipment changes?	5,6	N3	Documentation specific to products and processes does exist, it is updated periodically in a planned manner, the validity of the documents used is not analysed.	11,2
72	Control the capability of products to detect failures, control failure detection means, facilitate maintenance.	How are product testability and maintainability controlled?	17,6	N4	Application of built-in tests (PBIT, CBIT, IBIT) and testability complements by one (or several) external test means.	52,8
73	Inspection, measurement and test equipment is used to assure that the measurement uncertainty is known and is compatible with the required measurement aptitude. Test software or comparison references used as inspection means are verified before they are put into service to demonstrate that they are capable of checking that the product is acceptable.	What steps are taken to control how inspection, measurement and test equipment is compatible with needs?	11,3	N3	Inspection, measurement and test equipment is used in such a manner that the measurement uncertainty is known and is compatible with the required measurement aptitude. There is no verification of inspection equipment before it is put into service.	22,6
74	Handling, preservation and storage of inspection and measurement equipment assures that precision and usability are maintained. Inspection, measurement and test equipment, including the test benches and test software, are protected against manipulations that would invalidate calibration settings.	How is the environment of inspection, measurement and test equipment controlled?	11,7	N3	Inspection, measurement and test equipment is protected against aggression that could damage it, it is also protected against manipulations that would invalidate calibration settings. Handling, preservation and storage of inspection equipment are not defined by strict procedures.	23,4

N°	Recommendation	Question	Weight	Answers	Description	Rating
75	When the working environment is important for product quality, appropriate limits must be specified, controlled and verified (layout of the workshop, ergonomy of the workstation, etc).	How is the working environment controlled?	10,8	N3	Workstations are specific to equipment. The working environment is controlled and verified.	21,6
77	A clear statement of persons authorised to approve process changes must be available. These changes requiring acceptance by the customer must be identified before they are applied. Any change affecting processes, production equipment, tools and programs, must be documented and must lead to a procedure to control its application. Make sure that results of process changes produce the required effect and that the changes have not reduce the product quality.	How are changes to manufacturing processes controlled?	13,9	N3	Process changes are recorded, persons authorised to approve changes to production processes are clearly named. Changes requiring acceptance by the customer are identified before application. Any change affecting processes, production equipment, tools and programs is described in a document and a procedure must be produced to control its application. However, there is no systematic check that the results of changes to processes produce the required effect and that these changes have not modified the product quality.	27,8
78	Product handling methods and means are provided to prevent damage or deterioration to the product and include: - transport procedures, - handling methods specific to each product.	Are handling and transport methods defined?	9,9	N3	Handling methods specific to the product are written down, specific means are provided to prevent any deterioration during manipulations. There is no verification about their application.	19,8
79	Make sure that written procedures describe the following activities, for all production means, tools and programs: validation before use, maintenance, periodic inspection according to written procedures.	How are production equipment, tools and programs for numerical control machine controlled?	11,3	N3	The periodic inspection of means and tools is submitted for validation, formal procedures identify periodic inspections to be carried out.	22,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
80	A procedure is necessary to take account of specific requirements for the following at the different production steps, if applicable in accordance with the manufacturer's recommendations and/or applicable regulations: - cleaning, - prevention, detection and removal of foreign bodies, - handling adapted to sensitive products, - marking and labelling, including safety marking, - control of shelf life and stock rotation, - dangerous equipment Produce special management procedures for perishables. Eliminate all products that have passed their useful life and unidentified products. Suggest criteria for evaluating and analysing the quality of storage conditions. List and analyse failures related to lack of quality in storage.	How are handling, storage, packaging, preservation, and delivery controlled?	11,3	N3	Handling, storage, packaging, preservation and delivery conditions are coded, there are procedures specific to each product.	22,6
81	Further description When special processes are used (processes for which results cannot be fully verified a posteriori by an inspection or test of the product, and for which the consequences of deficiencies in application will not appear until this product is used, for example gluing, soldering: The special processes to be implemented must be identified. The supplier verifies that all parameters of special processes (for example materials, personnel, procedures and software) produce satisfactory results. The supplier identifies and documents significant operations and process parameters to be controlled. Any modification to these operations and parameters must be described in a proposal justifying this modification and guaranteeing that it does not introduce any harmful effect on the result of the process. The supplier must verify special processes by making one or several typical parts under the conditions defined for the phase. Special processes or subcontracted processes must be qualified before use. The supplier must keep qualified special processes up to date.	How are special processes controlled?	15,2	N2	Special processes are identified. The parameters for these processes (materials, personnel, procedures and software) are evaluated. These processes are not documented, or not defined by strict procedures.	15,2

N°	Recommendation	Question	Weight	Answers	Description	Rating
82	Further description When they have an influence on the quality and reliability of the product, services and supplies such as water, compressed air, electricity and chemicals used must be controlled and verified regularly to make sure that their effect on the process is constant.	How are services and fluids in the working environment controlled?	12,2	N3	Services and supplies such as water, compressed air, electricity and chemicals are controlled and verified periodically to make sure that their effect on the process is constant.	24,4
91	Set up protections against ESD for subassemblies during manipulations and storage.	Have you set up specific protections against ESD for subassemblies during manipulations and storage?	17,4	N3	There are validated procedures for protection against ESD defining practices recognised as protecting the subassemblies.	34,8
114	The inspection file must contain: criteria for acceptance and refusal, a sequential list of inspection and test operations to be done, inspection result record documents, a list of specific and non-specific inspection instruments, the documents associated with specific inspection instruments for their design, production, validation, management, use and maintenance .	Is there an inspection file containing acceptance criteria, the sequential list of inspection and test operations, inspection result record documents, list of specific and non-specific inspection instruments?	5,7	N3	The inspection file defines acceptance or refusal criteria, and the list of operations to be done. It proposes inspection result record documents.	11,4
116	Nonconformity documents must specify: the product identification, the description of the nonconformity, the cause of the nonconformity, actions taken to prevent recurrence of the nonconformity, reworking or repairs if necessary, check of characteristics affected by the reworking or repairs, the final decision.	Is there any documentation specific to the nonconformity?	11,1	N4	Nonconformity documents specify the product identification, the description of the nonconformity and the cause of the nonconformity. Actions are formalised to prevent recurrence of the nonconformity, reworking or repairs if necessary and checking of characteristics affected by the reworking or repairs.	33,3
	Support activities					
umé	Recommendation	Question	Weight	Answers	Description	Rating

N°	Recommendation	Question	Weight	Answers	Description	Rating
3	Allocate the infrastructures necessary for production and integration operations to obtain the reliability level predicted by reliability studies during the product design (no degradation of reliability during these phases). Perform the Process FMECA. Examples: supply appropriate power networks, clean rooms, ergonomic buildings, application of 5S methods. The improvement in the environment may consist of: Increasing the surface areas (easier manipulations), Improving lighting, Reducing operator fatigue, Imposing storage and cleanliness standards, Improving the quality of tools, Making personnel aware about reliability.	Have the conclusions of reliability studies in terms of necessary infrastructures for production and integration been taken into account?	7,4	N3	Workshops are provided with structures to provide protection against risks of damage to equipment caused by unsuitable infrastructures (for example electrostatic discharges), personnel have been trained in their use.	14,8
4	Set up Reliability engineering indicators. Fix objectives to improve the company's Reliability engineering; Audit the company's Reliability engineering (get the reliability specialists to attend further training, make presentations in reliability conferences).	Are there any objectives to improve reliability engineering in the company? Are there any indicators about the current position relative to these objectives?	6,6	N3	Some indicators have been set up (maintenance of performances, performances of prediction methods), the company's baseline includes documents related to Reliability engineering. Directives are regularly updated.	13,2
24	Collect information about product reliability in its operational environment from customers and users of the product, and carry out associated action plans.	Are customer comments about product reliability collected during operational functioning?	7,9	N3	Customer satisfaction inquiries have been carried out dealing with the reliability aspect.	15,8
27	Fix objectives for improving the company's reliability engineering annually.	Are there any objectives to improve the process to construct product reliability?	6,3	N3	The reliability construction process is described, progress actions are defined informally.	12,6
45	Certify the company quality system according to ISO 9001 V2000	The company has one or several quality certifications, for example ISO 9001 Version 2000	6,5	N3	The manufacturer has set up a quality system and has obtained a certification. For example ISO 9000 V2000.	13
55	The Operating Dependability (Reliability) business participates in all phases of the project, from phases before the development and until series production. The Functional Dependability business is also involved in production and operational monitoring	Does the Operating Dependability business participate in all phases of the project?	8,8	N3	Persons responsible for reliability engineering participate fully (complete service according to the meaning in the recommendation) in the project, but this participation is not	17,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
					formalised in a plan or procedure.	
56	Train personnel concerned with reliability, with training varying from awareness to expert refresher courses for reliability managers, depending on the criticality of reliability performances expected for the product. Make production personnel aware about non-degradation of products.	Is training of persons working on reliability appropriate for the criticality of reliability performances expected for the product?	7,5	N3	Awareness actions have been carried out for company personnel concerned by reliability (e.g. production personnel informed about non-degradation of products). Persons responsible for reliability studies have received training and are experienced.	15
58	Allocate the necessary resources (hardware means, access to technical data, and time necessary to perform reliability studies).	Are technical data necessary for reliability studies accessible? Are the necessary tools available? Have the necessary time and financing been allowed for?	8,3	N3	Means (human and equipment) are satisfactorily allocated to reliability activities.	16,6
59	Control of documentation related to reliability studies: recording, saving, archiving, validation, management of documents in configuration.	Are reliability study documents managed?	5,4	N3	Assumptions related to predicted calculations are specified in documents. Documentation related to reliability studies is controlled but not systematically: (Recording, saving, archiving, validation, management of documents in configuration not done systematically.	10,8
68	Before signing the contract (with the subcontractor) identify risks associated with the reliability of the subcontracted product.	Have risks related to reliability of products at subcontractors been identified?	7,2	N3	The reliability risk analysis was made before the contract was signed and is described in a formal document. These risks are not managed.	14,4
69	Integrate the Reliability theme in the company quality policy and breakdown this policy at levels concerned by reliability engineering.	Is the reliability theme present in the company quality policy?	7,4	N4	Reliability is one of the major objectives of the quality policy.	22,2
76	Control monitoring and measurement devices, the metrology of measurement instruments and industrial means. Control the verification, calibration and rating of measurement instruments and test and trial benches used by the company. APMs are tied to national standards.	What procedure is there to control monitoring and measurement devices, the metrology of measurement	7,8	N3	There is a verification, calibration and rating procedure for measurement instruments and test and trial benches in the	15,6

N°	Recommendation	Question	Weight	Answers	Description	Rating
		instruments and industrial means?			company, and it is applied.	
85	Make operational reliability measurements of products in operation (monitoring of technical events, analysis of causes of failure, allocation of the origin of failures, recording the real product usage profile, reliability evaluation, analysis of these measurements and take account of the result for studies on new products).	Are product reliability measurements actually made in operation?	8	N3	Feedback from operations for evaluation of reliability data, analysis of causes of failure, allocation of the cause of failures, record of the real product usage profile. Role to observe feedback from operations, not used to quantify the reliability of new projects.	16
104	Appoint a person responsible for reliability for each project, who will guarantee that product reliability objectives are achieved. This person shall report on progress with studies and problems encountered.	Has a person responsible for reliability studies been appointed?	8,5	N4	A reliability study manager has been named and integrated into the project, he is trained and has the required experience in the field. He makes regular reports on progress with studies in meetings or in reports.	25,5
105	Organise periodic meetings with the subcontractor, in which the reliability of subcontracted products will be systematically discussed.	Are periodic reliability meetings organised with the subcontractor?	5,7	N3	Periodic meetings with the customer are defined in project plans, in which reliability aspects are dealt with. These are held sporadically.	11,4
108	Include information about system engineering tasks in the various project plannings.	Are tasks related to reliability taken into account in project plannings?	6,3	N4	Reliability tasks are described and there is a planning for them tied to other company plannings	18,9

N°	Recommendation	Question	Weight	Answers	Description	Rating
109	Include mechanisms for "communication on reliability aspects" with the subcontractor in the project management plan, and mentioning the frequency and nature of meetings, permanent agenda, content of minutes, reliability aspects of communications.	Are tasks related to reliability taken into account in project plannings?	4,1	N4	Requirements for the communication with the subcontractor dealing with reliability aspects are described in a project management plan, and are applied (proofs of this application).	12,3
110	Plan activities related to reliability improvement in the reliability plan. Describe fundamental activities related to reliability improvement in plans and perform them completely, with records of these actions.	Are reliability activities including reliability improvement organised?	9,1	N4	Fundamental activities related to reliability improvement are described in plans and are done completely and records of these actions are produced	27,3
111	Plan reliability studies to guarantee that product reliability objectives are achieved and to synchronise reliability studies and product design.	Are reliability studies planned?	7,3	N3	Reliability studies appear on the project planning.	14,6
118	Maintain the product reliability in production: Analyse potential degradations that could occur during production and integration operations during the design phase (example Process FMECA).	Are measures taken to maintain the product reliability in production?	8,1	N4	A Process FMECA is done systematically to evaluate and reduce risks of degrading the reliability of new products or product ranges.	24,3
119	Consult customers regularly on operational reliability aspects and take their comments into account for the design of new products.	Are there periodic consultations planned with customers related to reliability aspects?	7,3	N4	The company regularly consults its customers about the reliability of its products (formal interviews or investigations by questionnaires). These feedbacks are used and are the subject of action plans, the results of which are distributed to the customer. The effectiveness of this process may be demonstrated by the customer's satisfaction.	21,9
142	Select the components used, analyse the market, evaluate component reliability.	Are reliability criteria considered when selecting the components used?	12,9	N4	The company baseline requires that components should be selected based on the reliability (and/or manufacturing quality) criterion. This is effective and is based on detailed analyses (use of manufacturer data, manufacturer audits, evaluation of the technologies used).	38,7

N°	Recommendation	Question	Weight	Answers	Description	Rating
143	Select component suppliers, analyse the market. Evaluate how component reliability is taken into account.	Select component suppliers, analyse the market. Evaluate how component reliability is taken into account.	10,8	N3	The company baseline requires that component suppliers should be selected based on the reliability (and or manufacturing quality) criterion. This is effective and is based on an analysis of data provided by suppliers.	21,6
146	Monitor and control (plan, record) corrective actions done by the subcontractor related to product reliability.	Are corrective actions done by the subcontractor related to reliability monitored	7,2	N3	A system has been set up for periodic monitoring of corrective actions that the subcontractor has been asked to take, but it is not completely or satisfactorily controlled.	14,4
148	Deal with the theme of reliability in the agenda of management reviews (progress objective, action plan, measurement of the extent to which objectives are achieved, and reliability assessment of products at customers).	Is the reliability aspect dealt with in management reviews?	5,6	N3	The reliability of products is systematically dealt with during Management Reviews.	11,2
149	Set up an anomaly processing system that can cover the entire FIDES life cycle. This system is intended to: - record the circumstances of the anomaly, - record references of the defective product, - propose remedial action, - analyse the causes of the anomaly, - propose corrective/preventive actions, - check the efficiency of the corrective/preventive actions. Processing in this system is suitable for: - quickly finding identical anomalies observed previously, - producing statistics, - use as feedback from operations.	What process is set up to collect technical events, produce anomaly reports and measure improved reliability? How are hardware upgrades managed?	8,3	N3	The manufacturer has set up a system for processing anomalies, that partially satisfies the requirements of the recommendation. It is fully applied to the project.	16,6
151	Use statistical methods adapted to the use of feedback from operations.	Are statistical methods adapted to the use of feedback from operations?	6	N4	Feedback from operations is recorded, it is processed using relevant statistical methods and it is distributed to users.	18
152	Validate that the subcontractor has actually taken contract reliability requirements into account and that his project baseline takes them into account.	Has the reliability management baseline of the subcontractor been validated?	7,7	N4	The subcontractor has produced a reliability management reference document (management plan or reliability plan), that repeats the original requirements of the prime contractor. The	23,1

N°	Recommendation	Question	Weight	Answers	Description	Rating
					manufacturer validates that this baseline is applied (progress meeting, audit, etc.).	

Pi Process result =	**1,974**