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ArtEmis

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Awareness and resilience through European multi sensor system

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Requirement Specifications of the Sensors

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Disclaimer

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Abstract

This document describes the requirements specification for the sensor units of artEmis. It includes the essential sensor parameters, mechanical dimensions and deployment details. The core of the unit will be a low-cost gamma detector, but various ancillary sensors, like a temperature sensor, may be added as needed. Within a few months up to six early demonstrators shall be realized for testing purposes. Thereafter, an advanced demonstrator with 30 units will be provided. As soon as the complimentary alpha sensor is developed it will be included and series production of 100+ units will follow.

The sensor unit will be designed such that sensors can be configured to the measurement needs of particular sites. This flexibility assures stepwise improvements, and also cost efficiency. Another important requirement is autonomous operation, requiring features like self-calibration and identification and recovery from failure states.

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1 Introduction

This document specifies the requirements for the sensor units of the artEmis project, to be developed and realized in WP1. The sensor system shall comprise of a network of low-cost radiation sensors preferentially deployed in ground-water sites. The primary goal of the sensors is the detection of the characteristic gamma and/or alpha radiation following the decay of radon (Rn) in water, respectively the location-dependent variation of the Rn activity within the network. As much as reasonably possible other parameters like temperature and hydrologic head (pressure) should be measurable with the same sensor device.

The core of the sensor device will be a scintillation detector, e.g. a CsI(Tl) crystal of adequate total volume and shape to efficiently detect gamma radiation. The same or another scintillator will be used to detect alpha radiation. The scintillation light will be read out in any case by silicon photomultipliers (SiPMs). Highly-integrated signal forming and processing electronics will be arranged at the detector units. Adequate computing power will be made available on-board of the detector unit as well as bias generators, environmental controls like temperature sensors, and appropriate communication channels. Here, the projects relies on the latest electronics and data acquisition (EDAQ) developments available from large nuclear physics experiments. Relying on the experience of the groups involved, the mechanical structure of the sensor-unit will be optimized for underwater operation in the wanted depth range.

Gamma energy spectra and other sensor's information will be collected and transmitted in suitable intervals, e.g. every ten minutes for further analysis employing control units coupled to a network. These units and the network are being developed and realized within WP3.

The device must be able to operate autonomously without human supervision. Introducing machine-learning concepts will allow for innovative, autonomous, unsupervised operation, calibration and control of the detection system, constituting a smart radiation detector.

The artEmis project relies on the availability of a few sensor units at the earliest possible time, but with limited sensor capabilities. Therefore, it was agreed to produce 5-6 sensor units (early demonstrator) from available components within the first six months of the project. After 12 months, an advanced demonstrator should be available with additional features and improvements derived from the early operations. Finally, after 24 months the full demonstrator with 100+ units shall be available for deployment. As it is assumed that the development of a proper alpha detector requires long development time, it will be only available at that stage.

2 Requirement Specifications

Table 1 shows the specifications of the cost optimized standard sensor units. Additional sensors with enhanced parameters can be built as needed. However, in most cases, they will be considerably more expensive, and extra development time may be needed.

Table 1: Requirement specifications

parameter	value	comment
Sensor parameters		
Rn measurement intervals	3600 s	shorter time reduces detection limit
Rn detection limit	1 Bq/l	lower limit requires longer measurement time or larger detector
temperature measurement intervals	30 s	
temperature measurement accuracy	0.1 °C	
water pressure measurement intervals	1 s	
water pressure measurement accuracy	1 kPa	
water acidity (pH) measurement intervals	30 s	
conductivity	5µS/cm	
Mechanical dimensions		
max. sensor diameter	5 cm	
max. sensor length	10 cm	
max. weight	0.5 kg	
Deployment details		
max. water depth	2 m	larger depth requires thicker housing, reducing the 222Rn detection limit
min. well diameter	sensor diameter + 20 cm	the larger the water volume around the sensor the higher is the sensitivity
min. water temperature	0 °C	
max. water temperature	45 °C	higher temperatures require active cooling of the Rn detector
aggressive water		special coating of the housing or more expensive housing material
bacteria/algae		special coating of the housing or more expensive housing material
data storage time	1 day	only for failure recovery, control unit provides logging
data transfer		standard serial data bus to the control unit
power supply		by cable from the control unit

2.1 Data acquisition and processing

The backbone of the sensor units will be based on a FPGA and a CPU (could be embedded in the FPGA) with ToT for the scintillator signal digitization feeding into the FPGA and I2C data bus for other sensors. The data protocol for the communication with the control unit is to be agreed with WP3.

The sensor units are supposed to operate autonomously. Therefore, a unit must be able to

• calibrate itself automatically,

• self-control its operation modes,

• monitor its functioning,

• identify and recover from failure states,

• set off regular status messages and alarm messages in case of abnormal events or malfunction.

The algorithms for that purpose will run on the CPU. If appropriate AI and ML concepts might be included.

2.2 Mechanical layout

As the characteristic gamma lines to be measured for the 222Rn detection have a lower limit of 50 keV, the sensor unit housing needs to be made from light materials like plastic or coated aluminium. Mechanical stability for depth up to 2 m is essential as well as water tight connection of the power and data cable.

For alpha detection the Rn dissolved in the water needs first to be extracted. This requires a complex pumping system which is suggested to be located outside the water reservoir to be maintainable.

3 Time line

Table 2 shows the timeline for the planned availability of the various units.

Table 2: Timeline

Version	Date of availability	Quantity of units	Comment
Early demonstrator	M6	6	Basic set-up with gamma detector and limited additional sensors to be defined
Advanced demonstrator	M12	30	Set-up with all sensors but no alpha detection
Series device	M24	100+	All sensors including alpha detection
Special devices	On demand	As requested	To be discussed