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D5.5 — PathoDRONE Water sampling mechanism

WP5 — Situation Awareness

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LEAD BENEFICIARY	KIOS CoE		
RESPONSIBLE AUTHOR	Odysseas Oikonomides		
CONTRIBUTIONS FROM	Andreas Odysseas Oikonomides, Stylianos Exadaktylos, Panayiotis Kolios, Demetris Eliades (UCY), Panagiotis Rousseas (NTUA)		
ABSTRACT	The goal of D5.5 is to design and create a water sampling mechanism that advances the state-of-the-art and can be attached to a UAV to facilitate and automate the water sampling mechanism process. A demonstration video is provided at the following link: https://www.youtube.com/watch?v=tk95oLc1nlU		

Document History

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ABBREVIATIONS/ACRONYMS

UCY	University of Cyprus
FR	First Responders
UAV	Unmanned Aerial Vehicle
PCB	Printed Circuit Board
SSR	Solid State Relay

Executive summary

Drone technology can effortlessly be employed for autonomous collection of water samples from aquatic environments to expedite the process and reduce the associated health and safety risk. Towards this direction, this deliverable details the PathoDRONE Water sampling mechanism and specifically the design, manufacturing and testing of the apparatus for efficient water sampling. A demonstration of the drone flight and the use of the PathoDRONE water sampling mechanism is provided in the following video: https://www.youtube.com/watch?v=tk95oLc1nlU

1. Introduction

Although technological advancements in the past decade have enabled the design and creation of smarter and more efficient devices, the field of water sampling has not seen any significant improvements that facilitate and improve the process. This deliverable, D5.5 PathoDRONE Water sampling mechanism, works toward advancing the water sampling mechanisms state-of-the-art, and designing and creating a device that can be attached to a UAV to automate the process. Special caution is given to the employed water sampling mechanism process, and materials, since they play a vital role in mitigating errors imparted during the analysis of the results. “Sampling is so important that, in some cases, it represents the main contribution to the error of the whole analytical process, especially when trace contamination is being measured” [1].

Over the last decade, the technology of UAVs has advanced rapidly, making applications that were not feasible before possible. The main limiting factors to the usage of UAVs in water sampling in the past were (i) payload weight, (ii) flight time. With the advancement of UAV technology, several attempts were made to take water samples using a UAV. The first publication of such research was Ore et al. (2013). Since then, key limitations of all UAV trials include [3]:

(i) the small volume of water sample (the max reported volume is 330ml)
(ii) low success rate (60%-83%)
(iii) inconsistencies in water chemical parameters of drone-assisted and traditional water sampling methods

Most attempts for UAV water sampling use a custom-designed UAV in order to make their trials. Consideration should be given to the use of larger off-the-shelf UAVs, which could be extended to undertake water sampling missions. Examples include the MATRICE 300 RTK (930g payload weight [4]), and the DJI Agras T30 (30Kg payload weight [5]).

In PathoCERT, a custom water sampling mechanism has been developed, to support first responders and water authorities in collecting water samples for surface waters, to be analyzed for pathogens using a relevant technology, such as PathoTESTICK.

This report is structured as follows: Section 3 presents the requirements analysis, Section 4 summarizes the key design and development characteristics, and Section 5 presents results from the field testing.

2. Requirements Collection

Following several meetings with various EU water sampling specialists that were both partners in the PathoCERT consortium and other collaborators, insights were collected on the currently implemented methods, along with minimum requirements, and possible recommendations/ good-to-have solutions. Specifically:

- Requirements:
    - Sampling from a specific water depth
    - Minimum water amount collection
    - No alteration/contamination of the sample(s)
    - Acquisition of multiple samples

- Recommendations:
    - Easy attachment and detachment of the water sampling mechanism to the UAV

3. Design and Development

3.1 Concept Design

Taking into account the state-of-the-art, the water sampling requirements, and the fact that the proposed mechanism is intended to be attached to a UAV, two different concept prototypes were designed with the following features:

1. The acquisition of multiple water samples
2. Ensuring no contamination/alteration of the water sample(s)
3. Sampling at a specific depth
4. Lightweightness of the mechanism
5. Low power consumption
6. Ease of usability

Figure 1 – 3D Design of two concept water sampling mechanisms. Left: A. Right: B.

Both designs (Figure 1) use standard chemistry tubes, employed to save/store the water sample(s). Design A is initially submerged into the water and a solenoid valve is subsequently opened in order to let water flow into the tube, whereas design B uses mini water pumps to suck water into the tube. Out of the two concept prototypes, design A was selected because of its simplicity, versus design B.

A single mechanism consists of (Figure 2):

1. A standard chemistry glass tube. This part was selected owing to:
    a. It is an industry standard that can be easily/readily sourced in various sizes
    b. The tube material (glass) does not affect/contaminate/ (react with) the samples
2. A custom, soft rubber 3D-printed cap. The cap has two holes on top so that the plastic tube and the electric solenoid's cylinder can pass through
3. An electronic solenoid that can open/close the rubber cap's hole on demand
4. A standard flexible plastic tube

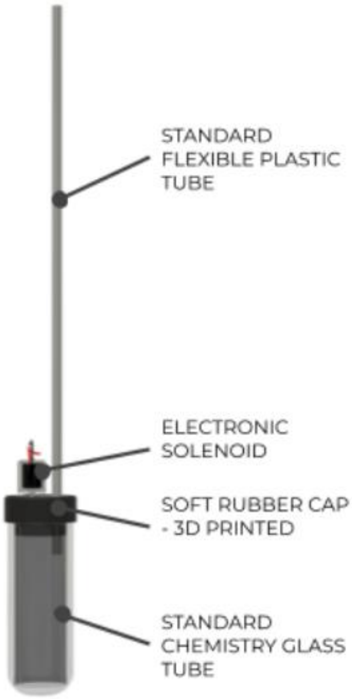

Figure 2 - Single water mechanism parts

The mechanism works as follows:

The whole mechanism is mounted on the underside of a UAV. During the sampling process, the UAV descends and submerges the whole mechanism up to the desired sampling depth. A key part of this design is that the plastic tube's end should be long enough to not be submerged. When the mechanism reaches the desired water depth, the UAV will stabilize itself to the specific altitude and the electronic solenoid will be activated to pull the cylinder and reveal the hole on the rubber cap. The water will flow through the hole, without creating positive pressure inside the tube. That is because the air inside the tube can be removed, above the water's level, through the plastic tube. After the samples are taken, the chemistry tubes will be replaced with new ones to prepare the mechanism for the next sampling mission.

Assumptions:

1. The electronic solenoid functions underwater. In case it fails to do so, it could be replaced with a pneumatic one.

Possible issues:

1. The rubber cap, electronic solenoid and the plastic tube could contaminate the samples if not replaced after each mission with new ones
2. The mechanism will be hanging below a UAV. In this case, the center of mass of the mechanism will be lower than the UAV's center of mass which might affect the UAV stability and flight control.

3.2 Electronics Testbed

In order to proceed with the development of a prototype, an electronics testbed was designed (Figure 3). The electronics testbed was used to verify and develop the electronic circuit that controls the water sampling mechanism.

It mainly consists of three parts:

1. Arduino UNO microcontroller
2. Motor driver
3. Mini breadboard with extra electronic components

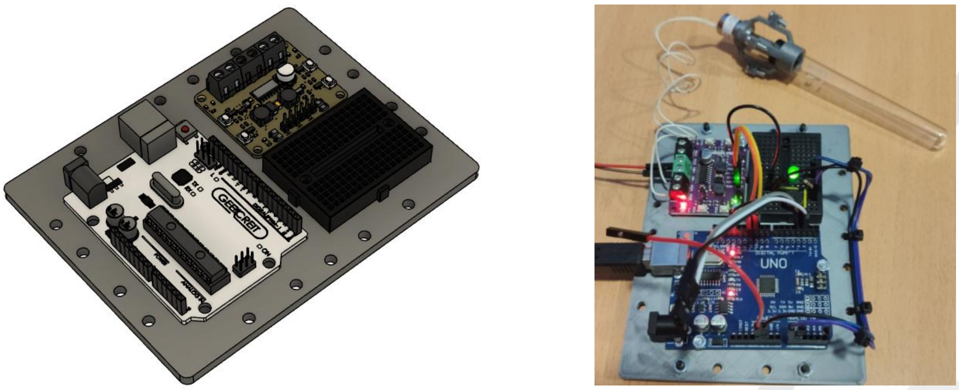

Figure 3 - Electronics Testbed

3.3 Water Sampling Mechanism Design

A cap (Figure 4) was designed and 3D printed, using flexible TPU material that will serve the function described above (Figure 2).

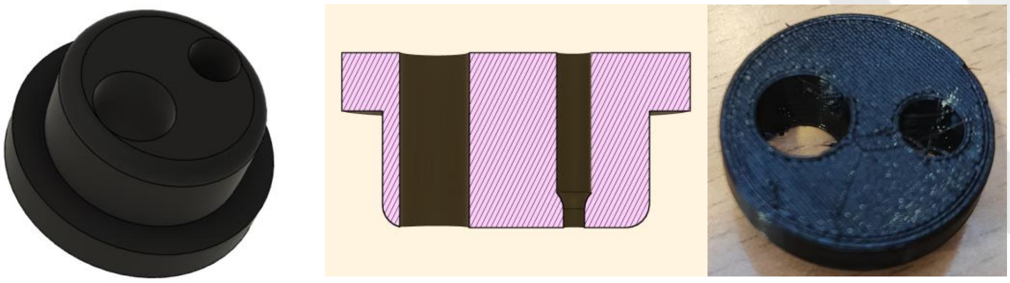

Figure 4 - Custom TPU chemistry tube cap

The aforementioned cap is fitted into the solenoid valve and the plastic tube (Figure 5).

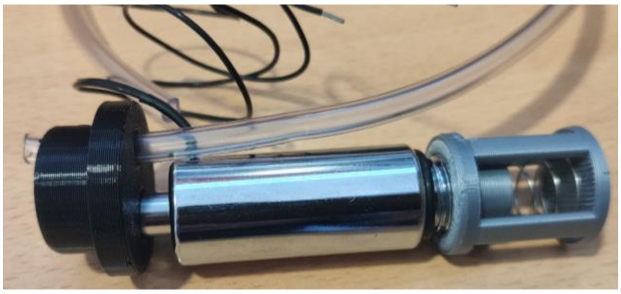

Figure 5 - Chemistry tube cap assembled with the solenoid and the plastic tube

A mount was designed and 3D printed to fix the solenoid with the glass tube and assemble the water sampling mechanism (Figure 6).

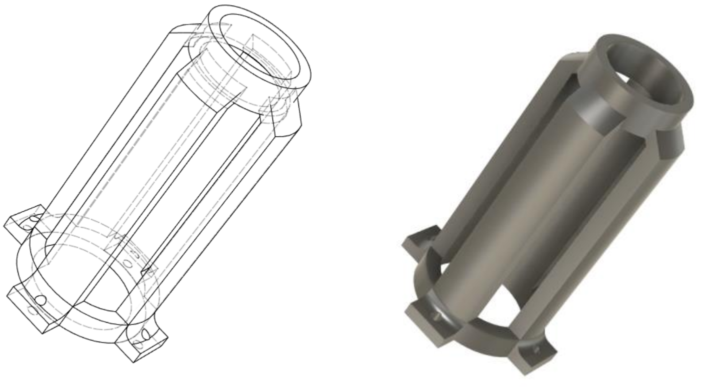

Figure 6 - Solenoid and cap to chemistry tube, mount

The final assembly is shown in Figure 7.

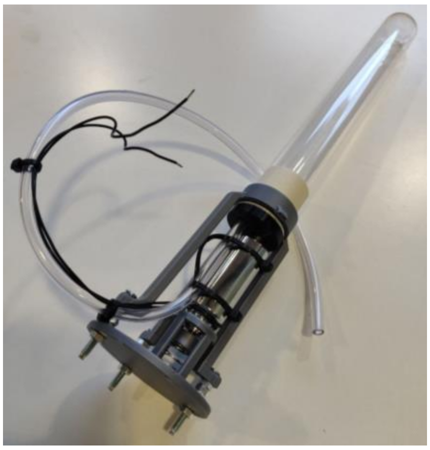

Figure 7 - Final water sampling mechanism assembly

3.3 Custom PCB Design

After the electronics circuit was verified with the help of the electronics testbed, we proceeded with the design of three custom PCBs in order to minimize the size and the weight of the electronic circuitry that is mounted on the UAV. An atmega328p microcontroller was selected as the link between the external hardware (water sampling mechanism) and the UAV control board.

Figure 8 - Custom microcontroller PCB. Bottom (right) and top (left) sides

Figure 9 - Custom USB link. Bottom (right) and top (left) sides

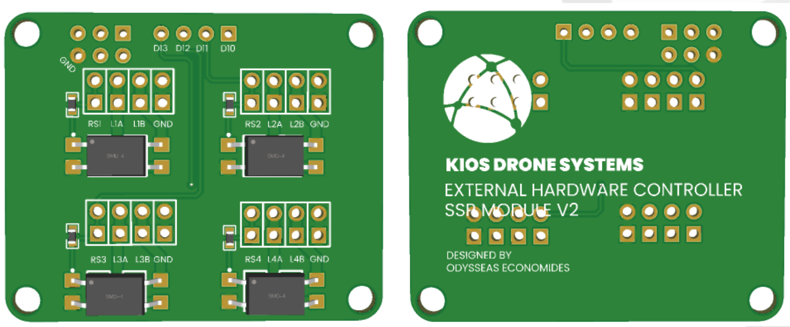

Figure 10 - Custom SSR circuit. Bottom (right) and top (left) sides

The above three designs were sent to be manufactured. The final boards are shown in Figure 11.

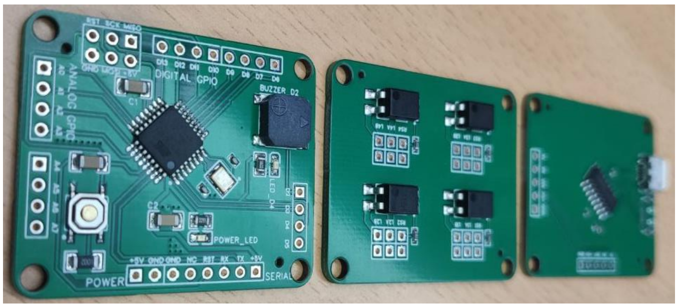

Figure 11 - Custom water sampling controller PCBs

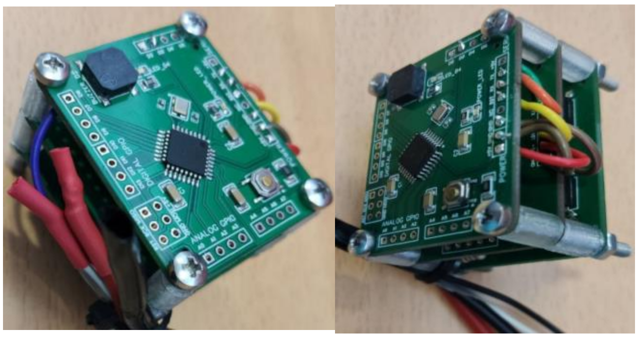

Figure 12 - Custom water sampling controller PCBs - assembled

A block diagram of the total system is presented below:

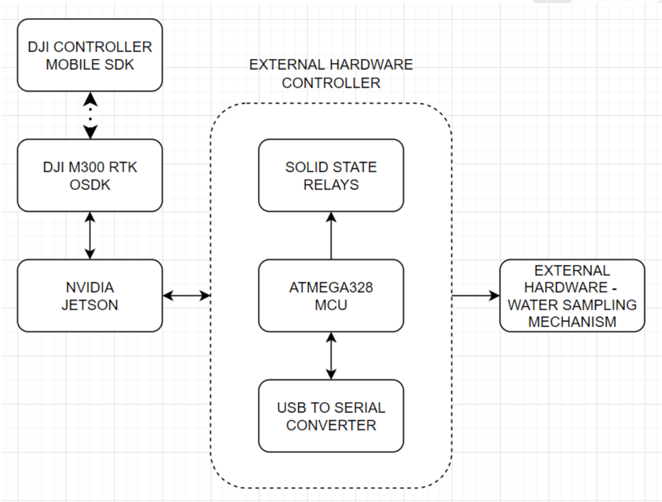

Figure 13 - Electronics block diagram

3.4 Water Sampling Mechanism UAV Mount

An electronics mount was designed in CAD and subsequently, 3D printed, using a PETG filament, with the following guidelines in mind:

1. Small footprint
2. Lightweight
3. Easy to attach and detach to the drone

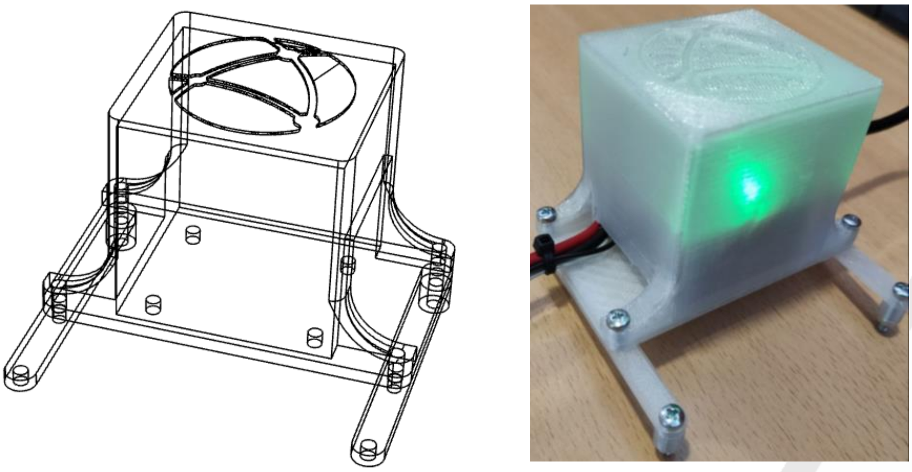

Figure 14 - Water sampling mechanism controller box and UAV mount

The final assembly of the water sampling mechanism, plus the electronics controller can be viewed in Figure 15.

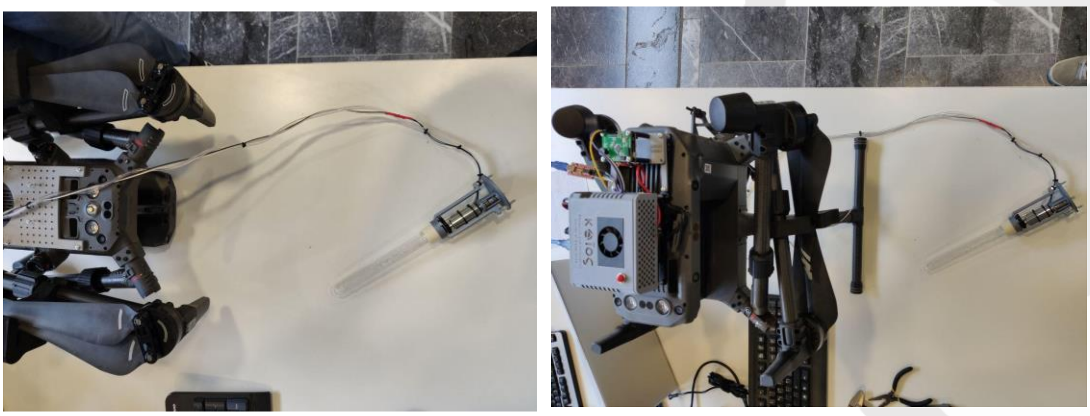

Figure 15 - UAV water sampling mechanism final assembly

4. Field Testing

The field testing was conducted at the lake of Athalassa's National Forest Park, Nicosia, Cyprus (35.142691, 33.401283). The final test was successful and water samples were collected and retrieved. A video demonstrating the result is provided in https://www.youtube.com/watch?v=tk95oLc1nlU

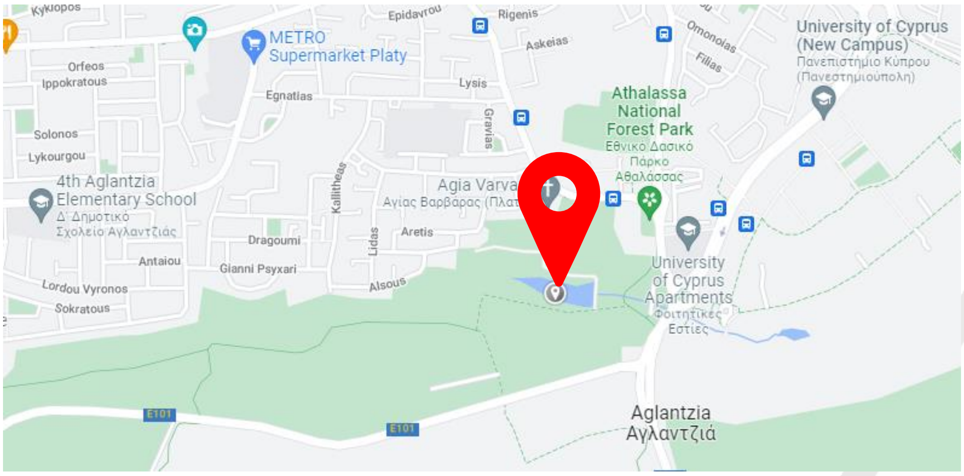

Figure 16 - Field testing location

Figure 17 - UAV Field testing images

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