

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/344952344>

# MAqD –Watermark For Live Online Dynamic Monitoring, Rivers Or Offshore

Conference Paper · October 2020

DOI: 10.5281/zenodo.4167329

CITATIONS

0

READS

114

10 authors, including:



**Constantin Vilcu**

National Research and Development Institute for Gas Turbines

13 PUBLICATIONS 16 CITATIONS

[SEE PROFILE](#)



**Valentin Vladut**

National Institute of Research - Development for Machines and Installations Desig...

282 PUBLICATIONS 338 CITATIONS

[SEE PROFILE](#)



**Gheorghe Voicu**

Polytechnic University of Bucharest, Faculty of Biotechnical Systems Engineering

264 PUBLICATIONS 371 CITATIONS

[SEE PROFILE](#)



**Daniel Roig Broman**

6 PUBLICATIONS 112 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



23SMES2009 [View project](#)



REMUNE [View project](#)

**MAqD – WATERMARK FOR LIVE ONLINE DYNAMIC MONITORING, ON RIVERS OR OFFSHORE /  
MAqD – REPER DE APĂ PENTRU MONITORIZARE DINAMICĂ DIRECTĂ REALĂ, PE RÂURI SAU ÎN LARG**

Ph.D. Stud. Eng. Vilcu C.\*<sup>1)</sup>, Ph.D. Eng. Vlăduț V.<sup>1)</sup>, Prof Ph.D. Eng. Voicu Gh.<sup>6)</sup>, S.R. Eng. Broman D.R.<sup>2)</sup>, S.R. Eng. Bourouah M.<sup>3)</sup>, Prof Eng. Loupis M.<sup>4)</sup>, Ph.D. Eng. Vlad G.<sup>5)</sup>, Prof Ph.D. Eng. Maican E.<sup>6)</sup>, Ph.D. Eng. Alecu L.G.<sup>7)</sup>, Ph.D. Eng. Lehr C.B.<sup>8)</sup>, Ph.D. Eng. Bogateanu R.<sup>9)</sup>,

<sup>1)</sup>INMA Bucharest, Romania; <sup>2)</sup>Innovation Training Centre S.L., Spain; <sup>3)</sup>Hahn-Schickard-Gesellschaft für angewandte Forschung e.V., Germany; <sup>4)</sup>ITC-KKT S.A., Greece; <sup>5)</sup>ICPE BISTRITA SA, Romania; <sup>6)</sup>“Politehnica” University of Bucharest – Faculty of Biotechnical Systems Engineering, Bucharest, Romania; <sup>7)</sup>National Institute for Research and Development in Electrical Engineering ICPE-CA Bucharest, Romania; <sup>8)</sup>ECOIND – National Research and Development Institute for Industrial Ecology, Bucharest, Romania; <sup>9)</sup>National Institute for Aerospace Research “Elie Carafoli” – INCAS, Bucharest, Romania;  
Tel: +40720392341; E-mail: [constantin.vilcu@inma.ro](mailto:constantin.vilcu@inma.ro)

**Keywords:** Water quality monitoring, Remote Operated Vehicle (ROV), Autonomous Surface Vehicle (ASV), Autonomous Underwater Vehicle (AUV), Aquatic drones

### ABSTRACT

*Multifunctional Aquatic Drones for surface waters (MAqD) is an operational tool, a “Water-mark” for “live, online dynamic monitoring” of aquatic environments in-situ. For surface running water, for lakes and / or offshore, MAqD in the image below represents a radically new approach for in-situ robust, reliable and environmentally responsible water monitoring.*

### REZUMAT

*Dronele acvatice multifuncționale pentru apele de suprafață (MAqD) reprezintă un instrument operațional, o „marcă de apă” pentru „monitorizarea dinamică directă, reală” a mediilor acvatice în situ. Pentru apele curgătoare de suprafață, pentru lacuri și / sau în larg, MAqD din imaginea de mai jos reprezintă o abordare radical nouă pentru monitorizarea în situ robustă, fiabilă și responsabilă cu mediul.*

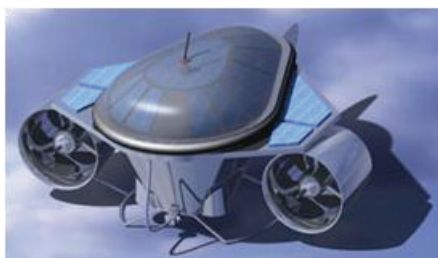


Fig. 1 – 3D MAqD

### INTRODUCTION

For monitoring of the “health status” of aquatic ecosystems, there is used an increasing diversity of intelligent multi-parameter sensors, which allow the measuring and on-line transmission of recorded values for a series of physicochemical and biological quality indicators, with the purpose of increasing the speed of both the evaluation and the intervention if necessary (Andronie et al, 2010). Today, the floating buoys for supporting the multi-parameter sensors in situ have also been developed to stand up to the specific hydro-meteorological functional conditions (<http://oceanexplorer.noaa.gov/technology/subs/subs.html>, 2017). In this context, the paper presents a multifunctional aquatic drone, with technical features which ensure the necessary instrumentation for working as a floating body for water quality monitoring and pollution control.

Energetically autonomous and adaptable to various meteorological conditions, the floating drone can also work with reduced maintenance in isolated locations. For the configuration of the floating system geometry and for its structure optimization, computational techniques have been used. Due to its versatility, the structure adds novelty in the area of drones for water quality monitoring. Depending on the equipment fitted to the drone, it can be used as a station for both surveillance and investigation monitoring, for all kind of surface water.

More aquatic drones placed in mesh network in a hydrographical basin subject to monitoring lead to a system of permanent acknowledgement of the ecological status of aquatic environment and are an important factor in taking intervention decisions for warning situations in case of pollution risk.

This paper presents the Computer Aided Engineering (CAE) approach in designing and optimizing the *MAqD* drones (Fig. 1). In this context, for the multifunctional *MAqD* drone, the autonomy is 100%, based on renewable energy for all the equipment on-board.

### METHODOLOGICAL APPROACH OF THE *MAqD* DRONE AS A WATERMARK

What is the *MAqD*? It is an autonomous and floating drone with the possibility of immersion, intended for monitoring the aquatic environment (surface water), especially for monitoring the quality indicators of river water in order to warn in case of pollution of the aquatic ecosystem. Complex construction (category: ultra-light vessel, small ship, ROVs, AUVs), the *MAqD* drone requires a multidisciplinary group, in partnership for conception, design and manufacturing. Fig. 2 shows the flow of CAE steps for the realization of the *MAqD*.

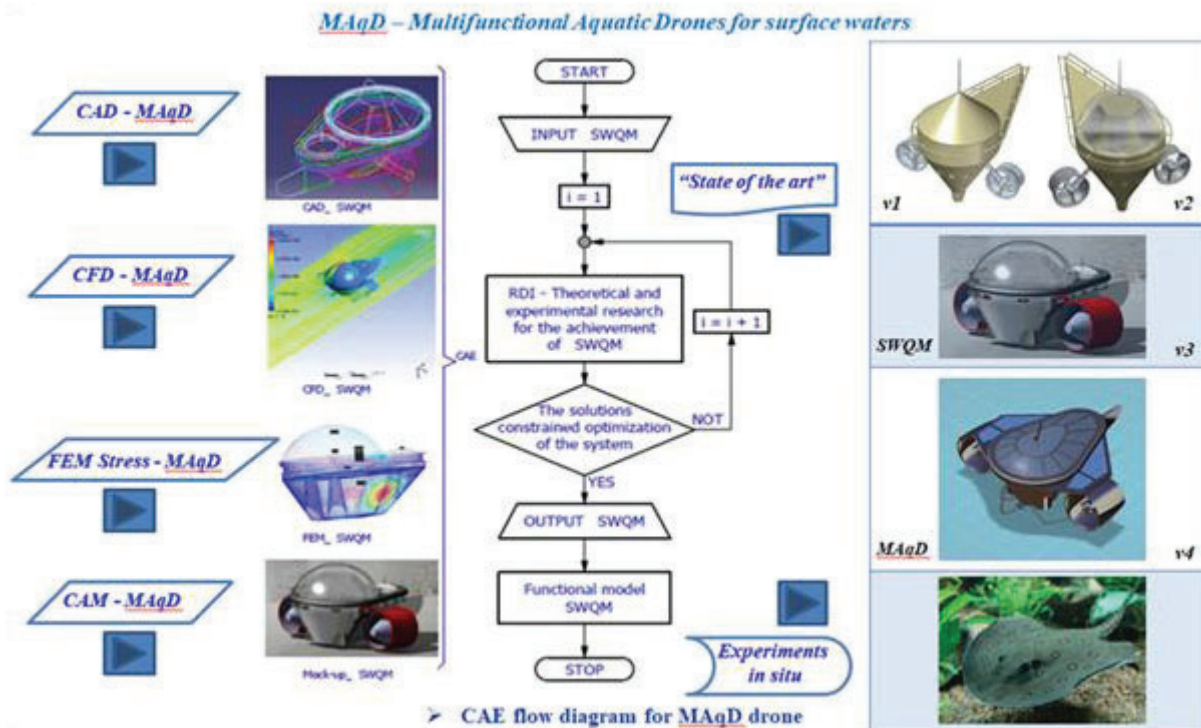


Fig. 2 – The CAE steps for design and optimization of the *MAqD* drone

The START action corresponds to a national or European program as a necessity for a sustainable development of the environment (LPM, 1995; WFD, 2000; TNMN, [www.icpdr.org](http://www.icpdr.org), 2009; WISE, [www.water.europa.eu](http://www.water.europa.eu), 2013).

The INPUT sequence (SWQM - Smart Water Quality Monitoring) contains data on the "State of the art" (<https://www.srbc.net/>, 2020; <https://www.nexsens.com/>, 2020; <http://www.anhydre.org/>, 2020) in conjunction with the requirements established by the environmental agencies and entities regarding the monitoring of the aquatic environment in accordance with "The Water Framework Directive - WFD, Directive 2000/60 / EC".

The PROCESSING of the *MAqD* drone from TRL1 to TRL9 is done within a DO cycle of RDI optimization through CAE computational technique. The constraints on the basis of which the optimal technical solution is realized from a functional point of view are imposed by the TRL maturity levels ([https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt\\_accordion1.html](https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html), 2012).

In the OUTPUT sequence a demonstration *MAqD* functional model with real-environment experimentation and on-site operation capabilities will be obtained. In situ experiments, numerous missions in case studies, all should be completed as successful operations in order to demonstrate the feasibility of the *MAqD* drones in any type of aquatic environment monitoring process (Ciolpan O., 2005).

The STOP action is virtual and corresponds only to the CAE flow for closing the project. After realizing the prototype of the *MAqD* drone and market rollout, the *MAqD* product will know further developments and transformations according to future research directions.

## DISCUSSIONS AND PRELIMINARY RESULTS

Currently, the decentralization of the monitoring-warning systems regarding the protection of the environment is being sought (*Dobricenseanu et al, 2007; Iulia Simion, 2012; Povară I., 2007*). *MAqD* drone meets this desire regarding aquatic environments. Through embedded sensors, through on-board integrated hardware-software, *MAqD* drone achieves the following:

- Continuous real-time measurement of in-situ state of the aquatic environmental parameters;
- Acquisition of environmental data, data processing and analysis in order to evaluate the real state of the aquatic environment;
- Wireless transmission of environmental data to the local terrestrial node with Internet connection and ecological risk warning in case of pollution.

The multi-parameter probes on board of *MAqD* drone is installed in the throne-conical areas of the ship, in moist protected compartments. Two of them are symmetrically mounted to the bow, aboard and starboard, and the third one to the stern. For the current gauge of the *MAqD* drone, only three points for continuous sampling of water quality indicators are provided. The multi-parameter probes cover the groups of water quality indicators for the river subsystem (*www.ysi.com, 2018*):

- ✚ IG group - general indicators (T, CE, pH, NTU, ORP, SAK);
- ✚ RO group - oxygen (DO, CBO5, BOB);
- ✚ RN group - nitrogen (N-NH4 +, N-NO3-, N-NO2-, N, P-PO43-, P, Chlorophyll "a");
- ✚ AP Group - Chlorides, petroleum products;
- ✚ Sensors for hydro-morphological parameters (depth, speed and flow of flowing water); sonar and video camera are optional and can be installed on request depending on the application.

On land or on water, a common feature of the aquatic environment monitoring stations is given by the integration of photovoltaic panels. Isolated operation in situ requires the establishment of stations operating in "standalone mode". For the *MAqD* autonomous drone, a hybrid system of renewable energy is integrated: solar (dome and photovoltaic wing) + hydro-kinetic (two intubated hydro-generators mounted in the console under the photovoltaic wing).

The spherical shape of buoyant represents the perfect geometry of the floating structures. They are specially designed for monitoring the marine and meteorological environment, and the equipment on board requires a high capacity UPS (Unite Power Source) for autonomy. These floating structures indicate the simplicity of maintenance in operation, but reveal a major constraint in manufacturing - the sealing of dry compartments. The structure of the *MAqD* has an ovoid geometry dictated by its operation in running water. Sealing constraints remain an important issue for the dry compartment with electronic systems of the drone.

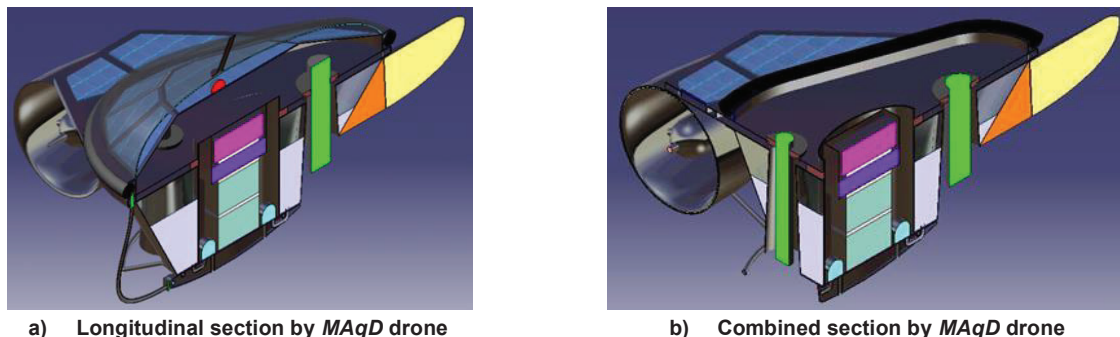


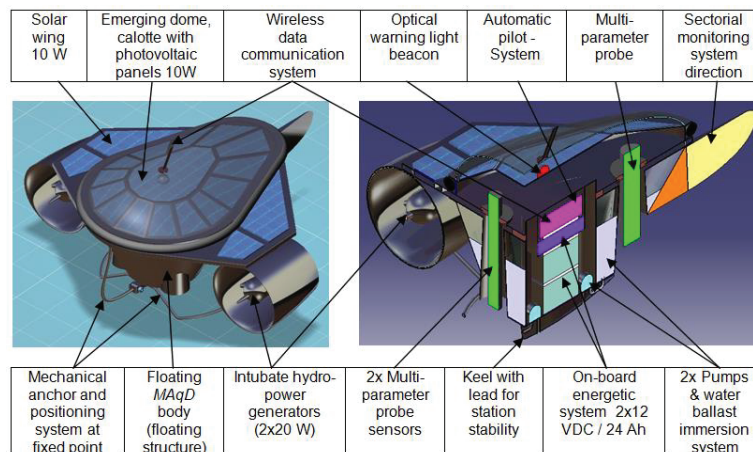
Fig. 3 – Compartments of the *MAqD* drone structure

The *MAqD* drone is designed as a buoyant in special construction (with variable average density of ship structure:  $\rho = 0. (6) \div 1. (1) \text{ [kg/dm}^3\text{]}$ ), so that the on-board controller adjusts easily on the go the buoyancy to immersion state and vice versa. Therefore, the skin of structure should be double, so that the drone has three volumetric compartments (Fig. 3):

- The dry compartment is the volume of the elliptical cylinder between the keel and the dome. It houses the UPS 24 VDC, an inverter, the on-board controller, and peristaltic pumps. Other electrical devices are installed to accomplish any specific function. For the structure, this compartment is the central pillar of resistance and lowers the centre of gravity (CG) as close as possible to the keel for a better drone stability;
- The wet compartment is the volume of the throne-conical areas communicating in the floating plane of the *MAqD* drone (solar wing). Multi-parameter probes are installed by means of cable glands on the drone hull, inside the wet compartments that also protect the probes from potential impact with external bodies;
- The floodable compartment is the volume bounded by the outer skin of the station fairing with the adjacent areas of the compartments described above. This watertight compartment perfectly communicates with the aquatic environment by means of two peristaltic pumps mounted in parallel (depending on the reliability of the system), provided with the sift heads hidden in keel. The water supply in this compartment is under pressure under the air pillow until the average density of the station exceeds 1 [kg/dm<sup>3</sup>] required for immersion. The lifting of the station to the waterline for the buoyancy status is achieved by the inverse process of removing the water from the floodable compartment. This technique allows the following:
  - protects the drone from the ice formed at the water surface during winter time;
  - allows the drone to monitor the investigated water body at the desired level;
  - *MAqD* drone achieves the state of weight required for travel in underwater work missions.

The component parts of the *MAqD* drone are shown in Fig. 4:

- Buoyant body with ovoid fairing in horizontal section;
- Solar wing;
- The emerging dome with the photovoltaic calotte;
- Intubated hydro-generators installed diametrically opposed in consoles under the solar wing;
- Landing train with stylish fixed bar for anchorage;
- Ballast keel;
- Drift for sectorial monitoring direction;
- Integrated Systems of Aquatic Environment Monitoring.



**Fig. 4 – *MAqD* Component and Integrated Systems of the Aquatic Environment Monitoring Drone**

The equipment onboard for the standard variant of the *MAqD* drone is presented in the double section executed in the drone body and listed in the equipment specification; it is considered when calculating the center of gravity. A reserve space for further equipment development is available under the photovoltaic calotte of the emerging dome. The multi-parameter probes are sealed using elastic mounting glands. The anchoring of the *MAqD* drone for fixed point operation is done by a traction cable connected to ballast (dead body weighing more than the drone). The length of the traction cable must be:  $L_{tc} = \sqrt{2} \cdot h_i$  [m], where  $h_i$  represents the maximum quota in case of flood from the location under investigation.

The 2D standard views (vertical, horizontal and lateral projections of the drone) shown in Fig. 5 reveal the following:

- Dimensions of *MAqD* drone:  $L * B * H = 1273 * 1335 * 694$  [mm];
- The height of the *MAqD* drone without the communication antenna is:  $H_s = 600$  [mm];
- The draft (draught) of the *MAqD* drone for buoyancy status is:  $T = \frac{2}{3} \cdot H_s = 4$  [dm];
- The mass of the empty hull of the *MAqD* drone is:  $M_s = 34.824$  [kg].

For the empty drone (without equipment) the center of gravity (CG) is positioned above the hull pressure center or careen center (CC) with 34.5 [mm]. The CAD model was made in CATIA-V5\_V21 (Fig. 5). Considering that the origin of the orthogonal coordinate system  $O(x, y, x)$  is set at 100 [mm] relative to the drone attack board (Bow) in the floating plane [CWL] and on the axis of symmetry of the float (PD), then the gravitational center has the following coordinates:

$$CG (0.44982, 0.00, -0.1398) [m]. \tag{1}$$

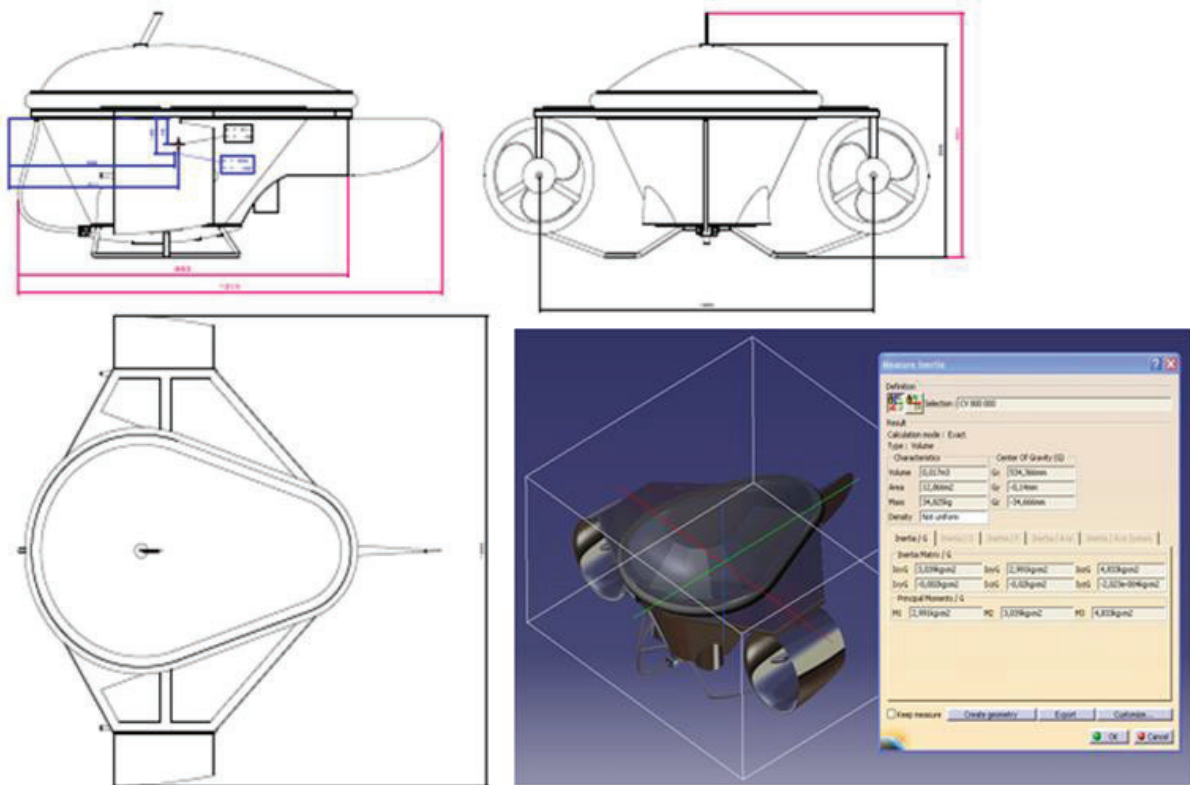


Fig. 5 – 2D & 3D of *MAqD* presentation, gauge and centre of gravity for naked drone

CAD (Computer Aided Design) version no. 4 was obtained from version 3 of the SWQM (smart water quality monitoring) by: dimensional increases of the float, a change of the profile of the emerge structure (dome and photovoltaic calotte), modification of the hydro-generator catchment, and a new solar wing in order to increase the photovoltaic surface. The CAD model allowed the automatic processing of the floating position (asset), centring (CG & CC) and  $\Delta_s$  displacement.

➤ In the first step (CAD model) the following results were obtained (2), with the data characteristic of the *MAqD* drone structure illustrated in Fig. 6:

- ✚ Sizes of the *MAqD* drone:  $L * B * H = 1273 * 1335 * 694$  [mm];
- ✚ Mass of the naked drone structure:  $M_s = 34.824$  [kg];
- ✚ Total mass of the *MAqD* drone (displacement):  $\Delta_s = 68.826$  [kg];
- ✚ Draught *MAqD* drone:  $T = 4$  [dm].

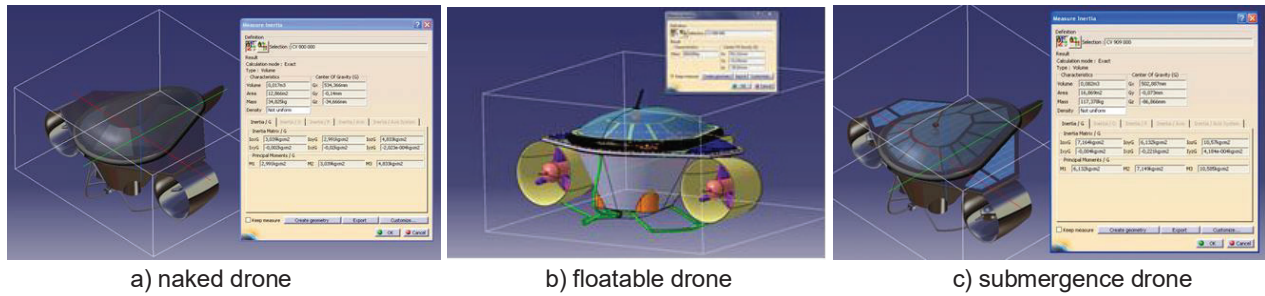


Fig. 6 – Calculation of centring (GC) and vessel displacement for MAqD

➤ In the second step (CFD - Computational Fluid Dynamics), the numerical simulations for the MAqD drone were processed in ANSYS R15.0 (CFX module), for various speeds of the working fluid (water):  $v_w \in \{1, 2, 3\}$  [m/s]. The virtual domain (3) has been established according to processing power of the server, but with dimensions not less than the following:

- Length:  $L_{HB} = 3 \cdot L = 3.819$  [m];
  - Width:  $W_{HB} = 2 \cdot B = 2.67$  [m];
  - Height:  $H_{HB} = 2 \cdot H = 1.388$  [m].
- (3)

All simulations are performed only for the immersion status of the drone into water. The CFD numerical simulations will also be performed for two-phase environment (case of buoyancy state), in which and the average wind speed from different locations will be taken into account.

On river water (average Danube water speed is considered  $v_w \cong 1$  [m/s]), the MAqD drone is anchored by a dead body and works at a fixed point (water flows). On lakes, depending on the investigated body of water, the hydro-generators operate in engine-propulsion mode and the MAqD drone becomes mobile at speeds less than 1 [m/s], necessary for monitoring or other types of investigations.

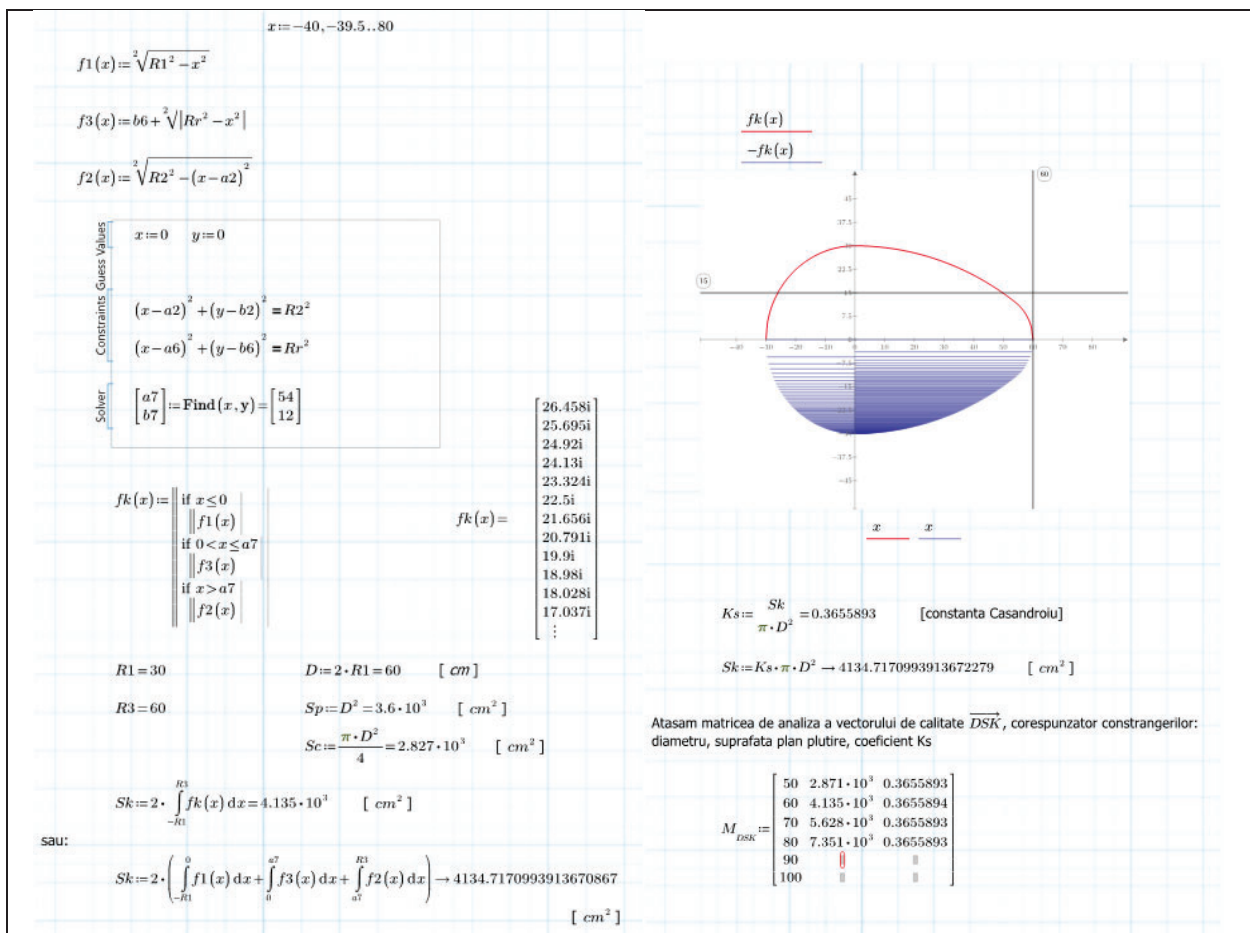


Fig. 7 – Mathcad model for horizontal section in floating plane of the MAqD drone

Fig. 7 shows the mathematical model in the case of a horizontal section through the body of the *MAqD* drone. The entire virtual domain of the floating section is shown in the Fig. 8 together with the hydrodynamics of the elementary body. The float section is profiled so that the resistance to advancement of the submerged body is minimal.

The mathematical model of the simulation program is based on the Navier-Stokes equations (4) for incompressible Newtonian fluids. In this case we have (Lukaszewicz et al, 2016):

$$\rho \left( \frac{\partial v}{\partial t} + v \cdot \nabla v \right) = -\nabla p + \mu \nabla^2 v + f \tag{4}$$

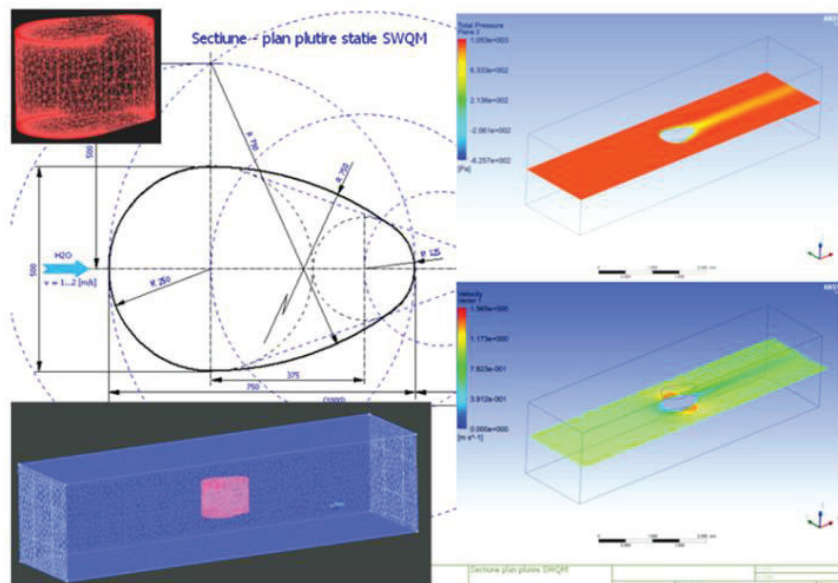


Fig. 8 – Hydrodynamics of ovoid-shaped section structures for the *MAqD* drone models

The CFD analyses shows that the current drone shape is optimized relative to the former version 3.

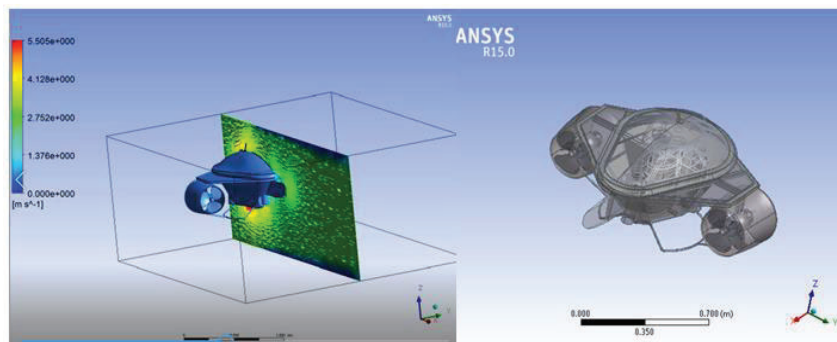


Fig. 9 – Speed chart (longitudinal section) for the immersed status of the *MAqD* drone

Through the animation (Fig. 9 - left image), for a stationary flow with the working fluid velocity  $v_w = 2$  [m/s], the velocity graph corresponding to the immersion state in all longitudinal sections of the *MAqD* drone can be obtained and analyzed. The main achievement in the current version is the lack of turbulence in the critical area between the hydro-generators and the drone body. These neighbouring components can generate hydrodynamic interference, so they require a critical approach.

➤ In the third step of structural analysis (FEA - Finite Element Analysis), the drone's frame stress problem was addressed. Initially Nastran MSC was used for pre-processing and solving, while PATRAN was used for post-processing. The lack of flexible anchoring elements used to anchor the drone to reduce the degrees of

freedom was a problem. Therefore, a second attempt was made with CATIA V5R2 for stress calculations, as shown below.

Two distinct cases of loads were considered and analyzed:

- a) In the buoyancy state, the static pressure is distributed on the surface of the "live careen" of the float body and generates the Archimedean force that is applied in CC, balancing the weight of the drone applied in CG. The dynamic pressure depending on the water speed generates a braking force given by relation (5):

$$T = \frac{1}{2} \cdot \rho \cdot C \cdot S \cdot v_w \quad [N] \tag{5}$$

In this operating state the stress caused by the dynamic water pressure on the drone careen is dominant compared to the stress caused by the static pressure. Short-term variable forces caused by wind can be evenly distributed on the drone dome. Other concentrated forces caused by the impact with foreign floating bodies may accidentally stress the immersed structure of the drone. All of these are potential operating scenarios of MAqD and have been considered for the state represented in Fig. 10.

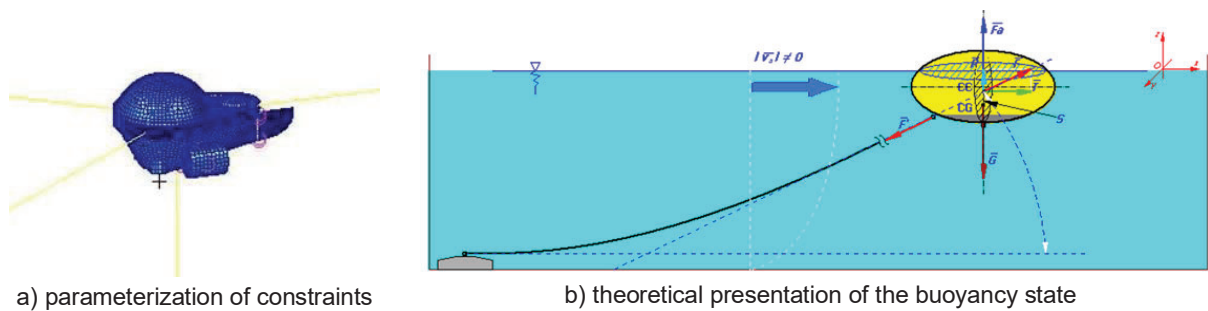


Fig. 10 – FEA case study for the floatability status of the MAqD drone

- b) In the immersion state when the drone has the same average density as the fluid in which it is immersed, the floating body is drifting for  $v_w = 0$  (weightlessness). The unstable balance is constrained by random disturbing forces. The traction force generated by a propulsion system can control the kinematics of the immersion drone. The static pressure exerted on the drone body increases in proportion to the height of the water column. The images in Fig 11 illustrate the surfaces of SWQM float with maximum load for maximum depth of  $10 \div 12$  [m] of the mouth of Danube into the Black Sea.

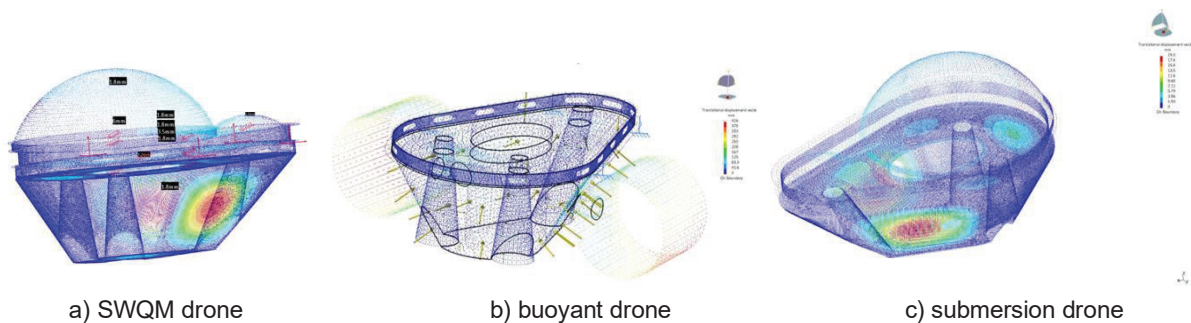
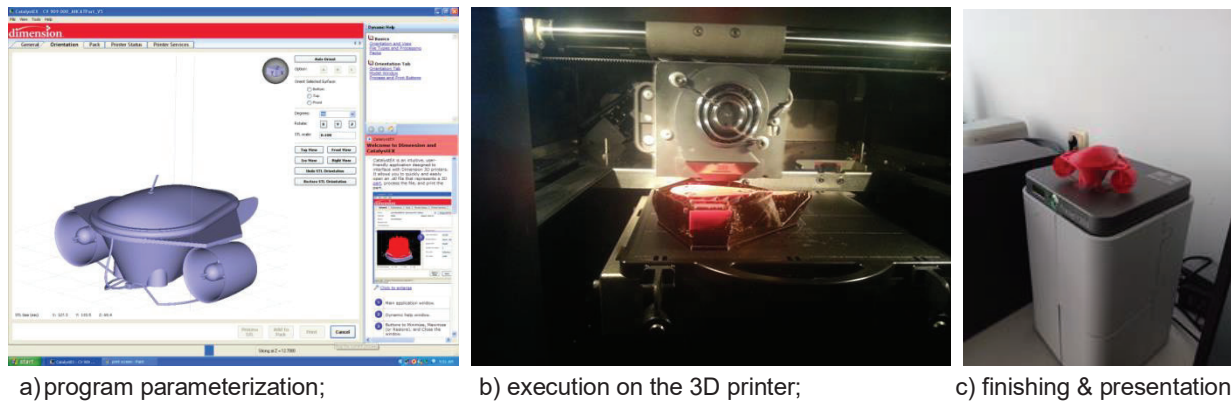


Fig. 11 – CAE Stress for the immersion status of SWQM drone

Research on the numerical simulation of stress on the surfaces and mechanical structure of the MAqD drone will continue for the case of offshore operation.

- In the fourth step (CAM – Computer Aided Manufacturing), the scaled (1:10) model of the MAqD drone was made.



**Fig. 12 – Computational-aided manufacturing at scale (1:10) using the CAD model of the MAqD drone**

Initially, a 1:1 mock-up of the former version no. 3 (SWQM) drone was made. The realization in a CAM programming environment of the MAqD drone was done later, the model of the aquatic drone being at a 1:10 scale according to the images presented in Fig. 12. Experimentation at this scale involves taking into account the theory of similitude and implicitly the risks associated with the interpretation and processing of experimental data. Subsequently, a physical demonstrator model (scale 1:1) was preferred for the basin of careens and for real (in-situ) experiments.

The stand-alone aquatic drone must be seen from the point of view of systems and on-board devices as a maritime platform or a "aircraft carrier". The MAqD drone is versatile. The equipment embedded is selected taking into account both the field of use and the work mission. For example: in the case of surface water monitoring, the on-board controller monitors in real time the profile of the investigated water body and controls the immersion status.

- The multifunctionality given by on board automatic systems for the aquatic drone MAqD are:
  - 1) Hybrid renewable energy system (HRES) for generation 24 VDC (with UPS storage buffer system);
  - 2) Monitoring system and data acquisition (DAQS) platform of the quality indicators of the investigated aquatic environment;
  - 3) Command and control system for MAqD drone (for buoyancy or immersion states);
  - 4) Remote data transmission system (data communication);
  - 5) Self-protection system for heavy weather conditions (frost protection) and anti-vandalism;
  - 6) Teledyne video camera and image recording system (optional);
  - 7) Drive system with robot arm for missions in difficult to reach spaces or with high radiation degree (optional).

We will now present the first two systems.

1) HRES for MAqD drone is represented in the Wiring diagrams of Fig.13. The electrical power installed on board is 123 [W]. Based on the simulated Energy Balance for heavy operating conditions of MAqD, a power requirement of 144 [W] resulted. Taking into account the diurnal character of electricity generation for photovoltaic panels and for a minimum speed of 1 [m / s] of running water, the maximum power generated (peak) is 212 [W]. The charging controller monitors the power node in the drone's electrical box. Continuous operation is ensured for 8000 hours / year as autonomy, 100% Renewable Energy which applies to all on-board equipment's (Maican et al, 2019).

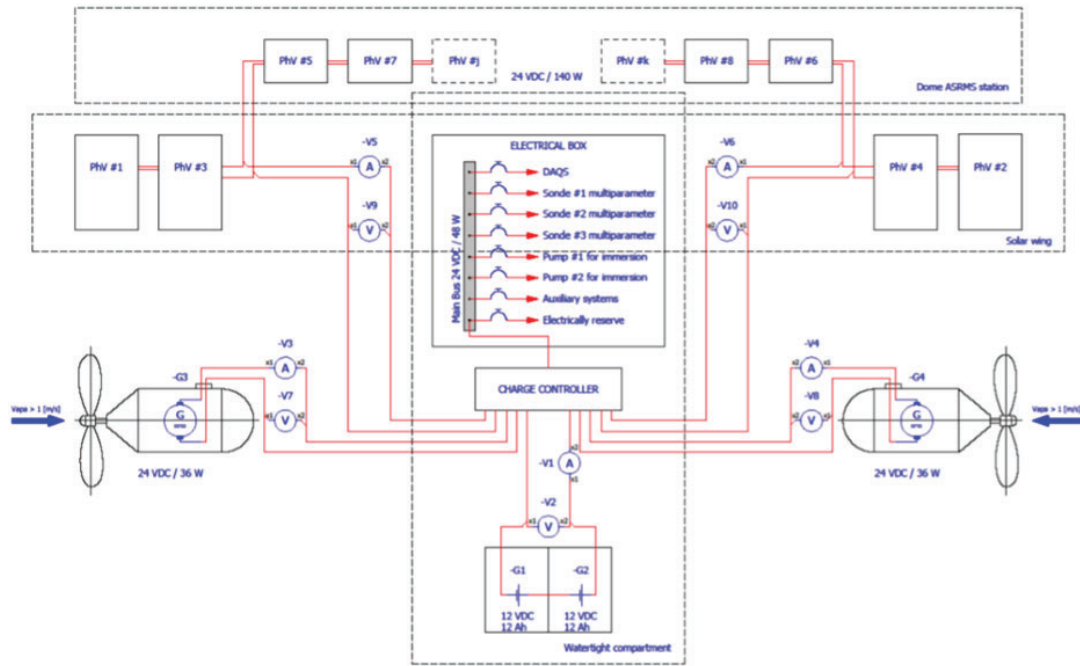


Fig. 13 – Wiring diagrams of HRES for the MAqD drone

2) DAQS for MAqD drone is represented in the monofilament wiring diagrams (Fig. 14). For signals of the water body state, the parameters measured by three multi-parameter probes of the station are adapted by the signal conditioners and interfaced by their protocols with the NI modular platform. The platform is scalable, can have 4 or 8 slots depending on the number of modules required for the application. The wireless transmission module performs data communication with the local land node of the aquatic environment data management network. Diagram also illustrates the place of the equipment on the drone.

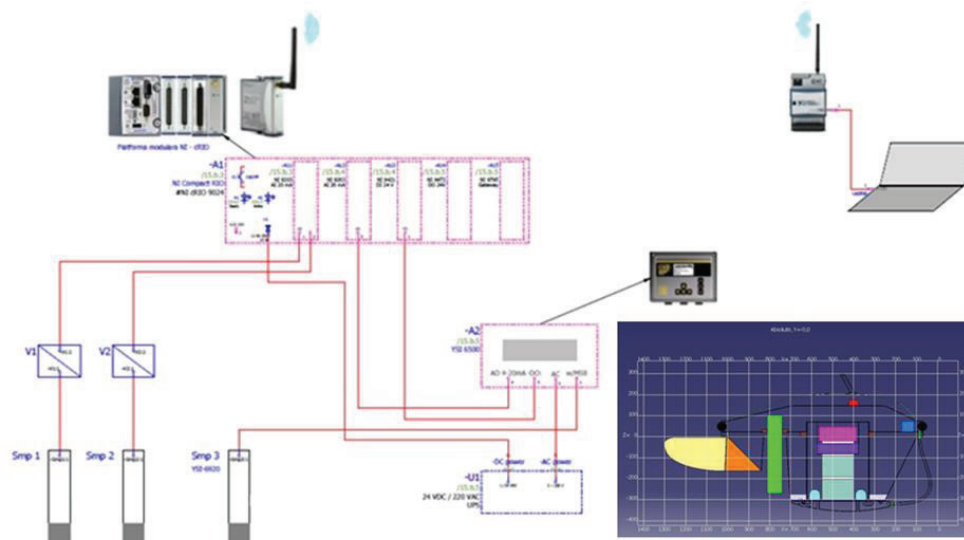


Fig. 14 – Schematic representation DAQS for MAqD drone

2.1. Sensor systems for "live online dynamic monitoring" of water quality

Today, the global market offers a wide variety of multiparameter probes manufactured from USA ([www.ysi.com/EXO2](http://www.ysi.com/EXO2), 2018) to China ([www.broadsensor.com/](http://www.broadsensor.com/), 2020). The length of these devices is often an impediment to their use, especially in shallow groundwater. This reason determined the finding of a European partner to execute custom sensor systems so that the MAqD drone can be miniaturized.

Hahn-Schickard (HS) of Germany will manufacture a system for water pollutants monitoring unit including sensor with different measuring principals, namely potential and optical based sensing

(<https://www.hahn-schickard.de/en/>, 2020). HS close the gap in the MAqD drone practicality with measurement system and sensors integration. HS has expertise in the field and relevant skills such as: hardware development for analog and digital circuits; design of communication interfaces; embedded software design; modelling and simulation of optical systems and fluid design. The main tasks of HS for the MAqD drone are listed now and will be presented in detail in the following article:

- Development of the transistor sensor platform with selective and ion sensitive field effect (ISFET) for the detection of ions, pH, CE and turbidity;
- The hardware architecture will be designed for sensor reading (see Fig. 15);
- The hardware and mechanical implementation of the mini-spectrophotometer will be used to cover the most relevant water parameters.

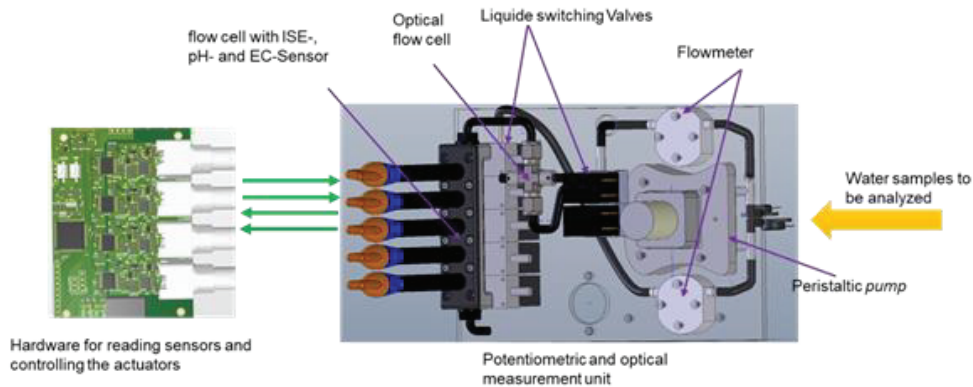


Fig. 15 – Multiparameter probes model HS

## 2.2. Aquatic environment data processing software and operator interfaces

Fig. 16 shows the integrated NI hardware and the implemented software on the MAqD drone, as well the operator interface, which includes several monitoring pages of the state parameters for water body investigated in-situ. The programming environment that was used was LabView-NG, which makes the MAqD drone a watermark for "dynamic live-online water quality monitoring".

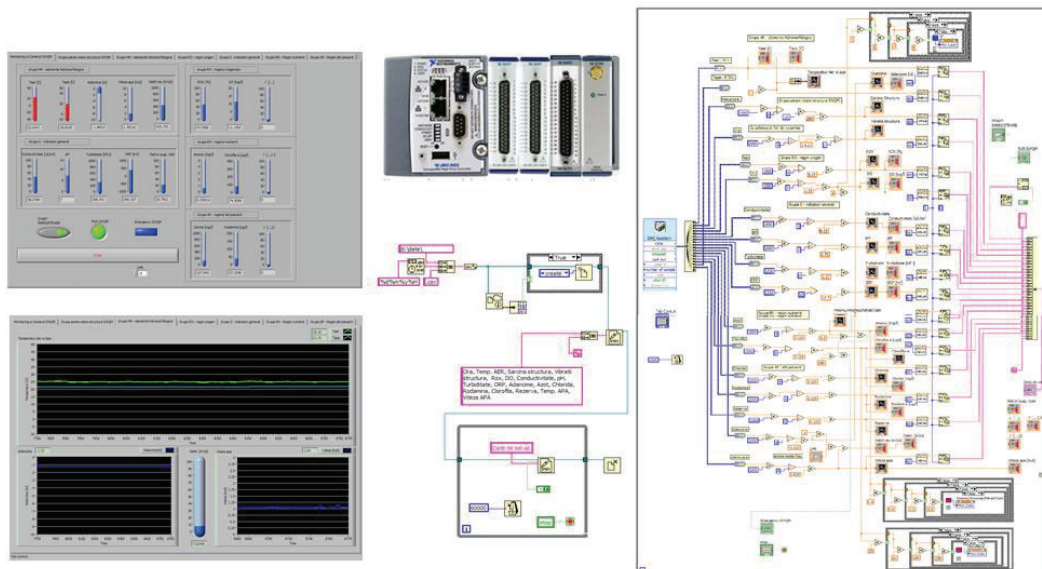


Fig. 16 – Hardware-software and pages interfaces of the MAqD drone

## RESULTS

Experimental in-situ research was undertaken as a case study on water quality monitoring with SWQM drone (v3) to demonstrate the usefulness of its realization. The quality of a water body is determined by studying and analyzing the experimental water state parameters in time and in various sections of the water body under investigation. A body of water was chosen as the location for investigation - Lake Herăstrău (of

Bucharest). Between June and September 2017, several daily campaigns to monitor the quality of the lake water were carried out by installing the SWQM drone in five sections of the lake. Continuous determinations of the water status parameters were performed with the SWQM monitoring drone and the data records were made in "data logging" mode. In Fig. 17 are located the monitoring sections upstream and downstream where the SWQM drone was anchored on the Herăstrău Lake.

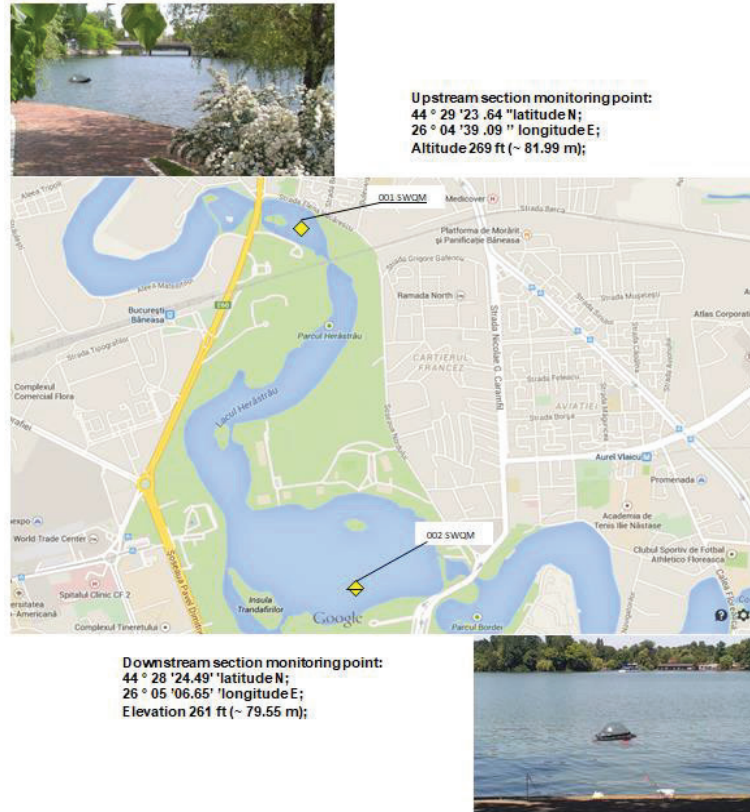


Fig. 17 – Spatial location of watermark drone in-situ measurements

Fig. 18 shows a graphics from the recordings made in situ (location: Herăstrău Lake of Bucharest) by ISB - UPB & ECOIND within a local investigation regarding the quality of surface waters from the chain lakes of Colentina river. The figure contains records of the parameters in the IG group - general indicators and the graph corresponding to the mediated values for a time period established in a priori manner. The values indicate a "good" quality of the investigated water body.

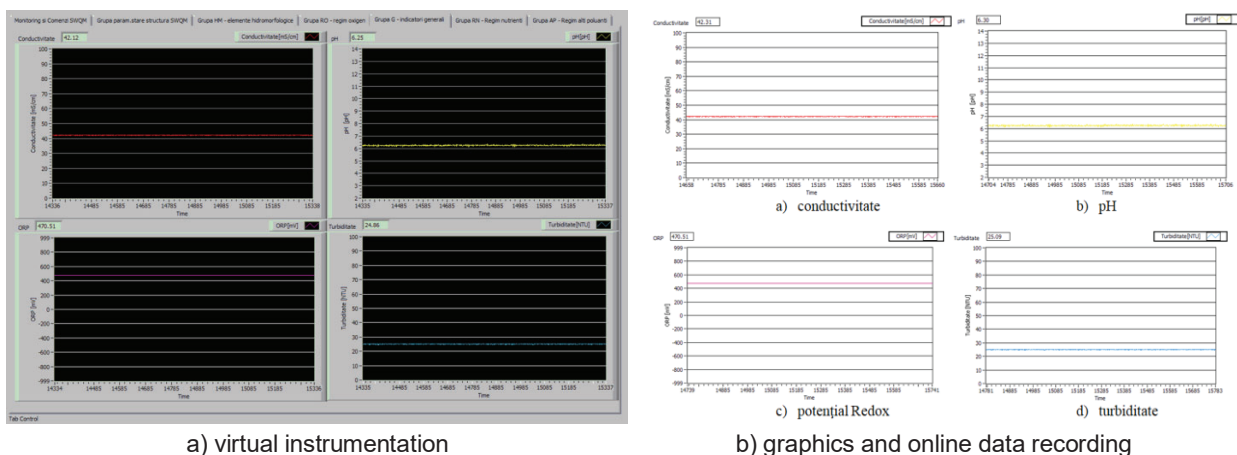


Fig. 18 – The graphs for IG group (general indicators of water quality)

CONCLUSIONS

A. Conclusions regarding the research and development flow for realization of the MAqD drone:

- i. The geometry of the surface water quality monitoring drone is a novelty element related to the current water landmarks used for monitoring the aquatic environment;
- ii. The mechanical structure of the aquatic monitoring drone is under special construction. Executed with double skin, the drone is provided with compartments designed to operate both in the buoyancy state and in the immersion state for surveillance and respectively monitoring of the water quality profile;
- iii. Carbon fiber fairing incorporates tensometric markers for measuring the internal stresses of the drone structure in dynamic operating regimes of buoyancy or immersion states to ensure the control of a safe and long-lasting functionality in insularized locations;
- iv. Water quality status monitoring program developed in the "LabVIEW Real-Time application" is dedicated to controlling surface groundwater pollution (rivers, lakes or offshore);
- v. Command and control system regarding the operation of the immersion drone for profile monitoring and adaptability to extreme climatic conditions (including vandalism);
- vi. The multifunctionality and versatility of the drone is ensured by the integration (upgrades) of the on-board equipment for special missions;
- vii. The designed water-mark continuously monitors "live-online dynamics monitoring" the quality indicators of the aquatic environment investigated by installing the *MAqD* drone directly in-situ;

#### B. Conclusions on in-situ experimentation with physical SWQM model (version 3 of the drone)

The on-site experiments with the monitoring drone, the allure and functionality of the integrated systems demonstrated by the results obtained that the determinations for the measured parameters did not deviate more than 7% from those calculated by numerical methods. The drone allure ensures functionality as a monitoring system and the integrated systems operate at optimal parameters. The SWQM structure is resistant to aquatic environmental conditions, ensures buoyancy and its anchoring is safe for prescribed operating regimes.

Of the 66 quality indicators for surface water [7], only 17% can be selected as status parameters for dynamic online monitoring using IQ sensors and multiparameter probes. The use of analyzers with unified signal output ( $0 \div 10$  V and  $4 \div 20$  mA) increases the percentage to 33% regarding the selection of quality indicators for real-time monitoring of the aquatic environment. For the other quality indicators that cannot be determined by direct in situ measurements (for technological reasons), samples are taken and make laboratory analyzes.

Experimental determinations performed in situ with the SWQM water quality monitoring drone allowed the analysis of 11 state parameters of the water body. They were selected from the 4 (four) groups of the quality indicators. Only those quality indicators considered to be able to provide useful information on the water body at the investigated location were monitored.

Following the analysis of the determinations performed, the following were found:

- the investigated water body does not face serious problems of contamination with pollutants;
- the lake water can be classified in quality class I in relation to the concentrations of some indicators or in class II (good quality) for the concentrations of other quality indicators;
- the transition from one quality class to another of the water body investigated several times during a calendar year recommends continuous or real-time monitoring;
- from a qualitative point of view, the lake water is suitable for aquaculture and / or fishing activities.

#### ACKNOWLEDGEMENT

We would like to thank our partners: ITC from Spain, HS from Germany and ITC KKT from Greece for their technical and logistical support for the timely completion of *MAqD* project proposal for Horizon 2020 – Environmental Intelligence: Call H2020-FETPROACT-2020-2; Type RIA; Topic FETPROACT-EIC-08-2020; Proposal ID 101017749; Acronym *MAqD*.

#### REFERENCES

- [1] Andronie I., Andronie M. (2010), "New perspectives for scientific research in the environmental field - result of developments in technology", <http://www.buletinulagir.agir.ro/articol.php?id=924> ;
- [2] Ciolpan O. (2005), *Integrated Monitoring of Ecological Systems / Monitoringu integrat al sistemelor ecologice*, Ars Doceni Publishing, Bucharest, Romania;

- [3] Constantin Rusu (1997), *Special Ship - Design Elements*, Publisher LEDA Constanța, Romania;
- [4] Dobriceanu M., Olteanu D., (2007), *Information Systems of Environment Surveillance. Quality and Environment Engineering and Management / Sisteme informatice de supraveghere a mediului*, Craiova, RO;
- [5] Domnisoru, L., (2010), *Strength analysis of a submerged vehicle with double-shell structure*, TEHNONAV 2010, ISBN 978-973-614-541-4, Annual Scientific Journal of Ovidius University – Mechanical Engineering Series, Volume XII, Tom I, Ovidius University Press, Romania;
- [6] Eco-Aqua, (2014), *Surface waters / Apele de suprafață*, accessed July 5, 2014, <https://eco-aqua.ro/> ;
- [7] EPL, (1995), *EPL - Environmental Protection Law / LPM-Legea Protecției Mediului din 29 dec. 1995*;
- [8] Iulia Simion, (2012), *Monitoring the quality of environment in the ecosystem of RDV municipality / Monitorizarea calității mediului din ecosistemul municipiului RDV*, accessed April 14, 2013, <http://www.scribd.com/doc/104605342/> ;
- [9] Lukaszewicz, G., Kalita, P. (2016), *Navier-Stokes Ecuations*, <http://www.springer.com/978-3-319-27758-5> ;
- [10] Maican E., Vlăduț V., et al, (2019), *Hybrid renewable energy systems for isolated farms, a review*, INMATEH Agricultural Engineering Journal, Volume 59/No.3/2019, Bucharest, Romania, DOI: <https://doi.org/10.35633/inmateh-59-09> ;
- [11] Povară, I., (2007), *Environmental geography. Pollution and environmental protection / Geografia mediului. Poluarea și protecția mediului înconjurător*, Editura Fundația România de Măine, București;
- [12] Project REACT (2013), *“Integrated system for dynamic monitoring and warning for technological risks in Romania-Bulgaria cross-border area”*, [www.project-react.eu](http://www.project-react.eu) ;
- [13] Project TOYROV (2008), *“Technological platform for the construction mini-robot remote underwater cable, commercial and agreement”*, Cod grant: UEFISCDI / CNMP PN II-CDI P4 TOYROV 3401/ 12-116/1.10.2008;
- [14] Radu Mihăiescu (2014), *Integrated Environmental Monitoring*, Cluj-Napoca, RO;
- [15] Rojanschi V., Bran F., Diaconu Gh. (1997), *Environment Protection and Engineering / Protecția și ingineria mediului*, Economic Publishing House, Bucharest, Romania;
- [16] Vilcu C., Voicu Gh., et al, (2014), *System for dynamic monitoring and warning in case of ecological risk for surface waters*, *Environment Engineering and Management Journal*, EEMJ-1757, Iasi, Romania;
- [17] Vilcu C., Voicu Gh., et al, (2017), *3SWQM - Watermark for pollution control of surface water, Actual tasks on agricultural engineering*, 45<sup>th</sup> International Symposium on Agricultural Engineering, Feb 21-24, 2017, Opatija, Croatia;
- [18] WFD-Directive 2000/60/EC, (2000), *Directive 60/2000/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy / Directiva Parlamentului și a Consiliului European 60/2000/EC privind stabilirea unui cadru de acțiune comunitar în domeniul politicii apei*, Jurnalul Oficial OJ L327, dec. 2000, EC;
- [19] \*\*\* (2020), <https://www.srbc.net/>;
- [20] \*\*\* (2020), <https://www.nexsens.com/> ;
- [21] \*\*\* (2020), <http://www.anhydre.org/> ;
- [22] \*\*\* (2016), <http://www.videoray.com/homepage/new/professional-rovs/mss-rov.html> ;
- [23] \*\*\* (2017), <http://oceanexplorer.noaa.gov/technology/subs/subs.html> ;
- [24] \*\*\* (2018), <https://www.yxi.com/EXO2> ;
- [25] \*\*\* (2020), <http://www.broadsensor.com/> ;
- [26] \*\*\* (2020), <https://www.hahn-schickard.de/en/> ;
- [27] \*\*\* (2020), <https://www.saildrone.com/> ;
- [28] \*\*\* (2012), NASA / DOD, *Technology Readiness Level*, [https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt\\_accordion1.html](https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html), 2012;
- [29] \*\*\* (1995), *Order 485 / of August 22, 1995 - for the approval of the Regulation on the organization and functioning of the Alarm System in case of accidental water pollution in Romania, SAPA-ROM, / Ordinul 485/22.08.1995 - pentru aprobarea Regulamentului de organizare și funcționare a Sistemului de Alarmare în caz de poluări accidentale a apelor din România, SAPA-ROM*, 1995, Monitorul Oficial al României, București, 1995;

- [30] \*\*\* (2006), Order no. 161, of February 16, 2006, approving the "Norm regarding surface water quality classification to determine the ecological status of water bodies" / *Ordinul nr. 161, din 16 februarie 2006, pentru aprobarea "Normei privind clasificarea calității apelor de suprafață pentru a determina starea ecologică a corpurilor de apă"*, Bucuresti, Romania;
- [31] \*\*\* (2006), Order no. 31, of January 13, 2006, regarding the approval of the Manual for the modernization and development of the Integrated Water Monitoring System in Romania (SMIAR), / *Ordin nr. 31, din 13 ianuarie 2006, privind aprobarea Manualul pentru modernizarea și dezvoltarea Sistemului de Monitoring Integrat al Apelor din România (SMIAR)*;
- [32] \*\*\* (2009), Water Quality in the Danube River Basin-2009, TNMN-Year book 2009, [www.icpdr.org](http://www.icpdr.org) ;
- [33] \*\*\* (2013), Water Information System for Europe – WISE, [www.water.europa.eu](http://www.water.europa.eu).