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Analysis of an Unmanned Aerial Vehicle Monitoring System for Resurveying of Shipping Routes

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Abstract **– The paper gives brief description of the conventional and innovative hydrography survey methods and constraints connected with the realization. Proposed hydrographic survey system based on the use of Unmanned Aerial and Maritime systems provides functionality to conduct hydrographic measurements and environment monitoring. System can be easily adapted to fulfil marine safety and security operations, e.g. intrusion threat monitoring, hazardous pollutions monitoring and prevention operations, icing conditions monitoring.**

Keywords **– Echosounder, environmental monitoring, hydrography survey, LIDAR, Remotely Piloted Aerial System (RPAS), Unmanned Aerial System (UAS), Unmanned Maritime System (UMS).**

I. Introduction

The geography of the Baltic Sea imposes special demands for navigation. The sea is very shallow with a median depth of only 43 m: 20 % of the water area is not deeper than 15 m, the draft of the deepest going vessels seen in the Baltic Sea today. 70 % of the water area is shallower than 70 m, depths which are considered relevant for the fuel efficiency of ships, which due to hydrodynamic effects consume less fuel in deeper water. Significant savings of fuel and emissions are possible if the vessel speed is adjusted according to the water depth. To decrease the environmental footprint of shipping even further, a vessel could deviate slightly from the direct course in order to maximize the water depth under the keel. Apart from this, the Baltic Sea is partly ice-covered during winter. This results in vessel tracks often not following the designated fairways, because they are routed depending on ice conditions. Long-time collections of AIS tracking data show that traffic patterns in the Baltic Sea are highly variable and that the major part of the water area is actively being used for commercial shipping.

Many charts which were adequate a decade ago, may have to be recompiled using new survey data, collected to a higher degree of accuracy and providing improved coverage. This deficiency may not be limited to sparsely surveyed waters of developing nations, but may also apply to the coastal waters of major industrial states. The advent of accurate satellite navigation, has made poorly positioned historical data an even greater problem for navigators. Fortunately, new survey technologies have improved the precision to which modern hydrographic surveys can be conducted.

As of today, almost two-thirds of the Baltic Sea area has not yet been charted to modern standards. Even close to major shipping routes, the depth information shown in some of the nautical charts and ENCs are still based on 19th century lead line soundings, sextant positioning and manual interpolation between sparse soundings [1].

II. Equipment and Methods Used in Bathymetry

It is important that the data collected meet the IHO S-44 2008 issue [2] that sets minimal hydrographic measurements standards. There are several depth sounding methods:

1. Acoustic Bathymetry Survey

Acoustics can adapted to scan beneath the water bottom's surface (sub-bottom profiling), scan across a seabed to identify bathymetric qualities, and combined with others to provide higher resolutions. However, acoustic surveys are typically time-consuming, as they typically have a relatively narrow scope. Most acoustic surveys cover approximately 10 % of the water depths in an area, leaving many gaps. Multi-beam echo sounders (MBES), which scan wider area than single beam echo sounders (SBES), are more costly and usually require additional monitoring tools. Scanning across a seabed offers a relatively wide coverage area, but lacks detail, and requires sampling to support findings [3].

2. LIDARs

Bathymetric LIDAR [4] is used to determine water depth by measuring the time delay between the transmission of a pulse and its return signal. Systems use laser pulses received at two frequencies: a lower frequency infrared pulse is reflected off the sea surface, while a higher frequency green laser penetrates through the water column and reflects off the bottom. Analyses of these two distinct pulses are used to establish water depths and shoreline elevations. With good water clarity, these systems can reach depths of 50 meters.

Bathymetric LIDAR is used to acquire data in areas with complex and rugged shorelines where surface vessels cannot operate efficiently or safely because of rocks, kelp or breaking surf. Some examples of these areas include Alaska, the North Atlantic Coast and the Caribbean [5].

3. Satellite Data and Photography

Satellite derived bathymetry (SDB) is a useful reconnaissance tool that can be used to map nearshore bathymetry, characterize a coastal area and to monitor seafloor changes that may have occurred since the last hydrographic survey was conducted [6].

Remote sensing can be regarded as one of the most promising alternative tool to map the bathymetry of the ocean, because of its extensive coverage of the area, low cost and repeativity. In recent years, successful launches of remote sensing satellites such as Ikonos, QuickBird, and Worldview-2 [7], [8] offer imageries with both high spatial and spectral resolution, but all these images need to be procured commercially. Since the procurement of commercially available images proves to be expensive for most of the developing countries. In the present work, application of the freely available Landsat 8 [6], [9] imagery data is done to map the bathymetry of the ocean (see Fig. 1).

Fig. 1. Landsat 8 Satellite image of Bahamas Islands. Different scale [9].

III. Development of an Integrated Unmanned Aerial Vehicle Multifunctional Monitoring System for Resurveying of Shipping Routes.

Monitoring system goal is to create a complex hydrographic data and environment monitoring data acquisition system. The system propose integration of multifunctional solution of navigation fairways resurveying providing high quality satellite and Remotely Piloted Aerial Systems (RPAS) data use in maritime surveillance and remote sensing through the development of an innovative integrated monitoring system using data from RPAS and Unmanned Maritime Systems (UMS) in the same time advising intelligent solutions for system command and control and advanced real-time and predictive data analytics technologies for end users.

Main system functionality is to conduct hydrographic measurements and environment monitoring. However, the system can be easily adapted to fulfil marine safety and security operations, e.g. intrusion threat monitoring, hazardous pollutions monitoring and prevention operations, icing conditions monitoring.

The system will have possibility to manage and controls simultaneously several UMS and RPAS devices. Autonomous devices will be acting as pseudo satellites, helping in establishing good communication and covering bigger areas for monitoring services.

IV. Description of UMS

To ensure safe navigation, exploitation and survivability of the device several systems are used. All systems of the device are connected to the main computer. The functional scheme of all UMS systems and elements is shown on Fig. 2 and Fig. 3.

1. Energy System

There will be developed different options for the power system of the device, allowing the selection of the most optimal for the different operation conditions, including severe once like Arctic. Following power sources will be foreseen in the device, allowing variations in between them or even using of all of the available sources in the system:

- Electrical energy accumulators;
- Solar panels;
- Fuel cells;
- Internal combustion power generator.

Before start of the mission the UMS is supplied with necessary energy stores using refuelling and charging port modules. To monitor the parameters of the energy system sensors module is used. Sensor module will send the data of different system units to the main computer: temperature (t_0), voltage (U), current (I) and capacity of electric energy sources (C).

2. Propulsion System

Propulsion system will consist of two identical modules (leftside and rightside), which will be mounted on different sides of the UMS ensuring movement and manoeuvrability of the device by the next principles:

– When modules are working intact with the same power, the UMS will move forward of backwards;
– When modules are working with the different power, the UMS will change moving direction.

Motor driver module will supply energy to electrical motor, controls the speed and direction of it‘s rotation. Electrical motor and propeller will rotate the propeller, which will move the UMS. Electrical motor can be mounted either inside of the UMS, and transfer the rotation over watertight shaft line to the propeller, or it can be mounted outside of UMS as one unit together with propeller. Motor driver module sensors will collect data about the performance of the system units and will send it to the main computer: temperature (t,°C), voltage (U), current (I), rotation speed (rpm).

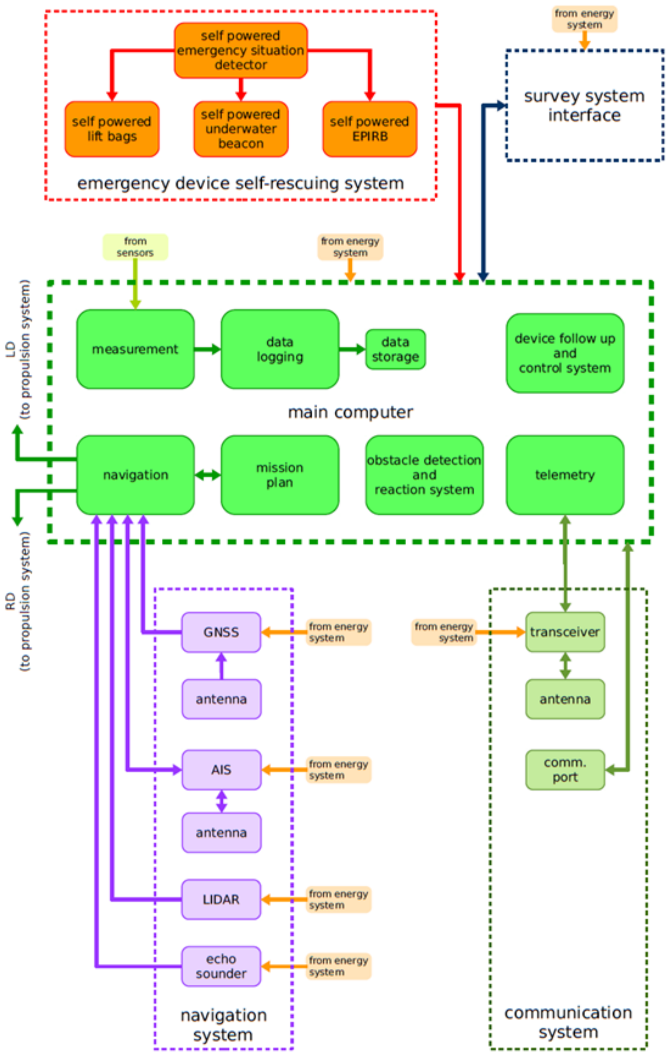

Fig. 2. Functional scheme of UMS systems and elements – 1.

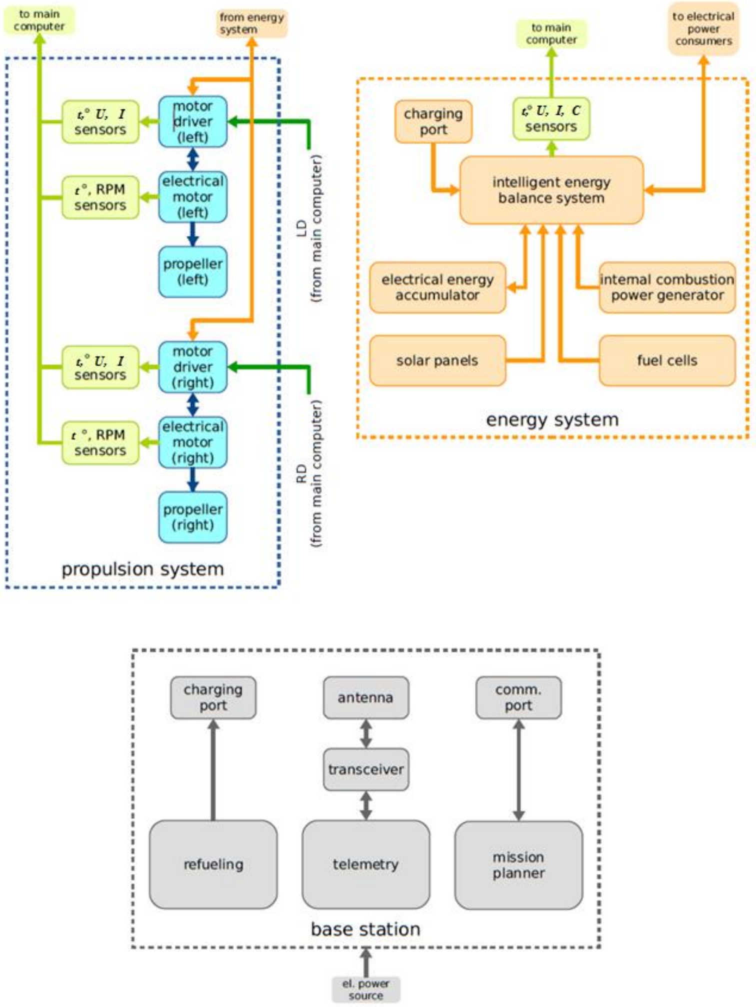

Fig. 3. Functional scheme of UMS systems and elements – 2.

3. Navigation System

The UMS will be operating in constantly changing environment with sometimes not accurate topological data, therefore to operate the device must orient itself in the surrounding environment. Navigation system is the unit that allows the UMS to „feel" the surrounding environment. The modules of the system are powered from the device energy system.

Navigation module is responsible for the safe navigation: it will receive information about the environment, compare it to the existing information in the mission plan module, and by the taken decision is controlling the propulsion system.

UMS also include Emergency device self-rescuing system, Communication system, Base station, Survey system interface, Main computer, Mission planner and control system, Measurement and Data logging and data storage modules.

V. Description of UMS – Capabilities and Systems Directly Related to Hydrographical Use

Depending on the needed survey requirements, there is a list of possible to mount survey sensors. For the convenience to mount there is a place foreseen for acoustic devices in between the hulls. The UMS can carry (see Fig. 4):

– Single beam echosounders (shallow water, medium water);

- Multibeam echosounders;
- Positioning devices as GPS, DGPS (with SBAS capability), RTK GPS (preference is paid towards dual GPS antenna systems, because it can replace gyro sensors);
- Motion reference units MRU and gyrocompass, with integrated inertial navigation;
- Depending from requested survey tasks survey system will carry sound velocity profilers SVP or CTD.

All acoustic survey equipment must be mounted in set such manner that acoustic transducers at the mission would not get an air bubbles and always stay underwater. Immersion depth at least must be 0.5 m guarantied. Regarding instrumentation selection preference is paid towards integrated (combined) instrumentation. This will save the space on the unit, saves the weight of it.

The last factor for survey systems is the acquisition software. On the market at present exists some advanced hydrographic data acquisition and processing software packages. Upon the used instrumentation those packages can be used. Some of them provides ready modules for USV (unmanned surface vehicle), some of them can be easy adjusted.

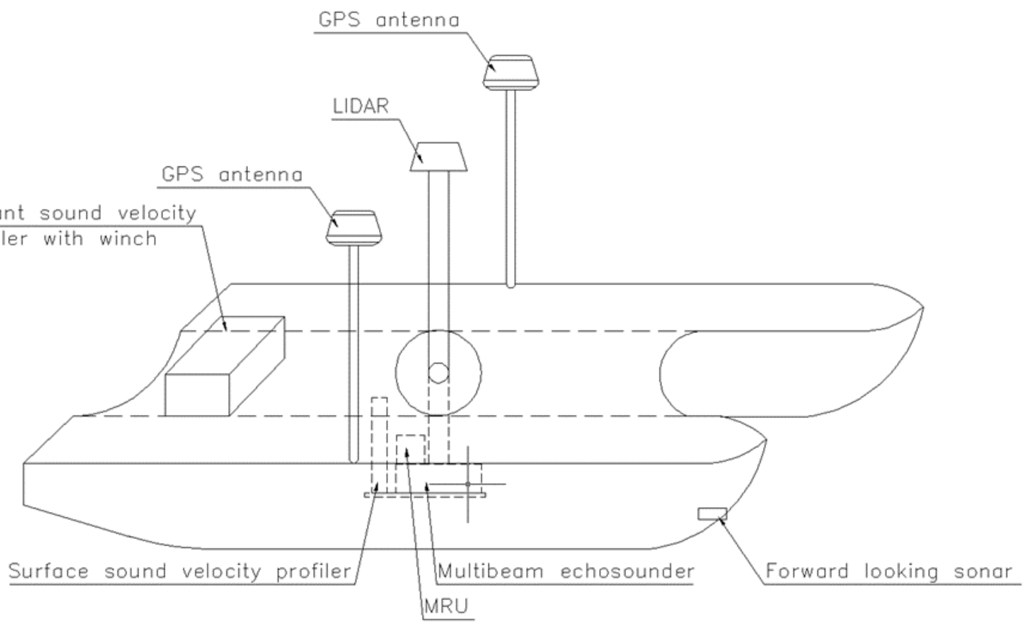

Fig. 4. Arrangement scheme of hydrography related equipment on UMS.

VI. DESCRIPTION OF RPAS

RPAS has significantly improved functional properties (including substantially altered the technical characteristics, components, materials, added software):

- The aircraft can perform remote monitoring flights up to 800 km distance;
- Aircraft design and aerodynamic characteristics are improved, allowing to develop speed up to 80 km/h;
- RPAS is equipped with a photocamera and two videocameras: one for driving, the other – exploration needs, as well as sensors that provide data collection;
- RPAS is equipped with an autopilot system, which can be operated manually with aircraft control box and by autonomous system as well, which requires only the flight plan;
- RPAS is a multipurpose and can perform a variety of thematic monitoring without constructive changes;
- To substantially strengthen the effectiveness of the observation by the object operational supervision and protection from the air with a significant (not less than 20 %) decrease in total costs.

Aircraft output parameters (Fig. 5) [10]:

- Wingspan – 3100 mm;
- Fuselage length – 2100 mm;
- Weight characteristics – 20 kg;
- The maximum flight time – 10 h;
- Flight distance – 800 km;
- Flight speed – 80 km/h;
- Payload – up to 10 kg;
- Powerplant type – gasoline internal combustion piston engine.

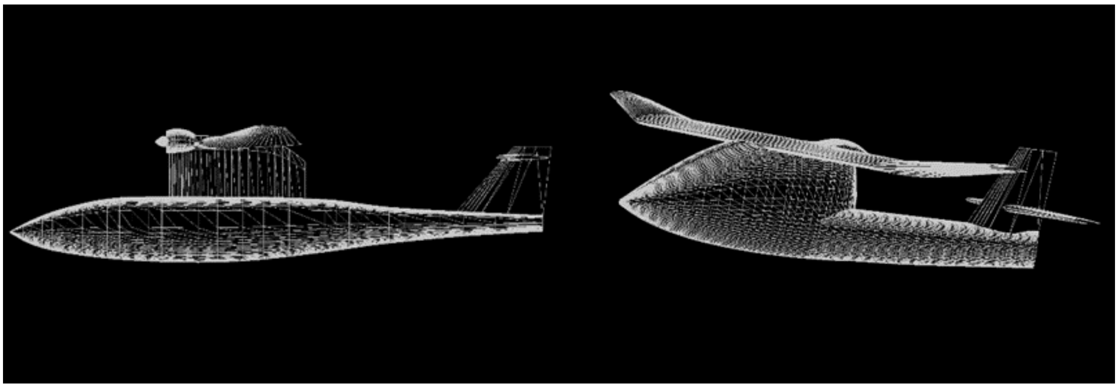

Fig. 5. Unmanned Aerial Vehicle schemes.

In case when the engine-propeller group is located in front or at the back of the aircraft it is impossible to keep working condition on fuselage when landing. In order to protect the engine and propeller from damage the optimal solution is to locate the powerplant on the pylon or install it in the fuselage top rear part.

Following this criterion of selection between two schemes was carried out – “high wing with the pulling powerplant on pylon” and “high wing with pushing powerplant in the fuselage top rear part”. Mentioned schemes were selected for further analysis (Fig. 5) and following aircraft parameters were adopted (Fig. 6) [11]:

- Wingspan – 3100 mm;
- Fuselage and the tail's length – 1840 mm;
- Wing profile chord – 350 mm;
- Wing projection area – 100 dm^2;
- Wing load – 190 g/dm^2 (at maximum take-off weight of 20 kg);
- Distance between the wing and fledged focuses – 1100 mm.

Fig. 6. Unmanned Aerial Vehicle 3D model.

Information gathered by RPAS will be used for the navigation chart data update (including possibility of automatic Electronic Chart Display and Information System update through the possible interaction of these two systems) instead of time consuming resurvey by special vessels and conventionally used satellite systems which are not always owned by National Hydrographic Service, effected by high costs and weather conditions. RPAS being interconnected with UMS both will be used for command and control system as any of them can act as pseudo satellite for other thus providing undisturbed control of both components of proposed system. Main task of UMS is resurvey of navigation fairways by means of payload carried within its structure. Data collected in the resurvey process from both components is transferred to the main command and control station where it can be integrated with other common systems.

VII. CONCLUSION

Much of the information shown on charts in use today has been obtained using old technology and techniques. Many of the world's charts still rely on information obtained up to two centuries ago when the methods of obtaining both position and depth were extremely limited. In the absence of any other data, many of today's charts contain significant amounts of information derived from non-systematic observations. These range from single observations of dangers reported by mariners to information derived from casual observations obtained as part of scientific expeditions.

Environment monitoring data acquisition system propose integration of multifunctional solution of navigation fairways resurveying providing high quality satellite and RPAS data use in maritime surveillance and remote sensing through the development of an innovative integrated monitoring system using data from RPAS and UMS in the same time advising intelligent solutions for system command and control and advanced real-time and predictive data analytics technologies for end users.

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