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**POSSIBILITY OF USE OF THE RIVER BADGE SHIP AS
A POTENTIAL AIRCRAFT CARRIER IN THE SECURITY OF
LOGISTIC AND CRITICAL INFRASTRUCTURE**

Summary. This article contains a description and analysis of the hypothetical application of the inland barge as an "aircraft carrier" with observation aircraft, both manned helicopters and unmanned drones. The equipment of the barge would include the infrastructure of aircraft servicing, storage and social space. This is the first presentation of such an idea in Polish literature and a continuation of previous researches on drones by the same author.

Keywords: inland waterway ship, inland waterway system, unmanned aerial vehicle, helicopter

1. INTRODUCTION

Aircraft are one of the best tools for inspecting various types of infrastructure, including logistics and critical infrastructure. However, it should be stated that no aircraft is single-handed. Its operation depends on the land or on-deck facilities securing logistics services. This ground service may be located in permanent bases (at airports) or may have a mobile character [1]. This study proposes a solution in which the ground handling is mobile and located on an inland ship. The advantage of this solution is the relatively high autonomy, the

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amount of space in the hold and the load capacity of vessels (especially for cars), but its disadvantage is the low speed rarely exceeding 10 km/h, as well as the limited availability of inland roads.

2. INLAND SHIP AS AN AIRCRAFT CARRIER

The inspiration for taking up such a topic was the inland transport development programme in Poland currently implemented by the Ministry of Maritime Economy and Inland Navigation [2]. The subject of inland vessels so far has been relatively rarely mentioned in the transport press. For several years, little has been written about it [5].

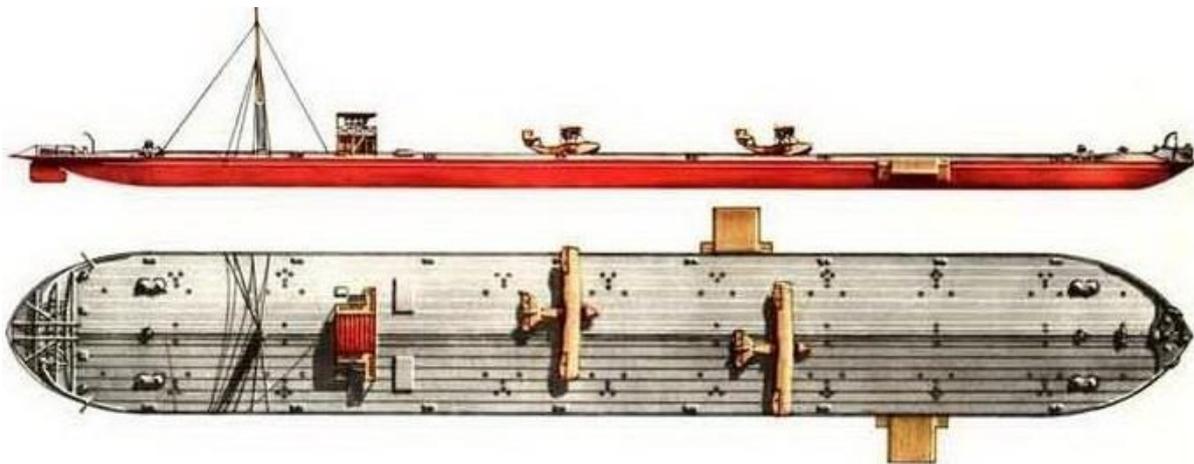


Fig. 1. Russian air barge "Komuna" (former tanker "Franciya"), in the year 1918 [6]

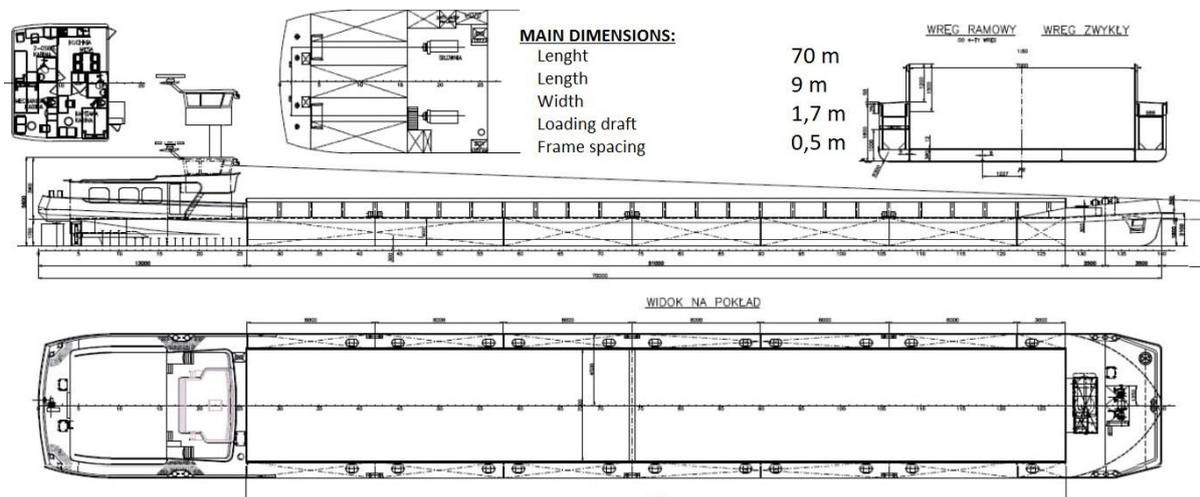


Fig. 2. Diagram of a modern twin-screw inland ship [5]

The first river barges adapted for handling and launching balloons were used during the American Civil War in the 19th century. During the civil war in Russia, the Bolshevik side had several "inland aircraft carriers" on the Volga river, including a barge called "Komuna", which carried 9 aircraft (flying boats Grigorovich M-9 and probably Nieuport 17 fighters) [6]. An unquestionable advantage of the inland unit in relation to the vehicle is its high load capacity and autonomy, it was remarked as the longest time that a ship can stay on the cruise,

performing its own tasks, without replenishing the stock and changing the crew. In extreme cases, the ship can continue to perform its tasks for up to several weeks. The load capacity of these vessels is quite large. For example, the motorized two-screw inland vessel BM-500, built and used in Poland can carry 155 tons (with a draft of 90 cm) to 465 tons (with a draft of 177 cm) [3, 4]. These are values that should be sufficient for the long-term security of air operations.

Polish shipyards offer designing and construction of inland vessels of various sizes and export them to the whole of Europe (mainly to Germany). Figure 2 shows an example of a large unit with a length of 70 m. We can also consider the concept of using a smaller unit, in this case, the 600 DWT motor bar offered by the Navicentrum office in Wrocław [7]. Experiences from a smaller unit can then be transferred to larger units.

To adapt the barge to the role of an aircraft carrier, a number of standards have to be met. This article omits detailed engineering information regarding the need to strengthen the ship's structure. It was assumed that the load capacity of such a ship is sufficient to accommodate the mass increase associated with the modifications. First of all, a helicopter landing pad must be on board. The design principles for such landing sites are derived from ICAO Annex 14 Volume II Heliports. Subsection 3.4 "Shipboard heliports" describes requirements for landing sites on ships. Among the requirements outlined therein, the most important is [8]:

3.4.3 A FATO on a shipboard heliport shall be circular and shall be of sufficient size to contain a diameter not less than 1.0 times D of the largest helicopter the heliport is intended to serve where D is the largest dimension of the helicopter when the rotors are turning.

3.4.8 For purpose-built shipboard heliports provided in the bow or stern of a ship, the TLOF shall be of sufficient size to: a) contain a circle with a diameter not less than $1 D$ of the largest helicopter the heliport is intended to serve; or b) for operations with limited touchdown directions, contain an area within which can be accommodated two opposing arcs of a circle with a diameter of not less than $1 D$ in the helicopter's longitudinal direction. The minimum width of the heliport shall be not less than $0.83 D$.

Tab. 1.

Basic technical data for MD-530 and SW-4 helicopters

TYPE	DIMENSIONS	TAKE OFF MASS	EMPTY MASS	RANGE	MAX SPEED
MD 530	D = 9,4 m H = 2,48 m	1157 kg	493 kg	605 km	282 km/h
SW-4	D = 10,57 m H = 3,05 m	1800 kg	1050 kg	790 km	260 km/h

Source: Own elaborated based on producer data.

The above records mean that the landing pad on the ship can be relatively simple. The Final Approach and Takeoff (FATO) can be one unit with the Touchdown and Liftoff (TLOF). The dimensions of the landing pad must not be less than the total length of the largest helicopter to be used with the rotor (D). The Novicentrum 600 DWT barge has a width of 9 m. The helicopters considered here have a comparable dimension D (10.57 m for SW-4 and 9.4 m for MD-500/530). It was assumed that the 600 DWT barge could have two helipads, one at the bow (where the landing would be safer) and one in the middle of the hull, where landing and takeoff would be more beneficial due to the lesser impact on the centre of gravity of the ship. For this reason, it was also proposed to have an aviation fuel tank under this helipad. The remaining part of the ship's hold can be freely used as a warehouse for

aircraft service equipment and a place for storing light unmanned aerial vehicles (UAV, colloquially referred to as "drones") supplementing helicopters in observation work.

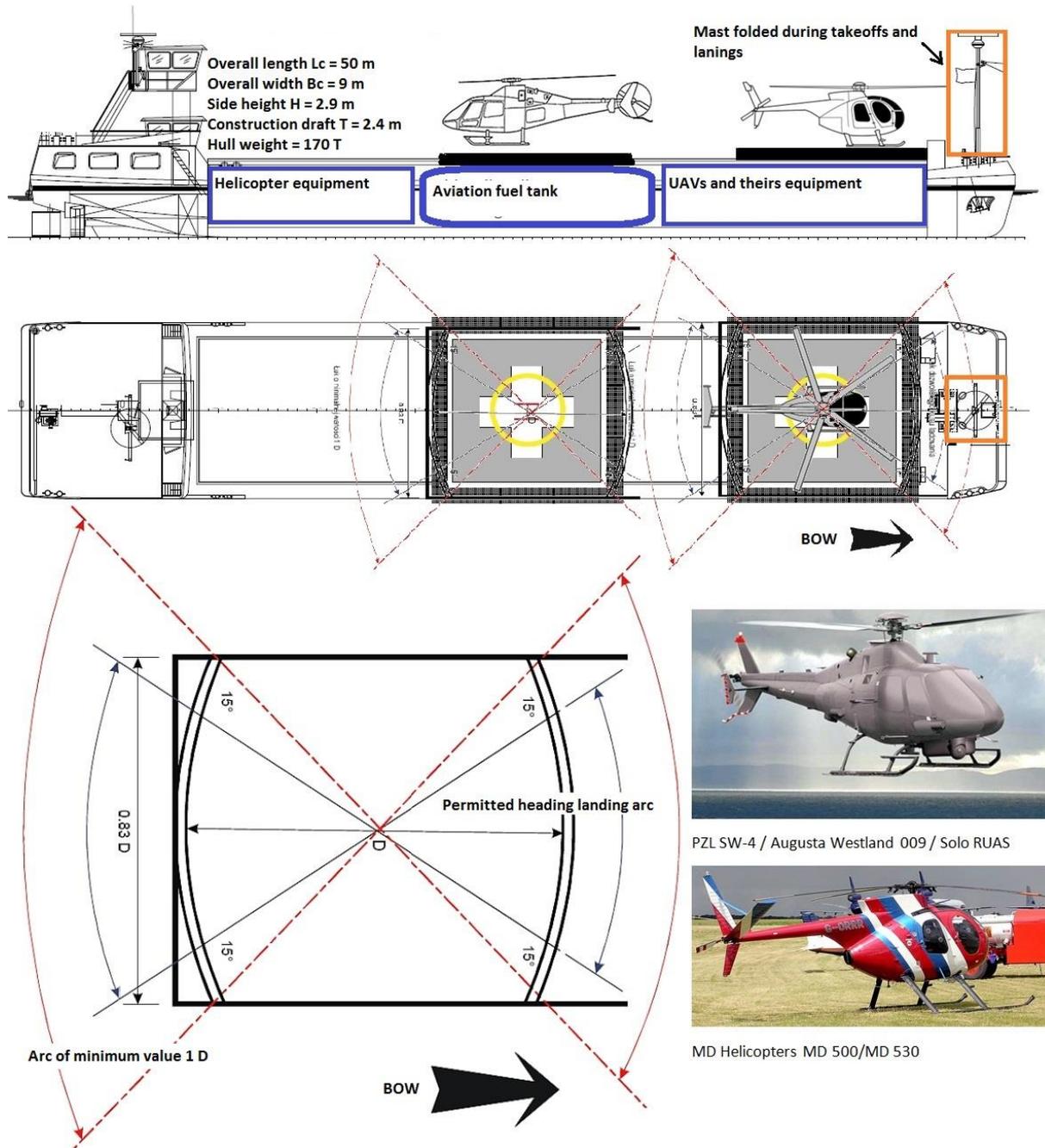


Fig. 3. The Navicentrum 600 DWT barge ship proposed to use for the role of a light helicopter carrier - the bottom part presents the scheme for limited heading operations taken from ICAO Annex 14 [own elaboration based on 7, 8]

Two types of helicopters have been proposed here. The first is the American Hughes/MD Helicopters MD 500/MD 530, one of the most popular light multirole helicopters in the world. It has a maximum speed of 282 km/h and a range of up to 605 km. Theoretically, it is a four-seater, but after installing a specialised observation system it usually takes only two

people. Helicopters of this type are at present successfully used in Poland to observe power lines. The second of the proposed machines is the Polish PZL SW-4/AW009 produced in PZL-Świdnik. Currently, the new owner of these plants is British-Italian Leonardo Helicopters Corporation (until 2016, Augusta Westland). They also tested its unmanned optionally piloted version, the Solo RUAS/OPH (Rotorcraft Unmanned Air System/Optionally Piloted Helicopter). SW-4 has speed up to 260 km/h and a range of 790 km. Theoretically, it can take four people, though only two pilots can be accommodated after installing specialist equipment.



Fig. 4. The interior of Navcom Systems mobile service station [9]

In the interior of the barge, you can also place a mobile aircraft service base, that is, a fully equipped mobile diagnostic and research laboratory with tools needed for servicing and some spare parts. Recently, such a laboratory placed in the car was developed by Navcom Systems from Świdnik. The manufacturer ensures that this equipment allows any kind of maintenance work to be carried out, including dismantling, inspecting or repairing the entire drive system together with the power transfer system and testing avionics modules without the need to deliver it to the workshop. The station has its own power supply with simultaneous connection to the power grid. In the absence of this possibility (for example, when the helicopter review takes place in an accidental place without any infrastructure), the station transports its own 6.5 kW power generator. It provides voltage for the system of all testers, and also provides voltage for the helicopter, so that it is possible to charge the machine's battery. The system enables testing of each element of avionics onboard the helicopter, including the VOR radionavigation system and the GPS receiver [9].

In addition to manned helicopters, the barge could also have a number of Unmanned Aerial Vehicles (UAVs). They could relieve manned helicopters in certain tasks. They have the advantage of incomparably lower operating costs. Poland is one of the leading producers of light UAV in Europe. This is the only type of aviation in which Polish industry has retained

(or rather created) full capabilities in the field of design and construction. Several Polish companies are offering professional UAVs of various types. One of them is the WB Electronics from Ożarów Mazowiecki. This company produces, among other UAVs types, the FT-5 Łoś, Manta LE, Manta VTOL and a number of specialised equipment at the latest modern level.



Fig. 5. Polish UAVs Manta and FT-5 Łoś (Moose / Elk) from WB Electronics [10]

Tab. 2

Basic technical data of UAV Manta and FT-5 Łoś

TYPE	LENGHT	WINGSPAN	WEIGHT	ENDURANCE	OTHER
Manta LE	3,3 m	6,6 m	Empty 70 kg MTOW 140 kg	12 h	V max 160 km/h
Manta VTOL	3,3 m	6,3 m	MTOW 115 kg	6 h	Zasięg 200 km
FT-5	3,1 m	6,4 m	Empty 55 kg MTOW 85 kg	12 h	V min 76 km/h V max 180 km/h

Source: Own study based on the manufacturer's data [10].

The Manta VTOL's vertical takeoff and landing plane would be most suitable for use on the ship. It is equipped with special fans enabling vertical takeoff and landing. The powerplant consists of two electric motors powered by batteries, which can also be powered from an on-board generator set powered by an internal combustion engine. Manta as well as the following reconnaissance sensors can carry: an EO/IR optoelectronic head with a rangefinder and a laser highlighter, a radioelectric recognition head, chemical, biological and radiological detecting heads, radar with a synthetic SAR aperture and other sensors as

LIDAR, AIS, NDVI. Another variation of the same airframe is Manta LE (Long Endurance) with extended range (flight endurance). It's a classic plane, which lands classically (for landing requires 150 m of space) using a three-point retractable gear. The maximum flight time of Manta LE has been extended to 12 hours, however, depriving the airframe of the possibility of vertical takeoff and landing. High-quality video data and telemetry data from on-board systems are transmitted to operator stations in real time by digital, encrypted radio lines [10].

Another type of UAV offered by this company is a twin-engine FT-5 Moose/Elk powered by a combustion engine. Its takeoff takes place using a specially designed mobile ramp. However, it needs 50 x 50 m field to land. Takeoff and landing are automatic. FT-5 is equipped with optoelectronic heads (for observation) as standard, light radio recognition systems and sensors for detecting contamination. Two cameras in the head (daylight and thermovision) allow observation of the terrain in two ranges of the band. Depending on the application, it is possible to modify the system equipment according to individual needs. The FT-5 has a useful weight of 30 kg of equipment and can take optoelectronic heads, COMINT/ELINT sensors, detecting detectors and weapons. Its equipment provides human detection from a distance of 5 km and recognition from a distance of 3 km. Four people are needed to serve it [10]. Manta VTOL could both take off and land on the ship. The FT-5 could take off from the ramp aboard the ship, but its landing must have to take place on land. Manta LE, on the other hand, would have to operate entirely from land, and could only be moved and served on the ship.



Fig. 6. The NSK/NSK-B UAVs control station built by WB Electronics [10]

All UAV types mentioned here can be controlled by a stationary or mobile NSK station offered by the same manufacturer. Integrated communication systems and own weather station provide situational awareness and connectivity with other sub-units in the field and higher levels of command. Communication with unmanned systems in real time is guaranteed by an external autonomous communication station. Heating and air-conditioning systems ensure operator comfort in all climatic conditions. Communication with unmanned systems in real time is guaranteed by an antenna mast with a height of 6 m integrated with the station. The integrated radio line permits the reach of communication range up to 180 km [10]. Such a station could be placed in the hold of the ship.

Another example of Polish UAVs that could be used on the barge come from Spartaqs firm from Katowice and are called "dronoids" by the manufacturer [11]. One of its main products is the UAV marked as OWL Vision, the multirotor built for tasks requiring long hours of hovering in the air. It has the possibility of practically unlimited endurance time (it is assumed that it should not exceed 10 hours) because the power supply can be supplied by a cable from a ground station equipped with a generator. OWL Vision is equipped with observation modules/sensors (infrared, camera with big zoom) and omnidirectional voice detecting device. OWL Vision is able to release the power cable and make a reconnaissance flight in the direction of the detected threat and return to the operator service area. This enables an independent power package. OWL Vision has a range of 2500 m and a useful load of 10.5 kg. Its construction is resistant to bad weather conditions (rain) [12].

Another interesting construction of this manufacturer is the Vector 4S multirotor, which has very original equipment, including testing and measuring equipment for air quality analysis, emission and pollution monitoring, high power LED spotlights for illuminating the terrain and a megaphone for voice messages. Vector 4S has a transmission range up to 10 km and flight duration (endurance) of up to 45 min. Another interesting construction of the Spartaqs company is the UAV Fire Fighter Drone constructed with the use of special materials with increased temperature resistance. With the help of its equipment, it is able to locate fire sources and analyse their spread. The ability to detect fire sites is especially useful when monitoring peat bogs, hard to reach green areas or when eliminating fires in the firefighting phase in large industrial areas. Its systems allow creating fire spread maps in real time. This UAV also has a chemical-pyrotechnical extinguishing charge, especially useful after detecting a fire source in the initial fire phase or during the extinguishing action [12].



Fig. 7. UAV Fire Fighting Drone designed by Spartaqs [12]

3. GEOGRAPHICAL CONDITIONS IN POLAND

Poland has favourable hydrogeological conditions for the development of inland water transport, although inland waterway transport has never been as developed in Poland as it is in Germany or some other western countries. It had a period of some prosperity in the communist era, but since the 1990s, there has been a degradation of its infrastructure in the country. The total length of waterways in Poland is about 3654 km, of which only a part of them have real transport importance at the beginning of the 21st century. Some useful value has been preserved in the Gliwicki Canal, the Upper Odra from Koźle to Brzeg Dolny, the Odra Dolna from Kostrzyn to Szczecin, the Western Odra, and the Lake District, Dąbie, Wisła from Bydgoszcz to Przegalina, Martwa Wisła, Nogat river, Szkarpawa, the Elbląg river and the Vistula Lagoon, the Vistula-Oder waterway on the section from Krzyż to Kostrzyn

a lot more equipment than a truck. However, the disadvantages include, first of all, low speed of inland vessels (usually 10-15 km/h), relatively poor condition of most Polish inland waterways and long periods when rivers are not navigable due to atmospheric conditions (especially in winter). In this matter, much depends on whether the programme of revitalization of inland waterways, currently announced by the Polish authorities, will be successful. In addition to the American helicopter MD-530, the article attempts to propose the equipment of the Polish constructions as much as possible. This applies to both Navicentrum 600 DWT, PZL SW-4 helicopter and light unmanned aerial vehicles, which have been designed and built in Poland. A similar barge could be developed in the air-medical configuration with a helicopter landing pad and a mobile hospital module. Such a ship could be useful during natural disasters and during mass events. However, this is a topic that deserves a separate study.

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