

The revival of the Wing-in-Ground craft and its potential for EU defence purposes

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Abstract— Wing-in-Ground (WIG) craft – a technology initially developed during the Cold War era – has recently regained attention for its potential applications in both the civilian and defence sectors. This paper is based on the research conducted within the research project SEAWINGS (Sea/Air Interphasic Wing-in-Ground Effect Autonomous Drones), funded by the European Commission under the European Defence Fund programme. The paper aims to raise awareness about this technology and its possible application for defence purposes within the European Union (EU). Preliminary information on the technology is provided in the initial part of the paper to illustrate to the reader the basic concepts behind this technology. The analysis then focuses on the European defence needs and priorities with a specific emphasis on Italy, Portugal and Spain, as the partners of the SEAWINGS consortium are established in these countries. The analysis is based on open-source documents and takes into consideration EU and national priorities, identifying those areas where the deployment of a WIG craft could be more relevant. It emerges that this technology represents a versatile instrument that could support several types of defence tasks and missions.

Keywords—defence, WIG craft, maritime domain, military doctrine, strategy, EU, technology

I. INTRODUCTION

Research on the Wing-in-Ground (WIG) crafts has emerged during the Cold War, when there was a strong interest – mostly on the Soviet Union's side – for the potential use of this technology in the context of the war. However, the enthusiasm for this innovation later started fading, mostly due to technical difficulties (e.g., aerodynamic instability), significant costs of the technology (especially for onboard sensors), lack of a clear regulatory framework and less strategic interest by the countries, a consequence of the improving relationship between West and East. The research was, hence, abandoned. Recently, the attention has risen again with different countries around the world studying how its benefits could be exploited. The renewed interest in this technology lays in multiple factors: innovation has progressed, thus allowing to reduce costs of sensors and other enabling technologies; the energy efficiency meets the need of a society increasingly focused on environmental solutions; its speed and manoeuvrability open opportunities for cheaper coastal transport, while its low detectability fits with new logistic military needs. This paper is based on the research activities conducted within the framework of project SEAWINGS (Sea/Air Interphasic Wing-in-Ground Effect Autonomous Drones), a research project funded under the

European Defence Fund (EDF). The aim is to raise awareness regarding this technology and its potential application in the defence sector. This paper takes into consideration some general technical aspects, while focusing on the key defence priorities at the European Union (EU) level to understand potential applications suitable for this category of assets. More specific information is provided for Italy, Portugal, and Spain – as the SEAWINGS consortium members are established in these three countries.

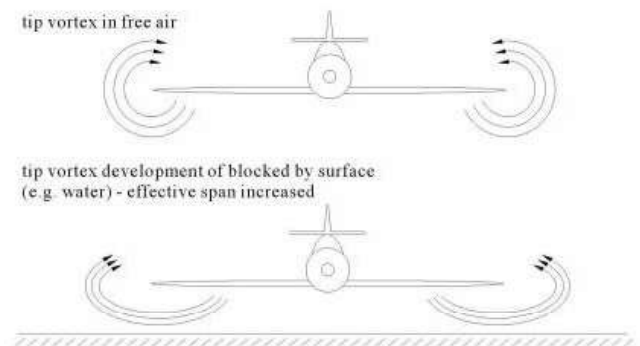
II. THE WIG TECHNOLOGY

A. Definition

According to the International Maritime Organisation (IMO), a WIG craft is a “*multimodal craft, which, in its main operational mode, flies by using ground effect above the water or some other surface, without constant contact with such a surface and supported in the air mainly, by an aerodynamic lift generated on a wing (wings), hull, or their parts, which are intended to utilize the ground effect action*” [1]. The critical factor, hence, is the exploitation of the ground effect, a phenomenon that occurs when the craft flies approximately one wingspan or less above the surface (either land or water) [2].

The ground effect is due to the presence of a boundary (i.e., the surface) below and near the wing. This surface compresses the flow under the wing, thus preventing its expansion as it would happen in free air (Fig. 1).

The boundary, indeed, interferes with the airflow patterns around the wing, reducing the wingtip vortices and downwash, hence decreasing induced drag and increasing lift). The closer to the surface, the more pronounced this effect



becomes (Fig. 2).

Fig. 1 – Tip vortices in free air and close to a surface [3]

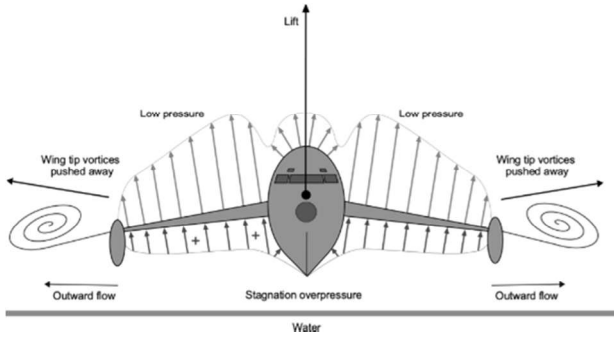


Fig. 2 - The Wing-in-Ground effect [4]

Consequently, the static pressure (surface pressure) under the wing rises, determining additional lift and thus improving the aerodynamic efficiency of the wing [5]. The increased lift combined with the reduced drag allows for faster acceleration, shorter take-off distances, and improved fuel efficiency [6].

However, this phenomenon can pose challenges in terms of longitudinal stability (due to the altered aerodynamics forces when operating close to the surface) [7] and performance, due to the sensitivity to surface conditions [8].

Within the context of the SEAWINGS project, strengths and weaknesses of this technology have been analysed in order to assess its potential role in the defence domain. Basic and applied research is performed to determine the most effective solution, based on the interests and needs of the EU Member States.

B. Types of craft

Different types of WIG crafts exist, which are characterised by diverse technical specifications and purpose of use. The IMO categorises WIG craft in three models:

- Type A – a craft certified for operation only in ground effect;
- Type B – a craft certified for main operation in ground effect and allowed to temporarily fly outside ground effect (but not exceeding 150m above the surface) in case of emergency or to avoid obstacles;
- Type C – a craft certified for the same operation as type B but exceeding 150m above the surface.

Type A and B WIG crafts are regulated by IMO, while type C are regulated by the International Civil Aviation Organisation (ICAO) [1]. The three types have increasing size and endurance, which make them suitable for different uses. Smaller versions (type A) can be used for surveillance, and communication relay as well as interception; type B are suitable for maritime transportation across coastal or island regions, search and rescue or amphibious operations; the capacity of type C allows for cargo operations, humanitarian support or troops and vehicles transport.

The SEAWINGS project looks at the exploitation of ground effect on water and takes into consideration all types of WIG craft with the purpose of identifying the one that could be more appropriate for the needs and requirements of the EU armed forces. The constant interaction with the representatives from the consortium countries (Italy, Portugal, and Spain) together with the involvement of other EU Member States helps to ensure the final solution will be able to meet such requirements.

C. Historical examples

The WIG craft is not a new technology. Research on this asset dates back to the Cold War with several projects conducted mostly by the Soviet Union. One of the most famous is the Caspian Sea Monster (Alekseev A-90), a WIG craft developed by Rostislav Alexeyev that has earned this appellation for its dimensions: 37.6m wingspan and 92.3m length, able to accommodate 900 marines and to fly at a maximum speed of 300 knots between 4 and 14m high. The craft was tested in real environment for fifteen years but never entered into service [9]. However, its studies represented the foundation for another vehicle, the Lun-Class Ekranoplan, which was the only WIG vehicle to become operational as part of the Soviet Navy, specifically the Caspian Flotilla [9]. Research on this technology was conducted also in Germany, where Alexander Lippisch developed the Lippisch X-113 model, although failing to break into the market [10].

As mentioned earlier, the WIG craft showed some weaknesses: technical limitations and budget considerations led to abandon research on this technology. However, in the past few years, the technological progress and the urgency of environmental-friendly technologies have brought new attention on the WIG craft and its potential application across multiple sectors.

III. COMPARISON BETWEEN WIG CRAFT AND OTHER CONVENTIONAL PLATFORMS

Ground effect allows a flying vehicle to move with an extra lift and a reduced aerodynamic drag, therefore improving dramatically its efficiency, performance and autonomy. WIG crafts can operate with significantly less energy consumption: estimations point at a 50% more of payload, spending 35% less energy than a similar size aircraft, and a 75% less energy than a similar size hydrofoil ferry [11]. In addition, a WIG craft can move over the sea or land and can operate in harsh weather conditions, while flying over hills.

Some information is available from Russian and Chinese sources on the capabilities of such craft. In particular, Chinese military analysts have highlighted the generic advantages of WIG crafts over other conventional ships and aircrafts [12]:

- Superb mobility. Due to the ground effect WIG craft can reach between 300 and 400 knots. Warships can move at 30 to 40 knots, hydrofoils can reach 80 knots.
- Economical operation. Only between 80 and 130 HP are required to move one ton, with less fuel consumption and more autonomy than a similar plane.
- Convenient maintenance. WIG crafts do not need permanent shore bases, cranes, chutes, or aprons, like hovercrafts.
- Diverse flight modes. WIG crafts can fly over any flat surface, as water, beaches, deserts, glaciers, grasslands and so on.

The table below summarises the key advantages of the WIG craft compared to other types of vehicles.

Table 1 - WIG craft compared to other conventional assets¹

Vehicle	Autonomy	Payload	Speed	Interaction	Sea Conditions	Wind
Fixed Wing UAV	+++	+	+++	-	+++	+
Rotary Wing UAV	--	--	+	+	+++	-
Surface Vehicles	+	+++	-	+++	-	++
Underwater Vehicles	+	++	-	+++	+++	+++
Autonomous WIGs	+++	+++	+++	+++	+++	+++

UAVs, both rotary and fixed wings, can reach the same areas as a WIG craft. However, a WIG craft is more energy efficient, hence its operational range is more extended and they carry much more payload than a rotary wing UAV. A WIG craft is less prone to catastrophic accidents as it is able to land on the water surface and keep floating indefinitely if an emergency condition is detected. WIG crafts can reach the same locations with a much better energy efficiency compared to USVs (Unmanned Surface Vehicles), as they are not operating under hydrodynamic charges. Moreover, WIG crafts can move at much higher speeds, making them much more suitable for fast response operations. Clearly, this is a general perspective: the advantage of the WIG craft over other conventional systems might be more relevant for some applications while less significant for others. Hence, this information must be complemented with the specific features of the WIG craft (type A, B, or C) and the task or mission these assets are expected to complete.

IV. WIG CRAFTS AND THEIR POTENTIAL APPLICATIONS

Several studies recognise the potential benefits behind the use of WIG crafts. Technological progress has allowed to overcome some technical limitations and improve performance in terms of manoeuvring, autonomy and on-board sensors. In addition, the reduced emissions and energy efficiency of WIG assets have contributed to increase the attention towards this category of systems, thus offering a new means that could support the environmental causes and contribute to achieve the target of 50% reduction in the carbon footprint of maritime transport and the goal of climate neutrality by 2050, as set by EU and IMO [13] [14].

Several countries are working on this technology, considering its use both for civilian and defence tasks. Singapore has produced Airfish8, designed for maritime transport and expected to entry into market by 2025 [15]. The Republic of Korea has invested in the WSH-500, a WIG craft type A for passengers' transport [16]. Iran has produced a "radar-evading" fixed-wing WIG craft, which has been delivered to the navy fleet [17]. In the United States, the Defence Advanced Research Project Agency (DARPA) has declared its interest in this technology with the Liberty Lifter program aiming to design a vehicle able to support fast logistic missions, sea-based Search and Rescue (SAR) and disaster response [18].

The SEAWINGS project confirms the increasing interest towards the WIG technology and aims to identify its usefulness for defence purposes. The research takes into consideration the defence strategic priorities at the EU level and the need to reduce duplication of efforts in the defence

sector, thus aiming to provide a system that could be deployed for multiple purposes and across the EU Member States.

To achieve this goal, the project combines different types of activities, such as basic and applied research, desk research and interaction with the end-users (e.g., Member States navies). Given the confidentiality and sensitiveness of the information retrieved, this paper only provides an overview of the defence priorities – as emerged from literature review – and indicate possible applications for the system, taking into account the diverse types (A, B, and C). It should be noted that, at the time of writing (May 2025), the consortium has already identified the type of system that could be more relevant for the European Navies on a cost-benefit scale and considering the interoperability with existing assets.

A. EU defence priorities

The security challenges for the EU have increased in the past 20 years, opening up multiple threat scenarios and a wide range of actors involved. Terrorism, geopolitical rivalry, territorial aggressions, cyberattacks, and proliferation of new weapons are just some examples of the security threats – sponsored by both state and non-state actors – that characterise the current landscape. This changing environment calls for the need to implement proactive strategies and be equipped with a *full range of military capabilities* able to address the different nature of such threats [19, 20].

It is clear the Union's intention to affirm its role as a global security provider. Consequently, given its geographical nature – a continental area surrounded by sea on three sides – it becomes paramount to strengthen the maritime posture, thus being able to face the diverse challenges that may arise in different locations. It should also be considered that besides the defence of the external borders, the Union is also committed to protect the interests of its Member States beyond the borders, contributing to international peace and security [20]. The civilian and military missions conducted under the Common Security and Defence Policy (CSDP), indeed, show a consistent EU commitment around the globe: around 3,500 military personnel and 1,300 civilian personnel are deployed in East Europe, Africa and the MENA (Middle East and North Africa) region [21].

The complexity and evolving nature of the threats faced in all these regions require the availability of adequate defence capabilities: acknowledging the need to keep pace to the mutating security challenges, the EU countries have introduced the Capability Development Plan (CDP), a comprehensive planning method to address the EU long-term security and defence challenges, initially launched in 2008 and regularly updated since then. The latest version (November 2023) [22] presents 22 priorities – 14 are specific for a domain (land, air, sea, space, and cyber) and 8 considered as strategic enablers and force multipliers. As it will be explained in the next section, SEAWINGS could offer a technology able to meet some of the priorities identified in the CDP, mostly related to the maritime domain (e.g., marine domain awareness or underwater and seabed warfare), the air domain (e.g., air transport) and strategic enablers (e.g., logistics, medical support, or critical infrastructure protection).

¹¹¹ Sources: [35], [36], [37], and other cited.

B. The cases of Italy, Portugal, and Spain

Besides the European perspective, it was relevant for the purpose of the project, to analyse the peculiar needs of the three countries where the SEAWINGS consortium partners are located, namely Italy, Portugal, and Spain. The initial interactions, indeed, were conducted with the Navies of these countries to narrow the range of possible assets that could have been more appealing to procure based on their national defence priorities, operational needs and existing acquisition plans. This process was necessary to agree on the key features of the system. This section, hence, illustrates the maritime defence priorities of the three selected countries that have been used – together with the inputs from the end-users that are not disclosed in this paper – to define the technical specification of the SEAWINGS WIG craft.

a) *Italy*. Italian maritime defence priorities focus on enhancing surveillance and situational awareness in the Mediterranean – specifically the Adriatic and Tyrrhenian Seas – and North Africa, strongly affected by threats like trafficking, migration, piracy and smuggling. Furthermore, the Mediterranean Sea is home of critical underwater infrastructures, such as communication cables and energy pipelines that require to be monitored and protected. Similarly, the securisation of key maritime routes and offshore energy infrastructures (e.g., Tap, Greenstream and Transmed for Italy's gas supply) is paramount [23]. Italy is also strongly committed in critical regions, such as the Gulf of Guinea, the Baltic Sea, the Arctic and Indian Oceans, with the objective of safeguarding national and allied interests. Italy, hence, actively participates in international joint operations such as Neptune Strike [24]. It is worth mentioning that defence investments have been directed towards unmanned systems, robotics and Arctic operational readiness, alongside traditional land and naval force enhancement [25, 26].

b) *Portugal*. Portugal's maritime strategy emphasises border and external defence, monitoring of its vast Exclusive Economic Zone (EEZ) and securisation of vital Atlantic sea lanes. The geographical position makes the country a strategic bridge between Europe, the Atlantic and the Lusophone area (i.e., Portuguese-speaking territories), contributing to maintain peace and stability also through regional partnerships. The country is also strongly committed to climate resilience and environmental sustainability, thus promoting maritime biotechnologies and integrating eco-friendly technologies and emission reductions into naval operations [27, 28]. In terms of technologies, Portugal is bolstering the integration of Unmanned Vehicles (UxVs) into its maritime strategy, promoting initiatives such as the REPMUS (Robotic Experimentation and Prototyping with Maritime Unmanned Systems) [29].

c) *Spain*. The Spanish approach to maritime security combines technological modernisation, strategic asset development, and multilateral collaboration with the EU and NATO. Key priorities include ensuring freedom of navigation, while safeguarding strategic maritime routes that are crucial for national stability, such as the key corridors that link Europe to Africa, the Mediterranean Sea to the Atlantic Ocean and the Americas, as well as the Balearic-Strait-Canary Axis. Similarly to Italy and Portugal, Spain has a strategic geographical position that allows to bridge different

countries and regions, while contributing to trade, energy supply and deployment of military operations [30, 31]. Spain is also committed to the protection of human lives at sea and of critical maritime infrastructures, such as ports, energy terminals and underwater cables. Strong attention is also devoted to environmental threats, including pollution and natural or man-made disasters, requiring preparedness, prompt reaction and logistic support. The integration of unmanned systems in warships, especially in multi-purpose assets is paramount: they role, indeed, is pivotal for real-time monitoring of vast areas, thus being able to support multiple types of Navy's missions and tasks [30].

Italy, Portugal, and Spain share several priorities in their maritime strategies, also reflecting a collaborative approach in security and defence. Key strategic areas include surveillance and deterrence, protection of critical infrastructures, and border control and countering of illegal activities. The engagement in multilateral and collective operations is also a cornerstone.

C. Defence priorities relevant for WIG crafts

Based on the general EU perspective and the maritime strategies and interests of Italy, Portugal, and Spain, it is possible to identify some common defence priorities. To assess the potential role of the WIG craft to accomplish these goals, each priority has been associated with related types of activities that could be performed using a WIG craft.

a) *Improved maritime awareness and information superiority*: it encompasses improving monitoring of waters and information sharing across the EU to ensure a comprehensive understanding of the maritime environment that could help securing the external border while guaranteeing freedom of navigation and protection of marine resources [32]. This priority includes the implementation of multiple activities, such as Intelligence, Surveillance, and Reconnaissance (ISR), SAR, monitoring and patrolling, anti-piracy and smuggling (including interdiction). Based on its type and configuration, a WIG craft could support several tasks: a small to medium asset could be used for intelligence gathering and patrol of vast areas, while bigger versions could be deployed for SAR and recovery of assets.

b) *Maritime interdiction, Anti-submarine and Anti-surface warfare (ASW and ASuW) capabilities to protect maritime routes and critical infrastructures*: being at the cross-road between Asia, Africa, and the Americas, the EU has the vital role of protecting the maritime routes that connect these territories against all the different and fast-emerging challenges and threats. Similarly, the wide range of critical infrastructures, including underwater cables, oil and gas pipelines, wind turbines and offshore platforms, that crosses international and national waters has to be protected, as it represents a vital element for the continent's security and prosperity and it is also a potential target of malicious actors. To defend maritime routes and critical infrastructures, it is necessary to monitor large areas (e.g., conducting ISR activities) and be able to intervene in case of threats, thus meaning escorting vessels and having ASuW and ASW capabilities. In addition, it is vital to guarantee logistic support, e.g., for the supply of spare parts offshore. A WIG craft could be deployed in different configurations, ranging

from smaller versions for intelligence gathering or ASuW/ASW to those with greater payload for logistics (see also point *c*). A small to medium version of a WIG craft could be deployed from a landing helicopter dock (LHD) – or similar asset – to monitor sea routes and collect intelligence, escort vessels on unsafe routes, and counter potential attacks from the surface and underwater.

c) Logistics and military mobility: military operations needs a strong logistic support that would guarantee the sustainability of the operations even in severe conditions. Likewise, military mobility is an essential enabler as it ensures efficient movements of personnel, assets and resources. Considering the maritime domain, the ability of military forces to deploy, move, and recover assets and personnel across vast areas is critical in order to permit its power projection in strategic areas. A small to medium version of the WIG craft could be exploited for transportation of goods, material and supplies to a military theatres as well as spare parts. A bigger version (type C) could be employed for transferring troops and armaments, thus representing a valuable support, for instance, to amphibious operations.

d) Disaster management and crisis response: the ability to prevent an address disasters and crisis events from happening are critical. ISR activities can help monitoring and early reaction, while SAR and logistics support can ensure rapid intervention. In this context, a WIG craft could be used for patrolling and ISR. Bigger versions could be deployed for SAR or delivering of goods and evacuation.

These examples show the versatility of this technology. The interest of a single country in a specific configuration of the craft might be influenced by budget constraints and the interoperability with existing naval assets. In the SEAWINGS project, the surface naval assets of the three countries have been thoroughly analysed to assess the interoperability of a future WIG craft and helped to identify the most attractive configuration for the naval forces.

V. CONCLUSIONS

The undeniable consequences of climate change, the need to promote environmental-friendly technologies, the urgency to optimize defence assets across the EU are all factors that have brought greater attention towards versatile solutions able to accomplish multiple tasks while reducing costs and carbon footprint. The WIG craft could represent a valuable candidate to achieve this goal. Research shows the environmental benefits of this technology, which allows to reduce emission and be energy-efficient by relying on ground effect (on land and water). As mentioned in Section III, several countries (e.g., Singapore, the Republic of South Korea, the United States, and Iran) are working again on this technology, recognising its potential for applications both in the civilian and military domain.

The SEAWINGS project explores the potential application of this technology for defence purposes in the European Union, starting from the cooperation among three maritime countries, namely Italy, Portugal, and Spain. The research conducted within the project has allowed to identify different areas where this technology could potentially be employed to meet defence priorities. These priorities include improved maritime awareness and information superiority, maritime interdiction and ASW/ASuW capabilities for the

protection of maritime routes and critical infrastructures, logistics and military mobility, and disaster management.

A WIG craft can be designed in different versions and dimensions. Smaller solutions can support ISR activities; medium size configurations can perform search and rescue activities and support logistic tasks; big size configurations are more adapted for troops or armament transport. The usefulness of this solution is clearly influenced by defence priorities, budget considerations and the interoperability with existing naval assets, etc. The SEAWINGS consortium has closely interacted with the representatives of the Italian, Portuguese, and Spanish Navies to ensure the final solution of the project will indicate an asset useful and usable by these services, thus paving the way for its development in the future. For reason of confidentiality, this paper does not include the final specifications of the system and the specific use that has been assessed as more critical for these countries.

ACKNOWLEDGMENT

This paper describes part of the research carried out by Zanasi and Partners in the SEAWINGS project, funded by the European Union under the European Defence Fund (EDF) programme between 2023 and 2026, under Grant Agreement No. 101102763. The information contained in this paper is based exclusively on open-source documents and do not include any additional information emerged from interactions with the representatives of the armed forces of Italy, Portugal, and Spain occurred during the project's implementation. Views and opinions expressed are however those of the author only and do not necessarily reflect those of the European Union or EDF. Neither the European Union nor EDF can be held responsible for them.

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