

BULGARIAN LIGHTHOUSES: REGULATORY, TECHNICAL, AND VISUAL CONSIDERATIONS IN DRONE DOCUMENTING OF MARITIME HERITAGE

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Abstract: *This study presents the authors' contribution to the aerial digitalized documentation of the lighthouses along the Bulgarian Black Sea Coast, undertaken within the Nasledstvo BG project in the summer of 2023. As certified drone pilots, the authors carried out systematic aerial photography and videography of all coastal lighthouse sites. The paper examines the applicable regulatory framework at the intersection of aviation and maritime administration, including certification requirements and granting of permissions imposed by national authorities. Technical aspects such as aircraft characteristics and equipment, meteorological specifics, and coastal geographical constraints are evaluated alongside human factors affecting flight safety. Particular attention is given to empirical strategies for documentary accuracy and aesthetic value, addressing light conditions, task-specific considerations, and artistic approaches in different visual contexts. This paper can be used as a manual, providing explicit information to aerial researchers regarding the operational specifics of the sites studied by the authors during the Nasledstvo BG project. The results highlight the authors' contribution to a safe, efficient, and high-quality drone-assisted digitalization of maritime cultural heritage.*

Keywords: *lighthouses; unmanned aircraft systems (UAS); drone photography; maritime heritage; Nasledstvo BG project*

INTRODUCTION

Direct digitization of architectural artifacts serves as an indispensable tool for cultural heritage preservation by enabling the creation of high-fidelity digital databases that optimize systemic analysis, dissemination, and asset management (Calisi, Botta, Cannata, 2023).

Completing a visual documenting task from the air is subject to several types of considerations – technical, regulatory, and visual. At their intersection, a particular flight plan can be set and put to execution, always accounting for the variation in time of some predominant factors: flying of other aircrafts in the zone, meteorological conditions, and light characteristics in the case of photogrammetry, photographic or cinematic footage. For coastal flights even more factors affect the success of drone operations.

The authors have contributed to the digitalization of maritime heritage within the project Nasledstvo BG with video-recordings and photographs from the air of all lighthouses along the Bulgarian Black Sea Coast. The paper outlines the main constraints in terms of authorizations, landscape, weather, light, and other parties on the premises, that are to be accounted for in order to assure safe and effective flights resulting in high quality digital documentary data and valuable aesthetic material.

RESEARCH METHODOLOGY

The general frame for operating unmanned aircraft systems (UAS) over the territory of Bulgaria is set according to the actual normative documents of the country's Directorate General "Civil Aviation Administration" (DG CAA). In the particular case of drone flights for visual documenting of lighthouses, access regulations are applied by the Hydrographic Service of the Bulgarian Navy (BNHS) under the Ministry of Defense.

All considerations on camera footage from the air of the lighthouses along the Bulgarian Black Sea Coast have been deducted from the authors' practical on-site experience while photographing and video-recording them with a DJI Mavic Air 2 S drone in the summer of 2023, as a particular task within the project Nasledstvo BG (Heritage BG). Following a contest selection by Sofia University "St. Kliment Ohridski", both authors have been hired as certified professional drone pilots to work on the digitalization of Bulgarian natural and cultural heritage for the project from 2021 to 2023.

Regulatory Considerations

For the execution of any flight – piloted or unmanned alike, several prior conditions have to be fulfilled regarding the certification of pilots, registering of operators and appropriateness of aircrafts. For Bulgaria, as one of the EU member states, the regulatory considerations are governed by the Rules for Unmanned Aircraft Systems (Regulations, 2019). Another crucial requirement before flying a drone over the territory of a particular country, is the acquisition, as per the respective State's procedures, of all the necessary permissions applicable to controlled flight zones, specific tasks, particular events or exceptional circumstances.

Categories of Civil Drone Operations

According to the regulatory documents, in force for Bulgaria as part of EU, the categories of drone operation (Operating a drone: categories, n.d.) are divided according to the risk level into: open, specific and certified. The 'open' category, which presents the lowest risk, is subdivided into: A1, A2, A3. The 'specific' category implies obtaining an authorization from the national competent authority before starting the operation. The 'certified' category caters for the operations with the highest level of risk.

Certification of Drone Pilots and Drone Operators

From the regulatory perspective and in terms of responsibility, there is a significant difference between the pilot who actually flies a drone and the operator who owns or rents UAS (Drone operators & pilots, n.d.).

Drone pilot certification for A1/A3, as well as for A2 categories is obtained following online trainings and upon online exams, with additional on-site assessment for A2 (W-Tesla 3X, n.d.). Drone pilot certification for Standard Scenarios (STS) enables operations in the 'specific' category, still upon submitting written requests presenting risk assessment and risk reducing plans.

Drone operators register themselves in the State where they have their residence for natural persons or where they have their principal place of business for

legal persons (UAS Operator Registration, n.d.). They receive a registration ID number from their State's Aviation authority, which has to be visibly shown on any UAS the operator owns and eventually rents.

Restricted Zones and Special Events

Drone flying areas, known as geo-zones, are classified as open (allowed), restricted (conditional), or excluded (prohibited). The different levels of restriction aim to protect people, critical infrastructure, airports and other aircrafts (Geo-Zones, n.d.). Every country's Aviation Authority can apply permanent or temporary restrictions and should make them accessible via interactive charts, downloadable files or other online means (Zone map DG CAA, n.d.). The DG CAA in Bulgaria defines two main types of zones – safety (blue) zone where flights are limited by height and security (red) where flights are subject to authorization upon written request (Request UAS, n.d.). Any operation in the red zones of the map falls within the 'specific' category. On the same map appear the NOTAM notifications for temporarily reserved or restricted zones. Other state services, ministries or departments, as well as some private entities like huge industrial plants might be entitled to grant or deny official authorization for flying over some areas or structures, even if those are not within DG CAA's restrictions. Moreover, UAS pilots are often constrained to consider additional limitations proper to the main drone producer brands (Zone map DJI, n.d.).

There are also regulations applying on the reserving of airspace for specific operations or major events with higher risk – massive gatherings of people at sport or concert performances, organized military activities, industrial plants, documenting natural disasters, etc.

Technical Considerations

Among the technical considerations, the type of aircraft used and the additional equipment it carries depend on the particular task and the results to be achieved. The meteorological conditions play a crucial role in the planning and execution of any manned or unmanned flight. Of course, some climate properties derive directly from geography. Other parameters, specific to it, like landscape, flora and fauna also influence drone operation.

Types of Aircrafts and Additional Equipment

In the previous century most aerial photos and videos were performed from piloted small airplanes or motorized delta gliders. Nowadays, unmanned aircraft systems are the safest method, most facilitated technically and with highest cost-effectiveness when it comes to documenting landscape, architecture or events from the air. Drones can differ in type and characteristics, as well as carry a variety of equipment depending on the task and the conditions where it is performed.

For long distance operation, some special drones have a power supply optical cord from land, but for documenting at remote locations it is much more common and feasible to use commercial drones with high-capacity batteries. Unmanned flights in extreme conditions would be easier and safer when performed by heavier aircrafts with powerful motors for better control. Photogrammetry, geo-refer-

enced data collecting, thermal, infrared or LIDAR camera recordings imply the use of drones specifically designed for those tasks or carrying the respective additional equipment which increases the overall weight of the UAS.

Meteorological Specificities

Every piloted or unmanned aircraft flight should closely consider the meteorological conditions in the planned zone of the task, as well as in the imminent surroundings. Forecast websites and on-site assessment of the conditions are crucial for the success and safety of drone operations.

The most typical weather characteristics for the sea shore areas are: unexpected powerful and even gale force gusts of wind, morning and evening sea breeze, dense and quickly moving mists, damp and excessively corrosive salty air. Due to the high humidity, abrupt temperature changes over the limit between land and water can increase the risk of hoarfrost or icing on the drones' propellers.

Geographical factors

In the particular case of coastal drone flights, the main factors to be accounted for are: excessive humidity, waves and splashes of salty water, sea froth and water drops carried by the wind to unexpected distances and heights, signal reflections from the sea surface often perturbing the drone's navigation sensors when flying low over the water. Abrupt changes of wind close to cliffs or big buildings cause turbulence and increase the risk of crash or loss of control, especially in the case of very light drones.

Birds, especially when in flocks or during the nesting periods, are always a major concern for drone pilots. In urban areas, flocks of pigeons show organized territorial behavior and could attack and damage drones. Along the sea coast, seagulls are the major threat as their bigger size and strength add to the risk for a flying drone, moreover while nesting, when they become extremely aggressive. Protected bird species in protected natural areas should not be disturbed, as an accident involving them could be considered a crime. Birds of prey, especially the very large species, can cause important damage to heavy drones or even involve danger for the pilot.

Human impact – pilot experience, other drone operating parties in the flight zone, individuals and crowds of bystanders

Many human factors have strong impact on drone operation, whereas crucial are the pilot's experience and adequate judgement of all dynamic conditions. Increased danger is associated with newly certified individuals without enough flight hours, not fully familiar with their equipment and misjudging the surrounding. Even for professionals, to reduce risk, it is recommended to use observers for complicated tasks, extreme weather, crowded areas, operations subject to authorization or under the 'specific' category. Another compulsory safety measure is to inform any groups of people in the flight area, so they are aware not to interfere with the drone operations. This becomes of primary importance in high touristic season, at popular spots, within crowded times of the day, which was the case at many of the lighthouse locations during the authors' project.

Visual Considerations

Visual documenting from the air would require different approach, specific equipment, particular pilot technique and skill according to the type of task performed and depending on the actual light conditions.

Types of Visual Documentation Tasks

Based upon the planned task and the additional tools carried by the drone for its completion, several types of operations can be distinguished.

Regular amateur flights using the drone's incorporated camera for footage normally do not require any specific additional certification, equipment or skills. The resulting photos and videos are suitable for personal archives, publications online, non-commercial presentations, even basic advertisement and other marketable visual products.

Professional flights accomplish more complex visual operation and have to comply with more light-related factors. While terrestrial photogrammetry often introduces perspective distortions and occlusions caused by architectural features on elevated vertical facades, UAS-assisted imaging circumvents these ground-based spatial limitations to deliver high-fidelity, comprehensive orthophotographic documentation critical for structural preservation. (Adami, Fregonese, Gallo, Helder, Pepe, Treccani, 2019) For photogrammetry tasks, only the times around noon would be suitable, to avoid the lack of detail of the half dark surfaces in the morning and evening hours. Likewise, in the case of documentary photography and videography flights, focused on contrast and discernibility of details, for the benefit of architecture and archiving, midday times would offer best results. Getting closer to the structures would allow for more data at high resolution, whereas the pilots have to show extra care to avoid incidents, risk for the equipment, and endangering the heritage items or any third parties on the premises.

When professional footage for the cinema takes place, often preferences would go for the artistic approaches like taking advantage of the golden hour, shooting at sunset and sunrise, against the sun or accentuating shadows. Uncommon framing and angles, sometimes involving higher risk for the drone could be justified as part of the aesthetic concept. High flying speeds, getting too close to unmoving or moving objects and people, as well as air acrobatics would increase the cinematographic value of the resulting movie. In such cases, heavy professional cameras might be replaced by high quality FPV drones offering increased resolution for video-recording.

Light Specifics and Dynamics

Light conditions play a crucial role in every photographic or video recording operation, moreover – when performed in the air. In the particular case of coastal flights over the water, due to reflections, the mutual position of sea surface and sun has a decisive impact on composition, framing, angle and parameters' setting. When flying over water, it is a common optical illusion that the drone is high, while it is too close to the surface and might get drowned. Strong reflections from water surface might trick the camera as if instead of light, there is a physical obstacle in front. Mist and excessive humidity could alter the quality of recorded material, especially very

close to the water. Over important distances, the absence of any objects on the sea surface would result in lack of perspective and depth.

Video and Photo Documenting of the Bulgarian Lighthouses as part of the Nasledstvo BG Project

The lighthouses of the Bulgarian Black Sea coast have been photographed and video-recorded in the summer of 2023, as part of the authors' participation in the project "Creation and development of "Heritage BG" Centre of Excellence" (Nasledstvo BG, 2018). The project is focused on digitalization of natural and cultural heritage items within Bulgaria and all its archive will be available free for educational and non-profit purposes on the project's website, once it is launched and open for general public access.

In the particular case of the Bulgarian lighthouses, feasibility of the drone flights to document them depends on the intersection of two sets of regulations – those of DG CAA and the ones of BNHS, as this is the authority granting access to the lighthouses located on military grounds (Hydrographic Service, n.d.). For such a complex aerial visual documentary project with dozens of restricted locations and publicly inaccessible structures, taking into account the reasonable aforesaid of weather forecasts, it is crucial to secure operational flexibility. It means to obtain authorization for duplicated flights, standby timeslots as well as to be provided with direct contact to the persons in charge for some of the Military Units with lighthouses on their premises.

Some of the lighthouses are outside of the red zones on the access map (Fig.1). In this case, the actual flights are authorized by BNHS via DG CAA, therefore those structures still have to be listed in the drone operation request. Additional regulatory considerations might concern specific zones or conditions, which applies for Evxinograd lighthouse, as access to it is granted by the National Service for Protection (NSP) of the Ministry of Internal Affairs. Thus, it was necessary to resubmit the request, because during the summer holiday months Evxinograd functions as Government residence with any drone operation at or around the premises being forbidden (Fig. 2).

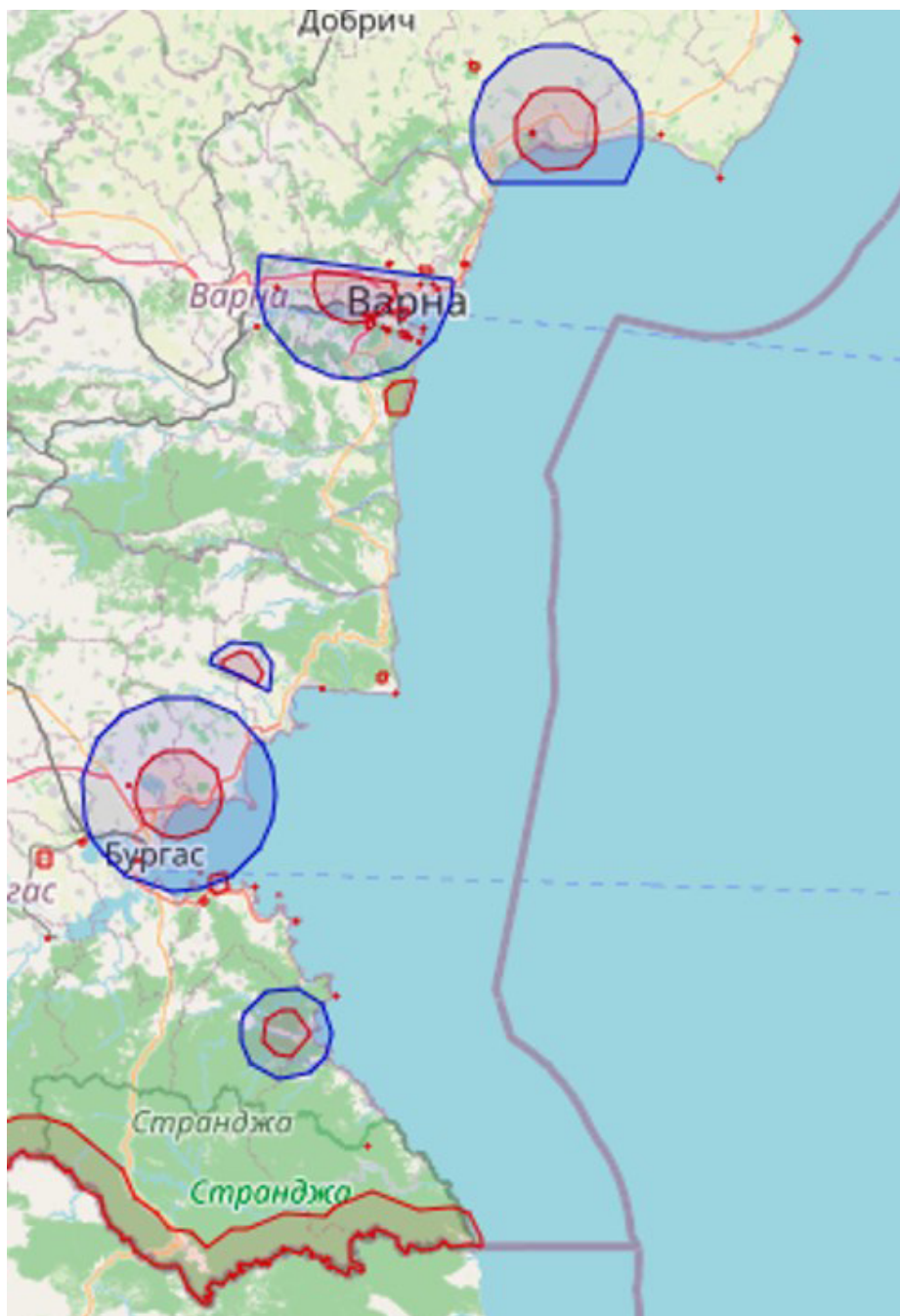


Fig. 1. General view of the DG CAA map for the Black Sea coast of Bulgaria with the two main types of zones – safety (blue) zone where flights are limited by height and security (red) where flights are subject to authorization upon written request.

A major geographical consideration along the Bulgarian Black Sea Coast is the sea lying east of the shore at most locations. This excluded the early morning hours for visual documenting, in order to avoid flying far over the water for securing clear contrast views of the towers. Lighthouses being normally thin tall structures, the best time frame for photos or videos would be around noon, unless half dark towers with elongated shadows are a desired artistic effect.

ЗАЯВЛЕНИЕ ЗА ИЗВЪРШВАНЕ НА ПОЛЕТИ С БЛС В ЗАБРАНЕНИ/ОГРАНИЧЕНИ ЗОНИ ИЛИ ЗА РЕЗЕРВИРАНЕ НА ВЪЗДУШНО ПРОСТРАНСТВО ЗА ОПЕРАЦИИ С БЛС <i>Application for conducting flights with UAS in forbidden/restricted zones or reservation of airspace</i>		
Отдел ВПТС Главна Дирекция „Гражданска въздухоплавателна администрация“ тел.: +359 (2) 937 1007; имейл: uas@caa.bg		Airspace & SAR Department Civil Aviation Administration Directorate General tel.: +359 (2) 937 1007; e-mail: uas@caa.bg
1	Моля, да бъде разрешено / I kindly request to: ☒ извършване на полети с безпилотна летателна система (БЛС) в зона/и / <i>conduct flights with unmanned aircraft system (UAS) in the following zone(s)</i> ☐ резервиране на въздушно пространство за извършване на полети с БЛС / <i>reserve an airspace to conduct flights with UAS</i>	
2	Цел/описание на дейността <i>Purpose/description of the UAS operation</i>	
2.1	Кратко описание на дейността <i>Short description of the UAS operation</i>	Заснемане на морски фарове (фарови кули) по проект BG05M2OP001-1.001-0001 „Изграждане и развитие на център за върхови постижения „Наследство БГ“, финансиран по Оперативна програма „Наука и образование за интелигентен растеж“ 2014-2020, приоритетна ос 1 „Научни изследвания и технологично развитие“, съфинансирана от Европейския съюз чрез Европейския фонд за регионално развитие (ЕФРР)*.
2.2	Категория експлоатация на БЛС <i>Category of UAS operation</i>	Неограничена / Open ☒ A1 или ☒ A2 или ☒ A3 Специфична / Specific ☐ A0 или ☐ LUC
3	Район за провеждане на полети с БЛС <i>The area of UAS operation</i>	
3.1	Кръг/ове с радиус в метри и център на кръга с координати в WGS-84 <i>(A) circle(s) with radius in meters and center with coordinates in WGS 84</i>	R= 100 m, 43°13' N 27°59.3' E
3.2	ПолYGON/и с координати в WGS-84 <i>(A) Polygon(s) with coordinates in WGS 84</i>	№ 1: № 2:
4	Височина на полетите <i>Height of UAS operation</i>	
4.1	Максимална височина на полета (над земята) <i>Max height (above the ground level)</i>	50 m

Fig. 2. The second request to receive authorization for drone flights around Evxinograd lighthouse.

The aerial documentary task has been performed in the summer months of 2023, by the flight crew consisting of both authors, using a DJI Mavic Air 2 S drone. Both pilots being A1/A3 certified, this allowed them to perform without restraint all flights under the 'open' category, whereas submitting a written request was compulsory to authorize the operations for the locations in the red zones of the DG CAA map and for other restricted areas – military units, government residence, industrial port grounds. Flight plans were set according to a tight program, accounting for the weather forecast and scheduled to cover all lighthouses of the Bulgarian Black Sea Coast within a limited timeframe. Durations and timeslots of the drone flights at each location were determined depending on light conditions and the type of task – visual documentary. If photogrammetry was to be performed, hours around noon would have been best and several times longer operation would have been requested (Benova, Nachev, 2021).

Challenging weather conditions at some locations affected the flights' length and pattern, thus predetermining the quality and exhaustiveness of video footage. Of course, in the meanwhile technology has evolved considerably in terms of flight duration as per battery capacity, performance in strong wind, resistance to signal disturbances, as well as video and photo quality.

Each lighthouse tower and location along the Bulgarian Black Sea Coast has different particularities to be observed when flying a drone for photo or video documentary purposes. The predominant regulatory, meteorological, landscape and light considerations denoted by the authors during the operation are specified for every lighthouse location according the following criteria: flight map color zone; type of area; access granting authority; strength of wind, including canceled flights; risk from sea froth or waves; impact on the flight by proximity of steep cliffs, crowds of bystanders, danger from birds; best time of day for footage – AM, noon, PM (Fig. 3). Those summarized observations are followed by aerial photos (Fig. 4-11) from the authors' archive for every documented structure. For the lighthouses where flights had to be canceled for safety reasons, land photographs show the towers (Fig. 4.c,d, e; Fig. 5.c,e). Moreover, images of previous structures at some locations (Benova, 2020) are given for comparison (Fig. 4.d, e; Fig. 7.b; Fig. 10.c; Fig. 11.b)

lighthouse / location	zone	area type	authorisation	wind	sea waves	cliffs	people	birds	best light
Shabla		military unit	DG CAA	**			*		AM
Kaliakra		military unit	DG CAA	***		**		**	AM
Kavarna		at pier		canceled	**		**		PM
Balchik		at pier		canceled	*		**		PM
Evxinograd		government residence	BNHS & NSP	*					noon
Varna breakwater		at pier		*			**		noon
Varna green entrance		at pier		*			**		AM
Varna red entrance		military unit at the pier	BNHS & DG CAA	*					PM
Varna Navy Museum		Navy Museum					**		AM
Galata		military unit	BNHS & DG CAA	*					noon
Galata old inactive		military unit	BNHS & DG CAA	*		*		*	noon
Sveti Atanas (Byala)		archaeological complex					**		PM
Emine		military unit	BNHS & DG CAA	**		**			AM
Nessebar		at pier base					*		AM
Pomorie		at the reef at sea		***	**			**	noon
Burgas		at pier		*			**		PM
Burgas green entrance		at pier		*			*		AM
Burgas red entrance		at pier, restricted port area	BNHS	*					AM
Sveta Anastasia Island		military grounds	BNHS & DG CAA			*	***	**	noon
Sozopol Kirik Island pier		military grounds	BNHS	*				**	AM
Sozopol green entrance		at yacht marina		*				**	AM
Sveti Ivan Island		military grounds/ reserve	BNHS & DG CAA	**				***	noon
Maslen Nos		military unit	BNHS & DG CAA	**		*		**	PM
Primorsko		at pier		*			**		AM
Tsarevo		at pier		*			**		noon
Tsarevo Yahou Rock		at rocks at sea		**	*			*	noon
Ahtopol		at rocks near pier		*	*		**	*	PM

Fig. 3. Main considerations for every lighthouse along the Bulgarian Black Sea Coast during the authors' drone operations.



Fig. 4. Lighthouses: a) Shabla, b) Kaliakra; navigation lights: c) Balchik, d) Kavarna former, e) Kavarna actual.



Fig. 5. Lighthouses: a) Evxinograd, b) Varna breakwater; Varna port entrance lights: c) red, d) green; e) former breakwater light, now in the yard of the Maritime Museum, Varna.



Fig. 6. Lighthouses Galata: a) both, b) old / inactive, c) actual.



Fig. 7. Lighthouses Sveti Atanas: a) now / inactive, b) in 2007 / active, c) Emine, d) Nesebar / inactive.

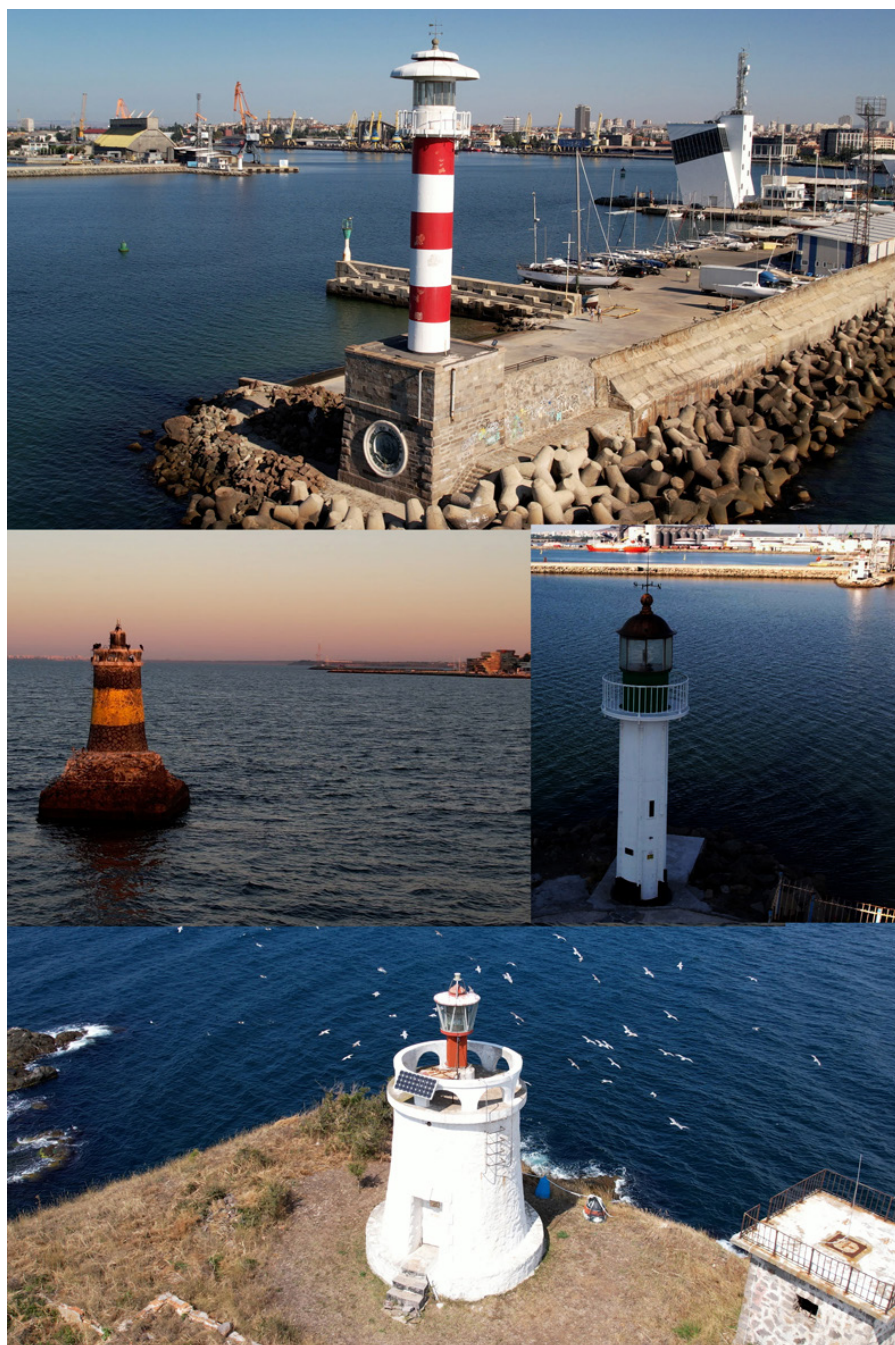


Fig. 8. Lighthouse: a) Burgas breakwater with both green and red entrance lights and the yacht marina light, b) Pomorie light, c) green and behind – red entrance lights Burgas, d) lighthouse Maslen Nos.

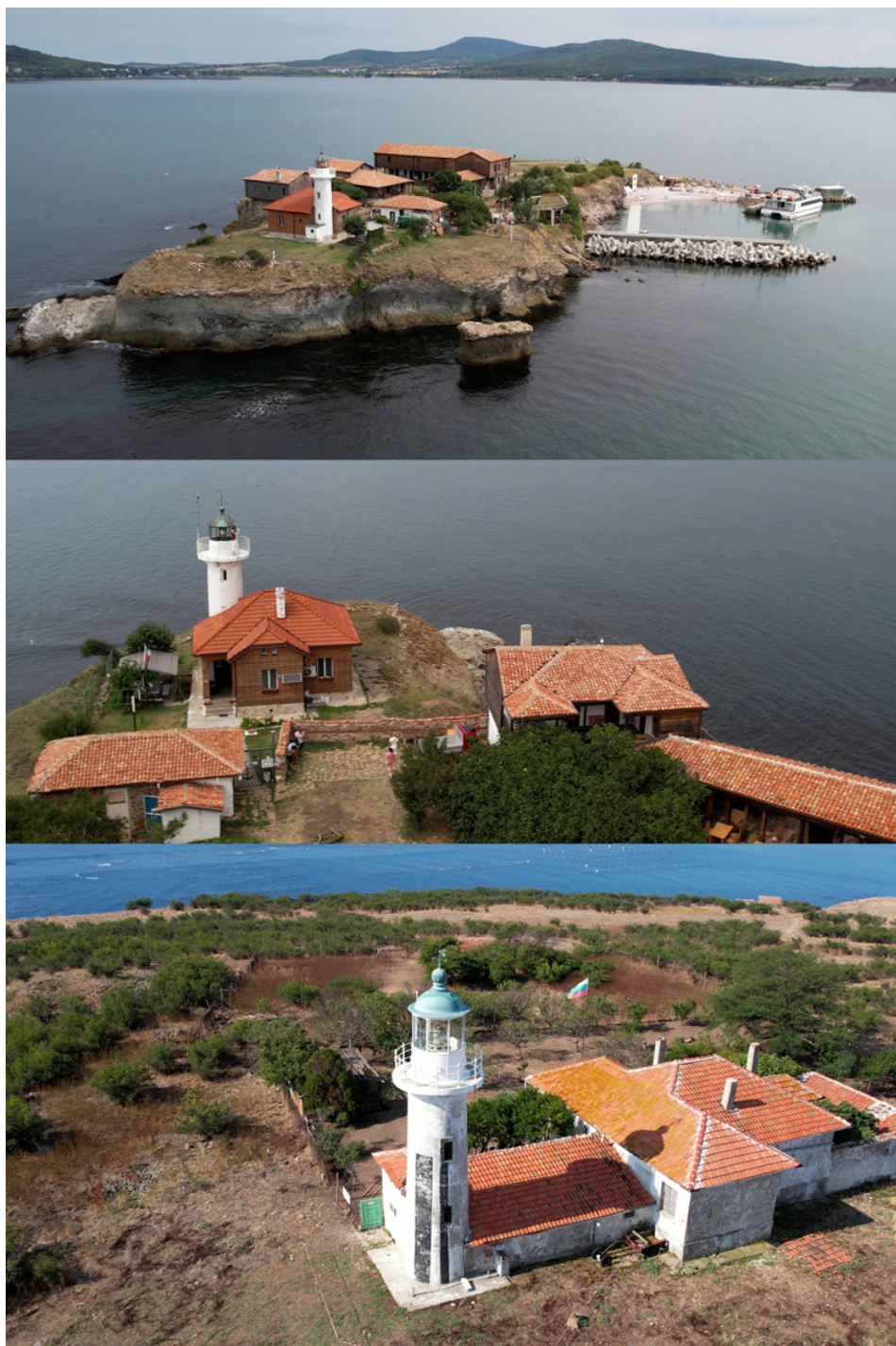


Fig. 9. Lighthouses on the island: a) and b) St. Anastasia, c) St. Ivan.



Fig. 10. Navigation lights: a) Sozopol red entrance and main at Kirik Island pier / both inactive, b) Sozopol green entrance at yacht marina, c) main Kirik Island pier light in 2007 / active, d) Primorsko lighthouse.



Fig. 11. Navigation lights: a) Tsarevo pier actual / statue, b) Tsarevo pier in 2007, c) Tsarevo at Yahou rock, d) Ahtopol.

CONCLUSION

The authors' drone documenting of all lighthouses along the Bulgarian Black Sea Coast demonstrates a significant contribution to the methodology for aerial digitalization of maritime heritage through the integrated examination of regulatory, technical, and visual considerations. Their practical implementation within the Nasledstvo BG project proves that meticulous planning, adaptive flight strategies, and professional expertise can address the complex constraints of shoreside aerial environments. The results' quality and usability rely equally on equipment capabilities and professional expertise. The authors define a reliable framework of good practices for safe, efficient, and aesthetically valuable drone assisted digital archiving of the lighthouses in Bulgaria as important part of the country's maritime cultural heritage.

Acknowledgements: The authors would like to express their gratitude to the team of Nasledstvo BG project for the opportunity to contribute to the digitalization and archiving of many items of architectural and natural heritage all over Bulgaria and in particular – for documenting in detail the lighthouses along our country's Black Sea coast.

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<https://x-tesla.caa.bg/home>
Zone map DG CAA (2026) <https://www.caa.bg/en/node/7062>
Zone map DJI (2026) <https://fly-safe.dji.com/nfz/nfz-query>

БЪЛГАРСКИТЕ МОРСКИ ФАРОВЕ: НОРМАТИВНИ, ТЕХНИЧЕСКИ И ВИЗУАЛНИ СЪОБРАЖЕНИЯ ПРИ ДОКУМЕНТИРАНЕ С ДРОН НА МОРСКОТО КУЛТУРНО НАСЛЕДСТВО

Резюме: Настоящото изследване представя приноса на авторите към дигиталното документиране от въздуха на фаровете по Българското Черноморие, осъществено в рамките на проект „Наследство БГ“ през лятото на 2023 г. В качеството си на сертифицирани дрон пилоти, авторите извършват въздушно заснемане на българските морски фарове. Статията разглежда нормативната рамка, приложима в България от авиационната и морската администрация, включително изискванията за сертификация и процедурите по издаване на полетни разрешения. Анализирани са технически аспекти като характеристики и оборудване на дроновете, метеорологични специфики и географски особености на крайбрежието, човешки фактор при безопасността на полетите. Специално внимание е отделено на емпиричния подход за постигане на документална достоверност и естетическа стойност на материалите, при отчитане на светлинните условия, спецификата на задачите и художествените решения в различни визуални контексти. Тази статия би могла да бъде използвана от изследователите като източник на полезна практическа информация за обектите, изследвани в рамките на проект „Наследство БГ“. Резултатите подчертават приноса на авторите за безопасна, ефективна и качествена дигитализация на морското културно наследство чрез използване на безпилотни летателни системи.

Ключови думи: морски фарове; безпилотни летателни системи (БЛС); дрон фотोगрафия; морско културно наследство; проект „Наследство БГ“

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