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Machrihanish Navigation Risk Assessment

2026

Project: Highlander

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1. Applicable and Reference Documents

ID	Definition
AD1	Marine (Scotland) Act 2010

2. Definitions and Abbreviations

Abbreviation	Definition
ADS-B	Automatic Dependent Surveillance-Broadcast
AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
CFA	Clyde Fisherman's Association
GPS	Global Positioning System
HSC	High Speed Craft
ISPS	International Ship and Port Facility Security Code
LCSS	Lochranza and Catacol Sea Society
MACC	Machrihanish Airbase Community Company
MCA	Maritime and Coastguard Agency
MD-LOT	Marine Directorate Licensing Operations Team
NMPI	National Marine Plan Interactive
NOTMAR	Notice to Mariners
NRA	Navigation Risk Assessment
RIFG	Regional Inshore Fisheries Group
RNLI	Royal National Lifeboat Institution
RORO	Roll-on/Roll-off
RYA	Royal Yachting Association
SEZ	Safety Exclusion Zone
SFO	Scottish Fisherman's Organisation
SPA	Special Protection Area
UKHO	United Kingdom Hydrographic Office
VDAA	Vessel Density Annual Average
VHF	Very High Frequency

3. Introduction and Purpose

This document presents the Navigation Risk Assessment (NRA) for a sub-scale rocket launch and sea-recovery to be conducted from Machrihanish Airbase, Scotland, and known internally as **Highlander**. The assessment is submitted by **Exotopic** in support of a Marine Licence application for the temporary deposit and recovery of launch vehicle components within UK coastal waters.

The purpose of this NRA is to:

- identify hazards to maritime navigation arising from the launch and recovery activity;
- assess the likelihood and potential consequences of those hazards to maritime users;
- define mitigation and control measures that reduce navigational risk to As Low as Reasonably Practicable (ALARP).

Highlander Pathfinder is a **single, time-limited activity** involving a short hazard window associated with:

- ascent over land followed by descent over sea;
- splashdown of the launch vehicle under parachute; and
- recovery of the vehicle by a small, crewed recovery vessel.

This NRA is mission-specific and applies only to the Highlander launch. It is not intended to represent a standing or site-wide navigational risk assessment for Machrihanish. The document has been prepared following engagement with the Marine and Coastguard Agency (MCA) and adopts a proportionate, narrative-based approach consistent with previously approved launch-specific NRA addenda in Scotland.

4. Regulatory and Licencing Context

4.1. Navigational Safety Authority

The Marine and Coastguard Agency (MCA) are the competent authority for matters relating to maritime safety and navigation within UK waters. This NRA has been prepared to demonstrate that navigational risks arising from the launch and recovery activities have been systematically identified, assessed, and mitigated in line with MCA expectations.

4.2. Marine Licensing

The proposed activity requires a Marine Licence under the Marine (Scotland) Act, administered by Marine Scotland – Licensing Operations Team (MD-LOT). This NRA forms part of the supporting documentation for that licence application.

The activity is temporary and non-routine in nature and involves the controlled splashdown and recovery of a launch vehicle following a test launch. All reasonably practicable measures are intended to be taken to recover the vehicle and avoid long-term deposition on the seabed.

4.3. Scope of This Assessment

This NRA:

- addresses navigational risk to maritime users only;
- supports, but does not replace, statutory maritime notification processes such as Notices to Mariners and navigational warnings; and

- does not assess aviation, spaceflight licensing, or ground safety risks, which are addressed through separate regulatory and safety documentation.

5. Description of Proposed Activity

5.1. Overview of the Highlander Pathfinder

Highlander Pathfinder is an early-stage test flight managed by Exotopic and is designed to demonstrate launch and recovery systems for future launch vehicles.
For the Highlander mission:

- the launch vehicle is expected to reach an apogee of approximately **16-20 km** above sea level;
- The impact dispersion will be between **~0-10km** down range with a spread of **~5 km** from the intended trajectory under **nominal conditions**
- the vehicle is launched westward from Machrihanish Airbase;
- descent is controlled using a dual deployment parachute system; and
- the vehicle is intended to splash down at sea and be recovered by a vessel shortly afterwards.

The primary objectives of the Highlander launch are to:

- validate **Exotopic's launch rail system** under live launch conditions;
- exercise and de-risk sea recovery procedures at short range;
- demonstrate basic tracking, communications, and coordination arrangements associated with a marine recovery.

The proposed launch is planned to take place within a launch window extending from **November 1st – December 31st**, subject to weather, operational readiness, and regulatory approvals.
The Highlander mission acts as a pathfinder for future launches adopting similar launch and recovery procedures.

5.2. Operational Safety Philosophy

Launches are conducted under strictly controlled conditions, including real-time visual monitoring, defined exclusion areas, and the ability to delay launch if hazards are identified.
It is recognised that not all recreational and inshore vessels carry AIS transponders. Consequently, operational monitoring arrangements rely on a combination of AIS data, stakeholder engagement, and direct visual surveillance.
The operation is characterised by a short launch duration, a small launch vehicle, a nearshore splashdown area, active recovery arrangements, and low baseline maritime traffic levels. These factors enable the implementation of proportionate control measures to reduce navigational risk to ALARP.

5.3. Launch Location

The launch will take place from Machrihanish Airbase, Argyll and Bute, located on the western edge of the Kintyre Peninsula at approximately **55.43932°N, 5.70887°W**. The vehicle will be launched on a broadly westward azimuth to ensure that the trajectory remains over the sea. Figure 1 shows the launch location and indicative launch trajectory; for clarity, the map has been orientated to a 270° heading. Minor variations in the launch heading may be required to

accommodate prevailing wind conditions during the launch window. These variations have been accounted for within the Safe Splashdown Zone described later in this assessment.

Figure 1 - Launch Location

5.4. Wind Weighting & Atmospheric Conditions

Given that the Highlander mission is expected to achieve an apogee exceeding 10 km, atmospheric conditions throughout the flight envelope will be assessed as a critical component of the launch safety process. In addition to standard surface weather observations, upper-atmospheric wind data will be collected on the day of launch via radiosonde to establish an accurate vertical profile of wind speed and direction from ground level to the predicted apogee. Upper-level wind measurements are widely used in launch operations to support trajectory assessment and ensure safe flight operations.

The measured atmospheric data will be incorporated into the Exotopic's custom wind-weighted trajectory prediction software. This software combines real-time atmospheric conditions with vehicle performance and aerodynamic characteristics to model the expected ascent trajectory, apogee position, descent profile, and recovery footprint. By using measured wind profiles rather than relying solely on standard atmospheric models, the uncertainty associated with trajectory prediction is significantly reduced, providing a more representative assessment of actual flight conditions.

Trajectory simulations will be updated using the latest available atmospheric data immediately prior to launch. The resulting predictions will be reviewed against the established marine and public safety exclusion zones to confirm that all credible flight and recovery scenarios remain within acceptable risk limits. Particular attention will be given to the effects of high-altitude winds on vehicle drift during ascent, descent under recovery systems, and the potential dispersion of landing locations.

Launch approval will be subject to the prevailing and forecast meteorological conditions remaining within predefined operational limits. The launch team will assess factors such as:

- Surface wind speed, gusts, and direction.
- Wind speed and direction throughout the expected flight altitude range.
- Wind shear and significant changes in wind direction with altitude.
- Visibility and cloud conditions affecting launch monitoring and recovery operations.

Any atmospheric conditions that may adversely affect vehicle stability, tracking performance, recovery operations, or public safety.

Should atmospheric measurements or trajectory modelling indicate an elevated risk of departure from the planned flight corridor, excessive recovery drift, or encroachment on established safe splashdown zones, the launch will be postponed until conditions return to acceptable levels.

The collection and application of upper-atmosphere wind data serves as an additional risk mitigation measure and provides increased confidence in trajectory prediction accuracy, supporting the safe conduct of the Highlander mission and the protection of personnel, marine traffic, property, and the environment.

5.5. Splashdown and Recovery Concept

For the Highlander mission, the nominal splashdown area is located approximately 2-16 km from the launch location, west of Machrihanish beach. Credible off-nominal recovery scenarios have been assessed through Monte Carlo analysis and are fully contained within the Safety Splashdown Zone described later in this assessment.

Recovery will be conducted by 2 small safety recovery vessels. The vessels will:

- be crewed by appropriately trained and licensed personnel;
- be positioned outside of the splashzone; one vessel will be positioned within 1km of the launch location and the other vessel will be positioned further downrange, ~10km from launch
- use GPS tracking data and visual cues, including coloured smoke signals, to locate the vehicle; and
- recover the vehicle shortly after splashdown, weather and sea state permitting.

The vehicle incorporates buoyancy aids to remain afloat during recovery. In the unlikely event that immediate recovery is not possible, the materials involved are non-hazardous, and the navigational implications of delayed recovery are considered within the hazard and mitigation sections of this NRA.

6. Trajectory Analysis and Safety Splashdown Zone

6.1. Hazard Area Determination

The Highlander trajectory assessment was undertaken using the RocketPy six-degree-of-freedom trajectory simulation framework. The assessment considered uncertainty in atmospheric conditions, launch vehicle performance and vehicle characteristics, including uncertainties associated with the airframe, propulsion and recovery system.

Atmospheric variability was represented using data covering 155 days drawn from five December periods. For each day, an atmospheric uncertainty model was applied to represent variation around the available wind profile. The magnitude of the applied uncertainty was scaled for the individual day according to the associated wind conditions, rather than applying a single fixed wind speed and direction across the complete assessment.

Vehicle and operational uncertainties were propagated through the six-degree-of-freedom simulations to determine the resulting range of ascent, descent and splashdown outcomes.

Candidate launch headings were evaluated in 10° increments across the permissible westward, seaward launch sector. For each increment, the resulting splashdown cases were assessed against the adjacent coastline and the identified North Channel Traffic Separation Scheme (TSS) and its safe boundary. The preferred heading increment was selected to maximise separation between the simulated splashdown cases, the coastline and the shipping route, while retaining the predicted outcomes within the defined maritime operational area.

The analysis was conducted using the [Redacted] solid rocket motor from [Redacted] , which is the baseline propulsion system for the Highlander launch vehicle. Three recovery scenarios were modelled:

- **Nominal recovery**: Dual-deployment recovery, with a drogue parachute deployed at apogee and a main parachute deployed later in descent.
- **Drogue-only scenario**: Failure of the main parachute, with descent continuing under the drogue parachute only.
- **Ballistic scenario**: Total recovery system failure resulting in an uncontrolled descent.

These scenarios were selected to represent both expected operations and credible failure cases, ensuring that the derived safe splashdown zone encompasses the foreseeable range of splashdown locations.

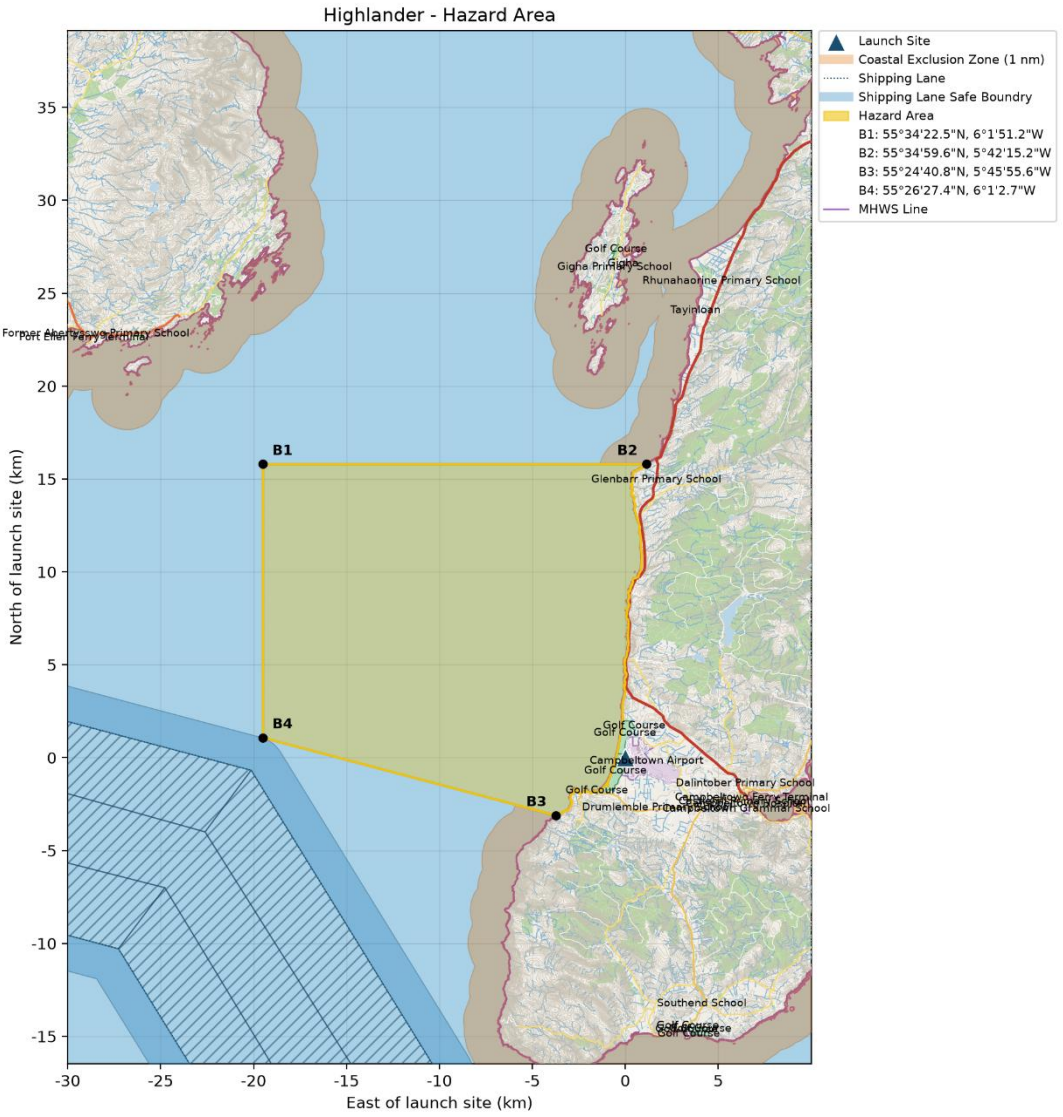

Figure 2 - Hazard Area

The Hazard Area, shown Figure 2, defines the maritime area subject to surveillance and launch control measures during Highlander operations. The area extends approximately **18 km (9.8 NM)** from the launch location and has a maximum north-south extent of approximately **19 km (10.3 NM)**. The Hazard Area has been established to encompass the operational area in which debris could reasonably be expected to descend under nominal and credible off-nominal flight conditions, whilst accounting for the adjacent coastline and local maritime constraints. Prior to launch, the Hazard Area will be monitored using a combination of visual surveillance, AIS data and on-water support vessels. Launch operations will not proceed if any non-participating marine users are identified within the Hazard Area. The coordinates of the Hazard Area boundary vertices (B1-B4) are provided in Table 1.

Table 1 - Marine Hazard Area Coordinates

Vertex	Latitude	Longitude
B1	55°34'22.5"N	6°01'51.2"W
B2	55°34'59.6"N	5°42'15.2"W
B3	55°24'40.8"N	5°45'55.6"W
B4	55°26'27.4"N	6°01'02.7"W

Note: The eastern boundary between B2 and B3 follows the Mean High Water Spring (MHWS) line shown in Figure 2 rather than a direct straight-line connection between the vertices.

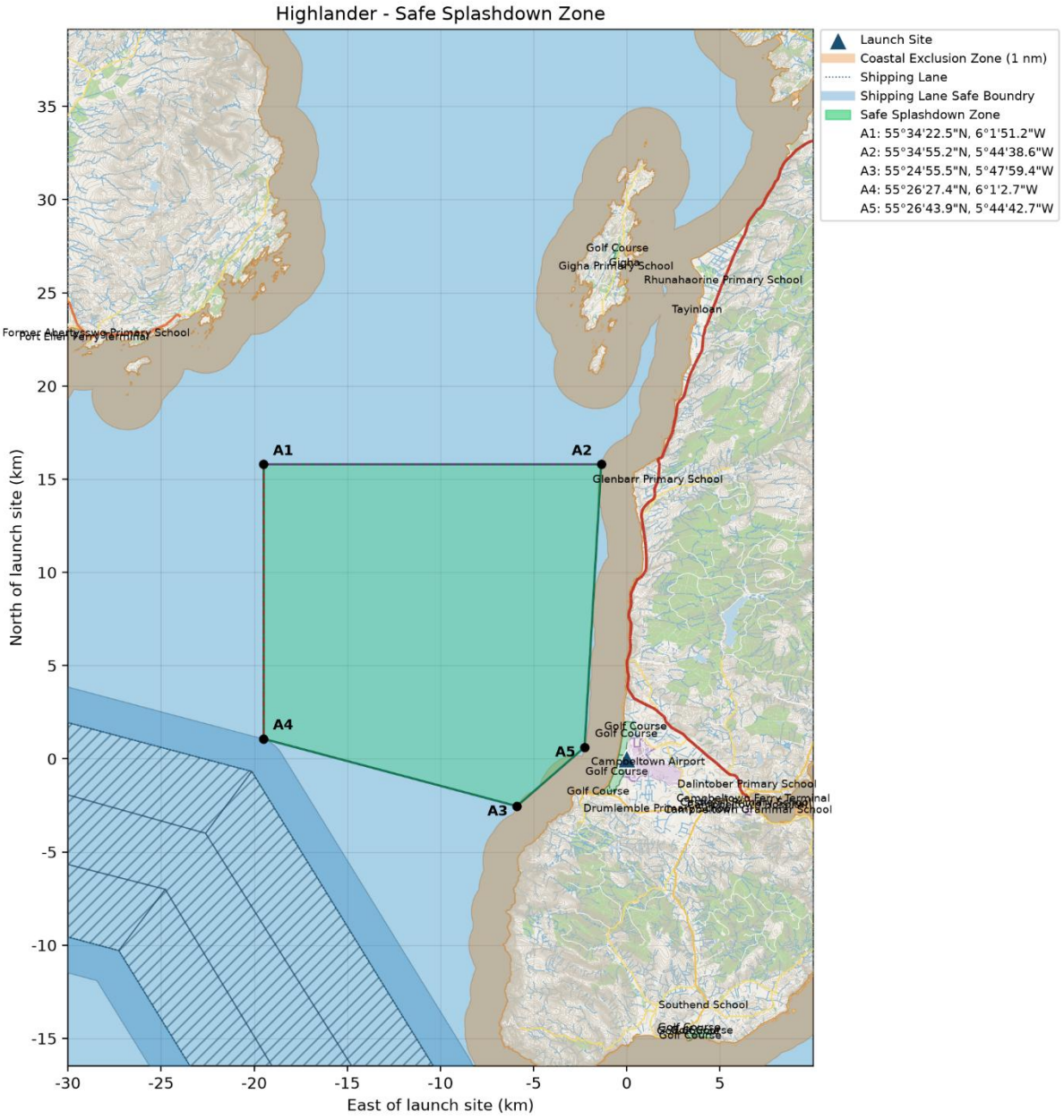

Figure 3 - Safe Splashdown Zone

The Safe Splashdown Zone, shown in Figure 3, represents the preferred area for rocket splashdown under nominal and credible off-nominal flight conditions.
The Safe Splashdown Zone is derived from the same trajectory analysis as the Hazard Area but excludes coastal waters within approximately **1 nautical mile of the shoreline**. This distinction reflects the operational requirement that, whilst the Hazard Area remains subject to surveillance and vessel exclusion measures, the nearshore coastal strip is not considered an

acceptable splashdown location when assessing launch-day meteorological conditions and trajectory predictions.
Prior to launch, the predicted splashdown footprint generated using the latest available atmospheric data shall remain within the Safe Splashdown Zone. Should trajectory modelling indicate that splashdown locations may extend outside the Safe Splashdown Zone, the launch shall be placed in a no-go condition until acceptable conditions return.
The Hazard Area and Safe Splashdown Zone therefore serve different operational purposes. The Hazard Area defines the maritime area that must be clear of non-participating marine users before launch, whereas the Safe Splashdown Zone defines the acceptable splashdown region used for launch-day trajectory assessment and weather-related go/no-go decisions.
The Safe Splashdown Zone has been selected to account for expected variations in flight performance, recovery system behaviour and environmental conditions while maintaining appropriate separation from the coastline. The coordinates of the Safe Splashdown Zone boundary vertices (A1-A5) are provided in Table 2 below.

Table 2 - Safe Splashdown Zone Coordinates

Vertex	Latitude	Longitude
A1	55°34'22.5"N	6°01'51.2"W
A2	55°34'55.2"N	5°44'38.6"W
A3	55°24'55.5"N	5°47'59.4"W
A4	55°26'27.4"N	6°01'02.7"W
A5	55°26'43.9"N	5°44'42.7"W

Note: Vertices A1 and A4 coincide with Hazard Area vertices B1 and B4 respectively. The eastern boundary between A2 and A5 has been positioned approximately 1 nautical mile offshore and forms the coastal exclusion applied to the Safe Splashdown Zone.
Should a change to the launch vehicle, propulsion system or other safety-critical flight hardware result in material changes to the predicted splashdown footprint, the trajectory analysis will be repeated using the updated parameters. Any resulting change that materially affects the suitability of the Safe Splashdown Zone or Hazard Area will trigger a reassessment of the operational area and consultation with the relevant regulatory authorities prior to launch authorisation.

6.2. Nominal Launch

Under **nominal recovery conditions**, where both the drogue and main parachutes deploy successfully, the predicted landing footprint remains concentrated close to the coastline and extends only a short distance offshore with a maximum possible extent of 10 km. This outcome reflects the controlled descent profile of the vehicle, with the 48-inch drogue parachute deployed at apogee followed by deployment of the 144-inch main parachute at approximately 1,000 ft (305 m) AGL. The resulting descent rate of approximately 5 to 7 m/s produces a low-energy splashdown within the nearshore environment.

6.3. Ballistic Scenario

The **ballistic landing scenario**, representing failure of both recovery parachutes, produces the most compact splashdown footprint with a maximum extent of ~18 km downrange. Owing to the significantly increased descent rate, atmospheric wind effects have less time to

influence the vehicle trajectory, resulting in impacts concentrated within a relatively smaller area offshore. Although this scenario represents the highest impact energy case, the predicted landing locations remain well within the defined Safe Splashdown Zone.

6.4. Drogue Only Deployment Scenario

The drogue-only recovery scenario represents a situation in which the drogue parachute deploys successfully but the main parachute fails to deploy. In this case, the vehicle remains under a controlled descent with an expected descent rate significantly higher than the nominal recovery scenario, typically in the region of 15-20 m/s. This scenario produces the largest offshore splashdown footprint of the three recovery cases assessed, with the predicted landing area displaced several kilometres west of the launch site. While the higher descent rate reduces the overall time available for wind-driven drift, the absence of the main parachute results in a broader distribution of potential splashdown locations when variations in weather conditions and vehicle performance are considered. Despite this increased dispersion, all simulated landings remain within the marine environment and are fully contained within the Safe Splashdown Zone. While this scenario results in a higher splashdown velocity than nominal recovery, the impact area remains predictable and presents a low risk to other maritime users provided the described maritime risk mitigations are implemented.

6.5. Launch Day and Wind Weighting

The Safe Splashdown Zone has been developed using historical atmospheric datasets and trajectory simulations to define an acceptable splashdown region for Highlander operations. Whilst this analysis provides confidence that suitable launch opportunities exist within the launch window, a further trajectory assessment is undertaken immediately prior to launch using atmospheric measurements collected on the day of launch, as described in Section 5.4. Measured upper-atmospheric wind data obtained from a radiosonde is processed using Exotopic's wind-weighted trajectory prediction software. The software evaluates a range of permissible launch headings and launch inclinations and identifies the combination that best centres the predicted splashdown distributions within the Safe Splashdown Zone, whilst maintaining appropriate separation from the coastline and other maritime constraints.

The assessment considers the nominal recovery case together with credible off-nominal scenarios, including drogue-only recovery and ballistic descent. Launch authorisation is conditional upon all modelled scenarios remaining within the Safe Splashdown Zone.

Where the software is unable to identify a valid launch solution, owing to prevailing atmospheric conditions causing one or more splashdown footprints to extend outside the Safe Splashdown Zone, a launch no-go condition will be declared and the launch will be postponed. Launch operations will only proceed once atmospheric conditions have improved sufficiently for an acceptable solution to be achieved.

Figure 4 illustrates an example of an unacceptable launch-day solution. In this case, the predicted nominal splashdown footprint extends into the coastal stand-off area and outside the Safe Splashdown Zone. Under these conditions, the software would be unable to converge on a valid launch heading and inclination and the launch would not proceed.

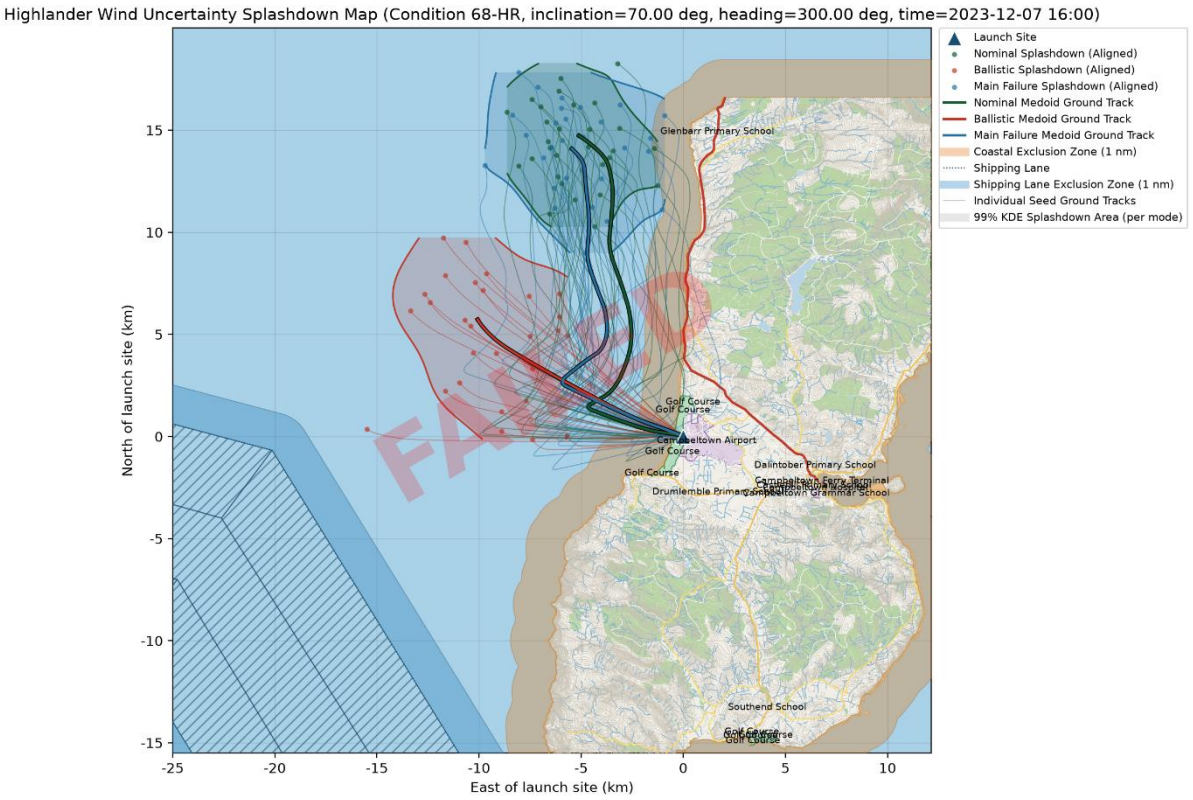

Figure 4 - Wind Weighting Failed Scenario

7. Site and Maritime Context

7.1. Geographic Location and Marine Setting

The Machrihanish area is located on the west coast of the Kintyre peninsula and is adjacent to open coastal waters exposed to the North Atlantic. The marine environment in this area is characterised by nearshore coastal waters rather than offshore or deep-sea conditions. The coastline in the vicinity comprises a broad sandy beach backed by low-lying dunes, with rocky shoreline present further north and south along the peninsula. The adjacent waters are open and exposed, with tidal flow, wind, and swell conditions typical of the Atlantic west coast of Scotland.

There are no enclosed waters, designated navigation channels, or harbour approaches within the immediate nearshore area west of Machrihanish. The waters are not constrained by fixed maritime infrastructure such as piers, breakwaters, offshore platforms, or permanent navigational installations.

The area lies entirely within UK territorial waters and is not associated with recognised international shipping lanes. Maritime activity in the nearshore zone is therefore influenced primarily by local and regional use rather than long-distance commercial routing.

7.2. Adjacent Coastline and Nearshore Use

The coastline immediately west of Machrihanish is characterised by an open sandy beach with direct access to the sea. The adjacent nearshore waters are used primarily for **local and recreational activities**, rather than structured commercial maritime operations.
Typical nearshore uses include:

- recreational beach activity;
- occasional use by small recreational craft;
- informal water-based activities such as surfing and paddle sports;
- limited nearshore transits by small fishing vessels operating close to the coast.

These activities are generally **weather-dependent and seasonal**, with higher levels of recreational use during summer months and periods of favourable sea conditions. Use of the nearshore waters is typically dispersed rather than concentrated along defined routes or channels.
There are no marinas, mooring fields, or formal small-craft facilities immediately adjacent to the Machrihanish coastline. As a result, small vessel movements in the nearshore area tend to be ad-hoc and locally generated rather than continuous or predictable.
Due to the informal nature of much of this activity, particularly for small craft and non-motorised users, comprehensive vessel tracking data (e.g. AIS) does not capture all potential nearshore use. This limitation is acknowledged and is addressed through precautionary assumptions and targeted mitigation measures described later in this NRA.

7.3. Local Stakeholder Engagement

Stakeholders have been identified through engagement with the Maritime and Coastguard Agency (MCA), UK Hydrographic Office (UKHO), harbour authorities, fisheries representatives, recreational boating organisations, and other maritime operators with knowledge of vessel activity within the waters surrounding Machrihanish. Engagement has been undertaken to ensure that organisations with a potential operational interest in the proposed launch and recovery activities are identified and given an opportunity to provide feedback or raise any concerns relevant to navigation and maritime safety. A full list of stakeholders identified and engaged as part of this process is provided in **Annex 1**. As correspondence progresses, any other relevant stakeholders identified will be updated on any relevant changes towards the mission.
Stakeholders are contacted with information relevant to the proposed operation, including:

- The proposed launch window of **1st November – 31 December.** This window will shorten as the project progresses (when regulatory/technical milestones are achieved, weather can be evaluated). Stakeholders will be given notice at multiple intervals leading up to the launch as the window is narrowed. (1 month before, 1 week before, etc).
- A summary of the planned launch, splashdown, and recovery activities.
- Details of the proposed **Hazard Area** and predicted splashdown area.
- Information regarding ongoing liaison with the **MCA**, **MD-LOT**, **UKHO**, and other relevant maritime authorities.
- Contact details for the project team to enable requests for additional information, provision of local knowledge, or submission of comments relating to the operation.

The stakeholder engagement process is used to supplement AIS-derived vessel activity data and publicly available information by incorporating local knowledge from organisations and individuals familiar with the area.

8. Maritime Receptors and Vessel Activity

8.1. Overview

Vessel activity west of Machrihanish has been characterised using density mapping from the National Marine Plan Interactive (NMPI), based on AIS-tracked vessel hours per square kilometre per month. This provides an indicative overview of maritime use and spatial patterns in the area.

The data indicates that activity within the splashdown area is generally low, typically ≤5 hours/km²/month. Higher-density traffic is limited to established offshore transit routes and constrained passages, with little concentrated vessel activity intersecting the proposed splashdown location. Some established routes briefly transit through the bottom left corner of the Hazard Area and one route bisects the Hazard Area with low concentration of activity. Maritime use in the vicinity is therefore predominantly characterised by low-density, transit-based movements within open coastal waters.

It is recognised that AIS datasets do not capture all vessel activity, particularly for smaller recreational craft and some inshore vessels. Stakeholder engagement indicates that AIS-visible recreational traffic represents only a proportion of actual usage, and the data should therefore be treated as indicative rather than comprehensive.

Recreational activity is strongly seasonal, with the majority occurring between May and October. As such, annual average density data may underrepresent peak usage. For this assessment, a conservative approach has been adopted whereby recreational vessel presence during peak months is assumed to be materially higher than annual averages, potentially of the order of up to twice the indicated levels.

While overall traffic density in the splashdown area is low, the occasional presence of vessels, particularly recreational craft operating nearshore, cannot be discounted. This is accounted for in the hazard assessment and informs the mitigation measures set out in subsequent sections.

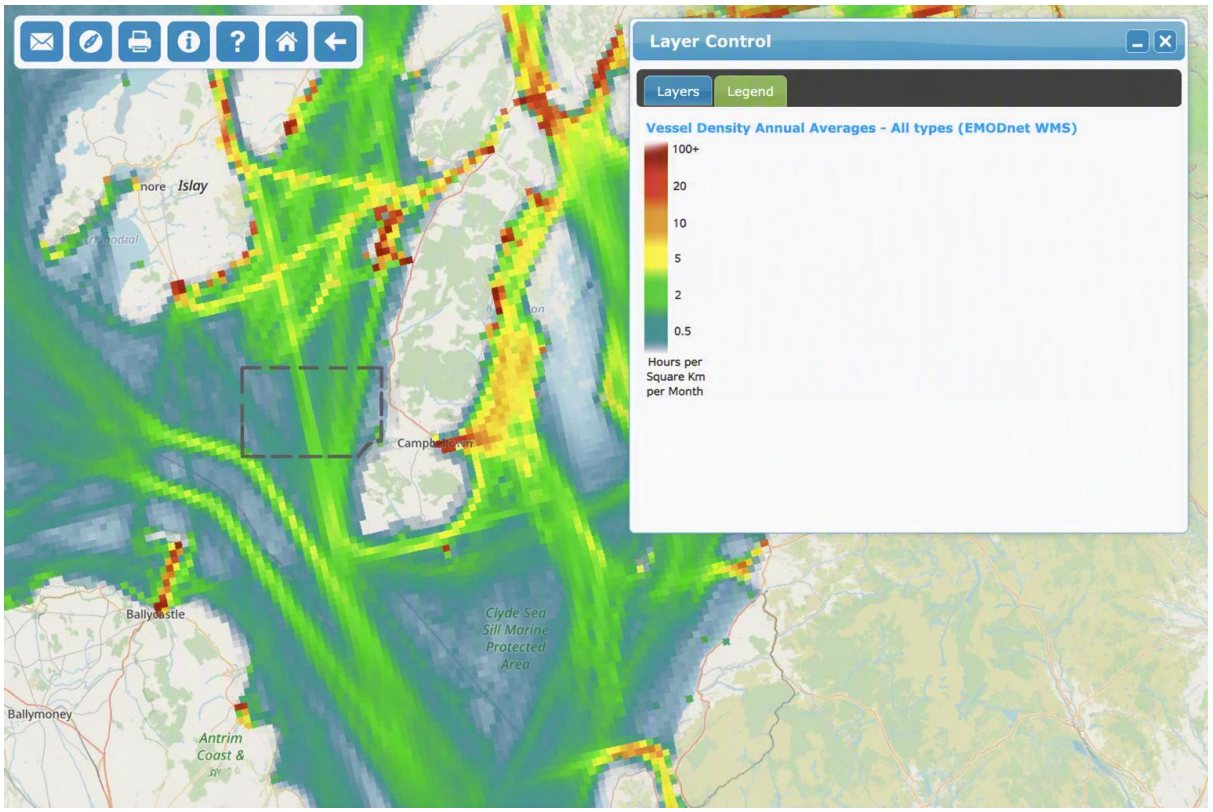

Figure 5 - All Vessel Density Annual Averages

Figure 5 shows all vessel activity in and around the area and provides a zoomed-out view of the Safe Splashdown Zone for reference when comparing vessel activity data presented in this assessment. The majority of vessel traffic follows routes around the southern tip of the Kintyre Peninsula and to its east and therefore remains well clear of the designated hazard area.

8.2. Fishing Activity

Fishing activity in the waters west of Machrihanish has been assessed using NMPI vessel density data for fishing vessels. The data indicate that fishing activity within and adjacent to the proposed Hazard Area is generally low, with vessel densities largely limited to ≤5 hours/km²/month. It is recognised that AIS-based datasets may under-represent total fishing activity, as some smaller inshore vessels do not routinely transmit AIS.

The revised Hazard Area partially overlaps an area of recorded fishing activity. The available data indicate that fishing activity in the vicinity is dispersed across the wider region rather than concentrated within a single fishing ground or route. Whilst fishing vessels may therefore be present within the Hazard Area, the density of activity remains relatively low and no heavily utilised fishing grounds have been identified within the operational area. The overlap area has been identified as an area of importance for surveillance.

Fishing vessels operating in the wider area are likely to originate from local ports including Campbeltown Harbour and Port Ellen (Islay). Any vessels present within the Hazard Area would be detected through a combination of stakeholder engagement, AIS monitoring where available, and visual surveillance conducted immediately prior to launch.

The temporary nature of launch operations, together with the implementation of Notices to Mariners and launch hold criteria, ensures that any interaction with fishing activity can be effectively managed. Launch operations will not proceed whilst non-participating vessels are present within the Hazard Area.
Overall, fishing activity within the vicinity of the proposed operations is considered low in density and manageable through the proposed operational controls. Fishing vessels remain a relevant maritime receptor for launch-day surveillance activities but do not present a significant navigational constraint to the proposed operation.

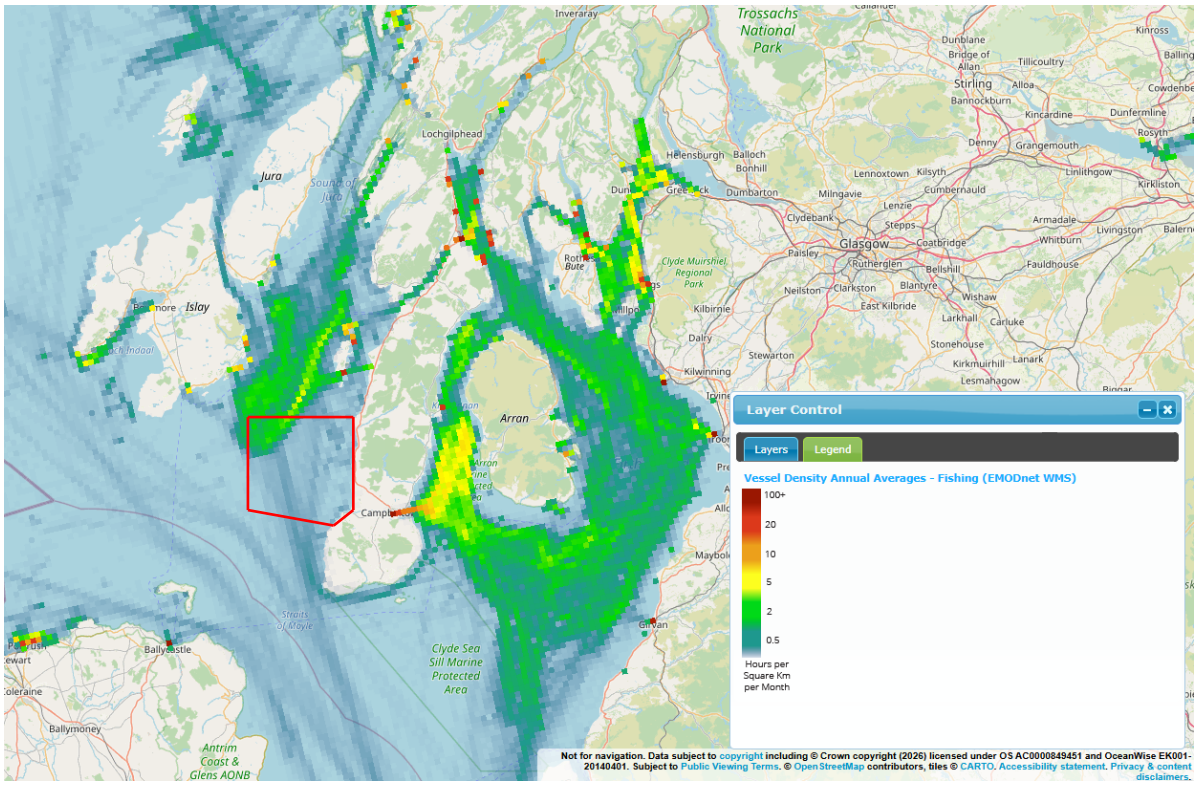

Figure 6 - Fishing Vessel Averages

8.3. Cargo and Tanker Traffic (Commercial)

Cargo and tanker vessel activity in the wider Machrihanish area has been characterised using NMPi vessel density data. The data indicate that commercial traffic is concentrated along a an established transit corridor associated with vessels navigating around the Kintyre peninsula and between the west coast of Scotland, the Clyde approaches and the Irish Sea. This corridor is highlighted as the North Channel Transit Separation Scheme (TSS).
Four principal transit routes are observed within the wider study area:

- **North Channel TSS:** The two established offshore transit routes located to the west of Islay form the northbound and southbound lanes of the North Channel TSS, which is a principal commercial shipping route connecting the Irish Sea with the North Atlantic. These routes exhibit some of the highest observed vessel densities within the wider study area and remain well offshore of the Scottish mainland. The Hazard Area does not extend into the TSS and has been bounded to maintain a minimum separation of approximately **1 nautical mile** from the scheme. This

provides sufficient sea room for vessels using the TSS and other vessels navigating outside the scheme, ensuring that normal commercial navigation can continue without creating a requirement to enter the Hazard Area during launch operations.

- **Islay-Jura channel route:** A further route passes between the islands of Islay and Jura and provides a connection between the Sea of the Hebrides and the North Channel. Vessel activity along this route is moderate and follows a well-defined transit corridor passing through the Islay-Jura channel then down around the Kintyre peninsula. This route directly intersects the Hazard Area but with a low vessel density, ~2hr/km sqrd/month.
- **Inner coastal route (Jura-mainland channel):** A fourth route, located closer to the mainland coast and passing between Jura and mainland Scotland after rounding the Kintyre peninsula, represents the route with the greatest potential proximity to the splashdown area. However, this route has the lowest observed VDAA of approximately 0.5 hours/km²/month, indicating relatively infrequent traffic.

Across all identified routes, cargo and tanker movements are characterised by predictable transit behaviour along established shipping corridors, with no evidence of routine loitering or stationary commercial operations within the proposed hazard area. Typical vessel types include bulk carriers, oil and product tankers, chemical tankers and general cargo vessels operating between ports in Scotland, the Irish Sea and the wider North Atlantic region.

The North Channel Traffic Separation Scheme (TSS), which accommodates the highest density of commercial shipping traffic within the wider study area, is entirely avoided by the Hazard Area. A minimum separation distance of approximately **1 nautical mile** has been maintained between the Hazard Area boundary and the TSS, providing a navigable corridor for vessels operating outside the scheme and ensuring that routine commercial traffic is not required to enter either the Hazard Area or the TSS as a result of launch operations.

Of the identified commercial routes, only the lower-density Islay-Jura transit route intersects the Hazard Area. Consequently, any potential interaction with commercial shipping is limited to relatively infrequent vessel movements rather than the principal north-south shipping flows passing through the North Channel. The temporary nature of the operation, together with Notices to Mariners, stakeholder engagement and real-time maritime surveillance, ensures that any vessel approaching the Hazard Area can be identified and appropriate launch hold criteria applied. Accordingly, commercial vessel activity is not considered to present a significant navigational constraint to the proposed operation.

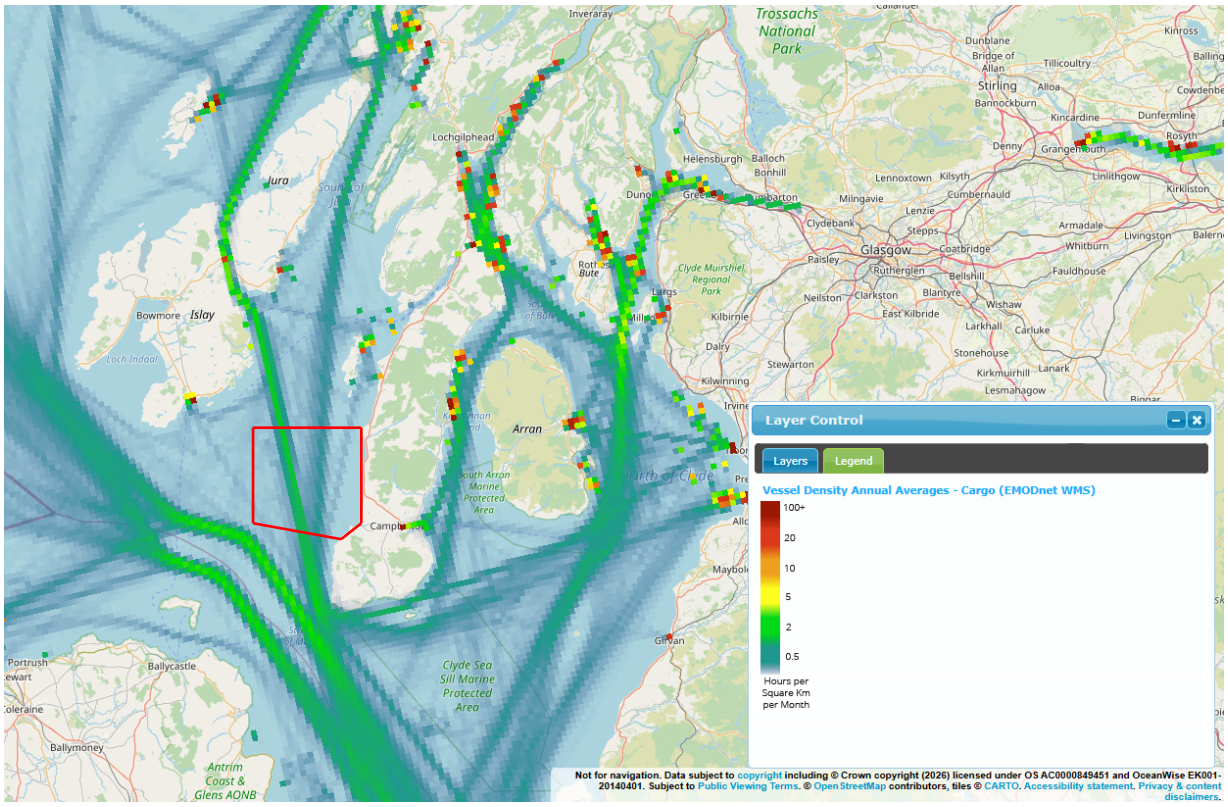

Figure 7 - Cargo and Tanker Vessel Averages

8.4. Passenger Vessels (Ferry)

Ferry

Passenger vessel activity in the vicinity of the proposed operations is limited and primarily associated with established ferry routes operating between mainland Scotland and nearby islands. The principal operator in the region is Caledonian MacBrayne (CalMac), which provides regular scheduled ferry services throughout the west coast of Scotland.

These services operate on fixed routes between designated ports (e.g. Kennacraig, Port Ellen, Port Askaig), transiting through the Sound of Islay and surrounding waters rather than along the open west coast of the Kintyre peninsula. As such, they do not require passage through the nearshore waters off Machrihanish.

The principal scheduled passenger ferry routes relevant to the wider region are summarised below:

Kennacraig – Port Ellen (Islay)	**CalMac**	**Multiple sailings daily**	**Year-round**	**Fixed route via Sound of Islay**	**~2 hrs 10 min**
Kennacraig – Port Askaig (Islay)	CalMac	Multiple sailings daily	Year-round	Fixed route via Sound of Islay	~1 hr 55 min

Port Askaig (Islay) – Feolin (Jura)	Local authority ferry	Frequent short crossings	Year-round	Local inter-island shuttle	~5–10 min

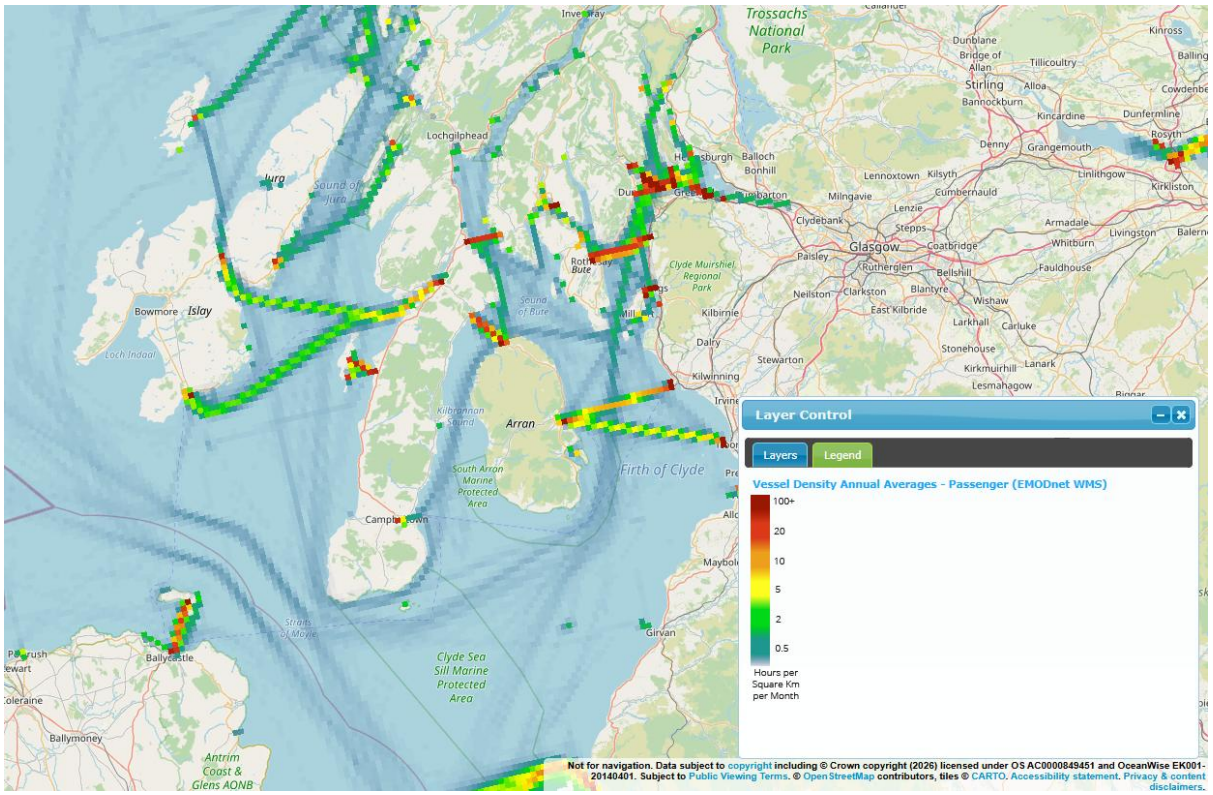

Figure 8 - Passenger Vessel Averages

High Speed Craft

High-speed craft activity west of the proposed hazard zone does not overlap and is extremely low in density. Higher concentrations of high-speed crafts can be seen in the wider study area, primarily along established ferry routes serving Ballycastle (NI) and Islay. A limited number of transit routes pass through the wider study area; however, vessel activity remains substantially lower than that observed for commercial cargo traffic.

Overall, high-speed craft activity in the vicinity of the proposed splashdown area is extremely low in density, predictable in routing and does not present a significant navigational constraint to the proposed operations.

In addition to these services, limited high-speed passenger craft (HSC) operate seasonally in the wider area, primarily through the Kintyre Express service linking Campbeltown, Ballycastle and Port Ellen (Islay). These vessels operate on defined point-to-point routes between ports and are considered separately above.

The NMPI vessel density data indicates very low levels of passenger vessel activity rounding the Kintyre peninsula, with only light and intermittent traffic observed close to the Machrihanish coast. This activity is likely associated with occasional transit movements of small passenger vessels, charter craft, or repositioning voyages rather than regular scheduled ferry services.

To further reduce the potential for interaction between launch operations and marine traffic, stakeholder engagement would be undertaken with relevant maritime authorities, harbour operators and local vessel operators during launch planning activities. In addition, appropriate navigational warnings, including Notices to Mariners, would be issued in advance of launch operations to inform mariners of the location and timing of the temporary hazard area. Given the predictable nature of high-speed craft movements and the limited duration of launch operations, these measures are considered sufficient to ensure that any potential interaction can be effectively managed.

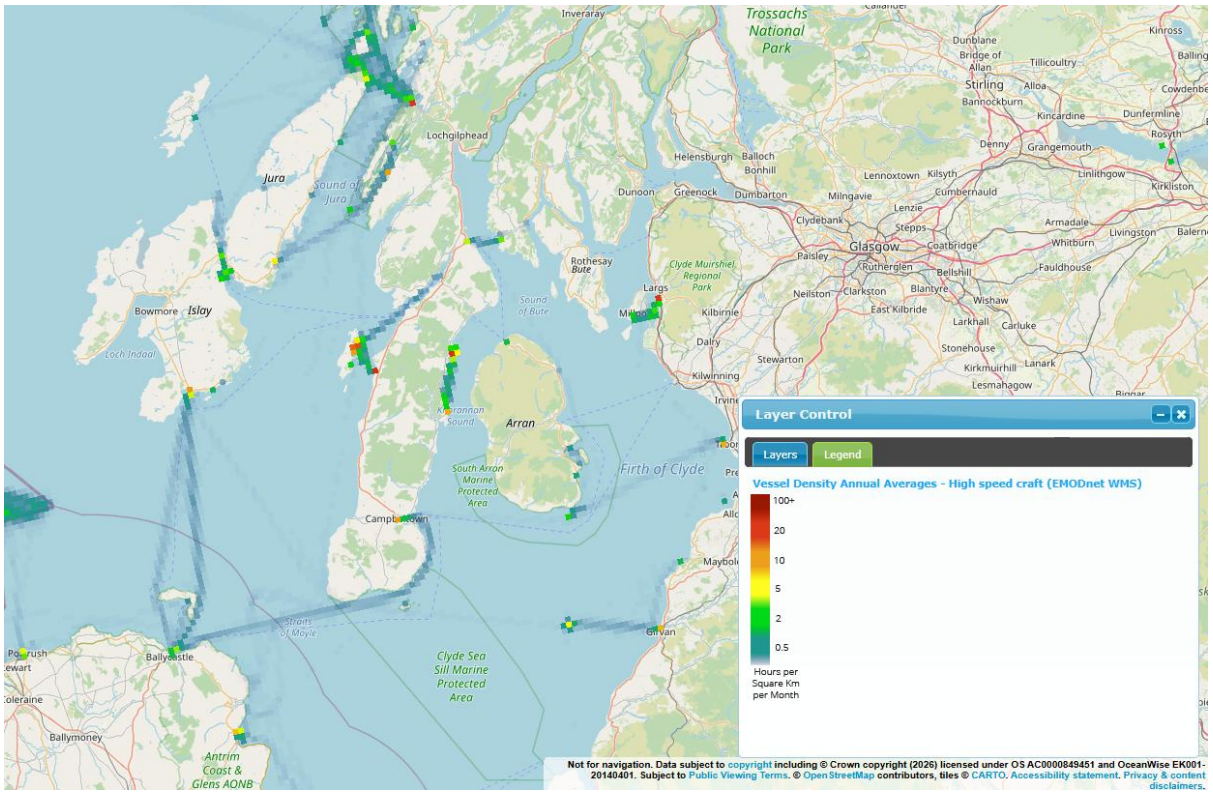

Figure 9 - High Speed Vessel Activity

Other Considerations

Aquaholics

Commercial charter and dive operators (e.g. small-vessel excursion providers operating between Ballycastle, Campbeltown and Islay) have also been considered. Available information indicates that diving activity associated with these operators is primarily concentrated around the Causeway Coast and Rathlin Island, with trips to Scottish locations such as Islay and Campbeltown typically comprising transit or tourism routes rather than regular dive site operations.

As such, diving activity is not concentrated within the vicinity of the Machrihanish splashdown area, and any vessel presence in this area would be occasional and transitory in nature. On this basis, such operations are not considered to present a material navigational constraint to the proposed activity.

8.5. Recreational and Small Craft Activity (Pleasurecraft)

Recreational and small craft activity, including sailing vessels and motorised pleasure craft, represents the most varied form of maritime activity within the vicinity of the proposed splashdown area not defined to specific corridors. NMPI vessel density data indicates that this category exhibits higher overall levels of activity than other vessel types in the region but geographically spread across the area of study.

The spatial distribution of activity shows a broadly continuous pattern of vessel movements around the Kintyre peninsula, with traffic generally following coastal routes and transiting between the Firth of Clyde, the west coast of Scotland, and the islands of Islay and Jura. In contrast to commercial shipping, these vessels are not constrained to defined corridors and frequently operate in nearshore waters.

Within the immediate Machrihanish area, vessel density remains low overall; however, the data indicates the presence of occasional activity close to the coastline, with localised areas of approximately 2 hours/km²/month. This is considered to reflect infrequent occurrences of vessels operating in close proximity to shore, such as short-duration stops, slow-speed transit, or anchoring behaviour. These occurrences are not persistent and do not indicate the presence of a defined or regularly utilised route through the splashdown area.

Recreational vessel activity in the region is also characterised by a high degree of variability in both routing and behaviour. Vessels may operate at low speeds, alter course unpredictably, or remain temporarily stationary. In addition, a significant proportion of recreational craft are not equipped with AIS transponders and therefore are not fully represented within the dataset. As such, the NMPI data is considered indicative of general patterns rather than a complete representation of all activity.

Consistent with wider UK coastal trends, recreational boating activity is strongly seasonal, with peak usage occurring during the period from May to October. As a result, levels of activity during these months are expected to exceed annual average values presented in the dataset. The proposed launch window is November-December negating this increased potential risk.

Overall, recreational and small craft activity in the vicinity of the proposed operations is characterised by low to moderate density, nearshore presence, and variable routing behaviour. While this vessel class represents the most relevant maritime receptor in the context of the proposed splashdown area, activity remains dispersed and unconstrained, with no evidence of concentrated traffic or fixed routes intersecting the operational footprint.

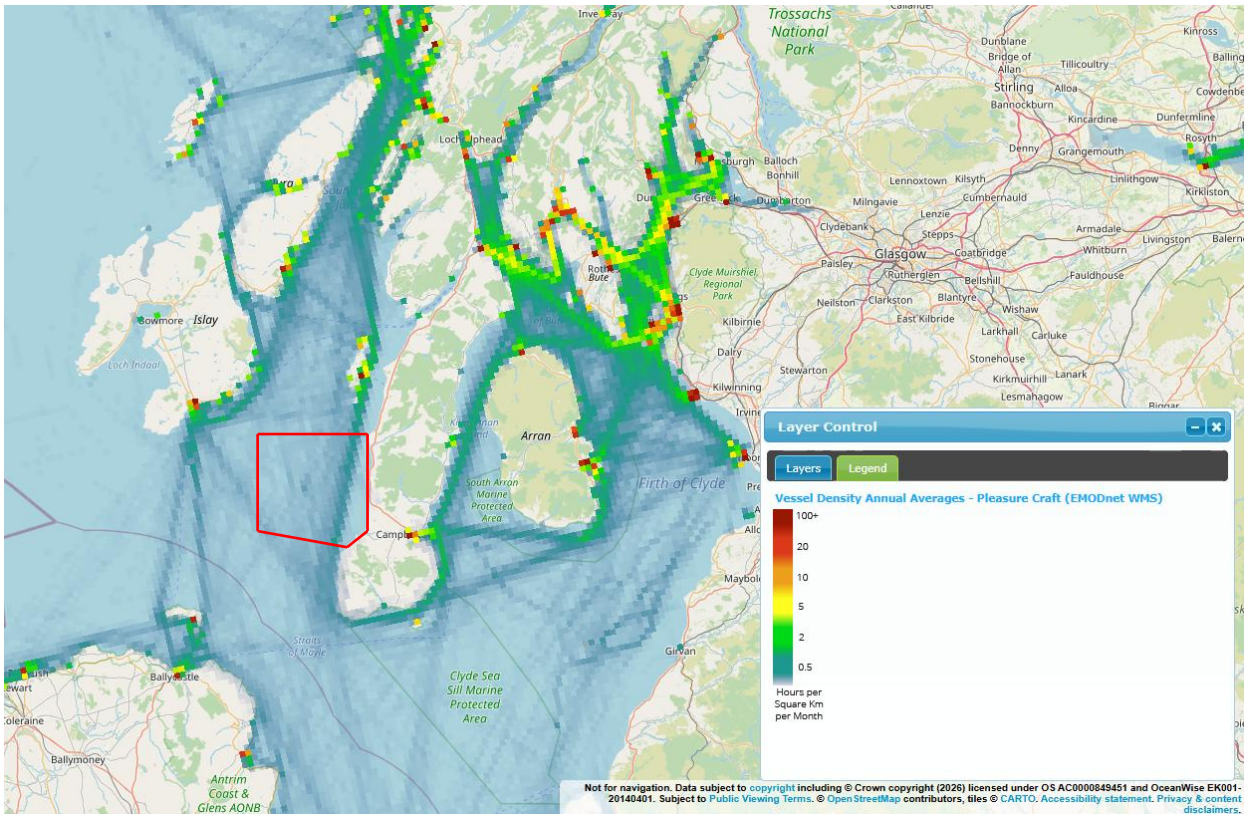

Figure 10 - Recreational Vessel Activity

8.6. Military and Law Enforcement

Military and law enforcement vessel activity in the vicinity of the proposed splashdown area is minimal, with NMPI data showing only isolated and infrequent presence and no defined routes. Accordingly, this activity is considered negligible for the purposes of this assessment.

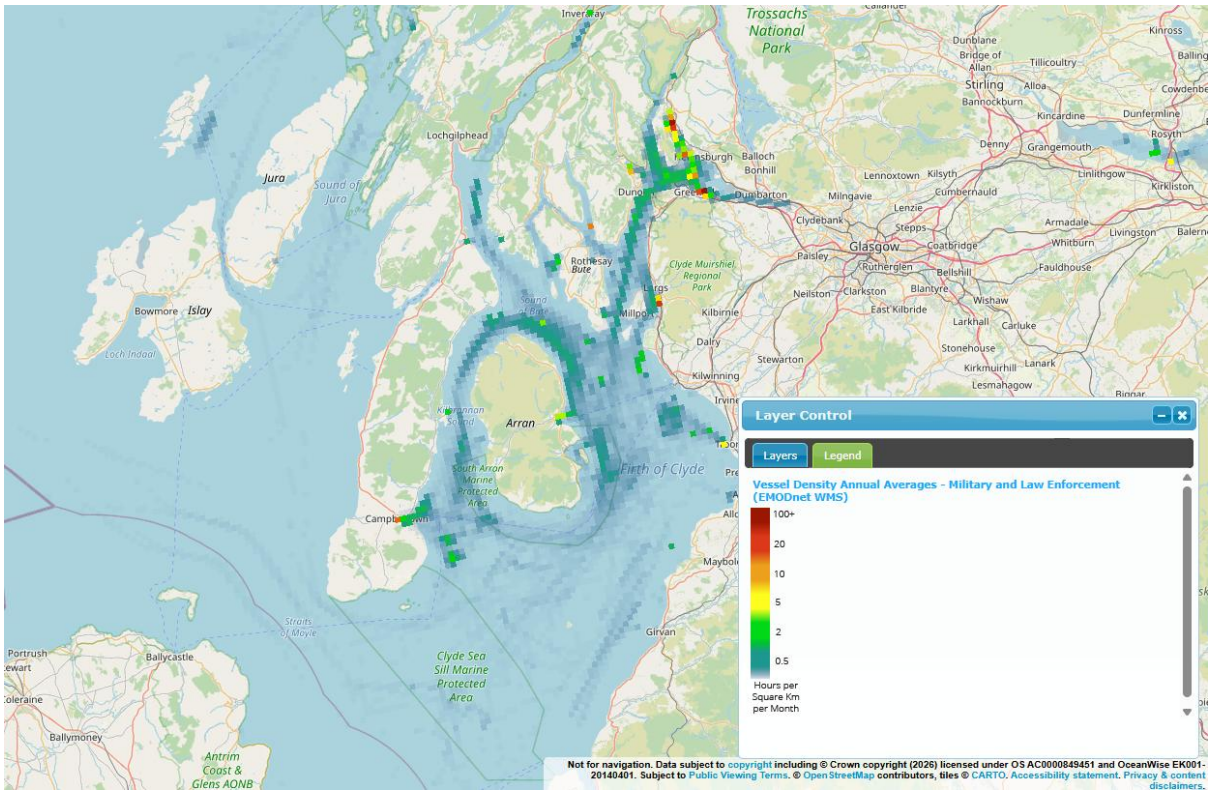

Figure 11 - Military and Law Enforcement Vessel Activity

8.7. Tug and Towing

Tug and towing activity in the vicinity of the proposed operations is limited and primarily associated with commercial shipping movements within the wider Clyde and west coast region. Review of NMPI vessel density data indicates that such activity is concentrated along established shipping corridors, with higher densities observed within the Firth of Clyde and in proximity to major ports such as Greenock. By contrast, activity west of Machrihanish is very low, with only occasional transit movements observed.

Local port guidance indicates that no tug vessels are permanently based at Campbeltown Harbour [1] with tug assistance provided on an as-required basis from operators located in the Clyde (e.g. Greenock). A designated anchorage area for towing operations (55°25.15'N 005°35.10'W) is located adjacent to Campbeltown Harbour, and no requirement exists for tug vessels to operate or remain on standby in the nearshore waters off Machrihanish.

Tug and towing movements are typically associated with, and spatially coincident with, cargo and tanker vessel traffic, following the same established transit routes around the Kintyre peninsula and through adjacent channels. While tugs may on occasion transit independently to or from vessels, such movements remain infrequent and route-based in nature.

The low density and predictable routing indicate that tug and towing activity is negligible in the context of the proposed operations. These vessels would also be expected to always have functioning AIS transmitters onboard and therefore would be identified using AIS mapping services like MarineTraffic. Any vessels transiting the wider area would be seen through AIS

1 https://www.argyll-bute.gov.uk/sites/default/files/2024-11/CBT%20TOWAGE%20GUIDLINES%20REV%2002%20APR-24.pdf

data and notified in advance of launch. Accordingly, tug and towing activity is not considered to present a material navigational constraint especially with the no launch order able to be given should an unlikely interaction take place in one of the mentioned corridors.

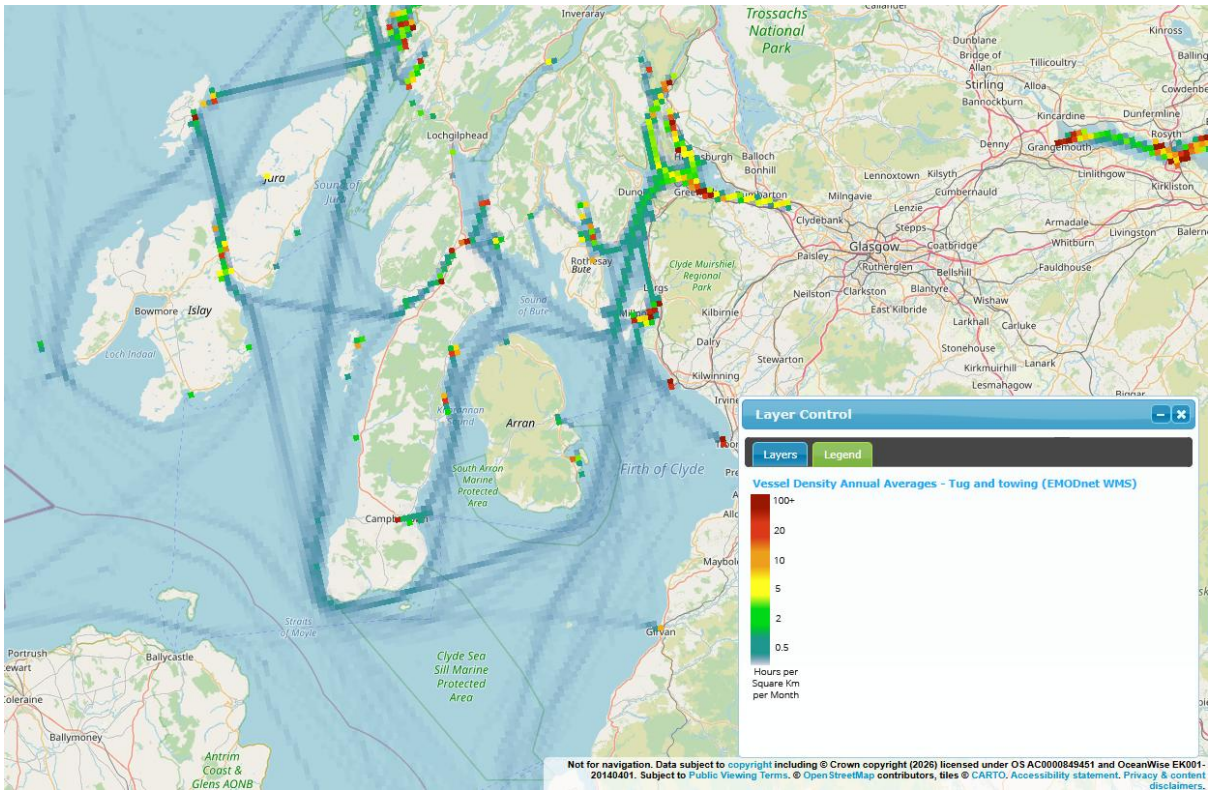

Figure 12 - Tug & Towing Vessel Activity

8.8. Other (Unidentified)

The NMPI dataset includes a category of “Other” vessels, representing AIS-tracked vessels that are not assigned to a specific classification or are inconsistently categorised. This may include a range of vessel types such as small service craft, survey vessels, harbour vessels, or vessels with misconfigured AIS transponders.

The spatial distribution of this category indicates that the majority of activity is concentrated within the Firth of Clyde and in proximity to major ports and high-traffic areas along the east coast of the Kintyre peninsula. This is consistent with the presence of mixed-use and harbour-related vessel activity in these locations.

Within the waters west of Machrihanish, including the proposed splashdown area, vessel density in this category is very low, with only sparse and intermittent activity observed (typically ≤0.5 hours/km²/month) which lies along the same navigational corridor (North-South) as commercial traffic.

In general, the patterns observed in this dataset broadly align with those identified for other vessel classes, including commercial shipping and recreational craft, indicating that this category does not represent a distinct or additional maritime receptor. Rather, it reflects a small proportion of vessels already captured within the overall maritime activity profile.

Accordingly, vessel activity within this category is considered negligible in the context of the proposed operations, and no additional control measures are required beyond those identified for other vessel types.

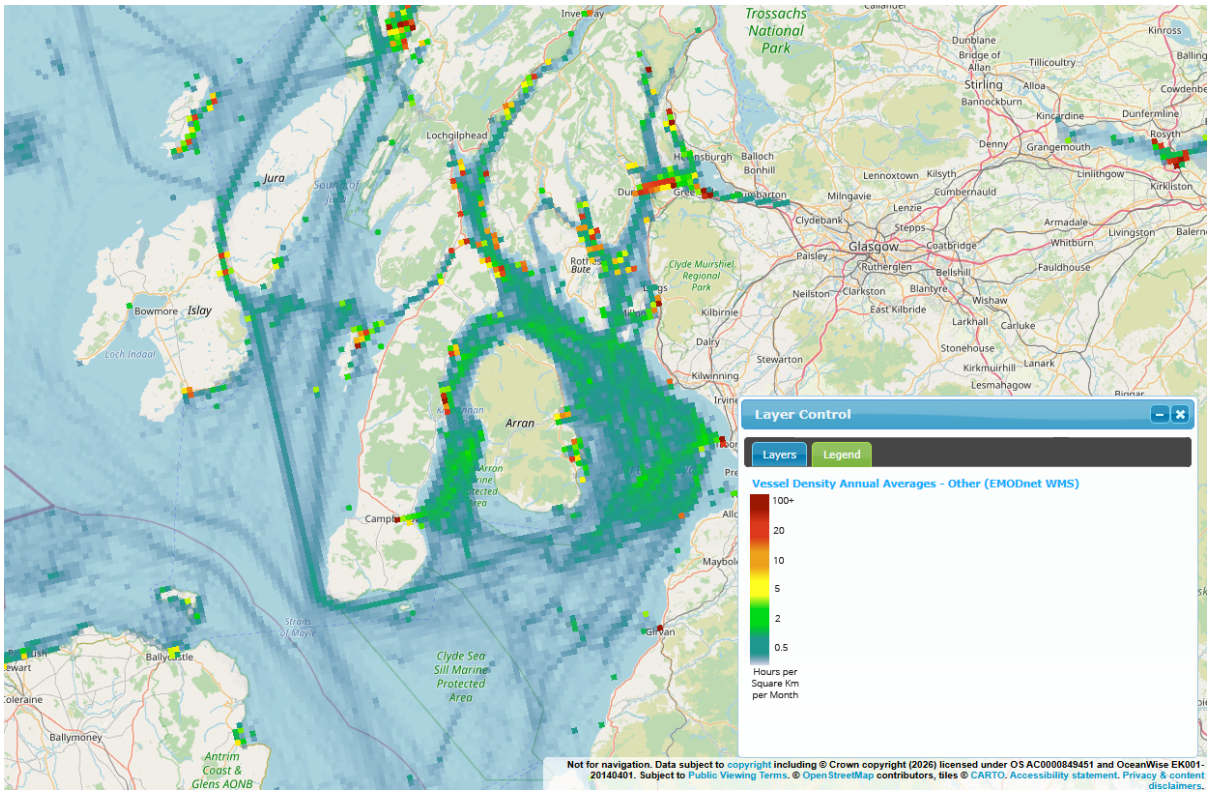

Figure 13 - Other Activity

9. Navigational Hazards

9.1. Recreational and Small Craft Interaction Risk

Recreational and small craft activity represents the primary navigational interaction risk associated with the proposed operations. As identified in Section 8.5, this vessel class exhibits some of the highest level of activity within the vicinity of the splashdown area, with vessels frequently operating in nearshore waters and following coastal transit routes around the Kintyre peninsula.

Unlike commercial shipping and passenger ferry traffic, recreational craft are not constrained to defined navigation corridors and may operate at variable speeds, alter course unpredictably, or remain temporarily stationary. This includes activities such as low-speed transit, short-duration stops, or anchoring, which may occur in close proximity to the coastline. NMPI vessel density data indicates occasional activity within the immediate nearshore area adjacent to the proposed launch site, although such occurrences are infrequent and not associated with any defined or regularly utilised routes.

A further consideration is that a significant proportion of recreational craft are not equipped with AIS transponders and therefore are not fully represented within vessel density datasets. As a result, the presence of vessels within the splashdown area cannot be reliably predicted

solely through AIS monitoring, and the potential for untracked or late-arriving vessels must be considered.
The seasonal nature of recreational activity is also a contributing factor, with peak vessel presence expected during the period from May to October, falling outside our proposed launch activity timeframe.
Based on these characteristics, the principal hazard associated with recreational craft is the potential for a vessel to be present within, or transit through, the splashdown area during launch operations. Such an interaction could result in:

- Close proximity of a vessel to debris splashdown location;
- potential interference with recovery operations; or
- risk to vessel occupants in the highly unlikely event of debris impact.

Although overall vessel density remains low and activity is dispersed, the combination of nearshore operation, variability in movement, and incomplete AIS visibility results in recreational craft being the most relevant maritime receptor for the purposes of this assessment.

9.2. Commercial Vessel Interaction

As highlighted in Section 8.3, 8.4 commercial shipping is concentrated in established routes which partially fall inside the debris splash zone. In the event that a commercial vessel ignores the notice to mariners and transits the safe exclusion zone, the same risks highlighted in 8.2 would be prevalent. Namely, the interaction resulting in

- close proximity of a vessel to debris splashdown location;
- potential interference with recovery operations;
- risk to vessel occupants in the highly unlikely event of debris impact

In this instance, there are several other risk mitigations that take place such as our on water visual surveillance and ability to hold launch until the area is clear.

9.3. Vessel Non-Compliance

A residual navigational hazard exists in the event that a vessel enters the defined hazard area despite the issue of navigational warnings or other communications associated with the proposed activity.
This risk is most relevant to recreational and small craft operators, as these vessels may not routinely receive AIS-based information, may not actively monitor navigational warnings, or may make last-minute routing decisions. In addition, some vessels operating in the area may not carry AIS transponders and therefore may not be visible through electronic tracking systems.
The consequences of vessel non-compliance could include a vessel being present within the splashdown area during launch or recovery operations, increasing exposure to the already remote risk associated with falling debris or recovery vessel manoeuvring.
The likelihood of vessel non-compliance is considered low due to the short operational duration, the limited size of the affected area, the sparse levels of vessel traffic identified in Section 8, and the layered monitoring arrangements that will be employed during launch operations. The launch team will maintain visual surveillance of the area and will not proceed with launch unless the hazard area is confirmed clear.

Consequently, vessel non-compliance is considered a credible but low-probability hazard. With the application of active monitoring and launch hold criteria, the residual risk is considered ALARP.

9.4. Recovery Phase Interaction

Following splashdown, a recovery vessel will enter the operational area to locate and recover the launch vehicle. During this phase there exists a potential navigational interaction between the recovery vessel, the recovered vehicle, and other maritime users.

The recovery operation will take place over a limited area and for a short duration. The recovery vessel will operate under normal maritime regulations and will be crewed by appropriately trained personnel. The vessel will maintain communications capability, including monitoring of VHF Channel 16, and will have access to real-time positional information from the launch vehicle tracking system.

The principal hazards during recovery are:

- interaction between the recovery vessel and third-party vessels;
- temporary obstruction caused by recovery activities;
- delayed recovery resulting in the launch vehicle remaining afloat for longer than anticipated.

Given the low levels of vessel activity identified throughout Section 8, together with the nearshore location of the operation and the rapid recovery objective, the likelihood of such interactions is assessed as low. The launch vehicle is specifically designed to remain buoyant, be visibly identifiable, and be recovered promptly, thereby minimising the duration of exposure to other maritime users.

Recovery operations will only be undertaken once the launch phase is complete and situational awareness of the surrounding maritime environment has been confirmed. Any approaching vessels can be readily observed and appropriate avoidance measures implemented.

Accordingly, the recovery phase presents a low navigational risk that can be effectively managed through standard maritime operating procedures and the controls described in Section 11.

9.5. Shoreline/Nearshore Interaction

The Highlander launch differs from many offshore launch concepts in that all phases of the operation occur within a nearshore coastal environment. As identified in Section 0, the Machrihanish coastline is used by members of the public for recreational activities, including beach access, walking, surfing, paddle sports, and occasional launch and recovery of small craft.

The principal hazard is the presence of persons or small watercraft within the immediate launch corridor, splashdown area, or recovery zone during operations. Such users are unlikely to be represented within AIS datasets and therefore require specific consideration beyond vessel traffic analysis.

The area immediately adjacent to the launch site is characterised by an open coastline with unrestricted public access. Consequently, reliance solely on maritime notification measures would not be sufficient to control this hazard. Direct observation and local management

arrangements are therefore necessary to ensure that launch operations only proceed when the relevant areas are clear.

Control measures include visual monitoring of shoreline areas, management of public access where necessary, coordination between launch and recovery teams, and the application of launch hold criteria should any person, vessel, or water user enter the defined operational area.

Given the limited duration of operations, the relatively remote location of the splashdown area, and the active control measures that will be implemented, the likelihood of an interaction with shoreline or nearshore users is considered low. The residual risk is therefore considered ALARP when the mitigation measures identified in Section 11 are applied.

10. Risk Evaluation

A structured set of control measures will be implemented to ensure that navigational risks associated with the proposed operations are reduced to As Low As Reasonably Practicable (ALARP). These measures apply proportionately to all identified maritime receptors and are designed to ensure that vessels are aware of, and can avoid, the operational area during launch activities.

10.1. Risk Matrix

The following Risk Matrix legend is used in describing the Risk Matrix for the Highlander operation with regards to marine the maritime environment:

	Minor - 1	**Moderate - 2**	**Major - 3**	**Severe - 4**	**Catastrophic - 5**
Almost Certain - 5	Medium 5	High 10	Very High 15	Extreme 20	Extreme 25
Likely - 4	Medium 4	Medium 8	High 12	Very High 16	Extreme 20
Moderate - 3	Low 3	Medium 6	Medium 9	High 12	Very High 15
Unlikely - 2	Very Low 2	Low 4	Medium 6	Medium 8	High 10
Rare - 1	Very Low 1	Very Low 2	Low 3	Medium 4	Medium 5

10.2. Evaluated Risk Table

#	Hazard	Risk / Impact	Analysis	Probability (1–5)	Severity (1–5)	Mitigation	Risk
1	Debris impacts recovery / boundary vessel (nominal launch)	Minor injury or superficial vessel damage	Under nominal conditions, debris descends under a controlled parachute system and remains visible throughout descent. Recovery and boundary vessels are actively tracking the vehicle and are therefore aware of its position at all times. Vessel crews are briefed and able to manoeuvre clear or take protective measures. Given the relatively low mass (≈ X kg) and controlled descent, significant impact effects are unlikely.	1	4	Vessel crew awareness; active tracking; manoeuvrability; pre-briefed safety procedures	4
2	Debris impacts non-involved vessel or person (nominal launch)	Injury to persons or minor vessel damage	Nominal descent is controlled and predictable, with splashdown occurring within a defined and monitored area. The hazard area is visually surveyed	1	4	NOTMAR; visual surveillance; AIS monitoring; launch only	4

			prior to launch, and operations are only conducted when the area is confirmed clear. The likelihood of an undetected vessel or person being present is low due to combined AIS monitoring and visual observation.			when area confirmed clear	
3	Debris impacts non-involved vessel or person (off-nominal launch)	Serious injury or significant vessel damage	In the event of parachute failure or other malfunction, debris may descend ballistically with increased impact energy. This represents a higher consequence scenario. However, trajectory modelling and conservative hazard area definition ensure that debris remains within a nearshore zone that is continuously monitored. Any vessels or persons in proximity are likely to be identified by observers. Radiosonde-derived weather profiles further inform trajectory predictions.	1	5	Conservative hazard area; trajectory modelling; radiosonde data; visual monitoring; exclusion of vessels prior to launch	5
4	Vessel enters restricted area prior to launch	Potential presence within hazard zone at launch	Vessels may approach or enter the hazard area prior to launch, either during normal transit or due to lack of awareness. This is mitigated through pre-launch monitoring of AIS data (e.g. MarineTraffic) to identify vessels in the wider area and assess their likely movement. Non-AIS vessels are identified via visual observation. Launch is not conducted unless the area is confirmed clear.	3	3	AIS monitoring; visual observation; NOTMAR; strict no-go criteria for launch	9
5	Vessel or person fails to comply with navigational warnings	Disruption to operations and potential exposure to hazard	Non-compliance with issued NOTMAR represents a credible but infrequent behavioural risk. In such cases, attempts can be made to establish contact via VHF (Channel 16), direct signalling, or via local harbour authorities. If compliance cannot be achieved, the launch is postponed.	2	3	NOTMAR; VHF communication; stakeholder engagement; no-go decision if non-compliance persists	6
6	Vessel enters hazard area during descent phase	Late-stage interaction risk	A vessel may alter course or enter the hazard area after launch has occurred but prior to splashdown. Given the short duration of the descent phase and continued monitoring of the area, the likelihood of vessel presence within the immediate splashdown footprint at the moment of impact is low.	2	4	Continuous monitoring; defined hazard zone; rapid decision-making	8
7	Third-party vessel	Operational interference or	Following splashdown, third-party vessels may approach	3	2	Rapid recovery; VHF	6

	approaches debris during recovery	minor collision risk	debris out of curiosity or coincidence. However, the recovery vessel is deployed immediately and is expected to reach the debris first. In the event of approach by another vessel, communication can be established via VHF Channel 16 to assert control of recovery operations.			communication; visible recovery operations	
8	Debris misses intended splashdown area (off-nominal trajectory)	Interaction outside designated hazard area	Off-nominal trajectory deviation could result in splashdown outside the defined zone. Conservative trajectory modelling and hazard area sizing are used to minimise this risk. The surrounding waters are also subject to monitoring, ensuring that any nearby vessels are detected.	1	4	Conservative modelling; extended monitoring area; radiosonde input	4
9	Debris becomes unrecoverable	Environmental impact or future interaction risk	Debris is designed either to be recovered promptly or to sink if recovery is not achievable. Components are tethered to minimise dispersion. GPS tracking and visual markers (e.g. smoke) enable rapid location and recovery. Residual risk to navigation is low due to limited floating duration.	2	2	GPS tracking; smoke markers; tethered components; prompt recovery	4
10	Misidentification of vessel position	Incorrect assessment of hazard area clearance	Human error in identifying vessel position or trajectory could result in incorrect assessment of area clearance. This is mitigated by multiple observers, cross-checking between AIS and visual observations, and conservative decision-making.	2	3	Multiple observers; AIS + visual cross-check; conservative clearance criteria	6
11	Man overboard from recovery vessel	Risk to recovery personnel	Personnel working on recovery vessels are operating in open water conditions. Standard maritime risks apply. All personnel are briefed, equipped with life-saving equipment, and emergency response procedures are in place, including immediate contact with HM Coastguard.	1	4	PPE (life vests); crew briefing; emergency procedures; Coastguard contact	4
12	Debris contains non-ignited fuel residue (off nominal)	Minor fire or contamination risk	In an off-nominal scenario, debris may contain residue from solid rocket motors. However, such motors are solid, commercially available systems and are unlikely to present ignition risk post-splashdown. Contact with water further reduces any hazard. Recovery personnel are trained to handle such materials appropriately.	1	2	Trained personnel; no ignition sources; water immersion reduces hazard	2

13	Debris separates from main tether (small components lost)	Minor debris scatter; negligible vessel impact risk	Small components (e.g. cameras) could detach from the vehicle. Individual items are of low mass and are unlikely to cause damage to vessels. Many components are expected to sink. The vehicle is designed with tethers and undergoes pre-launch checks to minimise detachment risk.	2	2	Secure fastening; pre-launch inspection; tethering of components	4

11. Risk Mitigation Measures

A structured set of control measures will be implemented to ensure that navigational risks associated with the proposed operations are reduced to As Low As Reasonably Practicable (ALARP). These measures apply proportionately to all identified maritime receptors and are designed to ensure that vessels are aware of, and can avoid, the operational area during launch activities.

11.1. Pre-Launch Information and Awareness

Prior to launch operations, appropriate navigational warnings will be issued to inform mariners of the planned activity and the location of the temporary hazard area. This will include the promulgation of Notices to Mariners (NOTMAR) and, where applicable, direct engagement with relevant local stakeholders and maritime users informing them of the launch window.
Given that vessels operating within the region are not constrained to fixed routes in the vicinity of the splashdown area, all vessel types are able to adjust their passage plans to avoid the operational area with minimal deviation. The provision of advance notification ensures that mariners can make informed navigational decisions prior to entering the area.

11.2. Monitoring and Situational Awareness

Continuous monitoring of the splashdown area and surrounding waters will be maintained during the launch window to ensure that the operational area remains clear of vessel traffic.
This will include:

- visual monitoring from land-based observation points along the Machrihanish coastline;
- the use of binoculars to observe vessel presence within the nearshore and offshore areas;
- AIS monitoring, where available, to track vessels equipped with transponders.
- On-water visual monitoring via 2 safety & recovery vessels placed downrange from the launch, ensuring line-of-site coverage of the SEZ

This combined approach ensures that both AIS-visible vessels and those not transmitting AIS can be identified, providing real-time awareness of maritime activity in the vicinity of the launch.

11.3. Launch Control and Hold Criteria

Launch operations will be governed by defined control procedures to ensure that the splashdown area is clear of vessel traffic prior to launch.
If a vessel is identified within, or approaching, the hazard area:

- the launch will be held or delayed;
- monitoring will continue until the area is confirmed clear.

Launch will only proceed when it is verified that no vessels are present within the defined hazard zone. This control measure ensures that the risk of vessel interaction during splashdown is effectively eliminated. Communication will be via radio to all team members.

11.4. Local Area Management

The immediate launch site and adjacent coastline will be actively managed during the launch window to ensure the safety of all local users.
This includes:

- monitoring of the beach and coastal areas to confirm that no members of the public are present within the flight path or recovery zone;
- coordination of launch operations from a central control point with oversight of both land and sea areas.

This provides an additional layer of assurance that both maritime and shoreline receptors are accounted for during operations.

11.5. Post-Splashdown Recovery Controls

Following splashdown, recovery operations will be undertaken using dedicated recovery vessels operating within the defined area.
The splashdown location will be clearly identifiable using:

- GPS tracking systems; and
- visual markers (e.g. smoke signals).

This enables rapid localisation and recovery of the vehicle, minimising the duration of any potential interaction with other maritime users.

11.6. Residual Risk Position

Considering:

- the low baseline levels of vessel traffic within the splashdown area;
- the absence of fixed or constrained navigation routes intersecting the operational footprint;
- the ability of all vessel types to avoid the area with minimal deviation; and
- the implementation of layered control measures including notification, monitoring, and launch hold criteria;

the residual navigational risk associated with the proposed operations is considered to be low and reduced to ALARP.

12. Conclusion

This Navigation Risk Assessment has considered the potential navigational hazards associated with the Highlander launch, splashdown, and recovery operations from Machrihanish Airbase. The assessment has demonstrated that the proposed Safe Splashdown Zone has been conservatively derived from trajectory modelling encompassing both nominal and credible off-nominal recovery scenarios, with all predicted splashdown locations remaining within the designated operational area.

Maritime activity within the vicinity of the hazard area is generally low and is not characterised by major established shipping routes, harbour approaches, or other constrained navigational channels. While recreational craft represent the most relevant maritime receptor, vessel activity remains dispersed and infrequent, and vessels can readily avoid the operational area with minimal deviation.

A layered mitigation strategy will be implemented throughout the launch window, including the promulgation of navigational warnings, stakeholder engagement, establishment of a clearly defined hazard area, active monitoring of the operational area, and strict launch hold criteria. Importantly, situational awareness will not rely solely on AIS-derived vessel information. Continuous visual surveillance from land & water-based observers and operational vessels will be used to identify recreational craft, paddle craft, surfers, and other water users that may not be visible through AIS systems. Launch operations will only proceed when the operational area has been confirmed clear of vessels and other water users.

In the event of an off-nominal outcome, the most consequential ballistic scenario remains fully contained within the Safe Splashdown Zone and forms the primary focus of maritime surveillance activities. Following splashdown, the vehicle will be located using onboard tracking systems and visual markers and recovered by a dedicated recovery vessel as soon as practicable, minimising any residual interaction with other maritime users.

Based on the evidence presented, the short duration of operations, the low density of maritime traffic, the conservative sizing of the hazard area, and the implementation of multiple independent control measures, the navigational risks associated with the Highlander launch are considered to be **As Low As Reasonably Practicable (ALARP)**. No additional reasonably practicable measures have been identified that would materially reduce the residual navigational risk without imposing disproportionate operational burden.

13. Annex 1

Marine Licensing

- Marine Directorate (MD-LOT)
- Maritime & Coastguard Agency (MCA)
- Northern Lighthouse Board (NLB)

NOTMAR and Navigational Information

- Cruising Association
- UK Hydrographic Office (UKHO)

Marine Organisations and Representative Bodies

- Caledonian MacBrayne Ferries
- Clyde Fisherman's Association
- Kingfisher Bulletin
- Royal Yachting Association (RYA Scotland)
- Scottish Fisheries Federation
- Scottish Fisherman's Organisation (SFO)
- Solway Yacht Club

Fisheries

- Campbeltown Fishery Office
- Regional Inshore Fisheries Group (RIFG), South West

Harbours, Marinas and Maritime Facilities

- Annan Harbour
- Ardglass
- Ardrossan
- Ballycastle Marina
- Ballylumford Harbour
- Bangor Marina
- Belfast Harbour
- Brodick Harbour
- Bruichladdich Pier
- Campbeltown Harbour
- Carradale Harbour
- Carrickfergus
- Clyde Marine Port
- Clyde Marine Services Ltd
- Clydebank Port
- Coleraine Harbour
- Colonsay Harbour
- Craighouse Pier
- Craignure Pier
- Craobh Marina
- Douglas Harbour
- Dunoon Pier
- Garlieston Harbour
- Girvan Harbour
- Glencaple Pier

- Gourock Pier
- Greenock Ocean Terminal
- HM Coastguard
- HM Naval Base Clyde
- King George V Dock
- Kingholm Quay
- Kennacraig Harbour
- Kilkeel Harbour
- Kip Marina
- Kirkcudbright Harbour
- Largs Harbour
- Larne Harbour
- Londonderry Port
- Oban North Pier
- Portavadie Marina
- Portpatrick Harbour
- Rhu Marina
- Rothesay Harbour
- Strangford Harbour
- Tarbert Harbour Authority

Ports

- Port Askaig
- Port Ellen Marina
- Port Kennacraig
- Port of Ayr
- Port of Cairnryan Ltd
- Port William
- Stranraer and Loch Ryan Port
- Tighnabruaich Port
- Tobermory Port
- Workington Port

Piers

- South Pier (Gigha)

Pontoons

- Lochranza Pontoon