Written Evidence Submitted by Paul Williams, Executive Director, Black Arrow Space Technologies Ltd

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Safety and Sustainability of UK Seaborne Space Launch Operations

A space launch facility hosts a complex array of capabilities, which allow for the preparation of the launch vehicle, safe storage for propellant and other consumables, protection for local populations and associated personnel against unintended blast and shock, and accommodation for business operations, workshops, offices and utilities.

All active spaceports will be licensed through the UK Space Industry Act 2018 (SIA), with added consideration to environmental and population impact and range integrity. The levels of risk to downrange populations, property and commercial overflight are also considered, for the assessment of liability. All launch sites, therefore, whether supporting vertical or air-launched missions, are closely related, with similar operational challenges. The level of challenge reflects the scale of the operation.

The seaborne launch construct, championed by Black Arrow Space Technologies, does not require a Spaceport License under the SIA, as it does not meet the definition of 'spaceport'. It does however, require greater depth in the Spaceflight License, to cover safety, ground operations and logistics.

The major benefits of the seaborne option, i.e. a stable launch site at sea, reside in the inherent security, integrity, sustainability and environmental impact of the infrastructure, logistics and applied operation; a function of the remote nature of the maritime construct.

Although the seaborne launch concept has been proven in the past (Sea Launch LLC), using bespoke purpose-built vessels, considered more of a commercial desire than an operational necessity, merchant vessels are widely available to the highest of marine design standards and provide a robust and easily modified shell for suitable conversion. Modern propulsion, electronic safety and tracking systems and quality accommodation are simple to install and the vessels are able to use existing port infrastructure around the UK and the World.

The inclusion of seaborne launch operations within the SIA has provided additional support to the global aspect of the seaborne option, with licensing available for operation in UK waters, as well as British Overseas Territories (BOT). This puts the UK at an advantage in comparison to all other nations, and provides the seaborne option with greater global relevance as a result.

The use of existing dock/port infrastructure, and the support of associated, often traditional, local skills in these areas, while preventing attributed damage to landmass, ground water, flora/fauna, air quality, noise/light levels, or transport routes, give seaborne launch an advantage.

On a technical level, the seaborne option is more likely to achieve planned launch frequencies, as mobility provides added mitigation of weather. Activities can be maintained within the Spacefleet despite non-optimal wind or cloud cover, and the possibility remains for the launch location to be modified at short notice, if required, depending on positive meteorological forecasting. Once again, this makes the seaborne option more efficient and reliable than land-based (including air-launch).

There is a concern around spaceport and launch pollution, especially when heavy fuel derivatives are used (Kerosene, or similar), with spillage on land (effects on ground water, flora/fauna), and at sea during recovery (effects on coastal environments, marine flora/fauna) and these are identical challenges to all sites, regardless of location. The use of less-polluting propellants and controlled recovery, that does not result in structural rupture and spillage, will assuage these concerns.

In all cases, the seaborne option is considered, on initial analysis, to be technically, operationally and environmentally superior to land-based sites. It has been applied successfully in US and China.

In operation, the spacefleet performs well in all 'spaceport' functions, including low-risk to personnel and property, environmental credentials, efficient operating costs, high safety and security

attributes, high efficiency of campaign and rapid turnaround, for greater flexibility and responsiveness.

The main challenge here is to ensure that the direct costs associated with operating and maintaining the vessels are controlled and mitigated: however, as the same company controls the launch vehicles, the spacefleet and the launch service, these costs can be balanced within the revenues package, with the above advantages given as attractive trade-off metrics (less environmental impact, less inherent risk to property/lower insurance, and greater security, reliability and flexibility).

The seaborne launch configuration comprises an extended set of functions, arranged across a standard dock interface, with secure vehicle, system and payload preparation areas and propellant storage at the dockside complex; and workshops, assembly rooms, launch table/gantry assemblies, storage, safety and fuelling systems, a localised tracking/control range, and all the assurance functions regulated by, and through the applicable UK Legislation, within the spacefleet vessels.

To achieve a seamless functionality, the two sides must be compatible in every sense – the dockside must be tailor-made for the seaborne segment; in dimension, utilisation, service, and operation. The seaborne part must be able to berth in any suitable facility: to receive fuel, supplies, or supporting services, although, for all direct functions, the dockside part is the only pure and tailored interface.

With all pre-campaign activities of vehicle, vessel and payload integration, verification and preparation performed in a secure dockside complex, all launch related tasks (including hazardous operations) are then transferred to the maritime location.

The central facilities are located in the Pad vessel, of sufficient size and volume to accommodate all functions safely and effectively, supporting storage, preparation, launch and range capabilities in one place, with on-site accommodation for parts, personnel and precision workshops.

A Command and Support vessel will accompany the Pad vessel to support the campaign, provide a manned telemetry and command centre, control security of the perimeter, and provide a safe refuge for the campaign team and ships' crew during hazardous, automated, operations and launch.

Modern merchant vessels fit the seaborne launch function well, with plenty of available volume for all preparatory activities, storage and tracking/control functions, while affording a high level of safety to personnel, hardware and vessel, and stability.

The balance of the vessel is also critical to optimise the launch operation, ease handling and maintain system efficiency. The launch table arrangement sits over the Centre of Buoyancy to avoid loading the hull and for stability provides a balanced exhaust vent for ignition and propulsion products, with lateral vents and internal blast/heat shields. The loads imparted onto the ship's hull during the few seconds of maximum thrust will be distributed evenly, via a load cage, ensuring a stable platform and optimal handling of the vessel during these events.

The launch operation requires external range and secure uplink/downlink capabilities to orbit, and to provide tracking of returned stages for recovery. These will be located according to requirement and likely include existing facilities operated by third parties under a special joint-utility agreement.

To maximise safety, propellant and other hazardous consumables are stored in a protected area forward of the launch table, with the hardware integration and verification spaces aft.

Internal security is ensured using restricted access and permissions to enter specific areas, especially those containing hazardous goods. These areas are also protected by lightning/spark and overpressure protection, preventing dangerous build-up of charge or pressure increasing the hazard.

Although technically agnostic to the particular vehicle system flying from the spacefleet, certain aspects do need to be considered to ensure compatibility: notably, the matching of the avionics systems; the propellants stored and transferred; and dimensional sizing of the vehicles to be flown.

The most optimal solution, of course, is for the spacefleet to be tailored to one particular system. This removes the need for added assurances of compatibility and safety between campaigns, and reduces the likelihood of avoidable errors, leading to major, critical or catastrophic hazard and delay, ultimately increasing the operational cost.

The launch location can be adjusted for direct Line of Sight to Orbit (LOSTO), with managed interaction with air (NOTAM) and marine operations (NOTMAR), and minimal overflight of national infrastructure.

Sea-launched systems can perform preparatory activities for launch operations at any time, and sail through any prevailing adverse weather to meet conditions to support a launch attempt.

This can be adjusted in minutes by on-board meteorological forecasting and assessment systems, in order to be able to launch as soon as practicable, even allowing a modest change of the range, should it be required, without major impact to specified flight plans.

In effect, the spacefleet can 'chase the weather' to minimise delay and maximise the likelihood of success, thereby neutralising the weather factor, a bothersome and unpredictable UK attribute.

The design of the spacefleet can incorporate many 'green' solutions such as non-toxic propellants, non-mined materials, and clean marine fuels, while assisting in resource protection activities.

Selection of a home port will take into account many different parameters, not least of which, is the long-term availability and suitability of the port and its regional communications and capabilities, with regards to planned future growth of both space centre and seaport.

The UK is surrounded by water and there is an abundance of seaports available which could be suitable to locate such a seaborne operation. In essence, the driving issues for home port location is security of resource, accessibility, and reducing the time 'at sea' to a minimum.

When the projected flight scenarios from UK waters are considered, it becomes clear that there are three areas which offer greatest suitability for direct LOSTO to either of the LEO trajectories provided earlier: the North Western point of the Faeroe-Shetland Channel (FSC); South-West of the Hebrides (Hebrides Terrace); or in the Western Approaches, South-West of Ireland.

Given the arguments regarding the rapidly changeable weather around the North of the UK at any point of time throughout the year, it makes sense to set a primary location to suit the latter locations.

The number of UK ports able to provide 24/7 deep harbour service for suitable vessels using these locations (within 3-5 days sailing time) are few, and the selection criteria for the port then become more complex, with an in-depth trade-off required, taking into account: available development areas for a secure preparation complex; deep water harbour with assured 24/7 access, and light to medium shipping traffic; ease of communications with the rest of the UK, as well as local industrial supply chains; an international airport within a reasonable distance; critical supplies within a short distance; and a well-skilled workforce.

When the trade-off is done, only a handful of ports located around the Bristol Channel, or in North West England are seen as the most favourable. There are also suitable options for a home port in Northern Ireland or the Republic of Ireland, which could serve the above locations equally well.

The oceans, as every schoolboy will tell you, make up 70% of the Earth's surface. In theory at least, that makes a seaborne launch option the most efficient of all 'spaceports', in that it could support satellite launch activities from 70% of the World's nations.

This opens all kinds of possibilities in the expansion of satellite design and manufacture, usage and exploitation around the world – to non-space nations, diverse populations and developing regions.

A perfect system for extending the societal benefits of utilising space for peaceful commercial space-related purposes, promoting skills and capabilities to all regions of the world.

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