ACP-2021-12

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STEP 2B OPTIONS APPRAISAL (PHASE 1) INITIAL

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Principal Author	
[redacted]	[redacted]
Mal AT 113	[redacted].com

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Executive Summary

The main business demand for the Spaceport-1 (SP-1) facility is for the operation of sub-orbital sounding rockets. It was envisaged that orbital launches would be facilitated sometime in the future and in the interests of economies and future proofing the launch site, this Airspace Change Proposal (ACP) originally covered both sub-orbital and orbital airspace requirements despite the requirements being significantly different. The planning application for the SP-1 launch site is however limited to sub-orbital launch only and to avoid confusion and possible misinterpretation of intent, it was decided that the ACP should focus solely on sub-orbital rocket launch. This ACP was subsequently de-scoped in September 2022 to capture only the requirements for sub-orbital sounding rocket launch; all stakeholders were informed accordingly through the Step 2A engagement process.

The airspace change Sponsor developed a variety of airspace design options which were shared with a wide range of identified stakeholders including those who were engaged in Stage 1B of the process. Feedback on the design options and how they aligned to the Design Principles (DPs) was invited. Despite a four week engagement period, feedback received was limited to the three main stakeholders; the Ministry of Defence (MOD); Highlands and Islands Airports Ltd (HIAL); and NATS. From the feedback obtained and meetings held with MOD and NATS, it was concluded that only three of the six options presented were credible to take forward into Step 2B, namely:

- Option 3 - New fillet of airspace around launch site and use of existing Danger Areas D701;
- Option 4 - Creation of a whole new bespoke modular airspace structure from the SP-1 site; and,
- Option 5 - Used in conjunction with Option 3 and applying sub-divisions/reconfiguration of D701.

Stage 2B requires an initial appraisal of the impacts of the design options against a “do nothing” option. The chosen methodology was to conduct a simple qualitative assessment of the three different options, both positive and negative, against the headings identified in Civil Aviation Publication (CAP) 1616, Appendix E, Table E2: “Guide to expected approach to key analysis for a typical airspace change”. An initial indication of safety implications was also produced.

From the options appraisal, Option 3 emerged as the preferred option, followed by Option 3 with Option 5, and then Option 4. The latter option is considered the most costly in terms of operational cost (for ANSPs and the MOD Hebrides Range) especially when balanced against planned use (10 launches per year). Moreover, there are potential negative safety implications associated with two similar airspace structures with different airspace management procedures being superimposed in the same area.

QINETIQ/23/00010

1. Introduction

1.1 Introduction

The report is compiled as part of the ACP process prescribed in CAP 1616 [A] for a permanent airspace change. ACP-2021-12 has been commenced in order to establish segregated airspace to facilitate sub-orbital rocket launch from the Spaceport 1 (SP-1) launch site on the Outer Hebrides as shown in *Figure 1.*

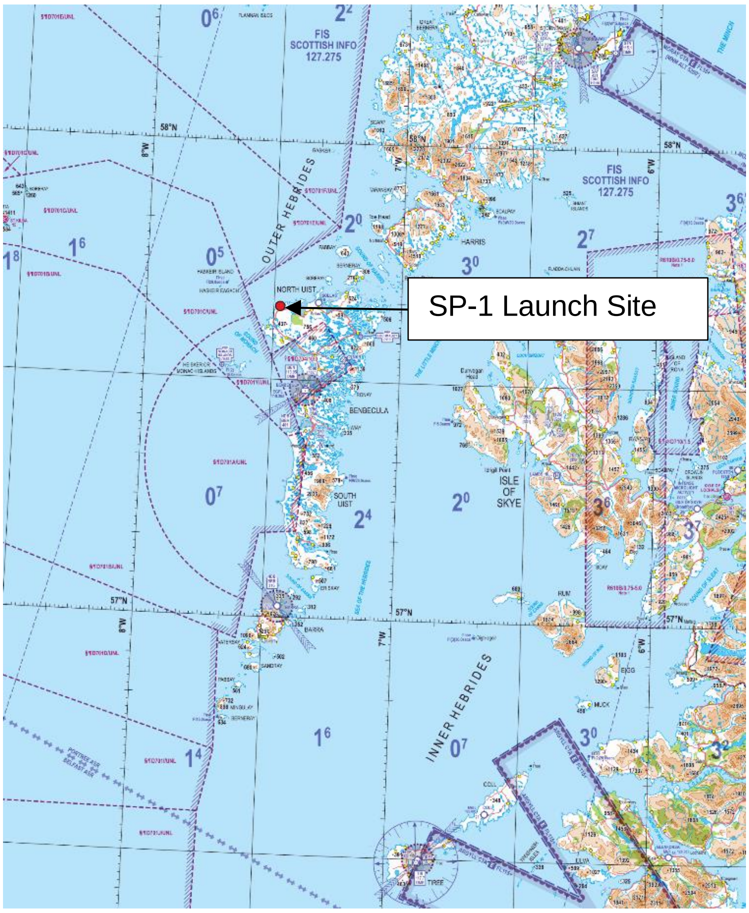

Figure 1: SP-1 Launch site location

The SP-1 consortium led by the local council, Comhairle nan Eilean Siar, and comprising Highlands & Islands Enterprises (HIE), private investors and QinetiQ, are developing, subject to planning consent, a vertical launch spaceport located at Scolpaig, North Uist. This site is being developed as an opportunity in support of the UK government's spaceflight programme, 'LaunchUK', which aspires to grow the UK's global market share of the space sector to 10% by 2030 and be at the forefront of small satellite launch capability. QinetiQ is the airspace change Sponsor for this proposal, which seeks to secure suitable airspace for the safe operation (from launch to splashdown) of sub-orbital sounding rockets operating from the SP-1 launch site at Scolpaig, North Uist.

Despite the main business demand for the SP-1 facility focusing on the operation of sub-orbital sounding rockets, it was envisaged that orbital launches may be facilitated sometime in the future. It was therefore decided, in the interests of economies and to future proof the launch site, that this ACP should capture the airspace requirements for both sub-orbital and orbital rocket launches despite their differences. However, driven by the planning application for the SP-1 launch site, which only considers sub-orbital launch, it was subsequently decided to de-scope the ACP to facilitate just sub-orbital launches. This was to prevent any confusion and possible misinterpretation of intent to those stakeholders with a vested interest in the planning process. It is recognised that should orbital launches become an option in the future then this will be the subject of a new planning application and ACP.

This report makes a number of references to the airspace design options and design principle evaluation report available on the CAA airspace portal at Reference [B]. Furthermore, several items of evidence supporting the qualitative assessment used in this document refer to work undertaken in the ACP for a Temporary Danger Area (TDA) at the Scolpaig launch site (ACP-2021-37), details can be found on the CAA airspace portal at Reference [C].

The nature of modern sounding rockets, with limited pedigree and testing, means there is very limited evidential data available to conduct meaningful safety analysis so a more generic exemplar approach is made to determine the airspace requirements for rocket launches. This exemplar approach is underpinned by experience and safety assessment criteria used by QinetiQ for the rocket launches conducted during the At Sea Demonstration/Formidable Shield (ASD/FS) large scale military exercises that occur bi-annually at the MOD Hebrides Range. Using this data, combined with what is known of the various rocket types, a worst-case scenario is developed and the airspace volume designed around this to ensure aircraft operating at or outside the airspace boundary are not exposed to any additional credible risk. The airspace dimensions thus determined might be greater than actually required for all rocket launches and to address this, outside of the immediate[1] launch site, a modular design is promoted that enables different segments of airspace to be activated to meet the specific requirements of individual sounding rockets. Such a design may involve use of the existing airspace structure of EG D701[2], or design of a wholly new bespoke set of areas; both options are presented here along with the option to modify the D701 areas to enable more efficient use of the airspace.

At this stage of the process, it is not possible to monetise costs and benefits due to the nature of rocket launch where there are no benefits to other airspace users, only costs. Furthermore, the value of rocket launch is extremely difficult to quantify given the infancy of the capability and business. However, it has been identified that SP-1 will drive growth in the local economy, creating:

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[1] The minimum airspace requirements around the launch site are known and have been calculated using experience and safety processes used in launching ballistic missile targets from the MOD Hebrides Range and using an exemplar 'worst-case' scenario rocket type.

[2] EG is the ICAO designator for UK Segregated Airspace and D specifies Danger Area – EG D701 is abbreviated to D701 throughout this document.

- Much needed jobs for younger people (thereby slowing down the exodus of younger persons from the Outer Hebrides);
- Revenue for local businesses; and,
- Indirect benefits to local businesses providing support to the UK space sector.

The negative impacts are likely to be environmental cost associated with SP-1 operations where Commercial Air Transport (CAT) is required to re-route around the activity thereby increasing fuel burn and CO_2 emissions. It is not considered proportionate to provide a quantified assessment of what this impact will be for each of the options at this stage of the ACP process (this will be captured in later stages); suffice to state that any one of the three options will have an environmental impact.

1.2 Purpose

The purpose of this report is to demonstrate that the Sponsor has followed due process as defined in CAP 1616 [A] for Stage 2 Step 2B of the ACP process as far as it is practicably possible for a permanent airspace change to facilitate vertical sub-orbital rocket launch. The report forms part of the overall requirements for the Stage 2 Develop and Assess Gateway.

1.3 Report Structure

The report is split into the following sections

- Section 1
  - Introduction
  - Purpose
  - Structure
- Section 2
  - Statement of Need
  - Design Principles
  - Design options summary
- Section 3
  - Initial impact appraisal of design options
  - Methodology
  - The Do-Nothing option (Baseline)
  - Options appraisal
  - Conclusion of options appraisal summary
  - Evidence to be collected for full appraisal
  - 10 year forecast
  - Assessment of noise impact and high level assessment of other costs and benefits for each airspace design option
  - Noise modelling requirement
  - Tranquillity and biodiversity
  - Safety assessment
  - Airspace classification options
  - Airspace classification comparison

- Measures to reduce impact on other airspace users
- Section 4
    - Next steps
- Section 5
    - Glossary
- Section 6
    - References
- Appendices
    - A – Evidence from Environmental Impact Assessment (EIA)

2. Statement of Need & Design Principles

2.1 Statement of Need (SoN)

Since the SoN was written orbital rocket launch airspace requirements have been removed from this ACP.

"A consortium led by the local council (Comhairle nan Eilean Siar), comprising Highlands & Islands Enterprise, private investors and QinetiQ, are developing a vertical launch spaceport site, herein known as 'Spaceport 1', at Scolpaig, North Uist on the Western Isles. This site is being developed as an opportunity in support of the UK government's spaceflight programme, 'LaunchUK', which aspires to grow the UK's global market share of the space sector to 10% by 2030 and be at the forefront of small satellite launch.

Spaceport 1 has been the recipient of local government investment to construct a vertical launch spaceport that will enable small satellite launch. Development of the site and future use by operators will generate much needed revenue for local communities. It is envisaged that significant economic return will result from the creation of high quality job opportunities for local residents, direct and indirect financial income and an increase in personnel residing and visiting the area.

The location has been carefully selected in order to minimise disruption to the public and airspace users, the latter through the exploitation of the existing Ministry of Defence (MOD) managed Danger Areas known as the Hebrides Range; the EG D701 complex. Using irreducible spare capacity of the existing Danger Area complex will enable safe testing of suborbital 'sounding rockets' and future small satellite launch rockets[3]. The existing Danger Areas are fully integrated into systems and processes employed by the UK Airspace Management Cell (AMC) and the EUROCONTROL Network Manager enabling harmonised and dynamic planning of the Air Traffic Management (ATM) network. Moreover, it is envisaged that QinetiQ will manage any 'new' airspace created under the ACP in exactly the same fashion the Hebrides Range airspace is managed, thereby utilising existing airspace management processes and procedures enabling efficient use of airspace under the Flexible Use of Airspace (FUA) concept. Furthermore, this will facilitate expedient transfer of airspace use from MOD activity to Spaceport operations as well as accommodating short notice changes and, where appropriate, coincident operations.

The Spaceport 1 site at Scolpaig currently lies beneath Class G unregulated airspace but is only a few miles from the EG D701 complex. As rocket launch will pose a risk to other airspace users, there is a requirement to safely segregate such activity to minimise risk. Segregation is normally achieved through the promulgation of temporary reserved airspace activated by a Notice to Airmen[4] (NOTAM). However, as the airspace is likely to be needed on a regular basis, the promulgation of a NOTAM

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[3] The requirement for orbital launch options is no longer included in this ACP.

[4] Since the SoN was produced the CAA have changed the terminology to be gender neutral and should now read: 'Notice to Aviation'.

detailing the coordinates and control procedures for every launch is probably not appropriate as a long term solution. Furthermore, such temporary airspace is not fully integrated into the airspace management systems and has to be created on a case by case basis thereby increasing workload and, by necessity, the notification periods for activation.

It is therefore considered an ACP is required to provide a small fillet of segregated airspace that provides both adequate protection for the spaceport activities and connects the spaceport with the Hebrides Range Danger Areas. It should be noted that the MOD has developed an agreed process for non-MOD activities to be conducted in MOD sponsored Danger Areas such as the Hebrides Range. This formalised process is an enabler that should allow Spaceport 1 to operate, under certain conditions, in the Hebrides Danger Areas. The small fillet of airspace required under the ACP effectively joins the most easterly boundary point of D701E with D701Y, where the latter adjoins D704.

The ACP will enable both sounding rockets to be tested (nominally on a westerly bearing) and small satellite rocket launch to the North[5]; both trajectories maximising the use of the D701 complex."

2.2 Design Principles (DPs)

It should be noted that the expanded explanation of DP2 and DP3 make reference to orbital rockets, which have since been removed from this ACP. Furthermore, DP9 is no longer relevant as this relates solely to orbital rocket launch and is therefore Not Applicable (NA).

DP1	**Safety**	**The safety of all airspace users is the paramount factor in the airspace design**
DP2	**Safety**	**The airspace design will be of the smallest volume to safely segregate Spaceport rocket launches from other airspace users thereby minimising the impact on other airspace users**
DP3	**Operational**	**Minimise the impact (on other aviation stakeholders) of activating specific EG D701 Danger Areas in support of SP-1 operations**
DP4	**Operational**	**Use Flexible Use of Airspace (FUA) principles by integrating the airspace design into the extant Airspace Management (ASM) procedures operated within the EG D701 complex**
DP5	**Operational**	**Integrating/deconflicting SP-1 activity safely with MOD activity in EG D701 is a vital element of the operational use of the airspace design**
DP6	**Operational**	**The airspace design shall take into account Free Route Airspace (FRA) and Flight Planning Buffer Zones (FBZs) remaining cognisant of CAA Buffer Policy**

[5] Although the requirement for orbital 'launch to the North' has been removed, there remains a requirement to be able to conduct certain sub-orbital launches to the North where they can be wholly contained within D701.

DP7	**Environmental**	**The airspace design and associated activation of EG D701 need to consider the environmental impact of aircraft being re-routed around the airspace in addition to considering the noise, emissions and light pollution in the local area**
DP8	**Regulatory**	**The airspace design will need to consider any emerging regulations pertaining to spaceports and Ranges under the Space Industry Act 2018**
DP9	**Operational**	**Rocket stage drop zones may be required outside the EG D701 Areas and will need to be considered**

2.3 Design Options Summary

The Sponsor prepared a number of airspace design options upon which it invited feedback and comment from a range of stakeholders; this feedback incorporated a request to consider how each option was aligned to the DPs.

Six airspace options were presented including the baseline 'Do-Nothing' Option 0; this option was not considered viable for rocket launch as it does not provide any segregation – a critical element of the DPs and SoN. It is strongly argued that segregation of rocket launch is categorically essential in ensuring safety as rockets are unable to comply with the Rules of The Air (RoTA), thereby increasing the risk of mid-air collision and, following catastrophic failure or flight termination, create a debris hazard to other aircraft.

Option 1 required temporary airspace being designed for each launch necessitating a unique bespoke airspace design driven by the individual rocket safety assessment and safety trace analysis. Although this option utilised a smaller volume of airspace than the other options, it would require individual NOTAM and associated Aeronautical Information Publication (AIP) Supplement (SUPP) information to be created and published for each launch to enable segregation. Such one-off NOTAMs would not be fully integrated into the UK Airspace Management Cell (AMC) or EUROCONTROL Network Manager (ENM) ASM systems that enable the harmonised and dynamic planning of the ATM network. Furthermore, temporary airspace is not featured on navigation charts or in Air Traffic Control (ATC) and MOD Hebrides Range surveillance systems. Temporary airspace reservations have to be drawn using dynamic mapping tools – a lengthy process that induces a higher probability of plotting error. This option was therefore discounted as it failed to meet several of the DPs based on these issues.

Option 2, (using D701 but with a bespoke temporary airspace design around the launch site), was similarly discounted on the same grounds based on the fact a temporary airspace solution around the launch site would be needed for each launch and, unlike Option 1, the volume of airspace utilised was no less than the other options presented.

The three remaining options (Options 3, 4 & 5) were taken forward to the Options Appraisal.

2.3.1 **Design Options – Stakeholder Feedback**

Despite sharing the design options with a wide number of stakeholders (88 in total), only nine responses were received and, from these nine, just three provided feedback, two requested unrelated[6] information and the remainder had no comment. The feedback was limited to the main stakeholders namely, MOD, NATS and HIAL. The feedback included their view on whether the design option met the DPs; this information was used to help inform the DP evaluation and decision to consider three options in Step 2B. Two of the respondents, HIAL and MOD suggested Option 3 as their preferred option based on the fact this option largely uses an existing segregated airspace structure with well-established ASM processes and procedures. MOD proffered that they would support Option 5 (modification of the D701 areas) providing it was cost neutral to them and the benefits of such changes could be shown to be cost effective when all aspects were considered. Both options (3 and 5) require a new ‘fillet’ of segregated airspace to connect the launch site to the existing D701 and D704 Danger Areas (see *Figure 2*). NATS suggested Option 4 as the preferred option and challenged the fact several of the DPs made reference to the use of D701. The Sponsor acknowledged this observation and agreed that, by removing the reference to D701, at least three of the DPs would enable Option 4 to meet the DP requirements. Option 4 is therefore considered along with the other two options. All options require a small additional circular area of segregated airspace in the immediate vicinity of the launch pad in order to protect SP-1 personnel (while engaged in certain pre-launch activities), from the noise/distraction caused by low flying aircraft (see *Figure 3*). This additional small area also provides protection from Radio Frequency (RF) emissions from low flying aircraft should the rocket systems prove susceptible.

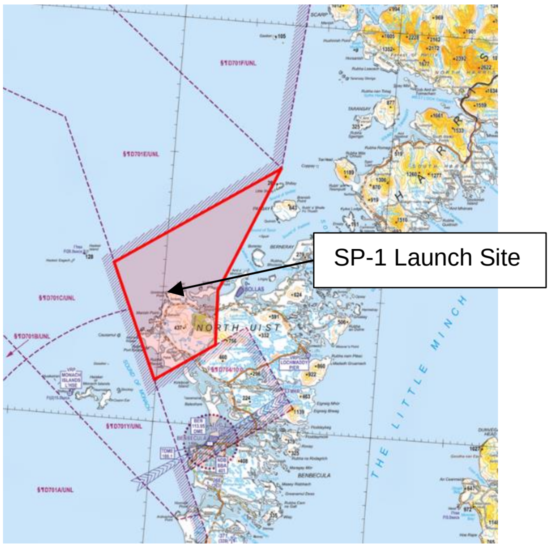

Figure 2: Airspace ‘fillet’ connecting airspace around launch site with D701 & D704

[6] Unrelated to the airspace design options or DPs. One respondent requested more information on the ACP process and the other wanted to better understand the relationship between the airspace safety volume and ground safety footprint. Details are captured in the Step 2A report at Reference [B].

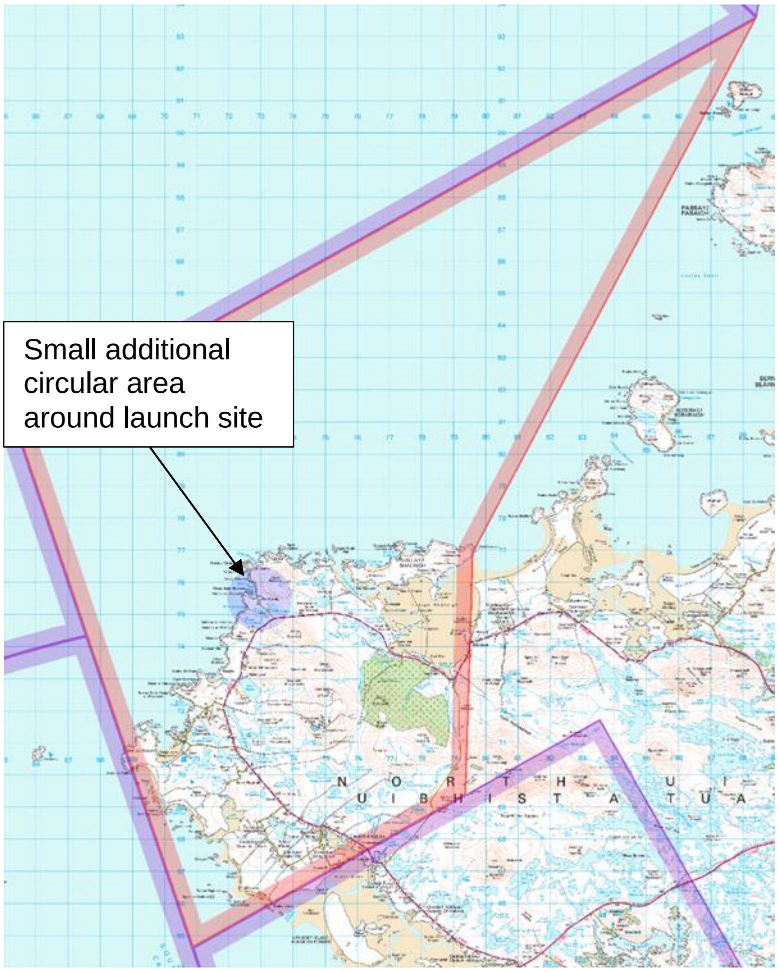

Figure 3: Small circular area of segregated airspace within 'fillet' to protect SP-1 ground personnel

2.3.2 **Option 3 – New Fillet of Segregated Airspace around Launch Site and Utilise D701**

This option includes the use of a new fillet of airspace around the launch site between D701 and D704 that could be activated by NOTAM in the same manner as the D701 areas. This would provide a permanent airspace solution over the launch site and connectivity to the D701 Danger Areas. The D701 areas could be activated in the normal manner using only those areas necessary to contain the safety trace of the rocket being launched. Both the fillet of airspace and D701 would be fully integrated into the systems and processes employed by the UK AMC and the ENM, enabling the harmonised and dynamic planning of the ATM network. Furthermore, this option provides the most straightforward operation for MOD Hebrides Range staff as each different sounding rocket launch would be treated in exactly the same manner as any MOD weapon firing or test and evaluation event. The new fillet of airspace would be treated as an extension of D701 for ASM purposes and the associated D701 areas would be activated accordingly to meet the safety trace requirements of the rocket being launched.

Notification, activation and deactivation would follow existing procedures and Letters of Agreement (LoAs).

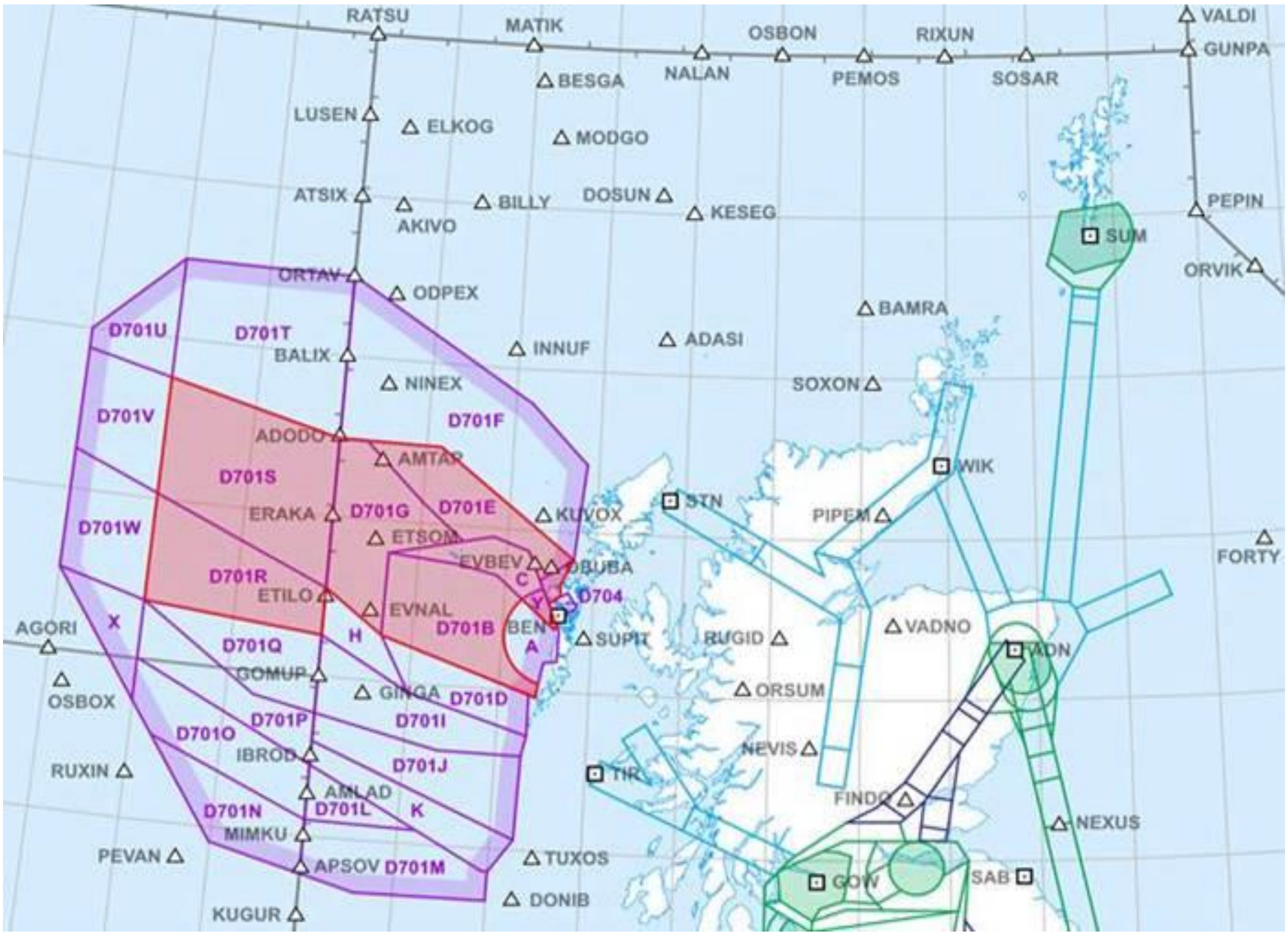

Figure 4: Option 3 – New fillet of segregated airspace around launch site and utilisation of D701 – Diagram depicts D701 areas activated for a long range sounding rocket

2.3.3 Option 4 – Construct New Bespoke Segregated Airspace Blocks from Launch Site

As many of the modern sounding rockets have very limited pedigree, endeavouring to accurately predict the launch profiles, and critically the safety traces, is not feasible at this stage (so far in advance of the launch). Therefore, any attempt to design new airspace blocks introduces risk unless a large bespoke modular design is used. Any such large bespoke modular design for sounding rockets would have to extend in excess of 250km west north-west from the launch site and be constructed of several different airspace blocks to enable a process of tailored activation (similar to that currently used for D701) to be adopted. With experience gained from the ACP pertaining to the redesign of the D701 areas in 2014, it is expected any such modular design would have to be largely aligned to the existing boundaries of D701 to enable minimum disruption to traffic routing to/from the Oceanic Entry Points

(OEPs) at 10° west. The modular design and alignment of the D701 Danger Areas may not always occupy the absolute minimum volume of airspace (with more airspace sometimes being activated than is absolutely necessary) however this alignment enables CAT to fly the shortest routes to/from the OEPs. Therefore, any additional unused airspace becomes largely irrelevant especially as this airspace is rarely used by anything other than CAT. For this reason, it was considered that any modular bespoke design would have to follow similar alignments to that of D701 as depicted in *Figure 5*. However, NATS in their feedback suggested a more symmetrical design as shown in *Figure 6.* Either airspace design would be fully integrated into the systems and processes employed by the UK AMC and the ENM, enabling the harmonised and dynamic planning of the ATM network. Despite the bespoke design, the airspace around the launch site would still need to be the same shape as the airspace 'fillet' required for Option 3 & 5 based on the safety analysis conducted for the TDA, ACP-2021-37 [C].

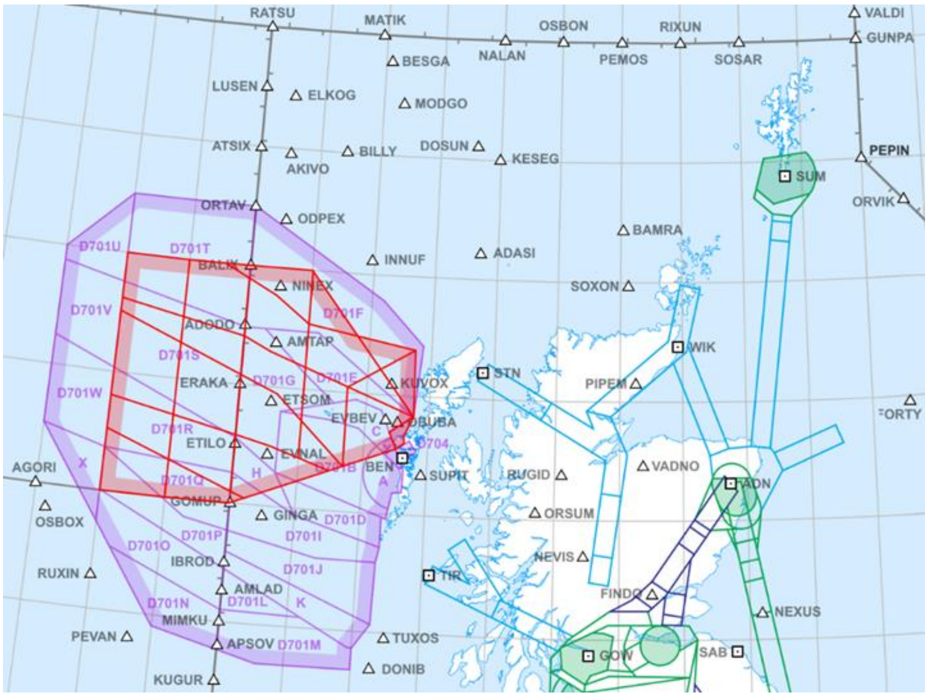

Figure 5: Option 4 – Bespoke airspace design originating from the SP-1 site with similar alignment to the existing D701 areas.

The new airspace blocks would overlay a significant part of the existing D701 areas (see *Figure 6*) and would require careful delineation to prevent confusion; this would be particularly important when simultaneous activities were occurring (MOD use of D701 and SP-1 use of new areas). New and separate (from D701) ASM process and procedures would be required for this option.

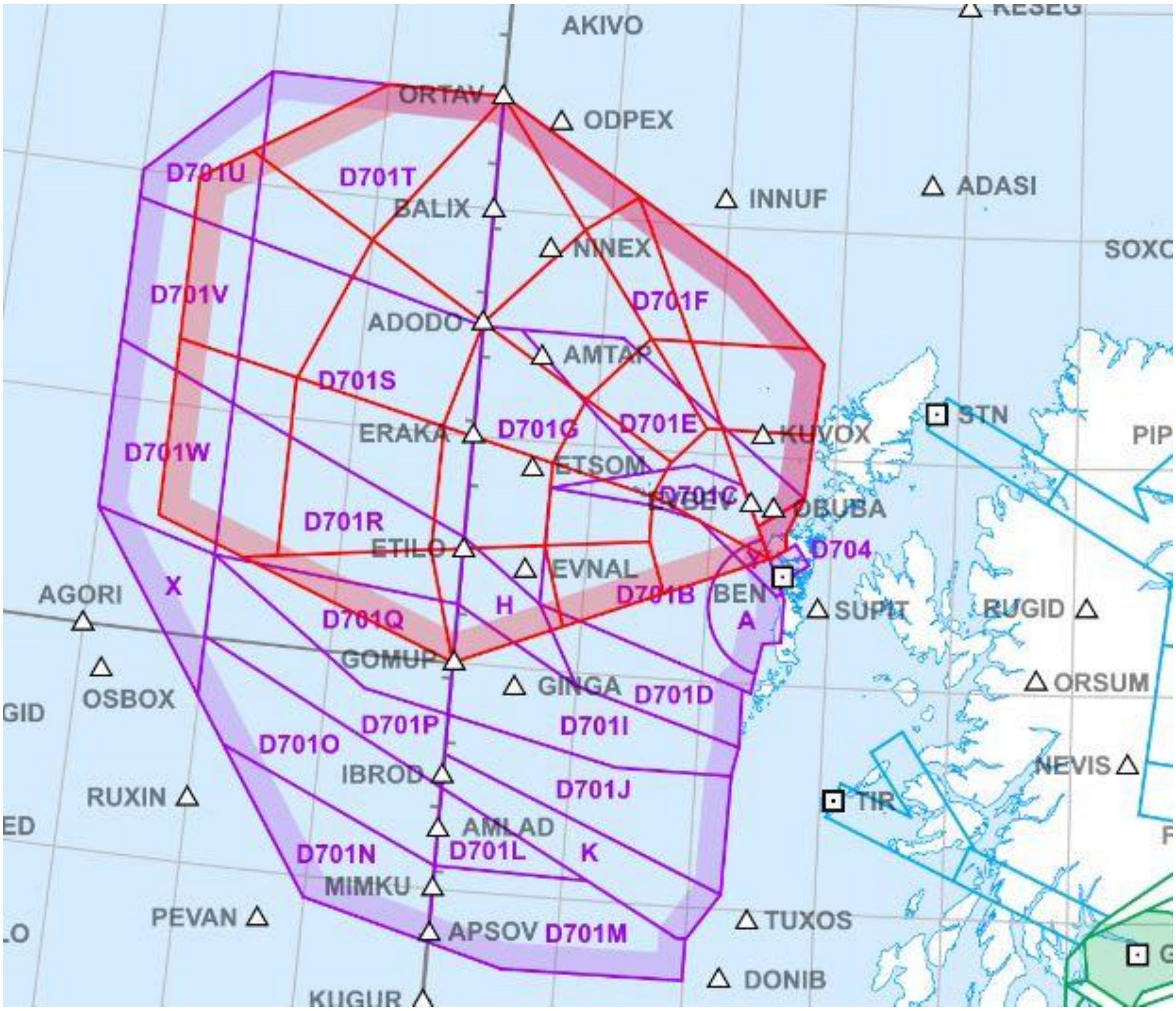

Figure 6: Option 4 – An alternative bespoke modular airspace design originating from SP-1 site with D701 overlay

2.3.4 Option 5 – Use in Conjunction with Option 3 Adding Sub-division of D701C, E, & F or reconfiguration of D701

This option introduces a series of sub-divisions of the existing D701 areas or reconfiguration of the existing layout in order to reduce the overall volume of airspace unavailable to other airspace users. The exact positions of these sub-divisions would require further work to conclude the optimum location; examples of what this might look like are depicted at *Figure 7.*

Whether the additional airspace made available by this option would be of benefit to other airspace users will form part of the analysis in this document. MOD suggested they would support this option if it was cost neutral to them however, they strongly suggested the cost benefits of this option should be carefully examined especially when balanced against the limited use (of 10 launches per year).

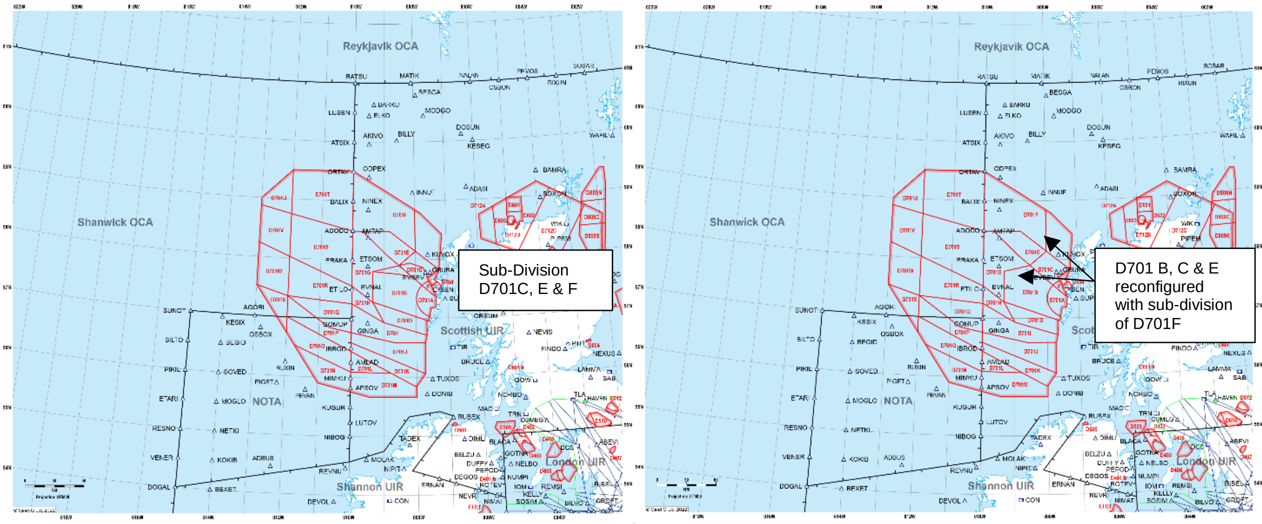

Figure 7: Option 5 – Sub-divisions of D701 or reconfiguration of existing areas

3. Initial Impact Appraisal of Design Options

3.1 Stage 2B - Methodology

Stage 2B requires an initial appraisal of the impacts of the design options presented in Section 2 against a “do nothing” option. The chosen methodology is to conduct a simple qualitative assessment of the different options, both positive and negative, against the headings identified in CAP1616, Appendix E, Table E2: “Guide to expected approach to key analysis for a typical airspace change”. This approach has been applied previously in other Airspace Change Proposals of similar scale/proportionality that have successfully passed the Stage 2 Gateway and it has been deemed compliant both with the spirit of CAP1616 and the Government Green Book.

3.2 The Do-Nothing Option

This option leaves the airspace as it currently exists (depicted in *Figure 8* and *Figure 10* below) with the SP-1 launch site sitting within Class G airspace. Although utilisation of D701 Danger Area could provide segregation for a portion of the rocket trajectory (where this is permitted), the area around the launch site would remain unsegregated. Without segregation, it is considered that rocket launch could not occur due to the risk to other airspace users as rockets will have no means of complying with the RoTA, thereby increasing the risk of mid-air collision and, following catastrophic failure or flight termination, create a debris hazard to other aircraft. CAP1616 requires that the Change Sponsor assess each option against a baseline; the ‘Do-Nothing’ option provides that baseline, describing the existing situation against which to assess the effect of implementing each of the proposed design options.

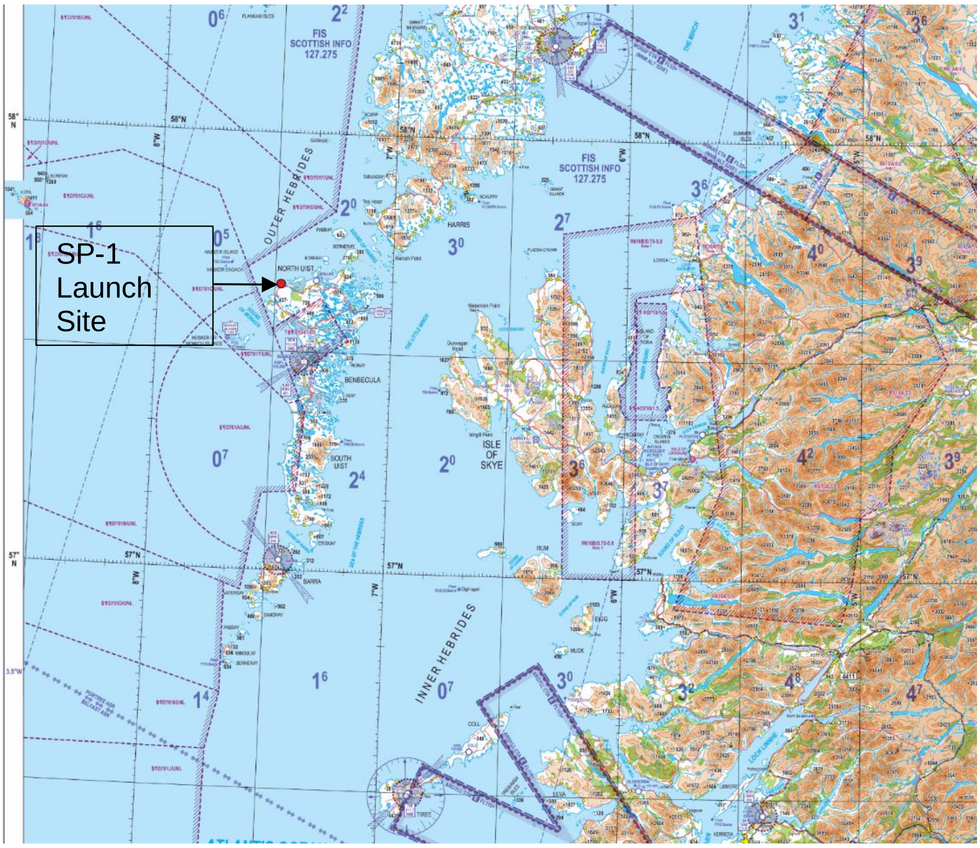

Figure 8: Local area airspace in the vicinity of SP-1 site

3.2.1 **Local Airspace**

The SP-1 launch site at Scolpaig, North Uist has Benbecula Airport approximately 10 Nautical Miles (NM) to the south, Barra beach landing strip 38NM south, the small beach landing strip at Sollas approximately 5.5NM to the east and Stornoway Airport approximately 58NM to the north east. The launch site is located between the MoD Hebrides Range Danger Areas D701 and D704 (see *Figure 8*). There is limited General Aviation (GA) activity in the local area with this mainly concentrated during the Sollas annual fly-in event during the summer. Other aviation activity is minimal, comprising prominently of scheduled flights to/from Benbecula (circa 6[7] flights per day during the busier summer months), occasional helicopter activity supporting local hotels and fish farms and coastguard, plus medical and lighthouse support aircraft. Military aviation activity in the local area is primarily focused on trials and testing of systems on the MOD Hebrides Range D701 and training flights. The latter

[7] Details obtained from the single commercial carrier Logan Air during the ACP TDA engagement 3 Feb 22 [C]

increase significantly twice a year for two weeks during the Joint Warrior Exercises and again for the biennial ASD/FS and Atlantic Thunder (AT) Exercises (that each occur alternate years). This increase in military activity also escalates the use of Benbecula airport with military support aircraft, although these flights predominantly occur several weeks before and after the main exercise periods.

Benbecula airport operates instrument approaches to two main runways namely 06 and 24; an extract of the approach charts contained within the AIP is shown at *Figure 9*.

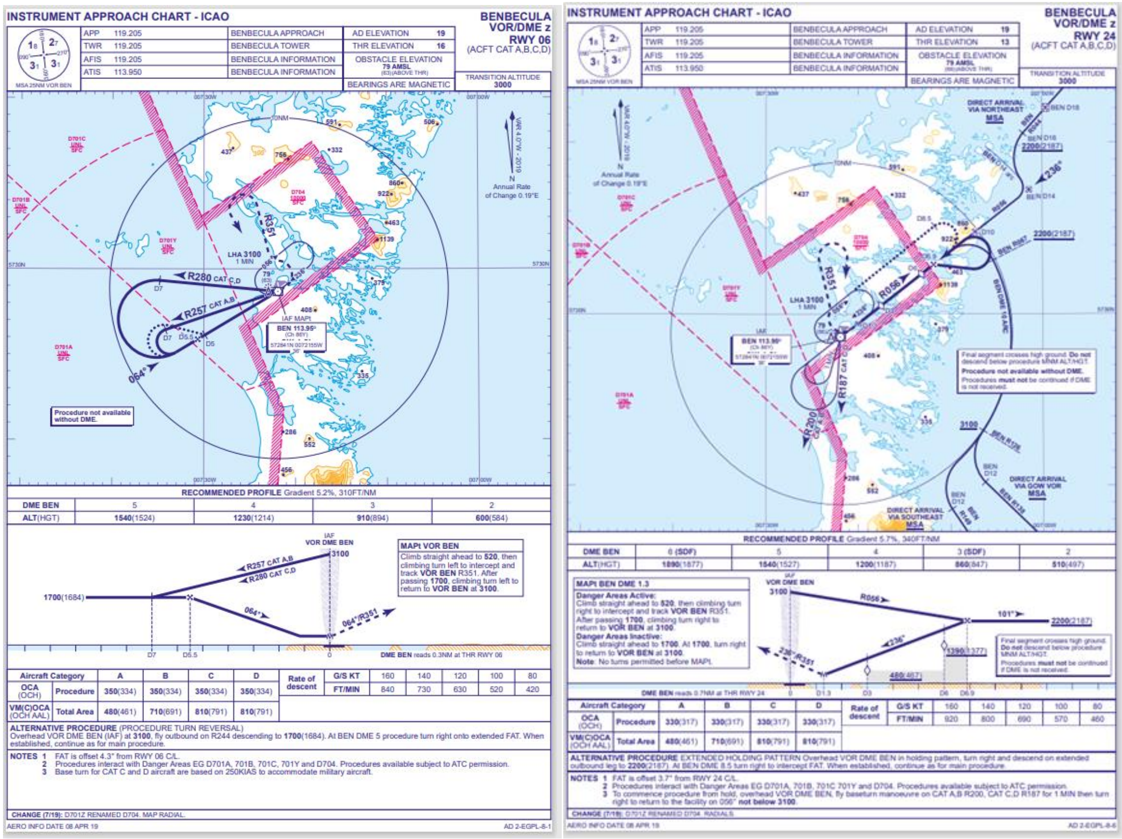

Figure 9: AIP extract depicting main instrument approach charts to Runway 06 and Runway 24 at Benbecula

Information gained during the TDA (ACP-2021-37) engagement process has indicated that rocket launch from the SP-1 site at Scolpaig should not impact on flights operating to/from, Barra or Stornoway Airports and with potentially only one approach to Benbecula affected; namely visual approach to Runway 06.

The airspace to be utilised under this ACP is largely over the ocean and includes very few land areas other than in the immediate vicinity of the launch site and a number of small generally uninhabited islands. Several of these islands have lighthouses that are serviced by helicopters operating on behalf of the Northern Lighthouse Board (NLB).

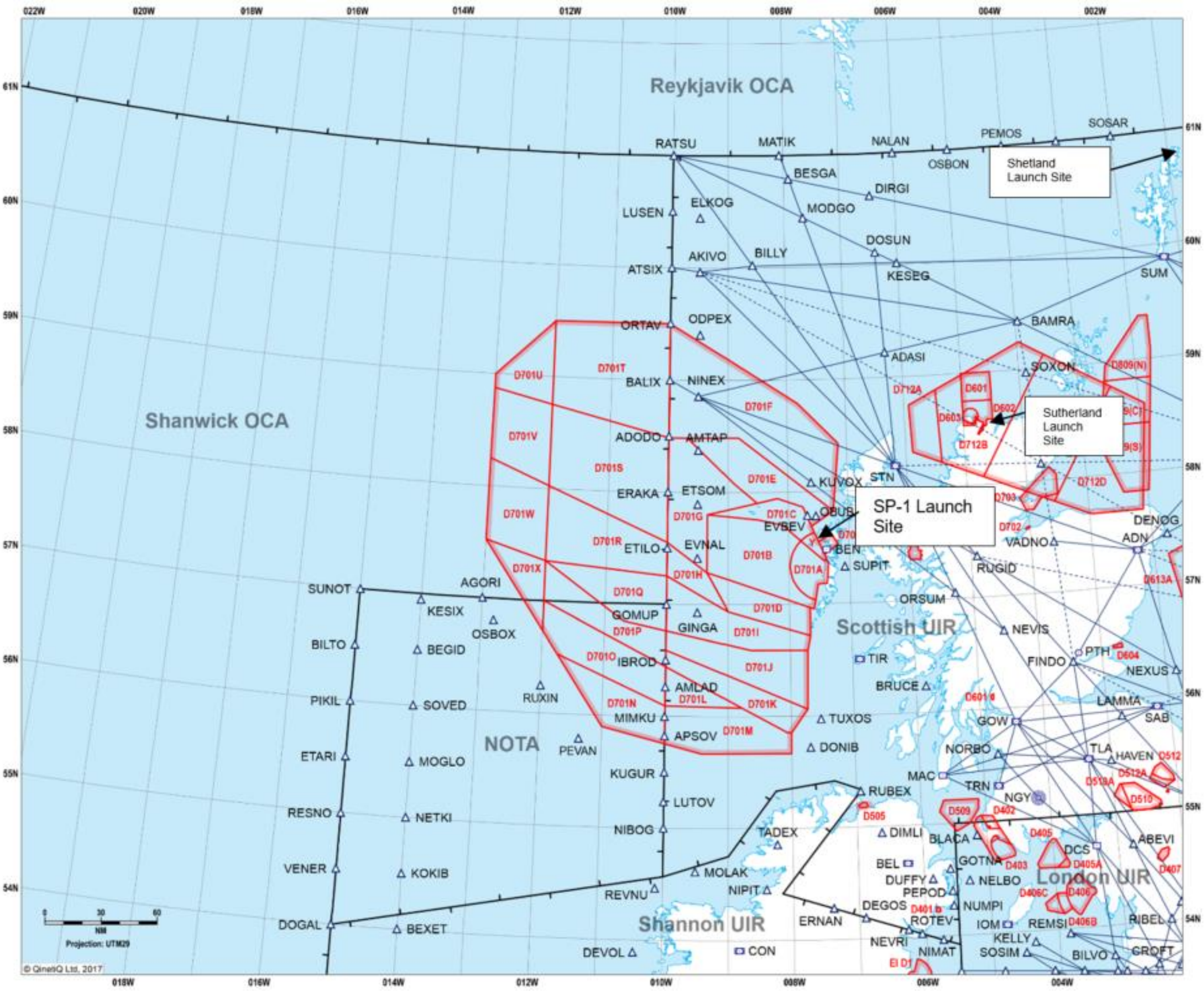

Figure 10: Adjacent airspace in relation to SP-1 launch site including other planned vertical launch spaceports

3.2.2 Wider Affected Area

Considering the airspace further afield, it can be seen that SP-1 activity will mostly affect CAT routing on the North Atlantic (NAT) oceanic tracks through the OEPs at 10˚ west and, potentially[8], MOD activity. There are also a number of other military sponsored Danger Areas over the North of Scotland that if active at the same time as SP-1 could have a blocking effect on CAT over Scotland. This is potentially further exacerbated by the development of other vertical launch Spaceport sites at Sutherland and Shetland (see *Figure 10*).

[8] SP-1 activity and use of D701 or airspace contained therein, will normally be deconflicted from MOD activity where possible – details will be contained in the relevant LoA between SP-1, QinetiQ and MOD.

The impact of activating D701 has on CAT and the ATM network is well documented and the methods used to minimise the impact are contained in the appropriate LoAs and Standard Operating Procedures (SOPs) for the MOD Hebrides Range.

The original design of the D701 Danger Area complex was driven by the need to have a flexible modular airspace structure extending outwards from the MOD Hebrides Range facility (target and ordinance launch pads) that could be activated area by area to accommodate the vast array of different systems being tested and trialled on the MOD Hebrides Range. This design further evolved to replicate the main upper air, Air Traffic Service (ATS) routes from the UK and Ireland, where these joined the OEPs at 10° west. This alignment of the area boundaries to the ATS routes accounts for the unusual shape of several of the D701 areas. This alignment enables the most efficient use of the airspace by minimising the number of routes and OEPs that would be unavailable when specific D701 areas are activated. This does have the consequential impact of occasionally having greater volumes of airspace segregated than is necessary to contain the safety traces of the systems being operated. It was considered the benefits of the alignment far outweighed the loss of usable airspace.

Since the D701 areas were re-designed (2014), the ATS routes have been discontinued and the upper airspace is now FRA. Although this means the criticality of having the boundaries of D701 aligned to air routes has been removed, the need to minimise impact on the OEPs remains. In essence, FRA still requires aircraft to route through the OEPs for their oceanic track and as such the routes flown under FRA are similar to the old ATS routes. It is understood that at some stage in the future, FRA will be introduced to the NAT thereby removing the need for OEPs.

The existing D701 Areas lie within Shanwick Oceanic Area and the Northern Oceanic Transit Area (NOTA). Here the Air Navigation Service Providers (ANSPs), NATS and Irish Aviation Authority (IAA), apply flight planning separation criteria to the boundary of the respective D701 Areas when active. The separation criteria applied east of 10° west is the standard 5NM radar separation criteria but once west of 10° west, NATS apply non-radar procedural separation of 30NM or 60NM for aircraft that cannot comply with the NAT Minimum Navigation Performance Specification (MNPS). The IAA apply standard radar separation criteria for the NOTA. It is expected that the procedural separation criteria will be reduced at some stage in the future with the advent of Automatic Dependant Surveillance–Broadcast (ADS-B) capability in the NAT. This is ongoing work within the International Civil Aviation Organisation (ICAO) working groups.

As the D701 Areas are fully integrated into the ASM systems[9] used by the UK AMC and ENM, they can be activated at relatively short notice with the airspace restrictions being automatically applied along with the necessary FBZs that are required for FRA. These can be activated for a number of scenarios dependent upon which D701 areas are activated. This means the available OEPs are known for any number of D701 activated areas and any restrictions such as FBZs are quickly applied or, conversely removed when the areas are deactivated. This enables the harmonised and dynamic planning of the ATM network in line with the FUA principles.

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[9] The UK AMC, NATS and MOD Hebrides Range use the EUROCONTROL preferred system called 'Local and sub-regional airspace management support system' (LARA) as an airspace management tool.

3.3 Options Appraisal

Table 1, Table 2 and Table 3 detail the appraisal of, respectively, Options 3, 4 & 5 and the 'Do-Nothing' baseline option against the high-level objectives and assessment criteria laid out in CAP1616, Appendix E, and Table E2. Over and above the requirement in CAP1616 Appendix E, Table E2, an additional row has been added to the table outlining initial safety considerations in brief. The list is not exhaustive and will be expanded as required as the options appraisal is matured.

Table 1: Summary of options appraisal for Option 3

Group	Impact	Option 3 - New Fillet of Segregated Airspace around Launch Site and Utilise D701	Do-Nothing
Communities	Noise impact on health and quality of life	It is recognised that the nature of sounding rocket launch will create noise at the time of launch albeit for only a short period of 1-2 minutes. However, there are only a small number of dwellings in the immediate vicinity of the launch site so the number of individuals affected will be low. Furthermore, the launch site is restricted to 10 launches per year so it is considered that the noise impact will be low. Details of noise profiling can be found in the EIA that has been produced as a requirement of the planning process for the SP-1 launch site. An extract from the EIA concerning noise modelling can be found at the Appendix to this document. The location of the airspace around the launch site should not cause any deviation of the scheduled flights operating to Benbecula or divert any GA or helicopter traffic in the local area such that there should not be any noticeable difference in local flying activity that would induce noise in areas not normally affected by aircraft noise.	Rocket launch not viable so there would be no associated increase in noise.
Communities	Air Quality	With no expected impact on GA or CAT aircraft operating below 7000ft in the local area, the air quality associated with this activity will remain unchanged. It is anticipated that the air quality in the immediate vicinity of the launch site may be affected for a short period (a few seconds) during the actual launch but this should quickly disperse and, given the prevailing wind is from the south-west, be experienced largely over the sea.	Rocket launch not viable so there would be no associated impact on air quality.

Table 1: Summary of options appraisal for Option 3			
Group	**Impact**	**Option 3 - New Fillet of Segregated Airspace around Launch Site and Utilise D701**	**Do-Nothing**
		It is not anticipated that the air quality for communities would be affected by any re-routing of CAT in the upper air caused by activation of D701 or the fillet of airspace around the launch site.	
Wider society	Greenhouse gas emissions	The nature of sounding rockets, engine design and fuel used will result in greenhouse gas emissions, which will vary between different rocket types and so is difficult to quantify at this stage. It is thought that the impact should be fairly negligible given the number launches will average at less than one per month. Of probably more significance is the greenhouse gas impact caused by CAT having to fly extended track miles to route around the active elements of D701, although this only becomes significant for the longer range sounding rockets where a large number of D701 areas are used. It is anticipated that several of the sounding rockets will remain within the 'inner' D701 areas – areas that do not noticeably impact CAT.	Rocket launch not viable so there would be no increase in greenhouse gas from any new activity. Furthermore, there would be no increase in greenhouse gas from existing aviation, since civil and military pilots would carry on as they do now so there would be no associated impact on greenhouse gas effect.
Wider society	Capacity / resilience	Where a large number of D701 areas are active this could potentially induce a capacity issue on the NAT track structure where other adjacent airspace reservations are also active. This can be alleviated by using the same extant airspace protocols and ASM procedures in place for D701, for SP-1 operations. This would mean certain adjacent Danger Areas not being active at the same time as D701. Moreover, by adhering to the limitations posed on the time of day when specific D701 areas are activated, the impact on the ATM network is further reduced.	There would be no change from present day.

Table 1: Summary of options appraisal for Option 3			
Group	**Impact**	**Option 3 - New Fillet of Segregated Airspace around Launch Site and Utilise D701**	**Do-Nothing**
General Aviation	Access	There may be a very small impact on GA when the airspace around the launch site is activated, especially on non-radio fitted aircraft. It is anticipated that access for radio fitted aircraft will be possible during periods where the airspace is activated but launches are delayed or awaiting full range clearance. As is current practice for the D701 areas, MOD Hebrides Range staff are able to permit aircraft to enter active Danger Areas when considered safe to do so. Given the extremely light levels of GA activity and the infrequent use of the segregated airspace around the launch site, any impact on GA is considered negligible.	There would be no change from present day.
General Aviation / commercial airlines	Economic impact from increased effective capacity	Not Applicable	Not Applicable
General Aviation / commercial airlines	Fuel burn	Activation of the fillet of airspace around the launch site is unlikely to invoke any increase in fuel burn for either GA or CAT; however, activation of D701 can lead to increase in fuel burn for CAT where they are forced to fly additional track miles around active Danger Areas. This increase in fuel burn can be calculated more easily for known combinations of D701 than for a new airspace structure such as Option 4. Extant ASM processes and procedures detailed in current LoAs associated with the MOD Hebrides Range, are an important facet in reducing the impact D701 has on CAT and their subsequent additional fuel burn. In particular, the limitations posed on the time of day when certain D701 areas are activated is crucial in reducing the impact on the ATM network. Utilising these same procedures and LoAs for rocket launch and use of D701 as proposed under this option, means that 'best practice' is being followed and consequential impact on CAT is minimised.	Rocket launch would not be viable therefore there would be no additional use of D701 so no change to current impact activation of D701 has on CAT and fuel burn.

Table 1: Summary of options appraisal for Option 3			
Group	**Impact**	**Option 3 - New Fillet of Segregated Airspace around Launch Site and Utilise D701**	**Do-Nothing**
Commercial airlines	Training costs	Not Applicable	Not Applicable
Commercial airlines	Other costs	Not Applicable	Not Applicable
Airport /ANSP	Infrastructure costs	Not Applicable	Not Applicable
Airport /ANSP	Operational costs	The operational cost should be minimal other than the cost of capturing the small fillet of airspace around the launch site into the ATC training system and any additional training associated with the minor amendments to extant LoAs and SOPs. By using D701 in its current form, the costs to ANSPs remains at the lowest possible as ASM processes and procedures remain largely unchanged. A similar argument applies for Benbecula airport where utilisation of existing LoAs, modified to include SP-1 and the fillet of airspace around the launch site, reduces the cost especially when compared to the creation of a new bespoke set of Danger Areas or, to a lesser degree, modification of the existing D701 areas.	No change to current ways of working.
Airport /ANSP	Deployment costs	The deployment cost should be minimal other than the cost of introducing the small fillet of airspace around the launch site into the ATC and ASM systems and applying a new FBZs where appropriate. Other costs would include making minor amendments to extant LoAs and SOPs and minor amendments to aeronautical charts including two new Aeronautical Data Quality (ADQ) points to be validated for the airspace fillet. Using D701 in its current form means the costs to ANSPs remains at the lowest possible as there would be no requirement to: • Introduce new additional reporting points.	No change to current ways of working.

Table 1: Summary of options appraisal for Option 3			
Group	**Impact**	**Option 3 - New Fillet of Segregated Airspace around Launch Site and Utilise D701**	**Do-Nothing**
		• Make large changes to ATC and MOD Hebrides Range systems mapping. • Introduce wholly new LoAs, ASM processes or procedures (and associated training costs). A similar argument applies for Benbecula airport where utilisation of existing LoAs, modified to include SP-1 and the fillet of airspace around the launch site, reduces the cost especially when compared to the creation of a new bespoke set of Danger Areas or, to a lesser degree, modification of the existing D701 areas.	
Safety Considerations (not exhaustive list)		Pilots may be unaware of the activation of the fillet of airspace around the launch site and inadvertently infringe the airspace – in particular non-radio fitted aircraft operating to beach landing sites.	It would be unsafe to conduct rocket launch so there would be no additional safety considerations.

Table 1: Summary of options appraisal for Option 3

Table 2: Summary of options appraisal for Option 4			
Group	**Impact**	**Option 4 - Construct New Bespoke Segregated Airspace Blocks from Launch Site**	**Do-Nothing**
Communities	Noise impact on health and quality of life	It is recognised that the nature of sounding rocket launch will create noise at the time of launch albeit for only a short period of 1-2 minutes. However, there are only a small number of dwellings in the immediate vicinity of the launch site so the number of individuals affected will be low. Furthermore, the launch site is restricted to 10 launches per year so it is considered that the noise impact will be low. Details of noise profiling can be found in the EIA that has been produced as a requirement of the planning process for the SP-1 launch site. An extract from the EIA concerning noise modelling can be found at the Appendix to this document. The location of the airspace around the launch site should not cause any deviation of the scheduled flights operating to Benbecula or divert any GA or helicopter traffic in the local area such that there should not be any noticeable difference in local flying activity that would induce noise in areas not normally affected by aircraft noise.	Rocket launch not viable so there would be no associated increase in noise.
Communities	Air Quality	With no expected impact on GA or CAT aircraft operating below 7000ft in the local area, the air quality associated with this activity will remain unchanged. It is anticipated that the air quality in the immediate vicinity of the launch site may be affected for a short period (a few seconds) during the actual launch but this should quickly disperse and, given the prevailing wind is from the south-west, be experienced largely over the sea. It is not anticipated that the air quality for communities would be affected by any re-routing of CAT in the upper air caused by activation of any new bespoke airspace design including the fillet of airspace around the launch site.	Rocket launch not viable so there would be no associated impact on air quality.
Wider society	Greenhouse gas emissions	The nature of sounding rockets, engine design and fuel used will result in greenhouse gas emissions, which will vary between different rocket types and so is difficult to quantify at this stage. It is thought that the impact should be fairly negligible given the number launches will average at less than one per month.	Rocket launch not viable so there would be no increase in greenhouse gas from any new activity. Furthermore, there would be no increase in

Table 2: Summary of options appraisal for Option 4			
Group	**Impact**	**Option 4 - Construct New Bespoke Segregated Airspace Blocks from Launch Site**	**Do-Nothing**
		Of probably more significance is the greenhouse gas impact caused by CAT having to fly extended track miles to route around the active elements of the new bespoke airspace structure although this only becomes significant for the longer range sounding rockets where a large number of bespoke areas are used. The new bespoke areas should be designed such that for the shorter range sounding rockets the subsequent areas activated over the sea have minimal impact on CAT.	greenhouse gas from existing aviation, since civil and military pilots would carry on as they do now so there would be no associated impact on greenhouse gas effect.
Wider society	Capacity / resilience	Where a large number of areas in both domestic and oceanic airspace are active this could potentially induce a capacity issue on the NAT track structure where other adjacent airspace reservations are also active. New bespoke airspace protocols would have to be agreed to minimise any such impact on capacity.	There would be no change from present day.
General Aviation	Access	There may be a very small impact on GA when the airspace around the launch site is activated, especially on non-radio fitted aircraft. It is anticipated that access for radio fitted aircraft will be possible during periods where the airspace is activated but launches are delayed or awaiting full range clearance. It is anticipated that MOD Hebrides Range staff should be able to permit aircraft to enter active Danger Areas when considered safe to do so. Given the extremely light levels of GA activity and the infrequent use of the segregated airspace around the launch site; any impact on GA is therefore considered negligible.	There would be no change from present day.
General Aviation / commercial airlines	Economic impact from increased effective capacity	Not Applicable	Not Applicable

Table 2: Summary of options appraisal for Option 4			
Group	**Impact**	**Option 4 - Construct New Bespoke Segregated Airspace Blocks from Launch Site**	**Do-Nothing**
General Aviation / commercial airlines	Fuel burn	Activation of the fillet of airspace around the launch site is unlikely to invoke any increase in fuel burn for either GA or CAT; however, activation of large volumes of airspace to the west of the Outer Hebrides can lead to increase in fuel burn for CAT where they are forced to fly additional track miles around active Danger Areas. This increase in fuel burn is unknown for any new bespoke modular airspace design and several different scenarios would need to be modelled to understand the full impact. New ASM processes and procedures detailed in LoAs associated with the new airspace would have to be developed with a view on minimising the impact on the ATM network, and consequent increasing in fuel burn) while balancing against the operational requirements of the Spaceport.	Rocket launch would not be viable therefore there would be no additional use of D701 so no change to current impact activation of D701 has on CAT and fuel burn.
Commercial airlines	Training costs	It is understood that airlines already have a training requirement (and associated cost) to fly in the NAT oceanic regions. It is not known if a new bespoke set of Danger Areas were created, whether this training would be impacted such that there is additional cost to the airlines.	NAT training costs already exist, these would remain unchanged.
Commercial airlines	Other costs	Not Applicable	Not Applicable
Airport /ANSP	Infrastructure costs	Not Applicable	Not Applicable
Airport /ANSP	Operational costs	Operational costs will increase when associated with ongoing training and currency that will become more complex through the introduction of two similar airspace structures in the same volume of airspace but managed in a different manner using separate ASM process and SOPs for each. A similar argument applies for Benbecula airport where ongoing training and currency is more complex thereby costs increase.	No change to current ways of working.

Table 2: Summary of options appraisal for Option 4			
Group	**Impact**	**Option 4 - Construct New Bespoke Segregated Airspace Blocks from Launch Site**	**Do-Nothing**
Airport /ANSP	Deployment costs	The deployment costs for this option would be the most significant of the three airspace options presented. New ASM processes and procedures would have to be developed, negotiated and implemented for the new airspace along with associated LoAs and SOPs. Furthermore, all ATC, ASM and MOD Hebrides Range systems would need significant updates to reflect the new airspace structure that would have to be made clearly distinguishable from the existing D701 areas. The following additional costs would also be applicable: • The requirement for 5 Letter Name Codes (5LNCs) being reserved with International Codes And Route Designators (ICARD) (new reporting points) that allows circumnavigation of the new airspace areas when activated. • Creating new FBZs for a number of different combinations of areas activated. • Validating all reference points in the new structure to ensure ADQ standards are met. • Special instructions and associated training costs for ANSP and MOD Hebrides Range staff • Integration of new areas into LARA and automated flight planning systems. • Major update to aeronautical and maritime charts. HIAL (operating Benbecula) would also see an increase in deployment costs compared to Options 3 and 5 through the development of new LoAs and SOPs pertaining solely to SP-1 and activation of the new bespoke areas – new agreements regarding access to the areas would need to be established for CAT and Cat A flights.	No change to current ways of working.

Table 2: Summary of options appraisal for Option 4			
Group	**Impact**	**Option 4 - Construct New Bespoke Segregated Airspace Blocks from Launch Site**	**Do-Nothing**
Safety Considerations (not exhaustive list)		Pilots may be unaware of the activation of the fillet of airspace around the launch site and inadvertently infringe the airspace – in particular non-radio fitted aircraft operating to beach landing sites. The new areas could be confused with D701 leading to errors in the flight planning management processes or confusion by pilots. MOD Hebrides Range and ATC staff become confused with operating different but similar areas under different but similar ASM arrangements and LoAs. Airspace charts become cluttered and are difficult to read with two sets of different Danger Areas overlaid. Simultaneous activation of both the bespoke SP-1 areas and D701 causes confusion to MOD Hebrides Range, ATC and aircrew leading to errors that could have safety impact.	It would be unsafe to conduct rocket launch so there would be no additional safety considerations.

Table 2: Summary of options appraisal for Option 4

Table 3: Summary of options appraisal for Option 5			
Group	**Impact**	**Option 5 - Use in Conjunction with Option 3 Adding Sub-division of D701C, E, & F or reconfiguration of D701**	**Do-Nothing**
Communities	Noise impact on health and quality of life	It is recognised that the nature of sounding rocket launch will create noise at the time of launch albeit for only a short period of 1-2 minutes. However, there are only a small number of dwellings in the immediate vicinity of the launch site so the number of individuals affected will be low. Furthermore, the launch site is restricted to 10 launches per year so it is considered that the noise impact will be low. Details of noise profiling can be found in the EIA that has been produced as a requirement of the planning process for the SP-1 launch site. An extract from the EIA concerning noise modelling can be found at the Appendix to this document. The location of the airspace around the launch site should not cause any deviation of the scheduled flights operating to Benbecula or divert any GA or helicopter traffic in the local area such that there should not be any noticeable difference in local flying activity that would induce noise in areas not normally affected by aircraft noise.	Rocket launch not viable so there would be no associated increase in noise.
Communities	Air Quality	With no expected impact on GA or CAT aircraft operating below 7000ft in the local area, the air quality associated with this activity will remain unchanged. It is anticipated that the air quality in the immediate vicinity of the launch site may be affected for a short period (a few seconds) during the actual launch but this should quickly disperse and, given the prevailing wind is from the south-west, be experienced largely over the sea. It is not anticipated that the air quality for communities would be affected by any re-routing of CAT in the upper air caused by activation of D701 or the fillet of airspace around the launch site.	Rocket launch not viable so there would be no associated impact on air quality.
Wider society	Greenhouse gas emissions	The nature of sounding rockets, engine design and fuel used will result in greenhouse gas emissions, which will vary between different rocket types and so is difficult to quantify at this stage. It is thought that the impact should be fairly negligible given the number launches will average at less than one per month.	Rocket launch not viable so there would be no increase in greenhouse gas from any new activity. Furthermore, there would be no increase in

Table 3: Summary of options appraisal for Option 5			
Group	**Impact**	**Option 5 - Use in Conjunction with Option 3 Adding Sub-division of D701C, E, & F or reconfiguration of D701**	**Do-Nothing**
		Of probably more significance is the greenhouse gas impact caused by CAT having to fly extended track miles to route around the active elements of D701 although this only becomes significant for the longer range sounding rockets where a large number of D701 areas are used. It is anticipated that several of the sounding rockets will remain within the 'inner' D701 areas – areas that do not noticeably impact CAT.	greenhouse gas from existing aviation, since civil and military pilots would carry on as they do now so there would be no associated impact on greenhouse gas effect.
Wider society	Capacity / resilience	Where a large number of D701 areas are active this could potentially induce a capacity issue on the NAT track structure where other adjacent airspace reservations are also active. This can be alleviated by using the same extant airspace protocols and ASM procedures in place for D701, for SP-1 operations. This would mean certain adjacent Danger Areas not being active at the same time as D701. Moreover, by adhering to the limitations posed on the time of day when specific D701 areas are activated, the impact on the ATM network is further reduced. Furthermore, by adding sub-divisions in D701 may cause less deviations for CAT and thus reduce the impact this has on capacity when compared to Option 3.	There would be no change from present day.
General Aviation	Access	There may be a very small impact on GA when the airspace around the launch site is activated, especially on non-radio fitted aircraft. It is anticipated that access for radio fitted aircraft will be possible during periods where the airspace is activated but launches are delayed or awaiting full range clearance. As is current practice for the D701 areas, MOD Hebrides Range staff are able to permit aircraft to enter active Danger Areas when considered safe to do so. Given the extremely light levels of GA activity and the infrequent use of the segregated airspace around the launch site, any impact on GA is considered negligible.	There would be no change from present day.
General Aviation / commercial airlines	Economic impact from increased effective capacity	Not Applicable	Not Applicable

Table 3: Summary of options appraisal for Option 5			
Group	**Impact**	**Option 5 - Use in Conjunction with Option 3 Adding Sub-division of D701C, E, & F or reconfiguration of D701**	**Do-Nothing**
General Aviation / commercial airlines	Fuel burn	Activation of the fillet of airspace around the launch site is unlikely to invoke any increase in fuel burn for either GA or CAT; however, activation of D701 can lead to increase in fuel burn for CAT where they are forced to fly additional track miles around active Danger Areas. This increase in fuel burn can be calculated more easily for known combinations of D701 than for a new airspace structure such as Option 4. Extant ASM processes and procedures detailed in current LoAs associated with the MOD Hebrides Range, are an important facet in reducing the impact D701 has on CAT and their subsequent additional fuel burn. In particular the limitations posed on the time of day when certain D701 areas are activated is crucial in reduce the impact on the ATM network. By utilising these same procedures and LoAs for rocket launch and use of D701 as proposed under this option, means 'best practice' is being followed and consequential impact on CAT is minimised. Furthermore, by adding sub-divisions in D701 may cause less deviations for CAT and thus reduce the impact this has on fuel burn when compared to Option 3.	Rocket launch would not be viable therefore there would be no additional use of D701 so no change to current impact activation of D701 has on CAT and fuel burn.
Commercial airlines	Training costs	Not Applicable	Not Applicable
Commercial airlines	Other costs	Not Applicable	Not Applicable
Airport /ANSP	Infrastructure costs	Not Applicable	Not Applicable

Table 3: Summary of options appraisal for Option 5			
Group	**Impact**	**Option 5 - Use in Conjunction with Option 3 Adding Sub-division of D701C, E, & F or reconfiguration of D701**	**Do-Nothing**
Airport /ANSP	Operational costs	The operational cost should be less than for Option 4 but greater that for Option 3. Costs will include training related to the new fillet of airspace and reconfiguration of D701 areas, and associated amendments to extant LoAs and SOPs.	No change to current ways of working.
Airport /ANSP	Deployment costs	The deployment cost should be less than for Option 4 but greater than for Option 3. The new fillet of airspace and reconfiguration of D701 will need to be integrated into the ATC, MOD Hebrides Range and ASM systems. Depending upon what the final design for any reconfiguration of D701 looks like there may be a requirement for the following: • Validating all reference points in the new structure to ensure ADQ standards are met. • Special instructions and associated training costs for ANSP and MOD Hebrides Range staff. • Integration of new areas into LARA and automated flight planning systems. • Minor amendment to aeronautical and maritime charts. • Amend current LoAs, ASM processes or procedures (with associated training costs). A similar argument applies for Benbecula airport where utilisation of existing LoAs, modified to include SP-1 and the fillet of airspace around the launch site, reduces the cost especially when compared to the creation of a new bespoke set of Danger Areas	No change to current ways of working.

Table 3: Summary of options appraisal for Option 5			
Group	**Impact**	**Option 5 - Use in Conjunction with Option 3 Adding Sub-division of D701C, E, & F or reconfiguration of D701**	**Do-Nothing**
Safety Considerations (not exhaustive list)		Pilots may be unaware of the activation of the fillet of airspace around the launch site and inadvertently infringe the airspace – in particular non-radio fitted aircraft operating to beach landing sites. New nomenclature for reconfiguration/sub-divisions could cause confusion for pilots, MOD Hebrides Range staff and ANSPs who are very familiar with existing taxonomy.	It would be unsafe to conduct rocket launch so there would be no additional safety considerations.

Table 3 Summary of options appraisal for Option 5

3.4 Conclusion of Options Appraisal Summary

3.4.1 Option 3 – The Preferred Option

Option 3 is considered the preferred option for the following reasons:

- It meets the SoN;
- It meets the majority of the DPs and those it doesn't meet are partially met;
- It is the least costly option;
- It is the simplest to understand and implement; and,
- It is considered the safest option.

It is recognised that this option will, on occasions, result in more airspace being used than is absolutely necessary to contain the safety trace of the sounding rocket. However, this is not unusual when testing/operating embryonic systems within a modular airspace structure. It is considered that the benefits of utilising an existing airspace structure and associated operating procedures and processes, far outweigh the reduction in overall airspace the other two options may make available. This is particularly pertinent when considering the limited use of the airspace (10 launches per year that probably equates to less than four airspace activations (accounting for contingency days) per month). Through careful planning and adoption of best practice currently in operation at the MOD Hebrides Range, the impact of these contingency days can be greatly reduced (as demonstrated in the ASD/FS exercises). Furthermore, the current airspace structure is well known to MOD Hebrides Range and ANSP staffs alike and is already fully integrated into the UK AMC and ENM ASM and flight planning systems (including LARA) – these will only require minor modifications to include the fillet of airspace around the launch site and rocket launch operations.

Option 3 is considered the least costly options due to the following:

- There is no requirement for 5LNCs being reserved with ICARD (new reporting points) to allow circumnavigation the new airspace structure as these are already in place and feature in existing flight planning system; so no updates[10] required;
- FBZs are already in place other than for the small airspace 'fillet';
- Only two reference points (associated with the 'fillet') will need to be ADQ validated;
- Special instructions and associated training costs for ANSP and MOD Hebrides Range staff will be less than those for the other two options where significant airspace changes are made;
- Only the small 'fillet' will require integrating into LARA as all other areas already exist;
- ATC and MOD Hebrides Range system mapping will only require minor modifications to include the airspace 'fillet';
- Only aeronautical charts will require a minor update (maritime charts will not require any amendment); and,
- It should be possible to make minor amendments to current LoAs, ASM processes or procedures rather than producing new standalone documents.

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[10] It is recognised that the new 'fillet' of airspace will need to be included in an update to systems but the change is very small in comparison with other options.

This option is considered the safest based on the fact it induces the minimum of change and adds little additional complexity to the existing airspace structure, unlike Option 4 and, to a lesser degree, Option 5.

3.4.2 Option 5 – An Alternative to the Preferred Option

Option 5 retains the external boundaries of D701 thereby removing the requirement for new additional reporting points and FBZs (other than around the airspace fillet). Furthermore, this option could use extant ASM processes and procedures, LoAs and other orders/instructions with minor modifications.

The main benefit of this option would be to reduce the overall volume of airspace that would need to be activated to contain the hazards associated with sub-orbital rocket launch; however, this reduction in volume of airspace needs to be balanced against expected use of available airspace when considering the number of launches each year and expected activation of airspace.

There will be a greater operational cost associated with this option compared to Option 3 although, this cost should be lower than for Option 4. Cost will include:

- Additional FBZs around the new airspace fillet;
- Several new reference points that determine the origin of each new line drawn to subdivide or reconfigure D701 will need to be ADQ validated;
- Special instructions and associated training costs for ANSP and MOD Hebrides Range staff are increased slightly when compared with Option 3; however, these will be limited if extant ASM processes and procedures are utilised and amended to include SP-1 activities;
- Minor changes to LARA;
- Minor changes and updates to ATC and MOD Hebrides Range systems mapping; and,
- Minor updates to aeronautical and maritime charts.

3.4.3 Option 4 – Least Preferred Option

Option 4 introduces an extremely complex airspace structure due to the presence of the existing D701 areas and there is concern the two could easily be confused as they are managed by the same organisations (MOD Hebrides Range staff and ANSPs). This would be particularly pertinent where new standalone ASM processes and procedures are developed and are operated in conjunction with existing procedures. Furthermore, both aeronautical and maritime charts would become complex; similarly the radar maps used by MOD Hebrides Range and ATC staff would be multifaceted.

This option is also considered the most costly due to the number and magnitude of the changes that would have to be made:

- Requirement for 5LNCs being reserved with ICARD (new reporting points) to allow circumnavigation of the new airspace structure;
- Introduction of a number FBZs around the new airspace structure depending upon which elements are activated;

- All new reference points for the origin of each line associated with this modular structure will need to be ADQ validated;
- Special instructions and associated training costs for ANSP and MOD Hebrides Range staff are increased significantly when compared against the other two options due to the size of the airspace change and associated standalone new ASM processes and procedures;
- Major update to LARA;
- Significant updates to ATC and MOD Hebrides Range systems mapping;
- Significant updates to aeronautical and maritime charts; and,
- Development and agreement of wholly new LoAs along with the development of SP-1 specific ASM processes and procedures including orders/instructions to MOD Hebrides Range and ATC staff.

3.4.4 Cost Benefit Analysis of Reduced Airspace Volume

While considering the benefits of reducing the overall volume of airspace used by either designing a wholly new bespoke modular airspace structure (Option 4) or, modifying the existing D701 areas (Option 5), the following factors should be taken into account:

- Usage of the airspace (how often will it be activated and for how long);
- Timings – what time of day the airspace is to be activated;
- What proportion of sounding rockets will be contained within the inner areas (as created by sub-divisions in Option 5) and what proportion will be medium/long range;
- Assessment on the 'usability' of any extra airspace made available by sub-divisions or a bespoke solution with regard to CAT routing through OEPs; and,
- A rough order of magnitude of costs associated with significant updates to MOD Hebrides Range and ATC radar mapping systems, aeronautical and navigation charts; the design of new ASM procedures, LoAs; and associated training costs.

3.4.4.1 Discussion

At this stage of the ACP process a quantitative assessment is not considered proportional especially as elements of the data are not yet known and it is acknowledged that further research is required to ascertain potentially affected traffic flows on the NAT. It has been established that the maximum number of launches is limited to 10 per year and it is recognised that there will be spare days. However, it is unclear how many spare days will be needed or how the exact ASM procedures will operate. It is anticipated that a worst case scenario is where the airspace is activated for a period (in the region of 2-3 hours) and the launch does not occur. A spare day would be utilised and the airspace activated a second time and possibly a third should the second launch not be successful. Given the resource involved – availability of the MOD Hebrides Range (regardless of Option selected) – it is considered highly unlikely there will be more than two spare days. This means in any year a worst case scenario could mean 30 activations of the airspace, although this is highly improbable based on MOD Hebrides Range experience of similar operations and it is probably more realistic to state the worst case scenario is in the region of 20 airspace activations in a year.

Considering 20 airspace activations, the majority will be planned to occur post 1300 Coordinated Universal Time (UTC), to minimise[11] the impact on the ATM network, with some launches potentially occurring later, circa 1500UTC. Furthermore, it may be assumed that 50% of the sounding rockets will be long range such that any sub-divisions will become ineffective. This means the number of occasions the airspace is activated where sub-divisions or bespoke solution provides benefit, is reduced to less than 10 occasions per year. When this is factored against the frequency the NAT tracks are planned through D701 (driven by the position of the jet stream), the times this number of airspace activations actually impacts on CAT is further reduced, especially when the timing of the launch is then factored in.

The cost associated with significant updates to MOD Hebrides Range and ATC radar mapping systems, aeronautical and navigation charts; the design of new ASM procedures, LoAs; and associated training is not known; however, it is not thought to be inconsequential especially for Option 4. These costs (once evaluated) will need to be balanced against the potential airspace use and number of occasions, when all factors are considered, the airspace has an impact on CAT. This evaluation will be conducted in later stages of this ACP.

3.5 Evidence to be Collected for Options Appraisal (Phase II) Full

The Sponsor will collect or firm up the following information to inform the next phase of the Options Appraisal:

- Using one or two different exemplar sounding rocket profiles, ascertain the likely areas of use for each individual option, then test these areas against worst case[12] NAT traffic flows for different times of day (probably a two-hour period prior to 1300 UTC and a two-hour period after).
- Evaluate the extra track miles flown by the number of CAT aircraft affected and calculate the approximate additional fuel burn and corresponding CO_2 emissions against each option.
- Ascertain how frequently, in an annual period, the Jet stream favours the NAT tracks to route over the D701 areas compared to over Ireland or South-west Approaches.
- Ascertain a rough order of magnitude of the costs associated with significant updates to MOD Hebrides Range and ATC radar mapping systems, aeronautical and navigation charts; the design of new ASM procedures, LoAs; and associated training.

3.6 10 Year Forecast

It is extremely difficult to predict at this juncture the demand for the Spaceport over the next 10 years. It is anticipated that the first two to three years will see fewer annual launches (maybe 6 during the first

[11] Utilising knowledge gained operating the MOD Hebrides Range and NATS traffic ‘heat maps’; NAT traffic reaches a peak between 0300-0700UTC and 1000-1300UTC with traffic numbers diminishing significantly after 1500UTC.

[12] The worst case will be assumed as when the jet stream dictates that the west bound transatlantic air traffic flow will pass over Scotland on a ‘north about’ track system based on 2019 traffic levels.

year and 8 in the second year) with a gradual build-up to 10 thereafter. The market remains too immature to forecast the requirement beyond this early period.

It is thought that demand for passengers and cargo flying to Benbecula will increase with the advent of the Spaceport, as personnel transit to/from the mainland and rocket equipment/support items are brought in. Local businesses (hotels and shops) should also benefit from the increase in personnel living on the islands, this will also increase supply chains. There may be a slight increase in helicopter support traffic where these are needed to recover any elements of the sounding rockets, although the details remain imprecise at this stage.

Transatlantic traffic levels continue to increase post COVID pandemic but are still some way below 2019 levels. It was initially anticipated (by EUROCONTROL) that traffic levels would recover quickly post pandemic with an upsurge in 2022 and 2023. However, these predictions have recently been reviewed and their forecasts now suggest that a return to 2019 traffic levels may not be seen for several years due to the global economic turndown as a result of the war in the Ukraine and other factors. The most optimistic prediction by EUROCONTROL (see *Figure 11*) is an increase on 2019 traffic levels of 18% by 2028; their 'Base' prediction is an 8% increase and their 'Low' prediction -5% on 2019 levels. Actual growth for 2022 (see *Figure 12*) has been somewhere between the Low and Base levels. Based on this simple analysis, it is suggested that traffic growth in the NAT region will only exceed 2019 levels towards the end of the 10 year period. It is therefore reasonable to argue that when determining the impact each airspace option has on the NAT traffic, using 2019 traffic levels will provide a sensible baseline.

FLIGHT FORECAST (OCTOBER 2022)

Summary of flight forecast for Europe (ECAC)

EUROCONTROL

ECAC*		2015	2016**	2017	2018	2019	2020**	2021	2022	2023	2024**	2025	2026	2027	2028**
IFR Flight Movements (Thousands)	High	.	.	.	.	.	.	.	9,431	11,142	11,768	12,124	12,467	12,755	13,045
	Base	9,923	10,197	10,604	11,002	11,085	4,979	6,231	9,287	10,243	10,883	11,157	11,399	11,629	11,873
	Low	.	.	.	.	.	.	.	9,126	9,583	9,994	10,150	10,285	10,405	10,530
Annual Growth (compared to previous year unless otherwise mentioned)	High	.	.	.	.	.	.	.	51%	18%	5.6%	3.0%	2.8%	2.3%	2.3%
	Base	1.6%	2.8%	4.0%	3.8%	0.8%	-55%	25%	49%	10%	6.3%	2.5%	2.2%	2.0%	2.1%
	Low	.	.	.	.	.	.	.	46%	5.0%	4.3%	1.6%	1.3%	1.2%	1.2%
Fraction of 2019 (compared to2019 level)	High					.	.	.	85%	101%	106%	109%	112%	115%	118%
	Base					100%	45%	56%	84%	92%	98%	101%	103%	105%	107%
	Low					.	.	.	82%	86%	90%	92%	93%	94%	95%

* ECAC is the European Civil Aviation Conference

** leap year

Source:
EUROCONTROL 7-year Forecast 2022-2028, October 2022.

EUROCONTROL Seven-Year Forecast Update 2022-2028 Document Confidentiality Classification: White 13

SCENARIO UPDATE (OCTOBER 2022)

Impact of war in Ukraine and Post-pandemic recovery

	HIGH scenario	BASELINE scenario	LOW scenario
Impact of war in Ukraine	• Most of the European states with **moderate** GDP growth in 2023 and beyond • **Limited impact** on demand from inflation (including jet fuel price)	• **Weak GDP** in 2023 for most European states • **High inflation** impacts demand	• A **significant** number of European states in **recession** in 2023 • **Demand** for **travel** strongly **reduced** by effects of inflation
Post-pandemic recovery	• **Good** passenger confidence • **Dynamic** tourism flows above 2019 levels • **Fast** bounce-back of business travel • Airports and airlines **mostly able** to bring back capacity in 2023 • Cargo: **limited** staffing issues on the whole sector and **increase** on global cargo output	• **Relatively good** passenger confidence • Business travel **partly** replaced by digital alternatives • **Growing environmental** concerns in some European states • Some airlines/airports experience **staffing/capacity issues** in **2023** (but **much less** than in **2022**) • Cargo: **slight increase** on global cargo output in 2023	• Occasional **resurgence** of COVID-19 variants: possible travel restrictions at local level • **Substantial replacement** of business travel (digital alternatives) • **Environmental concerns strongly** affecting travel choices • More extensive **staffing/capacity issues** at airlines/airports in **2023** • Cargo: **deterioration** of staffing issues on the whole logistic sector in 2023

EUROCONTROL Seven-Year Forecast Update 2022-2028 Document Confidentiality Classification: White 11

Figure 11: Flight forecast to 2028 and scenario description table (Source: EUROCONTROL 2022).

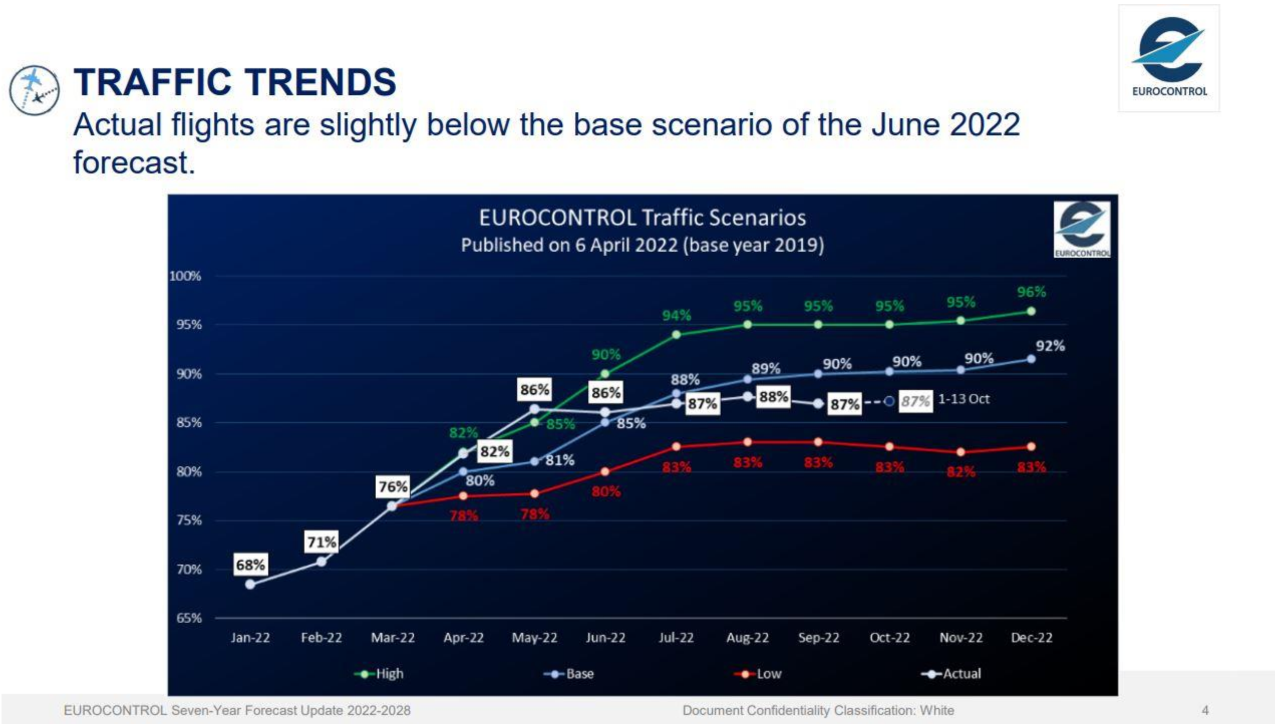

Figure 12: EUROCONTROL traffic trends 2022 (Source: EUROCONTROL 2022)

QINETIQ/23/00010

3.7 Assessment of Noise Impact and High Level Assessment of Other Costs and Benefits for Each Airspace Design Option

CAP 1616 requires the Sponsor to provide an indication of the likely noise impact for each design and a high level assessment of other costs and benefits. With regard to the noise impact, this will be the same for all three airspace options presented as, regardless of the airspace option, the noise created by a rocket launch will not be changed – full details of noise assessment is contained at the Appendix to this document and at Reference D. A summary of the Sponsor's initial assessment is found in Table 4 below:

Table 4 – Summary of likely noise impact and high level assessment of other costs and benefits

Design Option	Likely Noise Impact	Other Costs and Benefits
Do-Nothing Option	No additional noise by current airspace users as there would be no change. Rocket launch not viable so no increase in noise.	No change to the current status quo so no additional costs or benefits. As rocket launch would be unviable, the expected economic benefits SP-1 is expected to bring to the local and adjacent communities and economies, as well as the UK as a whole, will not be realised.
Option 3	Increase in noise for the local community for short periods (thought to be in the region of 43 seconds to 120 seconds at time of rocket launch). This will be limited to 10 launches per year.	Air Quality: May be affected in the immediate vicinity of the launch site for a short period (a few seconds) during the actual launch; otherwise unaffected. Greenhouse Gas: Rocket engines will have a negative Greenhouse gas effect as will CAT flying extended track miles to route around the active elements of D701, in particular for long range rockets. Capacity/resilience: A large proportion of D701 areas being active at the same time as other adjacent airspace reservations may impact on NAT capacity – this risk is reduced through extant D701 protocols. Access: Impact likely to be negligible as GA levels are extremely low in this area. SOPs for the MOD Hebrides Range would apply to the fillet of airspace around SP-1 thereby enabling access to the active DA when safe to do so.

		Fuel burn: There is likely to be an increase in fuel burn on those occasions where CAT have to fly extended track miles around the active D701 areas – this will be mitigated through extant ASM processes and agreements affecting the timings when the areas can be activated. Airport/ANSP operational costs: Minimal other than the cost of capturing the small fillet of airspace around the launch site into the ATC training system and any additional training associated with the minor amendments to extant LoAs and SOPs. By using D701 in its current form means the costs to ANSPs remains at the lowest possible as ASM processes and procedures remain largely unchanged. Airport/ANSP deployment costs: Minimal other than the cost of introducing the small fillet of airspace around the launch site into the ATC and ASM systems and applying a new FBZ where appropriate. Other costs would include making minor amendments to extant LoAs and SOPs.
Option 4	Increase in noise for the local community for short periods (thought to be in the region of 43 seconds to 120 seconds at time of rocket launch). This will be limited to 10 launches per year.	Air Quality: May be affected in the immediate vicinity of the launch site for a short period (a few seconds) during the actual launch; otherwise unaffected. Greenhouse Gas: Rocket engines will have a negative Greenhouse gas effect as will CAT flying extended track miles to route around the active elements of the bespoke airspace structure, in particular for long range rockets. The effect may be less than for Option 3 where it can be demonstrated using 'inner areas' (in particular for shorter range rockets) enables CAT to route more efficiently. Capacity/resilience: Where a large number of segregated airspace blocks is active simultaneously with adjacent airspace reservations, capacity on the NAT could be impacted – new protocols would need to be agreed. Access: Impact likely to be negligible as GA levels are extremely low in this area. New SOPs would need to be developed that could be applied to the new bespoke airspace structure to enable access when safe to do so.

		Fuel burn: There is likely to be an increase in fuel burn on those occasions where CAT have to fly extend track miles around the active bespoke areas – new ASM processes and agreements will have to be developed to help mitigate this risk. Operational costs: increased cost associated with ongoing training and currency that will become more complex through the introduction of two similar airspace structures in the same volume of airspace but managed in a different manner using separate operating procedures for each. Deployment costs: Most significant of the three airspace options presented. New operating procedures would have to be developed with associated LoAs and SOPs. ATC, ASM and MOD Hebrides Range systems would need significant updates to reflect the new airspace structure. Moreover, there is a requirement for new reporting points, FBZs and ADQ validation of reference points, incurring further cost.
Option 5	Increase in noise for the local community for short periods (thought to be in the region of 43 seconds to 120 seconds at time of rocket launch). This will be limited to 10 launches per year.	Air Quality: May be affected in the immediate vicinity of the launch site for a short period (a few seconds) during the actual launch; otherwise unaffected. Greenhouse Gas: Rocket engines will have a negative Greenhouse gas effect as will CAT flying extended track miles to route around the active elements of D701, in particular for long range rockets. The effect may be less than for Option 3 where it can be demonstrated any sub-divisions of D701 (in particular for shorter range rockets) enable CAT to route more efficiently. Where a large number of D701 areas are active concurrent to adjacent reserved airspace, this could potentially induce a capacity issue on the NAT track structure. Current airspace protocols in place for D701 help reduce this risk, which could be further reduced through the use of sub-divisions of D701 or reconfiguration. Access: Likely to be negligible as GA levels are extremely low in this area. SOPs for the MOD Hebrides Range would apply to the fillet of airspace around SP-1 thereby enabling access when safe to do so. Fuel burn: There is likely to be an increase in fuel burn on those occasions where CAT have to fly extended track miles around the active D701 areas – this will be mitigated through extant ASM processes and agreements affecting the timings when the areas can be activated.

		Operational cost: Costs will include training related to the new fillet of airspace and reconfiguration of D701 areas, and associated amendments to extant LoAs and SOPs. Deployment costs: ATC, ASM and MOD Hebrides Range systems would need significant updates to reflect the new airspace structure. This option may need additional reporting points, FBZs and ADQ validation of reference points. Current LoAs, operating procedures (with associated training costs) would need modifying to reflect airspace changes.

Table 4: Summary of likely noise impact and high level assessment of other costs and benefits.

3.8 Noise Modelling Requirement

CAP 1616 requires the Sponsor to confirm the minimum noise modelling category that is to be applied to the airspace change. While considering the category the Sponsor will defer to the EIA extract regarding noise modelling at the Appendix to this document, (see paragraph 19.9 'Assessment of likely significant effects' and attached 'technical appendix' for noise modelling and Reference D). Unlike other airspace changes where noise is associated with aircraft and their flight profiles (which can be modified or influenced by the airspace design), this is not the case for rocket launch. Rockets create noise as they are launched[13] and the initial launch profile is predominantly in the vertical plane then, as the rocket gains altitude, along a trajectory[14] line over the sea. However, by the time the rocket begins its transit along a trajectory line it is at such a high altitude that the noise becomes insignificant to personnel living in the vicinity of the launch site. It is therefore argued that the trajectory of a rocket over the sea does not influence the noise encountered at the launch site – this will be constant for any trajectory. Hence the airspace design has no impact on the noise created by rockets and potential nuisance to local populace; this can only be influenced by operational conditions (time of day/night) and environmental conditions (wind effect on blowing noise away). It is therefore argued that other than the EIA, there is no requirement to conduct any further formal assessment on noise as this is not within the scope of this airspace change.

It is acknowledged that the noise created by a sonic boom may be heard on St Kilda[15] for those shorter range rockets as they commence descent, (see Appendix to this document paragraph 3.2 of attached 'technical appendix' refers).

Because of the low concentrations of air traffic, including GA, operating below 7000ft in the vicinity of the Outer Hebrides, the existence of a small fillet of segregated airspace around the launch site is highly unlikely to cause any changes to current traffic patterns or flight profiles of aircraft flying in the region. It is therefore judged that current noise levels caused by aviation will remain unaffected by this airspace change, regardless of option selected.

3.9 Tranquillity and Biodiversity

CAP 1616 further requires the Sponsor to consider the effects of new airspace on tranquillity and biodiversity. In a similar vein to the noise assessment, the Sponsor proposes that formal assessments of effects on tranquillity and biodiversity as out of scope for this airspace change. It is acknowledged that the airspace change is a key enabler for rocket launch however, it is the physical effects of the rocket launch that causes any impact on tranquillity and biodiversity and these effects are considered in the planning application and covered within the EIA (extract contained at the Appendix of this

[13] Noise is assessed at lasting between 43 and 120 seconds.

[14] Trajectories are expected to be within the arc created by radials 212° and 352° from the SP-1 launch site.

[15] St Kilda has very few residents, the majority being engineering staff working for QinetiQ and tourists on day trips to the island.

document and at Reference D), and should not therefore feature in the airspace documentation since the airspace design options have no influence on them.

3.10 Safety Assessment

3.10.1 **Airspace 'Fillet' around launch site**

As part of the work to establish a TDA under ACP-2021-37 [C], a thorough safety assessment was conducted to establish the segregated airspace boundaries necessary for the fillet of airspace around the launch site to support the launch of sub-orbital sounding rockets. This assessment, available at Reference [C], will be used in this ACP as evidence to support the airspace design around the launch site.

Due to the lack of pedigree of modern sub-orbital rockets, QinetiQ MOD Hebrides Range and safety staff have conducted a generic safety analysis approach using key US military and Federal Aviation Authority (FAA) reference documentation as well as experience gained from launching ballistic missile target rockets from the MOD Hebrides Range since 2015. The analysis, conducted through a risk management process, includes but is not limited to: launch risk analysis and hazard identification, risk criteria, probability of failure, hazard thresholds, casualty areas, debris risk assessment, vehicle and debris dispersion modelling, risk uncertainties and assessment of other related risks. The outcome of the analysis provides evidence to the CAA that the boundaries of the proposed segregated airspace fillet at *Figure 2* present the maximum reasonable geographic extent of the region within which credible hazards could occur due to rocket launch and flight activities.

It should be noted that the safety analysis process for aircraft, and the parameters for assessing the volume of airspace required to ensure safety, are different to those when considering third parties on the ground, either on the land area or affected sea space. The variables, environmental effects and probability of harm are very discrete for each environment (air, land and sea) this invokes different boundaries. Furthermore, it is common practice to have an 'air Danger Area' over a land mass but this does not mean there is a hazard to all personnel on the ground beneath this volume of airspace. EG D704, which covers Benbecula airport and the surrounding area, is a good local example; this may be activated to segregate the hazardous activity from other airspace users but it does not mean third parties on the ground beneath D704 are at risk; the ground safety footprint will determine the risk to third parties on the ground, and the area will be cordoned off as necessary. For SP-1, this cordon is considered the boundary of the spaceport.

It was further identified, from experience gained launching ballistic missile targets from the MOD Hebrides Range during the ASD/FS Exercises, that there is likely to be a requirement to safeguard personnel (working at the launch site) from the hazard created by low flying aircraft. It is determined that these spaceport personnel may be at risk of harm while engaged in pre-launch preparation such as refuelling and arming phases of the rockets, if they are suddenly alarmed by the appearance and noise from a low flying aircraft; in particular fast jets. Because these refuelling/arming activities may occur several hours or even days before the intended rocket launch, it was determined, in the interests of FUA that it would be inappropriate to have the whole segregated airspace fillet activated for the purpose of protecting ground personnel. It is proposed that a small inner circular area around the launch pad, as depicted in *Figure 3*, is made available. This can be activated for longer periods of time without adversely impacting on other aviation stakeholders. This additional volume of airspace extends 1000m laterally from the launch pad, extending to 3000ft above ground level (AGL) and sits within the larger airspace fillet. The primary use of this small area of segregated airspace is to protect SP-1 personnel on the ground from the sudden appearance and noise from a low flying aircraft. It may further be of use (should it be deemed necessary by the rocket providers) to provide the rocket systems with RF interference protection from low flying aircraft during the same critical stages of preparation.

3.10.2 **Airspace volume beyond the Fillet**

With regard to assessing the airspace volume required outside the airspace fillet around the launch site, there are a number of factors to consider. Because of the limited pedigree of modern sounding rockets, many of the factors can only be fully evaluated during the launch planning cycle[16] where the full capabilities and performance of the rocket with corresponding payload/test equipment are finally known. Only then can the detailed safety assessment be conducted, under a variety of different environmental conditions, to establish the debris field and associated safety traces. This is where any environmental limitations will be imposed. Only when all this information is available and validated can the safety trace be overlaid onto the modular airspace structure as described in Options 3 – 5. The sub-areas that the safety trace sits within can then be notified active for the launch. Only a modular airspace design can facilitate any number of different sounding rocket types with varying degrees of pedigree and capabilities. This is exactly the same process and methodology used by MOD Hebrides Range staff to test and evaluate new weapon systems and aerial targets.

3.11 Airspace Classification Options

3.11.1 **Types of Airspace to Accommodate Vertical Spaceport Launches**

Rocket launches and flights pose a risk to other aviation users either through mid-air collision or, following catastrophic failure of the rocket (explosion), debris impacting other aircraft. To safeguard airspace users from these risks there is a requirement to segregate the activity accordingly. This is achieved through establishing segregated airspace in one form or other.

The SP-1 launch site at Scolpaig on North Uist currently sits beneath Class G ‘uncontrolled’ airspace. This means anyone is entitled to operate in this airspace without any specific equipment, training or air traffic control. Therefore, there is no method to safeguard them from SP-1 rocket launches. In the UK there are five classifications of airspace which can all provide a method of segregation. These are detailed and assessed for suitability by the Sponsor in the table below.

[16] This is likely to be a few months in advance of the launch.

3.12 Classification of Airspace Comparison A, C, D, E & G

Type of segregated airspace	Suitability for Rocket Launch	Sponsor Comment
Class A	No	- Instrument Flight Rules (IFR) flight is mandatory in class A airspace, rockets will be largely 'uncontrolled' after launch so will be unable to comply with ATC instructions applicable in Class A or comply with RoTA - Rockets will not be equipped with the necessary Communications Navigation & Surveillance (CNS) equipment for flights in controlled airspace - Controlled airspace is currently permanently on/active, therefore in the spirit of FUA it is not practicable to have Class A for the relatively few launches - Too restrictive on other airspace users (inability to access Class due to aircraft equipment and pilot limitations)
Class C	No	- ATC instructions mandatory in class C airspace, rockets will be largely 'uncontrolled' after launch so will be unable to comply with ATC instructions applicable in Class C or comply with RoTA - Rockets will not be equipped with the necessary CNS equipment for flights in controlled airspace - Controlled airspace is currently permanently on/active, therefore in the spirit of FUA it is not practicable to have Class A for the relatively few launches - Too restrictive on other airspace users (inability to access Class due to aircraft equipment and pilot limitations)
Class D	No	- Rockets unable to comply with ATC instructions that are mandatory in class D airspace or comply with RoTA - Inability to operate under either IFR or Visual Flight Rules (VFR) as rockets will be largely 'uncontrolled' after launch - Controlled airspace is currently permanently on/active, therefore in the spirit of FUA it is not practicable to have Class D for the relatively few launches

Type of segregated airspace	Suitability for Rocket Launch	Sponsor Comment
Class E	No	- Rockets cannot comply with IFR or VFR, or RoTA - Controlled airspace is currently permanently on/active, therefore in the spirit of FUA it is not practicable to have Class E for the relatively few launches
Class G Danger Area	Yes	- Less impact on other airspace users since it can be tactically managed (does not have notified hours of activation in UK AIP) – only activated by NOTAM when needed
Transponder Mandatory Zone (TMZ)/Radio Mandatory Zone (RMZ)	No	- Rockets may not be transponder equipped - Airspace would need to be controlled by approved ATC not MOD Hebrides Range controllers – resourcing issue - TMZ/RMZ would preclude many of the aircraft using the beach landing site at Sollas during periods when the Spaceport is not active

Table 5: Proposed airspace types for consideration with sponsor comment

3.13 Measures to Minimise Impact on Other Airspace Users

3.13.1 Classification of Airspace

Airspace with the least restrictions to other airspace users is uncontrolled Class G. This airspace still has the option to 'segregate' activity through the establishment of a Danger Area; such Danger Areas can be activated by NOTAM when needed. The Sponsor therefore proposes that the airspace classification around the launch site remains Class G[17].

[17] It is noted that above FL195 the airspace is Class C and Class A however, as for the D701 areas when activated (including airspace above FL195) the airspace is treated as Class G.

4. Next Steps

4.1 Next Steps in This ACP

This document, together with the 'options appraisal and design principle evaluation report' forms the documentary evidence for the Stage 2 DEVEOP and ASSESS Gateway assessment performed by the CAA. The Gateway is scheduled for 27th January 2023. On successful completion of Stage 2, the process will move to Stage 3 CONSULT. The following timeline is predicted:

CAP 1616 Descriptor	Planned Date
Stage 3 - Consult	31 March 2023
Stage 4 – Update & Submit	29 October 2023
Stage 5 - Decide	24 February 2024
Stage 6 - Implement	08 August 2024
Stage 7 – Post implementation review	To be determined (circa August 2025)

5. Glossary

Acronym	Meaning
5LNC	5 Letter Name Code
ACP	Airspace Change Proposal
ADQ	Aeronautical Data Quality
ADS-B	Automatic Dependent Surveillance - Broadcast
AGL	Above Ground Level
AIP	Aeronautical Information Publication
AMC	Airspace Management Cell
ANSP	Air Navigation Service Provider
ASD/FS 21	At Sea Demonstration/Formidable Shield 2021
ASM	Airspace Management
AT	Atlantic Thunder
ATC	Air Traffic Control
ATS	Air Traffic Service
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
CAT	Commercial Air Transport
CNS	Communication Navigation & Surveillance
DPs	Design Principles
EG D	UK Segregated Airspace Designator and Danger Area
EIA	Environmental Impact Assessment
ENM	EUROCONTROL Network Manager
FAA	Federal Aviation Authority
FBZ	Flight planning Buffer Zone
FRA	Free Route Airspace
FUA	Flexible Use of Airspace
GA	General Aviation
HIAL	Highlands & Islands Airports Ltd
HIE	Highlands & Islands Enterprises
IAA	Irish Aviation Authority
ICAO	International Civil Aviation Organisation
ICARD	International Codes And Route Designators
IFR	Instrument Flight Rules
LARA	Local and sub-regional airspace management support system
LoA	Letter of Agreement
MNPS	Minimum Navigation Performance Specification
MOD	Ministry of Defence
NAT	North Atlantic
NLB	Northern Lighthouse Board
NM	Nautical Mile
NOTA	Northern Oceanic Transition Area

NOTAM	Notice To Aviation
OEPs	Oceanic Entry Points
RF	Radio Frequency
RMZ	Radio Mandatory Zone
RoTA	Rules of The Air
SoN	Statement of Need
SOPs	Standard Operating Procedures
SP-1	Spaceport 1
SUPP	Supplement
TDA	Temporary Danger Area
TMZ	Transponder Mandatory Zone
UCT	Coordinated Universal Time
US	United States
VFR	Visual Flight Rules

6. References

A. CAP 1616 Fourth Edition published March 2021; online, available at: http://publicapps.caa.co.uk/modalapplication.aspx?catid=1&pagetype=65&appid=11&mode=detail&id=8127

B. ACP-2021-12 Stage 2 Step 2A Airspace Design Options and Design Principle Evaluation Report dated 21st November 2022, online, available at: Airspace change proposal public view (caa.co.uk)

C. ACP-2021-37 SP-1 TDA, available at: Airspace change proposal public view (caa.co.uk)

D. Environmental Impact Assessment Spaceport-1 Scolpaig, online, available at: https://planning.cne-siar.gov.uk/PublicAccess/applicationDetails.do?activeTab=documents&keyVal=R4RKXJROGNG00

E. Letter of Agreement between NATS (en Route) plc, MOD DE&S, AMC UK, QinetiQ Ltd, UK CAA, IAA and Shannon V1.0 effective 01 October 2020.

SPACE PORT 1

Appendix A – Environmental Impact Assessment Extract (Noise)

19 NOISE AND VIBRATION

19.1 INTRODUCTION

This chapter of the EIA Report describes the potential noise and vibration impacts that may arise during launch activities associated with the Project. The assessment evaluates the potential significant effects arising from noise and vibration from Launch Vehicles (rockets) on human receptors only. It is supported by Appendix 19-1: Noise Technical Report, which details the modelling methodology and criteria used in this assessment. This assessment was undertaken by Arcus Consultancy Services Ltd (Arcus).

Noise impacts on ecological and heritage receptors are assessed in the following chapters:

- Chapter 10: Archaeology and Cultural Heritage;
- Chapter 14: Ornithology;
- Chapter 15: Terrestrial Ecology; and
- Chapter 16: Marine Ecology.

19.2 STUDY AREA

Modelling has been undertaken to determine noise levels during rocket launches, as well as audible sonic booms generated by downward supersonic flight. A separate study area was generated for each of these impacts based on the modelled outputs.

The resulting study areas consider all noise sensitive receptors within 10 km of the Project site (specifically the launch pad) for rocket launch noise, and receptors within 150 km for sonic boom noise, as determined by the extent of the modelling predictions. No noise effects are anticipated outwith these study areas (Figure 19-1).

The nearest human, ecological and cultural heritage receptors are shown in Figures 1 to 6 in Appendix 19-1: Noise Technical Report.

19.3 LEGISLATIVE FRAMEWORK AND POLICY CONTEXT

This assessment follows the legislative framework outlined in the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017[1] (hereafter referred to as the 'EIA Regulations'). The EIA Regulations implement European Union (EU) Directive 2014/52/EU which amended Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment.

There is no guidance on the assessment of noise effects from commercial spaceport developments. As such, the following guidelines / polices have been used to inform the general approach to this assessment and to provide input to the assessment criteria. Details of these guidelines/policies can be found in Appendix 19-1: Noise Technical Report.

- Planning Advice Note PAN 1/2011 *Planning and Noise*[2];
- Technical Advice Note *Assessment of Noise*[3];
- BS 5228-1:2009+A1:2014 *Code of practice for noise and vibration control on construction and open sites. Part 1: Noise*[4];
- BS 4142:2014 + A1:2019 *Methods for rating and assessing industrial and commercial sound*[5];
- WHO *Environmental Noise Guidelines for the European Region* (2018)[6].

SPACE PORT 1

19.4 SUPPORTING SURVEYS AND STUDIES

In support of this assessment, a review of available literature and modelling methodologies for the prediction and assessment of rocket launch and sonic boom noise was carried out. The following guidance and studies are relevant to this assessment:

- *Acoustic Loads Generated by the Propulsion System*[7];
- *User Guides for Noise Modelling of Commercial Space Operations – RUMBLE and PCBoom*[8];
- *Procedure for the Calculation of the Perceived Loudness of Sonic Booms*[9]

A summary of the above studies can be found within the modelling methodology provided in Sections 3.1 and 3.2 of Appendix 19-1: Noise Technical Report. Two specialist software packages have been used to model and predict both launch noise and sonic boom noise. These are described in detail, along with the underlying calculation theory, in Sections 2.3 and 2.4 of Appendix 19-1: Noise Technical Report.

Rocket launch noise has been predicted using the RUMBLE[10] 2.0 software package. RUMBLE was developed in the USA under the Airport Cooperative Research Program (ACRP) to predict noise effects from commercial space operations.

In order to predict the effects and extent of sonic booms generated by the Project's Launch Vehicles (LVs), modelling has been carried out using the PCBoom v4.99 software package. PCBoom has been developed by Wyle Laboratories, Inc. in the USA under the ACRP to predict the extent of sonic booms from single flight operations taking into account vehicle type, atmospheric conditions and flight trajectory.

19.5 DATA GAPS AND UNCERTAINTIES

Regarding the prediction of noise from rockets, the following sources of uncertainty have the potential to result in variation in practice to the noise levels predicted and assessed:

- Source characteristics: the assessment has been carried out based on a 'worst-case' representative LV. In practice other types of LVs may be used, and any differences in the specification of these other types, could lead to corresponding differences in the noise emission and therefore the noise levels affecting receptors;
- Ground Reflections: the RUMBLE noise model assumes propagation over soft ground, i.e., the effects of reflection from water, sand or other acoustically reflective surface are not considered; and
- Atmospheric Effects: the effects of wind speed, temperature, pressure and wind speed gradients have not been considered; however, worst-case assumptions have been made in this respect.

Regarding the prediction of sonic booms, the following sources of uncertainty are present:

- Results of the modelling are shown at the calculation points only, and booms may be audible at other locations and may vary between points within the predicted boom area; and
- The model assumes calm conditions with no wind. It is possible that atmospheric wind conditions present during specific launches may result in different noise levels to these predicted here and refraction may result in booms being audible at other locations. However, these secondary booms would occur at a lower sound level than the primary booms considered in the assessment.

Overall, it is unlikely that these uncertainties could have a material effect on the outcome of the assessment. In practice, it is likely the assumptions made as part of this assessment will overestimate the levels of noise, and as such this assessment considers worst-case scenarios.

19.6 CONSULTATIONS

Following issue of the Scoping Report in 2018[11], consultation has been carried out with Comhairle nan Eilean Siar (CnES) Environmental Health to agree assessment methodology. Feedback has also been received from Marine Scotland in terms of underwater noise. The key points regarding noise and vibration raised by consultees are summarised in Table 19-1.

Table 19-1 Key issues raised by stakeholders during consultation

Stakeholder	Comment	Response/Action taken	Section cross-reference
Environmental Health – Scoping Response June 2018	No Comment to Scoping Report	N/A	N/A
Environmental Health – response to Planning Application (Noise) August 2019	Application refers to 10 launches per year and that the maximum sound that will be heard at the nearest noise sensitive premises, at a distance of 762 m would be 85 dB(A) with a maximum of 15 seconds of noise per launch; equating to 115 seconds in the year. Based on this information no concerns if launch numbers etc. are restricted to this.	Since this initial consultation, further modelling of proposed worst case rocket type results in predicted noise levels at these receptors of 95 dB(A). In addition, the distance to the nearest receptor has increased to 890 m.	Section 19.9
Environmental Health - response to Planning Application (Vibration) August 2019	It may be worth clarifying the potential for vibration, both ground and airborne, and if there is likely to be any impact given the distance to the nearest adjacent premises. Conditions covering vibration, as well as noise, for any of the launches may be applied.	Given large separation distances, both ground and airborne vibration at human receptors is scoped out in Section 19.7.5 Assessment of vibration at cultural heritage receptors is assessed in Chapter 10: Archaeology and Cultural Heritage.	Section 19.7.5, Chapter 10: Archaeology and Cultural Heritage.
Environmental Health – response to Planning Application (Operating hours) August 2019	It is assumed that the hours of operation of the site are tied to the individual rocket launches (which last for approximately 4 days for each of the 10 proposed launches) and will therefore not be continuous all year round.	Confirmed and this is assessed within this chapter.	N/A
Environmental Health – response to Planning Application (Construction noise) August 2019	In terms of construction, recommend that the normal noise [and dust] conditions are applied.	Due to the minimal amount of construction and large separation distance to nearest human receptor, no significant construction noise or vibration effects are anticipated.	Section 19.7.5

Stakeholder	Comment	Response/Action taken	Section cross-reference
Environmental Health, Comhairle nan Eilean Siar (CnES) – response to email consultation outlining assessment and modelling methodology April 2020	Agreed that BS4142 is not applicable and that suggested aircraft noise example (suggested by consultants) would be more appropriate. EH is not aware of any other relevant guidance, criteria or comparable noise sources, nor would they expect any other information, other than what [the consultants] have described, to be provided in the report.	As agreed, assessed noise from launches and sonic booms against noise measured aircraft and other common noise sources.	Section 19.7
Marine Scotland Licensing Operations Team (MS-LOT) 15/06/2021	Noted noise from jettisoned stage splashdown not likely to be of concern for marine mammals due to there being no explosion, impulsive or persistent noise, such as associated with piling activities.	No further action related to underwater noise.	Chapter 16: Marine Ecology

A planning application to develop a proposed Spaceport at Scolpaig Farm in North Uist was submitted to the Comhairle nan Eilean Siar on 26 June 2019 (Planning Reference 19/00311/PPD). The planning application attracted significant public attention and consequently, approximately 640 representations from the public were received. Comments raised from both the public and consultees highlighted key issues and concerns of relevance to the EIA process. Given the relationship to the EIA process, an analysis was undertaken of the representations submitted. The complete analysis is provided in Appendix 5-1: Review of Planning Representations.

In summary, there were 94 objections (15 % of the total of objections), which expressed concern over the unknown impact of noise pollution on local archaeological sites, wildlife (specifically birds) and the sense of peace and tranquillity for which the Uists are known. It was felt that noise and the accompanying vibrations from construction and use of the site could compromise the strength of Scolpaig Tower. The impact of noise and vibration on birds is covered in Chapter 14: Ornithology, and on archaeological features in Chapter 10: Archaeology and Cultural Heritage.

19.7 ASSESSMENT METHODOLOGY

Whilst the policy and guidance documents detailed in Section 19.3 of this report provide assessment methodologies for a wide range of noise generating developments, there is no specific guidance regarding noise generated from operation of spaceports. In addition, due to the occasional occurrence and short duration of the sound during rocket launches at the Project site, conventional noise assessment standards are of limited relevance.

In the absence of specific guidance, and as agreed through consultation with CnES Environmental Health, noise effects have therefore been considered with reference to levels generated by familiar noise sources, as detailed in Section 19.7.1 and 19.7.2.

This report therefore considers operational noise from the Project, which has two potential components:

- Noise from the launching of sounding rockets; and
- Sonic booms.

Two rocket models are assessed and presented in this chapter and Appendix 19-1 Noise Technical Report: Rocket A and Rocket B; each representing the 'worst-case scenarios' for noise from the launch of sounding rockets and noise generated by sonic booms respectively:

- Rocket A is a single stage rocket, and the largest rocket type proposed for launch at the Project site. It controls descent by way of early parachute deployment, which means that it does not reach supersonic speeds during this stage and as such will not produce audible sonic booms. Due to its size, Rocket A will generate the highest noise levels during launch and as such presents a worse case for launch noise;
- Rocket B is a two-stage rocket with the descent of the second stage reaching supersonic speeds, and as such generating an audible sonic boom. Rocket B presents a worst case for sonic booms.

The full details and specifications for Rockets A and B are commercially sensitive and as such are not reproduced here. Further details, including the methodology used to predict launch noise and sonic booms and modelling assumptions are provided in Sections 2.3 and 2.4 of Appendix 19-1: Noise Technical Report.

19.7.1 Launch Noise

Noise from each rocket launch will be of very short duration; the powered phase of Rocket A will last for approximately 120 seconds. The powered phase of the first stage of Rocket B will last for approximately 12 seconds, and the second stage powered phase approximately 31 seconds, i.e., the rocket will produce potentially high levels of noise for a total 43 seconds. However, the noise may not be audible for the full length of these powered phases, due to the altitude and distance covered. Launches will occur no more than 10 times per year, and during daytime hours only.

As agreed through consultation with CnES Environmental Health in April 2020, conventional approaches to the assessment of noise are not appropriate, given the very short duration and occasional nature of each event. Conventional methods for assessment of commercial noise (e.g., BS 4142) are typically based on the equivalent continuous ('average') sound level over a defined period of time (e.g., 1 hour) and are assessed against either absolute criteria, or against pre-existing background noise levels. Such an approach is not suitable for the assessment of occasional, short duration sounds such as rocket launches, where the maximum noise levels occurring during the launch event is likely to be more important than the 'average' over a period of time.

The WHO Community Noise Guidelines 1999 make reference to the use of L_{Amax} for the assessment of noise events which occur occasionally, for short duration or varying in level. As such, and as agreed with CnES Environmental Health in

April 2020 (see Table 19-1), the short duration noise levels (lasting up to 120 seconds) have been assessed by comparison to L_{Amax} noise levels generated by common noise sources. Table 19-2 provides a range of commonly experienced noise levels of increasing level.

Table 19-2 Commonly experienced L_{Amax} noise levels

Level, dB, L_{Amax}	Source	Effect / Comparison
60	WHO Guidelines for Community Noise 1999	Recommended limit for night-time noise outside of an open window. Daytime noise below this level highly unlikely to be disturbing.
65	Regulation (EU) 168/2013[12]	Road motorcycle at 40 m
70		Road motorcycle at 25 m
75		Road motorcycle at 15 m
80	BS 5228[13]	39 t road lorry at 10 m (Table C.6.21)
85		35 t bulldozer at 10 m (Table c.5.14 - 86 dB)
90		Dump trucks on haul roads at hard rock quarries at 10 m (Table c.9. 16-22)
110	WHO Guidelines for Community Noise 1999	Recommended limit for protection of hearing. Noise at this level or above may be harmful.[14]

Noise from rocket launches at the surrounding human receptors is therefore assessed by comparing the predicted noise level to the commonly experienced noise levels presented in Table 19-2, with an upper limit of L_{Amax} 110 dB.

19.7.2 Sonic Boom Noise

There are no standard assessment criteria for sonic boom noise. A review of relevant studies, as discussed in Section 1.4 in Appendix 19-1: Noise Technical Report, indicates that Perceived Decibel Level (PLdB) provides the most appropriate metric for consideration of sonic boom noise. The PLdB is a metric developed to take account of the human response to shock waves relating to sonic booms, taking into account their high levels of low frequency content. Whilst there are no standard criteria for the assessment of PLdB, NASA research indicates that a PLdB of up to 75 dB is *"acceptable for unrestricted supersonic flight over land"*[15].

In addition to the PLdB, the maximum overpressure during descent of the second stage is also predicted. As with launch noise, assessment of the maximum over pressure is compared against levels generated by a range of different aircraft travelling at supersonic speeds[16] as outlined in Table 19-3. Maximum overpressure is described in PCBoom in pounds per square foot (psf) (1 psf equals 48 Pascals) and is the pressure over and above normal atmospheric pressure (2,116 psf).

Table 19-3 Example measured maximum overpressure for comparison

Source	Source speed	Overpressure
Lockheed SR-71 Blackbird	Mach 3.0 at 80,000 ft (24 km)	0.90 psf
Concord	Mach 2.0 at 52,000 ft (16 km)	1.94 psf
Lockheed F-104 Starfighter	Mach 1.9 at 48,000 ft (15 km)	0.80 psf
NASA Space Shuttle	Mach 1.5 at 60,000 ft (18 km)	1.25 psf

Although there are no recommended criteria for overpressure from sonic booms generated by aircraft, it should be noted that a complaint was made relating to a sonic boom from Concord at 0.75 psf[17].

19.7.3 Sensitivity of Receptors and Magnitude of Change in EIA Methodology

The assessment is prepared in accordance with the EIA Regulations, and its purpose is to identify whether a significant effect will occur under this context.

Sections 19.7.1 and 19.7.2 of this chapter provide context for quantifying the level of noise with reference to other sources, and it is important to consider the sensitivity of receptor and magnitude of change to determine whether an effect is significant or not under the EIA regulations.

Sensitivity of receptors is an important consideration when determining the magnitude of impact. The sensitivity of receptors to potential impacts is based on their capacity to avoid, tolerate, recover from, or adapt to a particular impact. This is informed by the magnitude of change, which is experienced by a receptor of varying sensitivity. For the purposes of environmental assessment, magnitude of a change or "effect" is generally dependent on the degree to which the change affects the feature or asset, from a fundamental, permanent or irreversible change that changes the character of the feature or asset, to barely perceptible changes that may be reversible. Magnitude would also encompass the certainty of whether an impact would occur.

This assessment evaluates effects on residential receptors, and therefore all receptors are considered to be of high sensitivity. To draw conclusions on whether the noise levels identified as part of this EIA are significant, consideration is given to the magnitude of change, and whether this would be negligible; low; medium; or high. Definitions of these levels are presented in Table 19-4.

Table 19-4 Framework for Determining Magnitude of Change

Magnitude of Change	Definition
High	A fundamental change to the baseline condition of the receptor, leading to a total loss or major alteration of character.
Medium	A material, partial loss or alteration of character.
Low	A slight, detectable, alteration of the baseline condition of the asset.
Negligible	A barely distinguishable change from baseline conditions.

When classifying magnitude of change within the above framework, the following factors are taken into consideration:

- Extent;
- Scale, including predicted noise levels compared to those identified from the literature review as being applicable:
  - Launch noise: L_{Amax} 110 dB, based on WHO guidelines;
  - Sonic boom noise: 75 PLdB, based on NASA research.
- Duration;
- Frequency of timing; and
- Reversibility.

19.7.4 Significance Criteria

As per the EIA Regulations, as referenced in Section 19.3, the purpose of an EIA Report is to identify whether or not a significant effect is likely to occur as a result of a particular development.

For the purposes of this assessment and following consultation with the planning authority, launch and sonic boom noise criteria has been determined based on:

- The literature review summarised in Appendix 19-1: Noise Technical Report and Sections 19.7.1 and 19.7.2;
- Consideration of the magnitude of change experienced by a receptor, as set out in Section 19.7.3;
- Professional judgement.

Where the magnitude would result in an effect deemed to be a material or fundamental change to a high sensitivity receptor e.g., a *medium* or *high* magnitude of change, effects would be generally deemed **significant** in accordance with the EIA Regulations. Where effects are deemed to be as a result of *negligible* or *low* magnitude of change on a high sensitivity receptor, effects would generally be deemed **not significant** in accordance with the EIA Regulations.

19.7.5 Elements Scoped Out

The launching of rockets of the scale considered within this report is unlikely to be a significant source of vibration due to the low levels of sound and air overpressure being generated. In addition, the sound would be dominated by mid-range frequencies that are less prone to result in induced vibration in structures than low frequencies. As such, both ground and airborne vibration at human receptors have been scoped out of further assessment, however precautionary measures for protecting specific structures located within the site are set out in Chapter 10: Archaeology and Cultural Heritage.

Due to the minimal amount of construction required for the Project, as well as the large separation distances (approximately 890 m to the nearest noise sensitive receptor), no significant construction noise or vibration effects are anticipated. Construction noise and vibration impacts have therefore been scoped out of further assessment. However – and as indicated above - precautionary measures for protecting specific structures located within the site are set out in Chapter 10: Archaeology and Cultural Heritage.

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19.8 BASELINE DESCRIPTION

Due to its rural nature, North Uist has a quiet acoustic environment, dominated by natural sources including the wind and sea. Artificial sources are usually limited to low levels of road traffic, occasional aircraft, agriculture and shipping.

An existing MOD rocket range is present on South Uist, and the wider area is used bi-annually for Joint Warrior[18] and other military exercises, which can generate noise from activities such as missile firings, ships and aircraft, including low-flying supersonic fighter jets and helicopters. Although baseline noise levels in the area are normally low, there are existing noise sources which have a comparable character and pattern of occurrence to those associated with the Project.

19.8.1 Potential Noise Sensitive Receptors

This chapter considers impacts on human receptors only, with impacts on cultural heritage, ornithology, terrestrial ecology, and marine ecology receptors addressed in Chapters 10, 14, 15 and 16 respectively.

Figure 1 in Appendix 19-1: Noise Technical Report shows the locations of human noise-sensitive receptors. These have been identified from Ordinance Survey MasterMap AddressBase Plus data, a database that combines features shown on large-scale digital mapping with the Royal mail address database. These consist mainly of dwellings but also include other noise-sensitive buildings such as schools and places of worship. The closest noise sensitive receptors have been identified as follows:

- Scolpaig Farmhouse is located approximately 175 m from the launch site but is currently uninhabited. It is proposed that Byre 2 in the farm steading complex is modified for use as a covered workshop, assembly and communications area. There is no intention of reinstating Scolpaig Farmhouse as a residential dwelling;
- The next closest receptor is An Ataireachd Ard at approximately 890 m south of the launch site; and
- The closest receptors to the east are at a distance of approximately 1,900 m.

All noise sensitive receptors are considered to be of **high** sensitivity for the purposes of this assessment.

The locations of ecological / ornithological receptors, in the form of Designated sites and Nature Reserves are shown on Figure 2 in Appendix 19-1: Noise Technical Report. The assessment of noise impact on such receptors is covered in Chapter 14: Ornithology, Chapter 15: Terrestrial Ecology and Chapter 16: Marine Ecology.

Figure 3 in Appendix 19-1: Noise Technical Report shows the locations of Scheduled Monuments and records from the CANMORE historic site record. The assessment of noise and vibration impact on such receptors is covered in Chapter 10: Archaeology and Cultural Heritage.

19.9 ASSESSMENT OF LIKELY SIGNIFICANT EFFECTS

19.9.1 Launch Noise

Figure 1 in Appendix 19-1: Noise Technical Report shows predicted noise level contours for the powered phase of Rocket A's Stage 1 trajectory, which represents the worst-case scenario for launch noise. The near-circular shape of the contours and the fact that they are centred on the launch site indicate that the highest noise levels would occur shortly after lift-off.

The predicted L_{Amax} noise level is below the 110 dB criteria outlined in Section 1.7 of Appendix 19-1: Noise Technical Report at all identified receptors, and would only be experienced during the launch period, which is limited to 120 seconds at any one time, up to 10 times per year. Given the short duration that this noise level would occur for, this is not a considered to represent a material or fundamental change to the baseline conditions. The predicted noise level exceeds the criteria for a negligible magnitude of change, set out in Section 19.7.3, therefore, as a result of the predicted noise level but limited duration, this impact is characterised as **low** magnitude of change. The effects from launch noise are consequently assessed as **not significant** in the context of the EIA Regulations.

19.9.2 Sonic Booms

Based on the rocket dimensions and trajectory of the worst-case Rocket B, the footprint of the predicted PLdB of the sonic boom generated during the descent of the rocket has been calculated and is shown in Figures 4 to 6 in Appendix 19-1: Noise Technical Report, covering the most northerly trajectory of a potential flight path, the most southerly trajectory and a typical mid-range trajectory.

Westerly trajectory

The levels range from 67 PLdB to 97 PLdB occurring at distances of between 20 and 80 nautical miles outwards from the launch site. The proposed trajectory stretches out to the west of the launch site at a bearing of 275°. With this trajectory, sonic boom noise is predicted to be experienced on one habitable island, St Kilda, with a Perceived Decibel Level of 70 PLdB. This is below the 75 PLdB limit and would occur for less than a second, up to a maximum of 10 times a year. However, it is also important to note that not all LV specifications generate sonic boom, and the range of potential trajectories available indicate that the experience of sonic boom at these locations would be infrequent. Given the short duration that this noise level would occur for, this is not a material or fundamental change to the baseline conditions. The predicted noise level is below 75 PLdB limit identified through the literature review and the duration is limited to less than one second; therefore, the impact is considered to be a **negligible** magnitude of change as defined in Section 19.7.3. The effects from sonic boom noise at a westerly trajectory are consequently assessed as **not significant** in the context of the EIA Regulations.

Northern and southern trajectories

In order to allow flexibility in the trajectory of each launch event (the trajectory of any given launch can be subject to change depending on weather conditions), a Space Launch Hazard Area (SLHA) has been defined, ranging from bearings 212° to 352°, within which alternative trajectories can be used. As a worst case, the sonic boom footprint has been modelled for the southern-most possible trajectory at 212° (see Figure 5 in Appendix 19-1: Noise Technical Report) and the most northerly at 352° (see Figure 6 in Appendix 19-1: Noise Technical Report).

Figure 5 in Appendix 19-1: Noise Technical Report indicates that for the most southerly possible trajectory, the Perceived Noise Levels are predicted to be up to 85 PLdB on the Isle of Coll. For the most northernly (Figure 6 in Appendix 19-1: Noise Technical Report), sonic boom noise is predicted to be audible across the northern half of the Isle of Lewis with predicted Perceived Decibel Levels up to 95 PLdB. The Perceived Decibel Levels predicted for these worst-case trajectories exceed the suggested criteria at human receptors. However, the duration of these effects would be limited and occur for less than one second at a maximum of 10 times a year. Again, it is also important to note that not all LV specifications generate sonic boom, and the range of potential trajectories available indicate that the experience of sonic boom at these locations would be infrequent. Given the short duration that this noise level would occur, this is not considered to represent a material, or fundamental change to the baseline conditions. The predicted noise level exceeds the criteria for a negligible magnitude of change, as set out in Section 19.7.3. Therefore, as a result of the predicted noise level but limited duration (less than 1 second, up to 10 times per year), this impact is characterised as **low** magnitude of change. The effects from sonic boom noise, at a southern and northern trajectory, are consequently assessed as **not significant** in the context of the EIA Regulations.

It should also be noted that sonic booms will only be generated using two-stage rockets such as Rocket B, which represents a worst-case.

As well as Perceived Decibel Level, the maximum overpressure has also been calculated ranging from 0.01 to 0.54 psf. This is markedly below the overpressure measured for commercial and military aircraft, and almost 100 times lower than Concorde travelling at Mach 2 at an altitude of 16 km.

19.10 MITIGATION AND RESIDUAL EFFECTS

Due to the nature of the noise and its source, there are no physical mitigation measures such as screens or enclosures available to reduce the level of noise at the nearest receptors.

However, mitigation measures set out in Table 19-5 include community notification process (GM05 Pre-Launch Communications: Advance Alert and Community Notifications) and Maritime Management Procedures (MU01) for publicising information on the timing of launches through various media will be implemented so that the local population and visitors are aware of the possible occurrence of noise. This will also include a provision for alerting mariners to noise with the timing and location of launches.

Table 19-5 Mitigation Measures

Ref	Title	Description
GM05	Pre-Launch Communications: Advance Alert and Community Notifications	An Advance Alert / Pre-Launch Contact Service will provide advance notice of activities relevant to key stakeholders including emergency services, fishermen, hauliers and closest residential receptors. Stakeholders can register for the alert service on a dedicated email address and can view the range activity programme on a dedicated website. The Spaceport Operator will additionally publish notifications in local/social media, their website and at key information points in the surrounding locality to the wider community and stakeholders informed of key project activities and any associated restrictions. Measures are likely to include: • Regular updates via e-mail to local community groups. • Website – showing schedule of planned activity. Social Media – posts about planned activity.
MU01	Maritime Management Procedures	The Maritime Management Procedures will ensure the safe launch of LVs from the spaceport and include prior notification procedures and operational procedures throughout a launch campaign. Key measures to eliminate risk and minimise disruption to marine users include procedures relating to: • Maritime notifications – pre-launch, mission deviation, post-launch; (community updates through various mediums, advance alert service, Notice to Mariners (NtM), Navigation Warnings (NavWarning);

The residual effects of launch noise following implementation of the above notification process will remain **not significant**. Likewise, the resulting residual effects of sonic boom noise will remain **not significant** for the proposed westerly trajectory and **not significant** for the worst-case northern and southern trajectories for the duration of audible sonic booms (less than one second up to 10 times per year). Providing prior notice to residents will ensure that the effects have been further minimised as far as practicable.

19.11 ASSESSMENT SUMMARY AND CONCLUSIONS

This chapter assesses the potential noise and vibration impacts that may arise during launch activities associated with the Project. The assessment evaluates the potential significant effects arising from noise and vibration from Launch Vehicles (rockets) on human receptors only. It is supported by Appendix 19-1: Noise Technical Report, which details the modelling methodology and criteria used in this assessment.

Noise impacts on ecological and heritage receptors are assessed in the following chapters: Chapter 10: Archaeology and Cultural Heritage; Chapter 14: Ornithology; Chapter 15: Terrestrial Ecology; and Chapter 16: Marine Ecology.

Construction noise and vibration impacts have been scoped out of the assessment due to the minimal construction required for the Project, as well as the large separation distances from residential receptors. Construction best practice measures will be followed to minimise potential noise disruption.

The launching of rockets of the scale considered for the Spaceport are unlikely to be a significant source of vibration due to the low levels of sound and air overpressure being generated. Therefore, ground and airborne vibration at human receptors have been scoped out of further assessment, however precautionary measures for protecting specific structures located within the site are set out in Chapter 10: Archaeology and Cultural Heritage.

Noise from each rocket launch will be of very short duration, ranging from approximately 43 to 120 seconds. Launches will occur no more than 10 times per year, and during daytime hours only. The magnitude of the predicted launch noise is within the range of commonly experienced noise levels (L_{Amax} 110 dB) at all noise sensitive receptors and of a duration of up to 120 seconds. The impact of noise from rocket launches on human receptors has been assessed as **not significant.**

Sonic booms will occur during the descent of some rockets, although modelling of the worst-case rocket type and proposed trajectory indicates that these are likely to predominantly affect areas at sea, with a possible effect on St Kilda. Depending on the flight path of the LV, other surrounding habited islands may be affected. Levels predicted at St Kilda are below that defined as acceptable by NASA and at substantially lower levels than sonic booms from commercial and military aircraft. These effects will occur for less than one second up to 10 times per year and, when considering the overall negligible magnitude of change, the effects are assessed to be **not significant**.

It is likely that other launch trajectories will be adopted when necessary; limited to within the proposed SLHA. Levels above the 75 PLdB criteria are predicted on the surrounding habitable islands at the most northernly and southernly extremes of the SLHA. The limited duration of these effects (less than one second up to 10 times per year) suggests this is not a fundamental or material change to the baseline conditions, and results in a low magnitude of change. As such, the effects of noise at these trajectories are considered **not significant** for the duration of the audible sonic boom event (less than one second).

Implementation of a community notification process will provide advanced notice to residential properties.

19.12 REFERENCES

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[2] Planning Advice Note 1/2011: planning and noise, The Scottish Government, 2011

[3] Technical Advice Note: Assessment of Noise, The Scottish Government, 2011

[4] BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites. Part 1: Noise, BSI 2014

[5] BS4142:2014 + A1:2019 Method for Rating and Assessing Industrial and Commercial Sound, BSI 2019

[6] Environmental Noise Guidelines for the European Region, World Health Organisation, 2018

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[9] Bolander, Christian R., et al., (2019) *Procedure for the Calculation of the Perceived Loudness of Sonic Booms*, AIAA Scitech 2019 Forum

[10] For details, please see http://www.trb.org/Main/Blurbs/177510.aspx last accessed 15 July 2021

[11] Spaceport 1, Environmental Impact Assessment: Scoping Report, Atkins (2018)

[12] Regulation (EU) No 168/2013 of the European Parliament and the Council of 15 January 2013 on the approval and market surveillance of two- and three-wheeled vehicles and quadracycles. Annexe D defines a maximum permissible exhaust noise level for motorcycles >175 cc of 80 dB, $L_{A,max}$, measured according to UNECE regulation No 41 (at 7.5 m distance)

[13] BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites. Part 1: Noise.

[14] NB, on p41 of the WHO Guidelines for Community Noise 1999, it is stated that it is uncertain whether the relationships between hearing impairment and noise exposure given in ISO Standard 1999 (ISO 1990) are applicable for environmental sounds of short rise time. For example, in the case of military low-flying areas (75 – 300 m above ground), L_{Amax} values of 110-130 dB occur within seconds after the onset of the sound.

[15] https://www.nasa.gov/topics/aeronautics/features/sonic_boom_thump.html last accessed 15 July 2021

[16] https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html last accessed 15 July 2021

[17] "The Challenges of Defining an Acceptable Sonic Boom Overland", F. Coulouvrat, 15th AIAA/CEAS Aeroacoustics Conference, 2009

[18] Joint Warrior is a UK-led war exercise that takes place in spring and autumn each year. The Royal Navy, Royal Air Force and British Army are joined by forces from 13 other nations. Taking place over two weeks, Joint Warrior includes airborne assaults, amphibious landings, evacuations and live-fire exercises.

SPACEPORT 1
SCOLPAIG FARM, NORTH UIST

TECHNICAL APPENDIX: NOISE

DECEMBER 2021

SPACE PORT 1

TABLE OF CONTENTS

1 INTRODUCTION

This Technical Appendix supports Chapter 19: Noise and Vibration in the Environmental Impact Assessment Report (EIA Report) and details the underlining policy, guidance, noise modelling methodology and outputs. Also included in this Technical Appendix are figures showing the results of the rocket launch noise and sonic boom prediction modelling.

2 POLICY AND GUIDANCE

The following sections provide an overview of the policies and guidance referenced in Chapter 19 of the EIA Report.

2.1 Planning Advice Note PAN 1/2011 Planning and Noise

This document, produced by the Scottish Government, provides advice and guidance on the role of the planning system in limiting and preventing the adverse effects of noise. Whilst both documents provide guidance on a range of new noise generating development types, no guidance is given for noise generated by spaceports.

This document also provides advice on the role of the planning system in helping to prevent and limit the adverse effects of noise, with information and advice on assessment methods provided in the associated Technical Advice Note (TAN).

The PAN promotes the principles of good acoustic design and the appropriate location of new noise-generating development. The selection of a site, the design of a development and conditions that may be attached to a planning permission can all play a part in preventing, controlling, and mitigating the effects of noise. The level of detail required of a noise assessment should be balanced against the degree of risk to environmental quality, public health, and amenity.

2.2 Technical Advice Note: Planning and Noise

The Technical Advice Note: *Planning and Noise* (TAN) provides guidance on assessment methodology that may assist in the technical assessment of noise, although it is neither prescriptive nor exhaustive. It provides methodologies for the assessment of noise from various types of developments (not including spaceports).

2.3 BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites. Part 1: Noise

BS 5228:2009+A1:2014 *Code of Practice for noise and vibration control on construction and open sites* (BS 5228) refers to the need for the protection against noise and vibration of persons living and working in the vicinity of and those working on construction and open sites. It recommends procedures for noise and vibration control in respect of construction operations.

The standard provides measured sound pressure levels for a wide range of noise sources commonly encountered on construction and open sites.

2.4 BS 4142:2014+A1:2019 Methods for rating and assessing industrial and commercial sound

BS 4142:2014+A1:2019 *Methods for rating and assessing industrial and commercial sound* (BS 4142) describes methods for rating and assessing sound in order to provide an indication its likely effect upon nearby premises (typically residential dwellings).

The specific sound emitted from the Development (dB, L_{Aeq}) is rated by taking into account both the level and character (i.e. tonal elements, impulsivity, intermittency and distinctiveness) of the sound. This is achieved by applying appropriate corrections to the specific sound level externally at the receptor location, which gives the rating level of the sound in question.

This standard assesses the impact of sound over a period of 1 hour during the day (07:00 – 23:00) and 15-minutes during the night (23:00 – 07:00).

2.5 WHO Environmental Noise Guidance for the European Region (2018)

The WHO *Environmental Noise Guidelines for the European Region* (2018) recommend a limit of 45 dB(A) L_{den} for aircraft noise. L_{den} is an annualised average noise level with ratings applied to evening and night-time noise. Due to the small number of launches and their short duration, the L_{den} metric would not accurately represent the effect of noise from the Development and is therefore unsuitable for the current assessment.

The WHO Community Noise Guidelines 1999 make reference on a number of occasions to the use of other metrics for the assessment of noise which occurs occasionally or is of short duration or varying in level, including the $L_{A,max}$.

3 MODELLING METHODOLOGY

As stated in Chapter 19 of the EIA Report, only operational noise from the Development is considered, which has two potential components:

- Noise from the launching of sounding rockets; and
- Sonic booms.

Two worst-case rocket models are assessed and presented in the assessment of noise: Rocket A and Rocket B.

Rocket A is a single stage rocket and the largest rocket type proposed for launch at the Development. Its controlled descent, by way of early parachute deployment, means that it does not reach supersonic speeds during this stage and as such will not produce audible sonic booms during its entire trajectory. Rocket A generates the highest noise levels during launch and as such presents a worst-case for launch noise.

Rocket B is a two-stage rocket with the descent of the second stage reaching supersonic speeds and as such generating an audible sonic boom. Rocket B presents a worst-case for sonic booms.

The full details and specifications for Rockets A and B are commercially sensitive and as such are not reproduced here, however, key details used in the prediction of launch noise and sonic booms are provided in the relevant sections.

3.1 Prediction of Noise Levels

The levels of noise resulting during launch of Rocket A have been calculated using the RUMBLE[1] 2.0 software package. RUMBLE was developed in the USA under the Airport Cooperative Research Program (ACRP) in order to predict noise effects from commercial space operations.

The majority of noise is created by the rocket plume interacting with the atmosphere and combustion of propellants. This results in high-amplitude broadband sound which is highly directive.

RUMBLE calculates sound propagation between specific sources (vehicle trajectory points) and a grid of receiver points. The following factors are considered in the calculation:

- Source Sound Power Level;
- Forward Flight Effects;

[1] Airport Cooperative Research Program, (2018) *User Guides for Noise Modelling of Commercial Space Operations – RUMBLE and PCBoom*, Research Report 183

- Source directivity;
- Doppler effect;
- Geometrical spreading loss;
- Atmospheric Absorption; and
- Ground effects.

Sound Power Level

The sound power level of the source is estimated using the method described in NASA 1971[2], which the authors of RUMBLE validated through measurement. The following parameters define the sound power level:

- Number of engines / nozzles;
- Thrust;
- Exhaust velocity; and
- Acoustic efficiency, i.e. the proportion of mechanical energy that is converted into sound. This is calculated within the software.

Noise generated during unpowered flight, which occurs approximately 120 seconds after launch when thrust ceases, would be limited to aerodynamic noise which is likely to be negligible. It is therefore only necessary to consider the noise effects of the powered stage of the rockets' ascent.

Forward Flight Effects

A rocket in forward flight radiates less noise than the same rocket in a static environment. As the difference between flight velocity and exhaust velocity decreases, jet mixing is reduced which reduces noise emission. The maximum overall sound pressure levels are typically generated at subsonic vehicle speeds.

Directivity

Rocket noise is highly directive, with the highest noise level occurring at an angle of 65º relative to the exhaust direction, and with symmetry around the vehicle axis.

Doppler Effect

The doppler effect causes an apparent reduction in frequency of sound from an object moving away from an observer. Due to the reduced weighting of lower frequencies when applying A-weighting, overall A-weighted values are therefore lower from an object moving away from an observer, and vice versa.

Geometric Spreading

This is calculated using standard spherical propagation.

Atmospheric Absorption

RUMBLE calculates this factor based on the US Standard Atmosphere[3], which allows the relevant factors of temperature, pressure and relative humidity to be estimated for altitudes of up to 85 km.

[2] NASA SP-8072 Acoustics Loads Generated by the Propulsion System, National Aeronautics and Space Administration, 1971
[3] https://ntrs.nasa.gov/search.jsp?R=19770009539 last accessed 13 March 2021

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Ground Effects

The software assumes soft (acoustically absorbent) ground. There is therefore potential for levels in practice to be higher than those predicted by the model by around 3 – 5 dB at locations where reflection can occur over water or wet sand.

Model Inputs

The following details for Rocket A were inputted to the RUMBLE software model:

- Spacecraft details:
  - Number of engines / nozzles: 1
  - Thrust: 6745 lbf
  - Exhaust velocity: 7782 ft/s
- Trajectory:
  - First stage trajectory as defined in, in 5 s increments from launch
- Activities:
  - One launch per day
- Receivers:
  - 10 x 10 nautical mile area
  - 0.05 nautical mile grid point spacing
  - 201 x 201 calculation points
  - From 2.5 nautical miles west of launch and 7.5 nautical miles south of launch

Model Outputs

The model was set to provide results as A-weighted maximum sound pressure levels, i.e., dB, L_{Amax} as this was considered to be the most relevant metric given the short-term nature of the sound from a rocket launch.

The results from the model were exported as a grid of point values, which were then processed in ArcGIS Pro Software to determine noise contour lines in 5 dB increments.

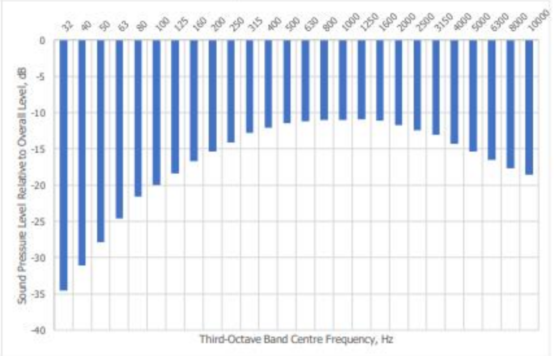
The results are for a neutral wind vector velocity. Launches could occur at surface wind speeds of up to 10 ms^{-1}. Under a negative wind vector velocity (i.e. upwind of the launch site), noise levels may be reduced by around 10 dB, based on studies carried out on wind turbines.

Atmospheric temperature, pressure and wind speed gradients at higher elevations may result in refraction of sound towards the ground under certain conditions. It is unlikely that this would result in higher levels than for trajectory points close to launch, due to the increased distance travelled by the refracted sound waves.

Frequency Content

The NASA 1971 method was used to calculate an indicative third-octave spectrum for the rocket noise source as this is not available from the RUMBLE software. This is shown in Chart 1. This shows that the mid-frequency range (500 - 2000Hz) is dominant in the overall sound. Broadband sound pressure levels in dB, dB(A) and dB(C) are consistent to within 1 dB due to the greatest relevance of the middle frequencies to the A- and C-weightings.

Chart 1: Indicative Rocket Noise Spectrum



Subjectively, the dominant medium to high frequencies is likely to result in a character of noise that resembles a screech, a description which is consistent with that provided by the rocket manufacturer and which is similar to some types of motorcycles.

Uncertainties

The following sources of uncertainty have the potential to result in variation in practice to the noise levels predicted and assessed within this report:

- Source characteristics: the assessment has been carried out for two representative rockets, anticipated to represent a worst-case for launch noise and sonic boom. In practice other types of rocket may be used, and any differences in the specification of these other types, could lead to corresponding differences in the noise emission and therefore the noise levels affecting receptors;
- Ground Reflections: the RUMBLE noise model assumes propagation over soft ground, i.e., the effects of reflection from water, sand or other acoustically reflective surface are not considered; and
- Atmospheric Effects: the effects of wind speed, temperature, pressure and wind speed gradients at the site have not been considered; however, worst-case assumptions have been made in this respect using the US Standard Atmosphere.

Overall, it is considered that these uncertainties will not have an impact on the outcome of the assessment.

3.2 Sonic Boom Prediction

Sonic Boom Theory

Sonic booms are the audible product of shock waves generated as an object travels supersonically. As an object approaches the speed of sound, pressure waves generated by the moving object are compressed to such a degree that they merge into a single shock wave which propagates away from the point of origin at speeds faster than the speed of sound. The generation of shockwaves from supersonic speeds is not limited to the moment

SPACE PORT 1

the sound barrier is broken but are continuously generated throughout the full duration of supersonic travel. The pressure of these shock waves is known as "overpressure" which refers to the increase in pressure of these shock waves over normal atmospheric pressure.

As the object continues to move at supersonic speeds, the shock waves form a "wave cone" which extends from the front of the object at its point, back towards the rear; due to the movement of the object, the wave cone appears to trail behind it, in the manner of a ship's wake. Where this cone intersects the ground, in a hyperbolic arc, the advancement of the object along its trajectory extends the coverage of this intercept creating a "boom carpet" within which sonic booms will be heard. Typically, two "booms" are heard when a supersonic object passes over a fixed reference point as shock waves are generated at two points; at the front of the object and again at the rear. These shock waves are separated by linear expansion relative to the length of the object and are experienced at ground level by an "n-wave"; initially peaking due to compression at the front of the object, expanding linearly until recompression occurs at the rear of the object.

Sonic Boom Prediction Modelling

In the case of this Development, Rocket B (considered to represent a worst-case scenario for sonic boom generation) is travelling supersonically for the majority of its flight (starting approximately 10 seconds after launch). However, only the supersonic flight of the rocket's second stage descent will give rise to audible sonic booms at ground level. In order to predict the effects and extent of sonic booms generated by the Development, modelling has been carried out using the PCBoom v4.99 software package. PCBoom has been developed for more than 20 years by Wyle Laboratories, Inc. in the USA under the Airport Cooperative Research Program (ACRP) in order to predict the extent of sonic booms from single flight operations taking into account vehicle type, atmospheric conditions and flight trajectory.

It does this by calculating the direction and magnitude of the shock waves generated by the rocket's supersonic flight, modelled as a "ray cone" which extends forward from the front of the rocket, perpendicularly to the "wave cone". The footprint of the sonic booms, where sonic booms are predicted to be audible at ground level, is determined by the intersection of the ray cone with the ground and is calculated for each point of the rocket's trajectory.

At steep climbing angles, such as vertical launches, the ray cone will not reach ground level unless refracted back via atmospheric gradients. As this is only likely to occur in rare circumstances (requiring a specific set of conditions) only the sonic boom generated as Rocket B's second stage descends towards the ground is considered.

PCBoom uses ray tracing to predict the extent and magnitude of a number of sound metrics associated with the sonic booms such as maximum overpressure (psf[4]), A, C and E weighted Sound Exposure Levels (dBA, dBC and dBE respectively), Peak Level (dB), and Perceived Decibel Level (PLdB)[5].

In order to do this, PCBoom requires the following information:

- Atmospheric pressure at ground level;
- Temperature and wind velocity at a number of altitudes throughout the atmosphere;
- Physical properties of the object in flight (dimensions, weight, etc.);
- Object Shape Factor (single figure representation of the geometry of the object);
- Object trajectory (heading, climb angle, angle of attack, etc.); and
- Object flight properties (total thrust, plume drag, etc.).

[4] Pounds per square foot

[5] Bolander, Christian R., et al., (2019) *Procedure for the Calculation of the Perceived Loudness of Sonic Booms*, AIAA Scitech 2019 Forum

Rocket B is smaller and lighter than Rocket A with a thrust of 1664 lbf and exhaust velocity of 6145 ft/s.

The input parameters required by PCBoom for Rocket B throughout its flight, taken at 10 seconds intervals, have been determined from information provided by the rocket manufacturer. It should be noted that the predicted PLdB has been calculated for each trajectory interval only and has not been interpolated to generate equal loudness contours. As such, it is possible that the magnitude of the PLdB may differ in-between points of similar level.

Model Assumptions

Due to the wide range of inputs required by PCBoom, a number of assumptions have been made. Atmospheric wind speeds and direction will vary between launches carried out at different times during the year. For simplicity, the model assumes wind at zero velocity.

The US Standard Atmosphere, determined by NASA in 1976[6], has been assumed for atmospheric temperature and is the same as the ISO International Standard Atmosphere up to altitudes of 32 km.

In practice it is unlikely that these assumptions will impact either the predicted sound levels, or the outcome of this assessment.

Shape Factor

This is a single figure, numerical representation of the shape of the rocket; based on the dimensions, planform area, and cross-sectional area of the rocket. The shape factor for Rocket B is 0.015.

Limitations and Uncertainties

The results of the modelling are shown at the calculation points only, and booms may be audible at other locations and may vary between points within the predicted boom area.

As previously stated, the model assumes calm conditions with no wind. It is possible that atmospheric wind conditions present during specific launches may result in different noise levels to these predicted here and refraction may result in booms being audible at other locations. However, these secondary booms would occur at a lower sound level than the primary booms considered in the assessment.

As for the modelling of noise, there are a number of uncertainties associated with the prediction of sonic booms effects, including the characteristics of the rocket, propagation and atmospheric factors, however these are unlikely to significantly affect the outcome of the assessment.

Key output sound metrics

PCBoom outputs a series of different metrics for predicted sonic booms, however there are two key metrics of interest relating to human response:

- Perceived Decibel Level (dB); and
- Maximum overpressure (psf).

Perceived Decibel Level (PLdB) is a metric developed to take account of the human response to shock waves relating to sonic booms. It takes into account the high levels of low frequency content present in sonic booms. Whilst there are no standard criteria for which to assess the perceived noise generated by sonic booms, NASA research indicates

[6] US Standard Atmosphere, 1976, NASA, NOAA and USAF, https://ntrs.nasa.gov/search.jsp?R=19770009539 last accessed 31 March 2021

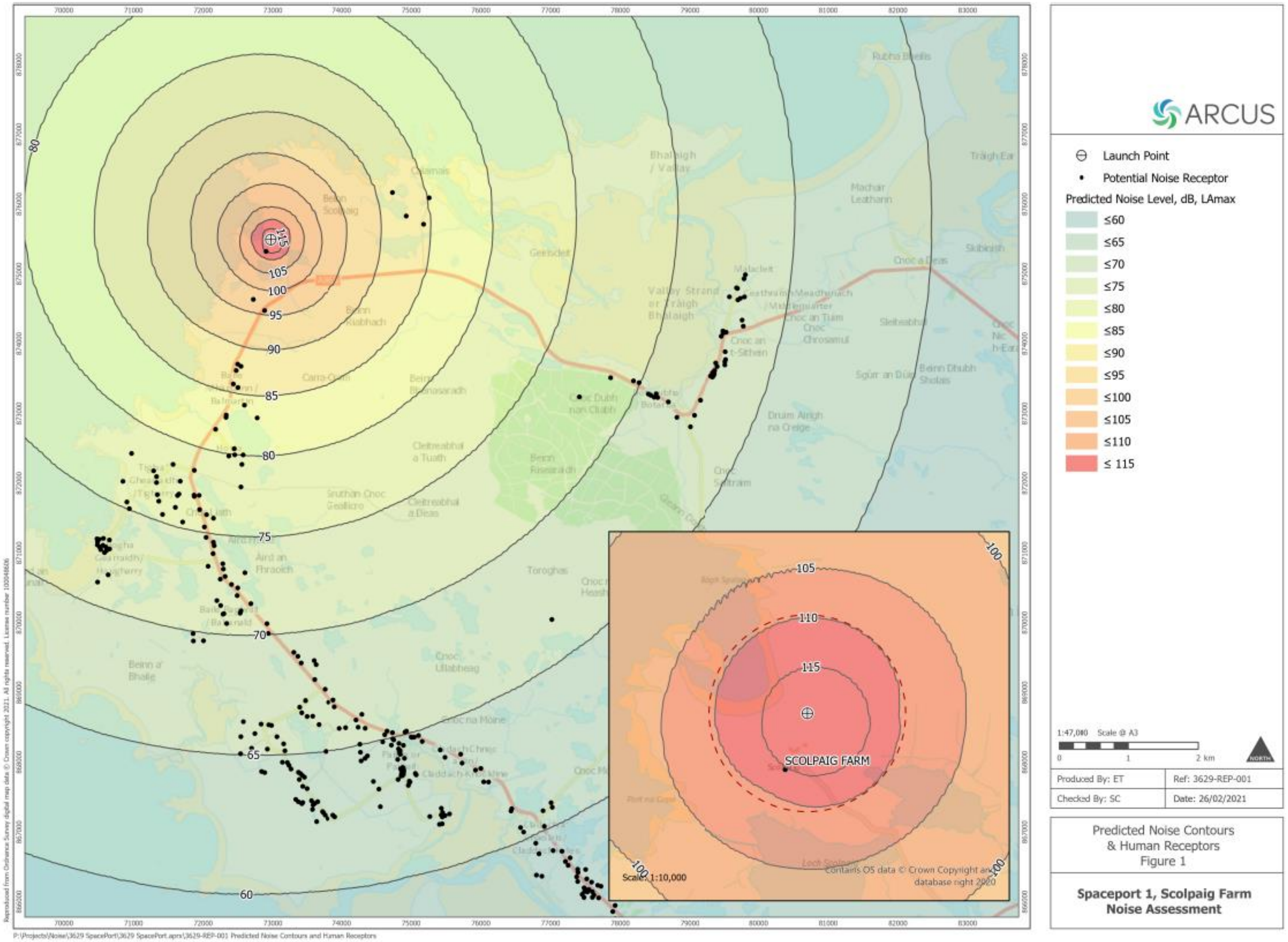
that a PLdB of up to 75 dB is acceptable for unrestricted supersonic flight over land[7]. To put this into context, the sonic boom noise level of Concorde was 105 PLdB, with NASA research (as of 2018) reducing sonic booms from commercial jets to as low as 79 PLdB. An increase of 10 dB is perceived as a doubling of loudness, as such the criteria is perceptibly an 8th of the loudness of Concorde.

Maximum overpressure is described in PCBoom in pounds per square foot (1 psf equals 48 Pascals) and is the pressure over and above normal atmospheric pressure (2,116 psf). As a reference point the following levels of overpressure have been measured for a range of different aircraft travelling at supersonic speeds[8]:

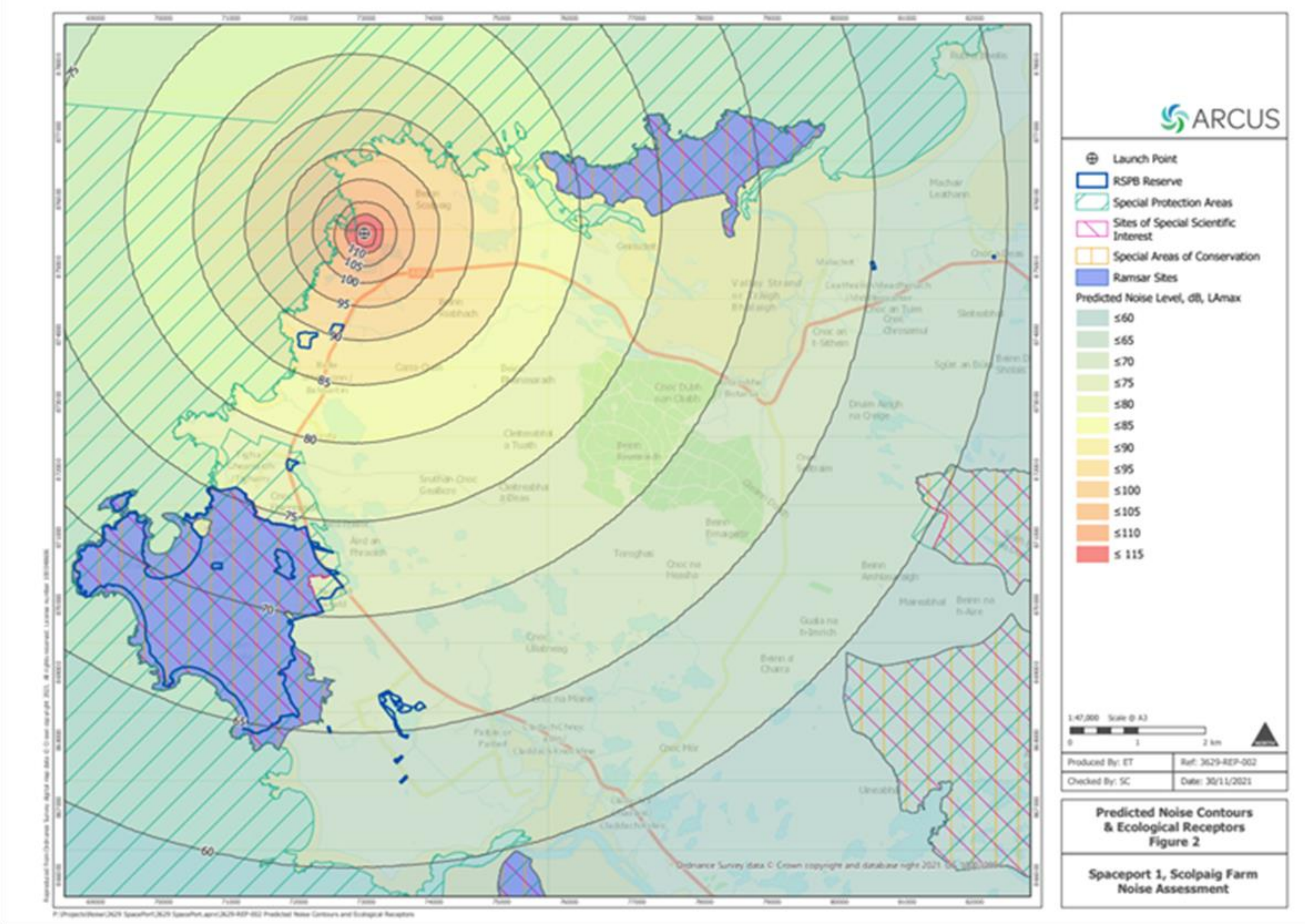
- Lockheed SR-71 Blackbird; Mach 3 at 80,000 feet (24 km): 0.90 psf;
- Concord; Mach 2 at 52,000 feet (16 km): 1.94 psf;
- Lockheed F-104 Starfighter; Mach 1.93 at 48,000 feet (15 km): 0.80 psf; and
- NASA Space Shuttle; Mach 1.5 at 60,000 feet (18 km): 1.25 psf.

Although there are no recommended criteria for overpressure from sonic booms generated by aircraft, it is worth noting that a complaint was made relating to a sonic boom from Concord at 0.75 psf[9].

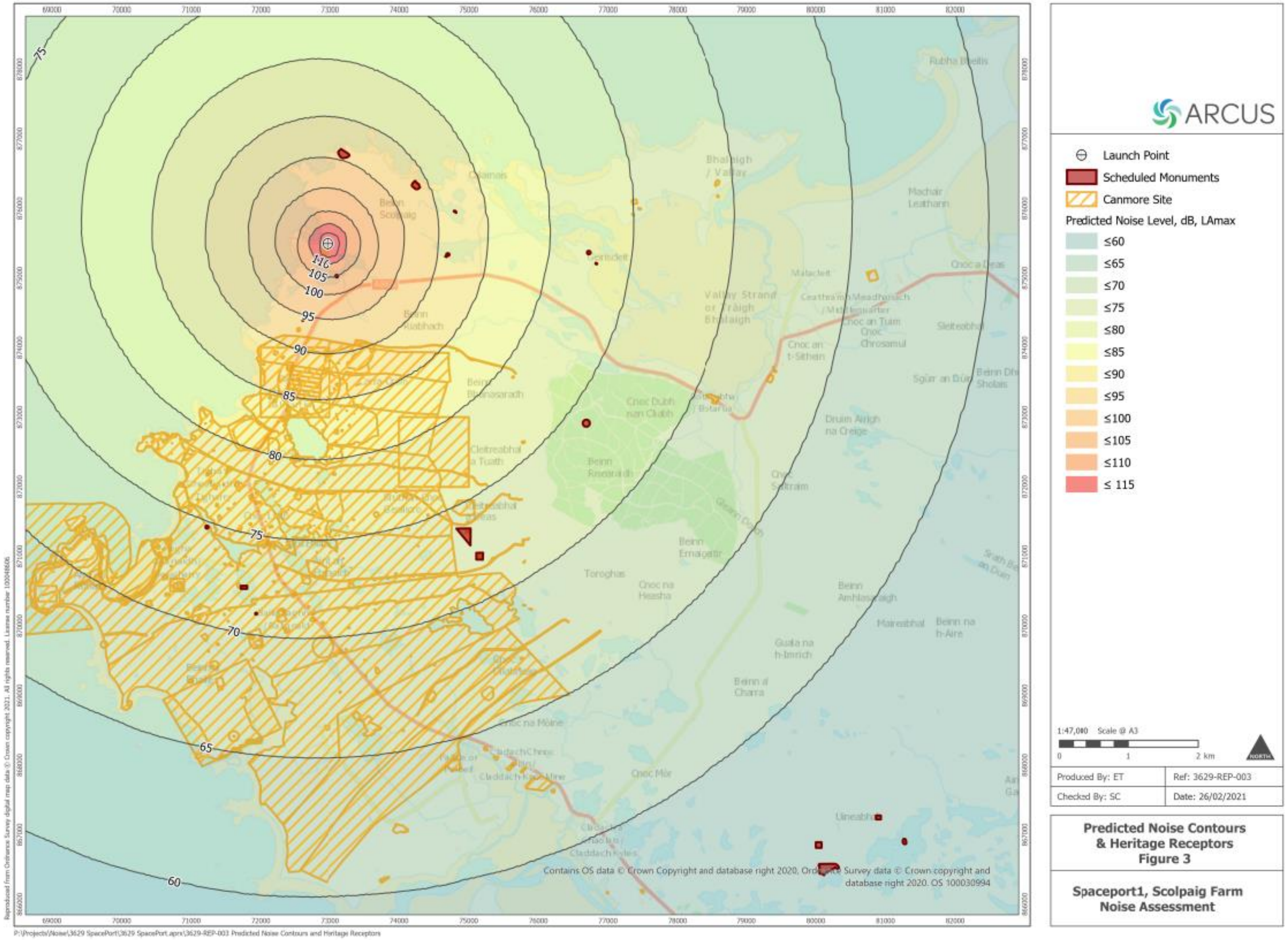
[7] https://www.nasa.gov/topics/aeronautics/features/sonic_boom_thump.html last accessed 8 March 2021
[8] https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html last accessed 15 April 2021
[9] "The Challenges of Defining an Acceptable Sonic Boom Overland", F. Coulouvrat, 15th AIAA/CEAS Aeroacoustics Conference, 2009



ARCUS
Launch Point
Potential Noise Receptor
Predicted Noise Level, dB, LAmax
≤60
≤65
≤70
≤75
≤80
≤85
≤90
≤95
≤100
≤105
≤110
≤ 115
SCOLPAIG FARM
Scale: 1:10,000
Contains OS data © Crown Copyright and database right 2020
Produced By: ET
Ref: 3629-REP-001
Checked By: SC
Date: 26/02/2021
Predicted Noise Contours & Human Receptors
Figure 1
Spaceport 1, Scolpaig Farm
Noise Assessment



110
105
100
95
90
85
80
75
70
65
60
ARCUS
Launch Point
RSPB Reserve
Special Protection Areas
Sites of Special Scientific Interest
Special Areas of Conservation
Ramsar Sites
Predicted Noise Level, dB, LAmax
≤60
≤65
≤70
≤75
≤80
≤85
≤90
≤95
≤100
≤105
≤110
≤ 115
1:47,000 Scale @ A3
0
1
2 km
Produced By: ET
Ref: 3629-REP-002
Checked By: SC
Date: 30/11/2021
Predicted Noise Contours & Ecological Receptors Figure 2
Spaceport 1, Scolpaig Farm Noise Assessment


ARCUS
Launch Point
Scheduled Monuments
Canmore Site
Predicted Noise Level, dB, LAmax
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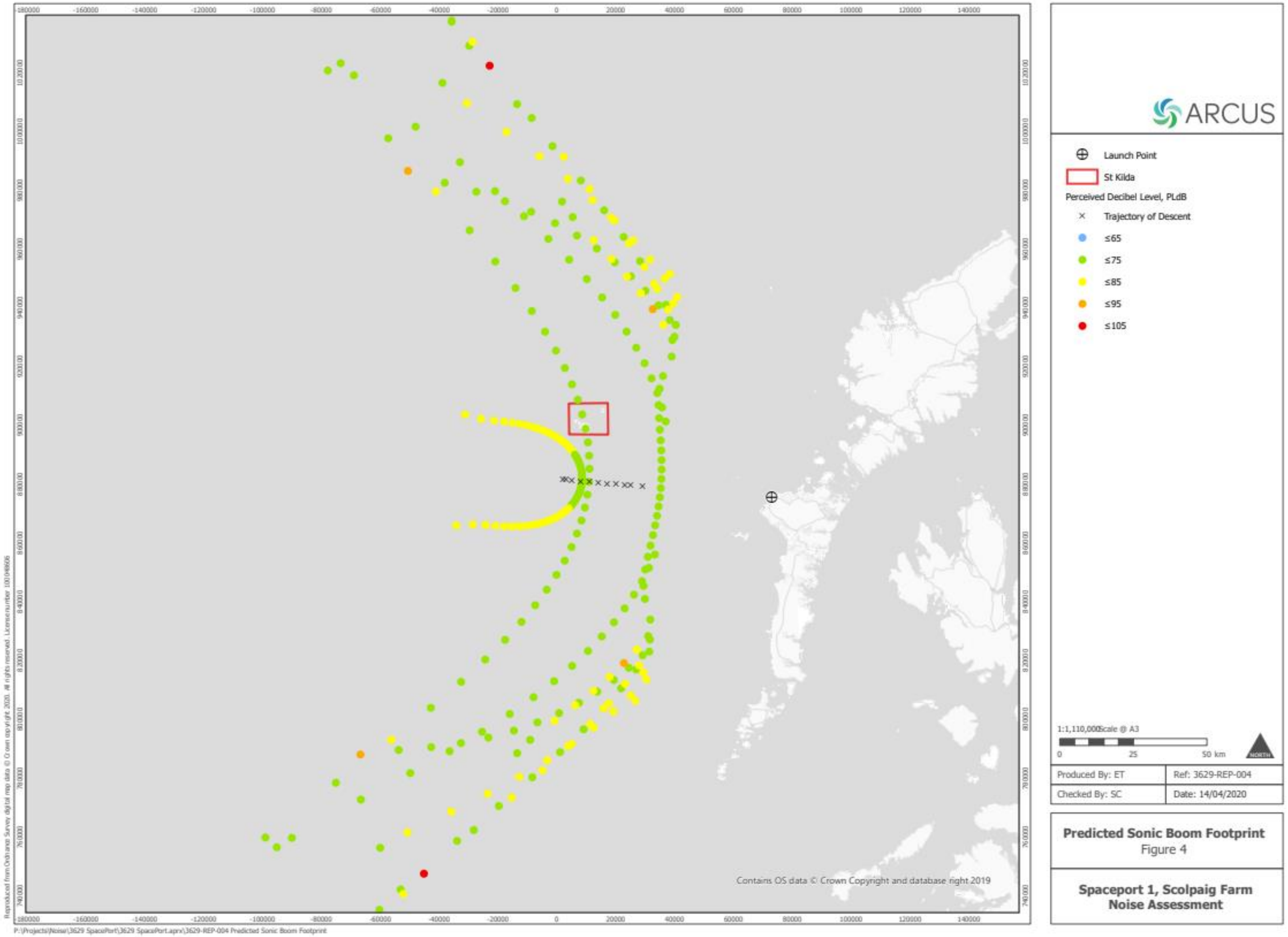
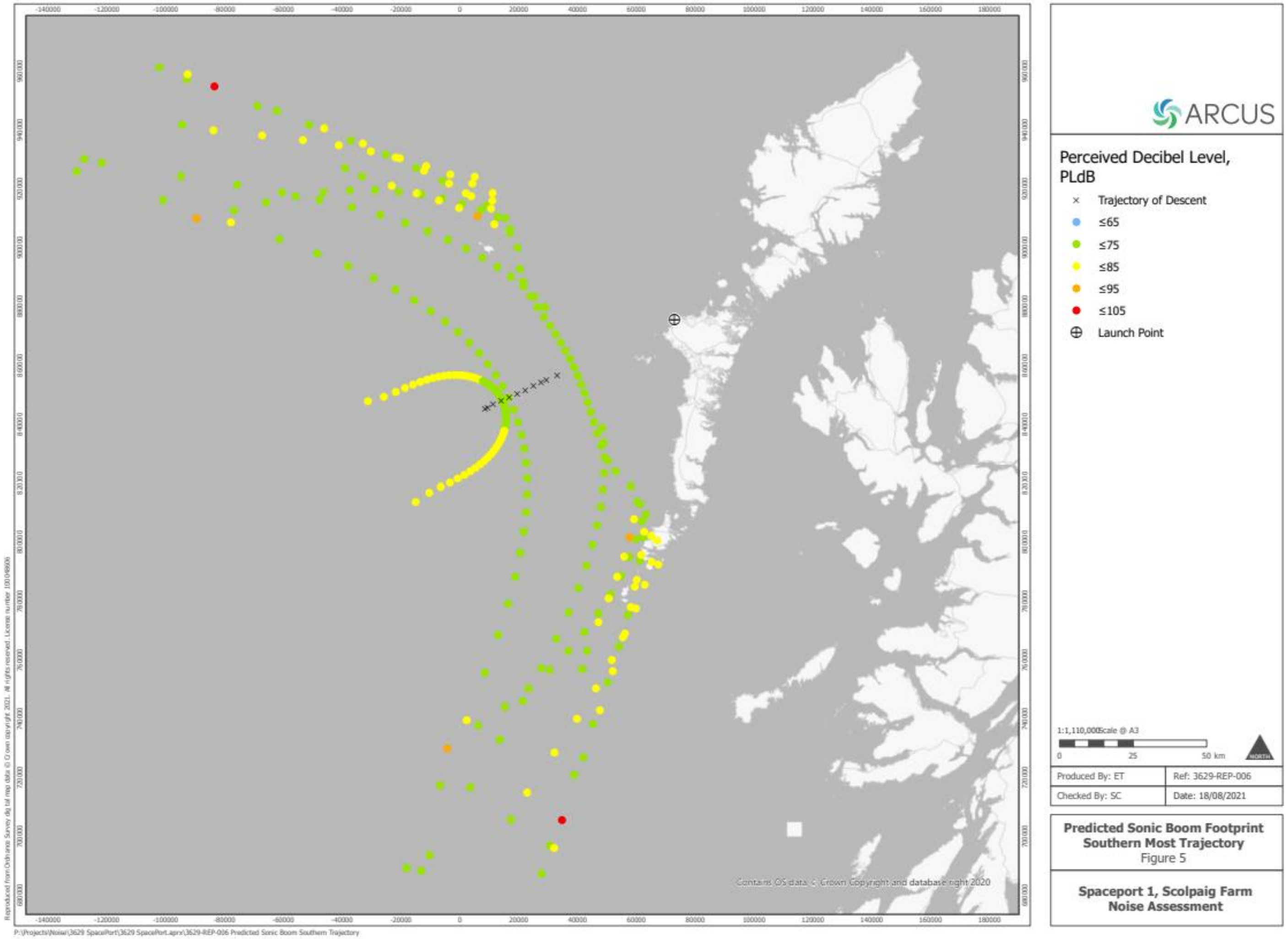
≤65
≤70
≤75
≤80
≤85
≤90
≤95
≤100
≤105
≤110
≤ 115
Scale @ A3
0
1
2 km
NORTH
Produced By: ET
Ref: 3629-REP-003
Checked By: SC
Date: 26/02/2021
Predicted Noise Contours
& Heritage Receptors
Figure 3
Spaceport1, Scolpaig Farm
Noise Assessment
Contains OS data © Crown Copyright and database right 2020, Ordnance Survey data © Crown copyright and database right 2020. OS 100030994


ARCUS
Launch Point
St Kilda
Perceived Decibel Level, PLdB
Trajectory of Descent
≤65
≤75
≤85
≤95
≤105
1:1,110,000Scale @ A3
0
25
50 km
Contains OS data © Crown Copyright and database right 2019
Produced By: ET
Ref: 3629-REP-004
Checked By: SC
Date: 14/04/2020
Predicted Sonic Boom Footprint
Figure 4
Spaceport 1, Scolpaig Farm
Noise Assessment


ARCUS
Perceived Decibel Level, PLdB
Trajectory of Descent
≤65
≤75
≤85
≤95
≤105
Launch Point
Produced By: ET
Ref: 3629-REP-006
Checked By: SC
Date: 18/08/2021
Predicted Sonic Boom Footprint
Southern Most Trajectory
Figure 5
Spaceport 1, Scolpaig Farm
Noise Assessment
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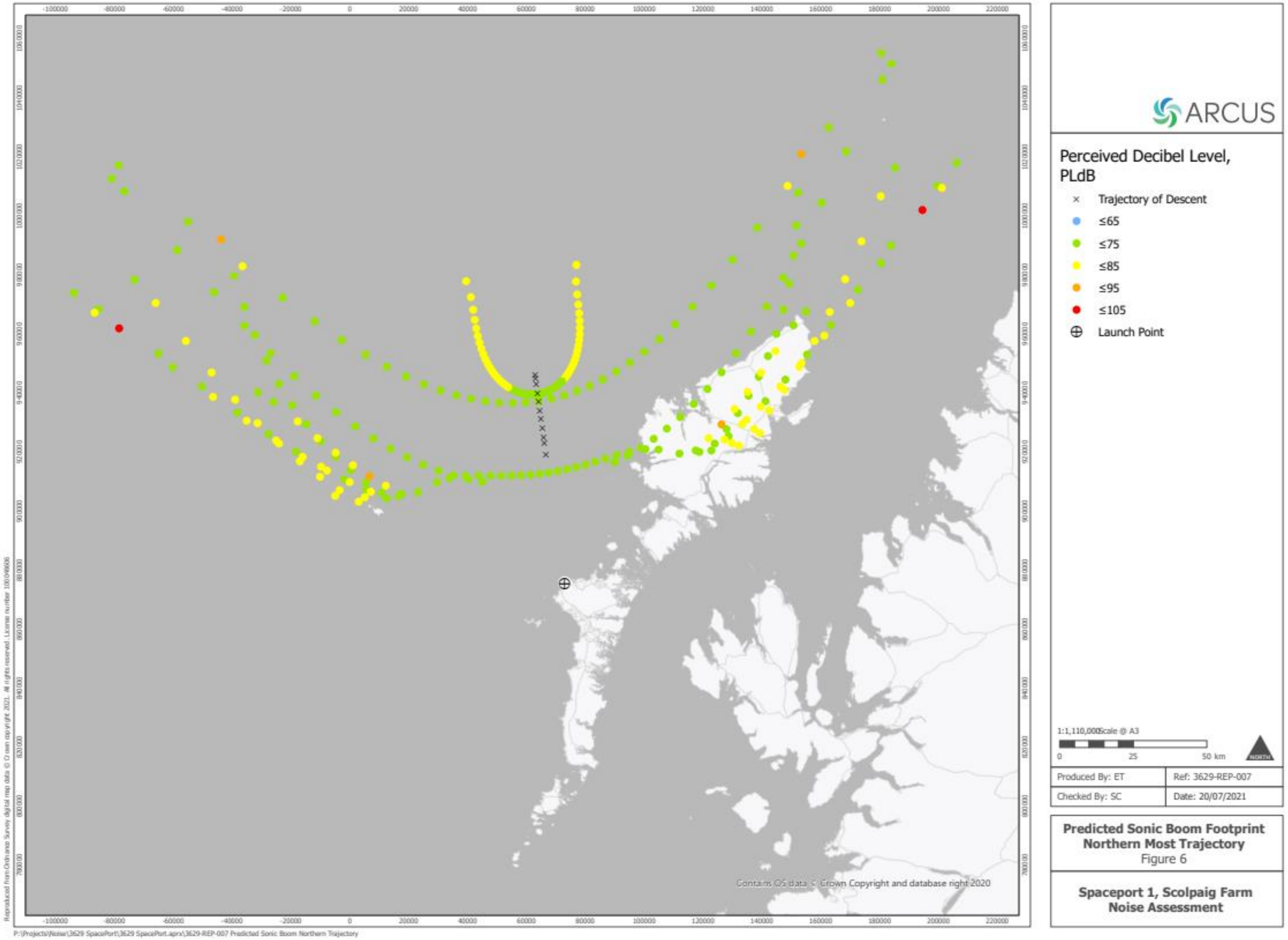
ARCUS
Perceived Decibel Level, PLdB
Trajectory of Descent
≤65
≤75
≤85
≤95
≤105
Launch Point
Contains OS data © Crown Copyright and database right 2020
1:1,110,000 Scale @ A3
0
25
50 km
Produced By: ET
Ref: 3629-REP-007
Checked By: SC
Date: 20/07/2021
Predicted Sonic Boom Footprint
Northern Most Trajectory
Figure 6
Spaceport 1, Scolpaig Farm
Noise Assessment

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