UK Civil Aviation Authority

Noise Impacts of Commercial Spaceflight

CAP 2518

Published by the Civil Aviation Authority, 2025

Civil Aviation Authority
Aviation House
Beehive Ring Road
Crawley
West Sussex
RH6 0YR

First published 2025

Enquiries regarding the content of this publication should be addressed to: noise@caa.co.uk

The latest version of this document is available in electronic format at: www.caa.co.uk/CAP2518

Contents

CHAPTER 1
Introduction

1.1 This report, produced for the Department for Transport, is intended to be a concise overview of the current knowledge on the noise impacts of commercial spaceflight operations, and the development of Spaceports. This is a new area in terms of human effects, and the document scope includes evidence presented in Environmental Impact Assessments and statements from Spaceports that are already licensed in the USA, and for Sutherland, SaxaVord and Newquay Spaceports within the UK.

1.2 The Department for Transport issued its document 'Guidance to the regulator on environmental objectives relating to the exercise of its function under the Space Industry Act 2018'[1] in 2021, which set out the government's environmental objectives relating to spaceflight and associated activities in the UK:

1.3 The environmental objectives for spaceflight are to:

- Minimise emissions contributing to climate change resulting from spaceflight activities;
- Protect human health and the environment from the impacts of emissions on local air quality arising from spaceflight activities;
- Protect people and wildlife from the impacts of noise from spaceflight activities;
- Protect the marine environment from the impact of spaceflight activities.

1.4 The effects of commercial spaceflight on local communities of people is a very new area of research, and there is a paucity of academic literature in this area. Olson et al (2024) from the University of Michigan, presented a review of community impacts due to spaceport development at the AIAA Aviation Forum and ASCEND conference in 2024.

1.5 The paper highlights the lack of research into the social impact on the communities around spaceport developments. When consideration is given to spaceport development, the environmental impacts are addressed, for example soil acidification and sonic impact, but little focus is given to communities.

1.6 The authors explain that the little amount of existing literature often focuses on examining the community impact of one specific spaceport, as will be seen in the

[1] https://assets.publishing.service.gov.uk/media/60d06eb88fa8f57ceec3ca03/guidance-to-the-regulator-on-environmental-objectives-relating-to-the-exercise-of-its-functions-under-the-space-industry-act-2018.pdf

remainder of this report, leaving a research gap in discussing commonalities in community spaceport effects. By combining existing literature, a list of these common community effects can be derived, allowing for a deeper understanding of how and why certain spaceports have excelled or failed at social integration to their host communities. As a result of this, the authors aim to achieve a set of social and technical best practices for new developments, which could serve as a centralised reference for effective and beneficial spaceport development in the future.

1.7 The authors conducted a literature search using variations on the term “spaceport community impact” across four engineering databases, yielding only one search result which focused on the economic impacts of spaceport development on a community, or analysis of the impact of rocket launches. The search was windend to two further academic databases, and google scholar, which resulted in the inclusion of nine papers, falling into one of two categories; reviews of established spaceports through anthropological, sociological or historical lenses, and governmental reports for developing and proposed spaceports.

1.8 Two studies examined the social impact of spaceports, one in French Guiana and one in Brazil. The remaining studies explored demographic and economic changes experienced during the development of Kennedy space centre in the 1960s, economic impact assessments relating to the development of spaceports, and journalistic articles on spaceport development in the US and abroad.

1.9 The authors identified four main effects within the literature:

- **Economic prioritisation** – the potential economic benefits of a spaceport to a host community. Common economic selling points include increased job opportunities due to the creation of new companies, and tourism revenue from the novelty of space launches. Location and socioeconomic factors, such as previous existence or lack of a spaceport within the nation or state, influence the particular approaches taken to sell a spaceport to the community.
- **Resource scarcity** – the lack of infrastructure and resources often experienced at new spaceports during the early stages of development. Scarcity in resources and infrastructure was noted across multiple spaceport developments, within the early stages of development. For example, in the early years of Kennedy Space Center, new residents flooded into the Brevard County area following spaceport job demand, over-taxing the existing infrastructure. This failure to keep up with population expansion created many social and health concerns.

- **Community resistance** – the level of resistance a community expressed towards a spaceport depends on whether the development compliments or disrupts with the established way of life and perceptions of the land. It is explained that within the literature, community resistance is heavily tied to how much a spaceport disrupts the existing way of life. Greater changes to natural resource access and established economic structure corresponds to increased push-back from local residents. The authors explain that this effect is perhaps most clearly seen in locations such as Alcântara Space Center in Brazil, and the proposed spaceport in Biak, Indonesia. The existing community structure of both locations is closely tied to land and natural resource access and are more greatly affected by land acquisition for spaceport development purposes.
- **Community reinvestment** – the tendency for established spaceports to work towards acquiring social license by reinvesting into a community, particularly through education and outreach programs. The authors explain that in order to minimise the disruption of community way of life, spaceport operating companies may choose to strengthen their bond with the local community through a variety of programs. Among these is investment into local education. Spaceport development is often driven by the promise of economic potential and new job opportunities for local residents. In circumstances where existing ways of life contrast heavily with the development of a spaceport, local community members may not have the prior experience necessary to secure newly created spaceport jobs.

  The authors describe this occurrence at Alcântara Launch Center, where residents expressed that they lacked the technical and scientific background to pursue the well-paying spaceport positions that had been marketed as a local community benefit. In cases such as these the spaceport operators may choose to offer education programs in the form of scholarships or involvement in university courses offered. It is also explained that the literature also highlighted the importance of environmental and social governance measures in establishing community trust and long term success of new developments.

1.10 The paper stresses the importance of thorough understanding of the local culture, history and traditions of local communities when developing spaceport locations. The ability to integrate into the local comminuty is important in limiting resistance from locals and disruption to the area. Re-investment in opportunities that complement the local skillset is also an important way to strengthen relationships with the surrounding community.

1.11 The authors conclude that the lack of academic literature on the non-economic community impacts of spaceports requires an interdisciplinary approach. Such a framework would integrate findings from social science, engineering and policy-making. Community engagement, and involvement in the decision-making

process would allow spaceport development that would provide value to the host communities, and contribute to their needs alongside the future of spaceflight.

1.12 The following chapters outline the environmental impacts that are considered within applications for spaceport licenses, within the UK and the US.

CHAPTER 2

Sutherland Spaceport

2.1 Highlands and Islands Enterprise (HIE) is the Scottish Government's economic and community development agency for the Highlands and Islands of Scotland. Since 2014, HIE has been exploring the possibility of establishing a vertical launch facility and have undertaken a number of high-level site selection exercises. The UK Space Agency call for Grants for Spaceports and Launchers brought forward 26 proposals from across the UK. Two proposals, from Lockheed Martin and Orbex, were successful and both proposed to launch from Sutherland.

2.2 HIE applied for planning permission to construct and operate a new proposed spaceport facility and would include a Launch Operations Control Centre, a Launch Site Integration Facility, the launch pad complex, access road, fencing and services.

2.3 An Environmental Impact Assessment Report (EIAR) has been prepared to support the application for planning permission. The purpose of the EIAR is to document the potential for significant environmental effects as a result of the proposed development, and to specify mitigations to avoid or reduce significant effects.

2.4 The proposed development is located at A' Mhòine, approximately 4 km southwest of the settlement of Melness in northern Scotland. The site boundary for the proposed development covers 307 hectares, although the area of the site directly affected by the proposed development is approximately 4.2 hectares.

2.5 The proposed development would be operated by a Launch Site Operator (LSO) to launch small satellites into high inclination orbits. The design of the proposed development allows for launch campaigns by multiple Launch Service Providers (LSPs) using different Launch Vehicles (LVs).

2.6 The EIAR found that there are potential sources of seascape, landscape and visual effects during the construction phase of the proposed development and the assessment of these has concluded that temporary significant impacts would be associated with disturbance, construction lighting and vehicle activity. However, it was noted that these impacts would be temporary, and short term. The assessment also concluded that significant impacts would be associated with the operational phase as a result of increased vehicle activity and noise and light disturbance impacts during a launch event. However, it was noted that these impacts would be of short duration and occur up to 12 times per year.

2.7 In terms of ecology and nature conservation, the EIAR concluded that without application of mitigation, significant effects were predicted associated with fragmentation of otter and water vole habitats during construction, and disturbance of water voles through piling as part of construction and during launch activities. Following the application of mitigation, which includes implementation of a Habitat Management Plan (HMP), no residual effects were predicted on designated sites, protected species and non-invasive species.

2.8 The impacts on birds were examined as part of the assessment. There are five sites with a statutory designation for ornithology, and with potential connectivity to the proposed development, within 10km of the proposed spaceport. Ornithological field surveys were carried out between 2017 and 2019 to collect information on bird activity in key locations where flight activity was predicted to coincide with the proposed development.

2.9 Bird species present in the study area include golden eagle, white-tailed eagle, merlin, greenshank, red-throated diver, golden plover, greylag goose, peregrine, pink-footed goose, hen harrier, barnacle goose, short-eared owl and dunlin.

2.10 The assessment concluded that without application of mitigation, significant effects on ornithological interests are predicted, associated with disturbance and displacement, and damage or destruction of nests during the construction stage, and disturbance and displacement during the operation phase of the proposed development. Following the application of mitigation, which includes implementation of Species Protection Plans, no residual effects are predicted on designated sites, and bird populations.

2.11 The noise and vibration assessment concluded that there is potential for noise and vibration effects from construction activities, construction traffic, operational traffic, noise associated with the launch including sonic boom and fixed plant installation.

2.12 However, the assessment concluded that only the noise associated with the launch is considered to have significant effect at the human receptor level. It is also important to consider the nature of this noise source, which is predicted to occur for approximately the first 67 seconds of a launch event, with launches happening up to 12 times per year. The report concluded that due to the large distances between sites and the receptors, no cumulative noise and vibration effects are considered likely.

2.13 The Noise and Vibration chapter of the EIAR outlines:

- Noise and vibration associated with the construction phase, including construction traffic noise.
- Fixed mechanical services plant noise emissions from the facility.

- Changes in traffic noise associated with the proposed development; and
- Noise associated with launch activity based on the defined representative launch, including assessment of potential for effects from sonic boom phenomena.

2.14 The categories of sensitivity to noise and a description of the type of places that fall into each category high, medium and low receptor sensitivity are described. For high sensitivity of receptors places such as residential properties, educational buildings, medical facilities and care homes are included. Medium level receptors include places of worship and offices, and low sensitivity receptor examples were commercial or retail premises. All receptors in this assessment were considered to be of high sensitivity as they are residential receptors. The report contains proposed values of noise and vibration for the construction phase of the spaceport, and for the operational state. Operational traffic 'magnitude of impact' is quantified by the long-term change in traffic noise level based on the guidance in the 'Design Manual for Roads and Bridges (DMRB). It is generally accepted that changes in noise levels of 1 dBA $LA_{10,18h}$ or less are imperceptible, and changes of 1 to 3 dBA are not widely perceptible. 3-4.9 dBA are classed as minor magnitude of impact, 5-5.99 dBA are classed as moderate, and changes over 10 dBA $LA_{10,18h}$ were classed as having a major magnitude of impact.

2.15 The external noise levels and the associated adverse effect levels and effect magnitudes used in this assessment are classified as:

- ≤50 dB $L_{Aeq,T}$ - negligible magnitude of impact
- 51-55 dB $L_{Aeq,T}$ – minor magnitude of impact
- 56-60 dB $L_{Aeq,T}$ – moderate magnitude of impact
- >60 dB $L_{Aeq,T}$ – major magnitude of impact

2.16 The internal levels cannot be calculated as the construction / building fabric of the receptors is unknown.

2.17 Operational plant noise emissions are assessed against BS4142:2014 'Methods for rating and assessing industrial and commercial sound' at the nearest noise sensitive receivers. The target rating noise levels are to be no greater than 5 dB above the existing background noise level. Therefore, where the target levels are met the magnitude is considered to be low. If they are between 5-10 dB above background level the impact is considered moderate, and above 10 dB the impact is classed as high.

2.18 The document details how residual effects are determined by comparison of the sensitivity of receptor with the magnitude of predicted impact based on

Scotland's Technical Advice Note for Noise. These are grouped as follows, with the largest effects seen when sensitivity of the receptor is high and the magnitude of impact is major or moderate.

- Very large: These effects represent key factors in the decision-making process. They are generally, but not exclusively, associated with impacts where mitigation is not practical or would be ineffective.
- Large: These effects are likely to be important considerations but where mitigation may be effectively employed such that resultant adverse effects are likely to have a Moderate or Slight significance.
- Moderate: These effects, if adverse, while important, are not likely to be key decision- making issues.
- Slight: These effects may be raised but are unlikely to be of importance in the decision- making process; and
- Neutral: No effect, not significant, noise need not be considered as a determining factor in the decision- making process.

2.19 On the basis of the above, very large and large adverse effects are considered significant in EIA terms.

2.20 The predicted noise levels from operational traffic indicate that there is not predicted to be any change at the receptors as a result of the operational traffic to/from the development. This is due to the location of the human receptors being at least 2 km from the A838. Thus, there is a neutral effect, which is not considered significant.

2.21 In terms of noise from lift off and flight, noise levels have been modelled at four representative altitudes (0 m, 390 m, 5,202 m and 10,600 m) for a radius of 5km. The predicted noise levels indicated that the levels will be in excess of the background noise climate until the LV is at least at 10.6km altitude. This will take approximately 70 seconds. Although this could be considered a significant impact (major impact on high sensitivity receptors), it should be noted that the events are of short duration (approximately 1 minute) with a frequency of up to 12 launches per year, i.e. infrequent.

2.22 The launch vehicle will create a sonic boom as it travels past the speed of sound, created by a series of shock waves that overlap as the vehicle continues to move. When the shock waves begin is not crucial, rather the line at which the shock waves meet and more particularly the point at which this shock wave hits the ground. This is referred to as the ground impact point and is where the sonic boom occurs.

Using the specific trajectory information provided (altitude, speed and angles) the ground impact point (in this case the sea) can be calculated. Taking a series of

altitudes points, beginning when the LV exceeds the speed of sound, a range of ground impact points were calculated.

2.23 The altitudes are reference altitudes only (i.e. inputs for the method for which other flight metrics are known) and not the location of the LV when the sonic boom is heard at ground level. The LV will have continued along its trajectory and beyond the ground impact point at which the sonic boom is heard.

2.24 The ground impact point is where the peak pressure occurs (known as shock overpressure) and is heard as noise. At these ground impact point locations, the sound pressure level ranges from 144 dB (at the lowest altitude) to 127 dB (at the highest altitude calculated above). However, the locations of the ground impact points are far offshore of the north coast of Scotland and the noise level on the mainland is considered to be 'just audible', with audibility mainly occurring as a result of the nature of the sound (different to other existing noise sources in the area).

2.25 In all cases, the duration of the sonic boom is calculated to be 0.2 seconds. This is brief as it is dependent on the size of the LV, which in this case is relatively short at 19 m long.

2.26 In terms of mitigation, there are various recommendations set out for each phase of the development. For mitigation during construction, the following recommendations are given:

- Plan working hours to take account of the effects of noise and vibration upon persons in areas surrounding site operations and upon persons working on-site.
- Where reasonably practicable, adopt quiet working methods, using plant with lower noise emissions.
- Where reasonably practicable, adopt working methods that minimise vibration generation.
- Locate plant away from noise and vibration sensitive receptors, where feasible.
- Use silenced and well-maintained plant conforming with the relevant EU directives relating to noise and vibration.
- Avoid unnecessary revving of engines and switch off equipment when not required.
- Keep internal haul routes well maintained.
- Use rubber linings for chutes and dumpers to reduce impact noise.
- Minimise drop height of materials.

- Start-up plant and vehicles sequentially rather than all together.
- Carry out regular inspections of noise mitigation measures to ensure integrity is maintained at all times; and
- Provide briefings for all site-based personnel to ensure noise and vibration issues are understood, and mitigation measures are adhered to.

2.27 No specific mitigation can be applied to reduce the noise levels during take-off and initial flight of the LVs. During the decommissioning phase, no specific mitigation is required, but best practice measures are expected to be applied.

2.28 Following the planning permission for the spaceport being granted in 2020, in November 2022 it was announced that Orbex would build and operate the spaceport facility. In December 2024 Orbex announced that it would be pausing the development of its own spaceport in Sutherland in order to focus on launching medium-sized rockets from Saxavord in Shetland. Their aim is to achieve a sustainable series of satellite launches into low orbit. Orbex will retain its lease to build and operate its own spaceport at Sutherland in order to give it flexibility to increase launch capacity in the future. It is explained on their website that this will be kept under continuous review.

CHAPTER 3

SaxaVord Spaceport

3.1 SaxaVord spaceport is situated on the Lambda Ness peninsula on Unst, which is the most northerly of the Shetland islands. The Civil Aviation Authority announced in December 2023 that SaxaVord had been granted a spaceport licence to host up to 30 launches a year, making it the first fully licenced vertical spaceport in Western Europe. In April 2024, the spaceport was granted a range licence by the Civil Aviation Authority, allowing them to control the sea and airspace to the north of the site around orbital launch trajectories.

3.2 In January 2023, German company Rocket Factory Augsburg (RFA) signed a multi-year launch agreement which would give exclusive access to the northernmost launch pad of the spaceport, Launch Pad Fredo. In January 2025, the CAA granted a launch licence for the RFA One rocket to reach orbit, the first of its kind in the UK and Europe. This licence is limited to 10 launches per year as well as no more than two in any given month, and must give 60 days notice for range safety purposes.

3.3 As part of the application for this license, an Assessment of Environmental Effects (AEE) report was produced in 2023, and outlined the potential effects on the following environmental aspects.

Population and human health

3.4 The AEE stated that “all launches will take place in a northerly direction over the sea. For safety reasons, launch vehicles will not fly over inhabited areas such as the Faroe Islands and Iceland to the north-west and Norway,to the north-east. Jan Mayen, located north north-west of Shetland and which is temporarily inhabited during the summer months, will also be a flight exclusion zone.”

3.5 This section highlighted the economic development opportunities a spaceport development would offer, through employment opportunities, the use of local facilities by workers on the site, and the increase in tourism to the area.

Biodiversity (ecology and ornithology)

3.6 To understand potential impacts of loud, short duration noise events, a background literature review of noise impacts on relevant bird species to the area was undertaken. This literature review looked at how impulsive noise (from various sources including aircraft, fireworks, military ranges and rocket launches) impacted on birds in order to help assess the potential noise impacts of the launches.

3.7 The AEE states that “the magnitude of predicted operational effects is either ‘no effect’ or ‘negligible’ for all bird species except one, a confidential Schedule 1 species. For this species, minor magnitude operational effects were considered likely to be significant in the absence of mitigation; however, after mitigation, all residual effects are predicted likely to be not significant.”

Air quality

3.8 It was proposed that emissions from launch events, project-related traffic and generator emissions were considered to have a negligible effect on air quality, therefore resulting in no likely significant effect.

Noise and vibration

3.9 Assessment of road traffic noise related to the site was deemed to be non-significant. Noise during engine tests and launches were assessed to be audible at noise sensitive receptors at levels exceeding the criterion for community annoyance associated with aircraft noise.

3.10 It was concluded that the short duration of audible noise ‘events’ associated with engine tests and launches, and their infrequent occurrence, would result in a reduction of the associated levels of annoyance to below that which may be associated with aircraft noise from conventional airports. Accordingly, adverse health effects were not anticipated.

Water

3.11 Likely operational effects included sedimentation or pollution of the water environment from surface run-off and fuel/chemical leaks and spills, and effects on the local groundwater quality and flow regime. Mitigation measures include no bulk storage of fuels at the Proposed Project and appropriate spill control procedures alongside a suitable Drainage Strategy to control and treat surface and drainage.

Marine environment

3.12 The potential impacts on water quality, biodiversity, and human activities in the study areas were assessed. It was concluded that all pathways would have a negligible or minor risk of a likely significant effect on the receptors. No likely significant effects were predicted.

Climate

3.13 An assessment of the potential effects of greenhouse gas (GHG) emissions associated with the Proposed Project on climate change was undertaken as part of the AEE. This considered emissions arising from the operation of the Proposed Project including transportation and electricity and fuel consumption. A

climate resilience assessment was also conducted to assess the vulnerability of the Proposed Project to climate change.

3.14 The assessment evaluated the impact of climatic variables such as wind speed, precipitation and temperature on sensitive receptors associated with the Proposed Project.

3.15 Standard mitigation was considered in the inference of effect significance. Mitigation measures include installing deluge pumps to protect against fire, undertaking a dust impact assessment and implementing a dust management plan, establishing a drainage system to minimise flood risk, and suspending activities during extreme weather events.

Landscape, Seascape and Visual Impact

3.16 The proposed launch pads would need to be lit at night for a short term during individual launch cycles for reasons of safety. The lighting will extend visual effects into hours of darkness for local visual receptors.

3.17 A number of significant effects were predicted including significant landscape effects on the landscape character of the site and its surroundings, visual effects on residents at settlements and tourists including recreational walkers. The physical changes to the landscape, such as the construction of access tracks, launch pads, and buildings would occupy only a small portion of the overall site area and the existing use of the land for grazing will persist.

Spaceport Cornwall

3.18 The Assessment of Environmental Effects (AEE) report for Virgin Orbit, LLCLauncherOne Operations from Spaceport Cornwall, at Newquay airport was published in July 2022. The report addresses the potential environmental impacts of a spaceport operator licence being granted to Cornwall Airport Newquay (CAN) by the UK CAA.

3.19 The proposed movements features a horizontal take-off, rather than a vertical rocket launch, and uses a Boeing 747 to carry the rocket under its wing to 10,000-12,000 metres above sea level, whereupon the rocket is then released. In terms of frequency of movements, one launch in 2022 was proposed, and two per year over the eight year period from 2023 – 2030.

3.20 Given the nature of the action, being a horizontal launch operation utilising a relatively standard Boeing 747 as a carrier aircraft at a licensed aerodrome (i.e., CAN), a number of the pre- to post-launch ground operations fall under existing licensed activities. Those activities that can already be undertaken at CAN or in the appropriate airspace under existing licences were scoped out of the AEE, including the take-off and landing and the carrier aircraft's transit to the rocket drop point, due to this being classed as existing activity. It was not assessed to be different to any other aircraft in transit, and did not pose any additional risks.

3.21 The release of LauncherOne, and resulting sonic boom over the Atlantic Ocean were considered to be new activity within the airspace and were scoped into the AEE, along with the re-entry and deposition of rocket debris into the ocean.

3.22 The main potential effects of spaceport activities were identified in the Environmental Impact Assessment (EIA) GAP Analysis and are listed below:

- effects of emissions on climate change,
- effects on local air quality,
- effect of spaceport noise on local receptors,
- effects on the marine environment from jettisoned objects, and
- socio-economic impacts

3.23 The report explains that the latter four could potentially cause direct impacts on human health. These impacts are considered as increased exposure to air pollution and noise, as well as safety limitations for offshore activities and seafarers due to jettisoned objects. The authors expaling that of these four impacts, potential impacts to human health via noise or air quality are unlikely to

be significant within the vicinity of CAN as noise levels will not exceed current levels, nor will numbers of vehicles or hours of operation of the airport increase.

3.24 Air quality and the potential impacts on Biodiversity were included in the EAA, and largely scoped out due to minimal effects in addition to normal operations at CAN. The following environmental topics were not evaluated further because the proposed Virgin Orbit activities at Cornwall Airport Newquay and over the Atlantic Ocean would not affect these environmental resources: population and human health; water resources; land, soils and peat; biodiversity (terrestrial ecology, flora, and fauna); noise and vibration; landscape and visual impact; material assets and cultural heritage; and air quality.

3.25 Further impacts are examined in detail, such as impacts on marine life, climate change, cumulative effects, socio-economic impacts and accidents and disaster consequences. The report concludes that all effects are considered short-term with exception of climate change (long term), rocket debris in the marine environment (long term), and socio-economics (long term). The impact on socio-ecomonics were considered to be moderately beneficial, with raising aspirations and inspiring young people cited, along with workforce and skills development and enhancing local academic research. Climate impacts were deemed to be moderately beneficial, with sustainable spaceport and airport operations, and the monitoring of climate change given as reasons for this.

3.26 The report concluded that there were no environmental reasons why a spaceport licence or launch operator licence could not be granted. The CAA issued this licence in November 2022.

3.27 Virgin Orbit’s Cosmic Girl, a modified jet took off from Spaceport Cornwall in January 2023. The aircraft reached space, but failed to deploy its nine satellites as planned due to a fault with the fuel filter. The aircraft safely landed back at the spaceport, but Virgin Orbit stopped operating in May 2023 and sold off their assets.

3.28 The spaceport now houses several businesses within the space and aerospace industry, and expects to host more launches in the coming years.

CHAPTER 4

Spaceports in the United States

4.1 There are currently fourteen licensed spaceports in the US. Figure 1 below is taken from the FAA website (last updated September 2022) and shows the locations of the licensed spaceports in blue. The other colours highlight federal sites (orange), FAA licensed re-entry sites (red) and non-FAA licensed sites (lilac).

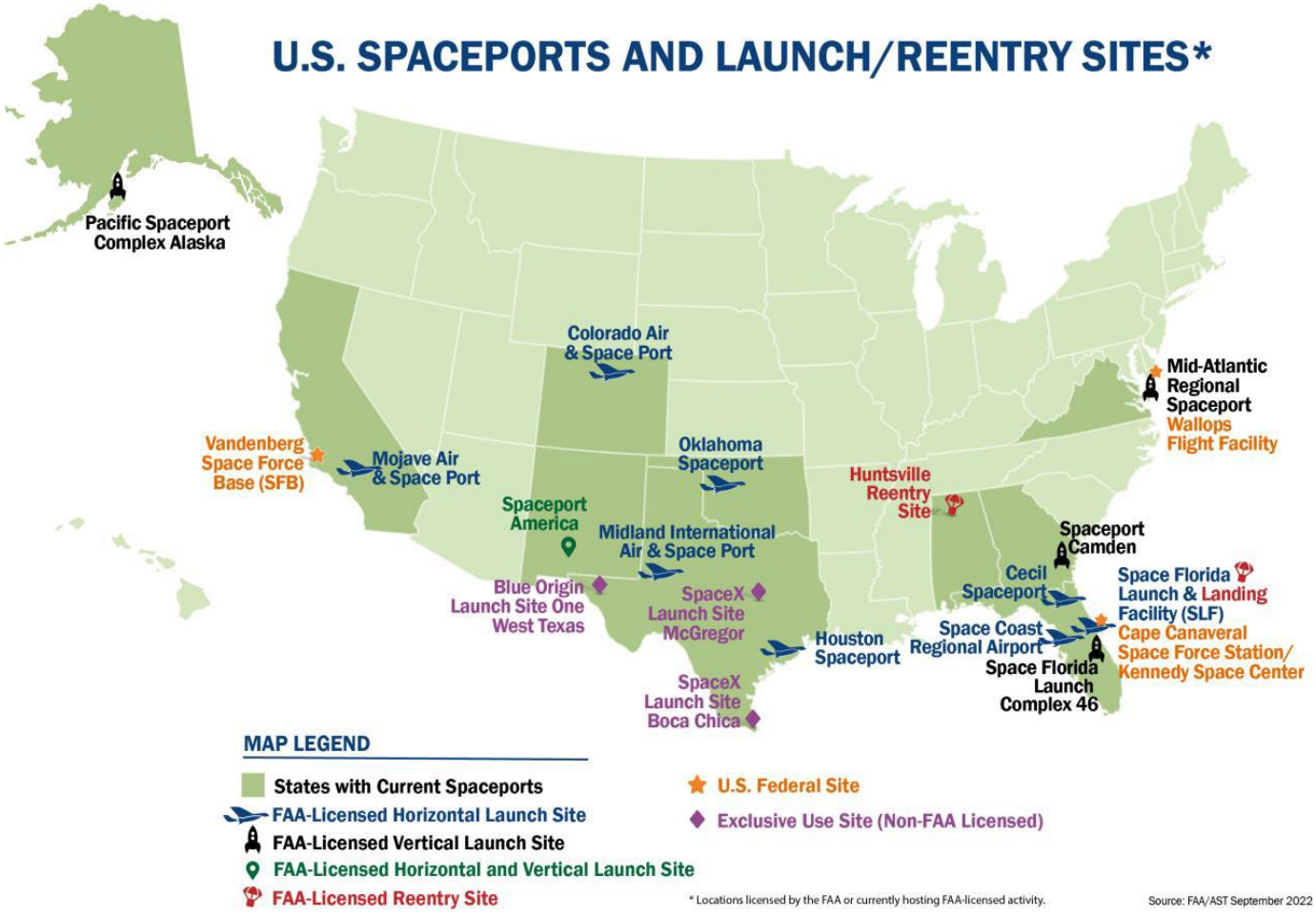

Figure 1: US Spaceports (taken from the FAA website).

4.2 The following paragraphs will summarise findings regarding noise impacts from the Environmental Impact Statements for each of the FAA licensed sites.

4.3 The first is the Mid-Atlantic Wallops Flight Facility (WFF) Spaceport, whose Programmatic Environmental Impact Statement (PEIS) was published in 2018. The Proposed Action considers a number of institutional support projects ranging from new construction, demolition, and renovation throughout the installation of

the Spaceport. In addition to continuing the existing operational missions, the Proposed Action also considers several new operational and mission activities including expansion of Department of Defence (DoD) programs such as the Navy's standard missile rocket (SM-3), introduction of a new weapons system currently under development comprising of a high energy laser and high-power microwave (Directed Energy). The future opportunities within the Expanded Space Program involve the potential for Liquid Fuelled Intermediate Class (LFIC) launch vehicles (LVs) and Solid Fuelled Heavy Class (SFHC) LVs; and consideration of commercial human spaceflight missions from WFF.

4.4 The Operational Missions and Activities noise impacts are summarised below:

- No significant impact anticipated from DoD SM-3.
- An increase in noise associated with Expanded Space Program, including LFIC LVs and SFHC LVs is anticipated.
- Potential for sonic boom during LV horizontal landing.
- During launch of LFIC LVs and SFHC LVs, no residences would be exposed to 115 dBA or greater noise levels (the Occupational Safety and Health Administration (OSHA) threshold for 15-minute exposure).

4.5 The PEIS states that some of the activities included as part of the Proposed Action would require the FAA to issue an experimental permit and/or launch license. These FAA actions are subject to FAA Order 1050.1F, Environmental Impacts: Policies and Procedures which states that special consideration needs to be given to the evaluation of the significance of noise impacts on noise sensitive areas, including wildlife refuges. A noise sensitive area is defined by the FAA as an area where noise interferes with normal activities associated with its use. Normally, noise sensitive areas include residential, educational, health, and religious structures and sites, parks, recreational areas (including areas with wilderness characteristics), wildlife refuges, and cultural and historical sites. FAA Order 1050.1F adds guidance that gives special consideration to the evaluation of the significance of noise impacts on noise sensitive areas within national parks, national wildlife refuges, and historic sites including traditional cultural properties.

4.6 Rocket activities generate the greatest noise levels on Wallops Island. Large rockets have the potential to produce sonic booms. Trajectories for rockets launched from WFF follow a predominantly south-eastern course over the Atlantic Ocean. The boom footprint or "carpet", if generated, would occur over the open ocean. Generally, the noise environments at the Mainland and Wallops Island are relatively quiet with the dominant noise sources being naturally occurring wind and wave action, due to their coastal location. Ambient noise is below 52 dB DNL.

4.7 A significant noise impact would occur if analysis shows that the Proposed Action would cause noise sensitive areas to experience an increase in noise of 1.5 dB DNL or more at or above 65 dB DNL noise exposure when compared to the No Action Alternative for the same timeframe.

4.8 The total land area, occupied structures, and estimated population under the LFIC LV and SFHC LV noise contours ranging from 115 dBA (the OSHA threshold for 15-minute exposure) to 130 dBA were calculated for Accomack County. Like the baseline conditions, there are no occupied structures or people located within the 115 dBA and greater noise contours.

4.9 The PEIS concludes that NASA is considering the use of commercial human spaceflight missions that could consist of commercial space tourism and commercial crew transport to the International Space Station and Low Earth Orbit. A number of launch vehicles have the potential to utilise WFF both for vertical launch and landings (Wallops Island) and horizontal launch and landings (Main Base) for commercial human spaceflight. All these platforms would be launched with technologies within the established noise envelope or within the new envelope for the above noted LFIC LV and SFHC LV.

4.10 Spaceport Camden EIS was published in June 2021 and evaluates the potential environmental impacts that may result from the FAA's Proposed Action of issuing a Launch Site Operator License to the County, which would allow the County to offer Spaceport Camden to commercial launch operators to conduct launches of liquid-fuelled, small, orbital, vertical-launch vehicles on a site that the County would purchase for the Spaceport. Development of the launch site includes construction of supporting buildings and infrastructure. Operations would include up to 12 vertical launches, up to 12 wet dress rehearsals and up to 12 static fire tests per year.

4.11 The report discusses the construction phase of the proposal, and states that during a typical working day, construction noise levels experienced at a distance of 2.5 miles would be approximately 45 dB DNL, with levels at 3.5 miles being around 43 dB DNL, which is well below established land use compatibility thresholds. There was not expected to be any significant community noise impacts from construction noise during the project.

4.12 The cumulative total noise energy generated during launch and static fire events would result in noise levels greater than 65 dBA DNL within 0.25 mile of the launchpad. These areas include 11 acres of waterways but do not affect areas outside of Spaceport Camden. Those areas within the Spaceport that would be affected by launch noise would be closed to personnel during launches. Sonic booms would occur over open water approximately 55 miles from shore in the Atlantic Ocean and would not pose a risk to structural damage e.g. broken windows on boats.

4.13 At the closest residence and the Settlement on Cumberland Island, noise would be expected to interrupt normal speech (i.e. 66 dBA) for less than 36 seconds during each noise event. Over a year, these two locations would be exposed to noise levels exceeding 66 dBA for up to nine minutes.

4.14 The Environmental Assessment for the Space Coast Air and Spaceport was published in 2020. After reviewing and analysing available data and information on existing conditions and potential impacts, the FAA determined that the Proposed Action would not significantly affect the quality of the human environment. Therefore, an Environmental Impact Statement was not required, and the FAA issued a Finding of No Significant Impact (FONSI).

4.15 Three vehicles were analysed in the report:

- Concept X Reusable Launch Vehicles (RLVs), which take off and land on a runway using jet engines like an aeroplane but, after reaching suitable airspace, transition to rocket engine power to achieve suborbital flight altitudes.
- Concept Y RLVs, which take off under rocket engine power and then make an unpowered, gliding landing on a runway.
- Concept Z Launch System, which is a two-part launch system that uses a separate carrier aircraft during take-off. Once the carrier aircraft reaches suitable airspace, the rocket detaches from the carrier aircraft and rocket engines are ignited. The carrier aircraft would return to the launch site and land under jet engine power. After completion of the rocket-powered phase of flight, the rocket would make an unpowered, gliding landing on a runway.

4.16 The report concluded that it was not anticipated that construction would occur close enough to residential areas or sensitive receptors to cause disturbances. However, specific measures could be considered during construction to further reduce noise, including limiting the time of day heavy equipment can be operated, or ensuring that equipment is shut off when not in use.

4.17 The noise impacts from potential sonic booms modelled DNL levels are much less than the DNL 65 dBA noise exposure criteria. The report states that the Proposed Action would not result in significant noise impacts.

4.18 An Environmental Assessment and FONSI regarding issuing licenses to SpaceX for Falcon Launches at Kennedy Space Centre (KSC) and Cape Canaveral Air Force Station (CCAFS) was published in July 2020. The EA also analysed the potential environmental impacts of issuing re-entry licenses to SpaceX for Dragon re-entry operations.

4.19 For noise and noise-compatible land-use considerations within the report, the following conclusions were drawn. Noise levels during launch operations,

including landings, would be of short duration and diminish quickly as the vehicle rises or lands. Previous Falcon launches at KSC and CCAFS have not resulted in significant noise impacts. Sonic booms would occur infrequently and would be similar to or less than the noise experienced during a clap of thunder in the majority of the sonic boom footprints. Noise modelling for the Proposed Action shows that the 65 DNL contour for all rocket operations in 2025 (the year with the maximum number of launch operations) is located within the CCAFS and KSC properties. These areas are not considered noise-sensitive for purposes of assessing significance of noise impacts. Therefore the Proposed Action would not result in an increase in noise by 1.5 dB DNL or more for a noise sensitive area that is exposed to noise at or above the 65 dB DNL noise exposure level, or that will be exposed at or above the 65 dB DNL level due to a 1.5 dB DNL or greater increase.

4.20 The EI explains the three types of noise occur during a standard vehicle launch or landing:

1. combustion noise from the launch vehicle chambers.
2. jet noise generated by the interaction of the exhaust jet and the atmosphere; and
3. combustion noise from post-burning of combustion products.

4.21 The initial loud, low frequency noise heard in the immediate vicinity of the launch pad is a result of the three types of noise combined. SpaceX measured noise levels for its May 22, 2012, Falcon 9 launch. The launch time was 3:44 p.m. with all nine Merlin engines firing. For the six locations measured between 800 and 2,500 feet from the vehicle, the noise levels were between 126 and 145 dB OASPL. SpaceX also measured near-field noise levels during the Falcon Heavy launches between 400 and 1,300 feet, with noise levels of 151 and 152 dB OASPL.

4.22 Another characteristic of typical launch or landing vehicles is that they reach supersonic speeds and generate sonic booms. Sonic booms are measured in pounds per square foot (psf) of overpressure. This is the amount of the increase over the normal surrounding atmospheric pressure (2,116 psf/14.7 psi). At one-pound overpressure, no damage to structures would be expected.

4.23 Overpressures of 1 to 2 psf are produced by supersonic aircraft flying at normal operating altitudes. The report states that some public reaction could be expected between 1.5 and 2 psf. Rare, minor damage may occur with 2 to 5 psf of overpressure. During the shuttle landing events, a double sonic boom was heard at times across central Florida and the east coast, depending upon the specific flight trajectory.

4.24 SpaceX performed a sonic boom study in 2014 to support its first landing operation; however, since that time, several other studies, including one by the USAF have been conducted.

4.25 To determine DNL for 2017, background noise levels were estimated, as was the DNL from all 2017 launch operations at CCAFS and KSC. Background DNL was rated using a method which provides estimated background noise levels for different land use categories and population density. The DNL estimated levels for rural or remote areas and several different categories of suburban and urban residential land use were used to represent DNL for the various land uses within the Space Centres, and surrounding areas. The daytime estimated background noise levels ranged from <48 dBA L_{eq} in rural or remote areas, to 60 dBA L_{eq} in quiet commercial, industrial and urban residential areas. For nighttime, this range was <42 to 54 dB L_{eq} respectively.

4.26 With regard to sonic booms generated during landing (descent), several studies have been conducted along with actual sonic boom overpressure measurements. PCBOOM, as well as NASA's 1122 sonic boom prediction method, was used and compared with actual overpressure measurements.

4.27 Sonic booms generated by most launch events would impact the ocean surface beyond 30 miles off the coast and would not be audible on land; therefore, these sonic booms would not produce any significant impacts in the surrounding areas. A sonic boom would impact parts of Florida during a polar mission. The majority of the areas impacted would experience an overpressure of around 0.25 psf, which is similar to distant thunder.

4.28 The Environmental Assessment and FONSI for Jacksonville Aviation Authority Launch Site Operator License at Cecil Field, Florida, was published in 2009. In the Proposed Action, Jacksonville Aviation Authority (JAA) would offer the launch site to launch operators for two types of horizontal, piloted RLVs, referred to as Concept X and Concept Z launch vehicles. The Concept X vehicle contains two turbojet engines and two rocket engines powered by Jet-A fuel and liquid oxygen. The Concept Z vehicle consists of two components - a carrier aircraft mated with a suborbital launch vehicle. The carrier vehicle would have turbo jet engines while the launch vehicle would use a hybrid rocket engine. There was a proposed maximum of 48 annual launches of the Concept X vehicle and 4 annual launches of the Concept Z vehicle.

4.29 The noise considerations within the report conclude that the jet engine noise created by pre-take-off activities, take-off, and landing of the Concept X and Concept Z vehicles would be similar to noise levels resulting from current aviation activities at Cecil Field. Noise from the Concept Z vehicle, which would produce the highest noise level of the proposed vehicles, would be similar to noise created from an F-18 aircraft, which operates at Cecil Field. Additionally,

the launch of the RLVs would occur in the offshore Warning Area, located 60 miles off the coast of Florida.

4.30 Rocket engine noise created during launches would have a minimal impact due to the remote launch location. Sonic booms may occur during ascent and descent as vehicles reach Mach 1. Both RLVs have the potential to create sonic booms. The magnitude of sonic booms associated with the Proposed Action would be 1.1 to 1.9 pounds per square foot (psf) for the Concept X vehicle and 0.5 to 0.7 psf for the Concept Z vehicle. In addition, the sonic booms would occur over the open ocean resulting in minimal impacts to human health, physical structures, and the environment. Sonic booms associated with the Proposed Action would not be expected to have a significant impact on the surrounding areas. Additionally, sonic booms would not have a significant impact on marine animals.

4.31 The Final Environmental Assessment and FONSI for Issuing a License to Virgin Orbit Launches at the Mojave Air and Space Port, Kern County, California was published in 2017. The report examines the potential environmental impacts of Virgin Orbit (LauncherOne), LLC's (L1's) proposal to launch the LauncherOne at the Mojave Air and Space Port, for purposes of transporting small satellites into a variety of Low Earth Orbits. The launch system consists of the rocket (LauncherOne) and a carrier aircraft (Boeing 747).

4.32 The conclusions from the report stated that noise from LauncherOne operations would not differ substantially from other aircraft currently operating at the Mojave Air and Space Port. Carrier vehicle take-offs and landings were not expected to change the average day-night sound level (DNL) contours or elevate the DNL more than 1.5 dB. Based on noise modelling results, no sonic boom would intersect land or human-sensitive receptors. Therefore, the FAA determined there would be no significant noise impacts.

4.33 The EIS for Spaceport America Commercial Launch Site, New Mexico was published in 2008 and considered the impacts of accommodating horizontal and vertical launch sites. The proposed site was in Sierra County near Upham, New Mexico (NM) at a location approximately 45 miles north of Las Cruces, New Mexico (NM) and 30 miles southeast of Truth or Consequences, NM. The vehicles proposed may carry space flight participants, scientific experiments, or other payloads. Horizontal LVs would launch and land at the proposed Spaceport America airfield. Vertical LVs would launch from the proposed Spaceport America and would either land at Spaceport America or in the U.S. Army's White Sands Missile Range (WSMR), which is located approximately 9 miles east of the site.

4.34 The FAA identified two alternatives and the No Action Alternative to the Proposed Action, which are considered in this EIS along with the noise impacts

for each scenario: Horizontal Launch Vehicles Only (Alternative 1); Vertical Launch Vehicles Only (Alternative 2); No Alternative Action.

4.35 The EIS explains that noise impacts were not expected to be significant. Construction noise level would be at background or ambient levels at the nearest residence. Also, DNL noise levels from construction traffic at residences along the roadways would be at peak associated with a small town. Vertical launches would have the highest noise levels, but occur for short periods of time, periodically, and only during daylight hours. Persons within three miles of the launch site would experience loud, but not damaging sound levels.

4.36 Test firing of rocket engines would be less frequent and less intense. Horizontal launches along with airport operations would generate noise that is more frequent than vertical launches, but noise peaks would be less. The noise levels expected from event activities would be greater and the DNL at the nearby Yost Escarpment would increase to that of a small town.

4.37 The traffic noise of operations would be less than that of the peak of construction, except during the X Prize Cup event, when noise levels are estimated at about 50 dBA at 300 feet from the road, a level that EPA associates with a small town.

1. Horizontal Launch Vehicles Only (Alternative 1)

   Noise impacts would be reduced as compared to the Proposed Action, due to the absence of vertical launches.

2. Vertical Launch Vehicles Only (Alternative 2)

   Alternative 2 would result in a significant reduction in noise impacts near the spaceport due to the absence of horizontal launches and re-entries, and lower levels of flight operations at the airfield.

3. No Action Alternative

   No new impacts would occur.

4.38 There are noise considerations to take into account during the construction phase of the site. The composite noise level would be 95 dBA 50 feet from the source, and the sound intensity would decrease with distance from the source, with noise levels approximately 75 dBA at 500 feet and 69 dBA at 1,000 feet without accounting for the sound dampening effect from air temperature, pressure, and relative humidity.

4.39 During operations the main sources of noise are rocket engines during launch and recovery, static rocket testing, sonic booms, normal airport operations, and traffic noise. Spaceport workers would normally be at least 2 miles away at the specific launch control centre during launches. It is unlikely that these workers

would be exposed to sound levels greater than 115 dBA, the OSHA 15-minute standard. However, any workers potentially exposed to noise greater than any OSHA standard would wear hearing protection.

4.40 The EIS contains data from Taurus launches. The Kodiak Launch Complex EA (FAA, 1996) provided a summary of three noise studies. One study consisted of actual sound level measurements of two static tests. Another data set for sound level resulted from computer modelling of a launch by Thiokol, the manufacturer of the Castor-120 motor. The third study was from the Taurus EA. The following graph (Figure 2) presents a composite curve of these three studies of the instantaneous sound level exposure at various distances after launch, as reported in the Kodiak EA.

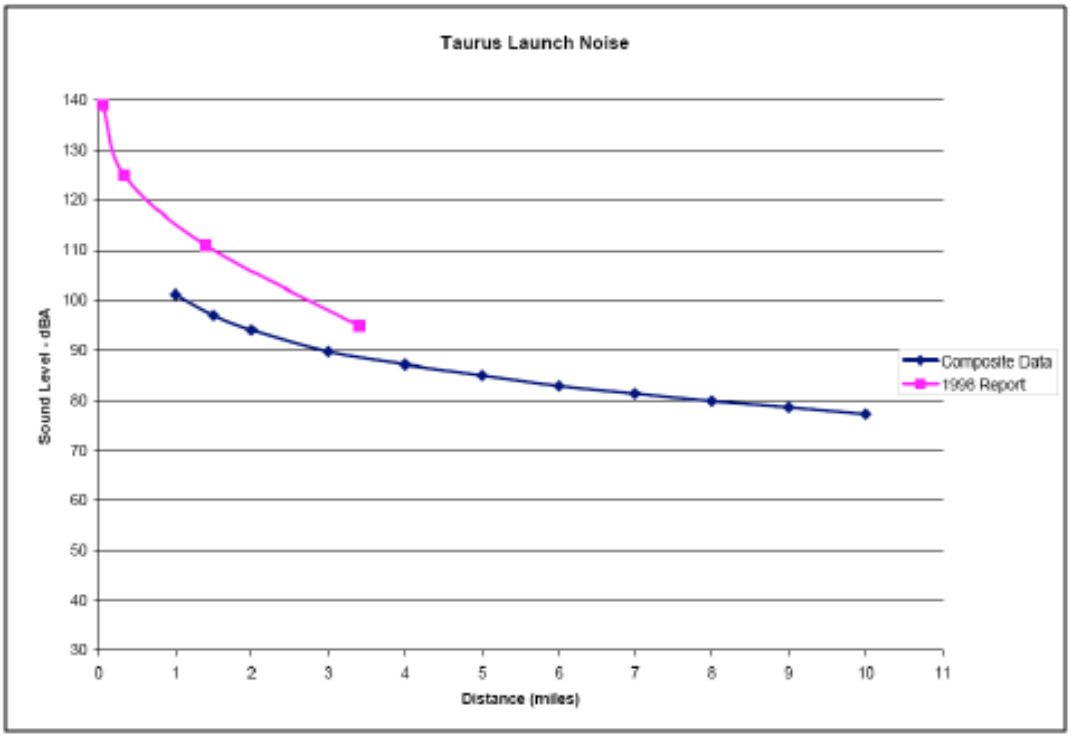

Figure 2: Predicted sound levels from a hypothetical Taurus launch.

4.41 Using the graph and extrapolating from it for noise levels at greater distances, the following interpretations are made in the EIS:

- Persons within 0.25 mile and who are fully exposed to the sound would need to wear hearing protection devices.
- Workers, visitors, and other persons within 3 miles would be exposed to moderate to very loud but not damaging sound levels.

- Persons on the County Road A013 at the west edge of the Spaceport, at the El Camino Real, or at the Yost Escarpment Key Observation Point (KOP) would be exposed to brief sound levels of 85-86 dBA (86 dBA is the typical noise level ¾ of a mile from touchdown at a major airport).
- Persons at the nearest residence, which is approximately 4 miles away from the launch area would experience sound levels of approximately 88 dBA.
- The few residents in nearby ranches and very small communities (7.4-18 miles distant) would be exposed to sound levels of 75-83 dBA (80 dBA is typical of a propeller plane flyover at 1,000 feet).
- More distant communities would experience sound levels typical in urban environments.

4.42 Community DNL values would not be increased significantly by vertical launches. The expected number of vertical launches per year (125 in 2013) equates to approximately one launch every 3 days. Also, vertical launches and test firings would not take place between 10 p.m. and 7 a.m.

4.43 The predicted static rocket test firing noise levels for Spaceport America and nearby locations were calculated using data from a rocket used for the Oklahoma Spaceport EA in 2006. The location distances ranged from 0.125 miles to 30 miles from the launch site, with respective estimated sound levels of 94 to 46 dBA.

4.44 The Programmatic Environmental Assessment for Spaceport Colorado was published in 2018. The Spaceport was proposed to be situated at the Front Range Airport (FTG) at Watkins, Colorado. Spaceport Colorado was proposed to commercial launch providers to conduct launch operations of horizontal take-off and horizontal landing RLVs.

4.45 The outcome of the EI was a FONSI, so a PEIS was not required. The noise analysis resulted in the following conclusions. Operational noise would consist of take-off, flight, descent and static hot-fire tests, however, because the rocket engine would be ignited at 45,000 feet, the engine noise at ground level would be far below FAA significance criteria and well below any conventional human noise annoyance standard. Upon descent, the sonic boom produced by the RLV would be similar to a clap of thunder and substantially lower than FAA's significance criteria. The majority of the area within the sonic boom area is sparsely populated agricultural land. Other activities associated with the Proposed Action would not result in a significant noise impact since all 65 dB DNL contours are on airport property and the increase is less than 1.5 dBA.

4.46 The Environmental Assessment for Oklahoma Spaceport was published in 2006. The proposed action would allow Oklahoma Space Industry Development Authority (OSIDA) to offer the Clinton-Sherman Industrial Airport (CSIA) to

customers wishing to conduct launch operations. Customers operating under a launch license may use the facility to provide for-profit launch services including tourism activities. Customers operating under an experimental permit may use the facility to conduct research, development, and testing of reusable launch vehicles (RLVs).

4.47 Within the EA, a summary of environmental impacts from the proposed action and alternatives are presented, the following is a summary of noise impacts. No substantial noise impacts would be expected from jet engine powered operations associated with Concept X and Z vehicles. Rocket engine powered operating noise associated with Concept X and Z vehicles may range from 60 to 70 dBA at ground level; this is roughly equivalent to the C-141A aircraft, and would not result in a change in noise exposure in excess of the applicable threshold of significance. Rocket engine launch noise from Concept Y vehicles would range from 76 to 86 dBA, this noise level is similar to existing jet engine noise at the CSIA and would not be expected to result in a change in noise exposure in excess of applicable thresholds of significance.

4.48 Concept X vehicles would produce sonic booms that range from 1.1 to 1.9 pounds per square foot. Concept Y vehicles would not reach supersonic speeds and therefore would not produce sonic booms. Concept Z vehicles would produce sonic booms that range from 0.5 to 0.7 pounds per square foot. Assuming up to 52 launches per year of these vehicles, the C-weighted day night average noise level would be less than the 61 C-weighted day night average noise level standard.

4.49 The EA and FONSI for Midland Spaceport was published in 2014. The purpose was for operation of the Lynx horizontal take-off and horizontal landing reusable launch vehicle (RLV) and engine testing at the site. Based on noise analyses conducted with respect to rocket launch noise, including sonic booms, the FAA determined the Proposed Action would result in no significant noise impacts and would not significantly impact land use compatibility.

CHAPTER 5

Summary

5.1 This report has summarised some of the considerations in the development and use of Spaceports within the UK and the US in terms of noise and environmental impacts. The location of spaceports is an important factor in minimising the impacts of noise on people and the environment, as highlighted in the successful application for a license being recently awarded to CAN, UK.

5.2 The need for an interdisciplinary approach to research the impacts on surrounding communities to spaceports is highlighted by Olson et al, and it is anticipated that this although there are few academic study findings published at present, this will be an area of research advancement as the international drive for spaceflight, and development of spaceport locations continues.