ACP-2017-079

SHETLAND SPACE CENTRE LIMITED (SAXAVORD SPACEPORT) AIRSPACE CHANGE PROPOSAL

CAP1616 STAGE 3 FULL OPTIONS APPRAISAL

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DOCUMENT CONTROLS

Document Reference

AVISU Reference	ACP_2017_079_Stage_3_Full_Options_Appraisal_V3_2_FINAL

Version History

Version	Date	Status	Author	Comments
~~V1.0~~	~~13 Jan 23~~	~~Issued~~	[redacted]	~~Approved and submitted to CAA.~~
~~V2.0~~	~~21 Mar 23~~	~~Issued~~	[redacted]	~~*Para 1.* Addition of "Introduction" paragraph; subsequent paragraph numbers renumbered accordingly.~~ ~~*Para 24.* Further explanatory comment added pertaining to AOI entry and exit points.~~ ~~*Para 34.* Fuel burn (kg/km); data source revised. Calculations at Table 2 and throughout amended.~~ ~~*Para 54.* Reworded to clarify.~~ ~~*Para 55.* Date error corrected; "19 Aug 19" is replaced by '13 Aug 19'. Reworded to clarify.~~ ~~*Appendix 1.*~~ ~~- Representative indication of noise contours added at Figure 11.~~ ~~- Sleep disturbance commentary expanded and supported by quantitative data.~~ ~~- Monetisation data updated with data points established on 16 Mar 23.~~ ~~Approved and submitted to CAA.~~
V3.0	6 Apr 23	Issued	[redacted]	*Glossary.* Glossary of terms and abbreviations added. *Para 2.* Addition of new Para 2, briefly outlining "current day" SaxaVord operation; subsequent paragraphs renumbered. *Para 15.* Expansion of current day operations and baseline position, incorporating reference to new Para 2. *Para 18.* Figure 4 and Footnote 5; added reference to ITAR for surveillance data. *Para 20.* Footnote 6 moved from Para 22 for clarification and amended, accordingly. *Paras 34.* CO2e replaced by "greenhouse gases". *Para 36.* Explanation of CO2e. *Para 43-48.* Revised Figure 8, subsequent amendment of Table 3 and supporting narrative. *Appendix 1.* Revised links to AEE and EIA provided. Footnote 21 cites reference to corresponding technical note.
V3.1	-	-	[redacted]	Version number not used.
V3.2	18 Apr 23	Issued	[redacted]	Change to consultation dates. Document renumbered to align with other Stage 3 artefacts.

Document Quality Management

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Technical Reviewer	[redacted]	[redacted]	18 Apr 23
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GLOSSARY OF TERMS AND ABBREVIATIONS

SaxaVord's convention is to introduce abbreviations at first use within any document. The table below, contains the list of abbreviations, acronyms and terms contained within this document.

Term/Abbreviation	Meaning
ACP	Airspace Change Proposal.
ADS-B	Automatic Dependent Surveillance-Broadcast. A surveillance technology and form of Electronic Conspicuity in which an aircraft determines its position via satellite navigation or other sensors and periodically broadcasts it, enabling it to be tracked.
AEE	Assessment of Environmental Effects
AMSL	Above Mean Sea Level.
ANSP	Air Navigation Service Provider.
AOI	Area of Interest
ATC/M	Air traffic control/management.
AQS	Air Quality Standard
Azimuth	(Launch) azimuths are the horizontal angular direction initially taken by a launch vehicle (LV) at lift-off, measured clockwise in degrees from true north.
BRRC	Blue Ridge Research & Consulting LLC
(UK) CAA	(UK) Civil Aviation Authority (i.e. the UK's aviation regulatory body).
(UK CAA) CAP1616	UK CAA Publication "Guidance on the regulatory process for changing the notified airspace design and planned and permanent redistribution of air traffic, and on providing airspace information".
CO2e	Carbon dioxide equivalent (CO2e) per kg of fuel burn. Carbon dioxide is the most prevalent atmospheric greenhouse gas and is the proxy by which greenhouse gas emissions are measured. CO2e allows other greenhouse gas emissions to be expressed in terms of carbon dioxide.
dB	Decibel is a logarithmic unit used to represent sound levels.
dBA	Weighting levels and curves have been developed to correspond to the sensitivity and perception of the human ear to different types of sound. The A-weighted decibel level (dBA) is commonly used to assess community sound.
EIA(R)	Environmental Impact Assessment Report
Eurocontrol	The European Organisation for the Safety of Air Navigation, commonly known as Eurocontrol (stylised EUROCONTROL), is an international organisation working to achieve safe and seamless air traffic management across Europe.
FIR	An airspace of defined dimensions in which a flight information and alerting services are provided, extending from the surface.
FL	Flight Level.
FTS	Flight Termination System
GA	General aviation
ICAO	International Convention of Aviation Organisations.
IFR	Instrument Flight Rules, i.e. the conduct of the flight without visual references and the pilot is utilising cockpit instrumentation.
km	Kilometre
kg	Kilogram
LAMax	Maximum A-weighted Sound Level (LAmax) is the highest A-weighted sound level measured during a single event.

Term/Abbreviation	Meaning
LOA(s)	Letter(s) of Agreement
LP(s)	(SaxaVord Spaceport) Launch Pad(s)
LV(S)	(Orbital and Sub-orbital) Launch Vehicle(s).
MOU(s)	Memorandum (Memoranda) of Understanding.
nm	Nautical mile(s).
SIA	Space Industry Act (2018).
SIR	Space Industry Regulations
SSO	Sun-synchronous Orbit
SFC	Surface
UTC	Coordinated Universal Time (or UTC) is the primary time standard by which the world regulates clocks and time.
UIR	Upper Information Region. A Flight Information Region in upper airspace (not extending from the surface)
UNLTD	Unlimited
VFR	Visual Flight Rules adhered to by flights outside controlled airspace, where the conduct of the flight is with visual reference to - *inter alia* - terrain and other airspace users.

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OVERVIEW

Introduction

1. Shetland Space Centre Limited (trading and hereinafter referred to as "SaxaVord Spaceport" and "SaxaVord") seeks to conduct vertical launch operations for orbital and sub-orbital activities from SaxaVord Spaceport on Lamba Ness, Unst. A suitable airspace reservation of defined dimensions is required to ensure the safety of other airspace users from SaxaVord launch activities and to ensure the safety of SaxaVord launch activities from other airspace users. The proposed airspace reservation would be activated for the minimum specified periods necessary to support nominated launch operations and would extend from surface (SFC) to unlimited (UNLTD).

2. Unlike an airspace change at a UK aerodrome, there is no "current day" operation to refer to as an operational baseline; thus, there is no operational *status quo* to maintain.

CAP1616 Full Options Appraisal Process Requirements

3. CAP1616, Step 3A requires the change sponsor to carry out the second of 3 phased options appraisals.[1]

> "As noted at Step 2B, the options appraisal evolves through three phased iterations, with the CAA reviewing the information in the appraisal at each phase."[2]
>
> As detailed in CAP1616 Appendices B and E, the second 'Full' phase to be completed in Step 3A requires the change sponsor to develop more rigorous evidence for its remaining option(s), compared as before with a 'do nothing' option. Although there is no requirement for a change sponsor to undertake further safety work at this stage, where a sponsor has done so, it must include that information in the package of consultation documents."[3]
>
> "After review by the CAA at Step 3B and sign-off at the 'Consult' gateway, the change sponsor must include the options appraisal in the package of documents on which it consults at Step 3C. This assists the change sponsor in identifying potential impacts and mapping potentially affected stakeholders, [*sic*] and allows those being consulted to see the potential impacts of different options and provide more information or comment. The responses to the consultation then allow the change sponsor to update the options appraisal in the light of any new information (and if necessary re-consult, as explained on [CAP1616] page 59)."[4]

Aim

4. The aim of this Full Options Appraisal document is to provide the necessary additional rigorous evidence to support SaxaVord's selected design option.

STAGE 3 DESIGN OPTION

Stage 2 Preferred Design Option

5. The airspace design options presented at Stage 2 was for a combined "box and wedge" shape with 2 variations: one non-segmented (Design Option 1), the other segmented (Design Option 2). As a result of Stage 2, the only preferred design option taken forward to Stage 3 was the segmented

1. CAP1616, Page 47, Paras 157 and 158.
2. *id*, Para 157.
3. *ibid*.
4. *id*, Para 158.

design (Design Option 2). The Stage 2 report also noted that the airspace design could evolve as the ACP process continued and options were matured and refined.

Design Option Evolution - "Design Option 3"

6. As Stage 2 progressed, performance data for potential launch vehicles (LVs) seeking to utilise the spaceport evolved; in turn, this precipitated a refinement of the airspace design being proposed at Stage 3. Design Option 3, therefore, further refines the box and introduces a revised segmentation mechanism within the wedge shape and remains the only design option to be consulted upon in Stage 3.

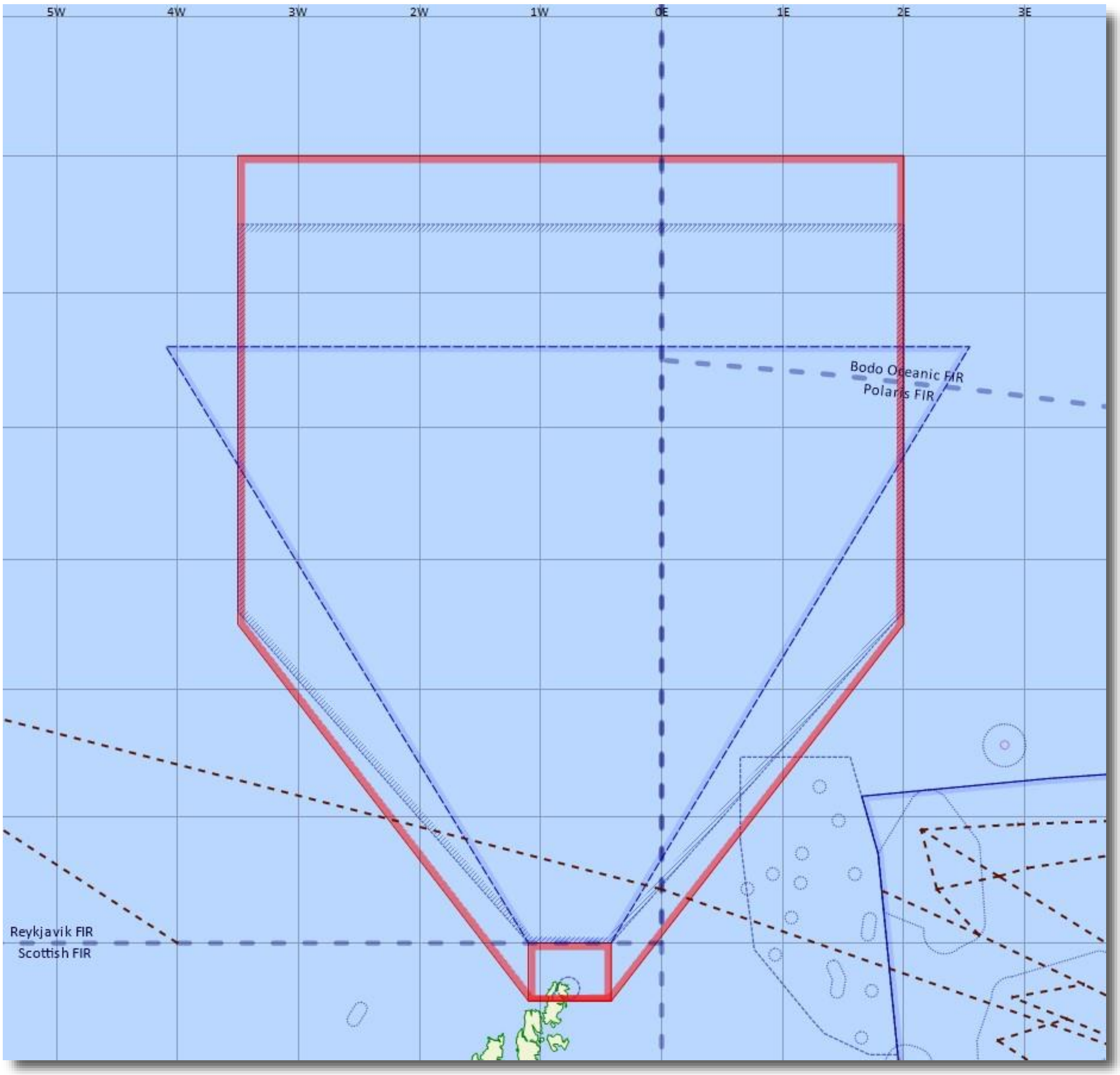


Figure 1 - Design Option 3 (Outline) Compared With Stage 2 "Box and Wedge"

7. The red outline indicates Design Option 3 compared with the Stage 2 (box and wedge) design(s) in dark blue. The overall longitudinal dimension of the airspace has increased by 42nm and the overall latitudinal dimension has decreased by 32nm.

Evolution of Box and Wedge Design

8. *Box*. The co-ordinates of the corners of the box element have been rounded for ease of use. The refinement of the co-ordinates does not materially change the location or shape of the box.

9. *Wedge*. From the northern corners of the box, the east and west radials are now approximately +/-40° from the centreline (360°True (360T)) to accommodate the new limiting case dispersion of trajectory for a passive guidance sub-orbital LV.

10. From the southern corners of the box, additional east and west radials are added to allow for sub-orbital launch azimuths to the east and west of north (main axis of the airspace).

11. Downrange, the sides of the wedge are aligned north/south, instead of the previous triangular shape, to remove unnecessary airspace volume for dispersion of trajectory of a passive guidance sub-orbital LV. The downrange limit of the wedge has been extended to accommodate the new limiting case dispersion of trajectory for a passive guidance sub-orbital LV.

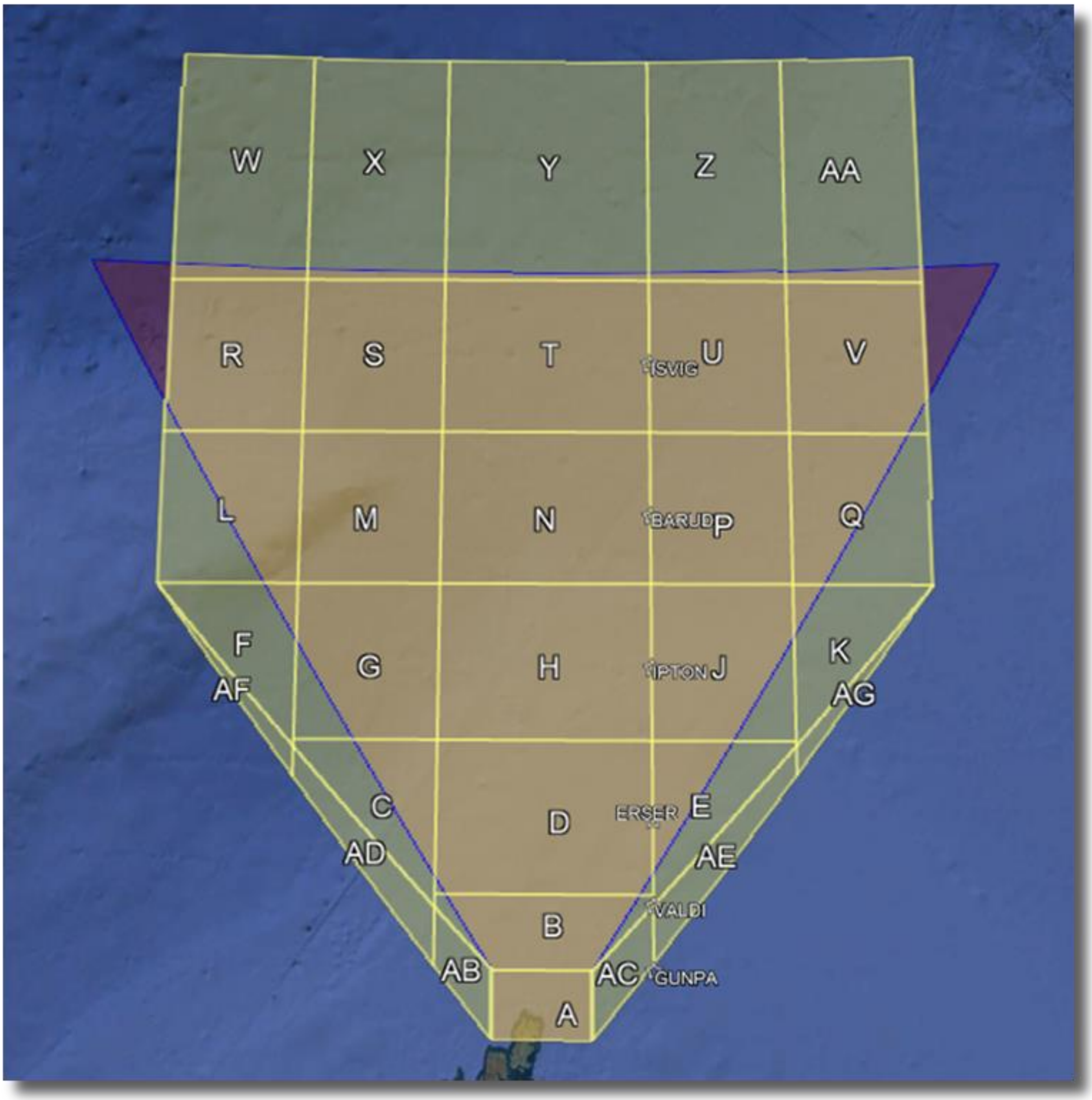
Evolution of Design Option 3 - Segmentation

12. The original segmented design concept proposed segments based on radials and range rings. Subsequently, SaxaVord determined that this could be an unnecessarily complicated solution to implement, as there would be many complex co-ordinates and some individual segments could traverse FIR boundaries. Consequently, SaxaVord refined the segmentation concept for Stage 3, which uses segments based on simplified lines of latitude and longitude.

13. The refined segmentation allows the activated airspace volume to be plotted more readily by airspace users. In addition, the increase in internal segments enables greater granularity in selecting the most appropriate airspace volume for a given space launch operation. Furthermore, refined latitudes of segments have been selected to avoid coincidence with established FIR boundary reporting points. Latitudes and longitudes were refined to ensure that segments do not traverse FIR boundaries.

Design Option 3

14. Figure 2, below, indicates Design Option 3 with revised segmentation, compared with the red Stage 2 "box and wedge" design; the box element (Segment A) remains consistent.



Source: Google Earth

Figure 2 - Design Option 3 (Segmentation) Compared With Stage 2 "Box and Wedge"

STAGE 3 - FULL OPTIONS APPRAISAL

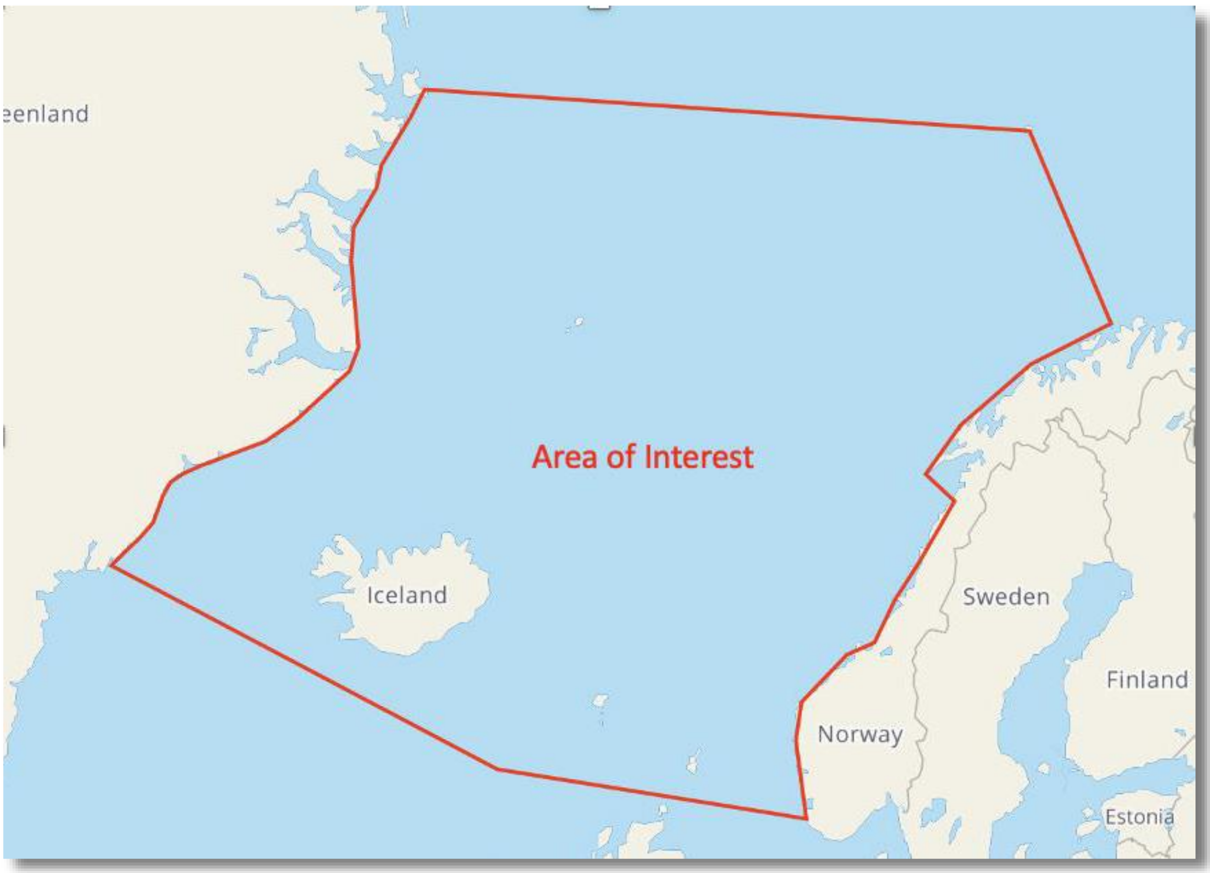
Full Options Appraisal Requirements

15. *"Current Day" Operations*. As outlined earlier at Para 2, above, unlike an airspace change at a UK aerodrome, there is no current day operation to refer to as an operational baseline; thus, there is no SaxaVord operational *status quo* to maintain. The baseline "position", therefore, is the identified prevailing traffic/network situation at a given time; SaxaVord assessed Design Option 3 against the baseline scenario (i.e. the extant aviation position).

16. *Baseline Position*. As detailed at Stage 2, SaxaVord conducted a baseline scenario traffic assessment relative to the potential traffic impacted by the activation of the proposed airspace designs for ACP-2017-079. This assessment and associated analyses were revisited for Design Option 3.

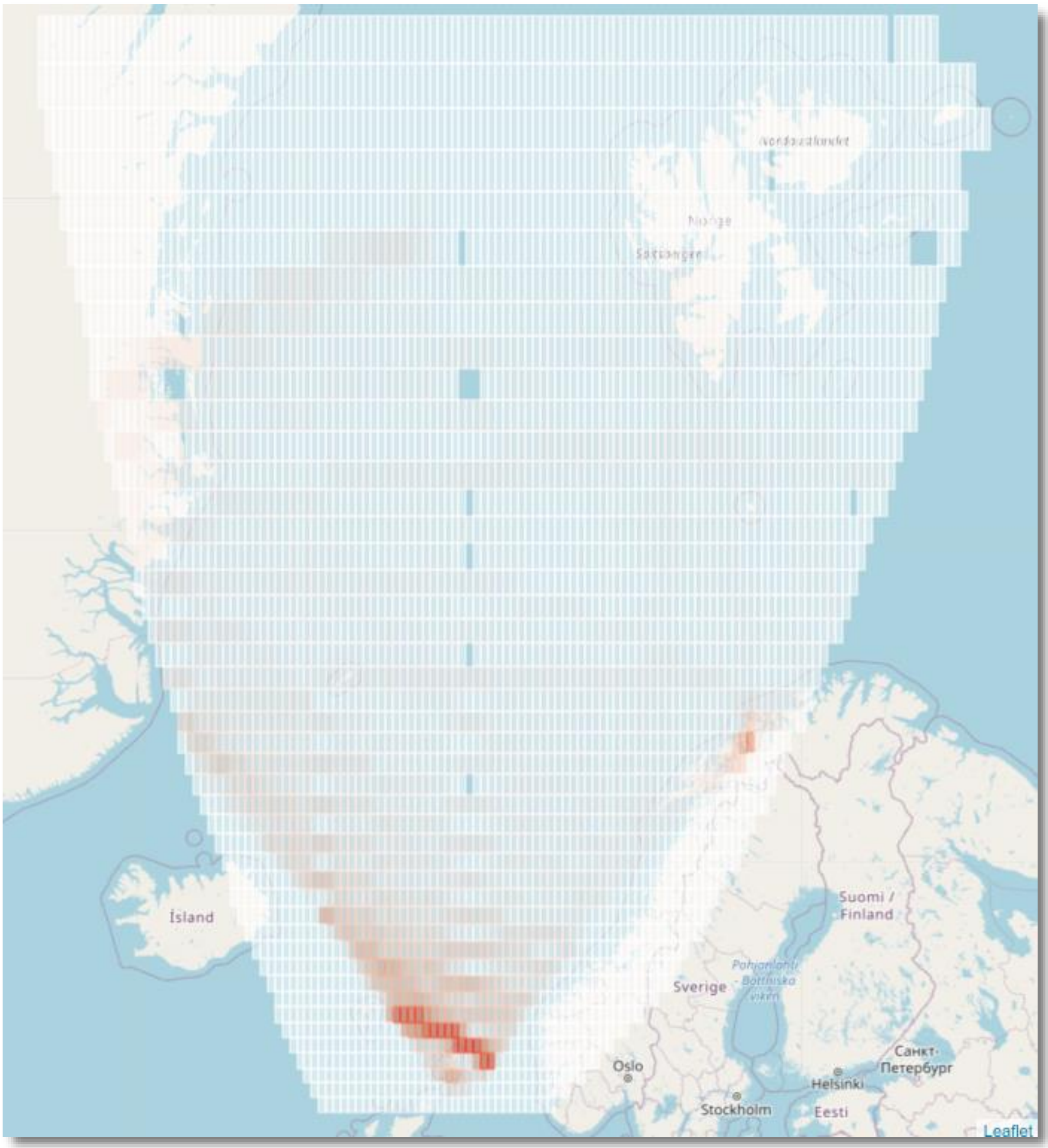
17. *Approach*. The airspace analysis approach was to apply a macro air traffic flow perspective to various micro assessments.

18. *Objective*. The objective of the traffic assessment and analysis was to obtain an appreciation of the lifecycle of air traffic movements in relation to the anticipated launch operations trajectories from the SaxaVord site, as defined by the supplied Area of Interest (AOI) (Figure 3); this traffic capture was chosen to be deliberately larger than the Range Analysis AOI (Figure 4).



Source: AVISU

Figure 3 - Range Licence AOI



Source: AVISU (Subject to ITAR)

Figure 4 - ADS-B 2019 AOI Traffic Heat Map

Traffic Sample Data

19. The assessment obtained a year's ADS-B surveillance data[5] for the period January to December 2019, selected specifically for pre-COVID-19 traffic levels. The data covers all three ADS-B out transponder versions (0, 1 and 2). Additionally, Eurocontrol traffic monitoring data shows that, overall, the aircraft fleet operating within the EU with at least one of these ADS-B versions is approximately 90% of all its monitored traffic. This percentage will be significantly higher in the SaxaVord range AOI

5. The ADS-B data and, therefore, source are subject to International Trade in Arms Regulation (ITAR); as such, the source cannot be divulged in this document.

(Figure 3), given that Eurocontrol monitoring includes traffic operating at low levels across the continent. Furthermore, related discussions with NATS confirmed the low incidence of visual flight rules (VFR)/general aviation (GA) traffic. As such, the data sample can be seen to be of sufficiently high fidelity for this assessment's purposes.

20. Over the year, approximately 30,000 aircraft transited the AOI (Figure 4), predominantly in an east-west orientation. Unsurprisingly, the traffic analysis identified seasonal variations, i.e. higher traffic levels in summer months and reduced levels in winter months.[6]

21. Within the sample traffic data, the peak day was identified as 2 Aug 19, when a total of 191 aircraft passed through the larger (Figure 3) AOI; peak periods were observed between 1300 and 1500 hrs, when 28 aircraft per hour passed through the (Figure 3) AOI.

22. Continuing to consider the peak day, Design Option 3 could be seen to impact a maximum of 12 flights per hour of activation.

6. The analysis of the traffic sample data was conducted using AVISU's AVISIM™ analytics tool (Avisim - Simulation and Analytics - AVISU).

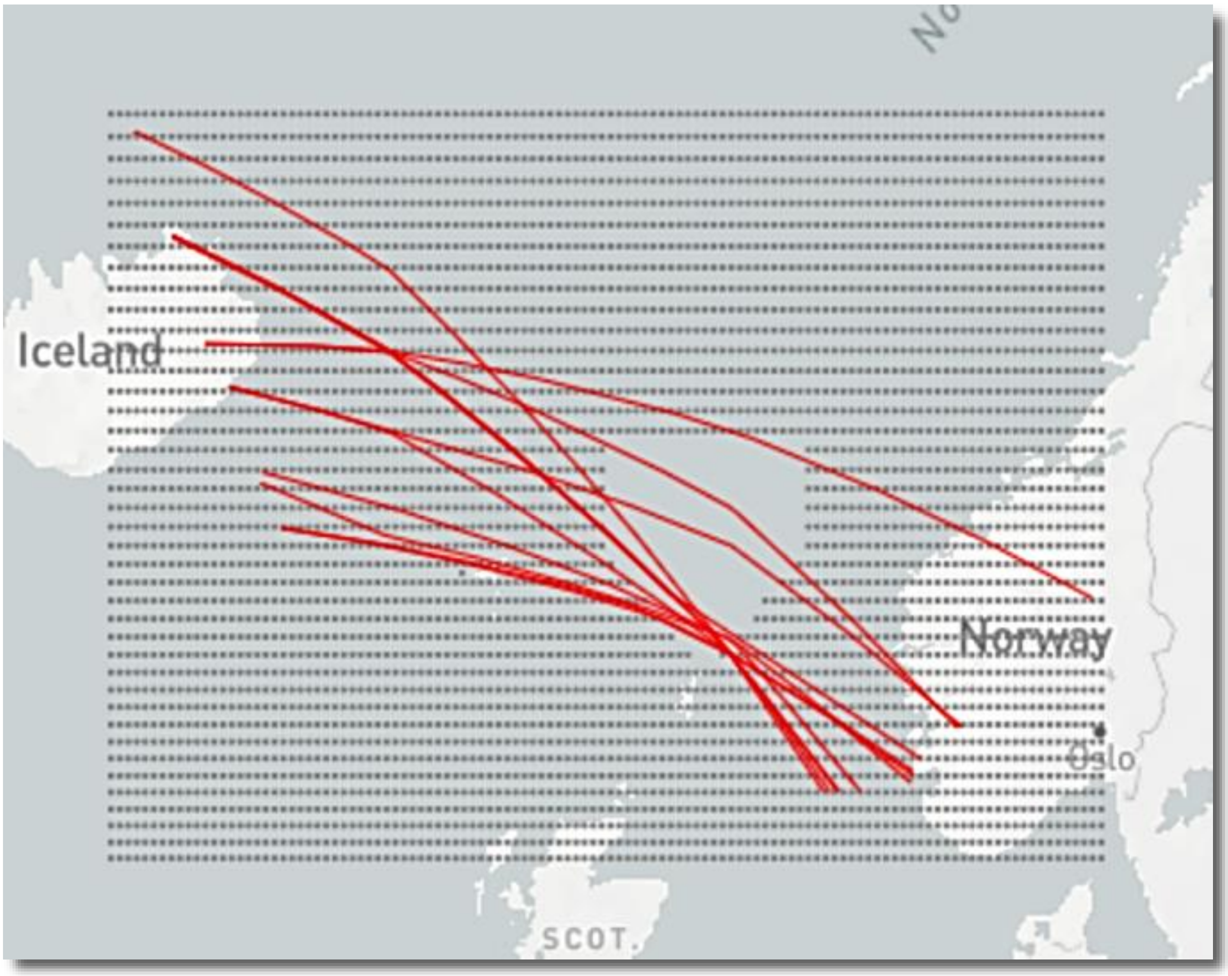
Design Option 3 Traffic Impact Assessment

23. *Design Option 3 Area of Interest.* The Design Option 3 volume is significantly smaller when compared with the original (and larger) traffic assessment area, as illustrated in Figure 5, below; Design Option 3 is depicted in the reddened area of the figure. Traffic re-route impact assessment focuses on those flights transiting the reddened area of Figure 5.

Source: AVISU

Figure 5 - Design Option 3 Area (in Red) Compared With the Traffic Assessment Area (in White)

24. *Re-route Extension and Emission Impact from Activation of the Proposed Airspace.* The traffic patterns of other airspace users were analysed against an anticipated airspace activation period of one hour. Airspace activation durations will vary based on the maturity of the LV and the trajectory and orbital requirements. The peak day was identified as 13 Aug 19 and a peak hour of 1300-1400 UTC was selected for analysis, during which 12 flights could potentially be impacted. The data indicated that aircraft currently plan longer distances than the great circles (given SaxaVord's AOI) most likely due to wind effects (i.e. normally to avoid headwinds). All traffic was observed to be travelling broadly east-west and is depicted in Figure 6, below.[7]



Source: AVISU

Figure 6 - Potential Peak Day Peak Hour Traffic Impacted By Airspace Activation - Original Route Segments

25. *Re-route Methodology.* The following simple re-route methodology was applied: entry and exit points within the assessment area are maintained (see also Para 25, below); flights that entered the assessment area south of the latitude of SaxaVord Spaceport launch site were re-routed to avoid the airspace design to the south, those entering north of the launch site were re-routed to the north of the airspace design. Only one aircraft was routed to the north. Re-routed traffic patterns of other airspace user are depicted in Figure 7, below.[8]

7. CAP1616, Page 166, Para B57 "Operational Diagrams".
8. *ibid.*

Source: AVISU

Figure 7 - Potential Peak Day Peak Hour Traffic Impacted By Activation - Simulated Re-route Segments

26. The methodology above offers a simplification of re-routing to avoid an airspace reservation; the reality, however, would be notably different. Undoubtedly, flights' routes would be planned on the ground, prior to departure, to accommodate known airspace reservations and constraints across the whole route of the flights' routes.

27. In addition, the methodology offered here reflects a more "tactical" management of the flow within the Eurocontrol airspace/ATM network, i.e. on the day of operation of the network, *vice* the "strategic" and "pre-tactical" aspects of network flow management. These latter activities seek to resolve network demand and capacity imbalances (between Day-7 and Day-1) and minimise air navigation service providers' (ANSPs') tactical management of airspace reservations.

28. The computations associated with a more detailed analysis are too numerate and, undoubtedly, would be influenced by - inter alia - the prevailing meteorological conditions, ATM route loading and airline routing policies/strategies.

29. *Analysis of Re-routed Traffic.* For the peak hour of the peak day identified from the data sample, Table 1, below, offers a comparison between the baseline original route through the wider AOI and a potential and unmitigated re-route; the latter is based on the methodology cited above.

Ser	Callsign	Original Route (km)	Re-route (km)	Route Δ (km)
1	PCH893	1116	1106	-10
2	JET1	1321	1325	4
3	UAL125	1210	1241	31
4	SWR40	1272	1266	-6
5	TSC701	1066	1047	-19
6	SWR38	1275	1277	2
7	AAL759	1268	1284	16
8	RJA12B	1063	1054	-9
9	N324CH	1054	1054	0
10	ACA845	1376	1370	-6
11	ACA891	1116	1100	-16
12	UAL47	1333	1358	25
			Total Difference	+12km

Table 1 - 13 Aug 19 Peak Day, Peak Hour Traffic Re-route Calculation

Table 1 concludes that the total re-route for the traffic sample of 12 flights is a cumulative additional 12km; however, analysing the most impacted flight offered a scale of the greatest potential impact at a peak period within that portion of the network.

30. The most impacted flight can be seen to be UAL125 (Athens to Newark International), at Serial 3 in Table 1, above, which could be subjected to a 31km route extension. The flight distance from Athens to Newark is approximately 8000km; an extension of 31km would, therefore, correspond to an increase of 0.39%, which could be considered negligible.

31. Were a 31km extension to be applied to ALL flights in the sample, this could result in a total route extension of 372km for the impacted flights. This working assumption is explored further, below.

32. It is also important to note that the data in Table 1 assumes a full one-hour airspace volume activation and makes no provision for either a tactical hand-back of the airspace to the network, which in turn would allow for ANSPs to apply a subsequent tactical re-route, or a re-route prior to the flight entering the AOI, potentially reducing extensions to impacted flights' tracks.[9]

33. *Potential Fuel Burn and Emissions Impact.* Analysis shows that, today, airlines often adopt slightly longer routes for wind, which may result in faster flight times. SaxaVord is unable to predict business decisions on airlines' routing as these are firmly the purview of individual operators.

34. The demonstrable negligible re-route impacts, therefore, show that the activation of Design Option 3 does not have a significant impact on fuel burn and greenhouse gas emissions, as, in some cases, the potential re-route could produce either a shorter or equivalent flight distance.

9. The subject of tactical notification and coordination procedures is an ongoing topic of discussion associated with LOAs and MOUs between SaxaVord and the relevant national and international parties.

35. The most impacted flight profile in the data sample from Table 1, above, was UAL125 from Athens to Newark International, a flight distance of 7952km. Using ICAO's Carbon Emissions Calculator[10], the representative aircraft type for this journey is a Boeing B777, or B777-300ER; on this route, the total fuel burn for this flight is offered as 76,399.60kg. This equates to an average fuel burn rate of 9.61kg/km.[11]

36. An accepted industry measure of carbon dioxide equivalent (CO2e) per kg of aviation fuel burned is 3.18kg of CO2e per kg of fuel.[12] The Athens-Newark flight of 7952km, therefore, produces 242,950.728kgs of CO2e, which equates to 30.55kgs[13] of CO2e per km. Thus, a 31km extension of this flight's route could produce an additional 947.12kg[14] of CO2e from an additional fuel burn of 297.84kg.[15]

37. The 947.12kg increase in CO2e associated with a re-route of 31km is a 0.39% (unmitigated) increase in the flight's overall CO2e. Similarly, the increase in fuel burn for the total route is 0.39%.

Annual Traffic Re-route, Fuel Burn and CO2e Impact Assessment

38. An annual traffic re-route impact was derived to quantify a worst-case scenario associated with the activation of Design Option 3.

39. *Assumptions.* To quantify an annual re-route **maximum** impact, the following assumptions have been made (see also Paras 25, 26 and 41):

- Launch Window Duration. The launch window duration is one hour.
- Traffic Sample. The traffic sample is 12 flights, highlighted at Table 1, above.
- Flight Distance. The flight distance for each flight is 8000km.
- CO2e per kg of Fuel. Flights will emit 3.18kg CO2e per kg of fuel.
- Re-route Extension. A 31km route extension was applied to ALL flights.
- No. of Instances. The no. of instances of activation is 30 times (i.e. SaxaVord launches) per annum.

10. ICAO Carbon Emissions Calculator (online). Accessed on 14 Mar 23.
11. 76,399.60kg divided by 7952km and reduced to 2 decimal places (dp).
12. CAP1616a, Page 24, Para 1.8.
13. 76,399.60kg divided by 7952km, multiplied by 3.18kg of CO2e/kg fuel and reduced to 2 dp.
14. 30.55 (2dp) CO2e per km multiple by 31 additional km.
15. 9.61 (2dp) kg fuel per km multiplied by 13 additional km.

40. *Annual Re-route, Fuel Burn and CO2e Impact Calculations*. The analysis of potential impacts and the calculations is offered in Table 2, below.

No Flights Per Peak Hour	12			
Flight Distance (km)	8000			km
Total Baseline Distance Flown (km) Per Peak Hour		96,000		km
CO2e (kg)/kg of Fuel	3.18			kg
Fuel Burn(kg)/km	9.61			kg
CO2e (kg)/km	30.55			kg
Total Baseline Fuel Burn (tonnes) Per Peak Hour		922.33		tonnes
Total Baseline CO2e (tonnes) Per Peak Hour		2,933		tonnes
No of Instances Per Annum	30			
Total Baseline Distance Flown (km) Per Annum			*2,880,000*	km
Total Baseline Fuel Burn (tonnes) Per Annum			*27,670*	tonnes
Total Baseline CO2e (tonnes) Per Annum			*87,990*	tonnes
Re-route per Flight (km)	31			
Potential Re-route Distance (km) Per Peak Hour		372		km
Potential Re-route CO2e (tonnes) Per Peak Hour		11.37		tonnes
Potential Re-route Distance (km) Per Annum			*11,160*	km
Potential Re-route Fuel Burn (tonnes) Per Annum			*107*	tonnes
Potential Re-route CO2e (tonnes) Per Annum			*341*	tonnes
Potential Total Distance Flown (km)			*2,891,160*	km
Potential Impacted CO2e (tonnes)			*88,331*	tonnes

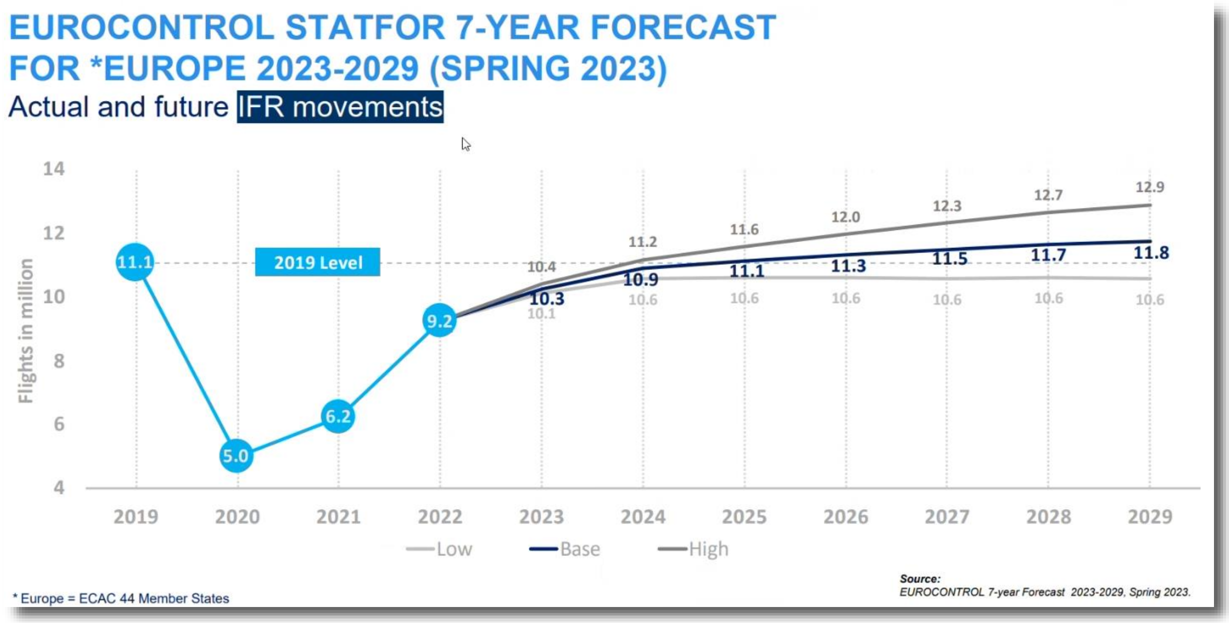
Table 2 - Traffic Re-route, Fuel Burn and CO2e Impact Calculations

41. Table 2, above, demonstrates that the activation of Design Option 3 at the peak hour of the peak day in the traffic sample on 30 instances (i.e. SaxaVord launches) per annum could precipitate an impact of an additional 11,160km flight distance, an additional 107tonnes of fuel burn and an additional 341tonnes of CO2e to the 12 flights in the exemplar instance at Table 1. These figures must, however, be viewed in comparison with their respective baseline calculations, 2,880,000km, 27,670tonnes and 87,990tonnes, respectively; the potential impact of a worst-case scenario represents an (unmitigated) increase of 0.39% in flight distance, fuel burn and CO2e.

42. Most importantly, these calculations do not consider Eurocontrol modelling and the identification of suitable launch windows to minimise impact on the airspace/ATM network, while satisfying specific launch orbit requirements. These latter activities could do much to further reduce the calculated impacts of the proposed airspace activation on the wider airspace network.

Forecast Traffic Levels

43. An extract from Eurocontrol's Traffic Forecast Update for Europe 2023-2029, dated Spring 2023, is offered at Figure 8, below.



Source: Eurocontrol

Figure 8 - Extract from Eurocontrol 7-year Forecast for Europe 2023-2029

44. *Forecast Assumptions.* For this element of the traffic assessment and analysis, the following assumptions have been made:

- The 12 impacted flights, as set out in Table 1, above, is the datum.
- The "Base" forecast (depicted in dark blue in Figure 8, above) is the measure for extrapolating data to 2028.
- The percentage growth of the Base forecast from 2024 to 2027 is +2%; thereafter, it reduces to +1%, annually. Accordingly, and in the absence of empirical data, when extrapolating the Base forecast beyond 2029, +1% is assumed to be the annual forecast growth for the years 2030-2034.
- Given the infinite combinations of airspace activation time(s) and routes/destinations of the prevailing flights potentially impacted, the traffic sample in Table 1, above, applies across all years in Table 3, below, which illustrates 10 years from the proposed implementation of the airspace change.
- Forecast meteorological conditions cannot be considered in this analysis.

45. *Forecast Analysis.* Eurocontrol do not forecast a return to 2019 Base traffic levels until 2025; accordingly, the assumed datum of 12 flights is an overestimation for 2022-2024 (incl.).

46. The assumed datum and application of percentage variance by year is set out in Table 3, below, and accompanied by an estimate on the potential number of flights impacted by the airspace activation. Although the Base forecast is assumed (Figure 8 in dark blue), Low (Figure 8 in light grey) and High (Figure 8 in dark grey) scenarios are offered for comparison.

47. Annual percentage growth for the Low forecast was +4% (from the 2019 datum) in 2023 and +1% in 2024, thereafter, reducing to 0%; accordingly, 0% is used to extrapolate beyond 2029. Annual

percentage growth for the High forecasts were +8% (from the 2019 datum) in 2023, +4% in 2024, +3% in 2025, 2026, 2027 and 2028, reducing to +2% in 2029; accordingly, this latter growth figure was extrapolated beyond 2029. In addition, numbers of impacted flights have been rounded up to ensure that a most limiting figure is shown.

Ser	Year	2022 Datum	Traffic Variance (%) (From Figure 8			Potential Impacted Flights (Rounded Up to Nearest Whole No)		
			Low	Base	High	Low	Base	High
1	2019		-	-	-	-	12	-
2	2020		-55	-55	-55	-	12	-
3	2021		-44	-44	-44	-	12	-
4	2022		-17	-17	-17	-	12	-
5	2023	12	-9	-7	-7	-	12	12
6	2024		-5	-2	+1	-	12	13
7	2025		-4	0	+5	12	12	13
8	2026		-4	+2	+8	12	13	13
9	2027		-4	+4	+11	12	13	14
10	2028		-4	+5	+14	12	13	14
11	*2029*		*-4*	*+6*	*+16*	*12*	*13*	*14*
12	*2030*		*-4*	*+7*	*+18*	*12*	*13*	*15*
13	*2031*		*-4*	*+8*	*+20*	*12*	*13*	*15*
14	*2032*		*-4*	*+9*	*+22*	*12*	*14*	*15*
15	*2033*		*-4*	*+10*	*+24*	*12*	*14*	*15*
16	*2034*		*-4*	*+11*	*+26*	*12*	*14*	*16*

Table 3 - Variance in Forecast Traffic Levels and Potential Impacted Flights

48. Drawing upon Eurocontrol's traffic forecast at Figure 8 and the analysis offered at Table 3, it can be shown that there is not a marked increase in the number of potential flights impacted by the activation of the Design Option 3. A further 2 flights potentially impacted in 10 years' time, whilst an increase in relative terms, is not considered a significant absolute increase.

49. Additionally, the analysis assumed the most limiting (i.e. greatest) volume of Design Option 3. It could, therefore, be posited that a reduced airspace volume of Design Option 3, tailored to the specific LV, could either impact a smaller number of flights, or produce a lesser impact on the same number of flights.

50. Finally, the analysis here does not consider the benefit of Eurocontrol modelling capabilities and suitable launch window selection, which would seek to identify and select the appropriate launch window to minimise impact on the airspace/ATM network and its users, while satisfying specific launch orbit requirements.

Network Traffic Analysis Summary

51. SaxaVord analysed a year's ADS-B surveillance data to establish a pre-COVID-19 baseline traffic assessment, thereby enabling the identification of the potential impacts of SaxaVord's Design Option 3 options on the ATM/airspace network and its users. The AOIs considered macro and micro levels of airspace volumes, to enable context and comparisons to be drawn and identify the maximum potential number of flights that could be impacted were Design Option 3 to be activated. In turn, this enabled the subsequent analyses of the potential impacts of re-routing flights to avoid the airspace

reservation, consider the associated impacts on individual flights routes (both positive and negative) and offer an initial assessment on environmental considerations (i.e. CO2e).

52. A peak day and hour were identified and, during that epoch, 12 flights could be impacted by the activation of Design Option 3; using Eurocontrol traffic forecast data, this could increase to 14 flights in 10 years.

53. Flight distances were observed to be impacted by between -19 and +31km. Despite an observed cumulative variation of +12km across the whole flight sample, SaxaVord assumed an absolute worst-case scenario of an additional 31km for each flight. Extrapolating this extended flight distance across 12 flights and 30 instances (i.e. SaxaVord launches), the annual impacts for flight distance, fuel burn and CO2e could be shown to increase by 11,160km, 107tonnes and 341tonnes, respectively, representing a 0.39% (unmitigated) increase in all metrics above the measured baseline calculations.

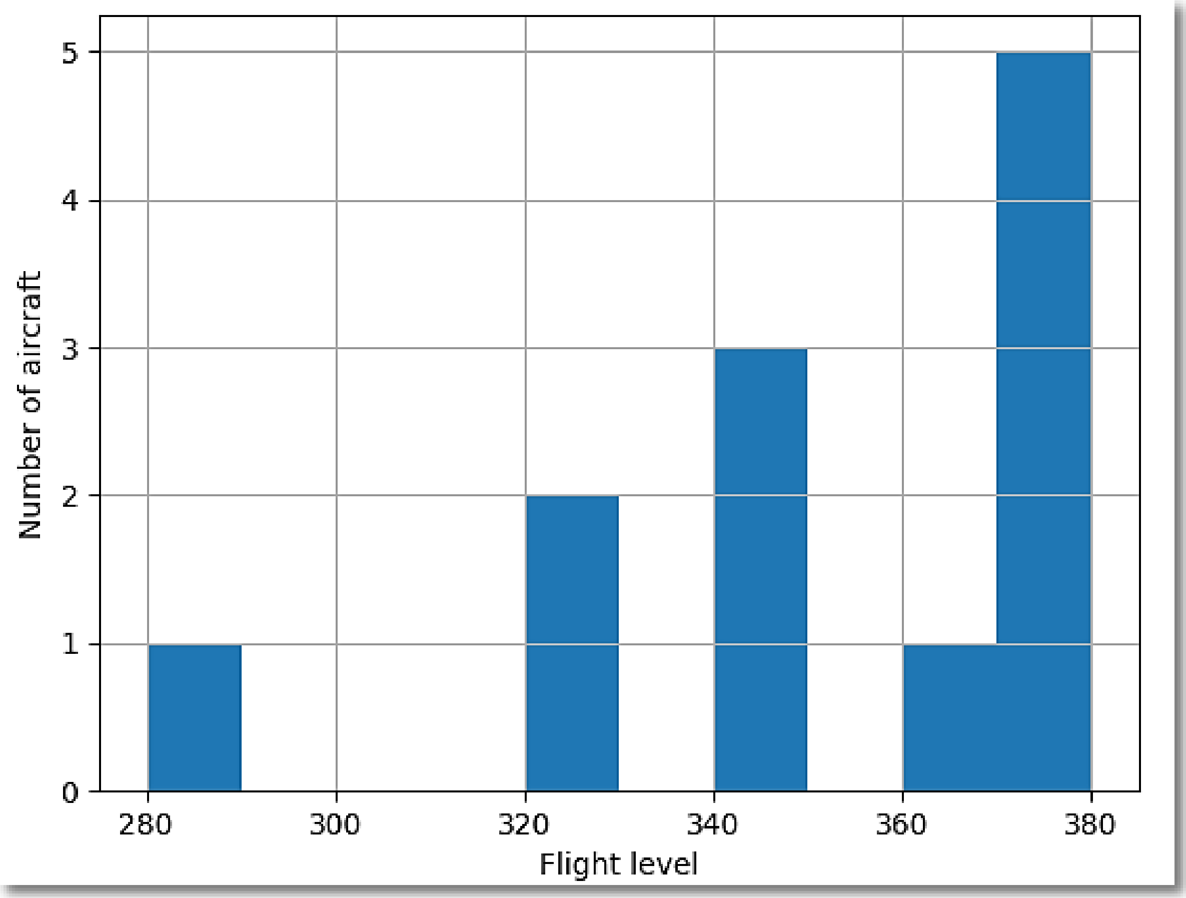
54. The analysis did not consider Eurocontrol modelling and the identification of suitable launch window that sought to select the most appropriate launch window to minimise impact on the airspace/ATM network, while satisfying specific launch orbit requirements. SaxaVord views these latter activities as key mitigation measures in minimising impact on the network.

55. SaxaVord, therefore, concludes that, even in a most limiting case, the wider ATM/airspace network and its users could incorporate the unmitigated activation of the whole of Design Option 3 with minimal/negligible impact on the baseline prevailing traffic scenario. Moreover, Design Option 3 would enable a reduced volume to be activated, commensurate with the launch profile and LV requirements; in turn, this could reduce impact further.

Additional Assessment Criteria

56. *Indirect Noise Impact.* For the sample peak day and hour, (i.e. 13 Aug 19 and 1300-1400UTC), the data shows that there were 12 flights none of which was below FL280. Consequently, there was no indirect noise impact below 7,000ft AMSL.[16]

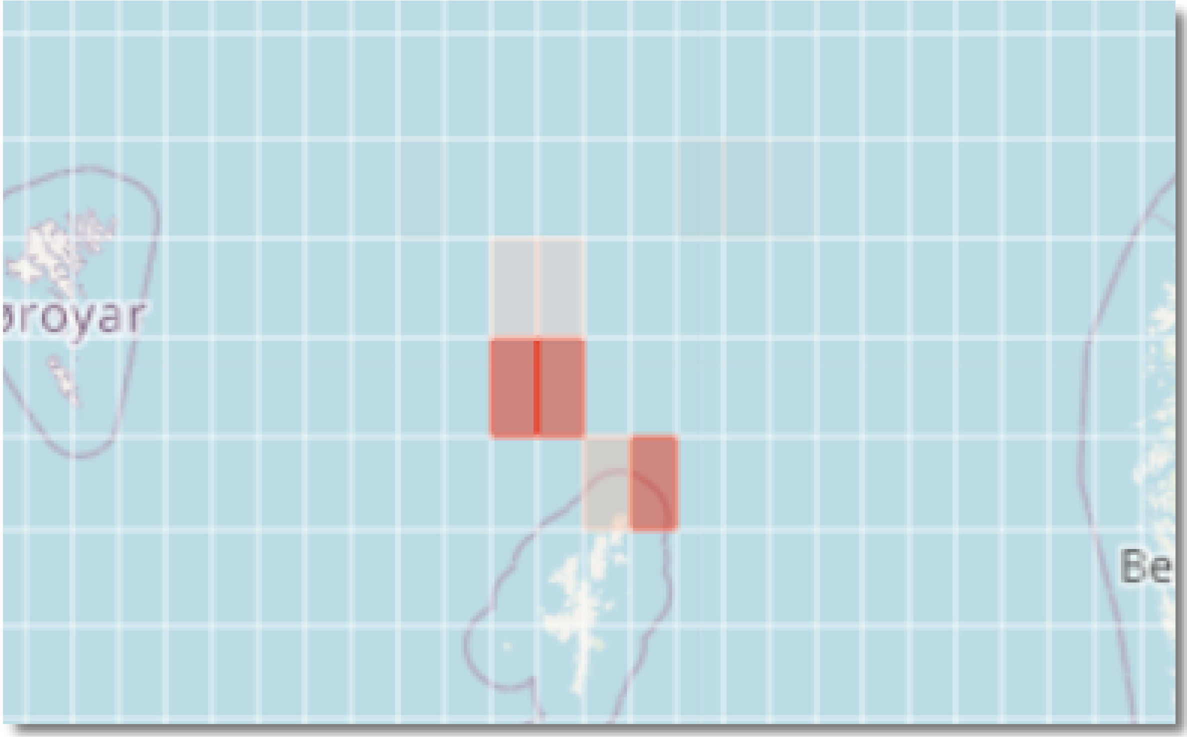
16. CAP1616, Page 26, Table 2, "Level 1" (online). Accessed 3 Jan 23.



Source: AVISU

Figure 9 - Peak Day and Peak Hour traffic Flight Levels

57. When analysing the year's traffic data solely for aircraft operating below 7,000ft AMSL within the Design Option 3 volume, the most impacted day is the 2 Aug 19 with at most 6 low-level aircraft throughput over the 24-hour period (see Figure 10, below).



Source: AVISU

Figure 10 - Traffic Below 7,000ft AMSL

58. When focussing on a single operating hour, at most only 2 aircraft are impacted and these were over the sea.

59. The surveillance data does not have flight plan information on these flights, so a re-route analysis is not possible; however, it is reasonable to assume that these could be local GA aircraft that could adjust their flight profiles and schedules to deconflict with the activation of the Design Option 3 and corresponding aeronautical restriction.

60. Thus, the activation of Design Option 3 is not considered a material change to "routes and/or traffic patterns … below 7,000 feet (above mean sea level)"; similarly, this does not precipitate a corresponding change in either emissions or noise impacts. See Appendix 1.

61. *Stage 3 Safety Statement*. SaxaVord acknowledges that "… there is no requirement for a change sponsor to undertake further safety work at this stage, where a sponsor has done so, it must include that information in the package of consultation documents."[17] The Initial Safety Statement and corresponding analysis provided at Stage 2, therefore, remain extant. Safety in the launch area will be by exclusion.

62. Launch activities by launch operators will be regulated and licenced by the CAA in accordance with the UK SIA 2018 and associated SIR. The flight safety analysis of the individual licenced launch will, therefore, dictate the need for a specific airspace reservation in the launch area. In addition, the design has been informed by representative orbital and suborbital cases that will encompass all anticipated LVs likely to use the SaxaVord launch site.

63. *Other Assessment Criteria*. See Appendix 1 for the assessment of Design Option 3 against Table E2 from CAP1616.

17. CAP1616 Page 47, Para 157.

64. *Monetisation*. Where a metric has been monetised, it should be noted that that the value(s) will be between the extremities of Baseline (i.e. no change) and the most limiting case activation of Design Option 3. Due to the numerous possible combinations of the activation of the airspace design and its impact on the wider ATM/airspace network and its users, it is not possible to monetise and quantify the individual scenarios.

SUMMARY

65. The CAP1616 Stage 3 Full Options Appraisal requires the change sponsor to develop more rigorous evidence for its remaining option(s), compared with a 'do nothing' option. SaxaVord recognises that considering any airspace design option that does not include a proportionate airspace reservation to protect airspace users from the proposed launch operations at SaxaVord (and vice versa) is untenable; consequently, a "do nothing" option was not presented to stakeholders at Stage 2, as it neither addressed the Statement of Need, nor did it align with the DPs.

66. From Stage 2, a segmented airspace design was selected. As Stage 2 progressed, however, performance data for potential LVs seeking to utilise the spaceport evolved; in turn, this precipitated a refinement of the airspace design being proposed at Stage 3. Design Option 3 further refines the box and wedge and introduces a revised segmentation mechanism within the wedge shape.

67. SaxaVord analysed surveillance data to establish a pre-COVID-19 baseline traffic assessment, from which to identify potential impacts of Design Option 3 on the traffic patterns of other airspace users. Considering macro and micro levels of airspace volumes enabled context and comparisons to be drawn and the maximum potential number of flights that could be impacted by the designs were identified; this enabled the subsequent analyses of the potential impacts of re-routing flights and an initial assessment on environmental considerations.

68. A peak day and hour were identified and, during that epoch, 12 flights could be seen to be impacted by the activation of Design Option 3. Flight distances were observed to be impacted by between -19 and +31km.

69. SaxaVord assumed an absolute worst-case scenario of an additional 31km for each flight. Extrapolating this extended flight distance across 12 flights and 30 instances (i.e. SaxaVord launches), the annual impacts for flight distance, fuel burn and CO2e could be shown to increase by 11,160km, 107tonnes and 341tonnes, respectively, representing a 0.39% (unmitigated) increase in all metrics above the measured baseline calculations. This analysis did not, however, consider Eurocontrol modelling and the identification of the most suitable launch window; SaxaVord views these latter activities as key mitigation measures in minimising impact on the network and its users.

70. Where metrics have been monetised, it should be noted that that the value(s) will be between the extremities of Baseline (i.e. no change) and the most limiting case activation of Design Option 3. Due to the numerous possible combinations of the activation of the airspace design and its impact on the wider ATM/airspace network and its users, it is not possible to monetise and quantify the full gamut of possible individual scenarios.

71. SaxaVord, therefore, concludes that, even in a most limiting case, the wider ATM/airspace network and its users could incorporate the activation of Design Option 3 with minimal/negligible impact on the baseline prevailing traffic scenario. Moreover, the inherent flexibility of Design Option 3 would enable a reduced airspace volume, commensurate with the launch profile and LV requirements, to be incorporated more readily, reducing impact further.

72. As a result of the foregoing, Design Option 3 will be taken forward and inform the stakeholder consultation activities in Stage 3.

Appendix:

1. ACP-2017-079 CAP1616 Table E2 - Design Option 3.

ACP-2017-079 CAP1616 TABLE E2 - DESIGN OPTION 3

Group	Impact	Level of Analysis	SaxaVord Response
Communities	Noise impact on health and quality of life	Monetise and quantify	DIRECT - The direct impact of noise due to vertical launch spaceflight activities at SaxaVord Spaceport was assessed in SaxaVord Spaceport AEE V2.1 Assessment of Environmental Effects dated 30 Sep 22 submitted to the CAA as part of Space Industry Act 2018 licensing activities. Volume II Chapter 8[18,19] considers noise and vibration. In addition, Volume IV Appendix 8.1 contains a copy of a report commissioned by SaxaVord from Blue Ridge Research and Consulting LLC (BRRC) titled "Noise Study for Launch Vehicle Operations at Shetland Space Centre" dated 02/10/20. The parts of the AEE related to noise (including the BRRC report) are external to this document but have been submitted previously at Stage 2. Prediction of noise associated with launch vehicles (LVs), including static engine tests and launches, has been undertaken by BRRC. BRRC is an acoustical engineering consultancy focused on critical noise and vibration challenges for aerospace, aviation, and US Department of Defense projects. With experience from more than 250 civilian and military noise studies, BRRC's team of acoustical engineers is recognised as a trusted advisor to public, private, and academic clients in the space industry around the world. BRRC utilise RUMBLE noise modelling software as recognised in CAP1766. In advance of the CAA publishing a guidance document on environmental assessment requirements for space ACPs, SaxaVord has referred to the following: - Guidance to the regulator on environmental objectives relating to the exercise of its functions under the Space Industry Act 2018. • *"Guidance to the regulator on environmental objectives relating to the exercise of its functions under the Space Industry Act 2018"*. - Air Navigation Guidance 2017. • *UK Air Navigation Guidance 2017*. - Additional guidance under s70(2)(ca) Transport Act 2000: Carrying out air navigation functions for the purpose of spaceflight activities. Date 16 Sep 21.

18. ITPEnergised (2022), "*SaxaVord Spaceport (ITPEnergised) AEE*", V2.1, dated 30 Sep 22. Chapter 8 (Noise and Vibration) of the AEE document was extracted and submitted to CAA to support Stage 2. Available at https://consultations.caa.co.uk/ (online). Accessed on 3 Apr 23.
19. SaxaVord Spaceport AEE is currently under evaluation by the CAA's Commercial Space Regulation team; therefore, results for environmental impacts from direct space launch events presented in this appendix and the wider ACP may be subject to change following the CAA's evaluation.

Group	Impact	Level of Analysis	SaxaVord Response
Communities	Noise impact on health and quality of life (contd)		• *"Additional guidance under s70(2)(ca) Transport Act 2000: Carrying out air navigation functions for the purpose of spaceflight activities"*. The following analysis is, therefore, presented: - "When assessing distinct and infrequent noise, such as rocket noise, measures of single events such as the maximum noise level (LAmax) and the sound exposure level (SEL or LAE) are most appropriate". See AEE section 8.8. • The closest residence highest predicted level occurs during launches with a predicted level of 102 dBL_{Amax} [AEE 8.8.14]. Hearing damage limit 110 dBL_{Amax} • There are no residences within the predicted level contour 120 dBL_{max} [AEE 8.8.27]. Structural damage limit 120 dBL_{max} • The highest predicted level at Herma Ness occurs during a launch from Launch Pad 1 and is 87 dBL_{Amax} - "Where the rocket launch noise footprint could result in exposures in excess of 80, 85, 90, 95 and 100 dBLASmax, these areas will be published on suitable maps and used to communicate with local stakeholders". • This will be done for actual launches based on individual launch operator's LV data. • Modelled noise for a SaxaVord representative LV launch from SaxaVord Spaceport Launch Pad 1 (LP1) is at Figure 11, below.

Group	Impact	Level of Analysis	SaxaVord Response

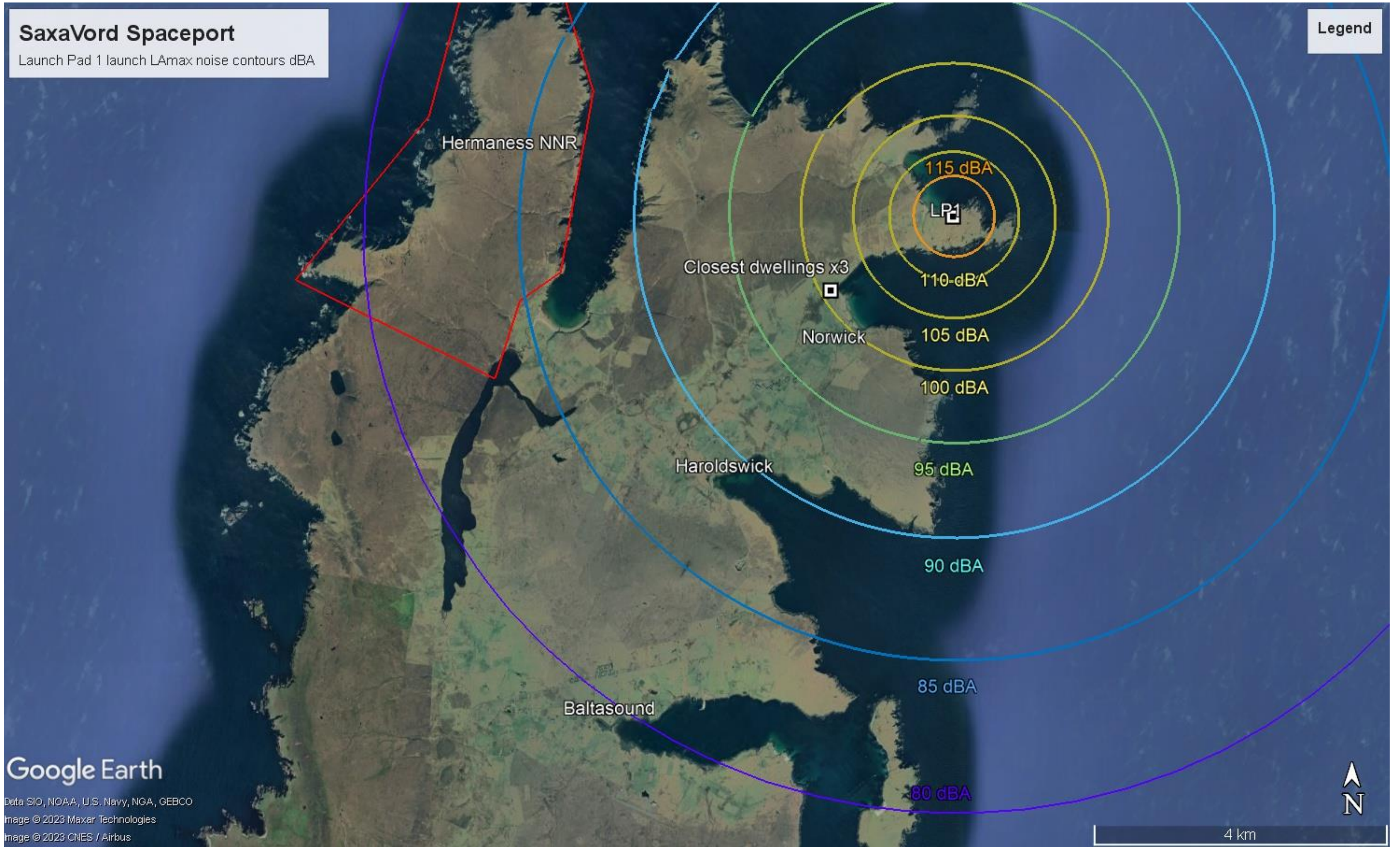


Figure 11 - SaxaVord Spaceport LP1 Launch LAmax Noise Contours dBA

<table>
<tr><th>Group</th><th>Impact</th><th>Level of Analysis</th><th>SaxaVord Response</th></tr>
<tr><td>Communities</td><td>Noise impact on health and quality of life (contd)</td><td></td><td>
- Sonic booms.
  • The sonic boom from launches is predicted to occur 60 km out to sea, away from populated areas; therefore, further consideration of air overpressure effects on structures and human receptors is not made [AEE 8.1.7].
- Sleep disturbance. See AEE 8.8.17-18.
  • Using the probability of awakening function given in the “Guidance to the regulator on environmental objectives relating to the exercise of its functions under the Space Industry Act 2018” and population data[20] aligned to noise level data from LP1 in Figure 11, above, gives the following data:
<table>
<tr><th>Location (Noise contour band)</th><th>Input value dB L_{Amax}</th><th>$P_{awakening}$</th><th>Population</th><th>Number of awakenings</th></tr>
<tr><td>Closest residences</td><td>102</td><td>0.17</td><td>8</td><td>1</td></tr>
<tr><td>100-95</td><td>100</td><td>0.17</td><td>32</td><td>5</td></tr>
<tr><td>95-90</td><td>95</td><td>0.16</td><td>94</td><td>15</td></tr>
<tr><td>90-85</td><td>90</td><td>0.15</td><td>40</td><td>6</td></tr>
<tr><td>85-80</td><td>85</td><td>0.15</td><td>130</td><td>19</td></tr>
<tr><td></td><td></td><td>Totals</td><td>304</td><td>46</td></tr>
</table>
Table 4 - Sleep Disturbance
  • For any one night launch it is estimated that 46 people out of a local population of 304 will be awakened
  • For the closest residence the noise level will have dropped back to baseline ambient level approximately 200 seconds after the launch (AEE 8.8.9).
  • On any one night, it is anticipated that there will be only one launch event of short noise duration (200 seconds at the closest residence). Furthermore, due to the low number of night launches expected across a year (approximately 10) this will further reduce the likelihood of any adverse effects on health due to night-time awakening.
  • Given the proposed frequency of launches and the short duration of the noise events associated with launches, and with reference to the 2006 Basner study which states that restricting additional awakenings due to aircraft noise to a maximum of one event per night is anticipated to have no adverse effect on human health, adverse effects associated with sleep disturbance due to night-time launches are considered to be minimal.
</td></tr>
</table>

20. Technical note ACP-2017-079 5 Apr 23 V1.0.

Group	Impact	Level of Analysis	SaxaVord Response
Communities	Noise impact on health and quality of life (contd)		INDIRECT - When the airspace is active no aircraft will be permitted to overfly or fly adjacent to the communities local to the spaceport. Hence, the indirect impact of aircraft noise on the local community due to the proposed airspace change will be no worse than the baseline condition. See Paras 56-60, above, for assessment of "Re-route Indirect Noise Impact from Airspace Activation". The activation of Design Option 3 is not considered a material change to "routes and/or traffic patterns … below 7,000 feet (above mean sea level)"; similarly, this does not precipitate a corresponding change in concomitant noise impacts. There is no requirement to monetise noise impacts as per the "Additional guidance under s70(2)(ca) Transport Act 2000".
Communities	Air quality	Qualitative or monetise and quantify, depending on the scope of the proposal	DIRECT - See SaxaVord Spaceport AEE V2.1 Assessment of Environmental Effects dated 30 Sep 22 submitted to the CAA as part of Space Industry Act 2018 licensing activities. The Non-Technical Summary (NTS) of this AEE has been submitted previously to support Stage 2. See Shetland Space Centre AEE Non-technical Summary, Chapter 11 and Chapter 16, specifically, Para 1.7.4: "Launch event emissions are predicted to have no perceptible impact at any identified receptors under prevailing wind directions. The maximum predicted impact at a sensitive receptor is predicted to occur with north-easterly winds which occur typically for less than 10% of the year. The maximum predicted 8-hour concentration of CO is 28% of the AQS. Emissions from launch events are therefore considered to have an effect of negligible significance on air quality, therefore resulting in no likely significant effect." INDIRECT - Not applicable; traffic data shows that there is negligible flying activity at or below 1000ft AMSL on the Shetland Islands. Design Option 3 does not, therefore, impact either traffic dispersion or total aircraft emissions below 1,000feet AMSL (CAP1616, Page 157, Appendix B, Para B14). Consequently, there is no corresponding impact on air quality associated with the activation of Design Option 3. Given the negligible traffic operating at 1000ft or below within the vicinity of the SaxaVord site, the extensive modelling required to monetise any variance in such a negligible number of aircraft movements is disproportionate.

Group	Impact	Level of Analysis	SaxaVord Response
Wider Society	Greenhouse gas impact	Monetise and quantify	DIRECT - A planning application for the Proposed Project was lodged with Shetlands Islands Council in Jan 21 and planning permission granted on 30 Mar 22 (document reference 2021/005/PPF). An environmental impact assessment was undertaken as part of the planning application for the Proposed Project and an Environmental Impact Assessment Report (EIAR) produced. Document reference: ITPEnergised (January 2021) *"Shetland Space Centre Environmental Impact Assessment Report (3148_1)"*. EIAR (with the rest of the planning documents) remain available online[21]. The chapter of the EIAR related to climate change (Chapter 15[22]) was extracted and submitted previously to support Stage 2; specifically, see Para 15.8.18: "Launch campaigns will directly result in up to 764 tCO_2e annually, as the rocket engines consume RP-1 fuel which has a high carbon content. The site will have capacity to support 30 launches per year, each generating an average of 25.45 tCO_2e" 764tCO_2e x \$93.93/tonne[23] = \$71,762.52 This is based on a typical liquid oxygen and kerosene low earth orbit capable launch vehicle that may launch from SaxaVord. This is a limiting case as it is expected that not all of the 30 launches in a year will be of launch vehicles this large. SaxaVord acknowledges that fuel technologies are constantly evolving and will encourage spaceport users to implement the use of propellants that are less harmful to the environment into their operations. INDIRECT - The most limiting case activation of Design Option 3 at the peak hour of the peak day in the traffic sample on 30 instances (i.e. SaxaVord launches) could precipitate an annual impact of an additional 341tonnes of CO_2e. See Paras 37-41, above, "Annual Traffic Re-route, Fuel Burn and CO_2e Impact Assessment". 341tonnes x \$93.93/tonne[24] = \$32,030.13 Monetisation of Design Option 3 impact on CO_2e will be between the extremities of Baseline (i.e. no change) and the most limiting case activation of Design Option 3; the total monetised additional direct and indirect impact cost of CO_2e could be up to \$103,792.65.
Wider Society	Capacity/resilience	Monetise and quantify	Not applicable; Design Option 3 would not impact the capacity/resilience of the wider UK airspace infrastructure.
General Aviation	Access	Monetise and quantify	Not applicable; Design Option 3 would have a negligible impact on the minimal general aviation operations in Unst.
General Aviation/ commercial airlines	Economic impact from increased effective capacity	Quantify	Not applicable; Design Option 3 would not impact forecast increase in air transport movements and estimated passenger numbers or cargo tonnage carried.

21. Shetland Islands Council (2023), *"2021/005/PPF \| Vertical launch space port including launch pad complex, satellite tracking station, assembly and integration hangar buildings, with associated security fencing, access, servicing and infrastructure \| Land at Lamba Ness, Unst, Shetland"* (online). Accessed on 4 Apr 23.
22. EIA Chapter 15 (online). Accessed on 4 Apr 23.
23. carboncredits.com (2023) (online). Accessed on 16 Mar 23. BBC News - Market Data (2023) (online). Accessed on 16 Mar 23. €1.00 = \$1.0613.
24. *ibid*.

Group	Impact	Level of Analysis	SaxaVord Response
General Aviation/ commercial airlines	Fuel burn	Monetise and quantify	The most limiting case activation of Design Option 3 at the peak hour of the peak day in the traffic sample on 30 instances (i.e. SaxaVord launches) per annum could precipitate an annual impact of an additional 107tonnes of fuel burn. See Paras 37-41, above, "Annual Traffic Re-route, Fuel Burn and CO2e Impact Assessment". 107tonnes of aviation (jet) fuel x $862.74[25] = $92,313.18 Monetisation of Design Option 3 impact on fuel burn will be between the extremities of Baseline (i.e. no change) and the most limiting case activation of Design Option 3 shown here.
Commercial airlines.	Training costs	Monetise and quantify	Not applicable. Airspace reservations and their management, by both pilots and ANSPs are a routine occurrence in aviation; Design Option 3 would not impose an additional training burden on commercial airline operations.
Commercial airlines	Other costs	Qualitative	Not applicable; Design Option 3 would not impose quantifiable other costs on commercial aviation.
Airport/Air navigation service provider	Infrastructure costs	Monetise and quantify	Not applicable. Airspace reservations and their management, by both pilots and ANSPs are a routine occurrence in aviation. Design Option 3 would not impose a change in ANSPs' infrastructure.
Airport/Air navigation service provider	Operational costs	Monetise and quantify	Not applicable. Airspace reservations and their management are a routine occurrence for ANSPs. Design Option 3 would not impose a change in ANSP operational costs.
Airport/Air navigation service provider	Deployment costs	Monetise and quantify	Not applicable. Airspace reservations and their management are a routine occurrence for ANSPs. Design Option 3 would not impose a retraining and deployment cost burden on ANSPs.

Table 5 - Table E2 Guide to Expected Approach to Key Analysis for a Typical Airspace Change

25. IATA (2023), "*Jet Fuel Price Monitor*" (online). Accessed 16 Mar 23. Price point: 10 Mar 23.