



LANDING AND TAKEOFF NOISE PREDICTION OF CONCEPTUAL SUPERSONIC AIRCRAFT

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Abstract

The biggest challenge in the design of commercial supersonic aircraft is the trade-off between minimizing drag and thus fuel consumption during supersonic cruise while reducing noise levels in areas close to the airport. In this study, two different conceptual designs of supersonic aircraft platforms - a business jet with a cruise speed of $Ma=1.4$ and an airliner with $Ma=1.8$ are used to investigate advanced take-off procedures to meet the required noise levels. In addition, the impact of engine technologies specific to supersonic applications, such as variable area nozzles on certification levels is examined. It is demonstrated that both aircraft can meet Chapter 14 noise certification requirements with significant margins.

Keywords: Supersonic Aircraft, Landing and Take-off Noise, Advanced Procedures

1. Introduction

Various manufacturers worldwide are again actively engaged in the research and development of the next generation of commercial supersonic aircraft. Among others, Boom Supersonic has disclosed plans for an airliner cruising at Mach 1.7 and a passenger capacity of up to 80 [1]. In terms of noise emissions, supersonic aircraft face two major challenges: (1) the landing and take-off (LTO) noise and (2) the sonic boom. It is expected that the upcoming generation of supersonic aircraft will be restricted to fly at subsonic speeds over land. This restriction stems from the fact that technologies for low-boom designs, which aim to mitigate the disruptive effects of supersonic booms, have not yet achieved market readiness. The potential impact of the sonic boom of conventional supersonic aircraft on people, animals and buildings is still considered unacceptable. As a result, several countries have banned supersonic flight over land, and supersonic speeds over water are also subject to restrictions with a necessary buffer distance from the coastline, as the secondary boom can propagate over long distances depending on the prevailing atmospheric conditions. Thus, the presented study will focus on LTO noise. Supersonic aircraft exhibit some fundamental differences to subsonic aircraft with regard to trade-offs between cruise performance and LTO noise. Whereas subsonic aircraft benefit from larger bypass ratios and consequently larger engine diameters both for cruise efficiency and LTO noise, for supersonic aircraft it is necessary to minimize the engine diameter in order to reduce the pressure drag for transsonic and supersonic speeds. On the other hand, the engine diameter has to be large enough to ensure subsonic jet velocities at takeoff conditions for noise certification. Additionally, airframes optimized for supersonic flight generally have higher minimum

drag speeds, resulting in a higher thrust requirement during takeoff compared to subsonic airframes. Unlike subsonic aircraft, which require the highest specific thrust during takeoff, supersonic aircraft require the highest specific thrust during cruise, resulting in excessive engine thrust for takeoff. These fundamental differences could cause supersonic aircraft to be unnecessarily noisy when using the conventional take-off procedures, and possibly not meet the certification limits for subsonic aircraft.

Recently, some manufacturers have reached a stage of development that necessitates the International Civil Aviation Organization (ICAO) to define applicable regulation standards. The certification regulations should ensure that supersonic aircraft are as sustainable as possible and are indistinguishable from conventional aircraft in terms of noise annoyance. However, governing bodies responsible for certification lack data on supersonic aircraft considering the latest airframe and engine technologies, as the last civil supersonic flight with the Concorde, a design of the 1960s was over 20 years ago. This gap must be closed by scientific studies that are made available to the ICAO CAEP working groups. Initial studies on supersonic business jets noise have been carried out by NASA [2] [3], JAXA [4] and DLR [5], for example. Further studies would be beneficial for the establishment of updated regulations in order to have as comprehensive data as possible including variations in cruise speed, aircraft size, number of engines, etc.

The EU project SENECA (LTO noiSe and EmissioNs of supErsoniC Aircraft, 2021-2024¹) aims to address this need and this study presents some of the results of this project. In SENECA, four different conceptual aircraft platforms were designed, ranging from business jets with cruise speeds of $Ma=1.4$ and $Ma=1.6$ to airliners cruising at $Ma=1.8$ and $Ma=2.2$. For each aircraft, an engine has been developed and optimized to reduce LTO noise and emissions. In line with the ICAO CAEP activities this paper focuses on the noise assessment of the $Ma=1.4$ Business Jet (referred to as Supersonic Business Jet, SSBJ) and the $Ma=1.8$ Airliner (referred to as Supersonic Airliner, SSAL). Preliminary low-fidelity results of the $Ma=2.2$ airliner were published by Villena Munoz [6]. Both the airframe and the engine designs of the two aircraft are presented in the section 2. The noise assessment taking into account the advanced take-off procedures and supersonic specific engine technologies is presented in section 5.

2. Aircraft Platforms

In order to conduct the certification noise assessment, representative aircraft platforms need to be chosen first. This section describes the general platform as well as the engine design for each of the two platforms considered.

2.1 Airframes

The aircraft platforms, including airframes and engines, are conceptual designs at a pre-design level. The platforms are defined to cover very different SST (supersonic transport) concepts: a business jets cruising at $Ma=1.4$, the lowest economically feasible cruise speed and a representative passenger aircraft cruising at $Ma=1.8$. The main design parameters are listed in Table. 1. Both aircraft have a range of at least 4000 nm to allow transatlantic flights. Further details on aircraft designs and specifications are given by Munoz et al. [7, 8].

2.2 Engines

New engines were designed for each aircraft platform. They were optimized for efficiency and thrust demand of the overall flight mission profiles while not jeopardizing the LTO noise certification limits. These are conflicting design goals, because cruise efficiency increases with a low Bypass Ratio and small engine diameter. This also increases the jet velocity during operation which is a significant driver of engine noise. The engine for the $Ma=1.4$ twin jet was designed by Rolls-Royce Deutschland and for the $Ma=1.8$ quad jet by German Aerospace Center (DLR) [9]. Only current technologies with a potential entry into service 2025 to 2035 were considered.

¹<https://seneca-project.eu/>

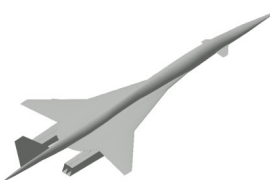
		
Cruise Mach number	1.4	1.8
Passengers	6	100
Range [<i>nm</i>]	4000	4000
MTOM [<i>kg</i>]	41697	144277
Number of engines	2	4
Wing area [<i>m</i> ²]	174.9	427.3
Wing loading [<i>kg/m</i> ²]	238.40	337.65
Overall length [<i>m</i>]	43.6	71.6
Span [<i>m</i>]	16.0	35.0

Table 1 – SENECA SST aircraft platform specifications

Aircraft	Ma 1.4 SSBJ	Ma 1.8 SSAL
Engine Architecture	2-stage fan, variable throat nozzle	2-stage fan, variable throat nozzle
Net thrust per engine, [<i>kN</i>]	62	133
TSFC, [<i>g/kNs</i>]	-	17.1
Fan diameter, [<i>m</i>]	1.35	1.64
Bypass ratio	2.04	3.19
Fan pressure ratio	1.79	1.94
OPR	18.5	21.9

Table 2 – Engine specifications at sea level, EOF ISA+10K (SSBJ) and +15K (SSAL) with Ma=0.25

3. Noise Assessment Methodology

This section covers the noise sources considered and the assumptions made in the noise assessment of the aircraft in question. The evaluation is conducted by different partners within the SENECA project: the Ma=1.4 SSBJ is assessed by Rolls-Royce Deutschland (RRD), while the Ma=1.8 SSAL is assessed by the DLR.

3.1 Noise Source Modelling

Installed jet noise scales approximately with the sixth power of jet velocity, so due to the small bypass ratio and associated high velocity, the jet is the dominant noise source at take-off. In order to increase the reliability of jet noise prediction, the project consortium has conducted a successful jet noise prediction benchmark test using different versions of Stone's empirical jet noise prediction model [10]. That activity is complemented by small-scale jet noise tests conducted at the NLR, which will also be used for validation purposes [11]. The models chose to calculate the jet noise are an in-house model developed by RRD and the Stone model of 1983 [12] for the SSBJ and SSAL respectively.

For fan noise prediction, an in-house method developed by RRD as well as an analytical method developed by DLR called PropNoise [13] are used. Especially for multi-stage fans, it is expected that the analytical method will provide more reliable results than empirical models such as the Heidmann model [14] or its updates by Kontos [15] and Krejsa [16].

Other noise sources typical for turbomachinery - compressor, combustor and turbine noise - are considered by RRD for the SSBJ using in-house models. Since these sources have been found to be

insignificant for the SSAL in preliminary studies, they are disregarded here.

Airframe noise was not assumed to be a dominant source, but was modelled for a representative trajectory using the NAU modification of the semi-empirical Fink model [17]. As expected this noise source was insignificant compared to engine noise and will not be discussed in this study.

The following assumptions are made in the noise source modelling:

- Airframe noise can be neglected
- No parasitic noise from the variable intake
- No parasitic noise from the variable nozzle
- The variable intake is closed in LTO operation
- The inflow into the engine is perfectly uniform
- The jet is a perfectly mixed single stream

3.2 Liners

Especially with the long intake, bypass and nozzle sections and small diameter of supersonic aircraft engines, the effect of liners on engine noise is essential for its assessment. The high ratio of component length to component diameter, L/D , makes liners particularly effective. Without liners, the transsonic fan will be the dominant noise source on both take-off and landing, as demonstrated by Graebert et al. [18].

The integration of liner effects into the noise assessment varies between the platforms: for the engine of the $Ma=1.4$ business jet, designed by RRD, the surfaces into which liners can be integrated are calculated. DDOF liners are assumed to be used in the intake ($L/D=1.115$) and SDOF liners in bypass duct ($L/D=6.89$) and thrust reverser section ($L/D=1.136$). In-house models are used to predict their respective impedance.

For the $Ma=1.8$ airliner, such models are not available, so a coarser assumption has to be made: since it can be assumed the liners work perfectly during take-off, their design point, a conservative attenuation of -20dB per L/D for tones and -10dB per L/D for broadband noise is assumed. This is applied to all frequencies, assuming that a perfectly tuned liner would be able to dampen the dominant frequency band. Superfluous attenuation of non-dominant components is assumed not to have a significant impact on the overall noise. For the approach, at significantly lower fan speeds, only partial effectiveness can be expected. The assumed liner attenuation is displayed in Table 3.

	Inlet	Bypass
L/D [-]	1.5	6.0
Take-Off Broadband attenuation [dB]	-15	-60
Take-Off Tone attenuation [dB]	-30	-120
Approach Broadband attenuation [dB]	-10.5	-42
Approach Tone attenuation [dB]	-21	-84

Table 3 – Assumed liner attenuation for M1.8 SSAL

3.3 Immission Modelling

The immission from source to the noise certification points is modelled differently by each partner. The models are listed in the Table 4

Atmospheric absorption	DLR ISO 6913-1[19]	RRD SAE ARP 866[20]
Installation effect	SAE AIR 5662[21]	RR VN02
Ground attenuation	SAE AIR 5662	SAE AIR 5662
Doppler shift	Included	Included

Table 4 – Models included in immission simulation by each partner

3.4 Certification Noise Limits

The certification noise limits for both aircraft platforms, outlined in ICAO Annex 16, Volume 1, Chapter 14, are displayed below.

	MTOM	Engines	Lateral	Flyover	Approach	Cumulative
Ma=1.4 SSBj	41697kg	2	94.0	88.0	97.9	265.9
MA=1.8 SSAL	144277kg	4	98.2	99.3	101.8	285.3

Table 5 – Chapter 14 noise certification limits

4. Landing and Take-Off Noise Reduction Measures

In order to reduce LTO noise, a change to take-off and landing procedures is considered for supersonic aircraft. Due to their poor low-speed aerodynamics and higher thrust availability, a departure from the procedures developed for subsonic aircraft can yield advantages. However, only advanced take-off procedures will be discussed in this paper.

4.1 Landing

The landing will be conducted with a regular 3° glideslope approach at a constant speed. The SSALs approach speed is $V_{AT} = 137kts$ which puts it in ICAO Approach Speed Category C., the SSBj's approach speed is $V_{AT} = 105kts$, corresponding to Category B.

With this glide path, the Approach noise certification point is passed at a height of 120m.

4.2 Advanced Take-off Procedures

As early as 1979, Grantham and Smith [22] assessed the LTO procedures of a supersonic aircraft with a payload of 273 passengers travelling at Mach 2.62 for community noise abatement purposes. They suggested a fast climb-out at a lower climb rate to overcome the so-called region of reversed command, where flying slower requires more thrust to overcome increasing lift-dependent drag. In order to also reduce the lateral certification levels, they proposed a thrust reduction prior to the cut-back point. This has since become known as a programmed thrust lapse rate (PLR) take-off. To ensure the same level of thrust reduction in day-to-day operations and to avoid additional workload on the flight crew during take-off, only a fully automatic FADEC (Full Authority Digital Engine Control) controlled thrust reduction should be considered for new certification procedures, in addition to allowing a higher climb out speed $V_2 + X$.

In addition to the thrust reduction at PLR and the take-off speed, there are four other degrees of freedom for the advanced take-off procedure: (1) the PLR activation height with a lower limit of the obstacle avoidance height of 35 ft, (2) the slope of the thrust reduction, which was investigated by Berton et al. [3] to also have an effect on certification levels, (3) a delayed rotation, where more speed is built up before rotation than the usual/minimum rotation speed and (4) the take-off thrust itself. In contrast to subsonic aircraft, supersonic aircraft have much more thrust available than is necessary for a safe take-off. Since the take-off thrust can be limited by the FADEC, it can be set to arbitrary level so long as mandated safety margins, depending on the runway length, are kept. The thrust setting and airspeed after take-off, which determine the maximum climb performance of the aircraft, will certainly have an effect on the noise certification levels. The trade-off occurring when using PLR

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is having a lower thrust level and thus lower noise levels at the lateral certification point, but also a decreased climb performance, lower flyover height and thus higher noise levels at the flyover point.

A diagram of the parameters and sections of an advanced take-off can be seen in Figure 1 and examples of advanced take-off trajectories in contrast to a baseline trajectory are displayed in Figure 2.

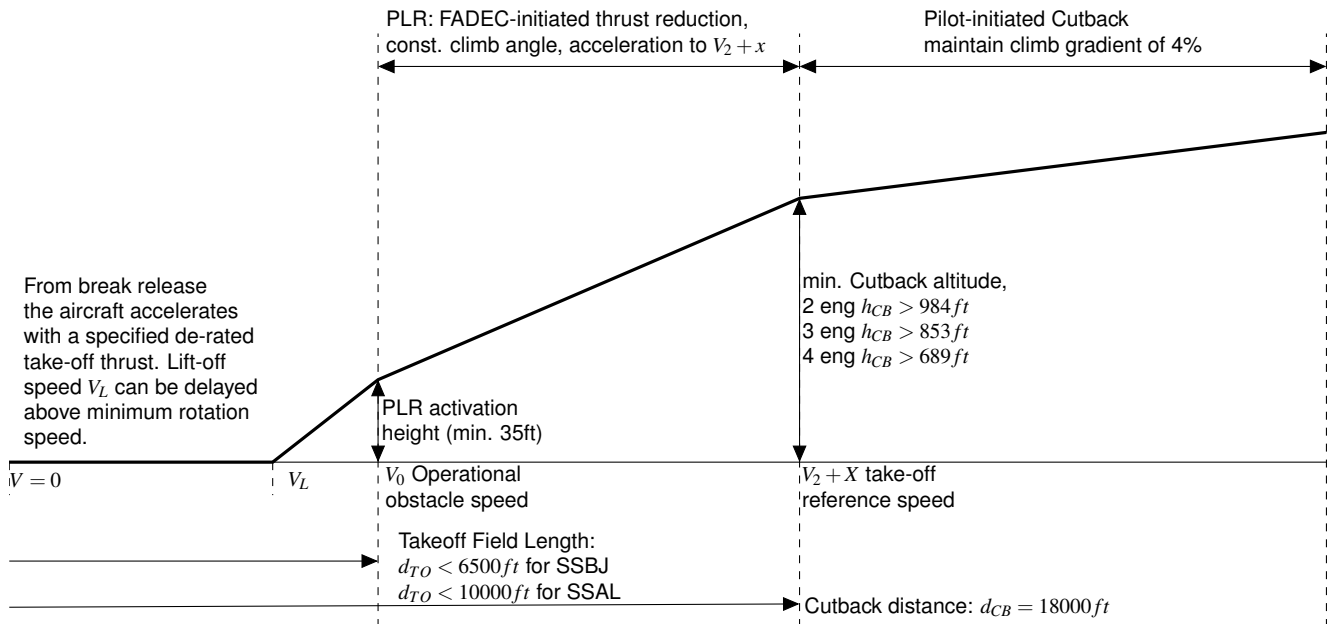


Figure 1 – Definitions of an advanced take-off trajectory (angles and lengths are not to scale and are exaggerated for illustration).

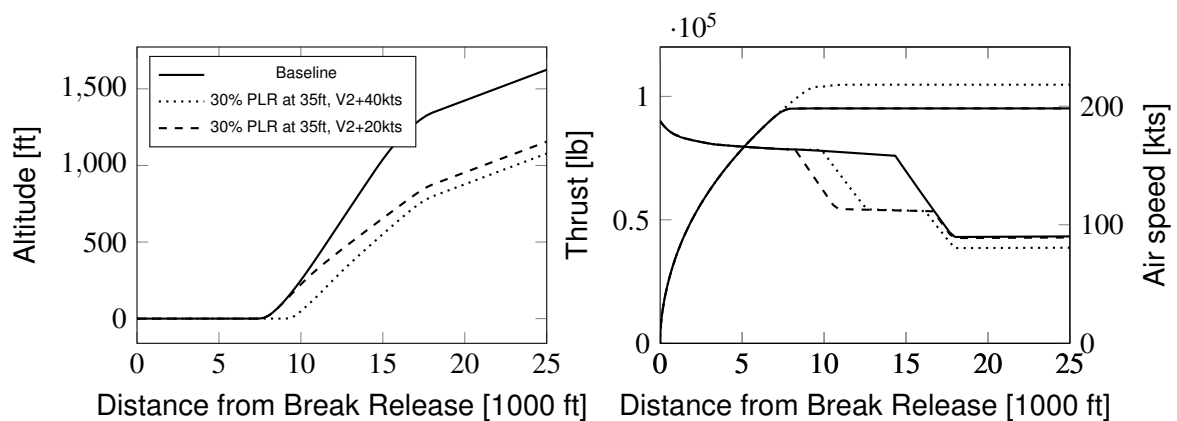


Figure 2 – Exemplary takeoff trajectories. Variation of thrust for a conventional subsonic take-off procedure and an advanced take-off procedures for commercial supersonic aircraft

The considered trajectory variations for the SSBJ and SSAL are displayed in Table 6.

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	Ma=1.4 SSBJ	Ma=1.8 SSAL
De-rated Take-Off Thrust[%]	100%	45%, 50%, 60%
PLR [%]	80%	90%, 80%, 70%
PLA activation height [ft]	35	35, 200
Climb-out speed [kts]	$V_2 + 20, V_2 + 40, 250$	$V_2 + 20, V_2 + 40, V_2 + 55, 250$
Delayed rotation speed [kts]	Optimized for noise	

Table 6 – Trajectory variations for both aircraft platforms

In this table, the de-rated take-off thrust scaled with the maximum available thrust, which is defined as the thrust at 100% fan speed with a nozzle setting to maximize efficiency (fully expanded jet at nozzle exit). With an open nozzle throat, the SSAL's fan operates very close to choking conditions, so the thrust that is available in realistic conditions is limited. This is the reason for the high de-rate. The PLR value is scaled with the thrust at PLR initiation, so the resulting thrust is dependent on the chosen take-off thrust.

For each trajectory, the climb is maximized before cutback as long as the target climb-out speed can be met, then minimized to 2.3° at the cutback point to minimize the thrust setting.

The limitations for each platform are displayed below:

	Ma=1.4 SSBJ	Ma=1.8 SSAL
Balanced field length [ft]	6500	10000
Minimum cutback altitude [ft]	984	689
Minimum climb angle [deg]	2.3	
Maximum climb-out speed [kts]	250	

Table 7 – Trajectory limitations for both aircraft platforms

Due to either cutback height or minimum climb limits not being met at lower thrust settings, the trajectory variations documented in Table 6 do not form a perfect matrix. For the 45 and 50% de-rated thrust take-offs, high climb-out speeds could not be achieved without violating these limits, so the respective trajectories have been eliminated from the following comparisons.

4.3 Engine Design Features

In addition to the advanced take-off procedure, the impact of engine design features on certification noise levels is being investigated, with a focus on nozzle design. Engines for supersonic aircraft will require variable features to ensure stable operation over the entire operating range. This can be achieved by using a variable inlet or a variable throat nozzle. The latter can be used to keep jet speeds subsonic during take-off and to shift the fan operating point closer to the optimum, both of which reduce noise. This is investigated for the SSBJ for the standard and advanced take-off procedures. For the advanced procedure, a 10% thrust reduction (90% PLR) is used at the same take-off speed as for the standard procedure. For the standard procedure a noise reduction of 2.3 cumulative EPNdB (Effective Perceived Noise dB) was achieved. For the advanced take-off procedure a cumulative reduction of 1.1 EPNdB was achieved. The results can be seen in Table 8.

Margin to Chapter 14 [Δ EPNdB]	Lateral	Flyover	Approach	Cumulative
Standard procedure, nozzle closed	-0.7	6.9	8.5	0.6
Standard procedure, nozzle open	1.0	8.1	7.6	2.9
Advanced procedure, nozzle closed	1.3	11.5	7.9	6.7
Advanced procedure, nozzle open	2.6	11.4	7.8	7.8

Table 8 – Impact of Variable Throat Nozzle on LTO certification levels

Fan stages for supersonic aircraft engines are subject to very high loads due to their relatively small diameter compared to conventional subsonic aircraft engines and the much higher pressure ratios. This leads to the question of whether the load should be split between two fan stages, at the trade-off of increased weight and cost. Gräbert et al. [18] have presented a detailed multi-dimensional optimization design process of a single and a two-stage fan for the Ma=1.8 Airliner engine, including aerodynamic and noise analysis. As a consequence of these findings, a two-stage fan design was chosen. The details of this design process and its results are not within the scope of this study and will be presented by the authors in another publication.

5. Noise Assessment

For both SSBJ and SSAL, certification noise levels have been calculated. For the SSBJ, the focus was on the variation of climb-out speed and nozzle operation. For the SSAL, multiple trajectory variations have been explored and trends discovered. These results will be discussed in this section, with the results being presented as margins to the Chapter 14 certification noise limits.

5.1 Ma1.4 Business Jet

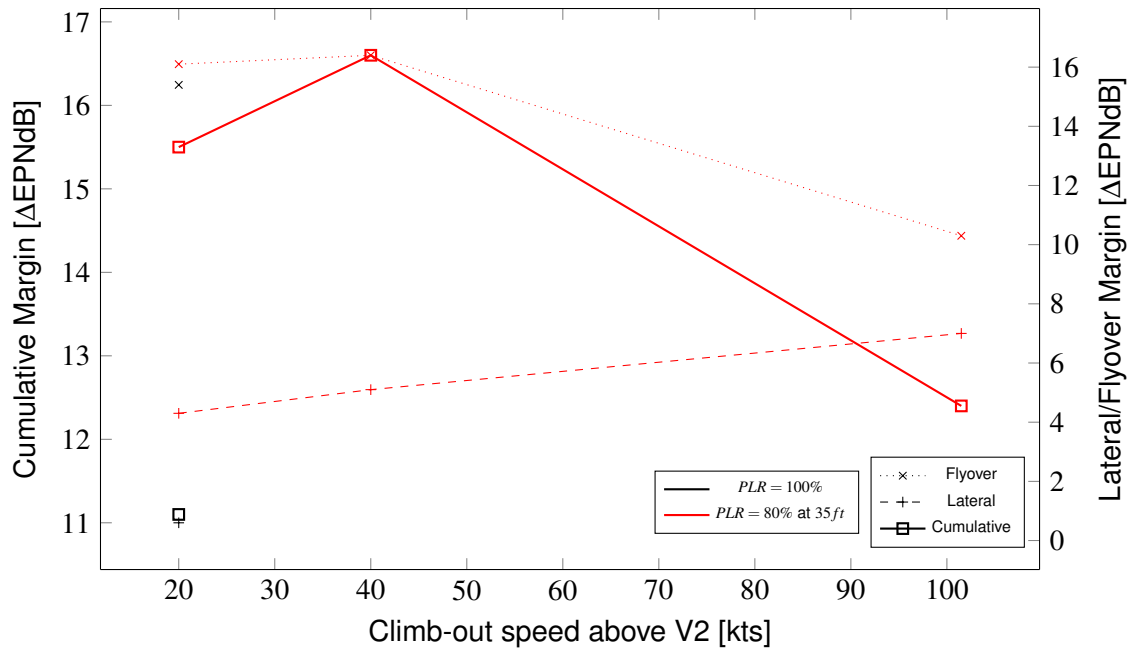


Figure 3 – Effect of increased climb-out speed on certification level margins of the SSBJ

It is clearly visible in Figure 3, that using PLR produces a significant advantage over using the standard subsonic take-off procedure (labeled 100% PLR). It is also observed that an increase in climb-out speed from $V_2 + 20kts$ to $V_2 + 40kts$ is advantageous for both lateral and flyover noise levels. Thus the cumulative margin increases significantly as well. Another stark increase to $250kts$ reduces the lateral levels further, but the lower climb performance leads to a lower height at the flyover certification point and decreases its noise margin so much that the cumulative margin decreases beyond the lowest climb-out speed. This can be explained, since the SSBJ is designed for low supersonic cruise Mach numbers and thus has a low V_2 . For that reason the absolute speed limit of $250kts$ translates to a much higher speed relative to ordinary operation, exceeding the point where the effects of thrust reduction from 'reverse command' and lower flight height cancel each other out.

The certification noise margins using the most improved trajectory (displayed in Figure 4) are displayed in Table 9.

Margin to Chapter 14 [Δ EPNdB]	Lateral	Flyover	Approach	Cumulative
Max. thrust, 20% PLR at 35ft, $V_2 + 40kts$	5.1	16.4	9.1	16.7

Table 9 – Maximum noise margins to Chapter 14 of SSBJ

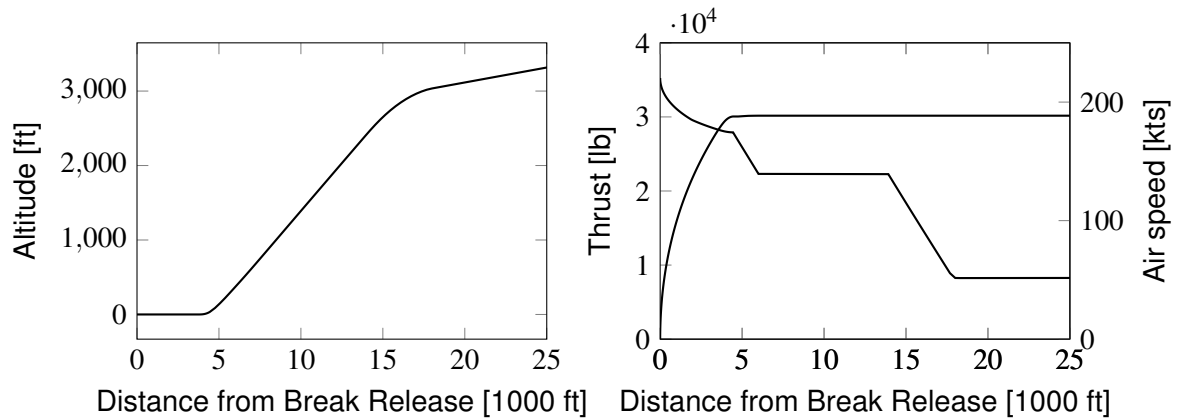


Figure 4 – SSBJ trajectory with the lowest cumulative certification noise: Max. take-off thrust, 20% PLR at 35ft with $V_2 + 40kts$

5.2 Ma1.8 Airliner

For the SSAL, first the impact of the parameters of advanced take-off procedures will be illustrated before the minimum noise margins for the optimized trajectories are presented. All certification noise levels for all trajectories can be found in the appendix.

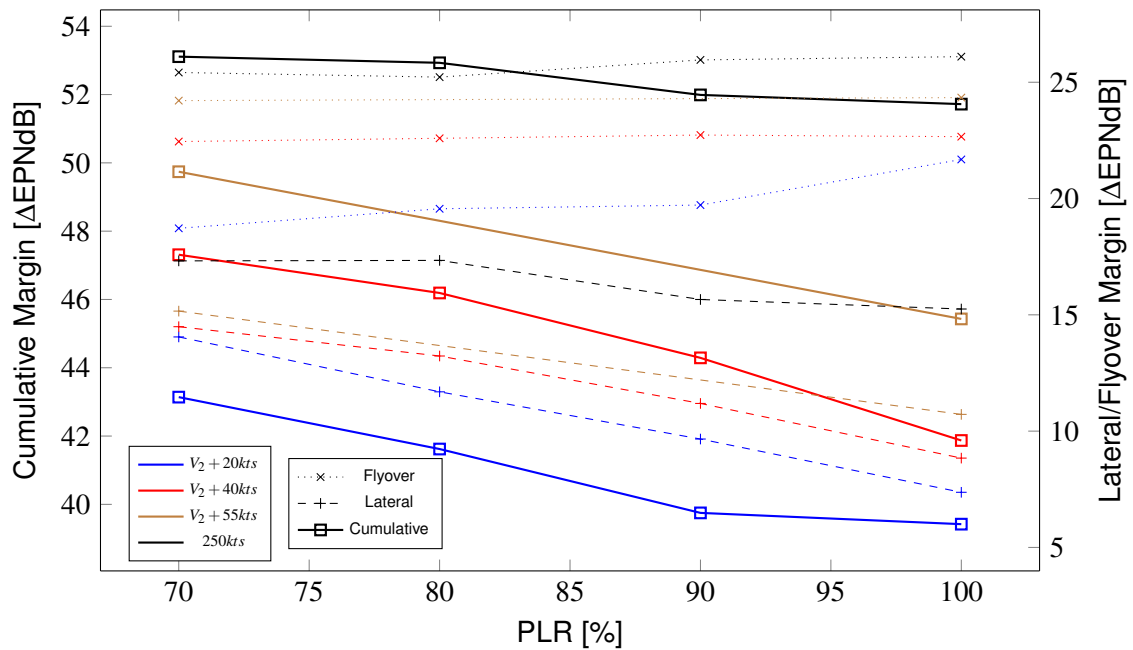


Figure 5 – Impact of PLR variation for the highest de-rated take-off thrust (60%) trajectories

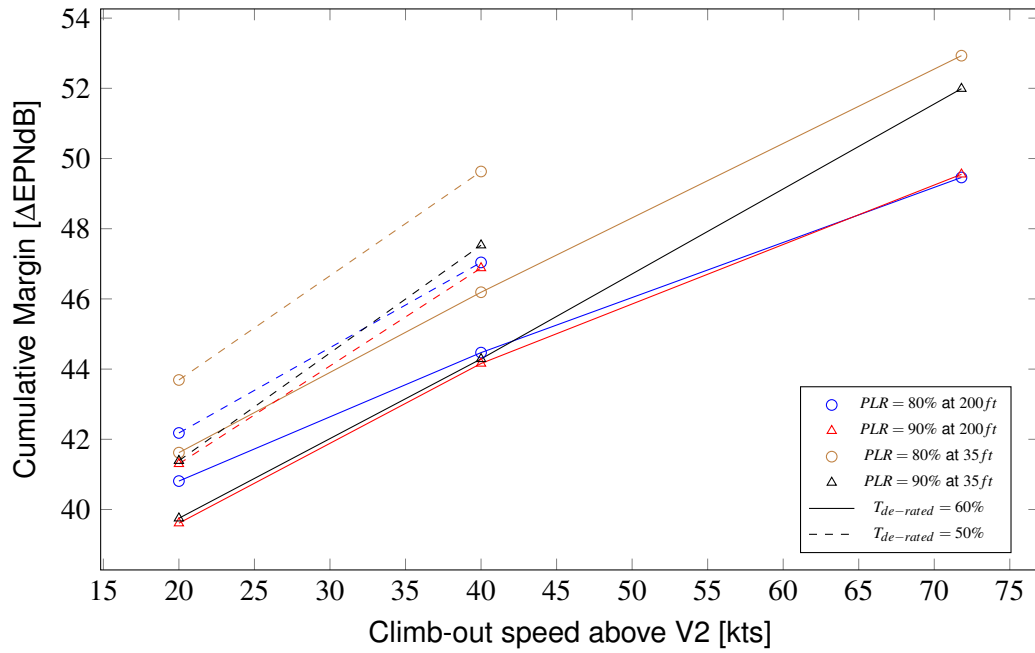


Figure 6 – Impact of climb-out speed variation across various trajectories

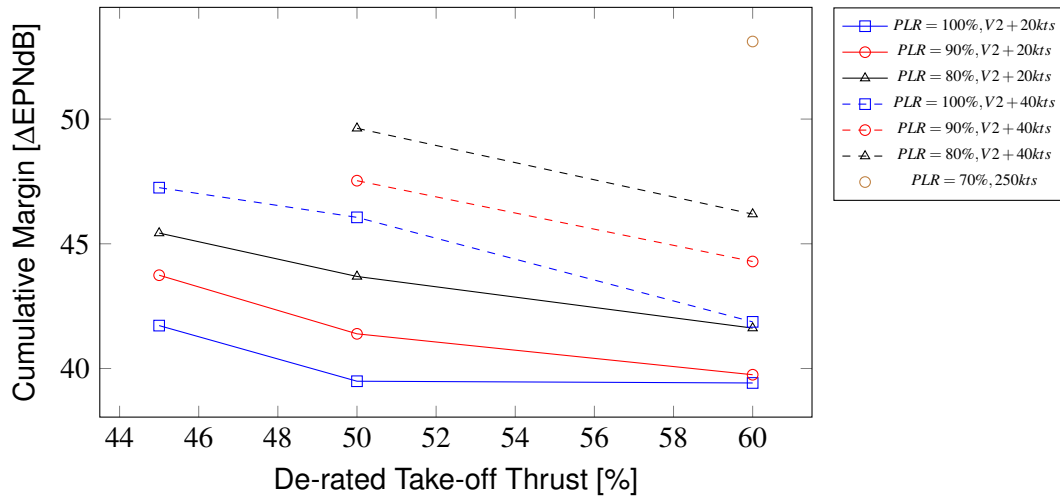


Figure 7 – Impact of the de-rated take-off thrust on various trajectories

As can be seen in the Figure 5, there is a trade-off between lateral and flyover certification noise when using PLR. However, the overall impact is positive, but with little improvement or even a decreased margin at 70%. In Figure 6 the impact of increased climb-out speed is clearly positive, as the cumulative margins increase. For the de-rated take-off thrust, the trends equally clear. For PLR cutbacks to 80% and a low climb-out speed of $V_2 + 20kts$, there is sufficient thrust to climb, so an increase in initial take-off thrust increases noise emissions and thus reduces certification noise margins. At higher climb-out speeds and higher PLR cutbacks, the potential for trajectory variations without violating the regulatory limit increases with higher initial thrust. Hence, increased climb-out speeds and bigger PLR cutbacks can only be reached with increased take-off thrust. The certification noise margins of these improved trajectories can be found in the upper right corner of Figure 7 and yield the highest cumulative margins.

Out of all trajectories considered, three yield very similar cumulative noise margins. Since the prediction methods cannot be expected to be perfectly precise, they will all be presented for the optimized results. The trajectories are plotted in Figure 8 and the respective margins can be found in Table 10

Margin to Chapter 14 [Δ EPNdB]

	LAT	FO	APP	CUM
60% de-rated thrust, 70% PLR at 35 ft, 250kts	17.3	25.4	24.4	53.0
60% de-rated thrust, 80% PLR at 35 ft, 250kts	17.3	25.2	24.4	52.9
60% de-rated thrust, 90% PLR at 35 ft, 250kts	15.6	25.9	24.4	51.9

Table 10 – Noise margins to Chapter 14 of SSAL

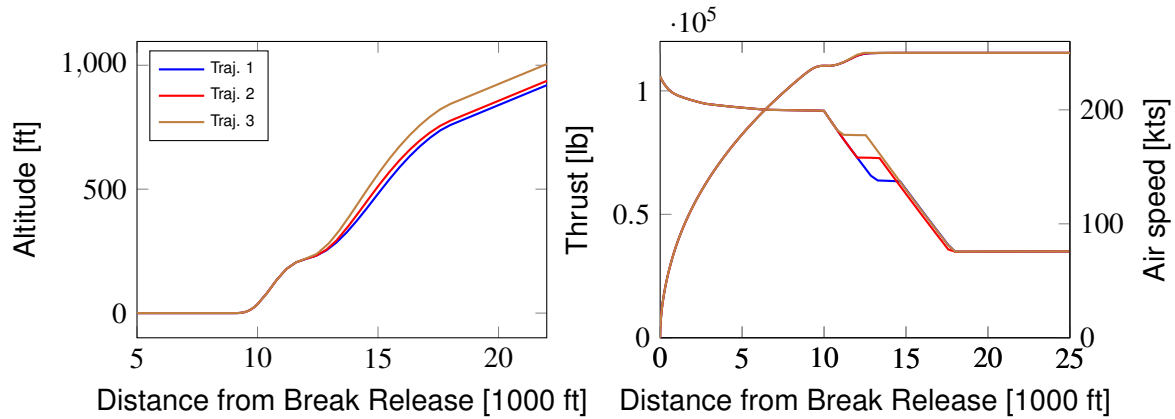


Figure 8 – SSAL trajectories with the lowest cumulative certification noise levels:

Traj. 1: 60% de-rated thrust, 70% PLR at 35 ft, 250kts;

Traj. 2: 60% de-rated thrust, 80% PLR at 35 ft, 250kts;

Traj. 3: 60% de-rated thrust, 90% PLR at 35 ft, 250kts

6. Conclusion

Both aircraft are able to meet Chapter 14 limits with significant margins. While uncertainties in the simulations have not been estimated, it can be assumed that this would be true for real aircraft as well.

Technologies and procedures specific to supersonic aircraft help reduce the LTO noise significantly. They are mainly concerning the engines, since their low-bypass design makes jet noise a bigger noise concern than on subsonic aircraft.

The variable throat nozzle allows for much lower, subsonic jet velocities in LTO operations without compromising cruise performance. This helps reduce the jet noise, the dominant noise source on take-off, substantially. Furthermore, the geometry of supersonic aircraft engines allows for the installation of liners in a large area which makes a large reduction in fan noise possible.

Increasing the climb-out speed significantly above the current limit yields higher overall margins. The reduction in thrust possible by improved aerodynamics helps reduce noise levels. The point at which the reduced climb performance counters any positive effect of the fast climb-out could be reached with the SSBj, but not the SSAL without violating the absolute speed limit below 10,000ft. The ideal speed for the SSBj is $V_2 + 40kts$, for the SSAL it is 250kts. PLR in the range 70-80% is ideal for the studied aircraft - higher thrust reduction does not yield lower lateral certification noise levels but increases them at the flyover point. An ideal delayed take-off speed can be found for each thrust setting and climb-out speed. Delaying the take-off and gaining more speed on the runways helps reduce certification noise by using ground attenuation mechanisms and reducing the thrust demand while after lift-off.

De-rated take-off thrust is necessary for the supersonic airliner, since the engine cannot provide full thrust without a supersonic jet, which would make it impossible to meet noise certification limits. With the highest chosen thrust setting, the lateral certification point is located exactly after take-off, so any

further increase would move the loudest point next to the runway and increase cumulative certification noise levels.

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LANDING AND TAKEOFF NOISE PREDICTION OF CONCEPTUAL SUPERSONIC AIRCRAFT

Appendix

De-rated thrust [%]	h_{PLR} [m]	PLR [%]	Nozzle -	DR -	$V2+X$ [kts]	Flyover [EPNdB]	Lateral [EPNdB]	Approach [EPNdB]	Cumulative [EPNdB]
100	35	100	1	1	20	72.6	93.4	88.8	254.7
100	35	80	1	1	20	71.9	89.7	88.8	250.4
100	35	80	1	1	40	71.6	88.9	88.8	249.2
100	35	80	1	1	101.5	77.7	87.0	88.8	253.5

Certification noise levels of the SSBJ for all trajectories

De-rated thrust [%]	h_{PLR} [m]	PLR [%]	DR -	$V2+X$ [kts]	Flyover [EPNdB]	Lateral [EPNdB]	Approach [EPNdB]	Cumulative [EPNdB]
45	200	80	Opt	20	82.2	81.94	77.44	241.58
45	200	90	Opt	20	81.77	82.54	77.44	241.75
45	35	100	Opt	20	81.43	84.79	77.44	243.66
45	35	100	Opt	40	78.77	81.92	77.44	238.13
45	35	80	Opt	20	82.55	79.96	77.44	239.95
45	35	90	Opt	20	81.92	82.28	77.44	241.64
50	200	80	Int	40	78.31	84.15	77.44	239.9
50	200	80	Opt	20	81.13	84.63	77.44	243.2
50	200	80	Opt	40	77.44	83.46	77.44	238.34
50	200	80	Min	20	81.82	82.6	77.44	241.86
50	200	90	Int	40	77.85	84.14	77.44	239.43
50	200	90	Opt	20	80.8	85.81	77.44	244.05
50	200	90	Opt	40	77.39	83.67	77.44	238.5
50	200	90	Min	20	81.23	84.97	77.44	243.64
50	200	90	Min	40	78.7	83.86	77.44	240
50	35	100	Opt	20	80.45	88	77.44	245.89
50	35	100	Opt	40	77.08	84.8	77.44	239.32
50	35	100	Opt	55	76.45	82.11	77.44	236
50	35	70	Opt	20	81.77	81.27	77.44	240.48
50	35	70	Opt	40	78.08	79.25	77.44	234.77
50	35	80	Int	40	78.44	80.89	77.44	236.77
50	35	80	Opt	20	81.21	83.04	77.44	241.69
50	35	80	Opt	40	77.62	80.69	77.44	235.75
50	35	80	Min	20	81.95	82.39	77.44	241.78
50	35	90	Int	40	77.83	82.88	77.44	238.15
50	35	90	Opt	20	80.9	85.65	77.44	243.99
50	35	90	Opt	40	77.36	83.05	77.44	237.85
50	35	90	Min	20	81.22	84.96	77.44	243.62
50	35	90	Min	40	78.62	82.35	77.44	238.41
60	200	80	Int	71.8	77.01	86.11	77.44	240.56
60	200	80	Int	40	76.64	86.83	77.44	240.91
60	200	80	Opt	71.8	73.4	85.08	77.44	235.92
60	200	80	Min	20	80.58	86.55	77.44	244.57
60	200	80	Min	40	77.42	85.05	77.44	239.91
60	200	90	Int	40	76.56	87.22	77.44	241.22
60	200	90	Opt	71.8	73.27	85.12	77.44	235.83
60	200	90	Min	20	79.73	88.6	77.44	245.77
60	200	90	Min	40	77.06	87.03	77.44	241.53
60	35	100	Opt	71.8	73.24	82.98	77.44	233.66
60	35	100	Opt	20	77.66	90.86	77.44	245.96
60	35	100	Opt	40	76.68	89.39	77.44	243.51
60	35	100	Opt	55	75	87.51	77.44	239.95
60	35	70	Opt	71.8	73.92	80.91	77.44	232.27
60	35	70	Opt	20	80.62	84.18	77.44	242.24
60	35	70	Opt	40	76.89	83.74	77.44	238.07
60	35	70	Opt	55	75.13	83.07	77.44	235.64
60	35	80	Int	71.8	74.48	82.52	77.44	234.44
60	35	80	Int	40	76.75	85	77.44	239.19
60	35	80	Opt	71.8	74.12	80.89	77.44	232.45
60	35	80	Min	20	80.64	86.54	77.44	244.62
60	35	80	Min	40	77.42	84.55	77.44	239.41
60	35	80	Opt	20	79.78	86.54	77.44	243.76
60	35	90	Int	71.8	73.72	83.62	77.44	234.78
60	35	90	Int	40	76.61	87.04	77.44	241.09
60	35	90	Opt	71.8	73.38	82.57	77.44	233.39
60	35	90	Min	20	79.69	88.57	77.44	245.7
60	35	90	Min	40	76.99	86.69	77.44	241.12
60	35	90	Opt	20	79.62	88.57	77.44	245.63

Certification noise levels of the SSAL for all trajectories