Powered Lift and Mechanical Flap Concepts for Civil Short-Haul Aircraft

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The objective of this paper is to determine various design and performance parameters, including wing loading and thrust loading requirements, for powered lift and mechanical flap conceptual aircraft constrained by field length and community noise impact. Mission block fuel and direct operating costs (DOC) were found for optimum designs. As a baseline, the design and performance parameters were determined for the aircraft using engines without noise suppression. The constraint of the 90-dB effective perceived noise level (EPNdB) contour being less than 2.6 km² (1.0 mi.²) in area was then imposed. The results indicate that for both aircraft concepts the design gross weight, DOC, and required mission block fuel decreased with field length. At field lengths less than 1100 m (3600 ft) the powered lift aircraft had lower DOC and block fuel than the mechanical flap aircraft but produced higher unsuppressed noise levels. The noise goal could easily be achieved with nacelle wall treatment only and thus resulted in little or no performance or weight penalty for all studied aircraft.

Introduction

THE future application of powered lift concepts for civil short-haul transport aircraft depends strongly on four items: 1) future requirements for short-field performance, 2) community noise impact, 3) fuel usage, and 4) overall operating costs. The requirements for short-field capability and low aircraft noise have a significant impact on engine and airframe design, and thus on block fuel consumption for any given mission profile. Minimizing fuel usage will continue to be a very important design criterion if fuel costs continue to increase as projected.

The objective of this paper is to determine various design and performance parameters, including wing loading and thrust loading requirements, for powered lift and mechanical flap (MF) conceptual aircraft constrained by field length and community noise impact.

Both advanced propulsion technology and powered lift aerodynamic technology have been factored into the study. The propulsion technology has been derived from the NASA-sponsored Quiet Clean Short-Haul Experimental Engine (QCSEE) program and the powered lift aerodynamic technology has been derived from the NASA-sponsored Quiet Short-Haul Research Aircraft (QSRA) program. The upper-surface-blowing (USB) concept now being developed in the QSRA program was coupled with the NASA/General Electric Company QCSEE turbofan to represent the powered lift aircraft. For the MF aircraft, the QCSEE and a modern high-bypass turbofan engine were studied in order to assess the impact of engine technology level. The field lengths studied ranged from 600-1500 m (2000-5000 ft).

As a baseline, the design and performance parameters were determined for the unsuppressed (i.e., no nacelle acoustical treatment) engines. These parameters included wing loading, thrust-to-weight (T/W) ratio, DOC, and block fuel as a function of field length for both aircraft concepts and engines. With the baseline aircraft determined, the community noise impact constraint was imposed. It was required that the 90-dB effective perceived noise level (EPNdB) contour be less than 2.6 km² (1.0 mi.²) in area. The required level of acoustic suppression to meet this goal was determined at each design field length for both aircraft and engine combinations and the associated performance penalties assessed.

Aircraft

The general arrangement for the MF aircraft is presented in Fig. 1 and shown for the powered lift USB aircraft in Fig. 2. Both aircraft were configured to carry 150 passengers and perform a 925 km (500 n.mi.) mission. Both aircraft are of a high-wing design. The USB aircraft is designed with four engines to provide for adequate engine-out roll and yaw control during takeoff and landing. In contrast, a MF aircraft will have yaw asymmetry only with one engine out. A twin-engine design configuration was chosen for the MF aircraft, based on economic considerations derived from previous STOL system studies.[1,2] Both aircraft have a wing aspect ratio of ten with the quarter-chord sweep set at 20 deg. The wing design was a compromise based on recent studies[3,4] that were aimed at reducing fuel consumption with small DOC penalties.

The basic cruise lift and drag coefficients were obtained as functions of Mach number, Reynolds number, wing aspect ratio, quarter-chord sweep, etc., as detailed in Ref. 5. For the MF aircraft, the lift and drag increments of the leading edge slats and double-slotted trailing edge flaps were computed as a function of deflection angle, as presented in Ref. 2. The powered lift aerodynamic coefficients of the NASA/Boeing QSRA[6] were used for the USB aerodynamic modeling.

The design field lengths selected for study of the MF aircraft were 900, 1200, and 1500 m (3000, 4000, and 5000 ft). For the powered lift USB aircraft, 600, 900, and 1200 m (2000, 3000, and 4000 ft) field lengths were studied. The MF aircraft were sized to meet the takeoff and landing performance requirements of FAR Part 25, with the USB aircraft sized to meet FAR Part 25 at sea level on a hot day of 308 K (95°F). Both the MF and USB aircraft were also required to have a cruise Mach number of at least 0.75 at an altitude of 9150 m (30,000 ft). The price of fuel assumed for this study was 7.9¢/liter (30¢/gal).

Engines

In addition to the two lift concepts studied, two engine cycles were also selected for study. A contemporary turbofan

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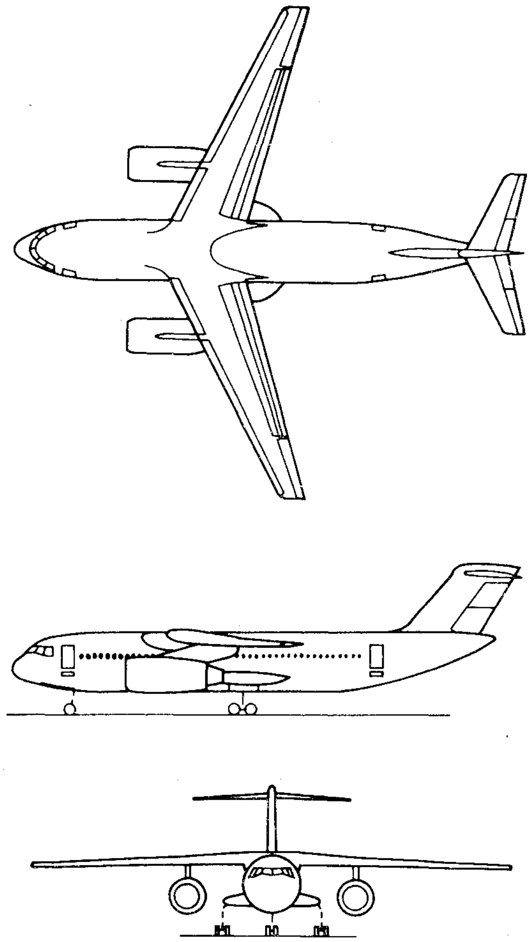

Fig. 1 Mechanical flap aircraft configuration.

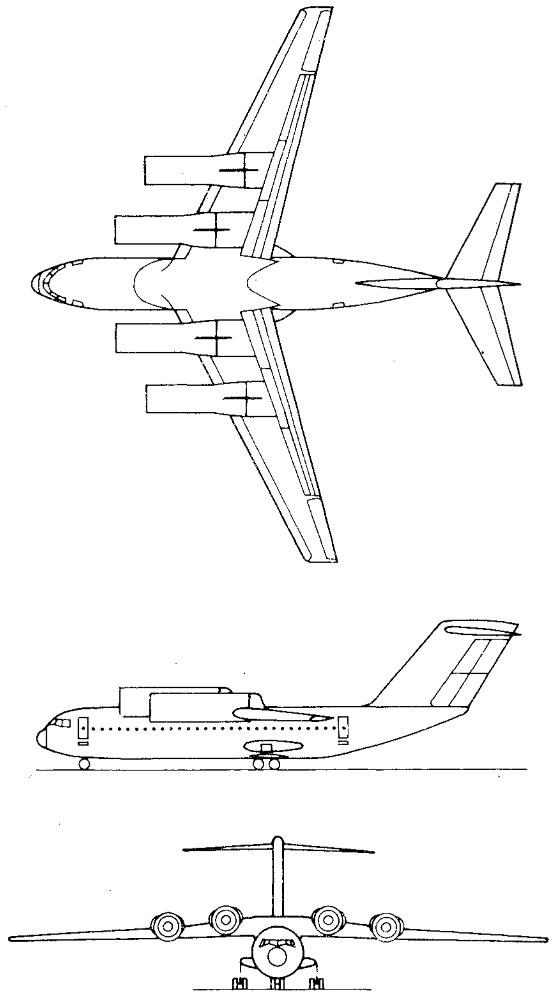

Fig. 2 Upper-surface-blown (USB) aircraft configuration.

with bypass ratio of six and an advanced technology BPR-10 engine, represented by the over-the-wing (OTW) QCSEE turbofan, were studied on the MF aircraft. Only the QCSEE turbofan was studied on the USB aircraft. Engine performance and noise data were provided by the NASA Lewis Research Center. The engine performance characteristics of both engines are presented in Table 1. A fixed-pitch fan design is used in each engine. The contemporary BPR-6 engine has a fan pressure ratio of 1.45, while the QCSEE has a geared fan design with a fan pressure ratio of 1.36. The QCSEE utilizes a low-speed fan with a tip speed of 350 m/s (1160 fps), while the BPR-6 engine has a higher tip speed of 475 m/s (1550 fps). Both engine designs have a mixed flow exhaust with a single convergent nozzle. The jet exit velocities are approximately 275 and 230 m/s (900 and 750 fps) for the BPR-6 and QCSEE turbofan, respectively. Both engines employ low-noise technology design features, including no inlet guide vanes and near-optimum rotor/stator blade number ratio and rotor/stator spacing. Engine scaling was done assuming constant specific thrust. Both engines have been flat-rated to 308 K (90°F) at sea level. The baseline engine/nacelle design for both the QCSEE and the BPR-6 engine incorporated fan-frame acoustic treatment between the fan rotor and outlet guide vanes. This treatment primarily provides acoustic fatigue relief, but also produces approximately 1 PNdB suppression of the fan noise. This baseline engine/nacelle configuration was used to represent the unsuppressed engine case in this study.

Aircraft Sizing Methodology

The MF and USB aircraft were sized by determining the required T/W ratio needed to satisfy the takeoff field length, cruise, engine-out approach/go-around climb, and landing requirements for a selected range of wing loadings. The takeoff field length was defined to be the balanced field length; i.e., the engine-out takeoff distance is equal to the accelerate/stop distance. The takeoff flap setting was optimized to give minimum required T/W, thereby satisfying both the field length and second segment engine-out climb requirements. The final selection of thrust loading and wing loading was selected to minimize DOC.

Shown in Fig. 3 is a sample sizing plot for a 900 m (3000 ft) MF aircraft. The required T/W needed to satisfy the takeoff field length and climb requirements increases with increasing

Table 1 Engine characteristics

	BPR-6	QCSEE
Bypass ratio	6.02	10.2
Fan pressure ratio	1.45	1.36
Cycle pressure ratio	25	15.5[a]
Turbine inlet temperature	1530 K (2300°F)	1675 K (2560°F)
Engine specific weight	0.188	0.139
Takeoff sfc-std. day	0.359	0.350
Fan tip speed	475 m/s (1550 fps)	350 m/s (1160 fps)
Jet exit velocity	275 m/s (900 fps)	230 m/s (750 fps)

[a] Because of funding limitations, the cycle pressure ratio of the QCSEE engine was not the optimum pressure ratio and, therefore, the specific fuel consumption was penalized. However, in a production engine the cycle pressure ratio would be improved, possibly by the use of boosters.

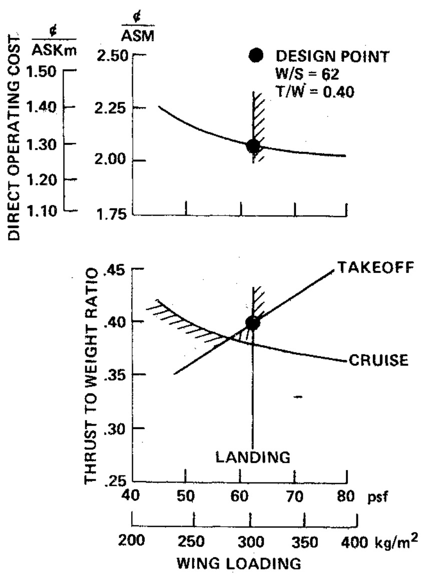

Fig. 3 Sizing plot for a 900 m (3000 ft) MF aircraft.

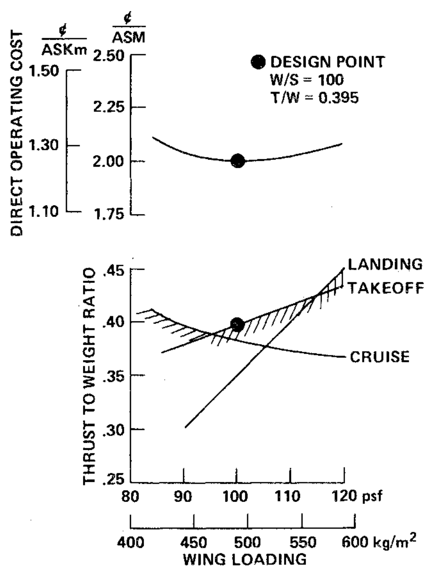

Fig. 4 Sizing plot for a 900 m (3000 ft) USB aircraft.

wing loading. This is due to the higher thrust requirements of the smaller wing associated with the higher wing loadings. The required T/W for cruise decreases with wing loading, reflecting the lower drag of the smaller wing. For the MF aircraft, the design wing loading for a given field length is a function of the maximum lift coefficient and the approach speed to stall speed ratio, and is independent of the T/W ratio. The approach speed was determined by the field length and a 4.57 m/s (900 fpm) approach rate of sink constraint. Combined with an approach-speed/stall-speed ratio of 1.3 and a maximum lift coefficient of 3.4, the required wing loading was determined as a function of the field length. This maximum lift coefficient is representative of an advanced technology slotted flap and leading edge device. With the general trend of decreasing DOC's with higher wing loadings (shown in Fig. 3), the landing line fixes the design wing loading for minimum DOC.

Presented in Fig. 4 is an example of the sizing plot used for a 900 m (3000 ft) USB aircraft. The general trends for required T/W for takeoff and cruise as a function of wing loading are the same as those for the MF aircraft. The takeoff flap setting was also optimized for minimum required T/W. For the powered lift USB aircraft, the landing sizing curve is not independent of the aircraft T/W ratio, because the lift coeffficient is thrust dependent. As the wing loading increased, the required T/W for landing increased, reflecting the higher thrust requirements of the smaller wing. For all the USB aircraft studied, the critical landing requirement was a 15 deg fuselage attitude angle at touchdown, which, in turn, determined the required landing flap deflection to provide the necessary angle-of-attack flaring margin. Also shown in Fig. 4 is a plot of DOC versus wing loading. In contrast to the MF aircraft, there is a combination of thrust loading and wing loading that results in a well-defined minimum DOC, and this point was selected for the final design of the USB aircraft.

Results

Wing Loading

Shown in Fig. 5 are the design wing loadings as a function of field length for the MF and USB aircraft. For both aircraft concepts, the design wing loading increases with field length, due to a corresponding increase in aircraft speeds associated with the longer field lengths. For the MF aircraft, the design wing loading is solely a function of the field length and independent of the engine cycle. At a given design field length, the USB aircraft has about 60% higher wing loading than that of the MF aircraft. For the powered lift aircraft, the thrust

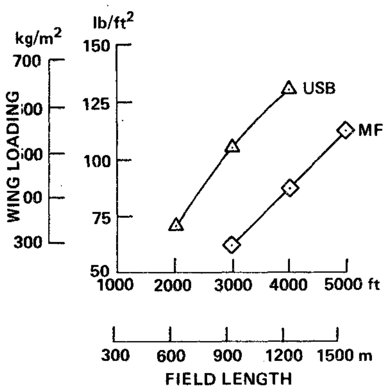

Fig. 5 Design wing loading as a function of field length.

supplies a significant portion of the lift, resulting in smaller required wing areas for a given field length requirement.

Thrust Loading

The design T/W ratio curves for the MF and USB aircraft are presented in Fig. 6 as a function of field length. The MF aircraft employing the BPR-6 engines were field length performance sized and show increasing design T/W with field length. This result is due to the higher takeoff thrust requirements of the smaller wing (i.e., higher wing loading) and the higher engine thrust lapse at the higher speeds associated with the longer field lengths.

The 900 and 1200 m (3000 and 4000 ft) MF/QCSEE aircraft were cruise sized and, as a result, show decreasing design T/W with field length. However, above 1200 m (4000 ft), the field length performance sizing requirements become dominant and the design T/W increase with field length. At field lengths greater than 1200 m (4000 ft), the design T/W of the MF/QCSEE is greater than that for the MF/BPR-6 aircraft due to the higher thrust lapse of the higher bypass ratio QCSEE.

The design T/W of the USB aircraft decreases with increasing field length. For the USB aircraft, the minimum DOC occurred at a point where the design T/W was determined by the takeoff field length performance requirement (Fig. 4). For a given takeoff field length, the required T/W is roughly proportional to the wing loading divided by the field length. For the USB aircraft, the design wing loading increases at a slower rate than the field length (Fig. 5). The net result is a decreasing design T/W with field length.

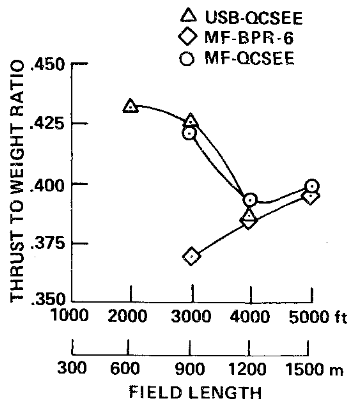

Fig. 6 Design thrust-to-weight ratio (T/W) as a function of field length.

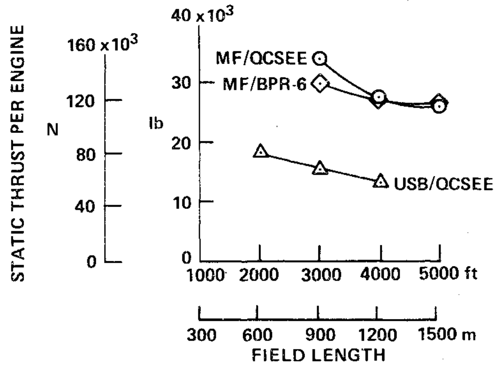

Fig. 8 Required static thrust per engine as a function of field length for minimum DOC configuration.

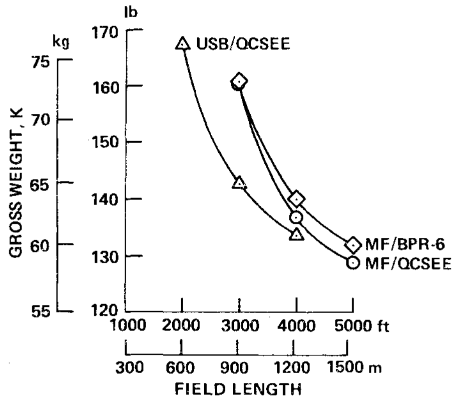

Fig. 7 Design gross weight as a function of field length for minimum DOC configuration.

Gross Weight

Presented in Fig. 7 are the design gross weights as functions of field length. For all aircraft, the gross weight decreases with increasing field length, due mainly to an associated increase in wing loading with field length. For the MF, the QCSEE aircraft show lower gross weight due to the lower block fuel consumed on the design 925 km (500 n.mi.) mission. Below approximately 1200 m (4000 ft) field lengths, the USB aircraft display lower gross weights than either MF aircraft. This is due mainly to the higher wing loadings for the USB over the MF at the same field length. All design points are for minimum DOC configurations.

Static Thrust

The static thrust per engine is shown in Fig. 8. For all aircraft studied, the thrust per engine is seen to decrease with increasing field length. The decrease in gross weight with field length compensates for any increase in design T/W with field length to give smaller engine size at longer field lengths. At field lengths less than 1200 m (4000 ft), the MF/QCSEE aircraft have a higher static thrust per engine than the MF/BPR-6 aircraft, due to the higher design T/W needed by the higher bypass ratio QCSEE aircraft to satisfy the cruise requirement. Note that the USB aircraft are four-engine aircraft, which accounts for the marked reduction in thrust per engine.

Cruise Point

Presented in Table 2 are the resulting cruise Mach number and cruise altitude for the design point aircraft. The cruise altitude was selected on the basis of minimum DOC for the design mission. All final design QCSEE aircraft cruised at maximum cruise power setting. The cruise Mach number associated with this power setting yielded lowest DOC over a range of cruise Mach numbers investigated. The MF/BPR-6 aircraft cruised at a Mach number of 0.82. This Mach number produced the lowest mission DOC's and was the maximum operating Mach number limit from airframe structural design considerations used in the study.

Block Fuel

Block fuel requirements for the design mission are presented in Fig. 9. On the MF aircraft, the QCSEE engine exhibits lower block fuel than the BPR-6 aircraft, due to the lower cruise specific fuel consumption of the QCSEE turbofans. Below approximately 1100 m (3600 ft) field lengths, the USB aircraft has lower block fuel requirements than the QCSEE-equipped MF aircraft. At 900 m (3000 ft) field length, the USB has lower required block fuel due to lower total installed thrust and higher cruise Mach number. At 1200 m (4000 ft) field length, both the MF and USB equipped with the QCSEE have about the same total installed thrust, but the MF has a higher cruise Mach number and thus lower block time, resulting in lower mission block fuel.

Direct Operating Cost (DOC)

Shown in Fig. 10 are the DOC's for the design point aircraft as a function of field length. The DOC decreases with longer field length for all aircraft studied, following mainly the gross weight and block fuel trend with field length. For the 900 m (3000 ft) MF aircraft, the higher thrust per engine and lower cruise Mach number result in higher DOC for the QCSEE-equipped aircraft. At the longer design field lengths, this trend is reversed, with the BPR-6 aircraft showing higher DOC, due mainly to the lower mission block fuel for the QCSEE aircraft.

Table 2 Cruise performance

Aircraft/engine	Cruise Mach no.	Cruise altitude[a]
USB-2000 ft/QCSEE	0.774	10,000 m (34,000 ft)
USB-3000 ft/QCSEE	0.790	9,000 m (30,000 ft)
USB-4000 ft/QCSEE	0.75	9,000 m (30,000 ft)
MF-3000 ft/QCSEE	0.781	10,000 m (34,000 ft)
MF-4000 ft/QCSEE	0.776	10,000 m (34,000 ft)
MF-5000 ft/QCSEE	0.785	9,000 m (30,000 ft)
MF-3000 ft/BPR-6	0.820	10,000 m (34,000 ft)
MF-4000 ft/BPR-6	0.820	10,000 m (34,000 ft)
MF-5000 ft/BPR-6	0.820	10,000 m (34,000 ft)

[a] Selected for minimum DOC.

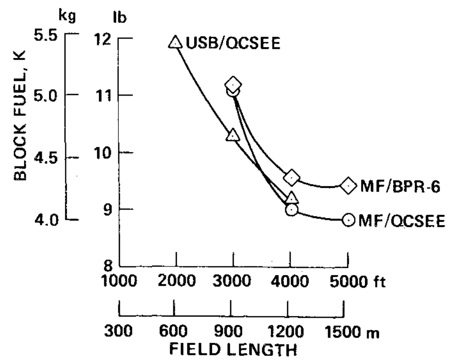

Fig. 9 Mission block fuel as a function of field length for minimum DOC configuration.

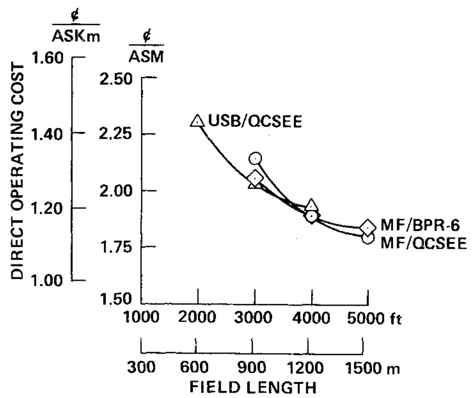

Fig. 10 Direct operating cost for minimum DOC aircraft as a function of field length.

Similar to the block fuel requirements, the USB shows lower DOC than the MF aircraft below 1100 m (3600 ft) field length. At 900 m (3000 ft) design field length, the combination of lower gross weight, mission block fuel requirement, higher cruise Mach number, and total installed thrust of the USB give this aircraft lower DOC's than the MF. At 1200 m (4000 ft) field length, the USB has a higher DOC than the MF, due mainly to the higher mission block time associated with the lower cruise Mach number for the USB aircraft.

Unsuppressed Noise

With the final point design aircraft determined, the unsuppressed (i.e., fan frame treatment only) noise levels of each aircraft were computed. Starting with the spectral acoustic data and following the procedures outlined in Ref. 7, the unsuppressed EPNL versus slant range curves were computed. For the MF aircraft, the methods of Ref. 7 were modified by replacing the jet/flap noise with the jet exhaust noise only and deleting all over-the-wing (OTW) shielding adjustments for the aft propagating machine component noise.

The takeoff profiles were computed for each aircraft using 100% power all-engine climbout. Because the proposed operations of these aircraft are in close proximity to the surrounding community, power cutbacks on takeoff were not considered. The climbout portion of the takeoff profile was optimized by allowing the aircraft to retract the flaps from the takeoff setting to a value that resulted in the maximum climbout flight path angle when the aircraft had attained an altitude of 120 m (400 ft). The approach flight path angle was determined by the approach speed and the 4.57 m/s (900 fpm) rate-of-sink constraint. With the approach speed increasing with increasing field length, the resulting approach flight path angle decreased with field length. The noise contours were then computed using the EPNL versus slant range curves,

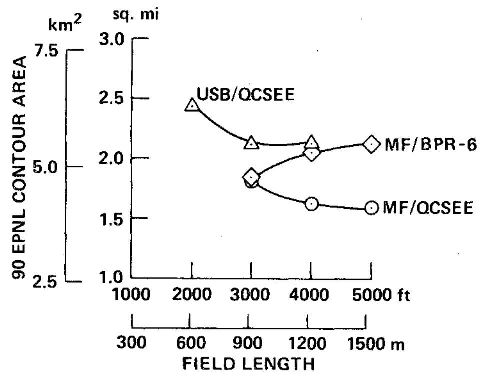

Fig. 11 Unsuppressed 90-EPNdB contour area as a function of field length.

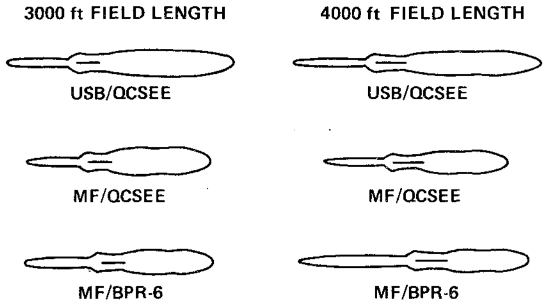

Fig. 12 Unsuppressed 90-EPNdB contour outlines for 900 and 1200 m (3000 and 4000 ft) aircraft.

combined with the takeoff and landing flight profiles for each design point aircraft.

Presented in Fig. 11 are the unsuppressed 90-EPNdB contour areas as a function of field length, and shown in Fig. 12 are the 90-EPNdB contour outlines for the 900 and 1200 m (3000 and 4000 ft) study aircraft. For the QCSEE-equipped aircraft, the contour area decreases with increasing field length due to the decrease in engine size. The noise contours for the MF and USB using the QCSEE are primarily takeoff-noise dominated, with the landing portion of the contour much smaller. The difference in the contour area between the USB and MF aircraft is due primarily to the higher takeoff climbout flight path angle for the MF aircraft which results due to its lower wing loading. With the QCSEE-equipped MF and USB aircraft having comparable design T/W, total installed thrust, takeoff/climb speeds, and flyover noise levels, the lower wing loading of the MF aircraft will result in higher flight path angles and hence a smaller contour area. The USB aircraft also exhibits a slightly larger landing contour area. For a given field length, both the USB and MF approach at the same flight path angle and aircraft speed. However, the USB aircraft approaches at a higher power setting, resulting in higher noise levels compared to the MF aircraft.

In contrast to the QCSEE-powered aircraft, the area of the 90 EPNdB contour for the unsuppressed MF/BPR-6 aircraft increases with field length. Due to the approach rate-of-sink constraint, the approach flight path angle decreases with increasing field length. This is true for all study aircraft. However, the part power setting noise of the BPR-6 engine is about 5 PNdB higher than the QCSEE engine. As a result, the landing portion of the noise contour for the BPR-6 aircraft is significant and becomes the dominant portion of the total noise contour at the longer field lengths.

Suppressed Noise

Presented in Fig. 13 as a function of field length are the required fan noise suppression levels in PNdB per engine needed to meet the 2.6 km² (1.0 mi.²) 90-EPNdB contour area noise goal. The fan noise dominates all other machine

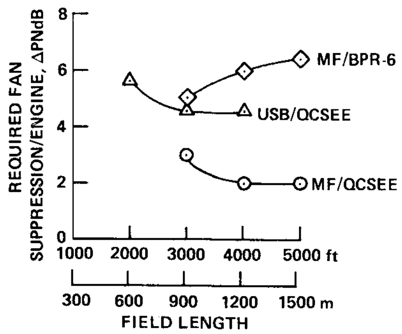

Fig. 13 Required fan suppression per engine as a function of field length.

noise sources for both the QCSEE and BPR-6 engines. As a result, only fan noise suppression was required. The required fan suppression follows the same general trends as those for the contour area with field length. Since noise sources add logarithmically, the BPR-6 engine with its higher jet noise component requires a greater suppression of fan noise than does the equivalent QCSEE aircraft to achieve the same overall noise level.

For the MF aircraft, the required suppression levels for the fan inlet and fan exhaust duct were the same. The required suppression levels needed at takeoff and approach power settings were also the same. For the USB aircraft, the required suppression level at the approach power setting was about 2 PNdB lower than that required at the takeoff power setting. The fan duct on the USB aircraft required little or no treatment because of the OTW shielding benefits of the USB configuration.

The required fan suppression levels for all study aircraft ranged from 2.0 to a little over 6.0 PNdB per engine. The two schemes considered for achieving these moderate suppression levels were nacelle peripheral wall acoustic lining and the high subsonic Mach number inlet.

For acoustic wall treatment only, the data contained in Appendix A of Ref. 8 indicate that over 7 PNdB of fan suppression can be attained with no inlet duct pressure drop, less than ½% fan exhaust duct pressure loss, and no additional weight penalty using load bearing acoustic treatment structure in the nacelle.

For a hard-wall nacelle, an inlet throat Mach number of about 0.75 would be required to provide the maximum needed suppression level of 6.0 PNdB.[9] The pressure drop associated with this Mach number would be on the order of 1%. For these high-bypass-ratio turbofans, this level of inlet pressure drop would produce a significant thrust loss.

A promising concept is the so-called hybrid inlet, which combines peripheral wall treatment with the high subsonic Mach number inlet. Based on data presented in Refs. 9 and 10, the maximum required 6.0 PNdB fan noise reduction could be achieved with an average inlet Mach number of 0.65 and an inlet pressure loss of approximately ½%. Using acoustic linings that were part of the load-bearing structure, no additional weight penalty would be incurred.

Based on the preceding, the required levels of engine suppression could easily be achieved using current technology noise suppression methods, including hybrid inlets and modest fan exhaust duct wall treatment. In addition, no (or very small) performance and weight penalties would be incurred.

Presented in Table 3 are the noise levels at various observer locations for the final design point aircraft with suppressed engines. The first three columns show the computed EPNL levels at the FAR Part 36 measuring points: 1) takeoff – 6.5 km (3.5 n.mi.) from brake release; 2) approach – 1.85 km (1.0 n.mi.) from the end of the runway; and 3) sideline – 0.46 km (1/4 n.mi.) parallel to runway at point of maximum noise after liftoff. Shown in parentheses are the differences between the March 1977 FAR Part 36 "Stage 3" noise requirement and the computed value. Also shown are maximum takeoff and approach 150 m (500 ft) sideline EPNL levels.

For takeoff and sideline, the levels are from 8-13 EPNdB below the 1977 FAR requirements and roughly 15 EPNdB below the original 1969 FAR 36 requirements. For approach, the computed levels are below the required 1977 values by 5-11 EPNdB and are about 13 EPNdB below the 1969 requirements. It should be noted that in computing the approach noise levels, the approach flight path angle was greater than 3.0 deg. Had all aircraft been required to approach along a 3.0 deg glide slope, the resulting noise levels would have been approximately 5 EPNdB below the 1977 Part 36 requirements.

The 150 m (500 ft) sideline noise levels range from about 95-99 EPNdB for takeoff and from about 88-90 EPNdB on approach. All aircraft exceed the 95 EPNdB sideline noise goal on takeoff of the QCSEE program with the exception of the 1200 m (4000 ft) USB, but easily meet the approach 95 EPNdB sideline goal.

Table 3 Suppressed aircraft

Aircraft	FAR 36 takeoff	FAR 36 approach	FAR 36 sideline	Takeoff, 500 ft sideline	Approach, 500 ft sideline
MF/BPR-6	82.0	89.8	87.8	98.5	87.7
3000 ft	(−9.5)	(−10.5)	(−9)		
MF/BPR-6	80.8	92.9	86.5	97.1	89.5
4000 ft	(−10)	(−7)	(−9.5)		
MF/BPR-6	80.6	94.6	86.1	96.7	90.0
5000 ft	(−10)	(−5.5)	(−10)		
MF/QCSEE	80.8	89.5	88.4	98.4	87.7
3000 ft	(−10)	(−10.8)	(−8.5)		
MF/QCSEE	82.3	91.3	87.5	96.4	88.2
4000 ft	(−8.3)	(−8.7)	(−8.5)		
MF/QCSEE	82.2	92.3	87.4	96.4	88.4
5000 ft	(−7.8)	(−7.5)	(−8.2)		
USB/QCSEE	83.1	89.5	87.7	96.8	89.4
2000 ft	(−13.5)	(−11.3)	(−10.5)		
USB/QCSEE	83.1	91.0	86.8	95.7	89.1
3000 ft	(−13)	(−9)	(−11)		
USB/QCSEE	84.6	91.7	85.8	94.7	88.7
4000 ft	(−11)	(−8)	(−11.5)		

Conclusions

This study has coupled advanced technology in propulsion and powered lift aerodynamics now being developed in the NASA-sponsored QCSEE and QSRA programs, respectively, into high-density short-haul transport aircraft designs. Both technologies were applied to the USB powered lift aircraft, while only the QCSEE propulsion technology was applied to the conventional MF-type aircraft. For comparison purposes, a modern MF/BPR-6 aircraft was also evaluated.

Field performance – both takeoff and landing – was the principal independent parameter in the study. For all conceptual aircraft and engines studied, the results indicate that the design wing loading increased with field length, while the design gross weight, DOC, and required mission block fuel decreased. At field lengths less than approximately 1100 m (3600 ft), the USB aircraft exhibited lower DOC and block fuel than both the MF aircraft, but exhibited higher unsuppressed noise levels. With a noise goal of 2.6 km^2 (1.0 $mi.^2$), a 90-EPNdB contour can easily be achieved with current technology noise suppression methods with no (or very little) penalty in performance or weight for both the MF and USB aircraft at all field lengths.

The trends established in this study show that QCSEE engine technology compared to modern turbofan engine technology will pay off in terms of reduced block fuel for aircraft optimized for the mission. There is no advantage in DOC, due to the higher assumed maintenance cost of the QCSEE technology engine. Coupling QCSEE engine technology with the USB powered lift concept has a definite payoff in terms of reduced block fuel for aircraft designed for a short field [less than 1100 m (3600 ft)]. For field lengths less than 900 m (3000 ft), there would be a cost advantage as well.

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