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Case for Small Supersonic Civil Aircraft

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Civil aviation progress in the last 40 years has included a significant expansion of the small civil aircraft market involving regional jets, business jets, and the emerging personal jets. A significant factor in the growth of the small civil aircraft market is the value of time. Recognition of the ever-increasing value of time has lead to increased interest in the feasibility of a small supersonic civil aircraft. The step to supersonic speeds offers the potential of a dramatic decrease in travel time. Feasibility studies of a small quiet supersonic jet (QSJ) have been conducted. Market research, environmental concerns, program and design requirements, and vehicle characteristics are summarized. Areas for concentrated future supersonic aeronautics research and development efforts are highlighted.

Introduction

THE remarkable progress and growth in civil aviation in the last 40 years has been fueled by advancements in a broad range of aeronautical technologies, combined with strong economic growth. Continued advancements in aerodynamics, structures, materials, avionics, and engine technology have provided the technical basis for the development of many different predominantly jet-powered civil aircraft models. These aircraft range from the very large transports used by scheduled air carriers to the very small personal jets emerging currently. Technical advancements coupled with economic growth have produced an exceptional record of aviation market growth, as shown in Fig. 1. This growth has included a significant expansion of the small civil aircraft market involving regional jets, business jets, and, now, personal jets.

One of the market factors that has proven important in the growth of small civil aircraft market is the value of time in transportation needs. Air travel provides the highest travel speeds for trips of significant distance. Scheduled carrier use of the regional jet satisfies the need to bring the time value of jet transport to low-density routes and markets. Business jet use by charter operators, fractional owners, public companies, private companies, and individuals is strongly tied to the value of time. Business jet use and the emerging personal jet use provide time value through jet aircraft speed and through broad destination flexibility. Exceptional field length performance enables the small civil aircraft to operate into a remarkable number of locations. Combine destination flexibility and jet aircraft speed in a competitive business environment and one has a highly valuable means to satisfy transportation needs.

Attraction

Recognition of the ever-increasing value of time has lead to increased interest in the feasibility of a small supersonic civil aircraft.[1–5] The step to supersonic speeds offers the potential of a dramatic decrease in travel time. As shown in Fig. 2, when speed is doubled from today's subsonic 0.8–0.85 Mach number to a 1.8 Mach number, global transportation paradigms transforms. Leaving New York City at 0700 hrs in a quiet supersonic jet (QSJ), one can be anywhere in the indicated circle for at least 2 h and be back in New York City by 1900 hrs. Alternatively, one could depart New York City heading westbound or eastbound and, with one stop, be essentially anywhere in the world in 10 h.

History

As shown in Fig. 3, supersonic aircraft progress from the first supersonic flight in 1947 has been impressive. In less than 15 years, the B58 was setting records for flights at Mach 2 between New York and London in less than 4 h. However, progress was almost completely limited to military aircraft. In the 1960s, three projects were initiated to bring supersonic civil transportation to market. The three different projects were nationally oriented. The U.S. supersonic transport (SST) program was stopped before an aircraft was even built. The Russian Tu144 was first to flight but ultimately was removed from service. Only the British/French Concorde continued service until 2003.

Continuation of the Concorde service was largely related to nationalistic pride in the remarkable aeronautical achievement embodied in the Concorde. Concorde economics and environmental impacts limited its utility and represent a challenge in the contemplation of future advancements in supersonic civil transportation. The lesson of Concorde, as well as the other two less successful attempts, is that aeronautical prowess is a necessary but not sufficient condition for the creation of successful programs in supersonic civil aviation. Economic justification and environmental compatibility are also required. Subsequent to the original SST Program, the U.S., on at least two occasions—supersonic cruise research (SCAR)[6] and high speed civil transport (HSCT)[7]—attempted to promote and develop a large supersonic civil transport, only to see the projects fail. In these later cases, the technical, environmental, and economic equations still could not be satisfied. Quite coincidentally, the announcement of Concorde service termination in 2003 coincides with the first flight centennial celebration year.

Whereas the stunning attraction of Fig. 2 is clear to most air travelers, the supersonic stagnation reflected in Fig. 3 demands a new approach. The studies conducted in the last few years[1,2,8] provide compelling evidence that the new approach should be focused on a much smaller vehicle as the first commercially and environmentally successful step in supersonic civil aviation. The history of advances in transportation has been more often defined by the introduction of a paradigm shift, first on a modest scale rather than a giant scale. These advances in transportation technology were usually aimed at the more affluent as a means of introductory affordability. Once the concept has been proven on a small scale for the more affluent, then technical advances and commercial competition have typically led to larger-scale vehicles that appeal to a broader segment of the population. This small-to-large stepping stone approach has clearly occurred throughout ship and aircraft transportation system history and reflects an intuitive risk management. In hindsight, it would seem that the aeronautical community has been trying to run supersonically before it can walk supersonically. It has been trying to create the giant supersonic transport before it developed the supersonic DC-3. Supersonic long-term vision took priority over

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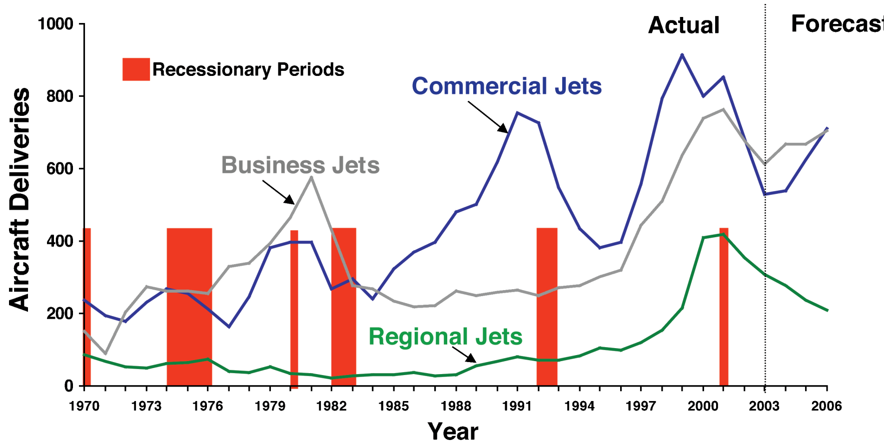


Fig. 1 Aviation market growth measured in units delivered per year.

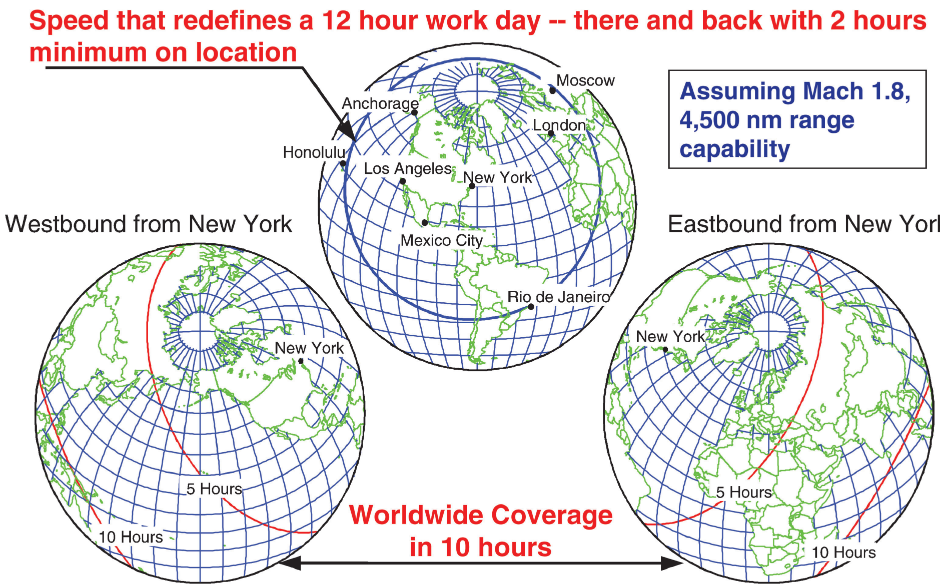


Fig. 2 Doubling speed brings remarkable transportation value.

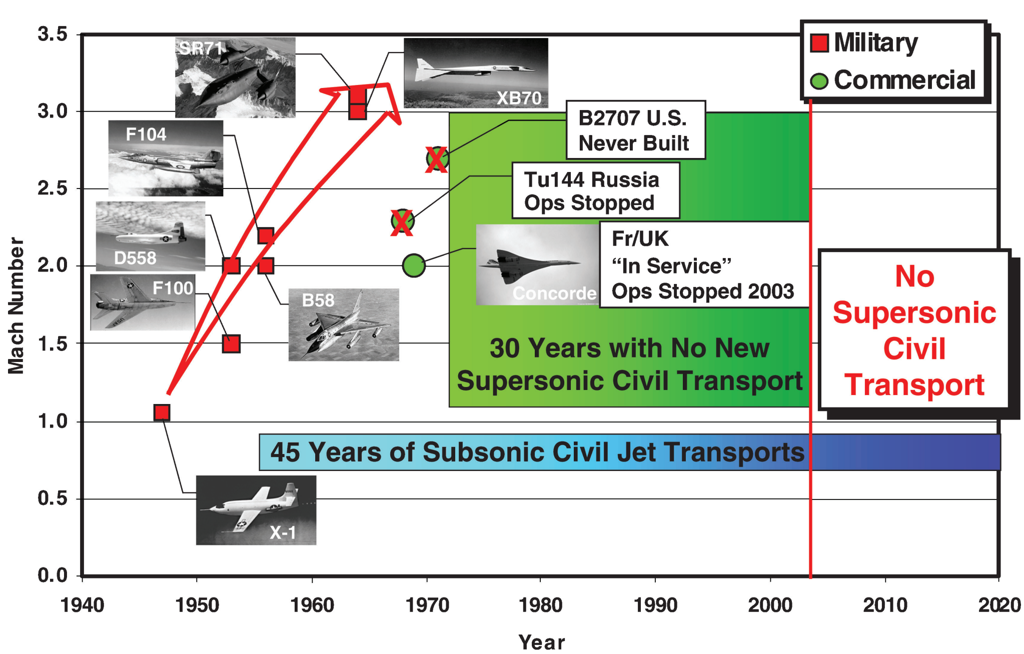


Fig. 3 Supersonic aircraft progress.

supersonic foundations. An effective supersonic vehicle needs to be introduced on a small scale first. The technical, economic, and environmental equations need to be solved on a lower-risk, small scale before the giant, supersonic transport solution is once again attempted.

QSJ Market Research

At least four different market research studies have been conducted on the small QSJ in recent years. Gulfstream internal market research has consisted of both a bottom-up approach and an analytical projection based on historical regression analysis. Independent market research studies utilizing direct customer contact and questionnaires have also been reported.[3–5]

The bottom-up approach was based on an assessment of the large-cabin business aircraft known customer base. This approach essentially amounted to a count of the individual customers who would step up to the next level of transportation productivity if it was available. The results of this study indicated a minimum market potential of 180 units over 10 years. This result did not include special mission or government sales and did not account for fractional ownership needs. The 180 unit number is a good threshold volume. A model run of 200 units is typical for programs throughout the 40-plus year history of Gulfstream Aerospace Corporation.

The analytical projection method extrapolated historic annual delivery data for large cabin business jet deliveries and inferred the potential for a QSJ product serving the same customer group. The historic annual delivery data were approximated by determination of a best-fit constant growth rate. This growth rate applied year-after-year yields a fleet size equivalent to the actual historic data. Once determined, this growth rate was used to extrapolate anticipated future deliveries. Historically, a conservative 10% capture is recognized for new-capability product introductions. This future delivery estimate, coupled with the 10% market capture, provides a means to estimate QSJ potential. The historic data, equivalent growth line, and projected QSJ deliveries are illustrated in Fig. 4. It is interesting that this long-term regression analysis discounts the blistering delivery levels of the late 1990s/early 2000s. As has been noted recently, delivery levels have retreated back to levels actually closer to the projection line. This projection method results in a QSJ market potential over a 10-year period to be over 350 units. Independent market research studies have also been conducted.[3–5] These studies have used extensive customer surveys and considered a number of questions to clarify product requirements. They have also introduced the concept of a small supersonic aircraft for scheduled service, as well as business aviation use. These studies have concluded that a small supersonic civil aircraft market of 250–450 units exists at a price between \$50M and \$100M per unit over a 10–20 year period. Additionally, a major fractional ownership company has conducted sufficient studies to conclude that a small supersonic civil aircraft has considerable appeal and seeks to participate in any such endeavor.

The current perspective indicates there is a significant market potential for a small supersonic civil aircraft. Market assessments have identified the following significant points:

1) Two Gulfstream market assessments identify conservative sales forecasts of 180–350 aircraft.

2) Two independent market assessments identify sales forecasts of 250–450 aircraft.

3) Supersonic overland flight capability is a requirement.

4) Range beyond 4000 n mile is a requirement.[1]

The supersonic overland flight requirement is key to the market feasibility. Sonic boom suppression is the key technology required to make supersonic overland flight acceptable. All of the market studies have confirmed significant value for this capability. A limitation to subsonic overland flight, as a result of unacceptable sonic boom characteristics, represents a severe blow to the value of a small supersonic civil aircraft. Production costs, both nonrecurring and recurring, for the supersonic vehicle are present whether or not the vehicle is limited to subsonic overland flight. The market price or value that the vehicle can command is strongly driven by its ability to maximize time savings. As shown in Fig. 5, much of small civil aircraft flight is over land. In this case, a random sample of flights was taken from actual flight records for the in-service Gulfstream GIV and Gulfstream GV aircraft for one year. The sample indicates that only 25% of the flight time was over water. Consequently, maximum time savings and maximum market value dictate supersonic overland flight requirements. If this higher market price (supersonic overland capability) is not achieved, the business case is weak, and we have not solved the economic equation. The supersonic-over-water-only assumption made in previous large supersonic transport studies certainly hindered, if not fatally restricted, the aircraft potential in the marketplace. Consequently, definition of an acceptable solution for sonic boom suppression is key to the success of a small supersonic civil aircraft.

Environmental Concerns

The viability of a supersonic civil aircraft hinges on the ability to design and manufacture a configuration that is environmentally

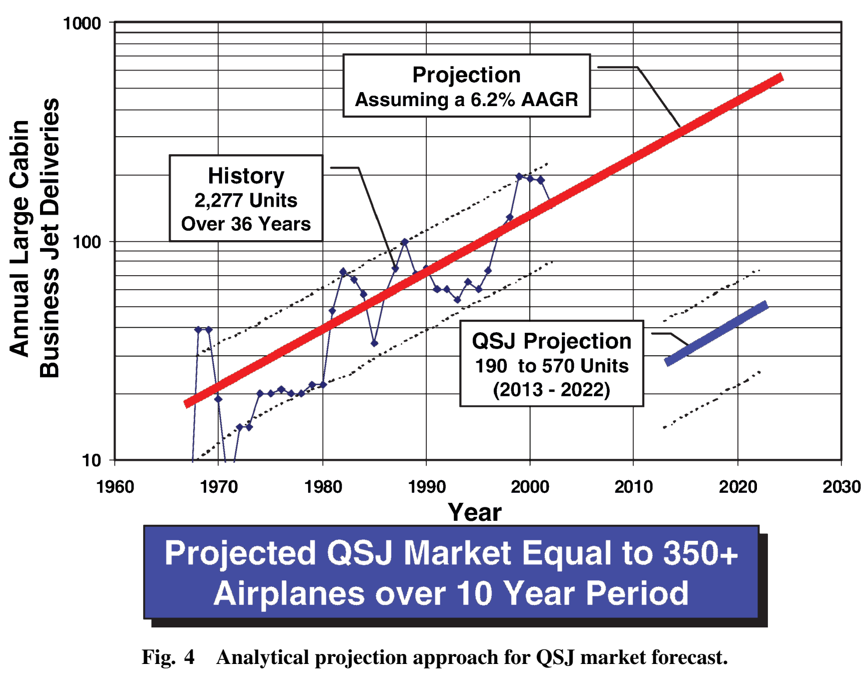


Fig. 4 Analytical projection approach for QSJ market forecast.

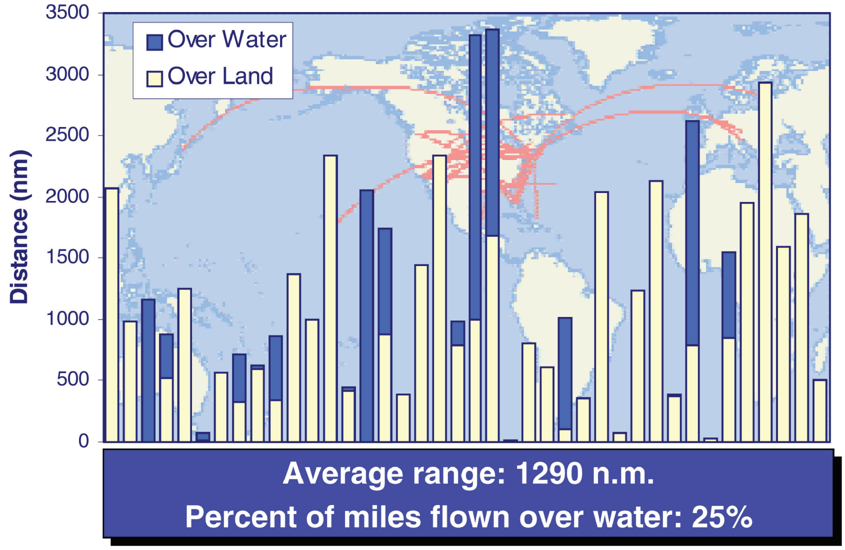


Fig. 5 Random sample of small civil aircraft operation.

compatible.[1,6] In this context, environmentally compatible means effectively addressing the following: 1) sonic boom, 2) engine exhaust emissions, and 3) airport noise. A feasible design must reduce the configuration's sonic boom signature such that supersonic flight over land is acceptable to the public. As discussed earlier, the market research studies have repeatedly confirmed that supersonic overland flight is of critical importance to the value of the vehicle.[1,3,5] The design must also minimize adverse atmospheric effects due to engine exhaust emissions throughout all operations. Emissions must be minimized during both low-speed, low-altitude airport operations as well as high-altitude supersonic cruise operations. Furthermore, a successful QSJ must be a quiet, good neighbor to the airport environment. It should make no more noise than today's quiet small subsonic civil jets.

Sonic Boom

The effort to suppress sonic boom successfully has several major aspects. First, the vehicle aerodynamic design is used to shape the sonic boom signature. Shaped signatures are defined by the prevention of coalescence of the signature into an annoying N-shaped pressure wave. Second, psychoacoustic testing is being used to establish signature levels and desired signature shapes that are considered environmentally acceptable. Third, a flight demonstration will be required to prove boom suppression acceptability. A flight demonstration will provide a foundation of scientific data necessary for regulation of supersonic overland flight, as well as risk reduction for the business decision to launch a production program.

When the physics of sonic boom are considered,[9] it is very clear that a small aircraft has a profound advantage over large aircraft. The size and weight of a vehicle has a first-order effect on the strength of the sonic boom signature. As the vehicle weight decreases, the sonic boom disturbance is decreased. Careful attention to the physical shape of the vehicle can result in a shaped ground signature rather than a coalesced N wave. Shaped ground signatures avoid the large abrupt pressure increases associated with beginning and end of a typical sonic boom N wave. Shaped signatures have lower initial and final pressure increases and are perceived as substantially quieter due to their more-sinusoidal, very-low-frequency character. Shaped signatures can be thought of as precoalesced signatures designed to a special wave shape.

Figures 6 and 7 show the impact of vehicle size and shaping on the sonic boom ground signature. These charts show data for a 300-passenger high-speed civil transport (HSCT), the Concorde, a generic supersonic business jet (SBJ), and two QSJ configurations. The effect of weight alone is shown in Fig. 6 by the line connecting three N-wave vehicles: HSCT, Concorde, and SBJ.

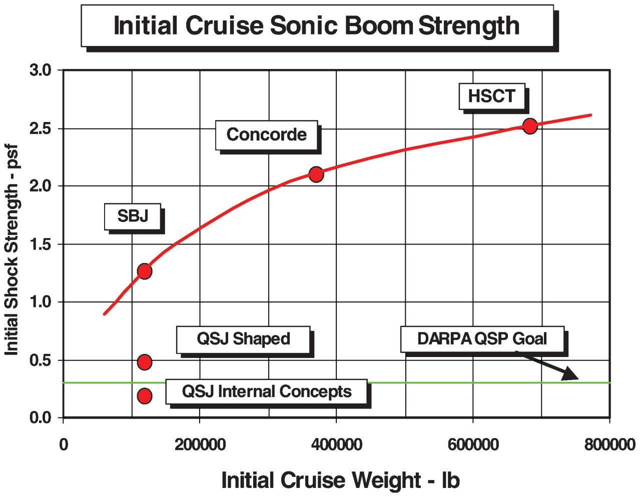


Fig. 6 Sonic boom initial overpressure strongly affected by vehicle weight.

Gulfstream has defined several unique airplane configuration details that reduce the initial overpressure and enhance the vehicle designer's ability to control the shape of the ground signature produced.[10,11] Results for several of these configurations are indicated in Figs. 6 and 7. Several of these design concepts have been validated in recent wind-tunnel testing conducted at NASA Langley's 4 Foot Unitary Wind Tunnel. As indicated in Fig. 8, the data for the advanced boom suppression concepts show very promising signature characteristics. Based on these computational fluid dynamics (CFD) and wind-tunnel test results, initial overpressures of less than 0.2 psf and peak overpressures of 0.5–0.6 psf seem quite achievable. Clearly, additional model and flight testing are needed to develop, validate, and fully exploit sonic boom suppression technology. This aerodynamic technology need is a long-standing aeronautical barrier that has not yet been adequately addressed.

Sonic boom strength for configurations with signatures such as those in Figs. 7 and 8 have been analyzed in terms of perceived level of noise in decibels (PLdB) and A-weighted noise in decibels [dB(A)]. The results shown in Fig. 9 show a remarkable improvement in the cruise signature acoustic strength. Results for configurations shown in Fig. 9 indicate that the noise levels can be reduced more than 35 dB below that of the Concorde sonic boom. These levels are at or below conversation-level acoustics. Such signatures are better characterized as sonic puffs rather than as sonic booms.

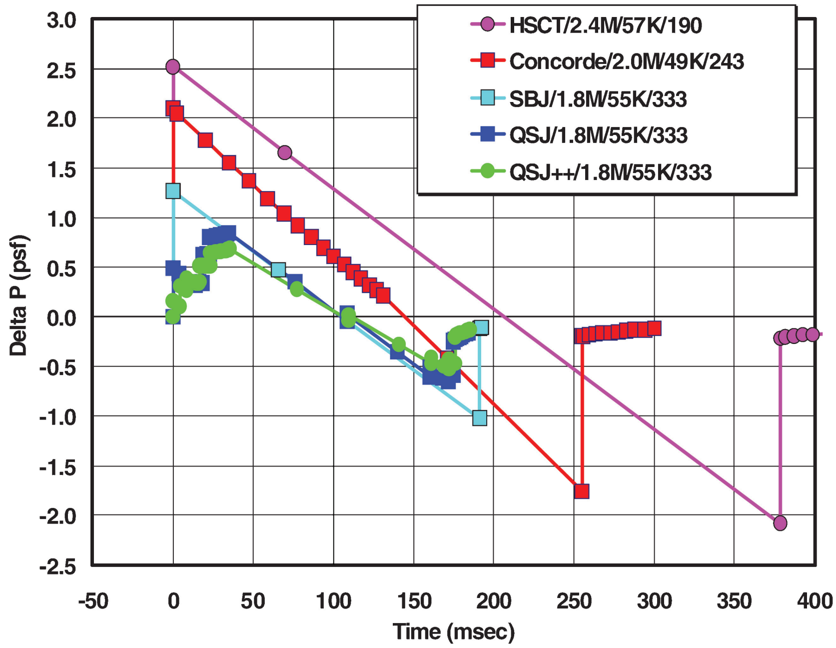


Fig. 7 Ground boom signature progression with vehicle size reduction and advanced shaping concepts.

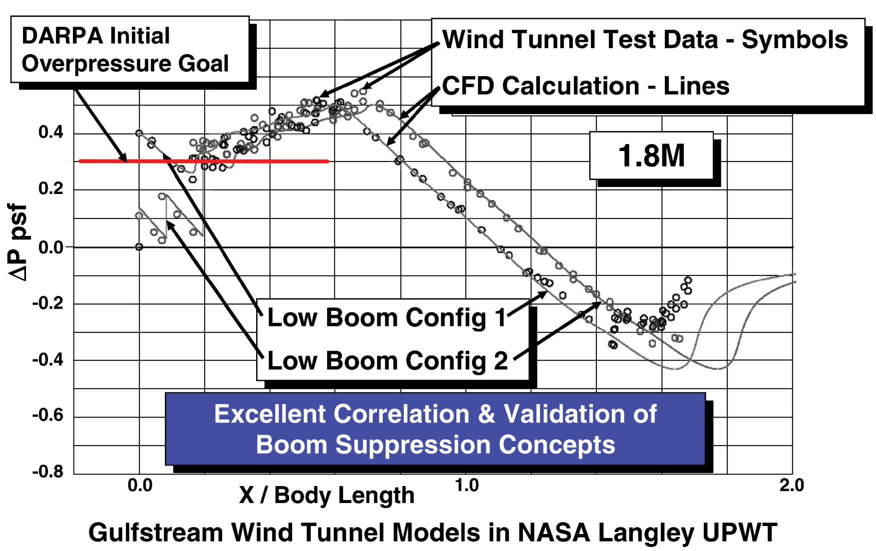


Fig. 8 Advanced boom suppression concept testing results.

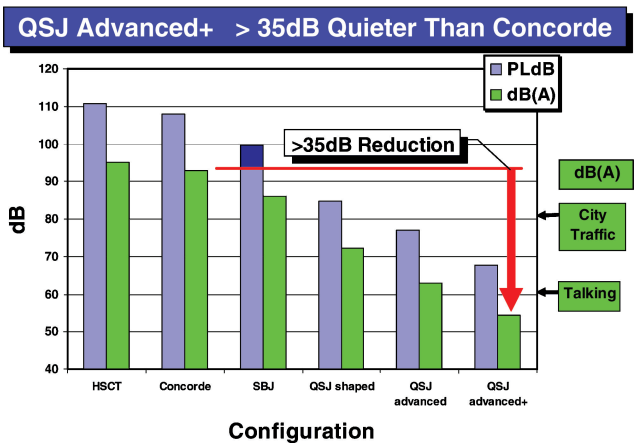


Fig. 9 Progress in lowering sonic boom strength.

Engine Exhaust Emissions

Engine exhaust emissions are another environmental concern that must be addressed responsibly. In the airport environment there are regulations that can be used as design goals. These regulations limit oxides of nitrogen (NOx), unburned hydrocarbons, carbon monoxide, and smoke emissions. These existing limits are well understood and currently considered well within the QSJ design capability. Unfortunately, this clearly defined situation is not the case for engine emissions at high-altitude cruise conditions. There are no current regulations or standards for cruise emissions. This absence of current regulations, however, does not mean the issue can be neglected. In fact, a lack of understanding about cruise emissions has been a key argument against previous supersonic transport programs.[6] The difficulty in early programs was lack of credible understanding of atmospheric science. The absence of such knowledge left the door open for wild and exaggerated claims of atmospheric trauma based on speculation, misinformation, and political agendas. The current state of knowledge has advanced sufficiently to make credible estimates of atmospheric impacts of aircraft cruise emissions.[12]

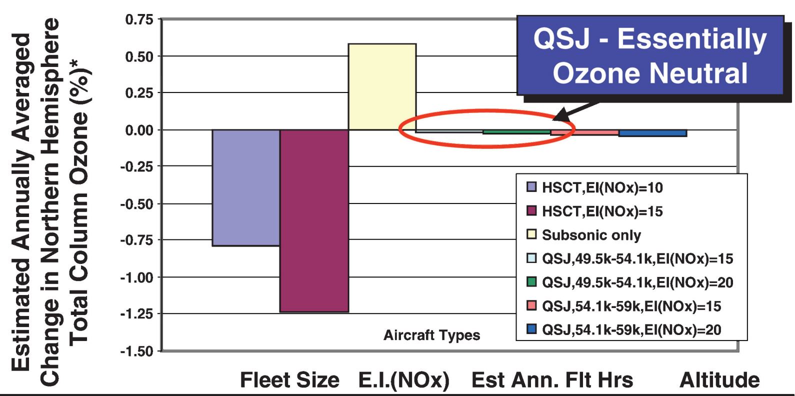
An analytical atmospheric model study has been conducted as a first proactive step toward understanding a QSJ fleet impact on the atmosphere. One important aspect of the study is an understanding of the impact of engine NOx emissions on atmospheric ozone. Figure 10 presents some of the results of this study relative to ozone impact.[12] The estimated annually averaged change in Northern Hemisphere total column ozone (in percent) due to the operation of a QSJ fleet is shown. Similar atmospheric impact data have been estimated for the current commercial subsonic transport fleet and a large supersonic transport (HSCT) fleet. These estimates are presented in Fig. 10 for comparison.

The results of this atmospheric model work indicate that the envisioned QSJ fleet impact on the Earth's ozone is essentially neutral when compared to either the subsonic fleet or an HSCT fleet. An important conclusion of the study is that the much smaller size of the QSJ, compared to the HSCT, combined with the slightly slower speed (1.8 vs 2.4 Mach number) yields a very favorable impact assessment. The slower speed is a primary factor in lowering cruise altitudes to near the crossover point, where the NOx impact on total column ozone changes sign (see Fig. 11). This atmospheric science understanding can now be exploited to minimize ozone impact through proper aircraft design requirements. If QSJ cruise altitudes can be held down close to the 47,000-ft. crossover point, then the ozone impact will be less than a few hundredths of a percent. This effect is several orders of magnitude less than was feared for an HSCT fleet and is likely imperceptible. It is also achieved with far less exotic combustor requirements, as indicated by the EI(NOx) values of 15,20.

In addition to NOx, emissions of H_2O and CO_2 need to be minimized. This minimization is easily translated into a minimization of aircraft weight and engine specific fuel consumption (SFC) concurrent with a maximization of aerodynamic lift-to-drag ratio (L/D). Of course, this menu is nothing more than the pursuit of fundamental aeronautical efficiencies. "Green Aircraft" solutions are still driven by aeronautical fundamentals. An aggressive, balanced program of continuous aeronautical research and development in L/D, SFC, structures, and materials technology is sorely needed to advance the low-emissions aeronautical state of the art.

Airport Noise

Operational flexibility requirements dictate that the QSJ must be designed to exceed the regulatory requirements for airport noise. Current regulations require aircraft to meet stage 3 noise limits. After 2006, all new aircraft will be required to meet stage 4, a



	Fleet Size	E.I.(NOx)	Est Ann. Flt Hrs	Altitude
High Speed Civil Trans.	500	10,15	1000 - 3000	56k - 66k
Commercial Subsonic	50,000 +		3000 +	32k - 43k
QSJ	400	15,20	1000	49k - 54k
QSJ	400	15,20	1000	54k - 59k

Fig. 10 Atmospheric modeling studies indicate minimal QSJ impact on ozone.

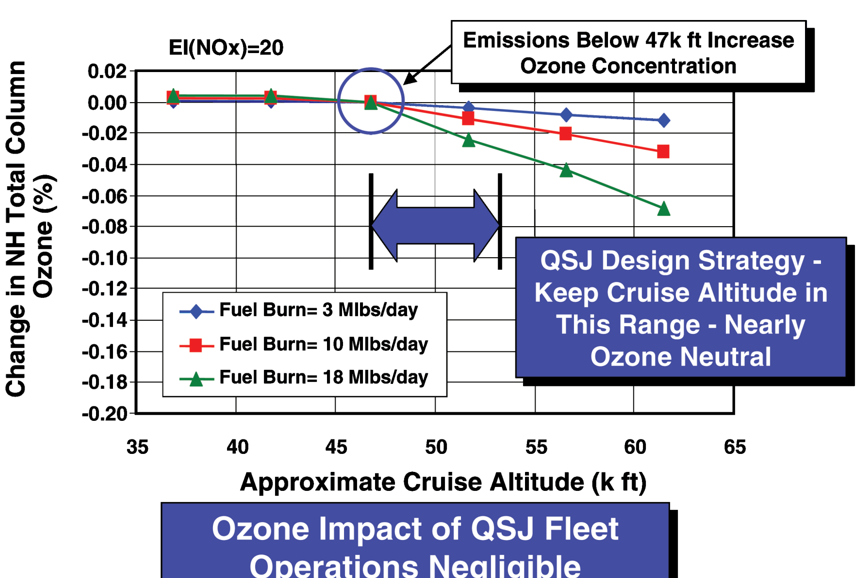


Fig. 11 NOx emission ozone impact crossover point and sensitivities.

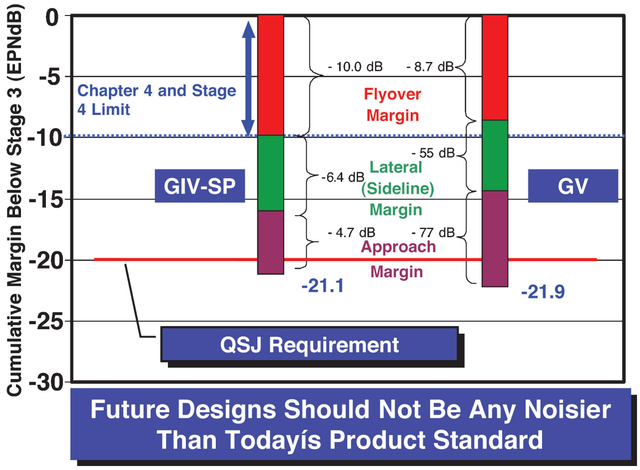


Fig. 12 QSJ community noise requirements.

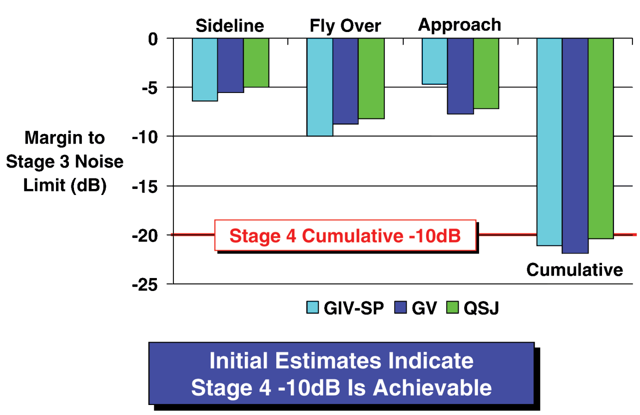


Fig. 13 Estimated QSJ certification noise levels.

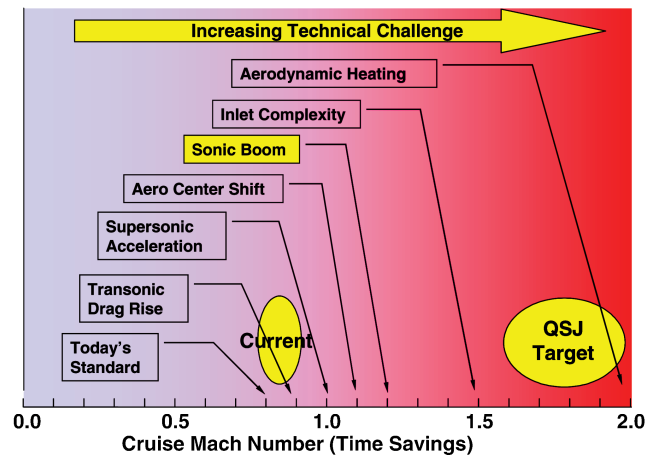


Fig. 14 Supersonic speed challenges.

10-dB-quieter cumulative level of acoustic performance relative to stage 3. Current Gulfstream production airplanes, the Gulfstream 300/400 (GIV-SP) and the Gulfstream 500/550 (GV), are already better than 10 dB quieter than stage 4. This community friendly sound level is illustrated in Fig. 12. A viable QSJ configuration entering service after 2006 will have to at least meet stage 4 limits from a regulatory standpoint. However, to ensure operational flexibility and product viability, the configuration must not be any noisier than today's quiet small civil jets such as the GIV-SP and GV. This noise requirement translates into nominally stage 4 minus 10 dB cumulative or stage 3 minus 20 dB cumulative, as indicated in Fig. 12.

To achieve this level of acoustic performance propulsion system, design, integration, and airplane performance have to be merged effectively. All three areas are being considered in QSJ configuration studies. By recognization of this noise requirement in QSJ configuration studies, the vehicle configuration concepts have moved in a direction to ensure low community noise is attained. Initial estimates for a baseline QSJ configuration acoustic performance are presented in Fig. 13. The estimate indicates that the stage 4 minus 10-dB requirement seems achievable.

Program and Design Requirements

Program Requirements

Program requirements for the QSJ are defined so that the technical, environmental, and economic equations can be solved with manageable risk for an identified market. These requirements can be summarized as follows:

1) Market potential must be significant.

2) Customer requirements for identified market must be satisfied.

3) Technical, environmental, and economic risks must be acceptable.

Market research efforts discussed earlier indicate that a market exists if a vehicle can be defined with supersonic overland flight capability. Clearly, supersonic overland flight is the highest risk item for small supersonic civil aircraft feasibility. Current U.S. regulations, adopted in a time of significant international political agendas, simply prohibit supersonic flight overland. This politically induced prohibition, implemented decades ago, was a simple, quick regulatory response to fears of environmental catastrophes perceived to be associated with SSTs such as Concorde. The need exists to supersede this prohibition with a rational rule that protects the environment while it allows the ability to advance with higher speed.

As discussed earlier, progress is being made to address sonic boom suppression technology. This progress should culminate in a flight demonstrator program. Such a program can provide at least three benefits:

1) It provides technical substantiation of boom suppression technology.

2) It provides regulatory authorities with a means to specify confidently a rational and accepatable sonic boom rule.

3) It provides a significant risk reduction for the business decision on the launch of a small supersonic civil aircraft production program.

Consequently, it is believed that a fundamental QSJ program requirement is a flight demonstrator program before a production program commitment.

A second program risk area is associated with an increase in technical complexity with increasing Mach number in the supersonic regime. As indicated in Fig. 14, technical challenges abound in the jump to supersonic. However, it must be said that these are not new and have been addressed in some fashion by the historical achievements shown in Fig. 3. When these challenges are put into a civil vehicle context and commercial business case, it is easy to draw a limit at Mach 2.0. Such a limit allows the program to avoid risk associated with aerodynamic heating at higher speeds. It also allows for reduced propulsion installation complexity and reduced temperature effects in the propulsion system. Slightly lower Mach numbers are favored to reduce the cruise altitude for considerations such as ozone impact. Slightly higher cruise Mach numbers are favored to maximize range through ML/D. Current Gulfstream QSJ program studies are focused on cruise Mach numbers between 1.6 and 2.0. The current Gulfstream QSJ program baseline is 1.8.

A third program risk area is associated with the combination of cabin cross section, vehicle gross weight, and range in excess of 4000 n mile. This is an interesting combination of characteristics. Operational flexibility for small civil aircraft dictates a maximum takeoff gross weight of 100,000 lb or less. This constraint comes about for a number of reasons. Foremost of these is a broad number of important airports with gross weight limitations set at 100,000 lb. The need for light weight for suppressed sonic boom also drives to gross weights of 100,000 lb or less. Unfortunately, detailed configuration design studies currently show that, for a vehicle at 100,000 lb the maximum allowable cabin size is not compatible with the large cabin business jet standup style cabin. This result is shown in Fig. 15.

In Fig. 15, three cabin cross sections are shown. The first is for the current large cabin market leader, the G550 (GV), and represents a minimum acceptable cross section deemed to be attractive for the long range business aircraft today. Its cabin height is 74 in. The second cross section is for a QSJ configuration that meets performance and boom requirements. The cross section is acceptable. Unfortunately, the takeoff gross weight is in excess of 150,000 lb. The third cross section is for a smaller configuration sized for a maximum takeoff gross weight of 100,000 lb. Unfortunately, the cross section does not meet minimum standards for a large-cabin aircraft where occupants could spend 5 h in the cabin. This risk area is one that needs additional research to develop a configuration satisfying all of the market requirements.

	G550	TOGW > 150K lb	TOGW = 100K lb
Max Fuselage Diameter	94.0	93.0	80.9
Aisle Height w/ Flat Floor	74.0	75.9	66.0
Aisle Height w/ Notch	n/a	n/a	68.9
Aisle Width above 25 in	20.0	20.0	20.0
Aisle Width below 25 in	20.0	20.0	15.0
Seat Width	26.0	26.0	24.0

(all dimensions in inches)

Fig. 15 Fuselage cross section comparison.

Design Requirements

Market requirements, environmental concerns, and program requirements can all be combined into a cohesive set of design requirements for a small supersonic civil aircraft. Performance goals such as cruise speed, range, payload capability, and field performance must be met while low noise, low exhaust emissions, and a sonic boom signature deemed acceptable for supersonic overland fight are simultaneously achieved. These requirements are summarized in Fig. 16. Also, provided in Fig. 16 are the current red/yellow/green color assessments of risk associated with the satisfaction of each requirement. The red areas are both associated with sonic boom. In addition, the certification concern includes the absence of any certification regulations for civil supersonic aircraft. Concorde certification was accomplished three decades ago through a large number of special conditions largely reflecting consideration of only the unique Concorde type design. Airworthiness certification standards for subsonic aircraft have substantially advanced to higher standards since the time of Concorde certification. Any new supersonic type will necessarily need to satisfy higher standard regulatory requirements for certification. The yellow assessments are for areas

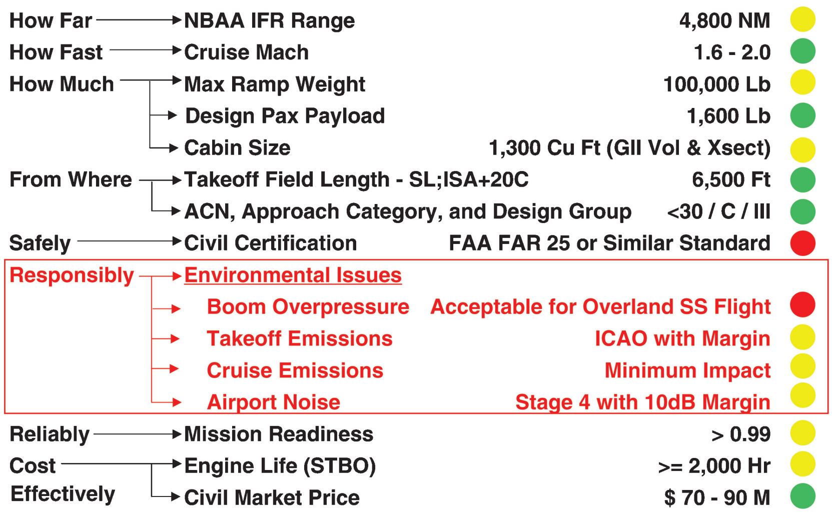


Fig. 16 Top level QSJ design requirements.

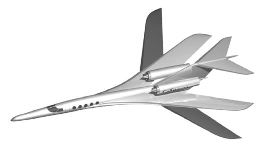
	Fixed	Variable Sweep
		
Pros	• Lower Complexity • Improved Structural Load Path • Greater Fuel Volume	• Improved Low Speed Perf. • Better for Noise • Improved Subsonic Range • Greater High Speed Potential
Cons	• Unacceptable Field Length Requirements (Operational Restrictions) • Poor Subsonic Performance (Reduced Flexibility)	• Increased Complexity (System & Operational Requirements) • More Difficult Certification • Weight Penalty

Fig. 17 Variable wing sweep favored for satisfying QSJ design requirements.

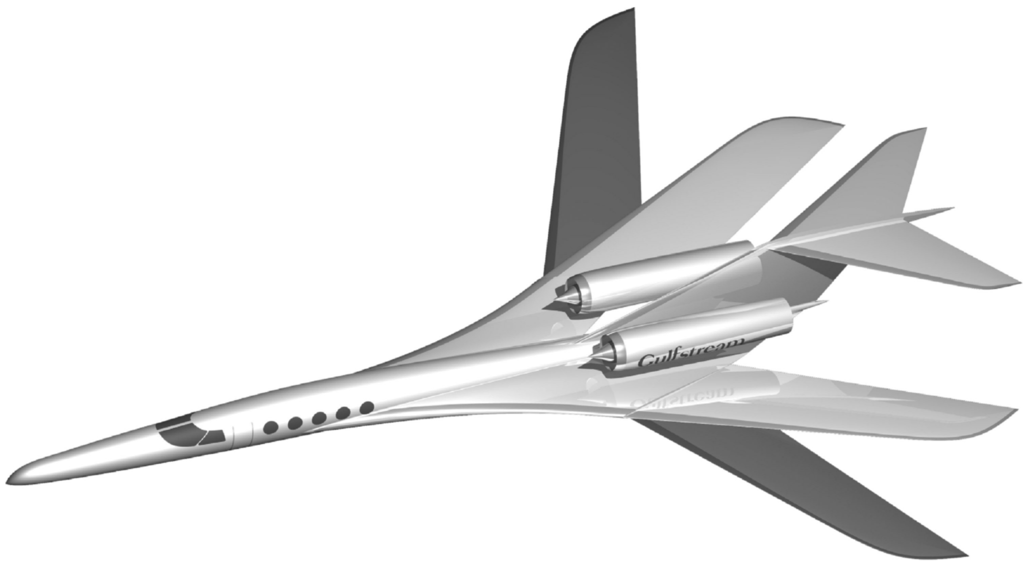


Fig. 18 QSJ baseline variable sweep configuration.

that need more research and technology development to achieve the desired level of performance.

Configuration Characteristics

One of the more significant design considerations that has been evaluated in the development of a configuration to meet the Fig. 16 design requirements is the wing geometry. The introduction of variable wing sweep geometry offers the potential of satisfaction of the diverse high-speed and low-speed requirements. Analyses to date indicate that variable wing sweep is favored. The precedents set with F-111, F-14, and B-1, as well as numerous foreign designs, confirm that this design approach is certainly ready for the civil market. As summarized in Fig. 17, the positives for variable wing sweep outweigh the negatives. The variable sweep wing has been a strong factor in the green assessment shown in Fig. 16 for takeoff field length. It is fundamental to the data shown in Fig. 13 for airport noise estimates. It provides for greater potential in the high-speed design area for both improvement of supersonic performance and suppression of sonic boom. A Gulfstream baseline QSJ configuration with a variable sweep wing is shown in Fig. 18.

Summary

A significant factor in the growth of small civil aircraft market is the value of time. Recognition of the ever-increasing value of time has lead to increased interest in the feasibility of a small supersonic civil aircraft. The step to supersonic speeds offers the potential of a dramatic decrease in travel time. Multiple market research studies of a small supersonic civil jet have been conducted. The current perspective indicates there is a significant market potential for a small supersonic civil aircraft, provided supersonic overland flight is achieved. Studies suggest a market size of 300+ units over a 10-year period can be expected.

Hindsight suggests that a first truly successful supersonic civil aircraft should, in fact, be a small vehicle. Vehicles of the business aircraft size provide a much greater opportunity for a successful solution of the technical, environmental, and economic concerns. Successful achievement of technical, environmental, and economic objectives with a business jet size vehicle will satisfy growing market demand and pave the way for future larger and more advanced vehicles.

Environmental concerns for sonic boom, engine exhaust emissions, and airport noise need to be addressed responsibly for any small supersonic civil aircraft design. Significant progress has been made in the development of sonic boom suppression technology. Boom suppression technology needs to be flight demonstrated to reduce risk to a point of commercial acceptability. Atmospheric chemistry models have advanced to the point of credible analyses of emissions impacts. Atmospheric studies of aircraft cruise emissions suggest advantageous cruise altitudes and strongly favor a small vehicle. An aggressive and continuing research and development program in aeronautical fundamentals is sorely needed to support low emissions in future aircraft designs.

The small supersonic civil aircraft is seen as an exciting opportunity finally to provide a successful supersonic transportation system. It is an opportunity to provide revolutionary capability to a market that values speed. It is an opportunity to provide the long-sought first successful supersonic civil aircraft.

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