6.3.7 Cruise

For an aircraft with a supersonic cruise segment, the cruise *L/D* must be estimated. This can be assumed to the value of $(L/D)_{max}$ at the cruise condition. This is dependent on both the aircraft shape and the cruise Mach number.

The estimation of supersonic $(L/D)_{max}$ is not addressed until Chapter 12 and the procedure in this chapter can be summarized as:

- Calculate $C_{D_{0supersonic}}$ using Raymer Eq. (12.41). Typical values are shown in Fig. 12.34
- In Eq. (12.41), get $C_{D_{wave}}$ from Eq. (12.45), where $C_{D_{wave}} = (D/q)_{wave}/S_{ref}$.
- In Eq. (12.45), get $(D/q)_{Sears\text{-}Haack}$ from Eq. (12.44).
- Estimate *K* for your airplane using Annotation 12.6.2, Fig 12.6.2.1. This figure applies to delta wing-body combinations, but there is a strong possibility that your configuration will be have a delta wing, or close to it.
- Calculate $(L/D)_{max}$ from Annotation 3.4.4, Eq. (3.4.4.6).

Unfortunately you have no assurance of getting the right answer, because you don't know the value of E_{WD} in Raymer Eq. (12.45).

A slightly simpler approach from Boeing (Ref. 6.3.7.1) is to base the minimum drag on the method from Jones and Cohen (Ref. 6.3.7.2) so that the value of $(L/D)_{max}$ for a supersonic transport flying at the optimum altitude is given by:

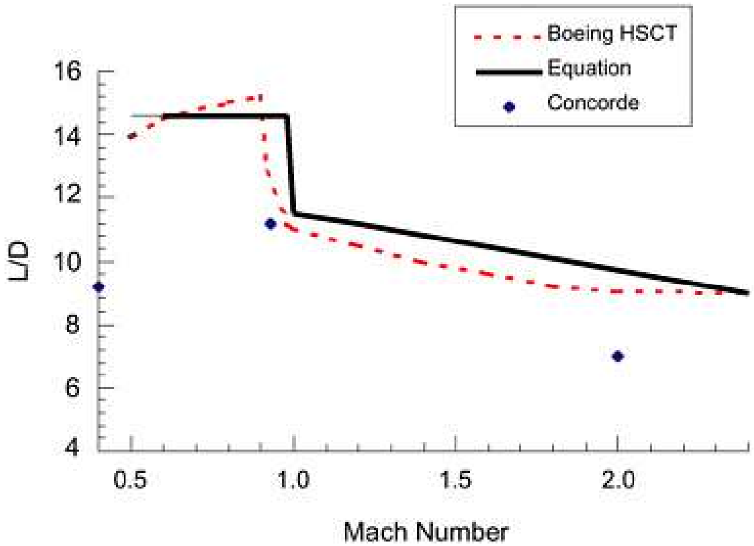
$$\left(\frac{L}{D}\right)_{max} = \left[\left(\frac{4}{\pi A} + \frac{2\left(M^2 - 1\right)}{\pi A_l}\right)\left(C_{D_0} + C_{D_{wave}}\right)\right]^{-\frac{1}{2}} \qquad (6.3.7.1)$$

where:		
	A	Aspect ratio ($= b^2/S$)
	A_l	Length aspect ratio ($= l^2/S$), where l is overall length
	C_{D_0}	Subsonic zero lift drag coefficient
	$C_{D_{wave}}$	Zero-lift wave drag coefficient

This method suffers from the same problem as that of the Raymer method in the difficulty of estimating $C_{D_{wave}}$.

Eq. (6.3.7.1) is plotted in Fig. 6.3.7.1 for the values of

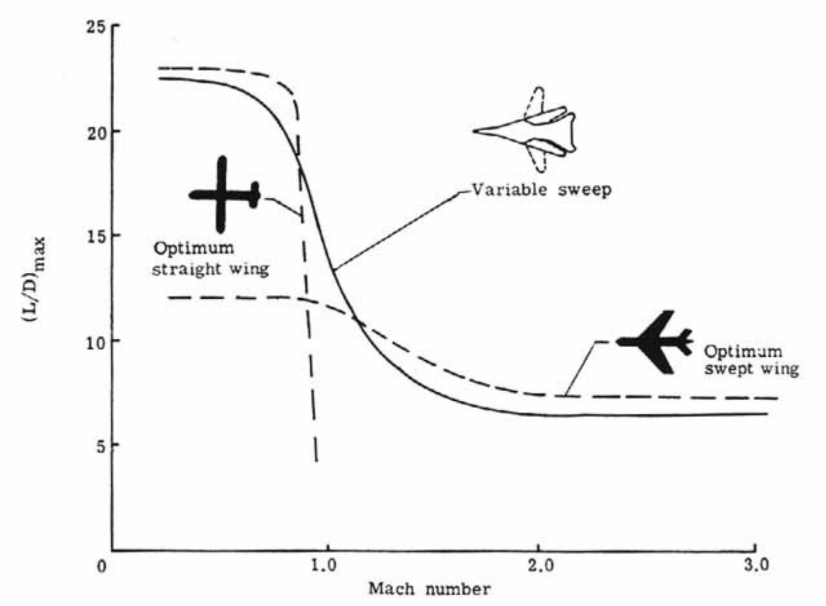
$C_{D_0} = 0.0100$
$C_{D_{wave}} = 0.0060$ (if $M < 1$ then $C_{D_{wave}} = 0$)
$A = 2.7$
$A_l = 10$ (if $M<1$ then term containing A_l is zero)



Source: Boeing

Fig. 6.3.7.1 L/D for Supersonic Transports

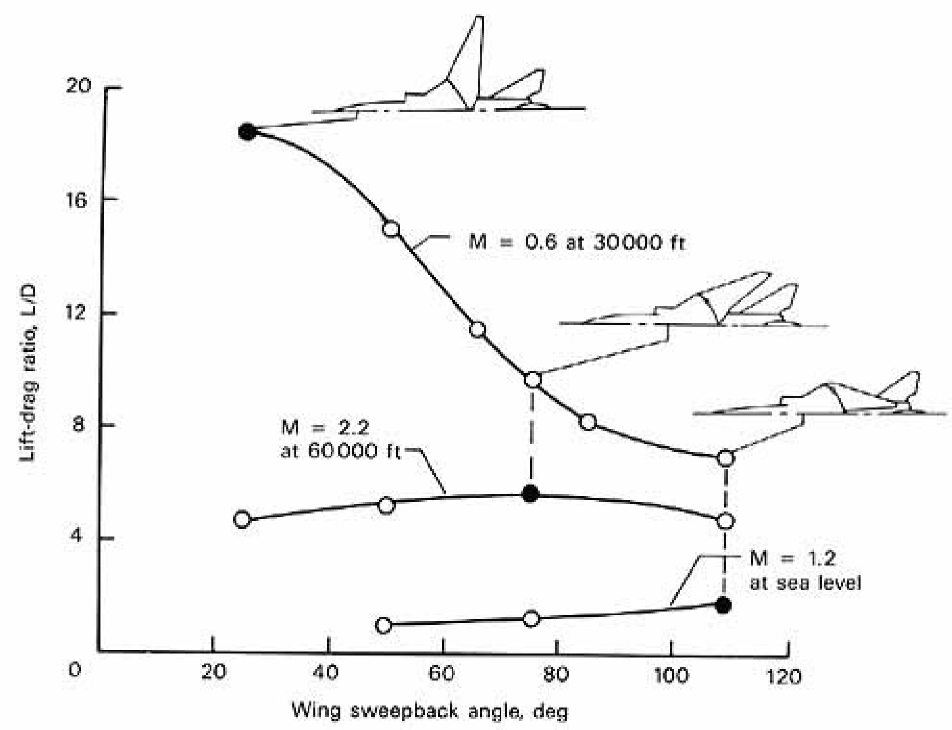
Supersonic transports are optimized for the supersonic cruise condition, with no compromise, except for other performance constraints such as takeoff and landing, for requirements such as low-observability or air combat. The value of *L/D* in Fig. 6.3.7.1 therefore represent a maximum value for supersonic-cruise aircraft.



Source: Airliners.net

Fig. 6.3.7.2 L/D of Three Configurations

Values of $(L/D)_{max}$ for other supersonic configurations are shown in Fig. 6.3.7.2. One configuration appears to be similar to that of the F-111, whose design is compromised for combat. Additional values of *L/D* for a configuration like that of F-111D for non-optimum sweep angles are shown in Fig. 6.3.2.3. Note that the maximum sweep angle for the F-111 is 72.5^0.



Source: Airliners.net

Fig. 6.3.7.3 L/D of F-111D at Three Mach Numbers

At this stage in the design process, a reasonable approach is to assume a value of supersonic $(L/D)_{max}$ based on a configuration that is similar to your design.

References

6.3.7.1 Jones, R.T., and Cohen, D., "High Speed Wing Theory", Princeton University Press, 1960

6.3.7.2 Wiley, Dianne S., et al., "Commercial Supersonic Technology, The Way Ahead", National Academic Press, 2001