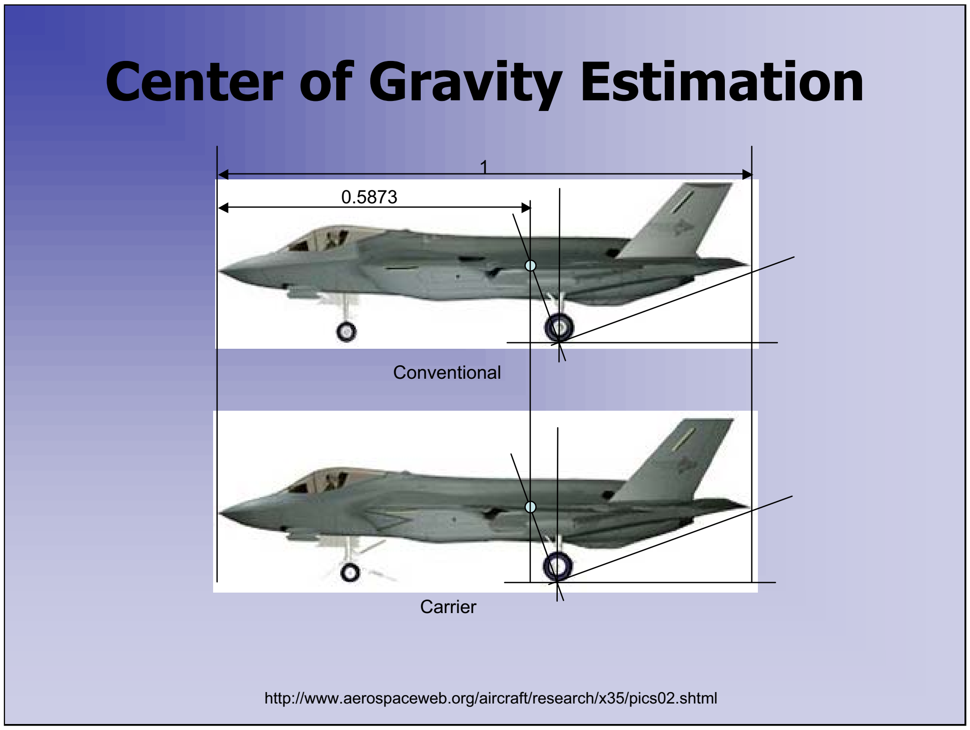
Study of Preliminary Configuration Design of F-35 using simple CFD

http://www.aerospaceweb.org/aircraft/research/x35/pics01.shtml

David Hall **Sangeon Chun** **David Andrews**

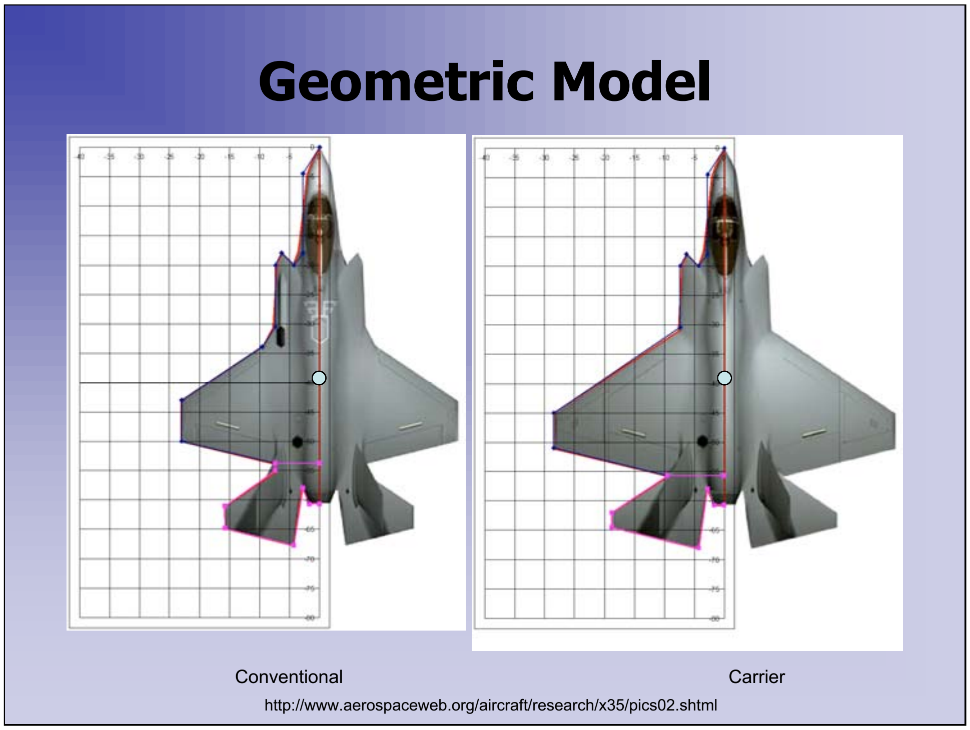


Center of Gravity Estimation

http://www.aerospaceweb.org/aircraft/research/x35/pics02.shtml

Since we could not obtain the exact C.G. point of F-35, we used the conceptual method of the tricycle landing gear geometry in Daniel P. Raymer's Aircraft Design.

As Raymer said, "For carrier-based aircraft the tipback angle frequently exceeds 25 deg." and F-35 is designed as carrier-based. Therefore this tipback angle should have been a key design parameter related with C.G. point. This is the reason that we chose the landing gear design concept here.



Geometric Model

Conventional

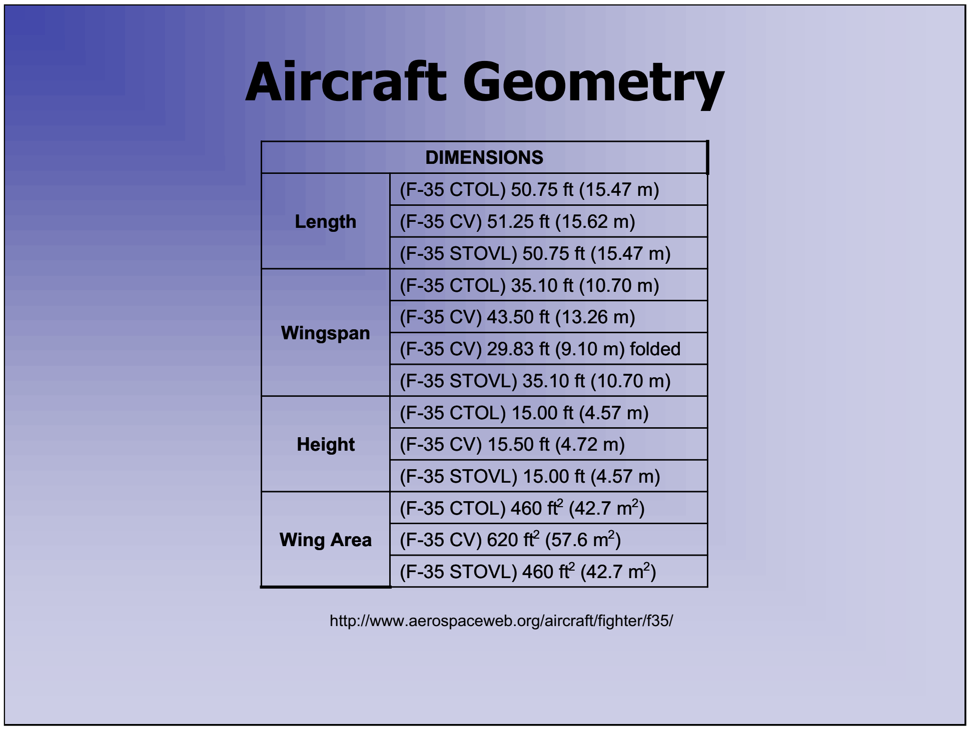
Carrier

http://www.aerospaceweb.org/aircraft/research/x35/pics02.shtml

This slide shows the way we decided the planform of two types of F-35.

Two key points were; (i) minimize the number of line segments, and (i) alignment of points close to each other along the streamwise direction.

Since this F-35 planform looks like having a streamwise tips for main and tail wings, the streamwise tip shaping was not a problem.

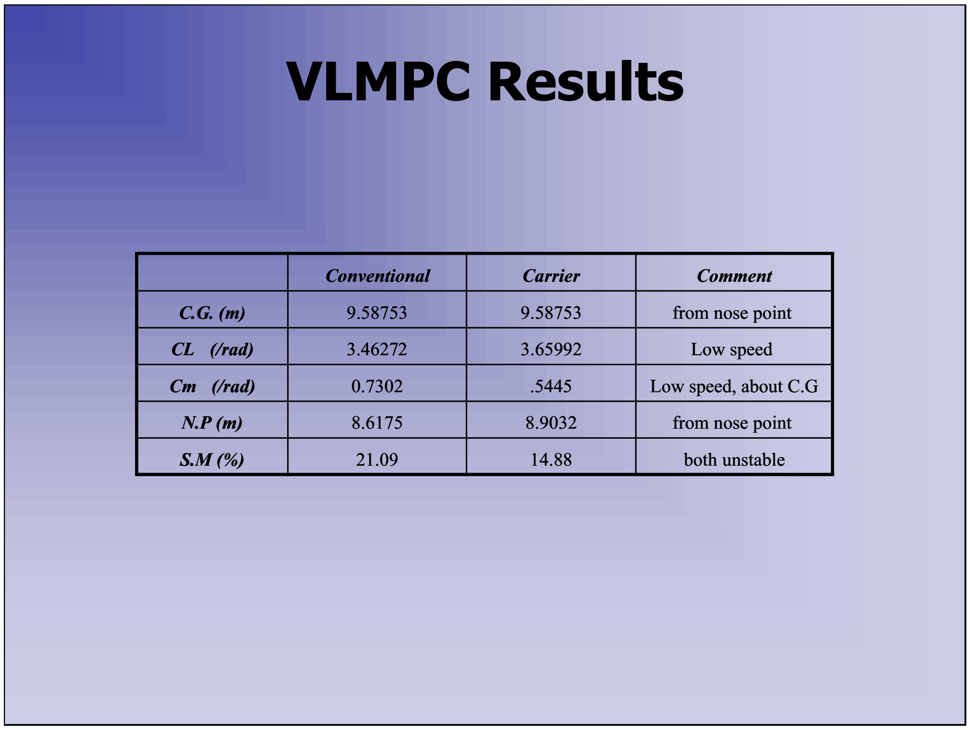


Aircraft Geometry

DIMENSIONS	
Length	(F-35 CTOL) 50.75 ft (15.47 m)
	(F-35 CV) 51.25 ft (15.62 m)
	(F-35 STOVL) 50.75 ft (15.47 m)
Wingspan	(F-35 CTOL) 35.10 ft (10.70 m)
	(F-35 CV) 43.50 ft (13.26 m)
	(F-35 CV) 29.83 ft (9.10 m) folded
	(F-35 STOVL) 35.10 ft (10.70 m)
Height	(F-35 CTOL) 15.00 ft (4.57 m)
	(F-35 CV) 15.50 ft (4.72 m)
	(F-35 STOVL) 15.00 ft (4.57 m)
Wing Area	(F-35 CTOL) 460 ft^2 (42.7 m^2)
	(F-35 CV) 620 ft^2 (57.6 m^2)
	(F-35 STOVL) 460 ft^2 (42.7 m^2)

http://www.aerospaceweb.org/aircraft/fighter/f35/

Geometry scaling was performed using the above table. As you can see in this table, F-35 has only two version from the aerodynamic configuration point of view.



VLMPC Results

	Conventional	*Carrier*	*Comment*
C.G. (m)	9.58753	9.58753	from nose point
CL (/rad)	3.46272	3.65992	Low speed
Cm (/rad)	0.7302	.5445	Low speed, about C.G
N.P (m)	8.6175	8.9032	from nose point
S.M (%)	21.09	14.88	both unstable

CG point was approximately calculated using the landing gear design concept as mentioned previously.

SM (Static Margin) was calculated from VLMPC results. Since this SM value depends on the CG point, this value can be changed to some degree but from this value we can assume that this aircraft is designed to be unstable.

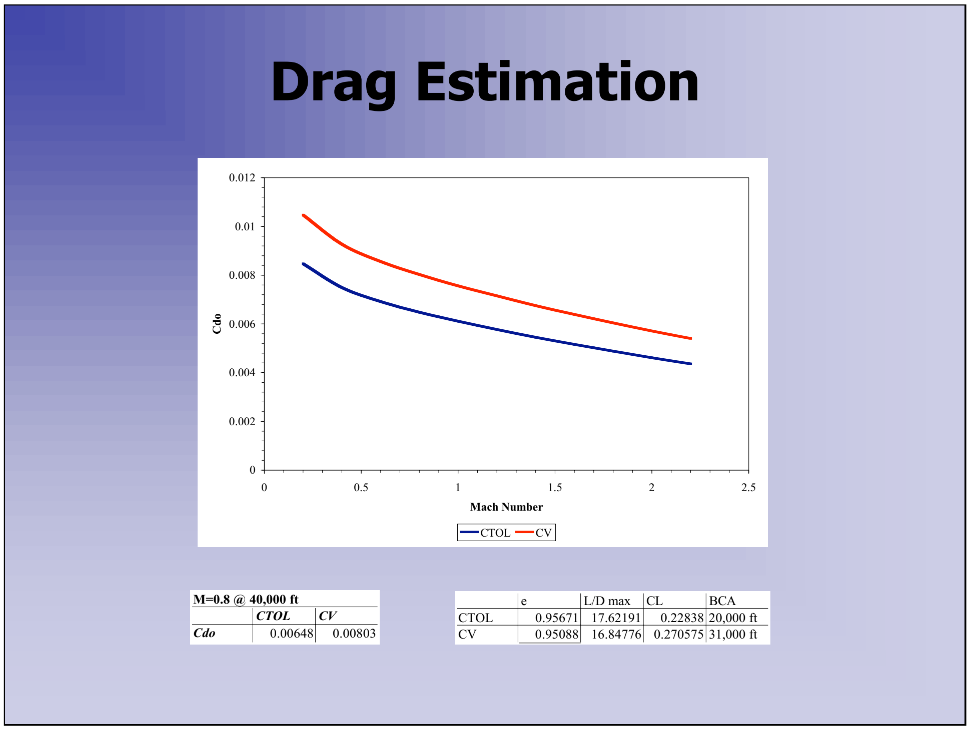
Airfoil Selection

NACA 65a-004

www.fas.org

www.fas.org

A specific airfoil for the F-35 was not available, so a study of airfoil sections of other fighter and attack aicraft was conducted. It was found, through www.aerospace.web, that the F-18 airfoil ranged from an NACA 65a-005 at the root to a 65a-003 at the tip. The F-16 airfoil was also a 65a 6-series airfoil and the F-15 airfoil was a 64a 6-series. The NACA 65a-004 airfoil was thus chosen as a reasonable representative of the type of airfoil found on other common aircraft.

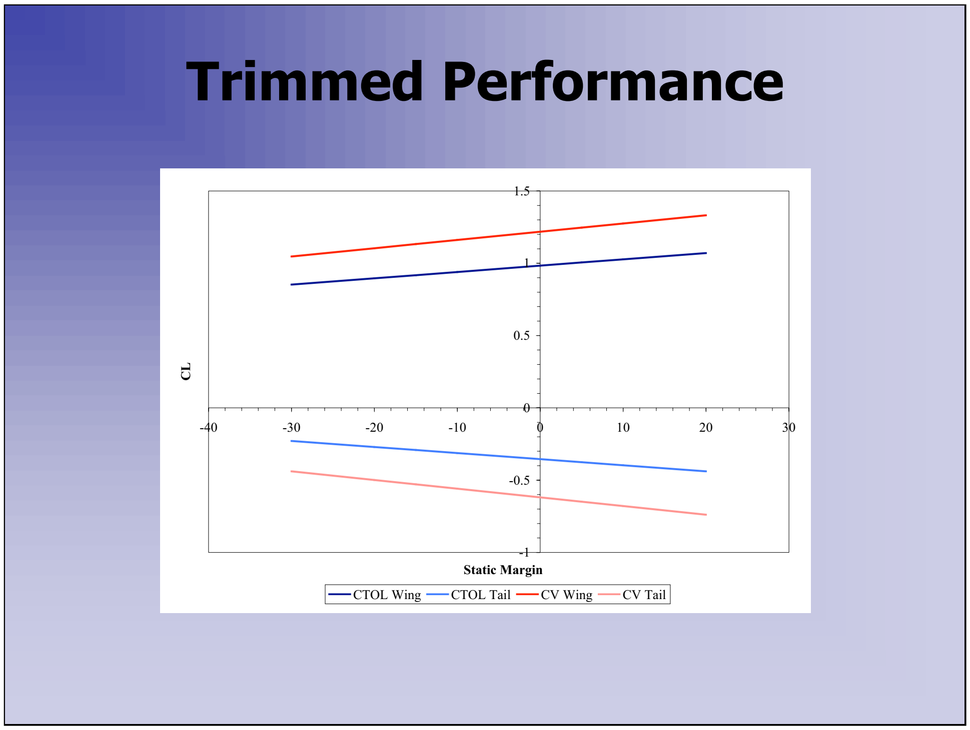


Drag Estimation

M=0.8 @ 40,000 ft		
	CTOL	***CV***
Cdo	0.00648	0.00803

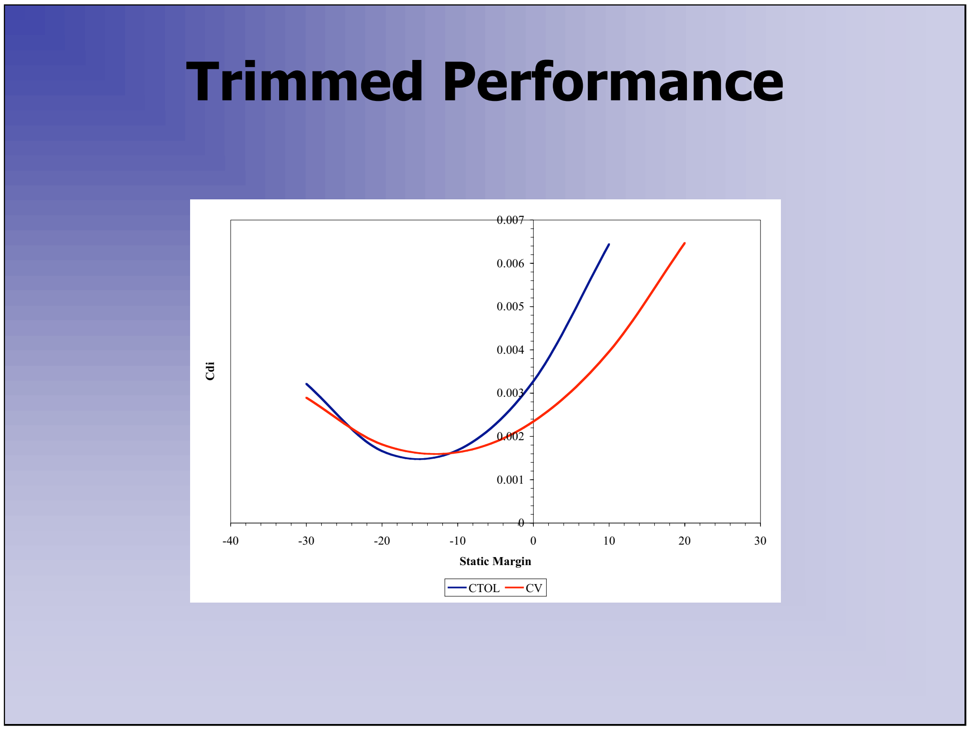
	e	L/D max	CL	BCA
CTOL	0.95671	17.62191	0.22838	20,000 ft
CV	0.95088	16.84776	0.270575	31,000 ft

The estimation of CDo was estimated through the use of the program FRICTION. The test case of M=0.8 at 40,000 ft resulted in a CDo of 0.00648 for the CTOL version and 0.00803 for the CV version, a increase of 24%. The planforms for the two versions also resulted in efficiencies, e, of 0.95671 for the CTOL and 0.95088 for the CV. Through the effieciency and L/D max numbers a best cruise altitude (BCA) was found of 20,000ft for the CTOL version and 31,000 ft for the CV version, a 50% increase.



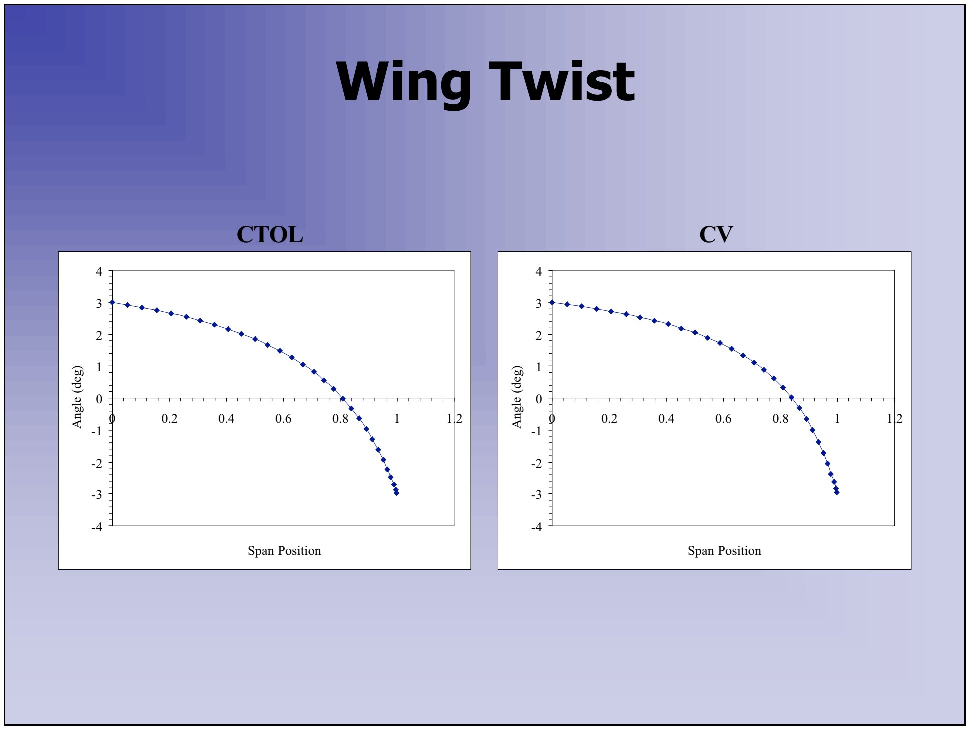
Trimmed Performance

The load split for trimmed performance was found through the use of LAMDES. The static margin of the aircraft was varied from -30 to 20 and the resulting load splits are seen above. As expected, though the total CL remains almost constant for both aircraft, the wing CL increases positively and the tail negatively.



Trimmed Performance

This trimmed performance analysis shows the minimum induced trim drag results at almost the design points of the current aircraft. Thus leading to the conclusion that LAMDES is a decent first cut analysis for an initail aircraft design.

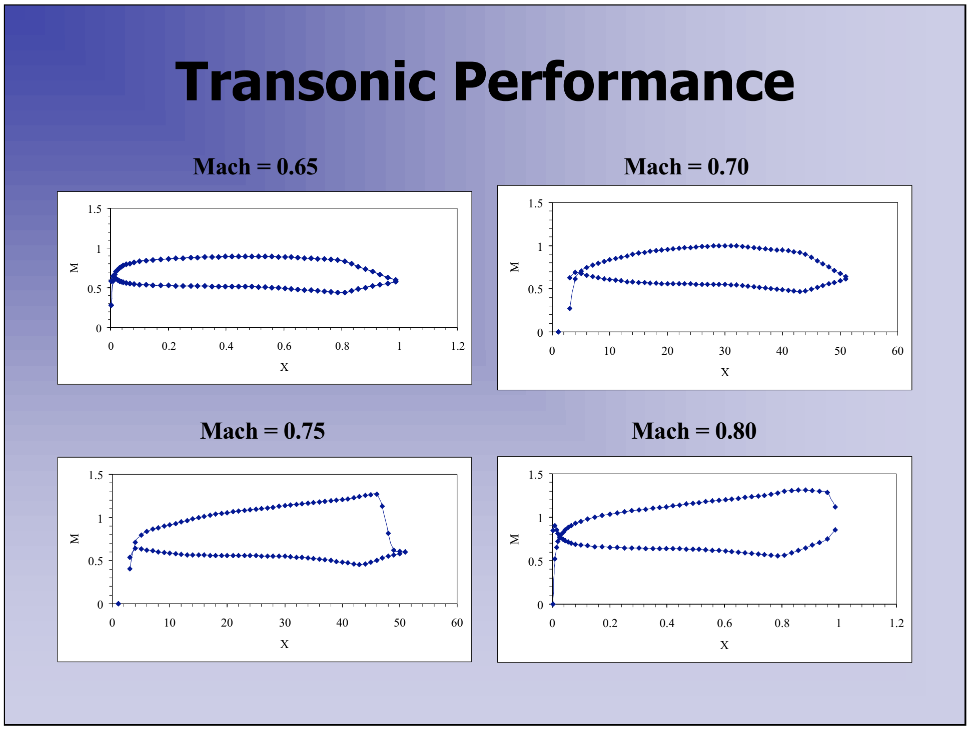


Wing Twist

CTOL

CV

Lifting line theory code was used to determine the wing twist. The assumptions are that this wing experiences a somewhat elliptical spanload. The LAMDES code we ran as a comparison to the lifting line theory yielded extremely flawed results for the wing twist and therefore the data was not included The LLT code was run with a +3 degree root twist and a -3 degree tip twist along with an aspect ratio of 2.678 for the conventional configuration and 3.052 for the carrier based configuration. A taper ratio of 0.238 for the conventional and 0.190 for the carrier based configuration was used.



Transonic Performance

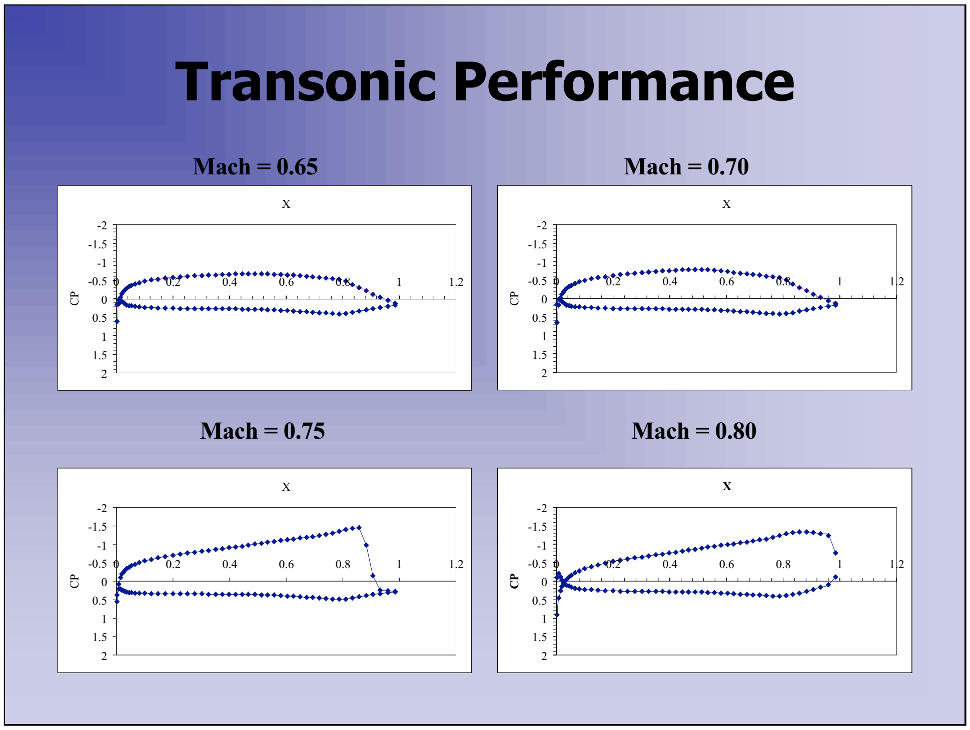
Mach = 0.65

Mach = 0.70

Mach = 0.75

Mach = 0.80

The local Mach number curves show the steady, shock-free flow over the wing at Mach numbers up to 0.70. At Mach 0.75 a shock was shown to be present near the rear of the wing section. This appears to be consistent with expectations of transonic flow. The local Mach curves above Mach 0.75 were somewhat flawed as the flow at those speeds is highly complicated and too complex for the program to solve reliably



Transonic Performance

Mach = 0.65

Mach = 0.70

Mach = 0.75

Mach = 0.80

Cp versus x/c plots were generated from TSFOIL2 and they are given in the presentation. The data from Mach 0.65 shows a steady pressure curve, as does the data from the Mach 0.7 flow. At Mach 0.75 the data indicates that a shock is present at slightly less than the 90% chord location.

Conclusion

1. Aircraft Comparisons
2. Program Effectiveness for Initial Design Analysis
3. Importance of Understanding the Programs