TF-8A Crusader with Supercritical Wing

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Justin Murtha, John Stephens, Mike Weronski

Outline

- History – F-8 and F-8 SCW
- Geometry
- Lift / Drag Analysis
- Wing Analysis
- Transonic Analysis
- Project Outcomes

F-8 Crusader

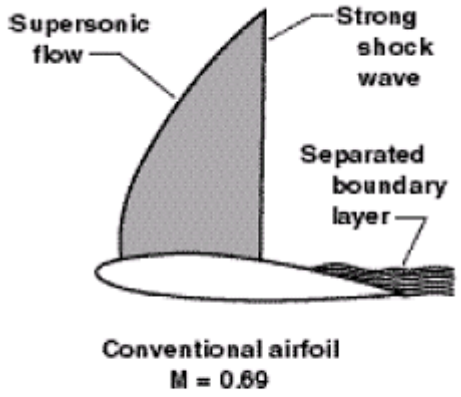
- Design began in 1952
- First Flight 1955
- Entered service in 1957
  - Logged over 2.25 million flight hours
  - Logged over 385,000 carrier landings
- Geometry
  - Length = 55 ft
  - Height = 15 ft
  - Span = 35 ft
  - Area = 375 sqft

F-8 Crusader

- Variable Wing Incidence (7 degrees)

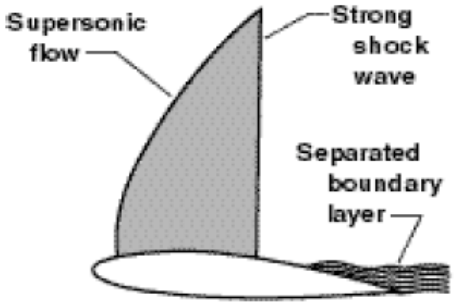
The problem…

- At high subsonic speeds, a shock can develop on the top and bottom sections of the wing
- The strong shock produced creates wave drag and separation of the boundary layer

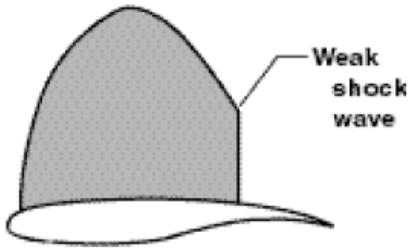


A Solution: Super Critical Wing

F-8 Supercritical wing in flight. (NASA photo EC73-3468)



Conventional airfoil
M = 0.69



Supercritical airfoil
M = 0.80

Supercritical wing diagram

Supercritical Airfoil

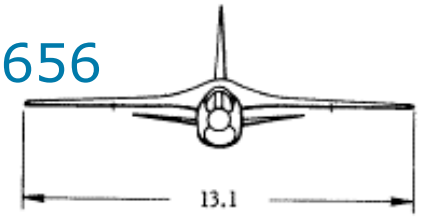
- Delays drag rise at higher subsonic mach numbers
- Richard T. Whitcomb: designed the F-8 SCW: with SC airfoil and area ruled fuselage (added bulge ahead and behind wing) designed most efficient at M=0.98
- 8-foot transonic pressure tunnel and other wind tunnels at Langley and Ames Research Center, Moffett Field, Calif.
- Rockwell International's North American Aircraft Division was awarded the $1.8 million contract to fabricate the supercritical wing. It was delivered to NASA in December 1969.

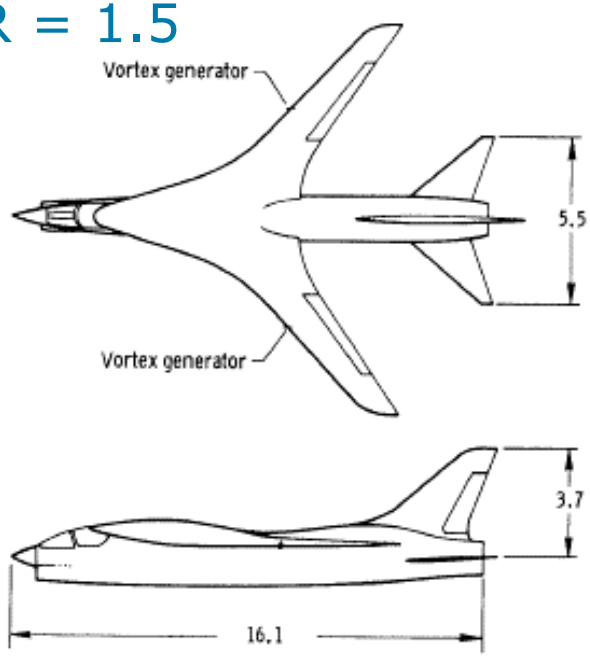
Why the F-8?

- Easily removable wing
- Landing gear retracted into the fuselage
- Capable of Mach 1.7

F-8 SCW

- Fuselage
  - Length = 52.8 ft
  - CG Loc = 31.6 ft from nose
- Wing
  - Area = 275 sqft
  - Span = 43 ft
  - MAC = 6.8 ft
  - AR = 6.773
  - Taper Ratio = .3656
- Horizontal Tail
  - Area = 93 sqft
  - AR = 3.5
- Vertical Tail
  - Area = 109 sqft
  - AR = 1.5





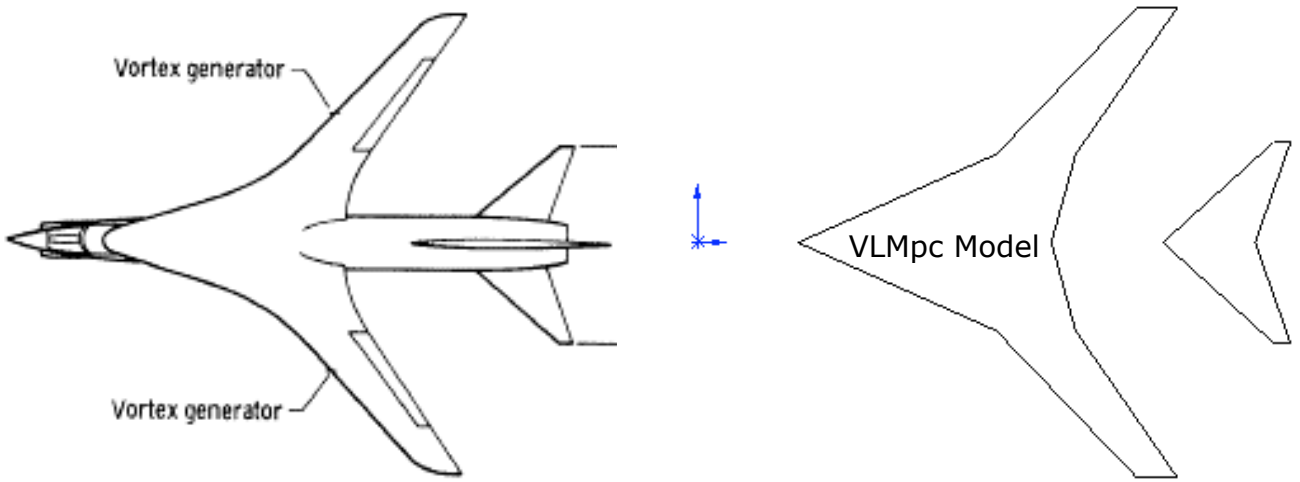
Basic Performance

- Base Weight (w/ fuel, no payload) = 18,000 lbs
- Takeoff/Landing – No high lift devices!
  - V_{TO} = 195mph on Edwards AFB 15,000ft Runway
  - $C_{L_{TO}}$ = 0.67
  - V_{LNDG} = 200mph on Rogers Dry Lake
  - $C_{L_{LNDG}}$ = 0.64
- Cruise Condition:
  - 30,000 ft
  - M = 0.96
  - $C_{L_{CRUISE}}$ = 0.165

Performance Data from http://www.nasa.gov/centers/dryden/news/FactSheets/FS-044-DFRC.html

Longitudinal Stability

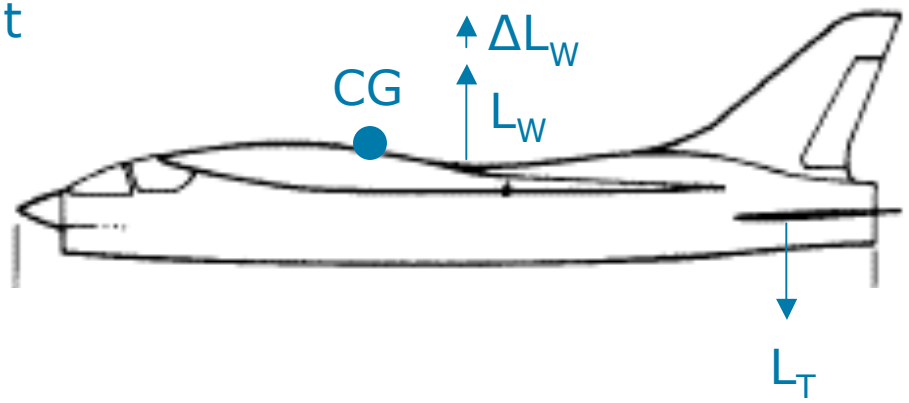
	Subsonic (M=0.26)	**Transonic** (M=0.96)
Flight Condition	Takeoff/Land	Cruise
CG	31.6 ft*	31.6 ft
AC	31.5 ft	32.3 ft
Static Margin	-1.7%	10.0%



*Locations listed aft of nose, found from VLMpc

Trim Drag (Supersonic)

- Tail Moment Arm: 17.5 ft
- Wing Moment Arm: 0.68 ft
- 2 equations, 2 unknowns
  - Sum of Moments around CG
  - Tail + Wing Lift = Weight
- L_W = 18727.1lbs
- L_T = 727.1lbs
- "e_{wing}"=1.01; "e_{tail}"=0.75
- $C_{L\Delta W}$ = 0.006678
- C_{L_T} = 0.01992
- $C_{Di_{\Delta LW}}$ = 2.09*10^-6
- C_{Di_T} = 0.0023
- **$C_{Di_{Trim}}$ = 0.0023095**



Drag Summary

- $C_{D_{Friction}} = 0.0176$
- $C_{D_{Form}} = 0.0043$
- $C_{D_0} = 0.0219$
- $C_{D_i} = 0.0012$ (at cruise, assuming 100%LES)
- $C_{Di_{Trim}} = C_{Di_T} + C_{Di_{\Delta LW}} = 0.0023095$

- $CD = C_{D_0} + C_{D_i} + C_{Di_{Trim}} = 0.0254$

Spanwise Twist

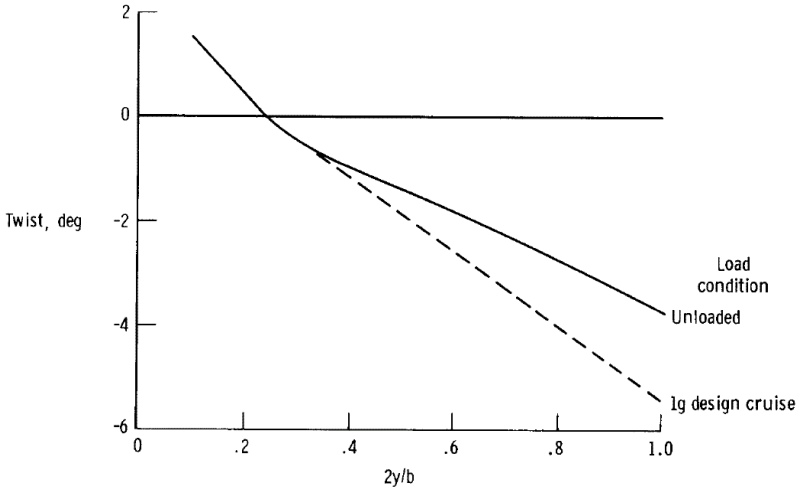
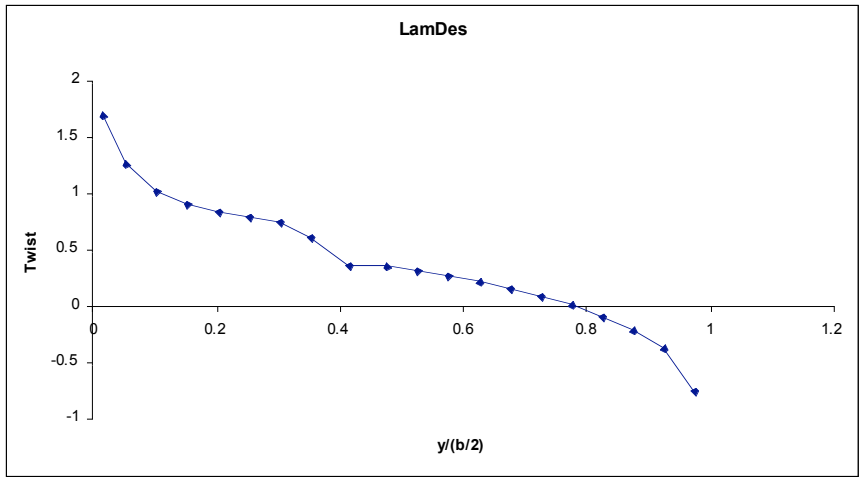


Figure 4. Wing spanwise twist distribution.



Row	2y/b
1	0.133
2	0.306
3	0.480
4	0.653
5	0.808
6	0.933

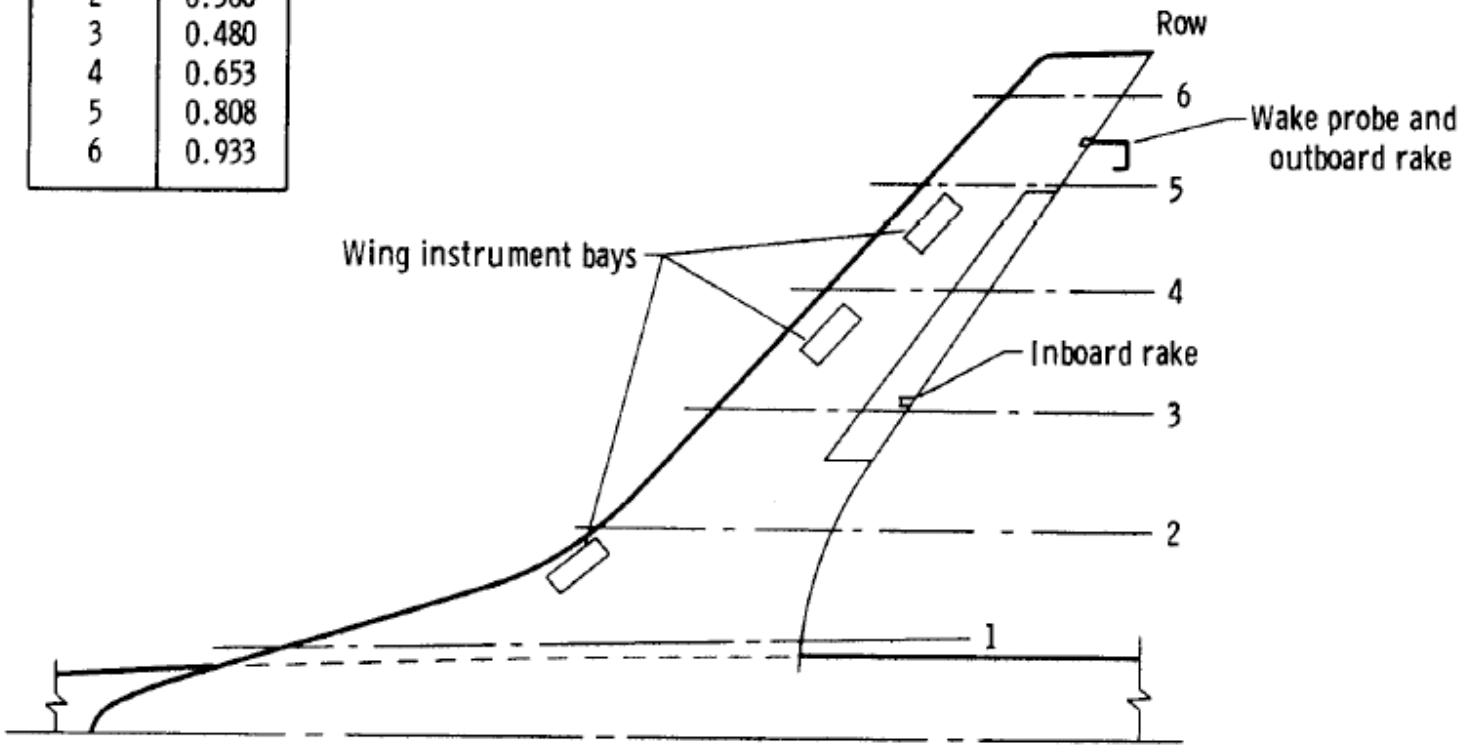
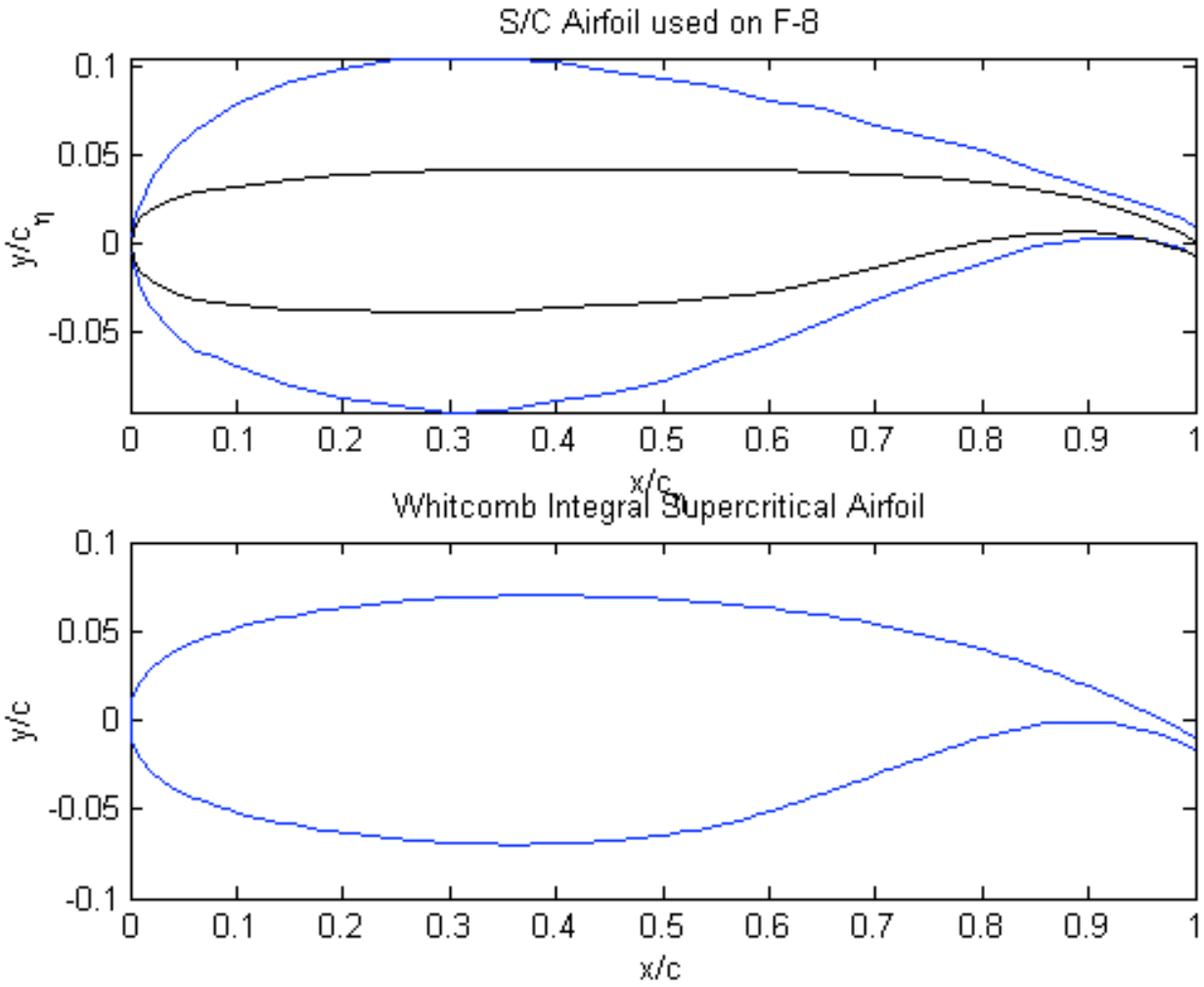
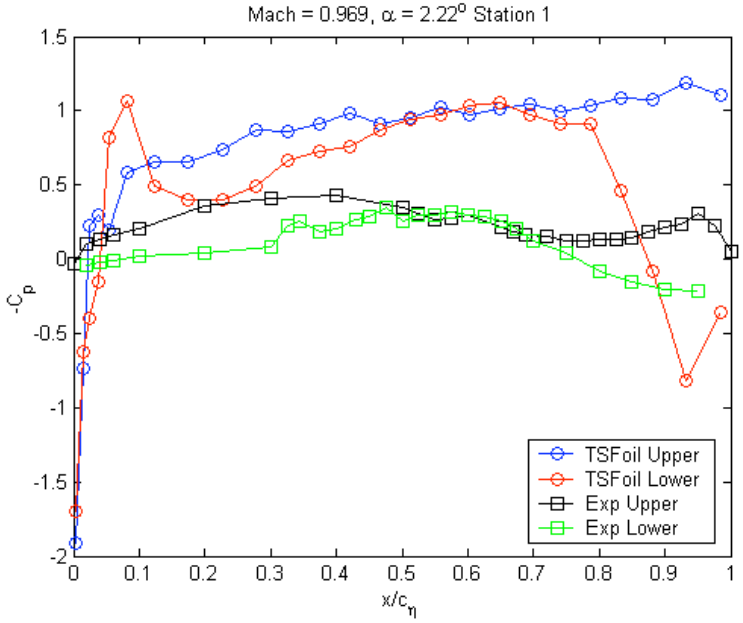


Figure 8. Location of pressure orifice rows, instrument bays, wake probe, and boundary-layer rake.

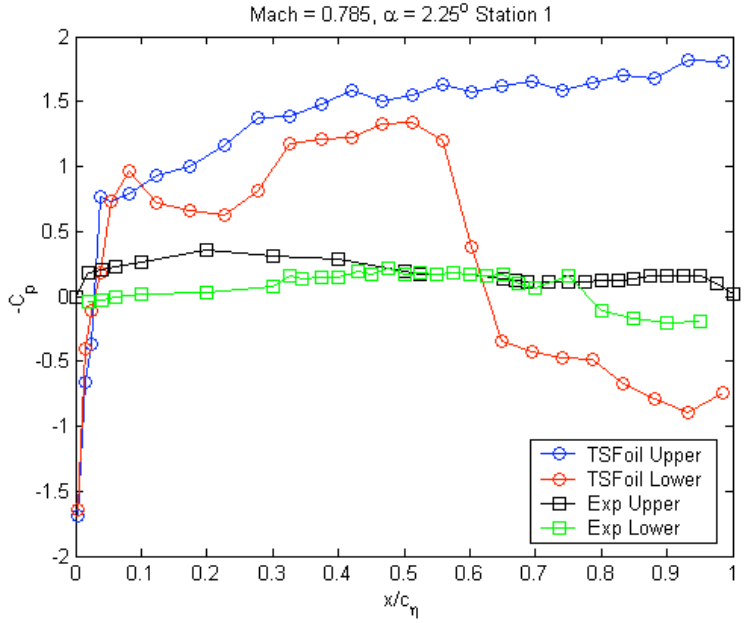

S/C Airfoil used on F-8
0.1
0.05
0
-0.05
y/c
η
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x/c
Whitcomb Integral Supercritical Airfoil
0.1
0.05
0
-0.05
-0.1
y/c
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x/c

TSFoil2 vs. Flight Test



Mach = 0.969

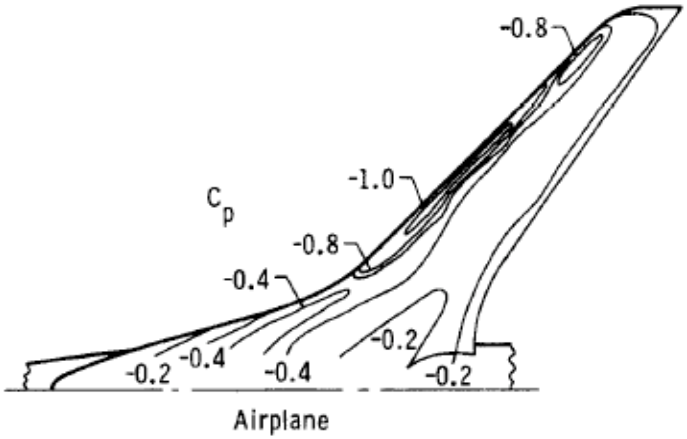
C_{Dwave} = 0.0010



Mach = 0.785

C_{Dwave} = 0.0189

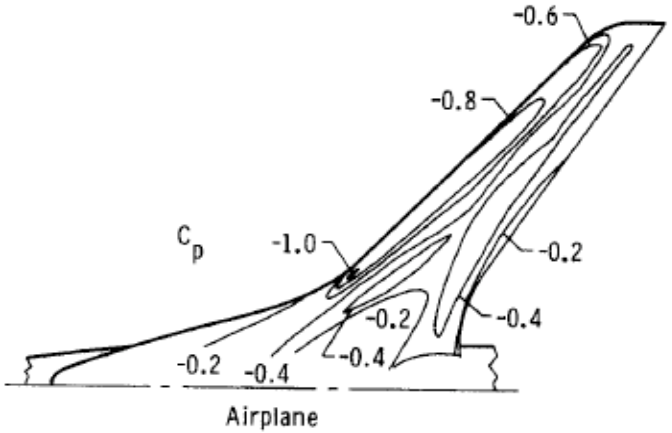
In-Flight Isobars



Mach = 0.90

α = 4.03°

Off-Design



Mach = 0.95

α = 3.86°

Near-Design

Flight Tests

- The F-8 Supercritical Wing (**SCW**) project flew from 1971 to 1973.
- First flight by Tom McMurtry on March 9, 1971
- Last flight by Ron Gerdes on May 23, 1973
- 86-flight program

Dryden Flight Research Center E-22944 Photographed 1971
F-8 SCW (NASA photo)

Outcomes

- **SCW** increased transonic efficiency of the F-8 as much as 15 percent
- Passenger transports with supercritical wings, versus conventional wings, could save 78 million (in 1974 dollars) per year for a fleet of 280 200-passenger airliners.
- The resulting technology base permitted an increase in cruise Mach number for transport aircraft from approximately 0.82 to above 0.9.

References

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http://oea.larc.nasa.gov/PAIS/Concept2Reality/supercritical.html

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NASA TM X-3544 – F-8 Supercritical Wing Flight Pressure, Boundary Layer, and Wake Measurements and Comparisons with Wind Tunnel Data

NASA SP-301 – Supercritical Wing Technology: A Progress Report on Flight Evaluations