TF-8A Crusader with Supercritical Wing

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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)

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!
  – $V_{TO} = 195$mph on Edwards AFB 15,000ft Runway
  – $C_{LTO} = 0.67$
  – $V_{LNDG} = 200$mph on Rogers Dry Lake
  – $C_{LLNDG} = 0.64$

• Cruise Condition:
  – 30,000 ft
  – $M = 0.96$
  – $C_{LCRUISE} = 0.165$

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

<table>
<thead>
<tr>
<th>Flight Condition</th>
<th>Subsonic (M=0.26)</th>
<th>Transonic (M=0.96)</th>
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<tbody>
<tr>
<td>CG</td>
<td>31.6 ft*</td>
<td>31.6 ft</td>
</tr>
<tr>
<td>AC</td>
<td>31.5 ft</td>
<td>32.3 ft</td>
</tr>
<tr>
<td>Static Margin</td>
<td>-1.7%</td>
<td>10.0%</td>
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*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
- $L_W = 18727.1\text{lbs}$
- $L_T = 727.1\text{lbs}$
- $e_{\text{wing}} = 1.01$; $e_{\text{tail}} = 0.75$
- $C_{L\Delta W} = 0.006678$
- $C_{LT} = 0.01992$
- $C_{Di\Delta L_W} = 2.09 \times 10^{-6}$
- $C_{DiT} = 0.0023$
- $C_{Di\text{Trim}} = 0.0023095$
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)
- $C_{D_{iTrim}} = C_{D_{iT}} + C_{D_{i\Delta LW}} = 0.0023095$

- $CD = C_{D_0} + C_{D_i} + C_{D_{iTrim}} = 0.0254$
Spanwise Twist

*Figure 4. Wing spanwise twist distribution.*
<table>
<thead>
<tr>
<th>Row</th>
<th>2y/lb</th>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
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<td>5</td>
<td>0.808</td>
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<tr>
<td>6</td>
<td>0.933</td>
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</table>

Figure 8. Location of pressure orifice rows, instrument bays, wake probe, and boundary-layer rake.
TSFoil2 vs. Flight Test

Mach = 0.969
$C_{D\text{wave}} = 0.0010$

Mach = 0.785
$C_{D\text{wave}} = 0.0189$
In-Flight Isobars

Mach = 0.90
\[ \alpha = 4.03^\circ \]
Off-Design

Mach = 0.95
\[ \alpha = 3.86^\circ \]
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
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

http://www.dfrc.nasa.gov/Gallery/Graphics/F-8SCW/Large/EG-0029-01.gif

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

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

NASA Conference Publication 3256 -- Proceedings of the F-8 Digital Fly-By-Wire and Supercritical Wing First Flight’s 20th Anniversary Celebration

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