Canards

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Outline

• Introduction, brief history of canard usage
• Canards vs. horizontal tails
• Beech Starship vs. X-29
• Long-EZ
• Generalized pros/cons of canards
• Conclusions
What is a canard?

- In French it means a duck!
- Sometimes referred to as a foreplane.
- Canards are lifting planes positioned in front of the main wing.

Fig 192 The use of foreplanes moves the neutral point ahead of the wing, requiring a forward CG position in order to maintain inherent stability.

Picture adapted from [5].
The Wright brothers – Wright 1903 Flyer

- The first plane that flew had a canard!

Source: [http://www.nasm.si.edu/nasm/arch/wrights.html](http://www.nasm.si.edu/nasm/arch/wrights.html)
40’s: Mikoyan Mig-8

- Made in 1945.
- Crew 1+2.
- Engine 110 hp.
- Speed at 0 m is 205 km/h.
- Amazingly, it performed well without any modifications - quite unusual for canard scheme.
- Note that the canard has a flap.

50-60’s: XB-70

- XB-70 is a mach 3+ bomber.
- Note the flaps on the canard.
- The wing tips can fold down as much as 65 degrees.
- Where the B-2 is invisible to radar, the XB-70 is easily detectable, but it moves so fast that it doesn't matter because nothing can shoot it down.
- It could reach an altitude in excess of 70,000 feet.

Source: [http://www.labiker.org/xb_photos.html](http://www.labiker.org/xb_photos.html)
70’s: SAAB 37 Viggen

- Country of origin: Sweden
- User country: Sweden
- Manufacturer: SAAB-SCANIA
- Crew: One; trainer – two
- Armor: Cannon, gun pods, missiles, rockets, bombs.
- Wing span: 10.59 m / 34 ft 9 in
- Length: 16.31 m / 53 ft 6 in
- Speed: 2 Mach / 2.400 kmh / 1.500 mph

Source: http://www.canil.se/~giffon/aviation/text/37viggen.htm
80’s: Rutan’s – Long-EZ

Long-EZ, N6KD Specifications:
- Empty Weight: 990 lb.
- Gross: 1600 lb.
- Fuel: 50 gal. U.S.
- Range: 1050nm
- Cruise: 170kts.
- Vne: 200kts.
- Canard Stall: 55kts.
- Touchdown Speed: 60kts.
- Top Speed 184kts.
The X-29 is a single-engine aircraft 48.1 feet long.
Its forward-swept wing has a span of 27.2 feet.
Each X-29 was powered by a General Electric F404-GE-400 engine producing 16,000 pounds of thrust.
Empty weight was 13,600 pounds, while takeoff weight was 17,600 pounds.
The aircraft had a maximum operating altitude of 50,000 feet, a maximum speed of Mach 1.6, and a flight endurance time of approximately one hour.
It has a fully movable canard.
90’s: Modern fighters

Eurofighter EF2000

Rafale

Eurofighter EF2000 Typhoon
• Length : 15.96m
• Wing Span : 10.95m
• Height : 5.28m
• Wing Area : 50.0 Square meter
• All-Up Weight : 23,000Kg
• Empty Weight : 10,995Kg
• Engine : Eurojet EJ200 Turbofan (Use After Burner : 9,185Kg) X 2
• Max Speed : 2,474Km/h+ (Mach 2.0+)
• Service Ceiling : 16,765m
• Range : 3,700Km
• Crew : 1
• Armament : 27mm Machine Gun, Hard point X 13

Dassault Rafale A
• Length : 15.30m
• Wing Span : 10.90m
• Height : 5.34m
• Wing Area : 46.0 Square meter
• All-Up Weight : 21,500Kg
• Empty Weight : 9,800Kg
• Engine : SNECMA M88-3 Turbofan (Use After Burner : 17,743Kg) X 2
• Max Speed : 2,474Km/h+ (Mach 2.0+)
• Service Ceiling : 15,240m
• Range : 3,335Km
• Crew : 1
• Armament : 30mm DEFA 791B Machine Cannon, Hard point X 12, Wing Tip Rail X 2

Source: http://www.strange-mecha.com/aircraft/Ente/canard.htm
Canard-Tail Comparisons

• A lot of research has been done on Canard-Tail comparisons, see for example [1-4].
• “The message seems to be clear: the selection of a canard vs. a tail is both configuration and mission dependent.”, [2].
• Three cases of such a comparison are presented in the following slides.
Case 1: Combat Aircraft
Fellers, Bowman and Wooler [1]

- The authors compared the three above configurations without Pitch Thrust
  Vectoring (PTV) and the tailless with PTV.
- The canard is close-coupled with the wing and slightly above it. It is of low
  aspect ratio and highly swept in order to have a large stall angle of attack with
  no abrupt lift loss.
- No canard flaps were considered.
- All three configurations have the same canted twin vertical tails.
- The aft-tail configuration without PTV was selected.
- With PTV the tailless configuration becomes comparable with the aft-tail
  configuration.
Case 1 continued

Tailless has a greater sensitivity to c.g. location.

Aft-tail has -11% MAC and L/D y 6.4

Canard has -17% MAC and L/D y 6.2

=> Canard configuration has greater risk in terms of developing a satisfactory control system.

FIGURE 34. COMPARISON OF MANEUVER L/D WITHOUT PTV
Figure adapted from [1].

Note: MAC = Mean Aerodynamic Chord.
Case 1 continued

Figure adapted from [1].

Aft-tail has the highest maximum trimmed lift coefficient.

Tailless has greater sensitivity to the level of stability.
Case 1 continued

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DESIRED VALUE</th>
<th>TAILORED (WITH PTV)</th>
<th>STANDARD (NO PTV)</th>
<th>AFT-TAIL (NO PTV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERFORMANCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damping moment</td>
<td>LARGE</td>
<td>0.3</td>
<td>0.7</td>
<td>0.3</td>
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<tr>
<td></td>
<td>SMALL</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Subsonic maximum lift</td>
<td>SMALL</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Subsonic maximum lift</td>
<td>SMALL</td>
<td>LARGE</td>
<td>SMALL</td>
<td>SMALL</td>
</tr>
<tr>
<td>Sensitivity to yaw moment</td>
<td>SMALL</td>
<td>MODERATE</td>
<td>LARGE</td>
<td>MODERATE</td>
</tr>
<tr>
<td>STABILITY &amp; CONTROL</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>CM, SUBSONIC, TAIL-ON, NMAO</td>
<td>K 15</td>
<td>10</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Maximum dive angle</td>
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<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Maximum lift angle</td>
<td>WAB 1</td>
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<td>5°</td>
<td>5°</td>
</tr>
<tr>
<td>Total control travel</td>
<td>SMALL</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
</tr>
<tr>
<td>Capability in other control modes</td>
<td>VCE</td>
<td>VCE</td>
<td>VCE</td>
<td>VCE</td>
</tr>
</tbody>
</table>

Figure adapted from [1].

- Configuration with aft-tail and no PTV was selected.
- Tailless with PTV competitive with aft-tail.
A canard-tail comparison was carried out for a multirole, supersonic Navy tactical aircraft concept.

Variable-wing-sweep was employed to meet the diverse mission requirements of a carrier-based fighter/attack design for the late 1990’s.

The objective of the study was to determine the extent to which a canard configuration benefits can be realized within the bounds set by critical stability and control requirements.
Case 2 continued

- The canard configuration was found to have superior trim characteristics
  - in terms of low-speed, high-lift generation and
  - high-speed lift-to-drag efficiency
- The canard exhibited these advantages at moderate levels of static and dynamics instability.
A canard arrangement was preferred over the tail arrangement for this multimission, variable-sweep aircraft concept.
Case 3: SAAB JAS 39 Gripen

Modin and Clareus [3]

Figure adapted from [3].

Picked this configuration
Case 3 continued

- Max cross sectional area is some 9% lower for 2105 in comparison with the 2102.

- Of particular importance to supersonic wave drag is the slope of the area distribution towards the aft end of the aircraft.

- The absence of an aft tail and the forward position of the wing on the fuselage makes it possible to obtain an aerodynamically clean aft end on the canard configuration with a favorable area distribution.

- The canard configuration has slightly lower zero lift drag at subsonic speeds.

- At supersonic speeds the difference in zero lift drag is quite significant.

Figures adapted from [3].
Beech Starship vs. Grumman X-29

A comparison of 2 canard aircraft designed for very different requirements
Beech Starship

• Burt Rutan design built by Beechcraft
• Large cabin business turboprop
• Aft swept wings with winglets for yaw control
• Small variable sweep canard on the nose
• 10% Stable
Grumman X-29

• Advanced technologies demonstrator
• Forward swept wing
• Close coupled canard just ahead of wing
• Advanced flight system for controlable flight
• 32% Unstable
Starship vs. X-29
Span Loading

Figures adapted from [6]
Starship vs. X-29

Wing Twist

Figures adapted from [6]
Long-EZ

• Homebuilt aircraft of Rutan design.
• Follows the natural configuration for a canard aircraft
  • Swept back wing in rear
  • Winglets used for yaw stability
  • Small canard on the nose
  • Pusher engine
• Early versions encountered problems with stall of the noseplane.
Long-EZ : The problem

- The nature of this canard configuration requires the foreplane to be more highly loaded than the wing.
- Canard airfoil: GU25
  - 60% laminar flow upper and lower surfaces
  - Low drag
- Flow contamination caused by bugs or rain causes separation to occur ahead of 60% at 25% chord.
- This stall was difficult to quickly recover from and many accidents resulted.

Source: http://www.angelfire.com/on/dragonflyaircraft/airfoils.html
Long-EZ : The solution

• Quick fixes
  – Trailing edge cusp filled in
  – Vortex generators placed ahead of cusp to maintain attached flow

• Canard airfoil replaced with Roncz 1145
  – Reduction of trailing edge cusp
  – Better stall characteristics

Source: http://www.angelfire.com/on/dragonflyaircraft/airfoils.html
Advantages

• Inherent instability adds maneuverability.
• Close coupled canard-wing reduces necessary wing twist (favorable washout from canard) [7].
• Canard allows for reduced trim drag, especially supersonic [4].
Disadvantages

- Possibility for adverse flow disturbances over the wing from the canard.
- High canard $C_{L_{\text{max}}}$ leads to low efficiency, $e$, and high $e$ leads to low $C_{L_{\text{max}}}$. 
- Canards have poor stealth characteristics.
- Canard sizing is very sensitive.
- Generally have a small moment arm to VT, requiring larger area.
Conclusion

As with any other configuration decision, use of a canard offers trade-offs. The desired performance characteristics drives all configuration decisions, some of which are well-suited to a canard, while others are not.
Questions/Comments/Complaints?
References