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

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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.

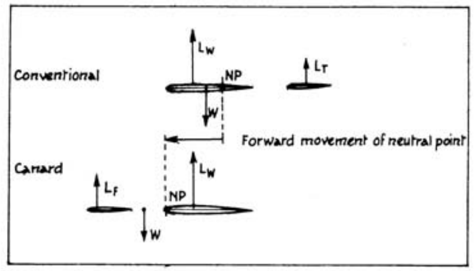
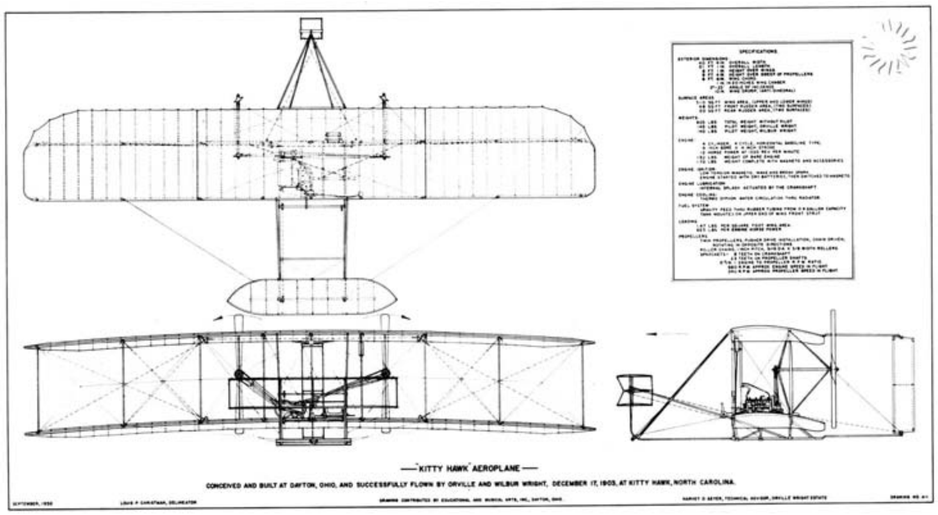


Fig 192 The use of foreplanes moves the neutral point ahead of the wing, requiring a forward CG position in order to maintain inherent stability.

Picture adapted from [5].

History

The Wright brothers – Wright 1903 Flyer



Source: http://www.nasm.si.edu/nasm/arch/wrights.html

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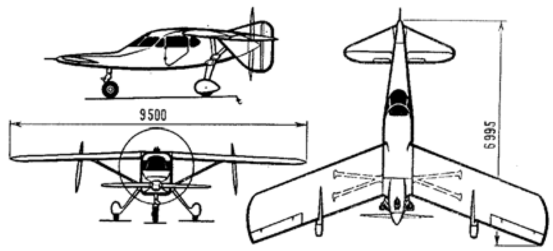
•The first plane that flew had a canard!

40’s: Mikoyan Mig-8



Source: http://www.ctrl-c.liu.se/misc/ram/mig-8.html

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•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

Source: http://www.labiker.org/xb_photos.html

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•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.

70's: SAAB 37 Viggen

Source: http://www.canit.se/~griffon/aviation/text/37viggen.htm

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•Country of origin: Sweden

•User country: Sweden

•Manufacturer: SAAB-SCANIA

•Function: AJ 37 - attack version; JA 37 - fighter version; SH 37 - sea reconnaissance version; SF 37 - version with cameras for photographing ground objects.

•Crew: One; trainer – two

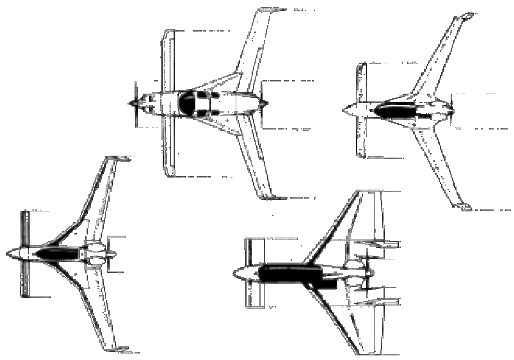
•Armor: Cannon, gun pods, missiles, rockets, bombs.

•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

80’s: Rutan’s – Long-EZ



Sources: http://www.desktopaero.com/appliedaero/configuration/canards.html
http://www.long-ez.com/gallery.html

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•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.

80's: X-29

Source: http://www.dfrc.nasa.gov/gallery/photo/X-29/HTML/EC91-491-6.html

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- 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

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

Eurofighter EF2000 Typhoon

•Length : 15.96m
•Wing Span : 10.95m
•Hight : 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

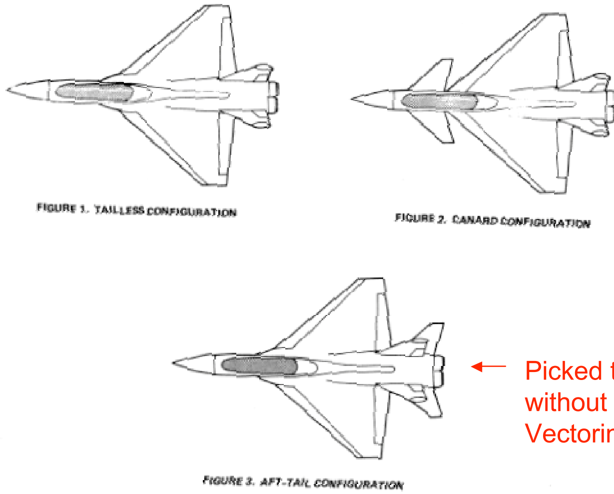
•Length : 15.30m
•Wing Span : 10.90m
•Hight : 5.34m
•Wing Area : 46.0 Square meter
•All-Up Weight : 21,500Kg
•Empty Weight : 9,800Kg
•Engine : SNECMA M88-3 Turbofan (Use After Burner : 17,743Kg) X 2
•Max Speed : 2,474Km/h+ (Mach 2.0+)
•Service Ceiling : 15,240m
•Range : 3,335Km
•Crew : 1
•Armament :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

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]



← Picked this configuration without Pitch Thrust Vectoring (PTV).

Figure adapted from [1].

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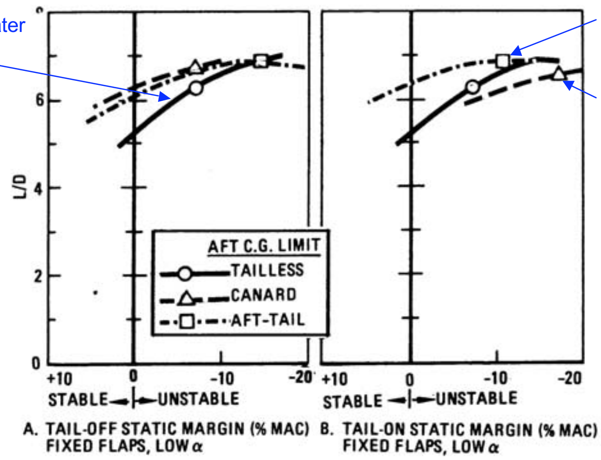
- The authors compared the three above configurations without Pitch Thrust Vectoring (PTV) and the tailless with PTV.
- The canard is close-coupled with the wing and slightly above it. It is of low aspect ratio and highly swept in order to have a large stall angle of attack with no abrupt lift loss.
- 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].

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Note: MAC = Mean Aerodynamic Chord.

Case 1 continued

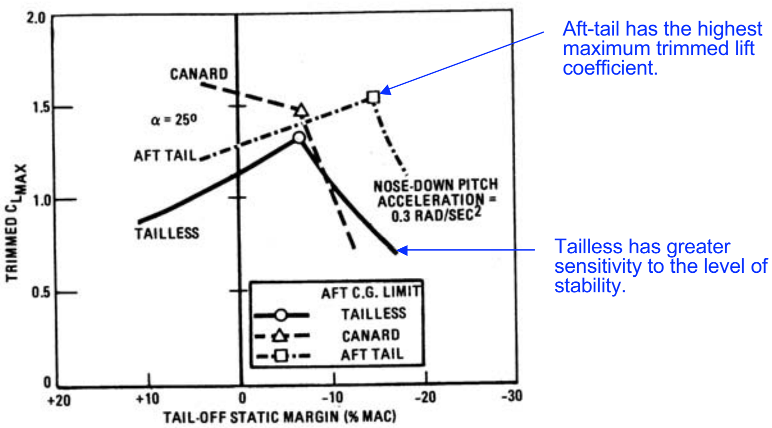

FIGURE 3:. COMPARISON OF MAXIMUM TRIMMED LIFT

Figure adapted from [1].

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Case 1 continued

PARAMETER	DESIRED VALUE	TAILLESS (WITH PTV)	CANARD (NO PTV)	AFT TAIL (NO PTV)
PERFORMANCE				
SUBSONIC MANEUVER L/D	LARGE	6.5	6.7	6.9
SUPERSONIC TRIM DRAG (C.G. – OPTIMUM C.G.), % MAC	SMALL	-5	0	-10
SUBSONIC MAXIMUM LIFT COEFFICIENT	LARGE	1.45	1.45	1.55
L/D SENSITIVITY TO SM	SMALL	LARGE	SMALL	SMALL
SENSITIVITY TO ABSOLUTE PITCHING MOMENT	SMALL	MODERATE	LARGE	MODERATE
STABILITY & CONTROL				
-SM, SUBSONIC, TAIL ON, % MAC	≤15	10	17	11
MAXIMUM UNSTABLE $d\delta/d\alpha$	SMALL	0.7	1.5	0.7
STABLE ABOVE ___ AOA	SMALL	25°	60°	25°
TOTAL CONTROL TRAVEL REQUIRED TO OPERATE TO 60 DEGREE AOA	SMALL	50°	90°	80°
CAPABILITY OF OTHER CONTROL MODES	YES	YES	YES	YES

FIGURE 37. COMPARISON OF CONFIGURATIONS USING PTV WHERE APPROPRIATE

Figure adapted from [1].

- Configuration with aft-tail and no PTV was selected.
- Tailless with PTV competitive with aft-tail.

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Case 2: Variable Sweep Fighter

Landfield and Rajkovic [2]

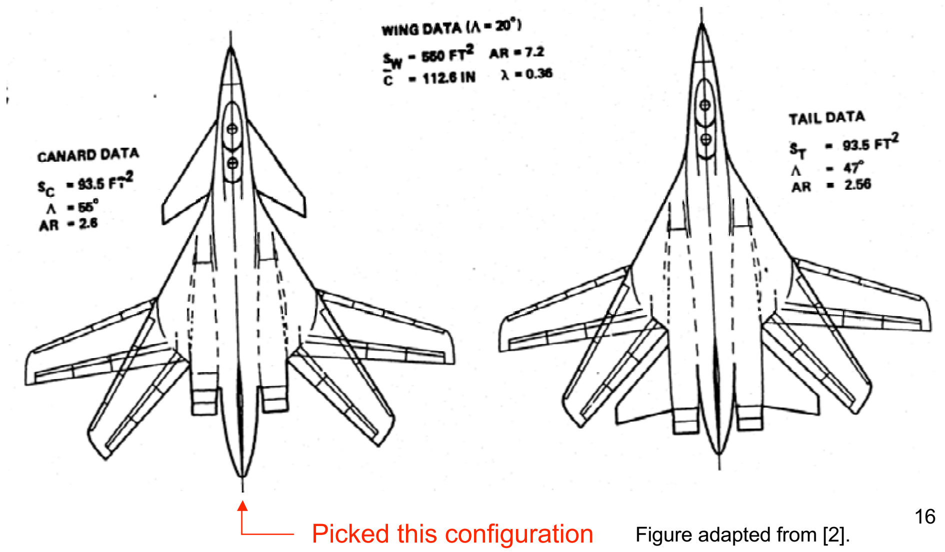

Figure adapted from [2].

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• 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

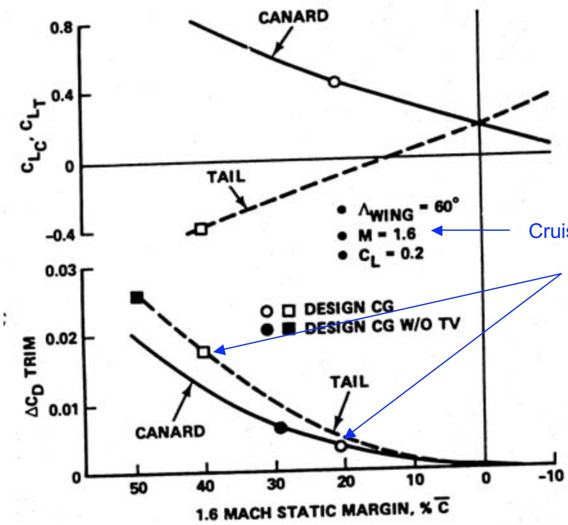

Fig. 16 Supersonic cruise trim characteristics.

Figure adapted from [2].

Cruise condition

At design CG the canard configuration has significantly lower trim drag.

This is due to:

- load sharing of canard with the wing
- a smaller stability increase from compressibility.

Note that the shift in CG due to Thrust Vectoring (TV) relieved canard/tail trim load substantially.

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- 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.

Case 2 continued

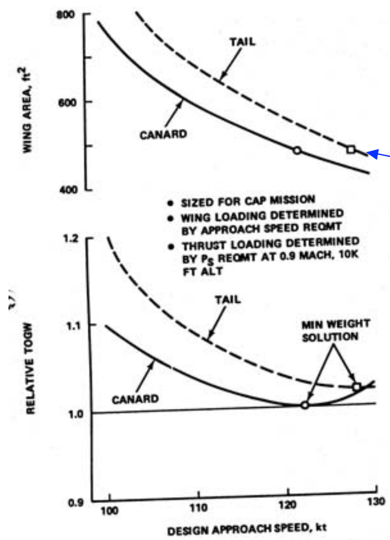

Fig. 19 Vehicle sizing impact of design approach speed.

Minimum weight solution obtained for both designs at wing area of 475 ft^2.

The canard configuration has lower TOGW and landing speed.

Figure adapted from [2].

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• 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]

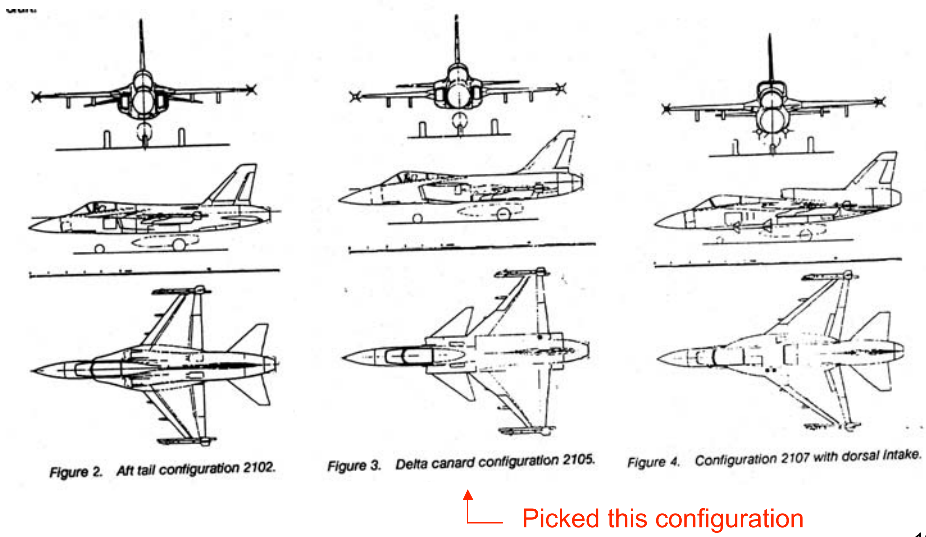

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Figure adapted from [3].

Case 3 continued

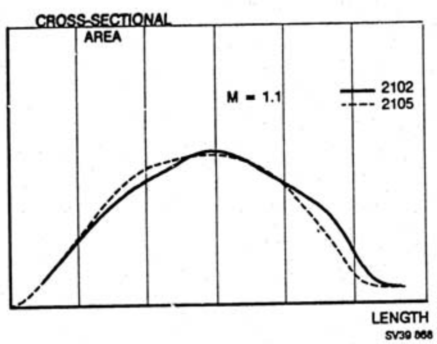

Figure 6. *Cross sectional area distribution less air intake at M = 1.1.*

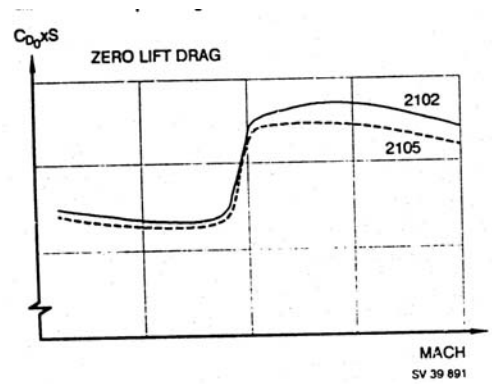

Figure 7. *Zero lift drag*

- 2105 (w/canard) has a favorable cross-sectional distribution.
- 2105 (w/canard) has significantly lower zero lift drag at supersonic speeds than 2102 (w/tail).

Figures adapted from [3].

- 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.

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Beech Starship vs. Grumman X-29

A comparison of 2 canard aircraft designed
for very different requirements

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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

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Grumman X-29

- Advanced technologies demonstrator
- Forward swept wing
- Close coupled canard just ahead of wing
- Advanced flight system for controlable flight
- 32% Unstable

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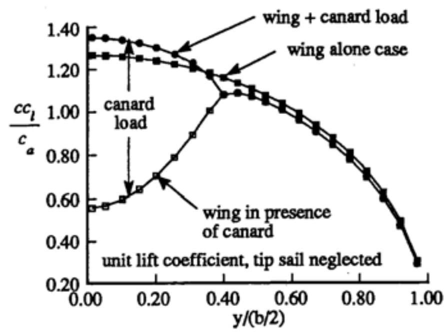
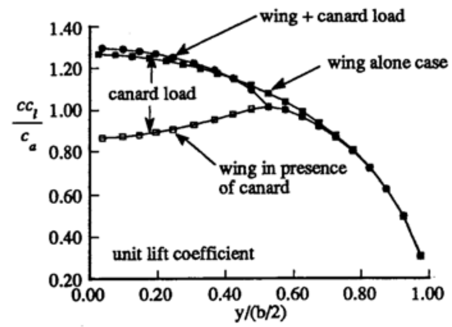
Starship vs. X-29

Span Loading



a) Beech Starship



b) Grumman X-29

Figures adapted from [6]

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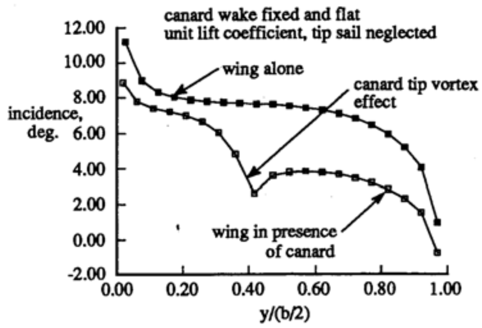
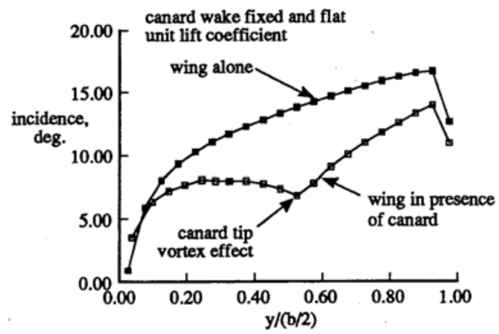
Starship vs. X-29

Wing Twist



a) Beech Starship



b) Grumman X-29

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.

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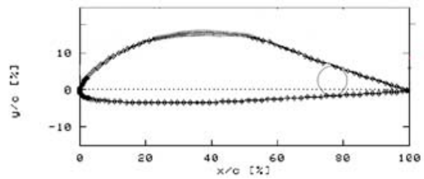
Long-EZ : The problem

- 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

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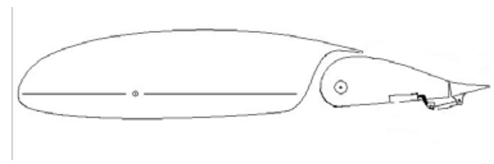
Long-EZ : The solution

- 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

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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_{Lmax} leads to low efficiency, e, and high e leads to low C_{Lmax}.
- Canards have poor stealth characteristics.
- Canard sizing is very sensitive.
- Generally have a small moment arm to VT, requiring larger area.

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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.

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Questions/Comments/Complaints?

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