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Flight Tests of Fuel Saving Formation Flight in General Aviation.

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Currently: Swedish Defence Research Agency
FOI

Formation Flight

Flight mechanics, Logistics and Fuel savings

- *Can we model drag reduction due to formation flight with accuracy using a vortex lattice method? –Yes!*

- *Thin wings*
- *Small angles of attack*
- *Incompressible*
- *Inviscous*
- *No wake relaxation*

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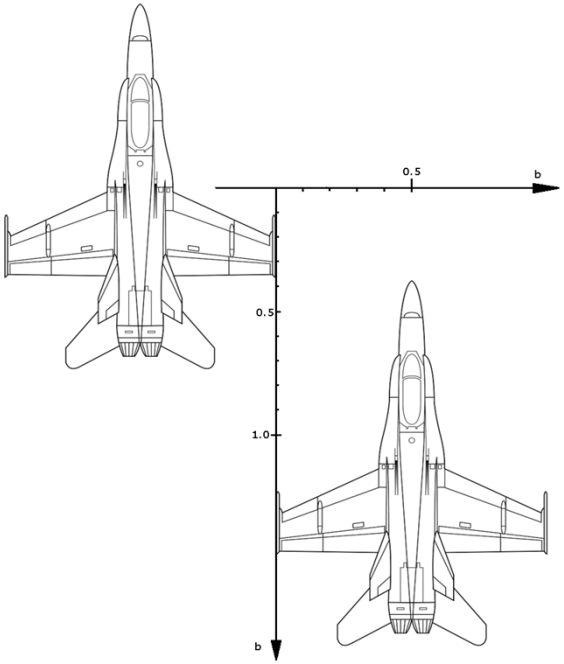
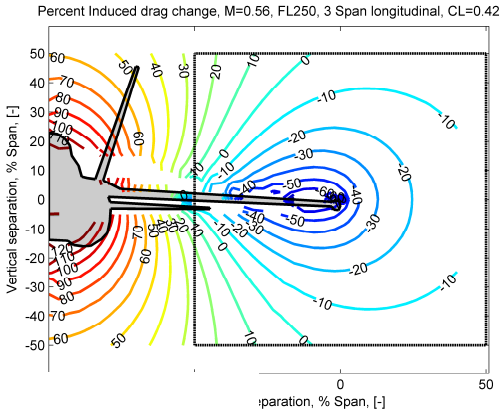
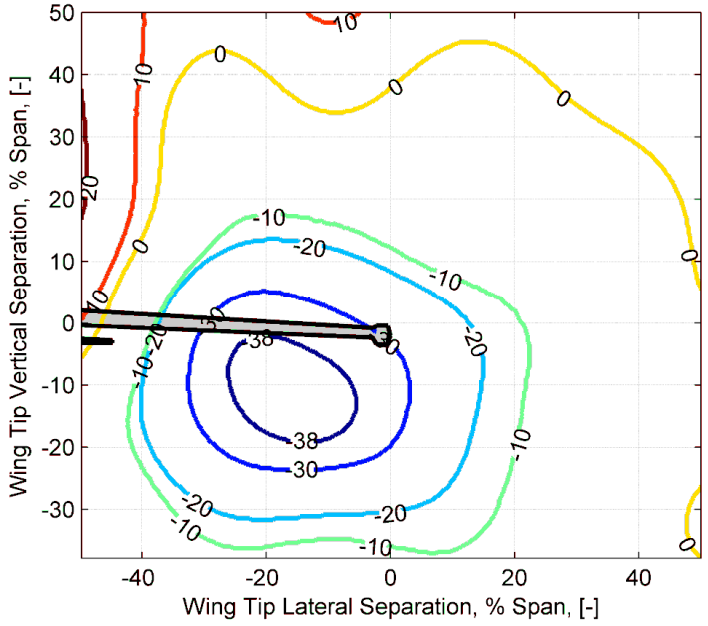
Code Validation

(CEAS2013)







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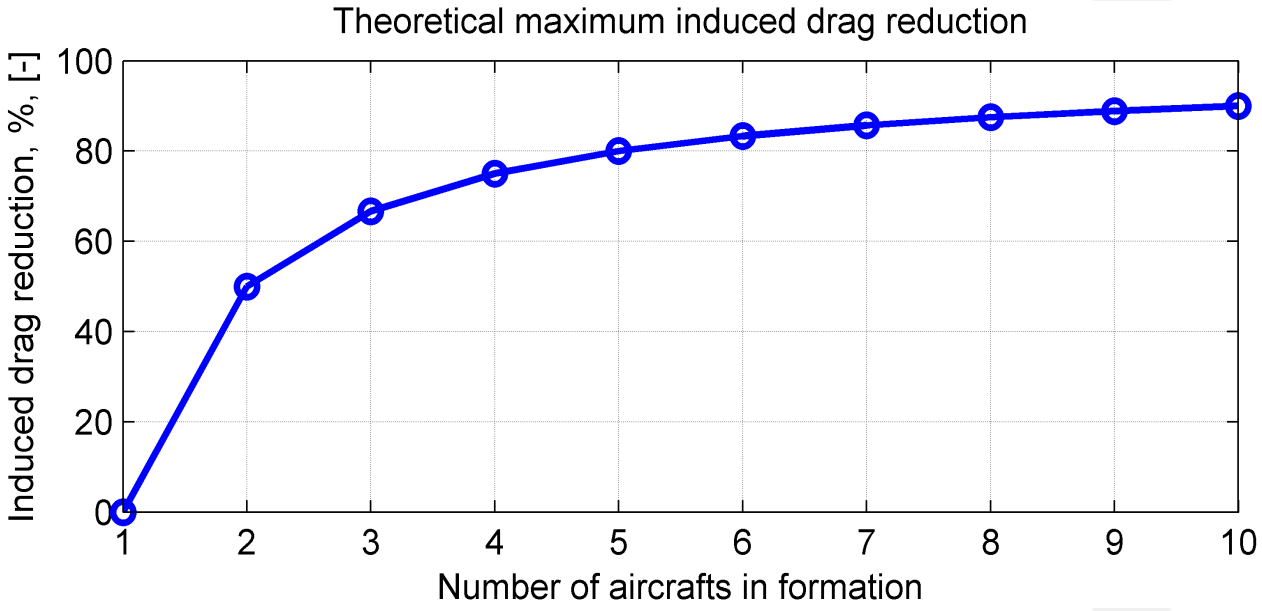
Effects on induced drag



$$C_{Di} = \frac{C_L^2}{\pi e \cdot AR} \qquad C_{Di,2} = C_{Di,1}\frac{AR_1}{AR_2} \qquad S = \left(1 - \frac{1}{n}\right) \cdot 100$$

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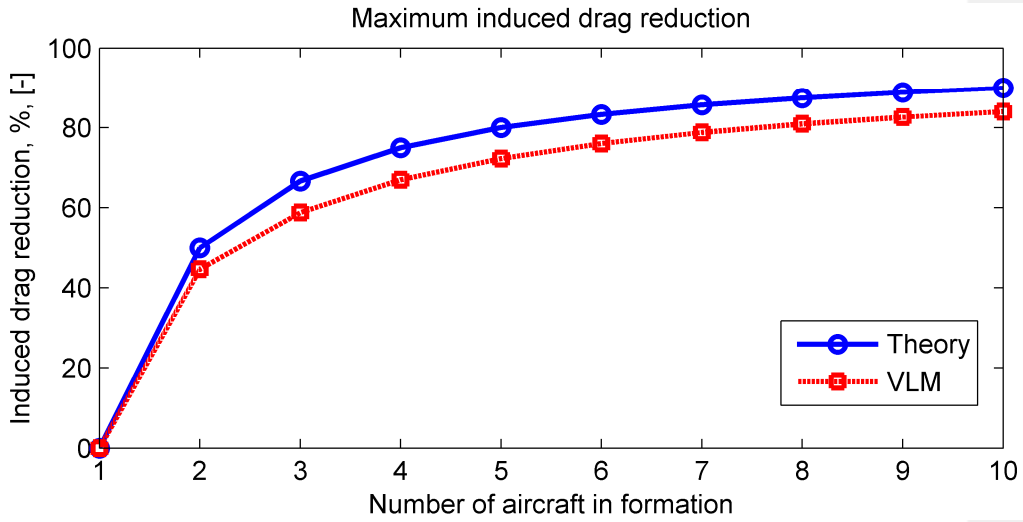
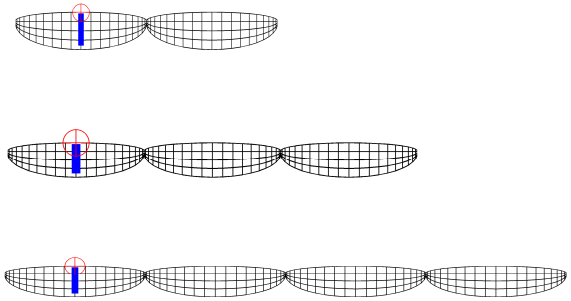
Effects on induced drag





0				
45	45			
46	84	46		
48	87	87	46	
49	89	89	89	49

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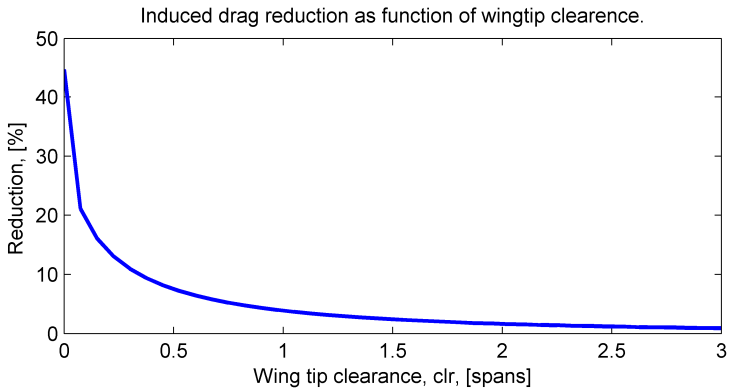
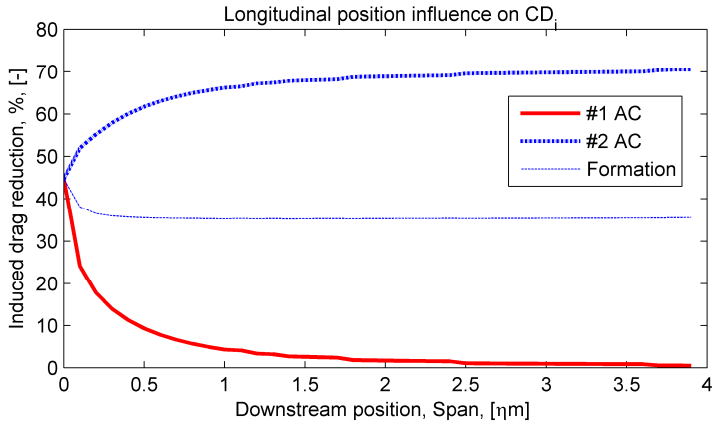
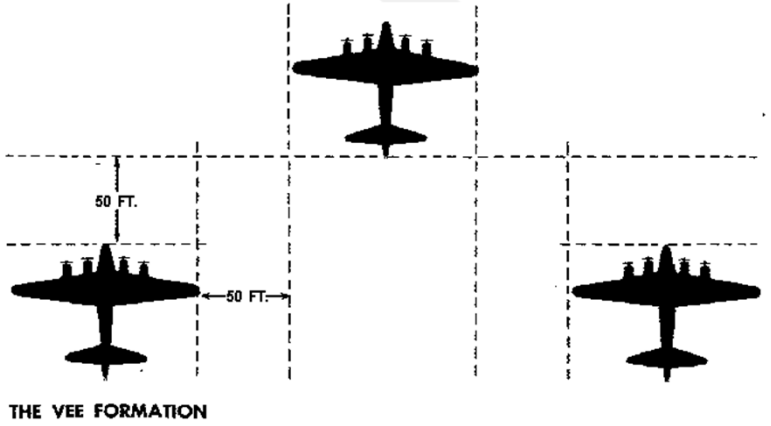
Effect of spanwise tip separation







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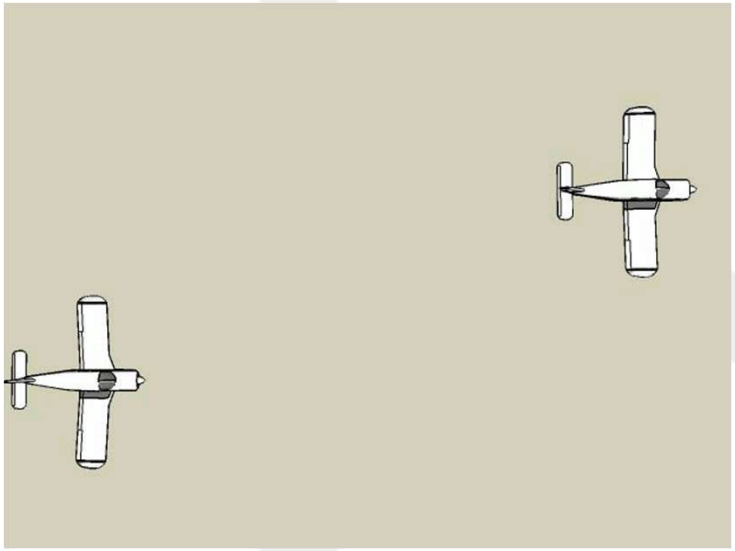
Test Setup

- Aircraft:
  - Piper PA-28 181 ARROW 2
  - Full fuel load, 2 pilots.
    970 kg
- Formation
  - 2.75 Span Longitudinal Separation
  - 0.9 Span lateral, 0.1 Vertical
  - 2000 ft, 75 kts. (CL = 0.7)



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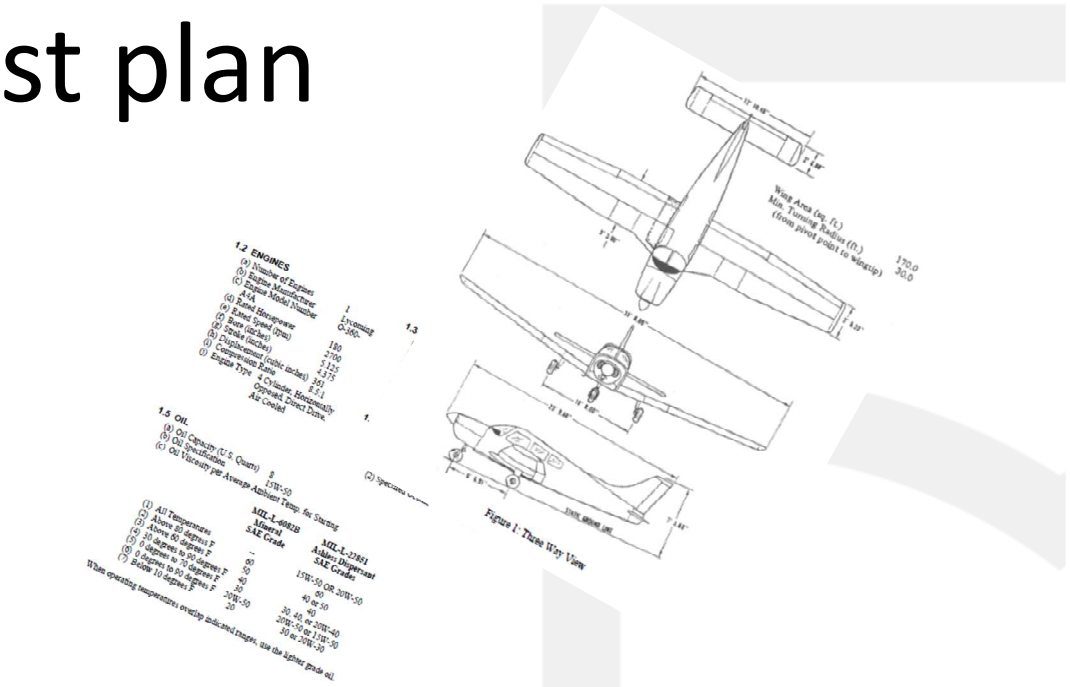
Test plan

- 3 Flights
  - Tare
  - Formation
  - Solo
- Full fuel
  - Calibrated bowser



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Tare Flight

- Tare Flight
  - TO,
  - climb,
  - round beacon Sturefors,
  - descend,
  - land.

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Formation Flight

- Formation Flight
  - TO
  - Climb
  - Sturefors,
  - Valdemarsvik,
  - Falerum,
  - Sturefors,
  - Descend,
  - Land

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Instrumentation

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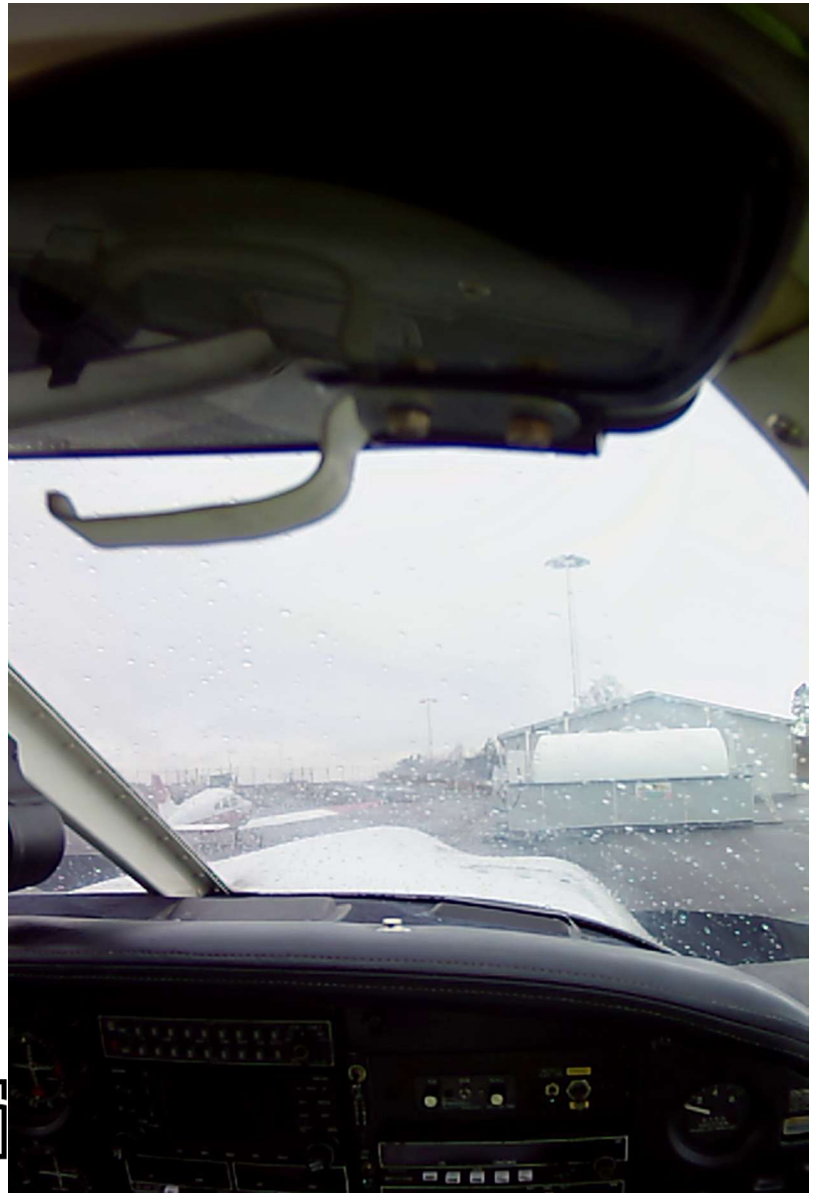
Deviations from plan



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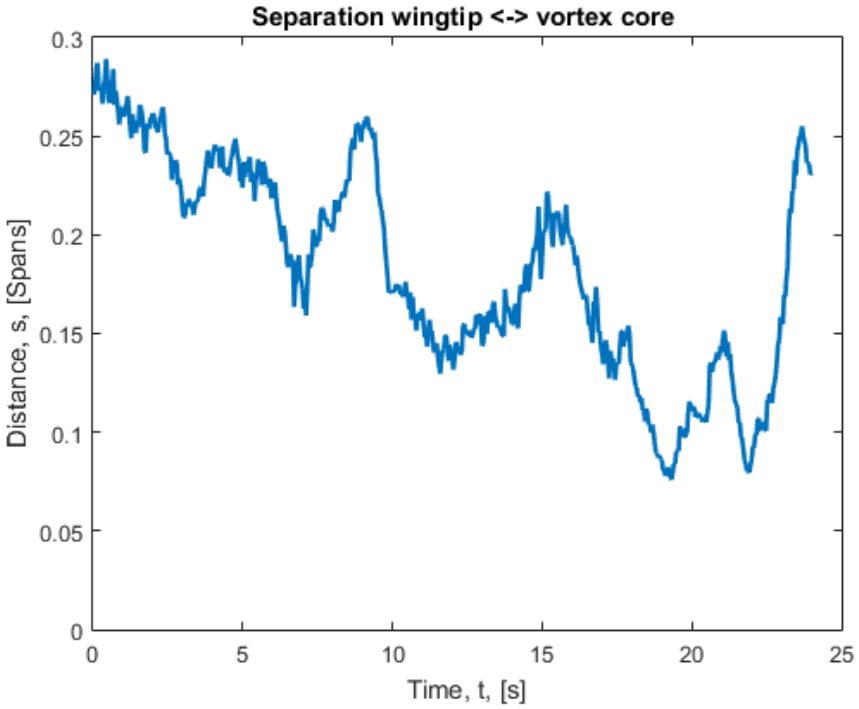
Assorted results

- Average 0.2 Span



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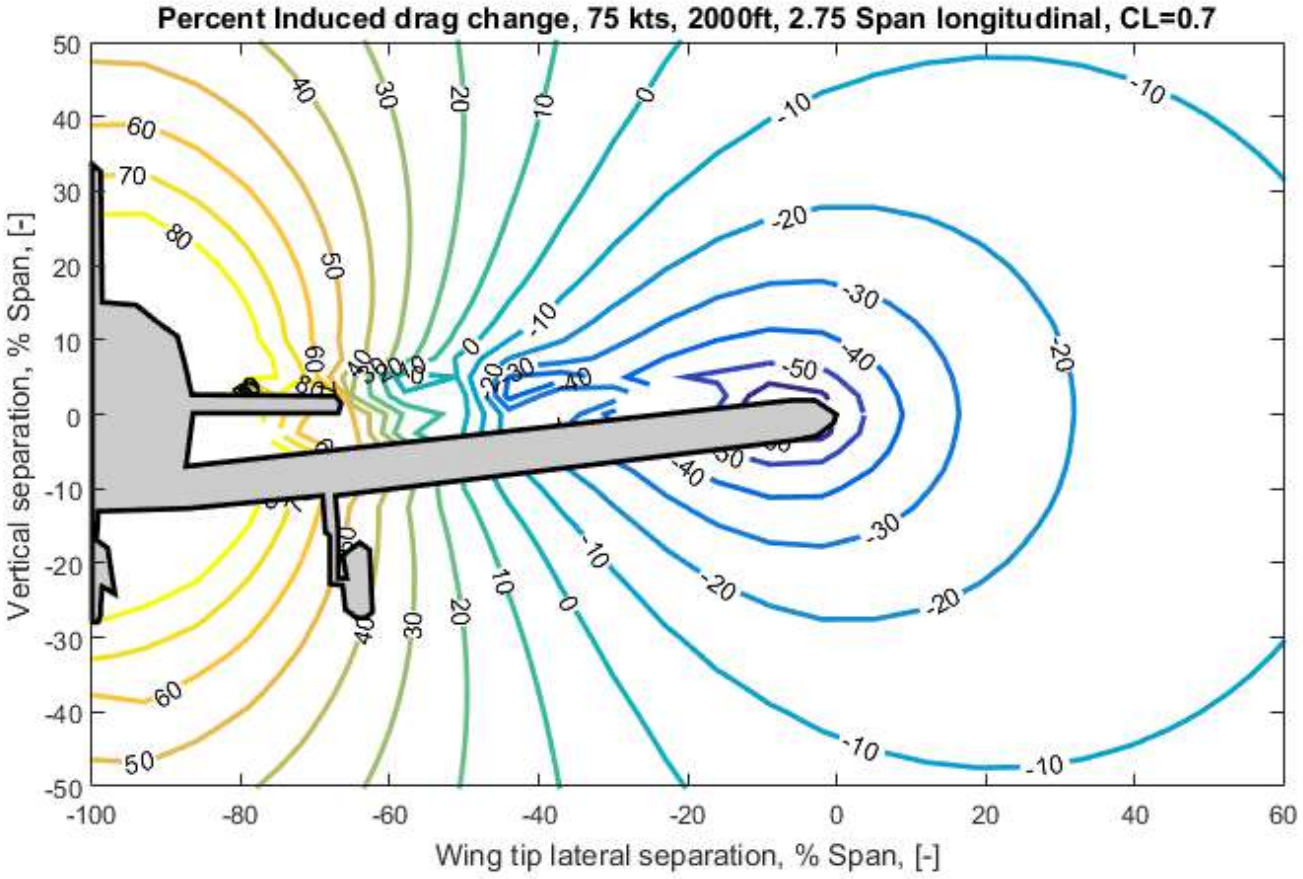
PA28 Simulated data

Di=0.4 D



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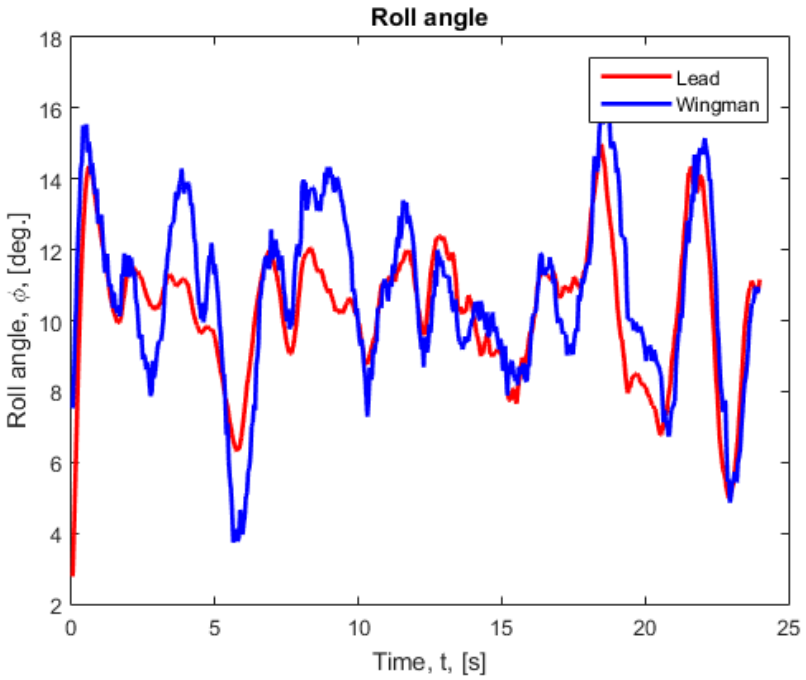
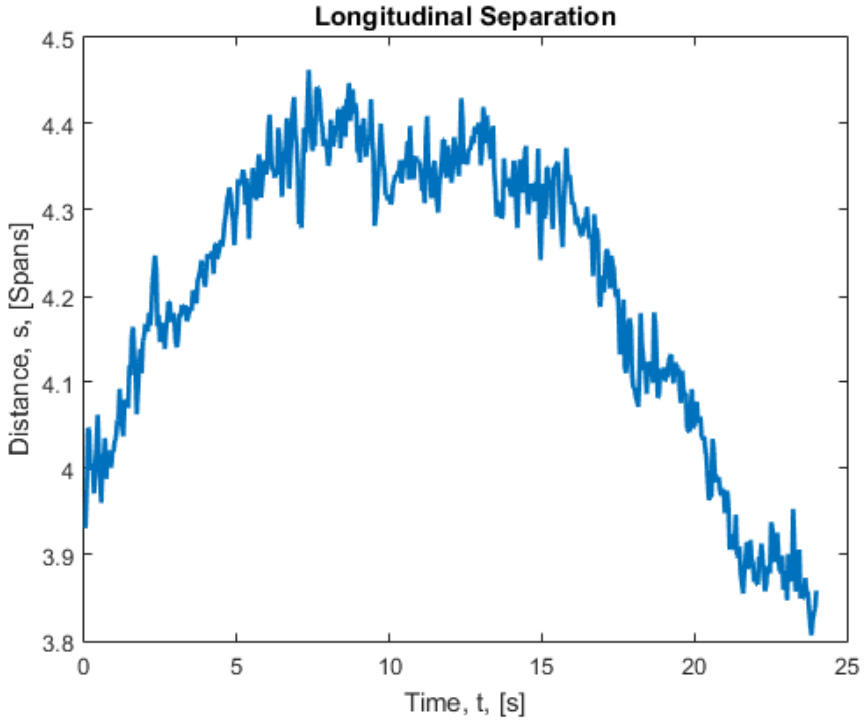
Assorted results





- Pilots comments

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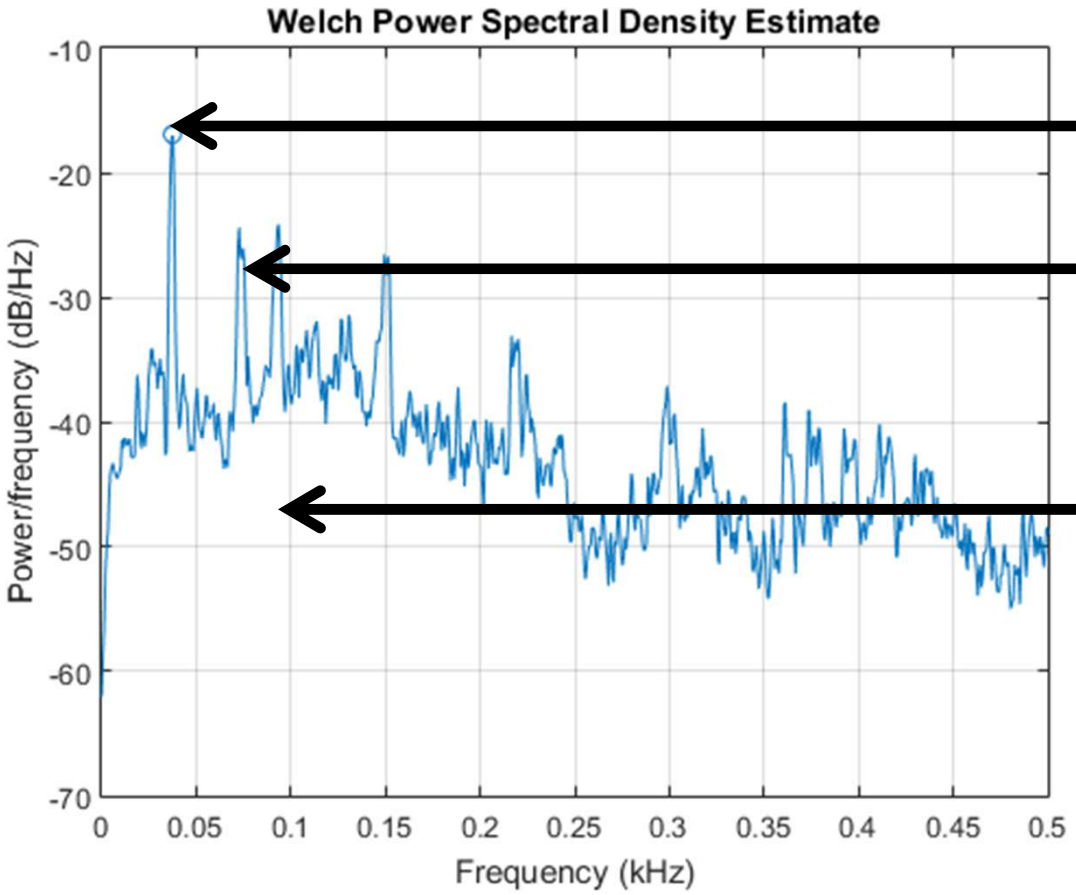
Throttle change



Shaft RPM

Blade passage, power stroke

Generator

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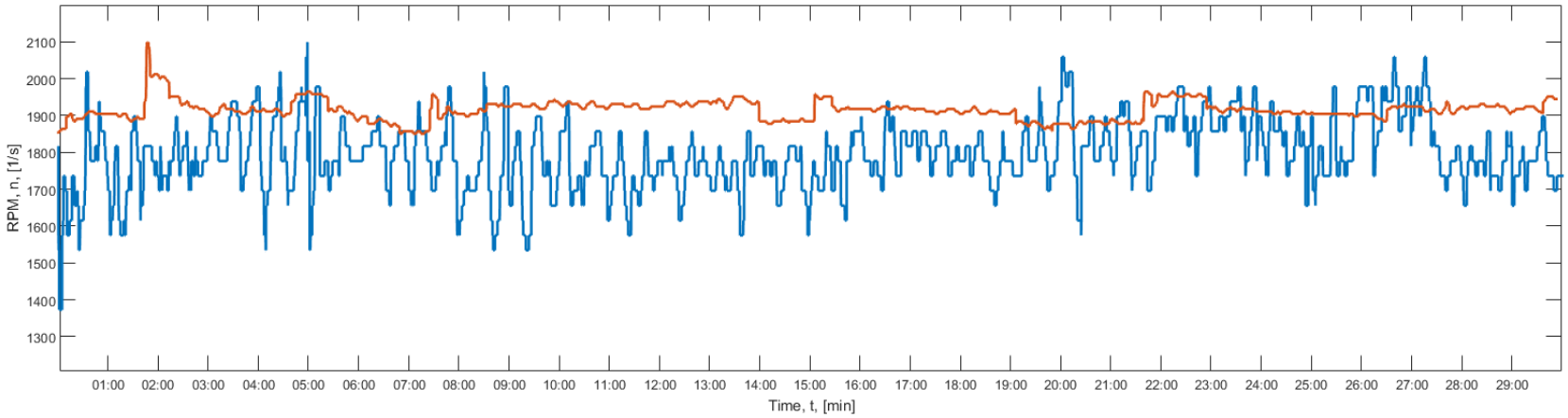
Difference in rpm

SOLO / WINGMAN



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Compliance

- COMMISSION REGULATION (EU) 2015/1039
  amending Regulation (EU) No 748/2012 as regards flight testing
  - Out of Scope.

- Skyddslag (2010:305), Lag (2016:319) om skydd för geografisk information.
  - Avbildningstillstånd från skyddsobjektägaren, spridningstillstånd från lantmäteriet.

- Deviation from ‘best practice’:
  - Flight test engineer also project manager
  - Mitigation: PIC informed.

- Finance, internal.
  - Research plan not externally vetted.
  - Mitigation: Enhanced Internal Review.

Thank you for your attention!

Questions?

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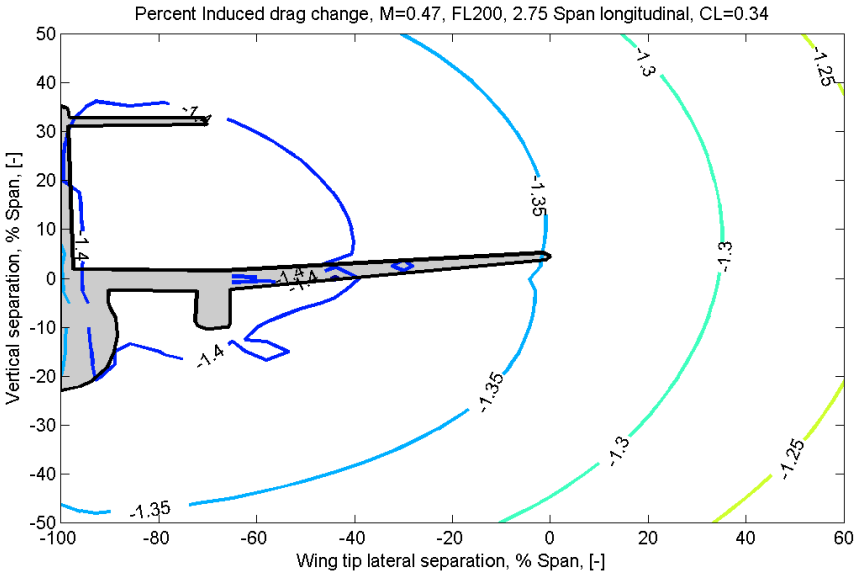
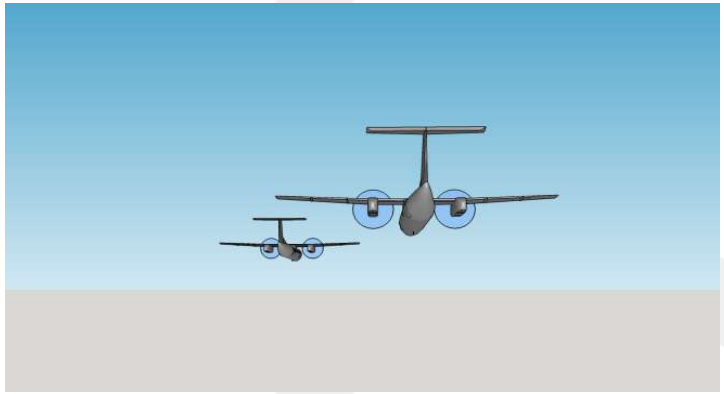
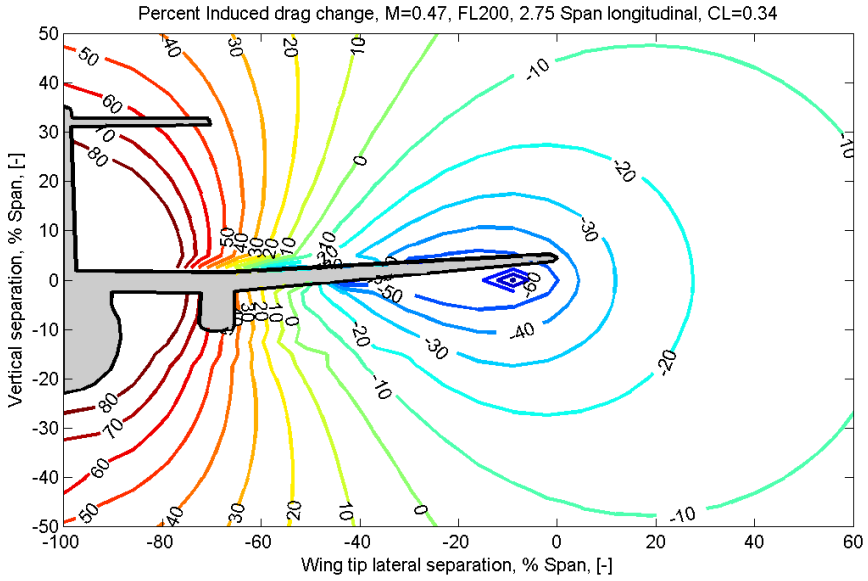
Commercial Application







Total Drag results. [dcts]			
	Baseline	Formation	Reduction
CD_i	35	21	40%
CD_0	139	139	0
Total	174	166	8%
L/D	19.5	20.7	

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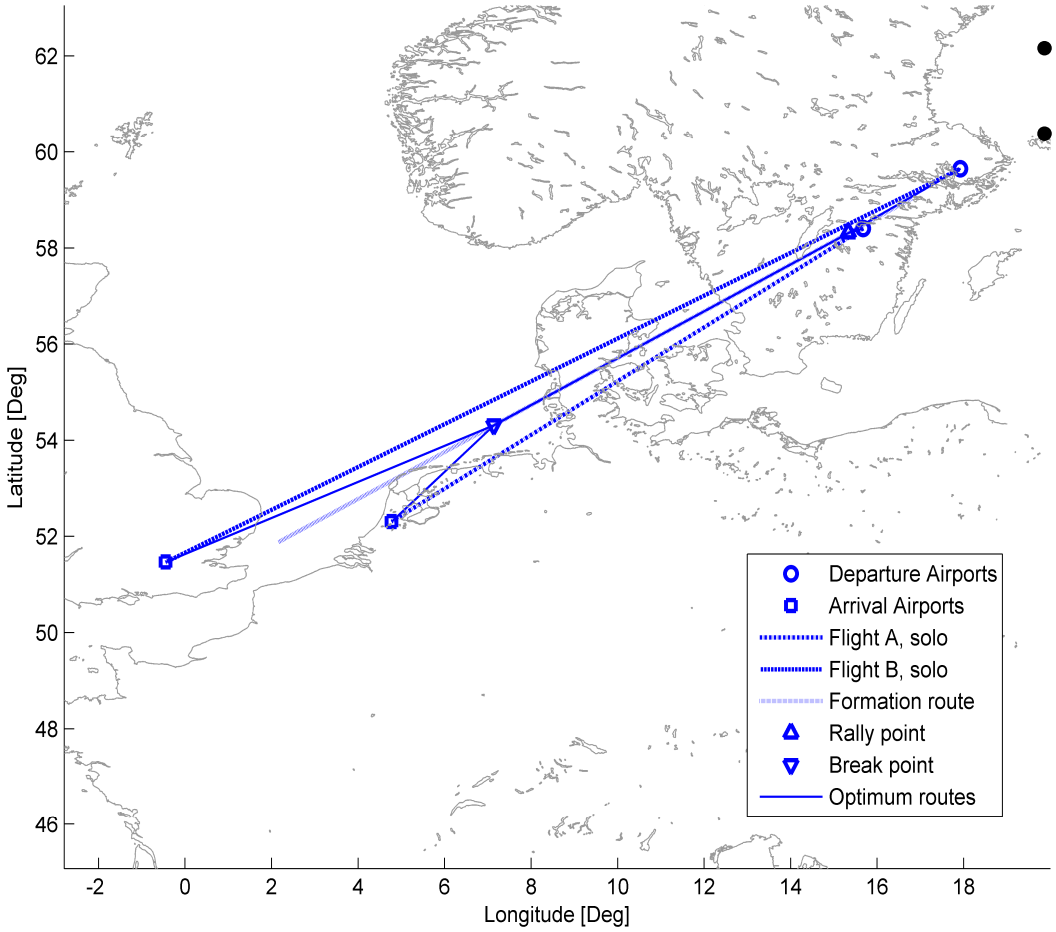
Operational Logistics

Merging Separate Routes



- Stockholm – London
- Linkoping – Amsterdam

SL +0.4 % cost
LA -1.2 % cost

SL +1.3% distance
LA +0.3% distance

SL 45% in formation
LA 70% in formation

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