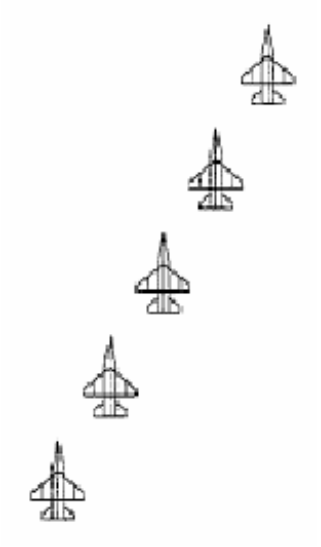
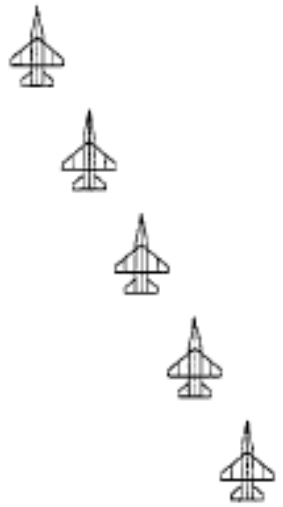
Formation Flight Project

Aircraft Stability and Control



1st Presentation

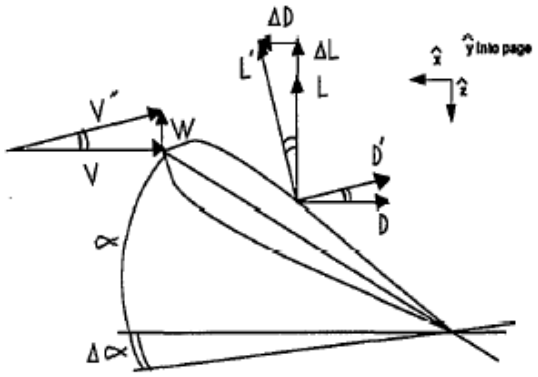


Sources:

- "Induced moment effects of formation flight using 2 F/A-18 aircraft", Hansen and Cobleigh
- "Close formation flight control", Proud, Pachter, Azzo

What is going on?

- Aerodynamics effects

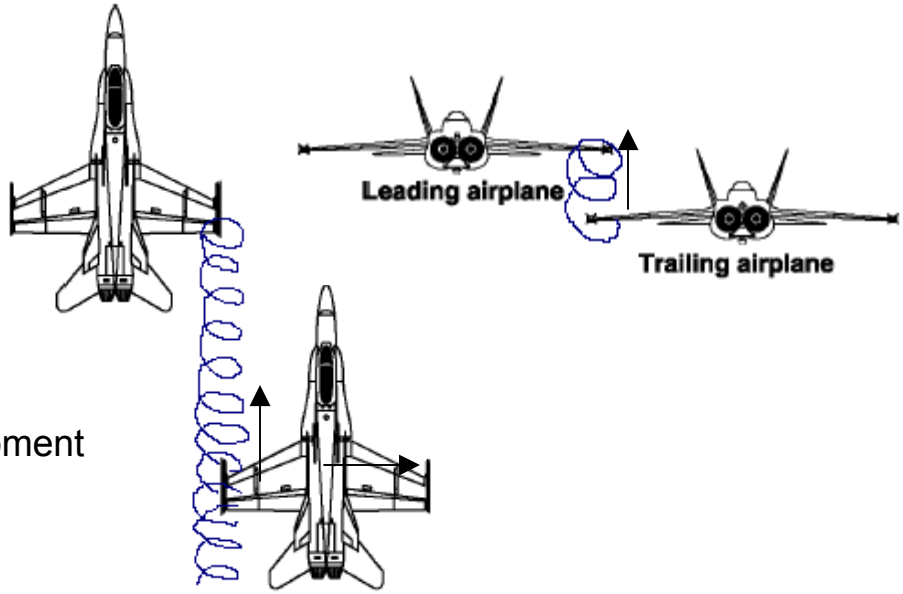


- Induced drag ↓
- Lift ↑

But only on one wing!

- Asymmetrical effect

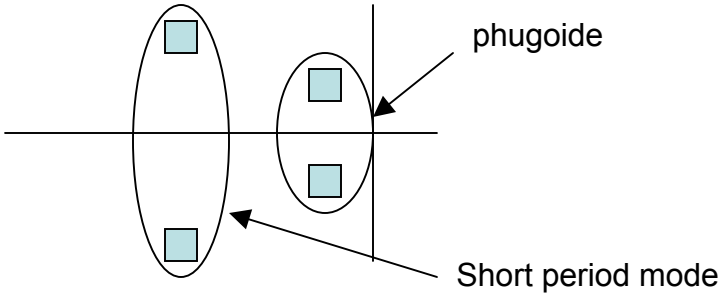
- Flight dynamics consequences



- Drag reduction -> Yawing moment
- Lift increase -> Rolling moment
- Pressure of vortex -> Side force
- Vortex upwash and downwash -> Pitching moment

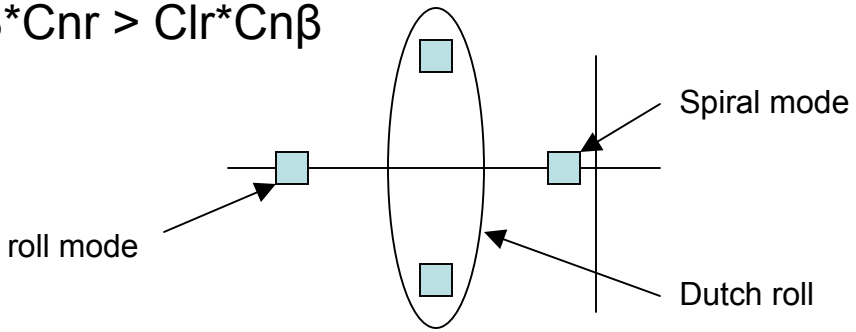
Stability?

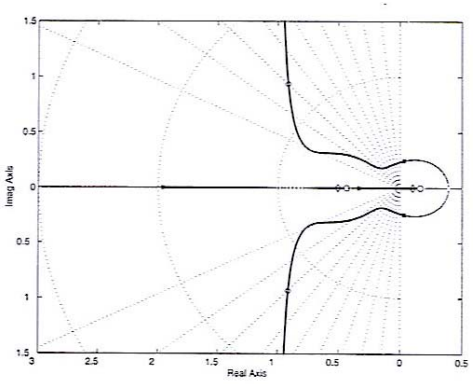
- Longitudinal (short period mode, phugoid) -> Ok



- Lateral (roll mode, Dutch roll, spiral mode)

  Spiral mode stability ↔ Clβ*Cnr > Clr*Cnβ



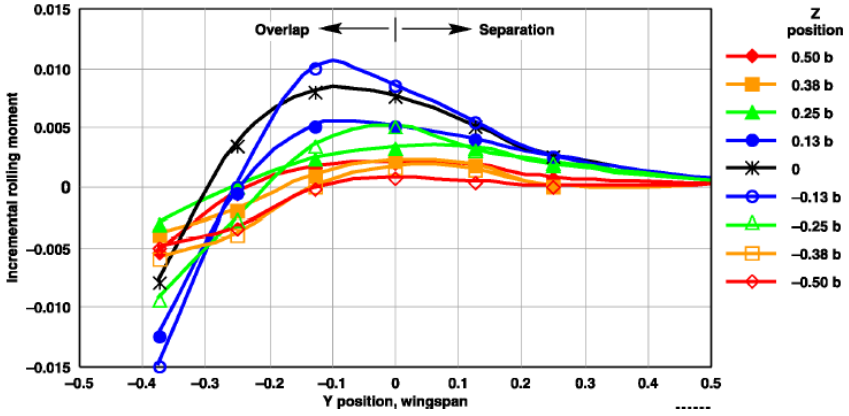


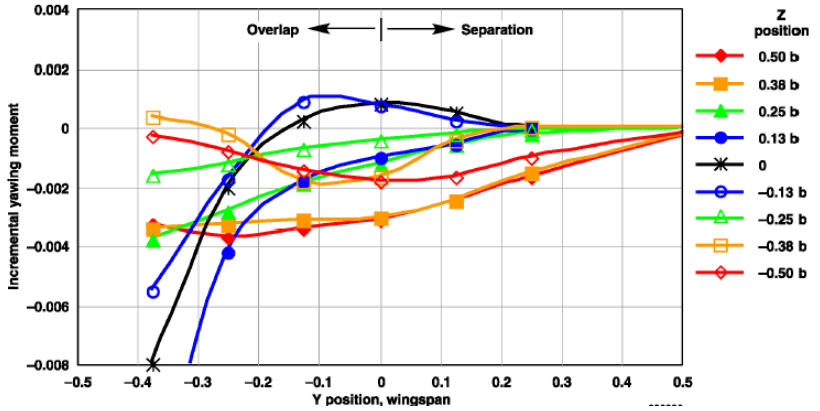
← Spiral mode can also become unstable when building controls

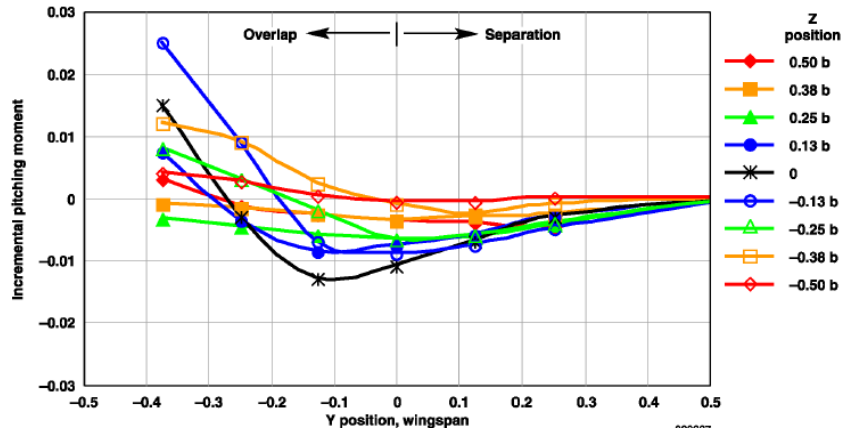
effects on stability of a loop of Φ on δa

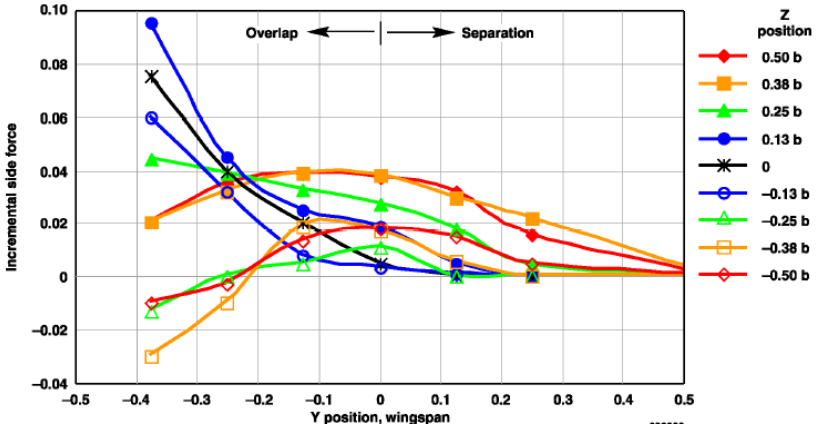
Flight dynamics results of formation flight experiments

- 55 ft nose-to-tail, M = 0.56, h = 25,000 ft



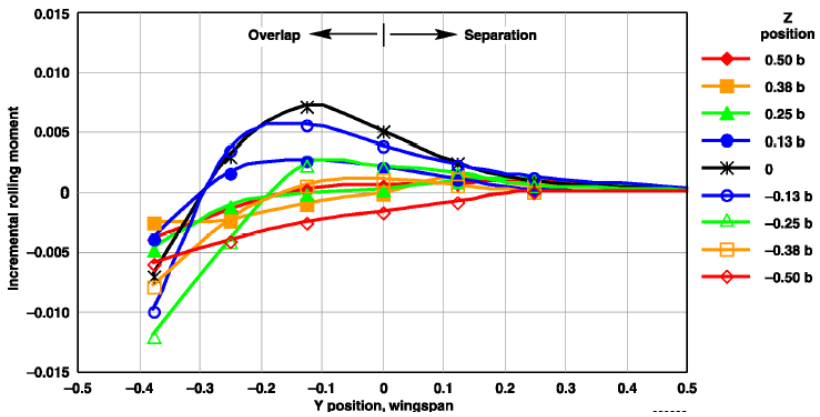


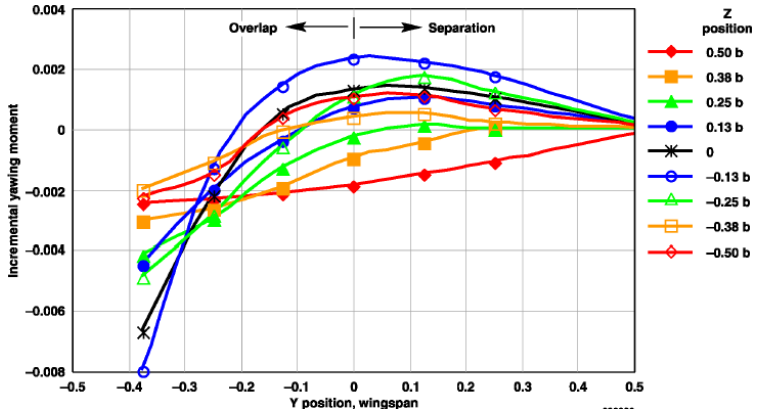


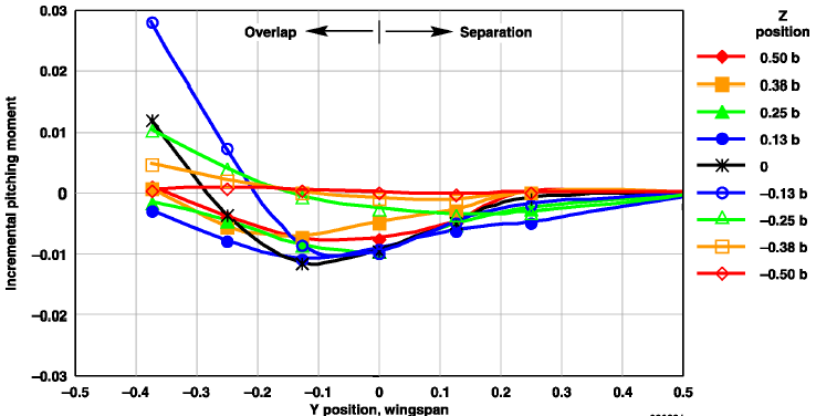


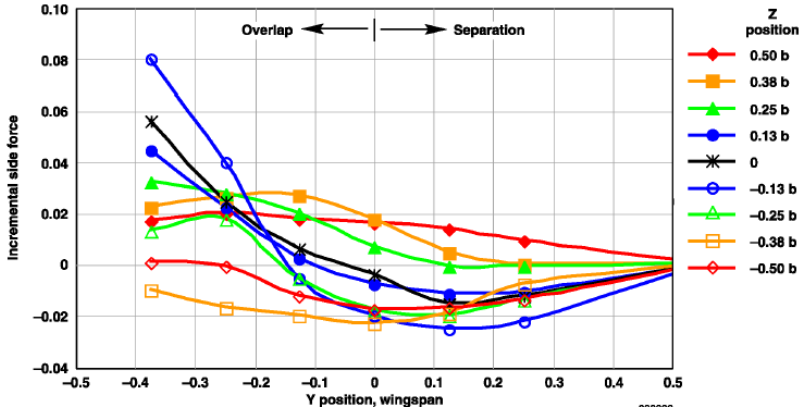
Peak vortex effects are coincident with the position for maximum drag reduction! ☹

❖ 110 ft nose-to-tail, M = 0.56, h = 25,000 ft



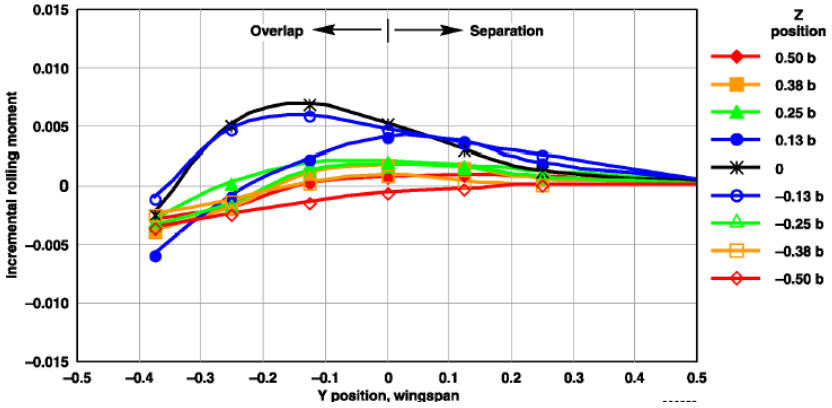


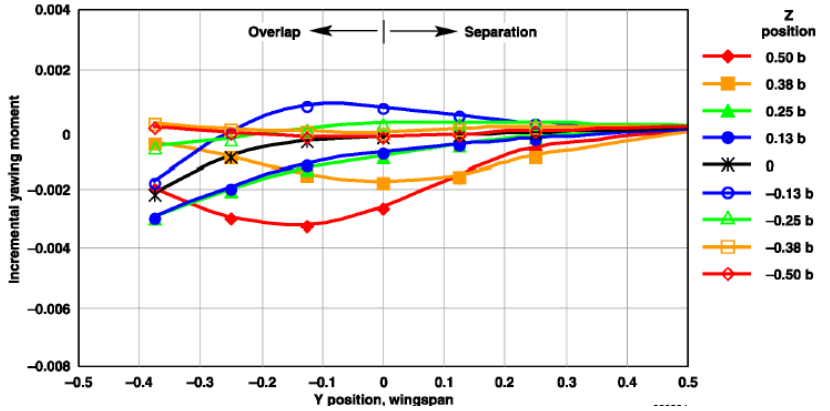


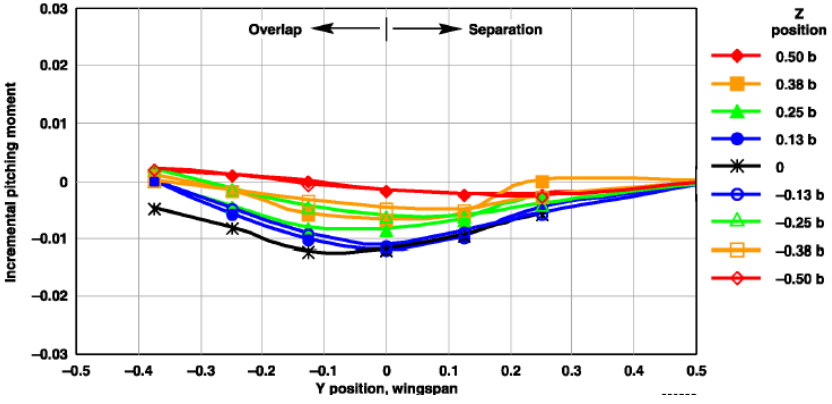


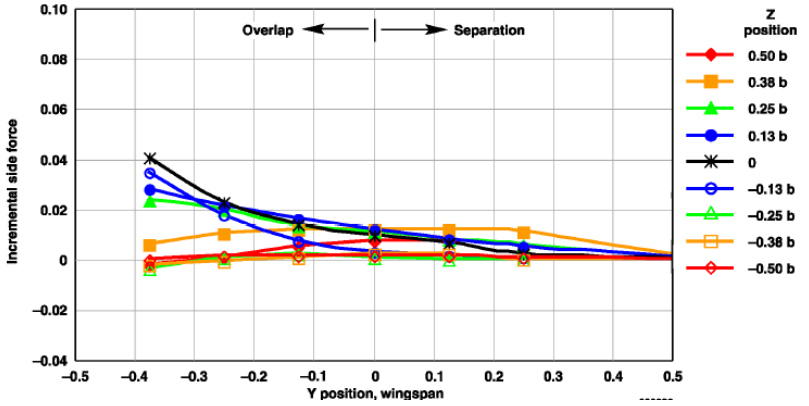
Longitudinal distance ↑ -> pitching, rolling moments ↓, yawing moment, side force ↑

❖ 55 ft nose-to-tail, M = 0.86, h = 36,000 ft



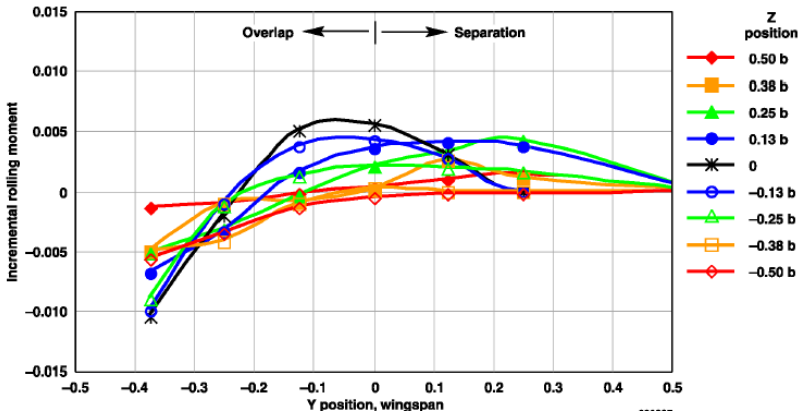


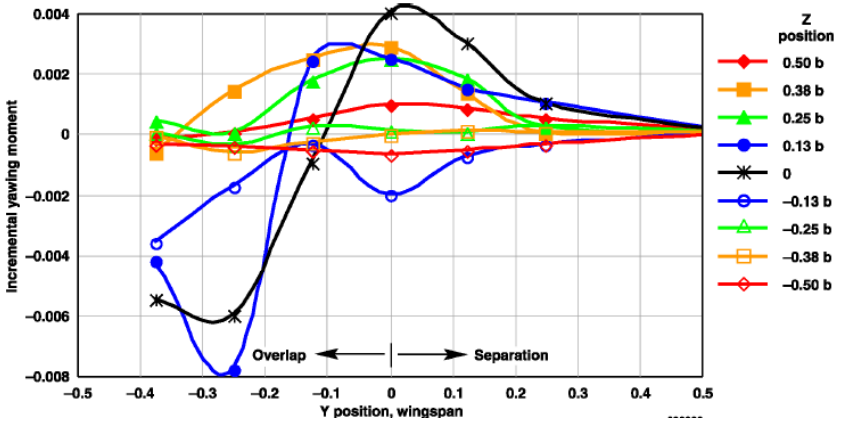


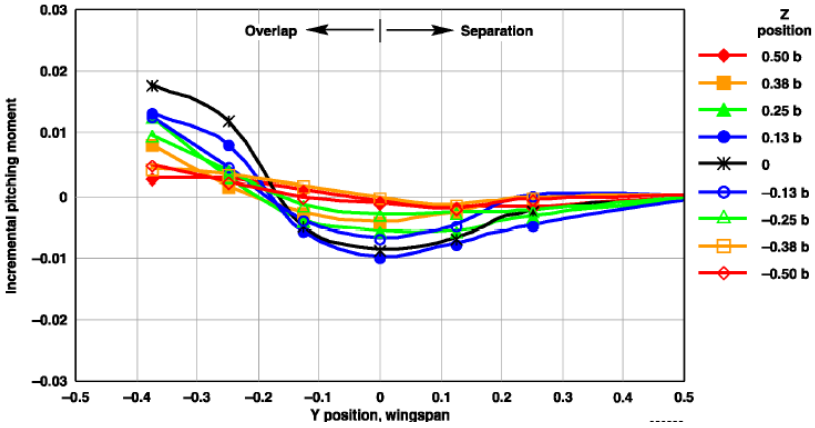


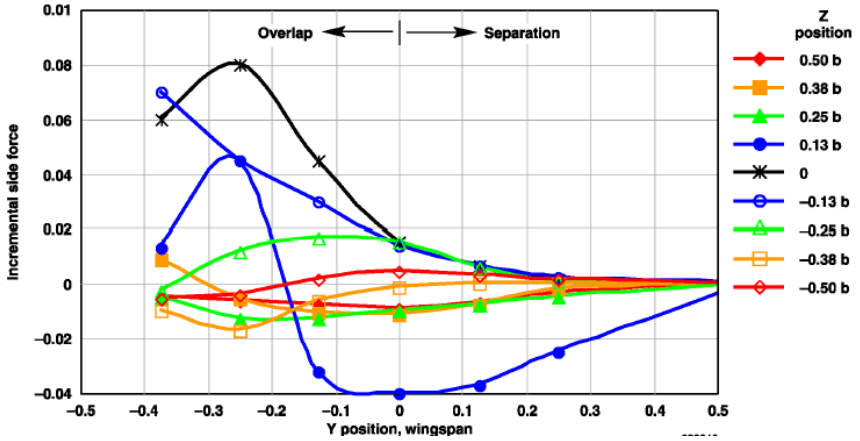
Vortex effects are weaker at transonic than at subsonic conditions

❖ 110 ft nose-to-tail, M = 0.86, h = 36,000 ft









M ↑ -> rolling and pitching moment ↓,
but yawing moment and side force ↑

<u>Configuration proposal:</u>

- ➢ 110 ft nose-to-tail, M = 0.86, h = 36,000 ft
- ➢ Yaw trim, fitted dihedral