**RTO AVT Technical Course**

Application of Adaptive Structures in Active Aeroelastic Control

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# Active Aeroelastic Design of a Vertical Tail

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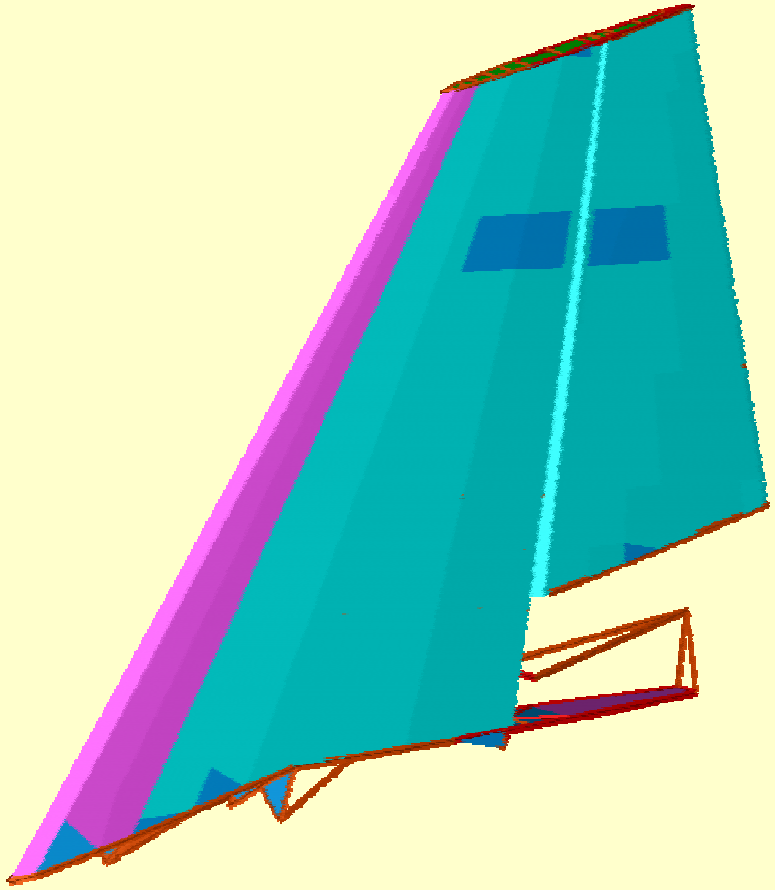


# Outline

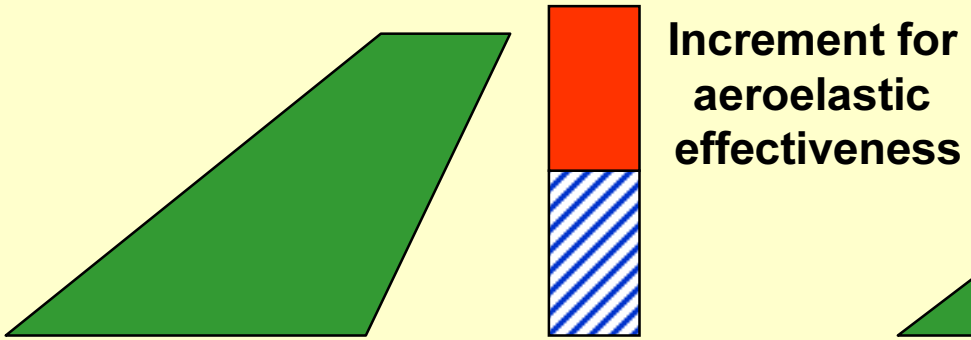
- Introduction.
- Classical vertical tail plus control surface
- All Movable Vertical Tail
  - attachment configuration
  - variable stiffness.
- Design studies
- Conclusion.

# Elementary Aspects of Vertical Tail Design

- Proper amount of directional stability throughout the whole flight envelope
- sufficient yaw damping
- directional control
- maneuverability

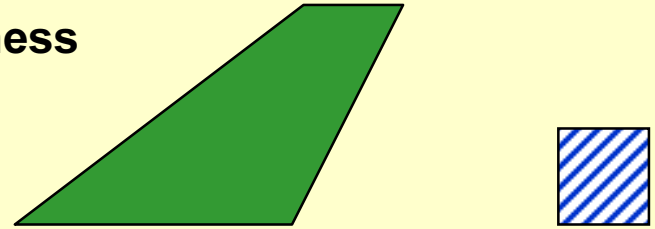
# Potential Benefits of Active Aeroelastic Concepts for Vertical Tails

**Conventional Vertical Tail**



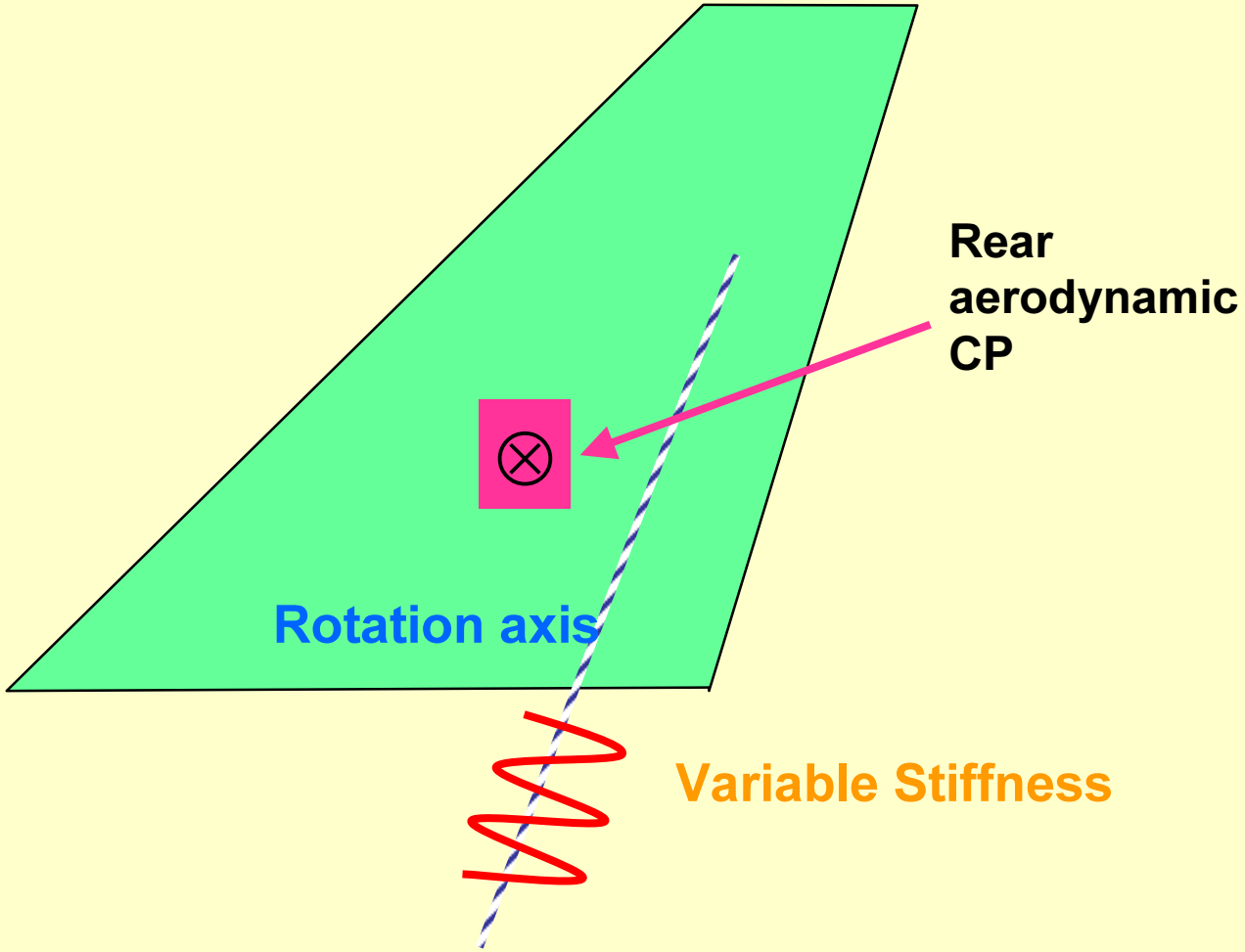

Size Weight

**Active Aeroelastic Vertical Tail**

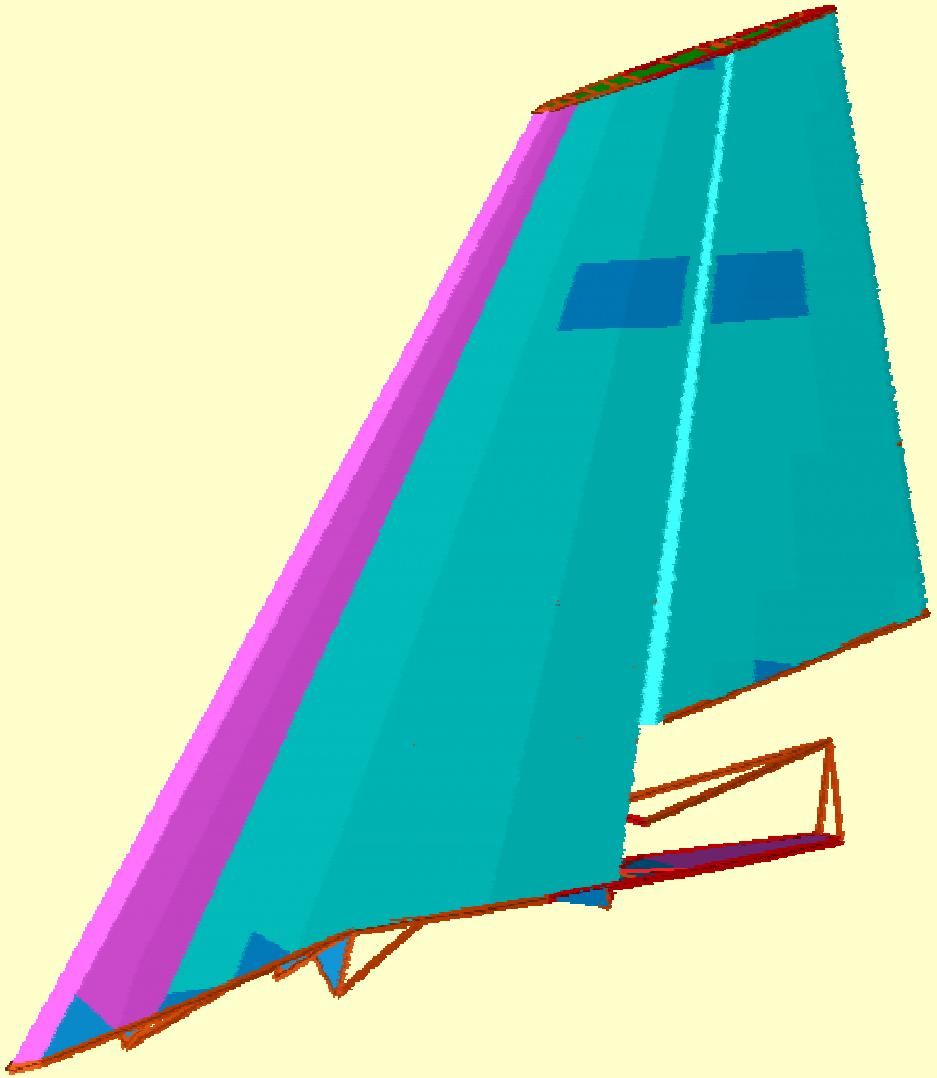


Size Weight

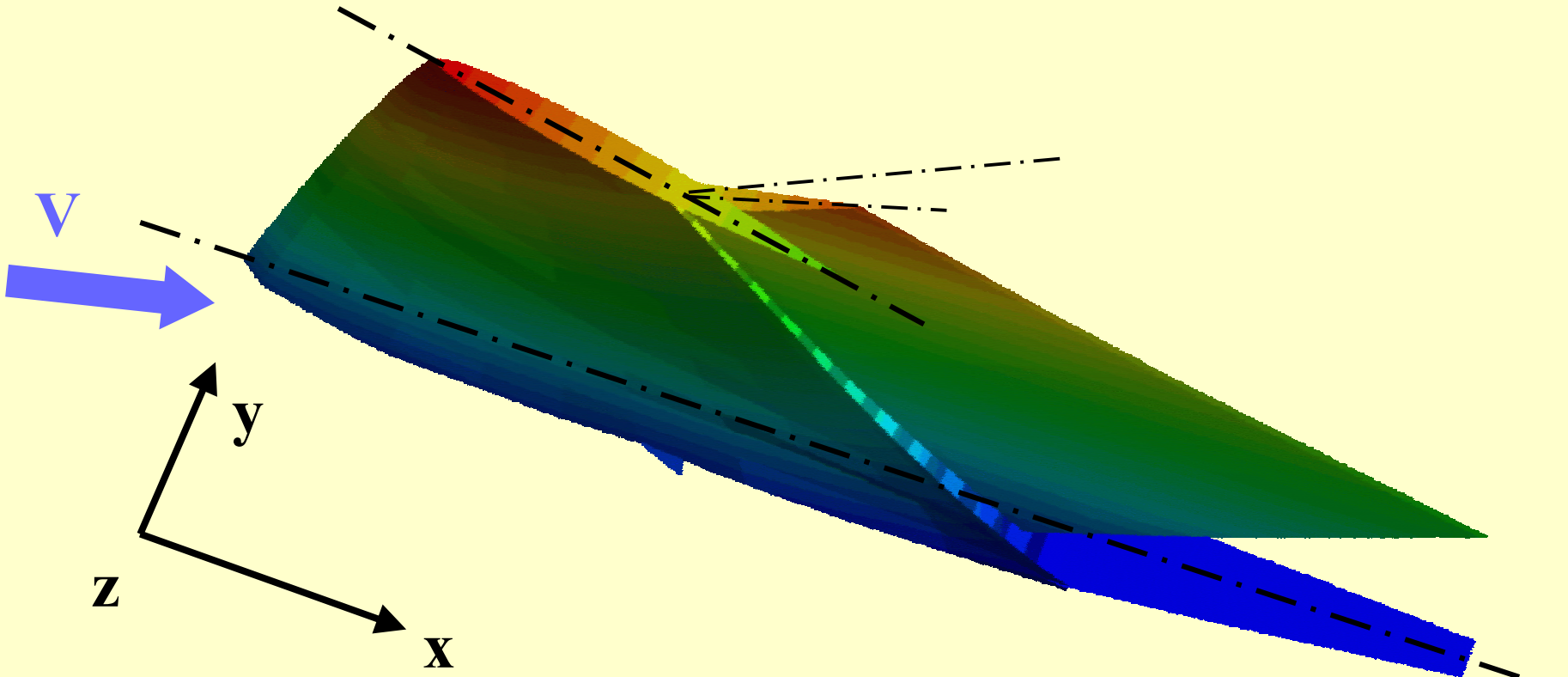
# Basic concept for Active Aeroelastic All-Movable Surfaces



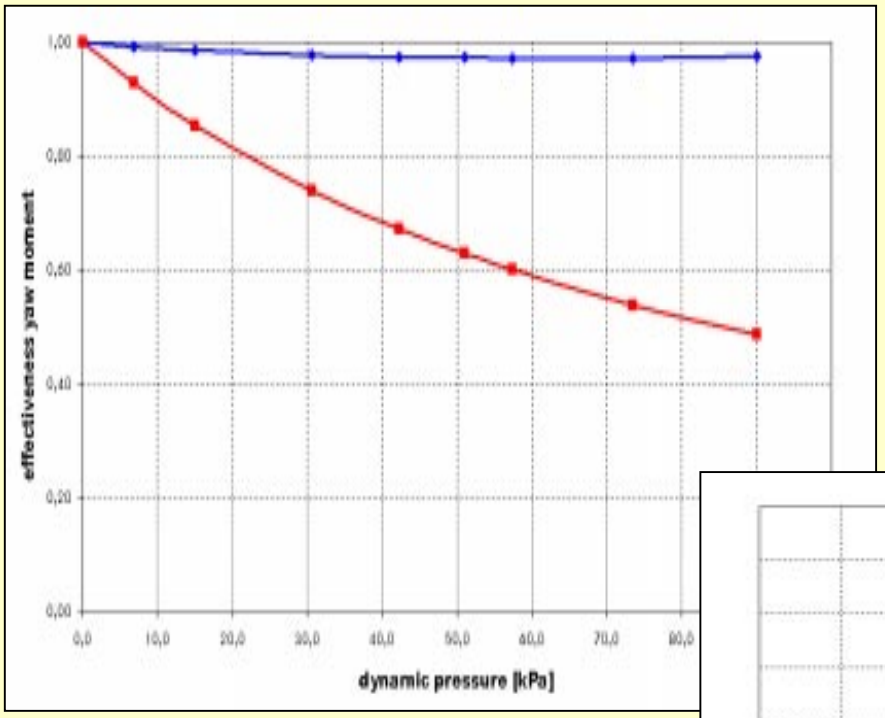
# Baseline design



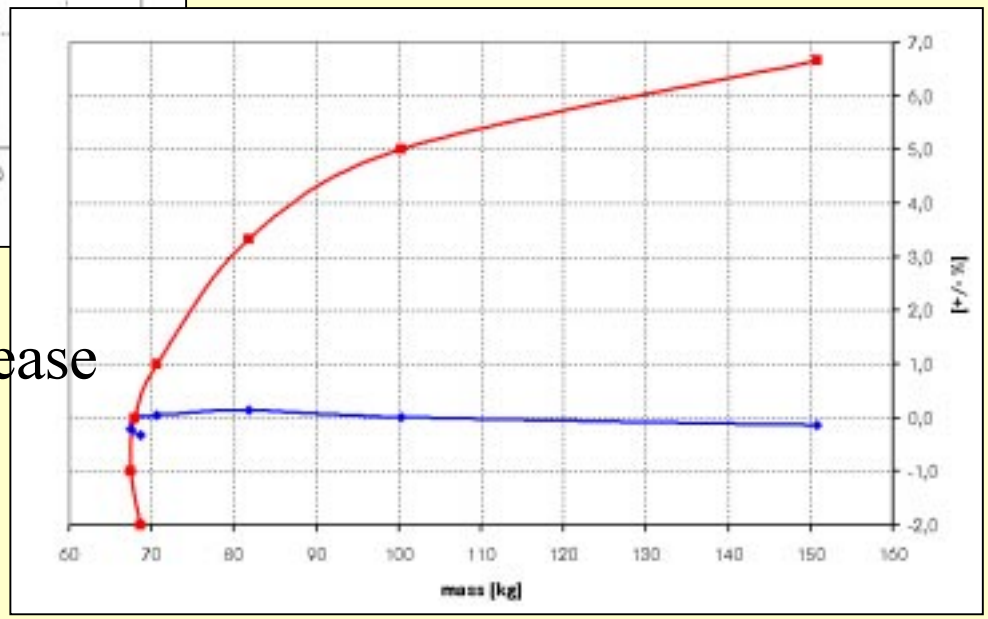
# Deformations of baseline design (View from top)



# Aeroelastic Effectiveness

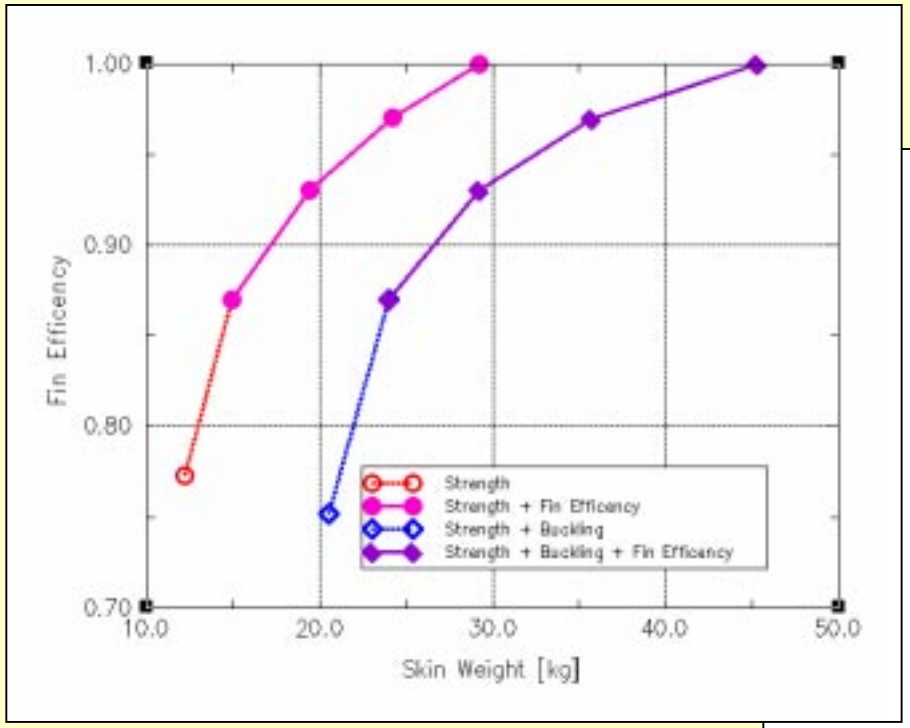


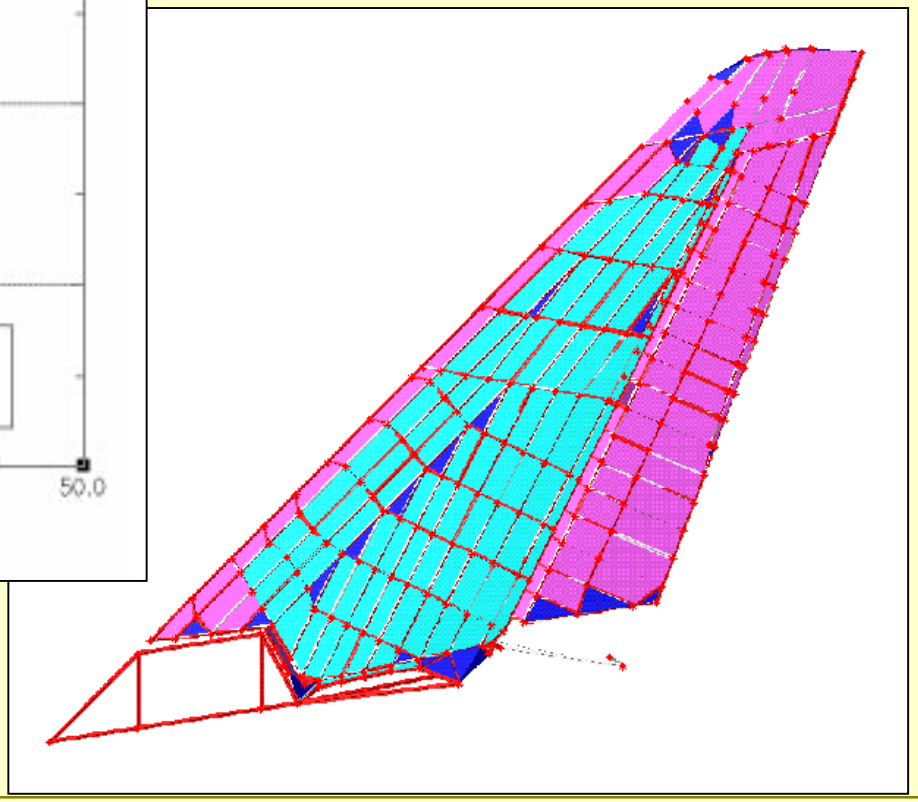

- Yawing moment and rudder effectiveness vs. dynamic pressure



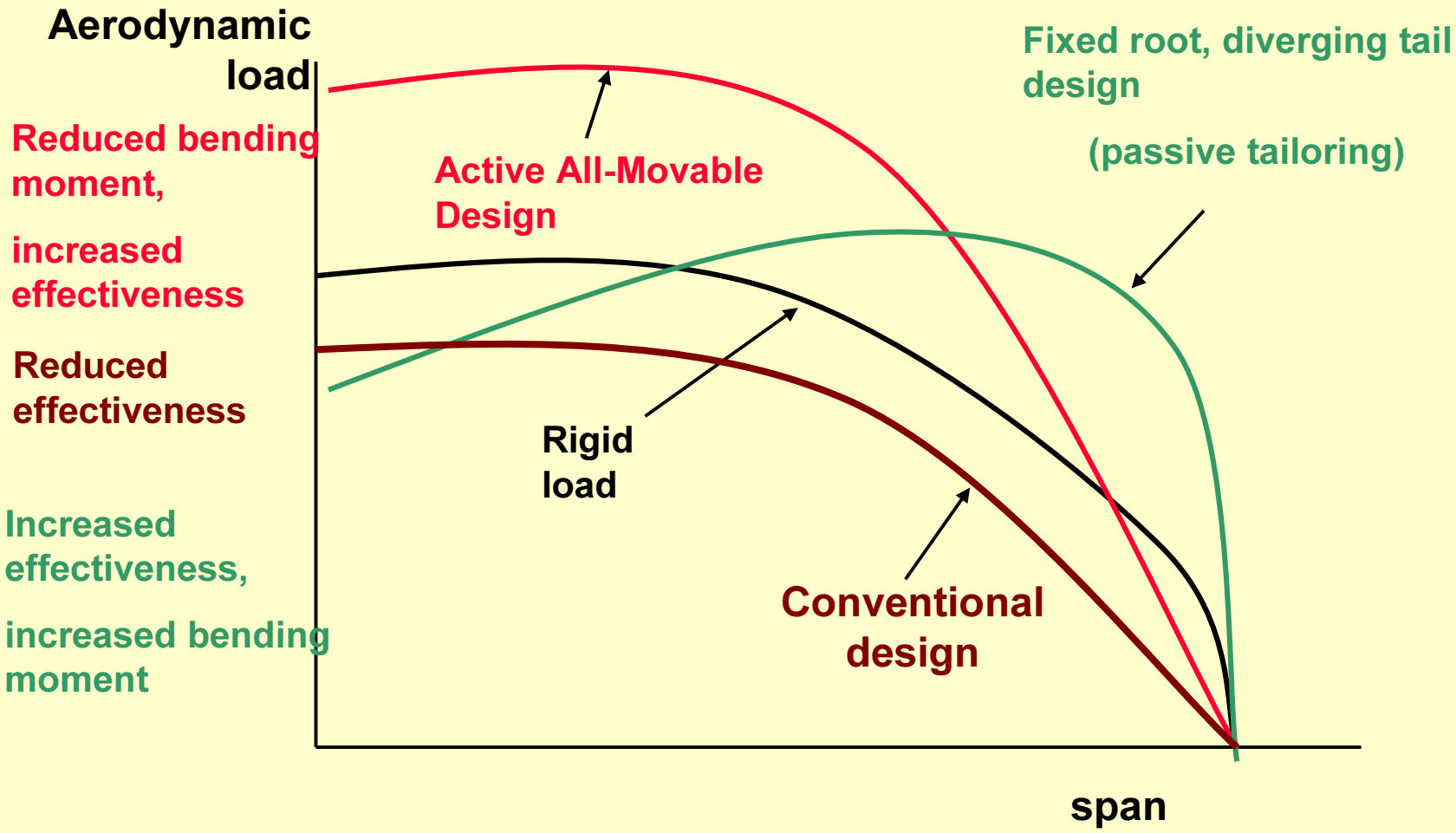

- Potential effectiveness increase by structural optimization (vs. mass)

# Optimization of yawing moment effectiveness for a generic EF2000 fin

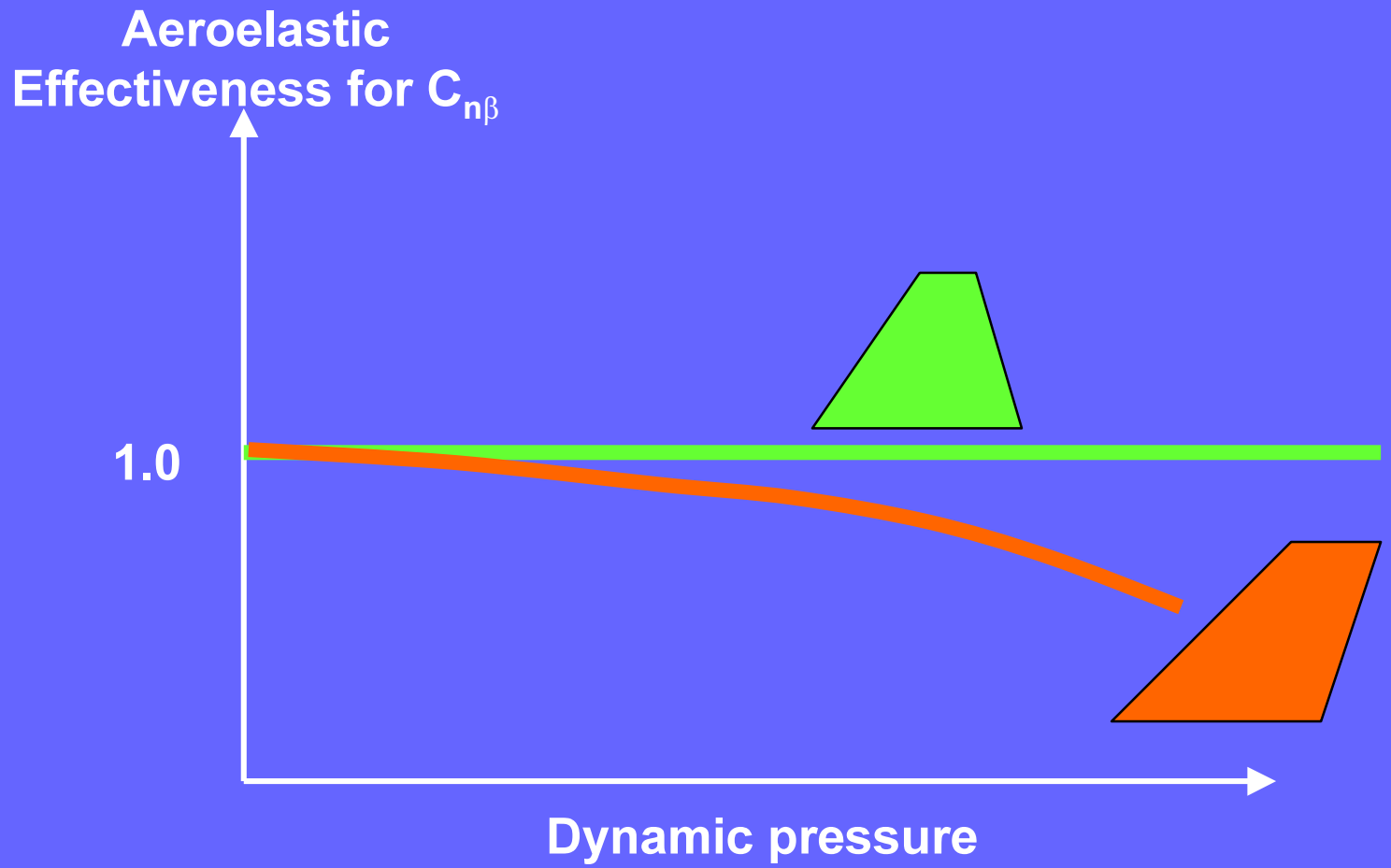


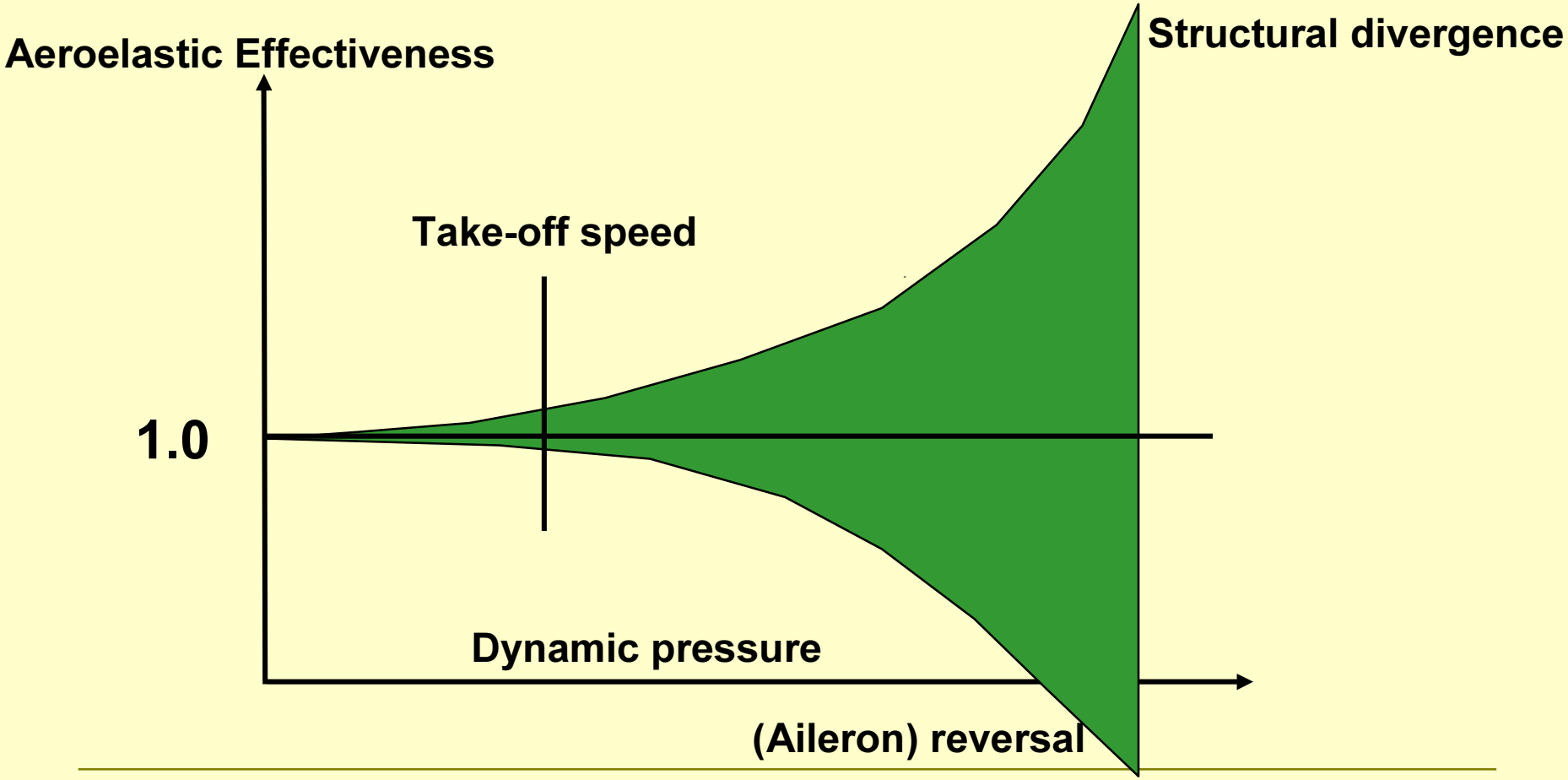
# Spanwise load distribution for different design approaches



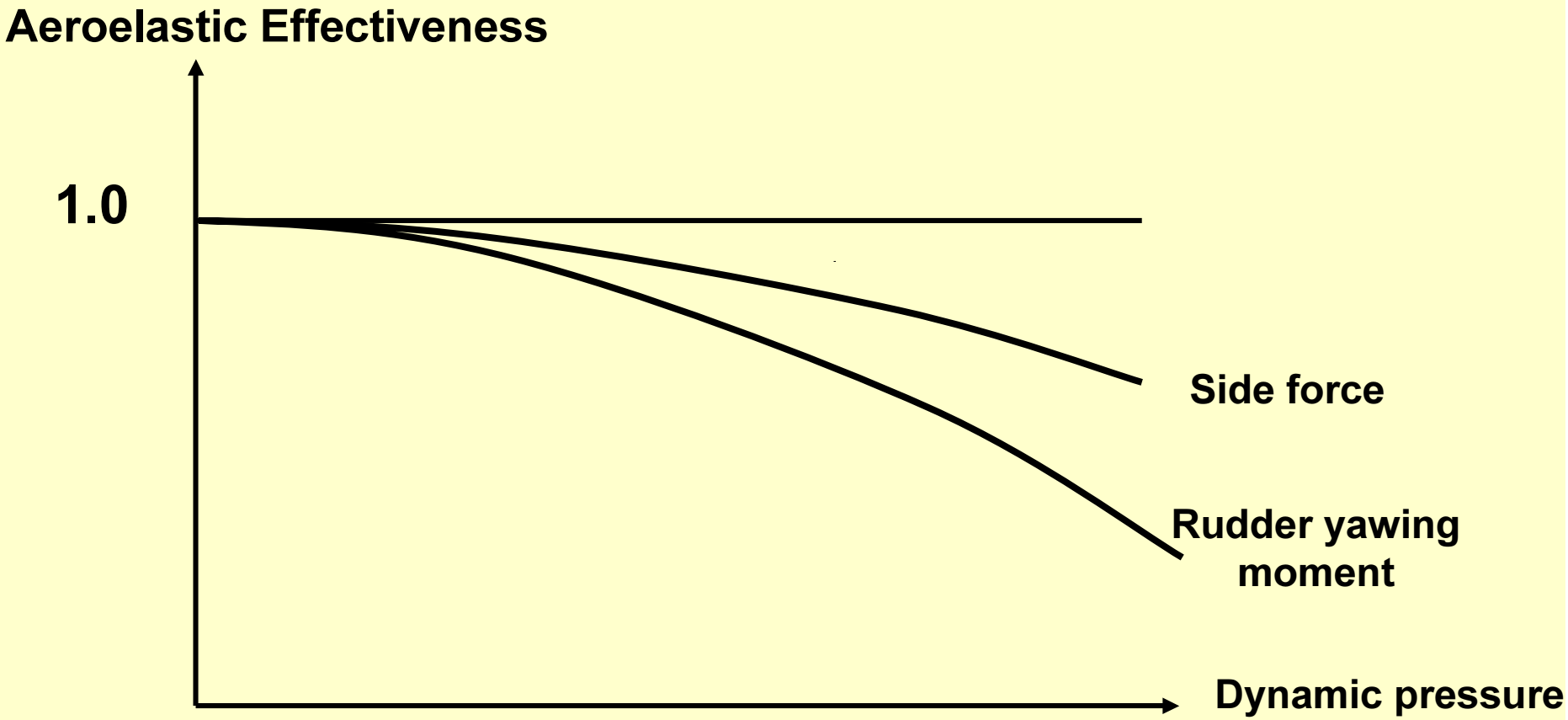
# Aeroelastic Sensitivity of Planform Geometry for Vertical Tails



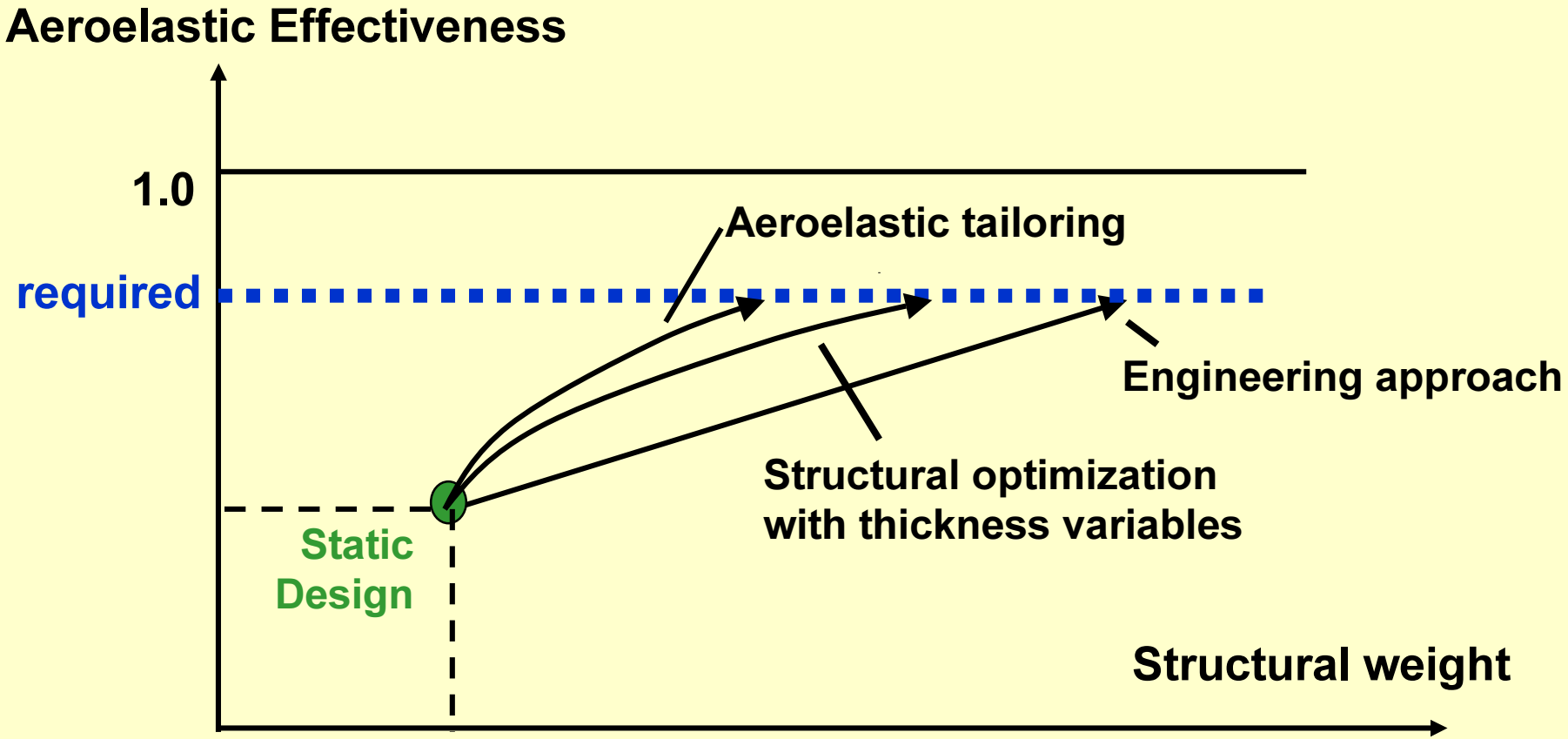
# Typical range of aeroelastic effectiveness values for a fixed root surface



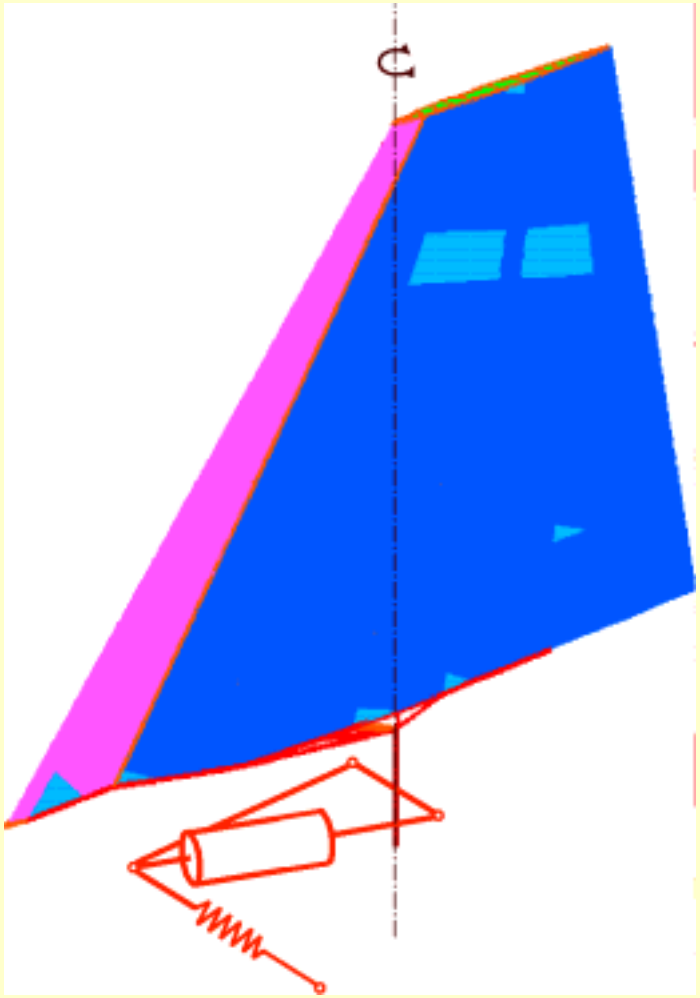
# Typical aeroelastic impacts on vertical tails

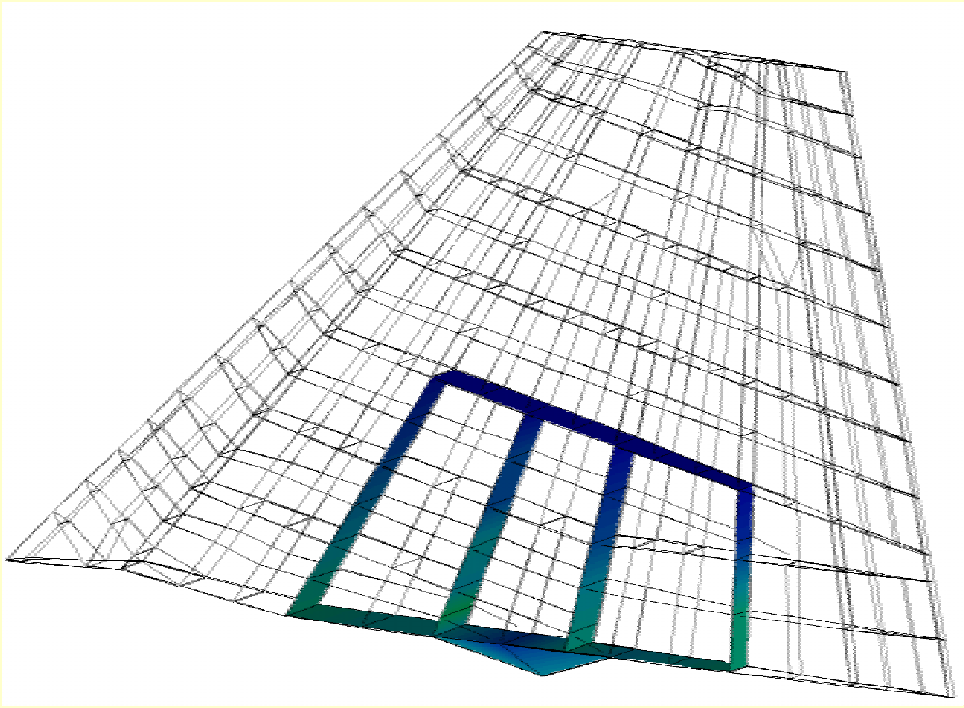


# Aeroelastic effectiveness and structural weight for a conventional vertical tail design

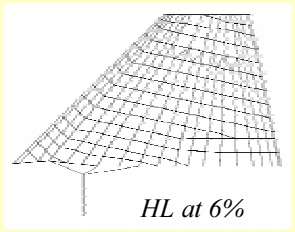


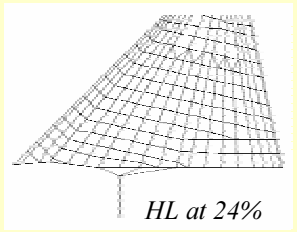
# Modifications for adaptive all-movable concept

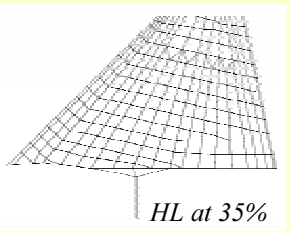


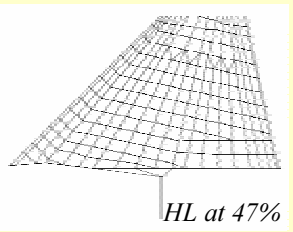


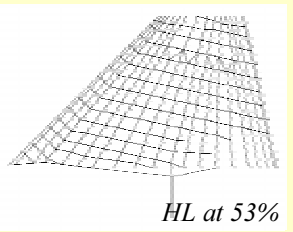
# Variation of attachment position



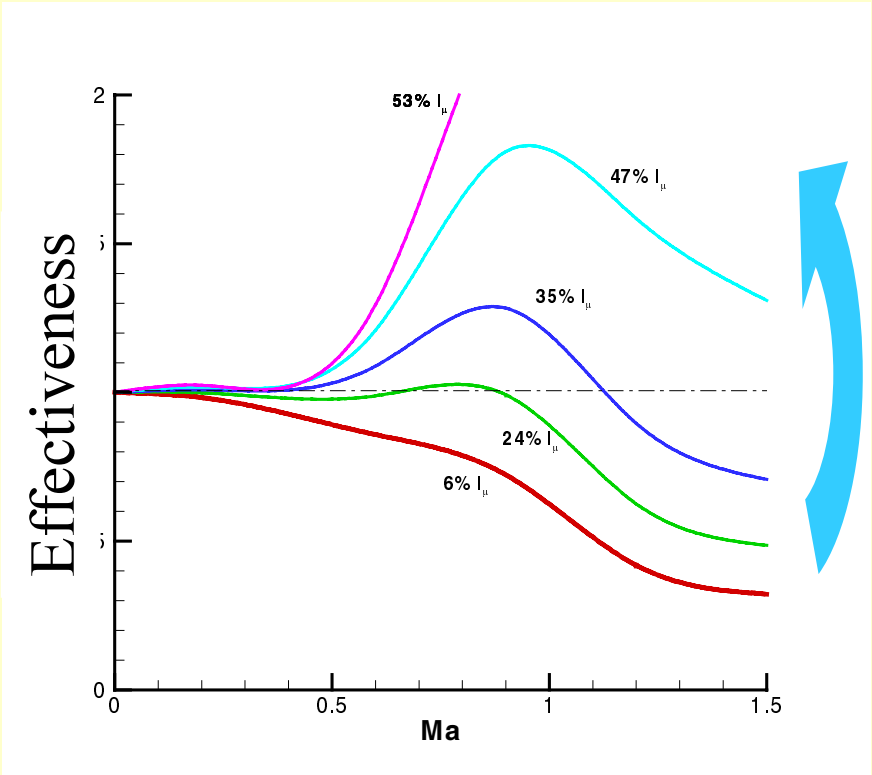



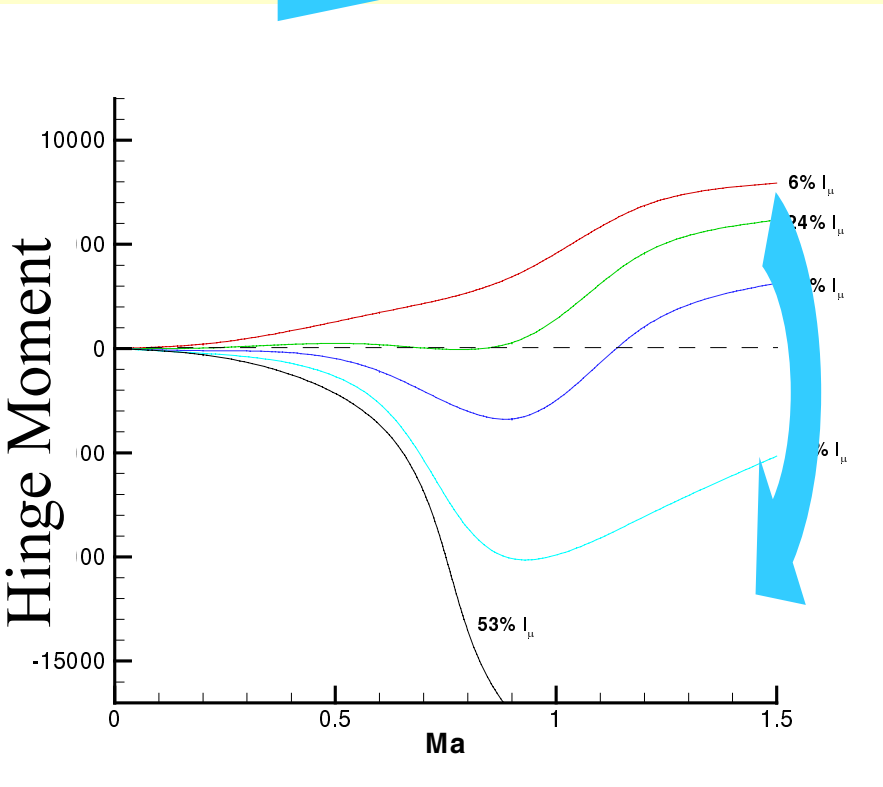



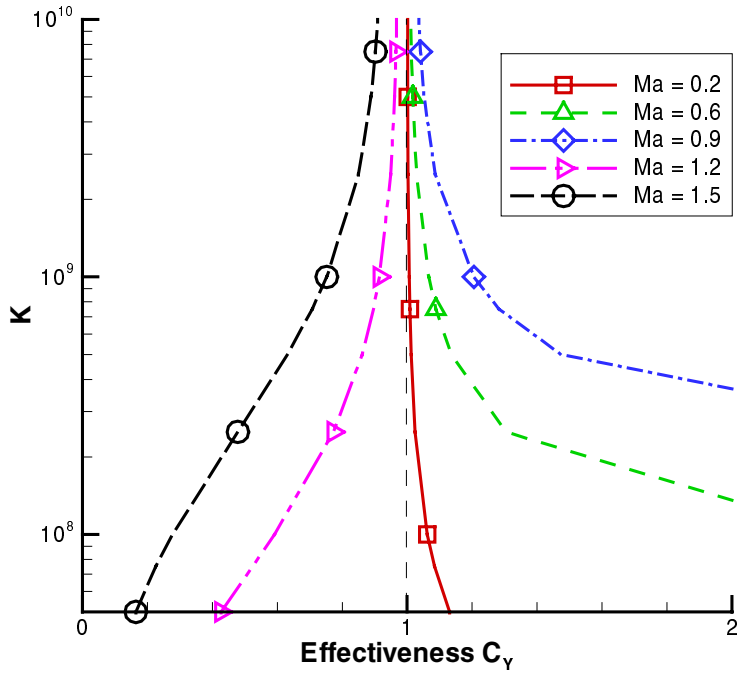

***backward position***



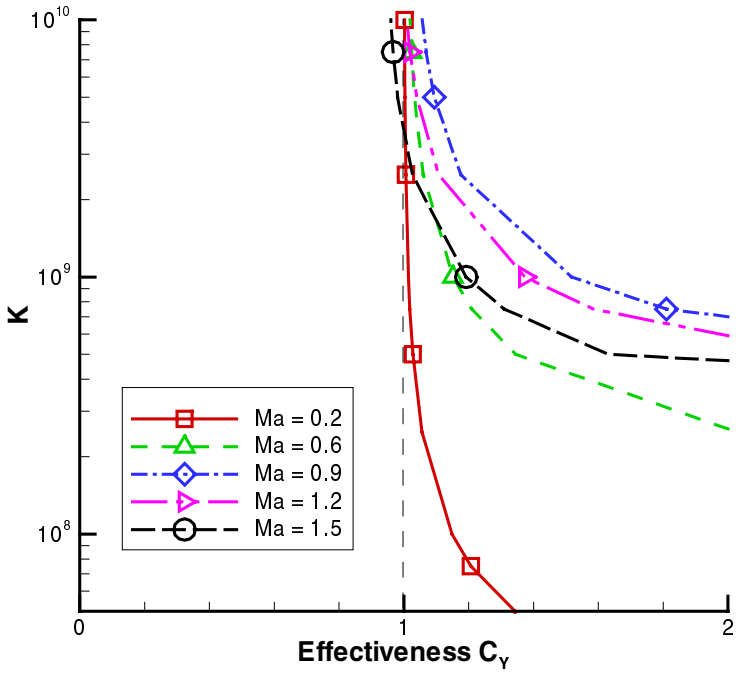



# Actuator Stiffness Variation

HL at 35% $l_\mu$

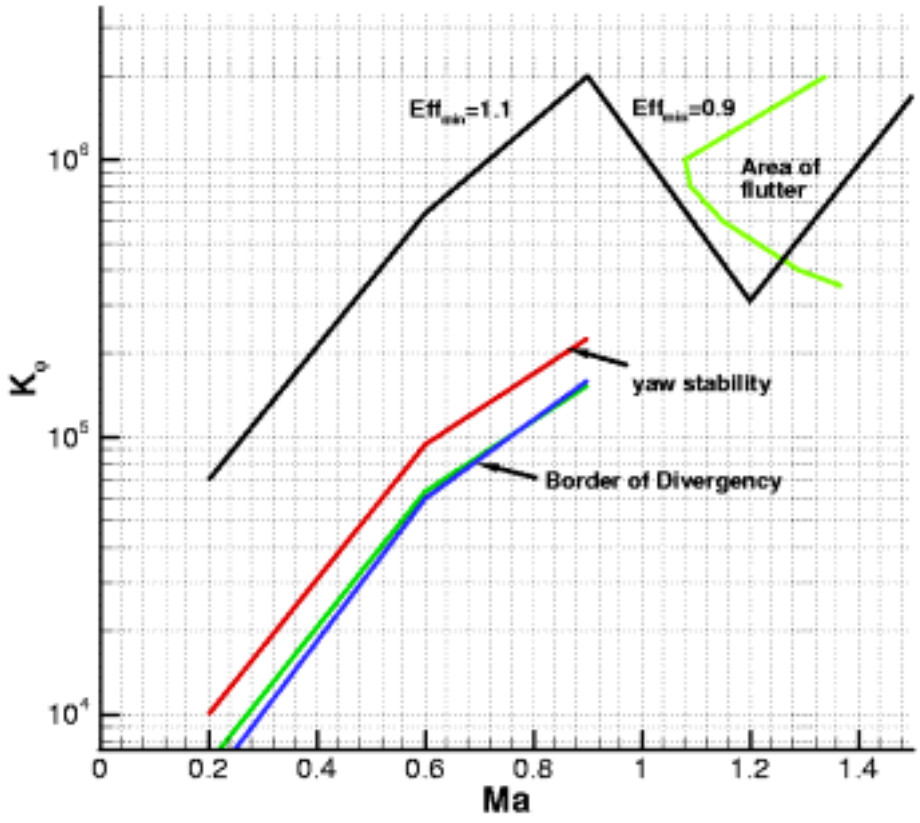


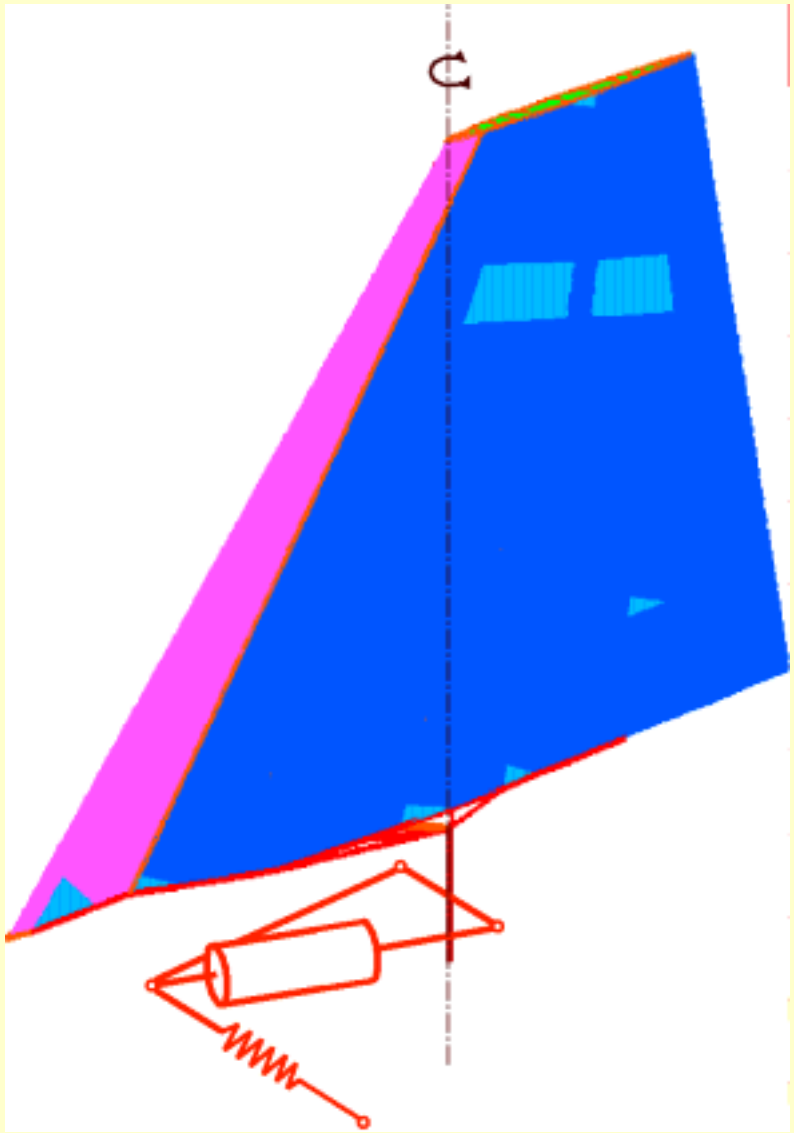

HL at 47% $l_\mu$



# Attachment Stiffness Requirements

HL at 35% $l_\mu$





# Variable Stiffness Attachment/Actuation Concepts

- Mechanically
- Hydraulically
- combination of both

# Realistic Fiction ?

Dryden Flight Research Center ED93-42152-10 Photographed 1993
X-31 Quasi-tailless photo concept

# Needs for Integrated Design of Airplanes with Active Aeroelastic Concepts

- Good understanding of the physically behavior
- The analytical description of active aeroelastic concepts must directly be included in the structural analysis model
- Choose of the proper analysis methods for the individual disciplines
- Quality and completeness of analysis models
- careful selection and combination of design variables and completeness of design requirements

# Conclusions

- An actively controlled all-movable fin concept needs no additional weight for aeroelastic effectiveness.
- Additional weight savings result from:
  - size reduction
  - loads reduction.
- Additional benefits:
  - Aerodynamic drag reduction
  - Reduced radar signature
  - Reduced buffeting loads
  - Higher flutter stability.