Load Alleviation

Load alleviation possibilities on a Fighter A/C

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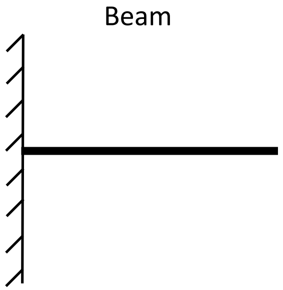
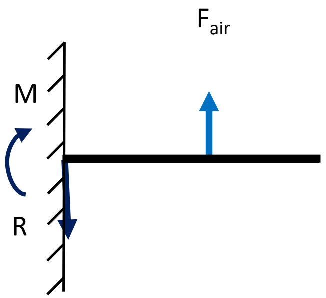
Load Alleviation - Content

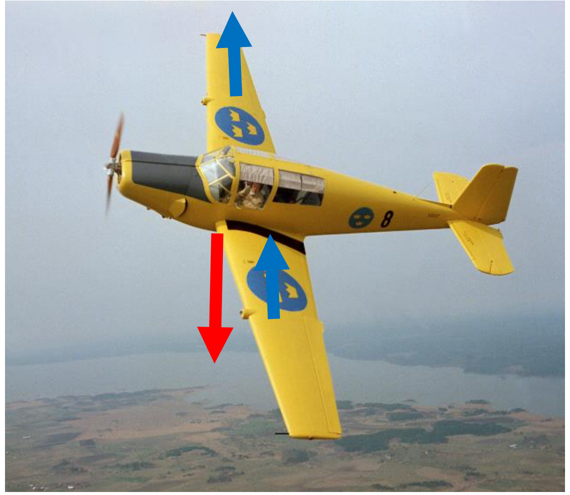
Load Alleviation - Introduction

Aircraft Design

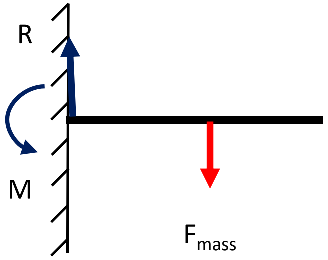


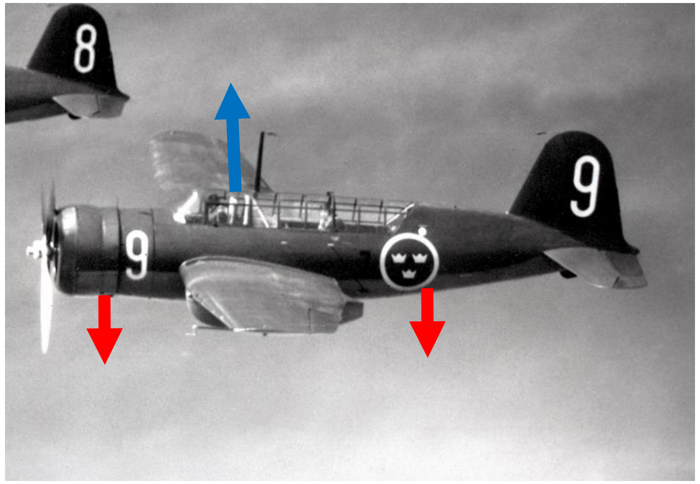
Wing





Fuselage





Load Alleviation - Introduction

Flying Wing Design

- Goal → Increase Performance
  - Reduce the Loads
    - Reduce Weight → Reduce Drag
    - ”Clean” Design → Reduce Drag

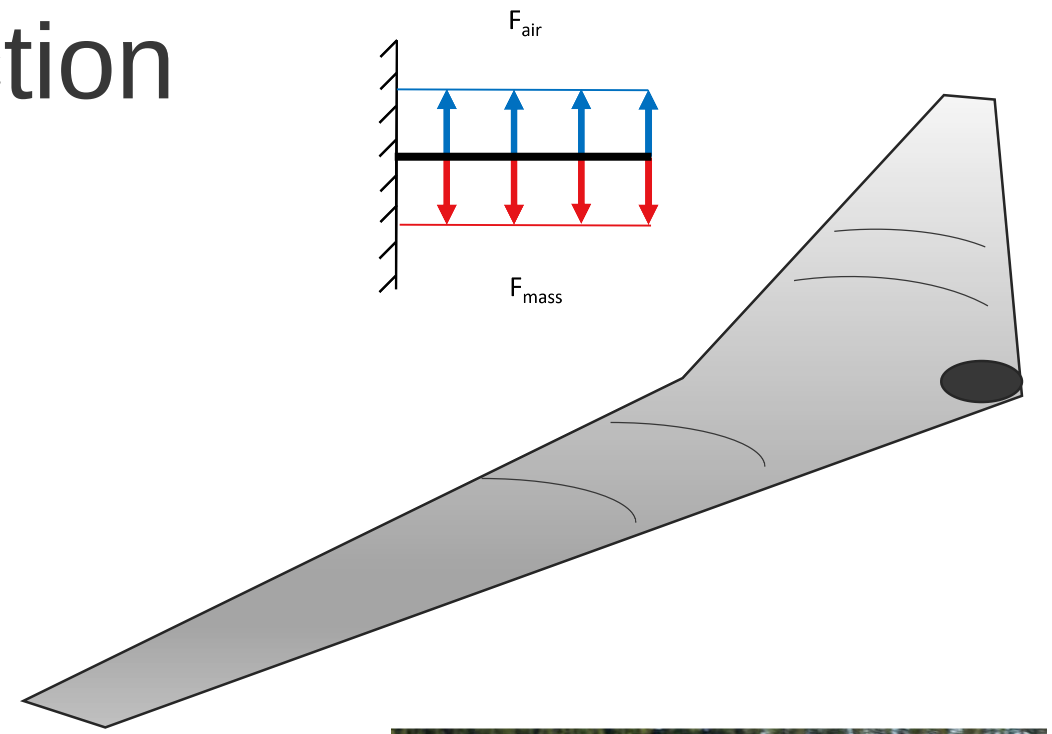
Exempels:

Northrop and Northrop-Grumman A/C:s:

- XB-35, 1946
- YB-49, 1947
- B-2, 1989
- Future passenger and cargo A/C concepts

Dassault-Saab

- Neuron



YB-49

Neuron

Load Alleviation - Introduction

Fighter A/C

- Other requirements regarding performance
  - High speed and maneuverability

Load Alleviation - Goal

Improve performance - maneuverability, speed and range

Drag: $C_D = C_{D_f} + C_{D_p} + C_{D_w} + C_{D_i}$

Load Alleviation may:

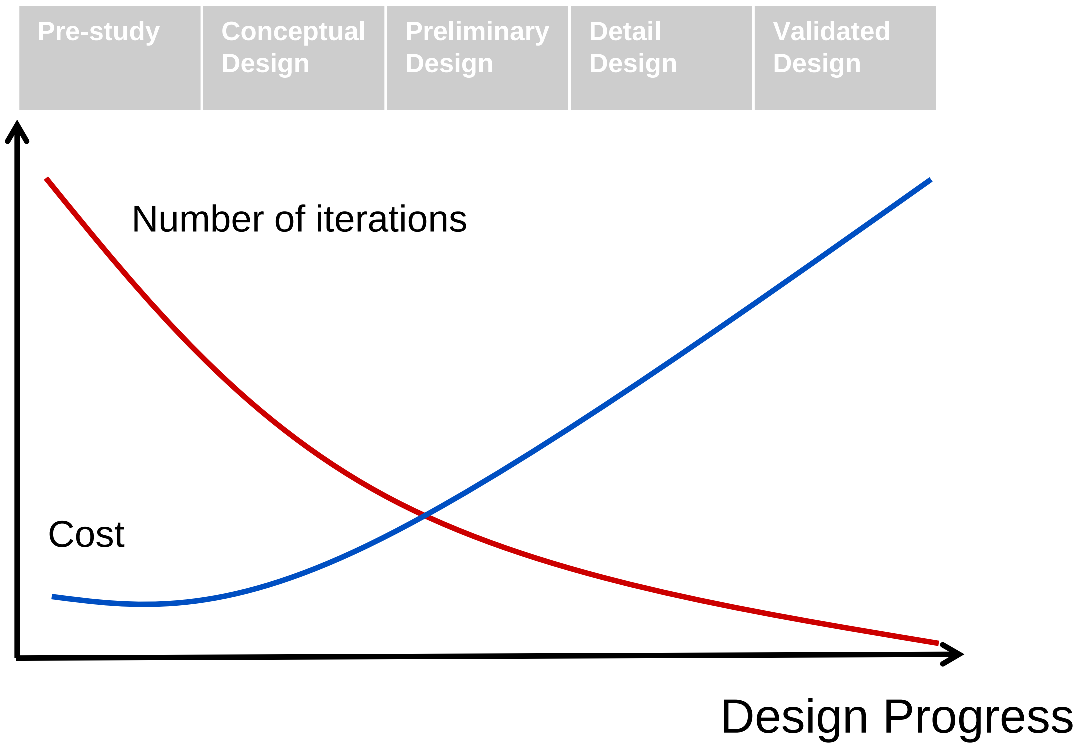
- Reduce A/C size => Reduce drag
- Reduce A/C weight => Reduce drag

- More Stealth
- Ease design
- Increase maneuver envelopes
- Increase A/C life
- Reduce cost

Load Alleviation - Design phases

- Pre-studies
- Conceptual design
- Preliminary design
- Detail design
- Verified design
- In service

- Optimization activities take place in all phases but the possibility to affect the design decrease as the project proceed



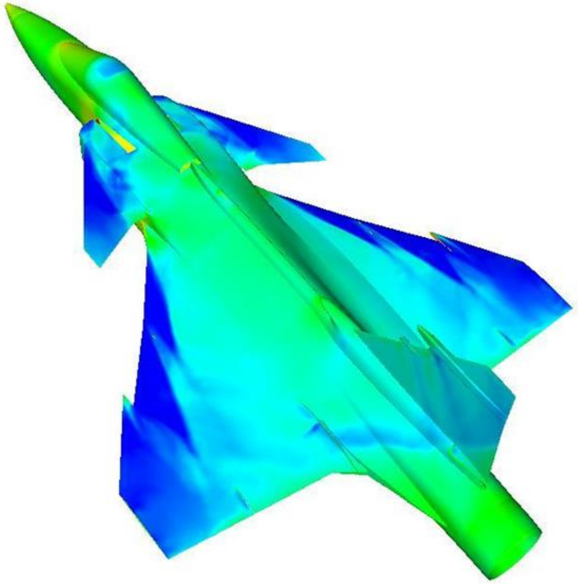
Load Alleviation - Optimization

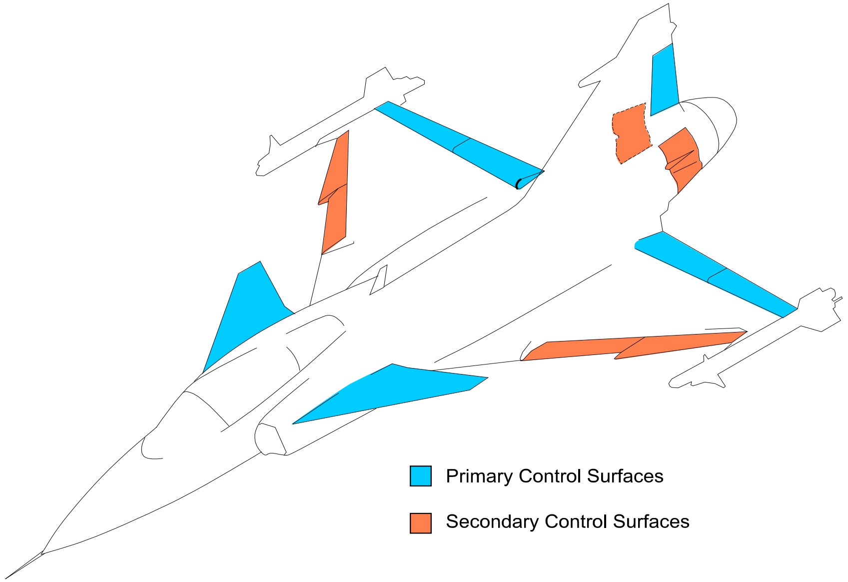
Multidisciplinary - Iterations

- **Working together to a common goal**

  - Cost
  - Customer requirements
  - Operational Analysis
  - Design
  - Aerodynamics
  - Performance
  - Stability & control
  - Loads & stress
  - Radar signature

- **The goal is an optimized product all together!**



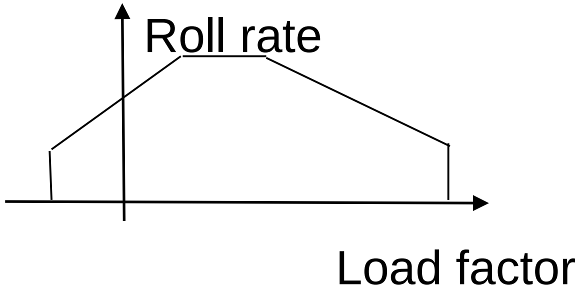


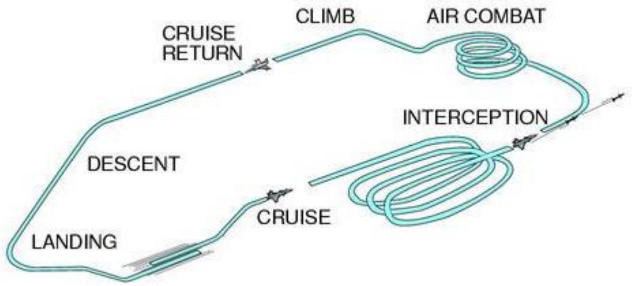
Load Alleviation - Types of

- Alleviate maximum loads – Design Loads
- Alleviate load spectra – fatigue loads and damage tolerance

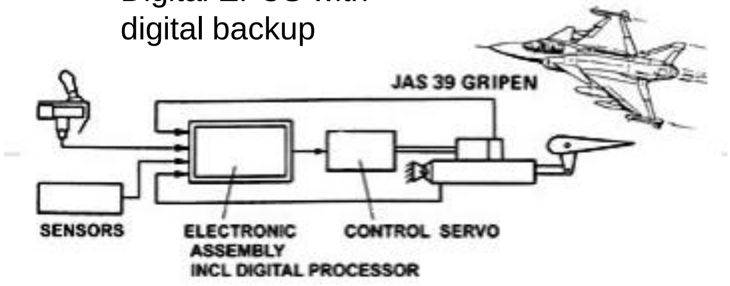
- Passive load alleviation
- Active load alleviation

- Global loads
- Local loads





Digital EFCS with digital backup



Load Alleviation - Fighter A/C vs Transport A/C

Fighter A/C

- Manoeuvers

Transport A/C

- Gusts
  - Identify gusts
    - Knowledge of turbulence
      - Weather reports
      - Low altitude
    - Sensors
      - Wind shear at nose
      - Acceleration
      - Radar

Load Alleviation – Gripen Examples

Global loads

- Fuselage
- Wings

Local Loads

- Wing tip Pylon
- Large stores
- Fuselage starboard Pylon
- Store release
- Fuel Emptying sequence
- Landing gear closing speed

Load Alleviation – Gripen Examples

Global loads - Unstable A/C

Gripen is an unstable A/C

- Load alleviation with unstable a/c:
  - Less control surface deflections and loads
  - Less wing area

- Less control surface deflections and less wing area => reduced drag
- Reduced loads => reduced weight and size => reduced drag

Increased performance!

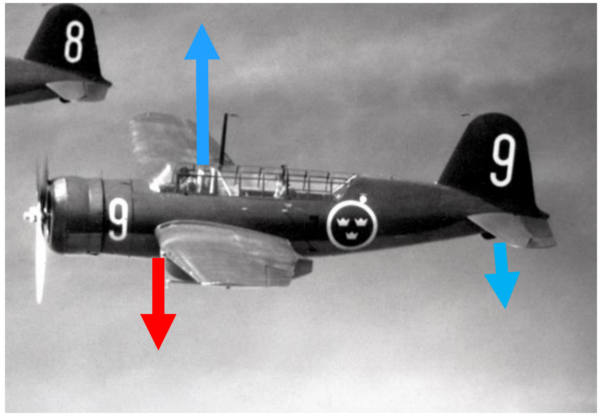
Load Alleviation – Gripen Examples

Global loads – Fuselage

Gripen has canard and trailing edge control surfaces

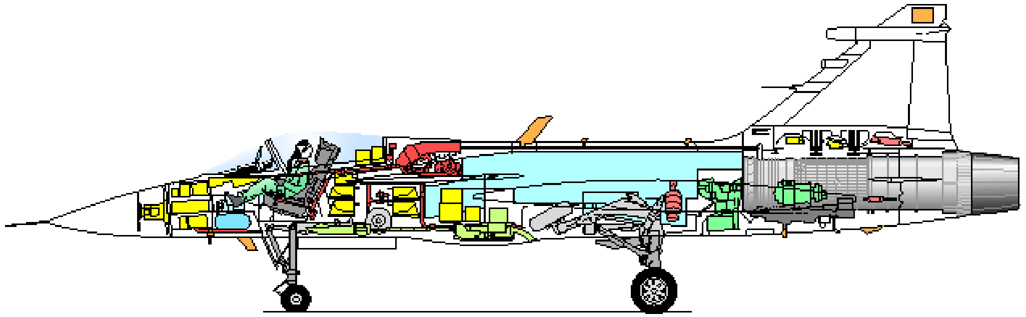
- Advantages with Canard:
  - Moment at maneuver give lift in the same direction as the wing => reduce loads on the wing
- The canard deflections can be
  - Drag optimized
  - Load optimized
- Gripen canard function in use is mainly drag optimized

Load optimized deflections regarding fuselage bending moment spectra has been studied but will on the other hand increase the canard load spectra



Load Alleviation – Gripen Examples

Global loads – Fuselage



Gripen has no Leading Edge Extension, LEX

- The main purpose with LEX is to generate vortices that increase wing performance
  - The Canard work as LEX in that respect
- LEX will also generate lift and reduce the forward fuselage bending moment and may thus reduce the weight. On the other hand the LEX installation with supporting structure will increase the weight. These effects has been studied on Gripen

Load Alleviation – Gripen Examples

Global loads – Wing

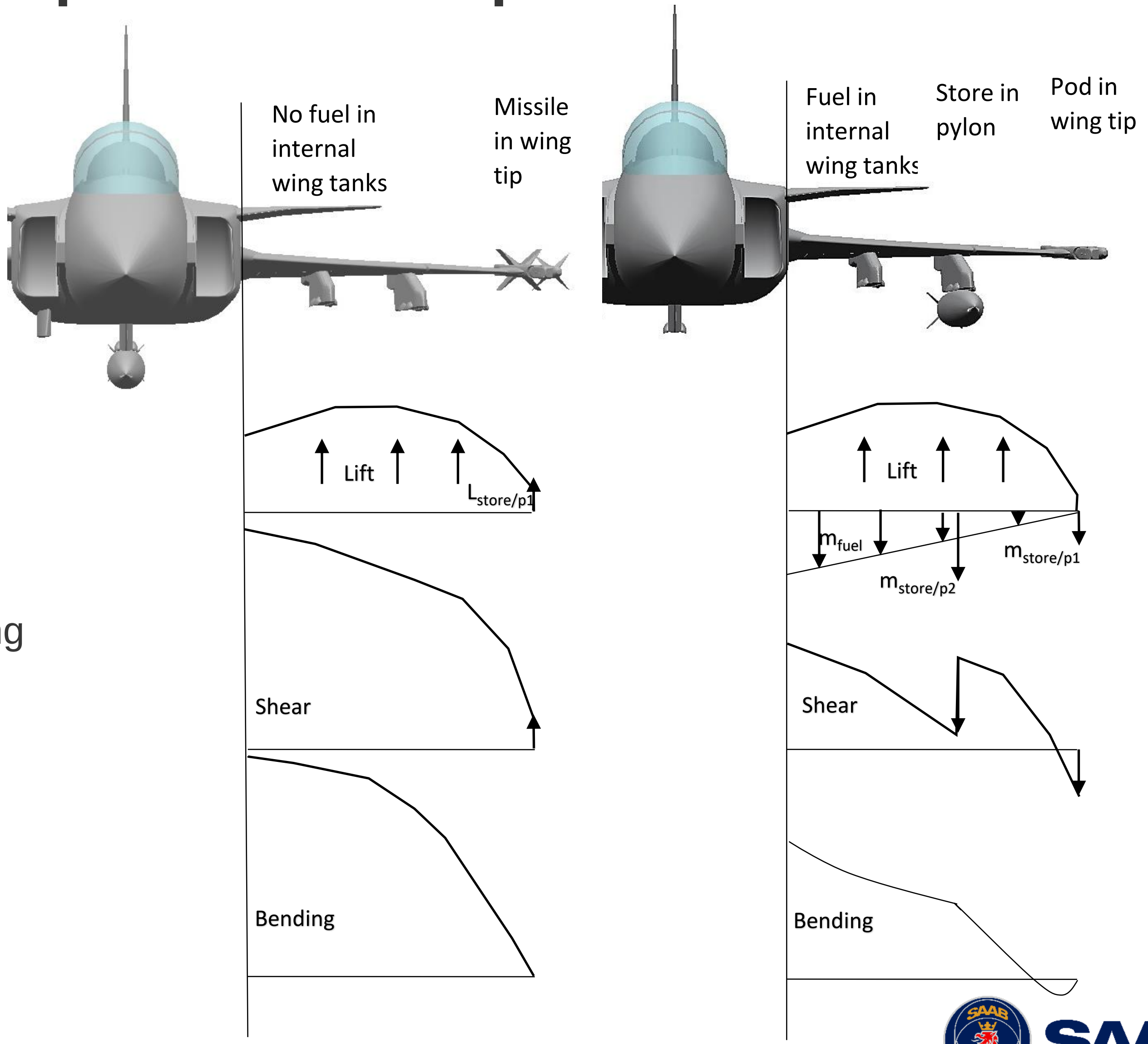
Wing profile, torsion and leading edge deflection optimization

Wing mass will alleviate wing bending moment

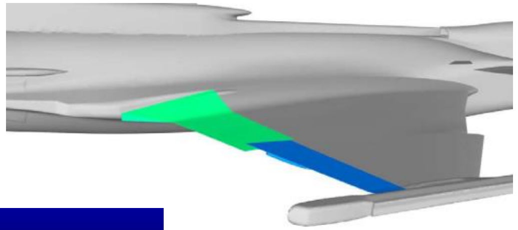
- Subsystems in wings:
  - Landing gears
  - Stores in wing pylons
  - Fuel in wing internal tanks
- Stores in wing pylon will alleviate wing bending moment but are more severe regarding loads on store and pylon

Preferable store configurations may be recommended to users

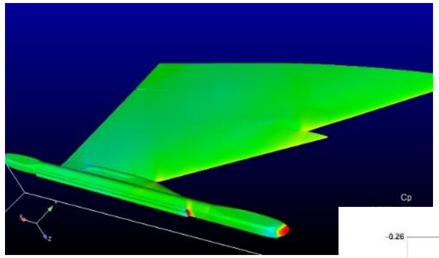
Wing internal fuel tanks are normally emptied before the internal fuselage tanks on Gripen



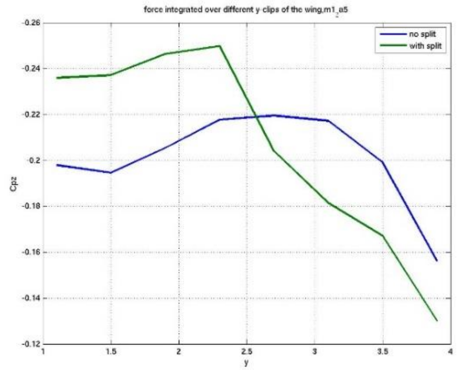
Load Alleviation – Gripen Examples



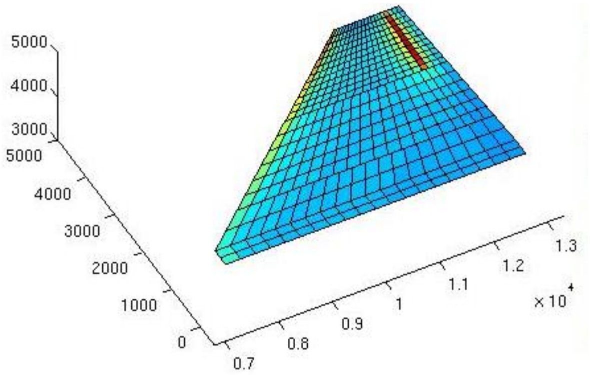
Global loads – Wing



- Elevon split is in use on Gripen to alleviate design loads Optimization study to alleviate design loads and load spectra is performed and flight tests will be done
  - Rigid A/C – CFD
  - Elastic A/C delta effect – panel method



Critical Wing section Speed: M>1 Load factor: $Nz=Nz_{max}$ A/C weight: $W_{A/C}=W_{design\ weight}$ Dynamic pressure $q=q_{max}$	Rigid Mx [kNm]	Elastic Mx [kNm]	%
No split	212	166	78
Split deo=-4.8 dei=3.2	179	158	88
%	84	95	74



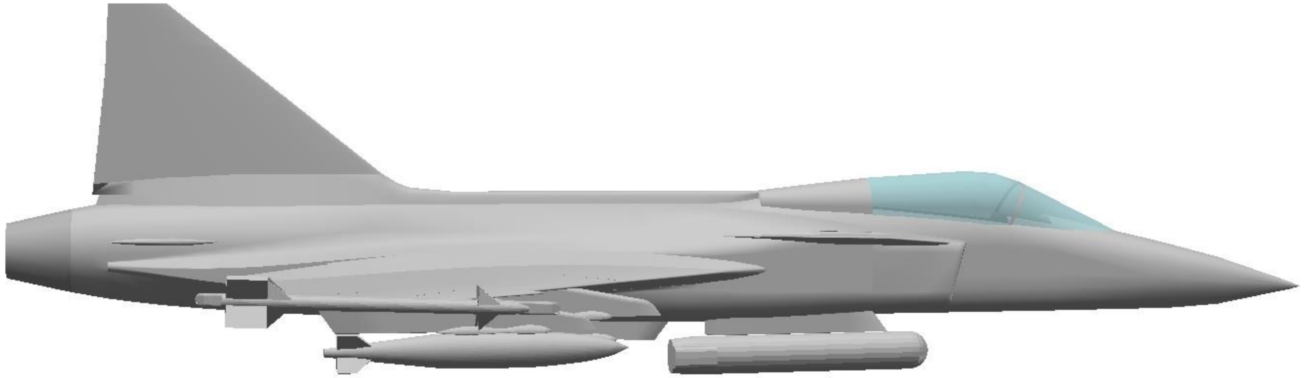
- Load alleviation about 5% for air load bending moment and about 10% for total bending moment
- Load alleviation result in about 5% increased drag

Load Alleviation – Gripen Examples

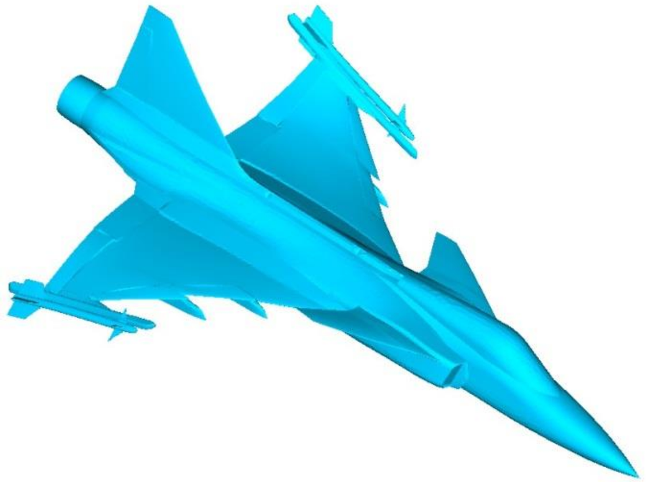
Global and Local loads – Wing tip pylon

- Pylon nose pitch down
  - Alleviate design loads and load spectra
- Pylon with ”tube” instead of complete missile
  - Alleviate load spectra

Wing tip pylon pitch down and training missile with removed lifting surfaces “tube” is used on Gripen. Optimization studies regarding pylon pitch down and optimal “tube” weight has been performed on Gripen



Load Alleviation – Gripen Examples



Local loads – pylon

Buffeting

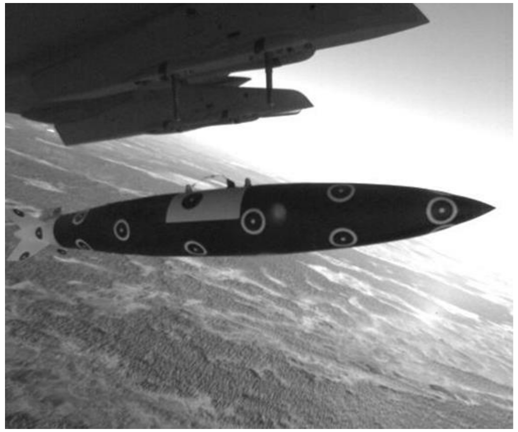
- Accelerations in wing tip pylon, especially with no store – contribute to pylon cross section load spectra
- Accelerations in wing tip pylon with store – mainly contribute to store- pylon and pylon-wing attachment load spectra
- Wing tip buffeting may also contribute to load spectra in nearby wing pylons

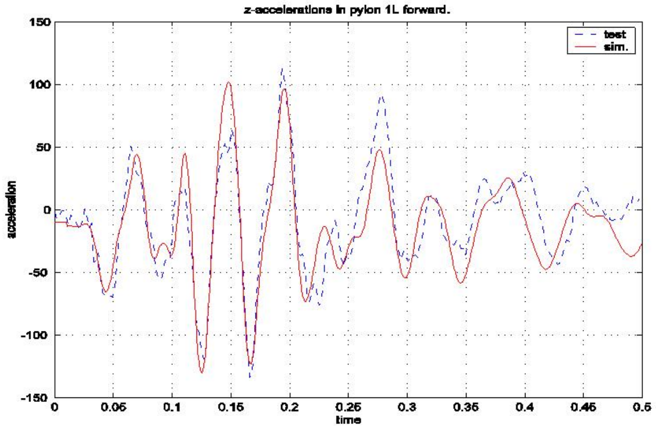
- Changed pylon geometry ”Coca-cola” to alleviate buffeting onset has been studied
- Leading edge deflection tuning to alleviate buffeting onset has been studied

Load Alleviation – Gripen Examples

Local loads – Store separation

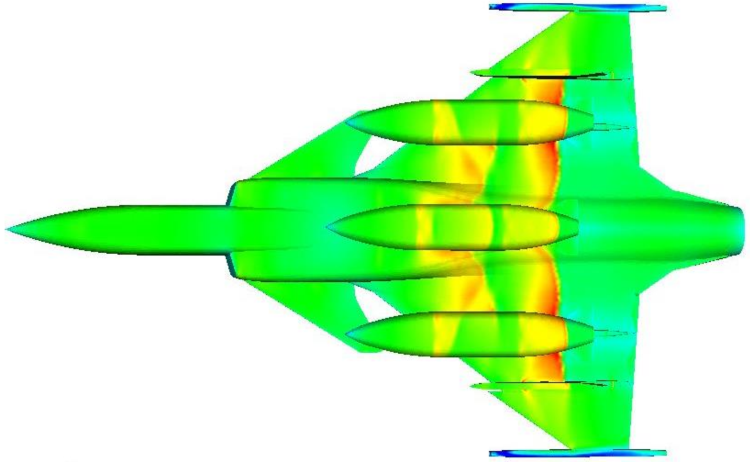
- Load alleviation at ejection release:
  - Minimize piston forces
  - Store release order
  - Time separation at multiple releases





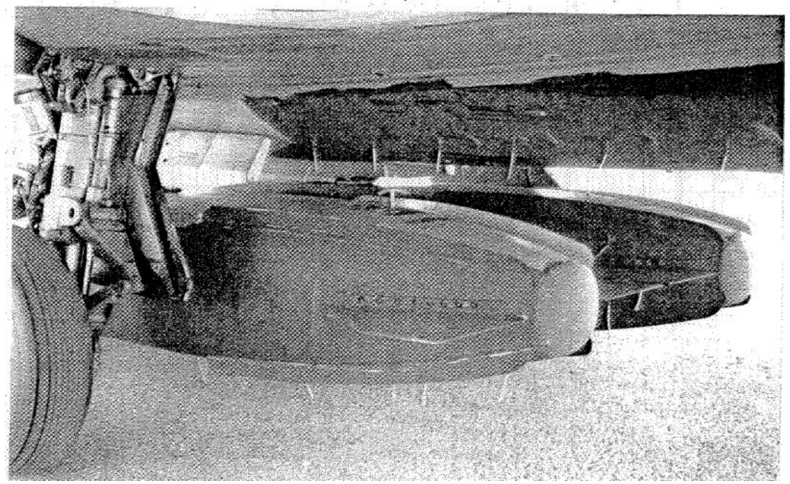
Load Alleviation – Gripen Examples

Local loads – Large stores



Buffeting (unstable shocks) may occur with large stores close to each other at specific flight conditions

- May contribute to load spectra
- Successful load alleviation studies performed on J-35 Draken with strakes on aft part of drop tanks



Load Alleviation – Gripen Examples

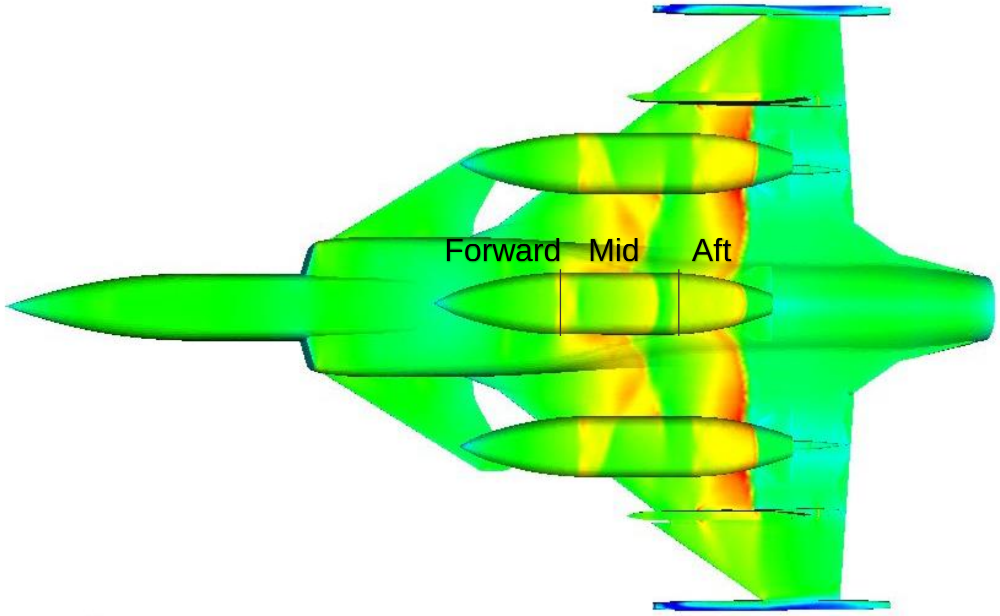
Local loads – Drop Tanks (DT)

DT emptying sequence:

- Normally DT in wing pylons first and then DT in fuselage pylon
    - From wing bending moment perspective DT in fuselage shall be emptied first but regarding loads on pylons and DT the used emptying sequence is optimal
- Aft section, forward section, mid section due to safe separation, A/C center of gravity and loads

Possible recommendation to user to alleviate load spectra:

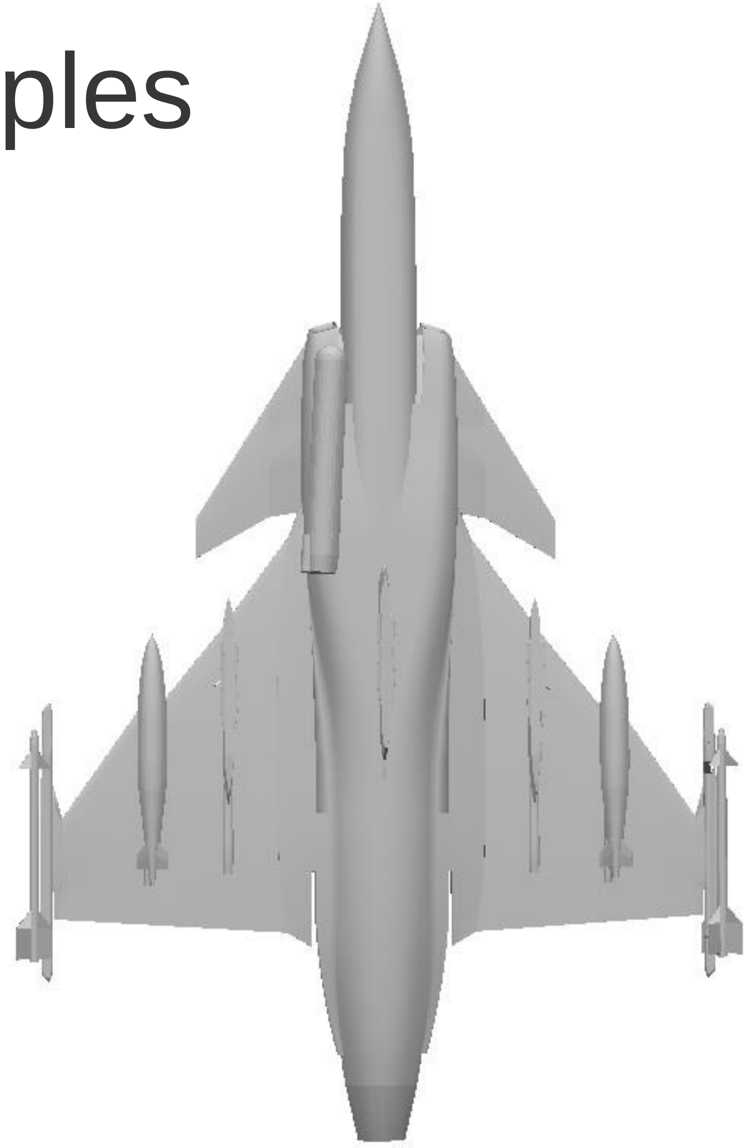
- Amount of fuel to match planned mission
- If possible, empty DT before severe maneuvering



Load Alleviation – Gripen Examples

Local loads

- Pylon 4 – Toe in
- Alleviate the pylon and store lateral loads
- Reduce the A/C drag



Load Alleviation – Gripen Examples

Local loads - Fuselage

- The landing gear and doors shall at latest be closed at a specified speed at max acceleration
- Landing gear closing speed shall not be to high since this result in high structural dynamic loads at stop
- The closing speed is reduced just before stop to alleviate the loads

Load Alleviation - Summary

Part	Loads to be alleviated	Loads due to	Solution	Possibilities			
Fuselage	Bending moment	Mass loads greater than lift	Increase lift or decrease mass loads	Move heavy equipment closer to CG or to the wings	Increase lift on Canard	Strakes or LEX	
Fuselage	Structural dynamic loads during retraction	High closing speed	Reduce closing speed at stop				
Wing	Bending moment	Lift greater than mass loads	Move lift inwards, change A/C mass distribution	Elevon split	Fuel in internal wing tanks	Wing tip pylon pitch down	Stores in wing pylons instead of fuselage pylons Landing gears and other heavy equipment in the wing instead of in the fuselage
Wing tip	Accelerations	Buffeting	Alleviate buffeting onset	Improve aerodynamic design	Tune leading edge deflections		
Pylons	Air loads on store	Flow direction	Store more in flow direction				
Pylons	Structural dynamic loads, piston forces	Store releases	Separation optimization	Lowest piston forces for safe separations	Release order	Time separation	
Drop Tank	Loads at maneuvers	Mass loads for DT with fuel	Minimize number of severe maneuvers with DT with fuel	Recommendations to operator			
Large stores	Buffeting/Unstable shocks	Flow between stores close to each over	Store configurations and aerodynamic design	Aerodynamic design, for instance strakes on stores	User to avoid problematic store configurations if possible		

The goal is an optimized product all together!

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