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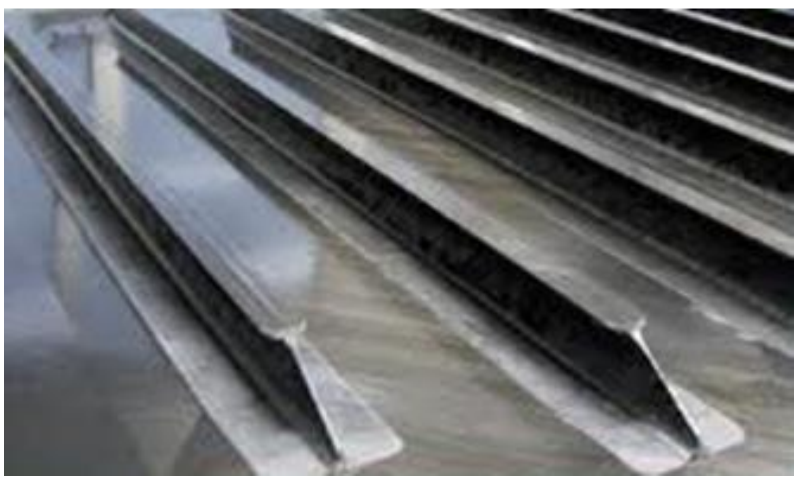
Composite Structures
– some basic issues and principles



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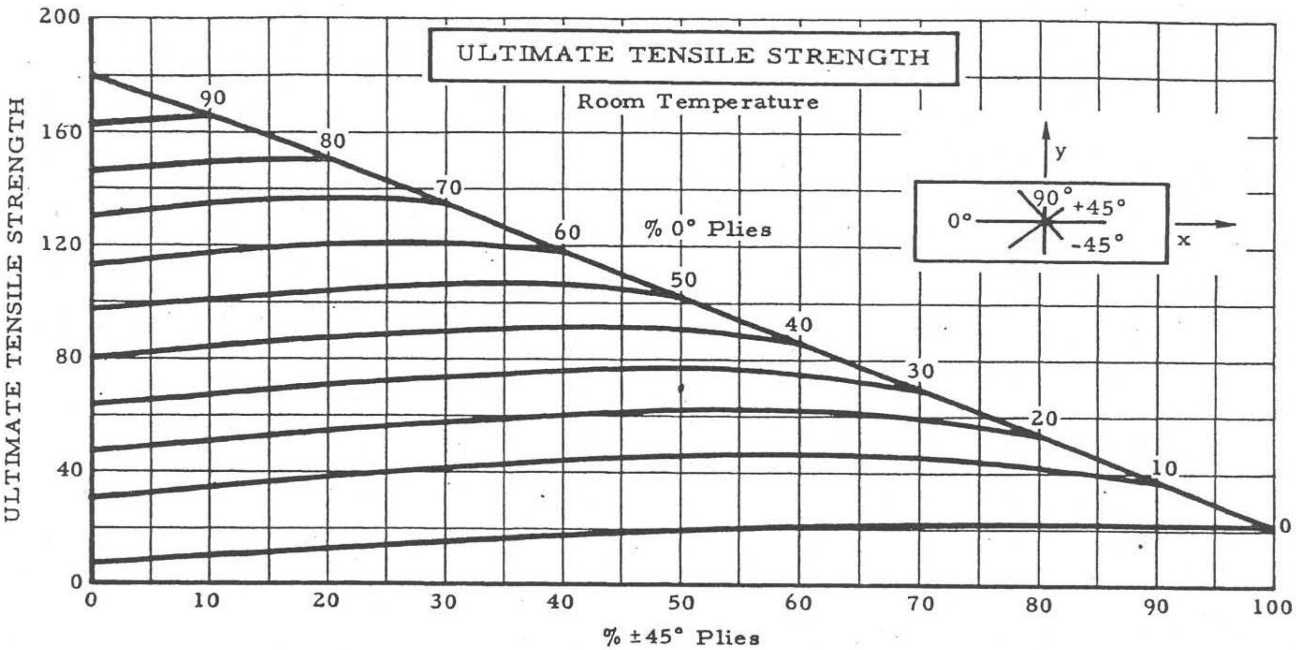
Contents

- Questions include….
  - Don’t impact damage and defects design all composite structure?
  - Surely you want better resolution, find smaller and smaller defects?
  - Why do quite small defects matter a lot in some areas while you will accept large defects in other areas?
  - Why doesn’t fatigue matter so much in composites?

- So what actually designs the composite structure….?

Composites – strength & stiffness



- Strength/ stiffness varies with layup
  - Carpet plots, above shows tension strength
  - Similar plots in
    - compression, shear etc
    - Strength / stiffness
    - Plain/ notched etc

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Skin panel layup

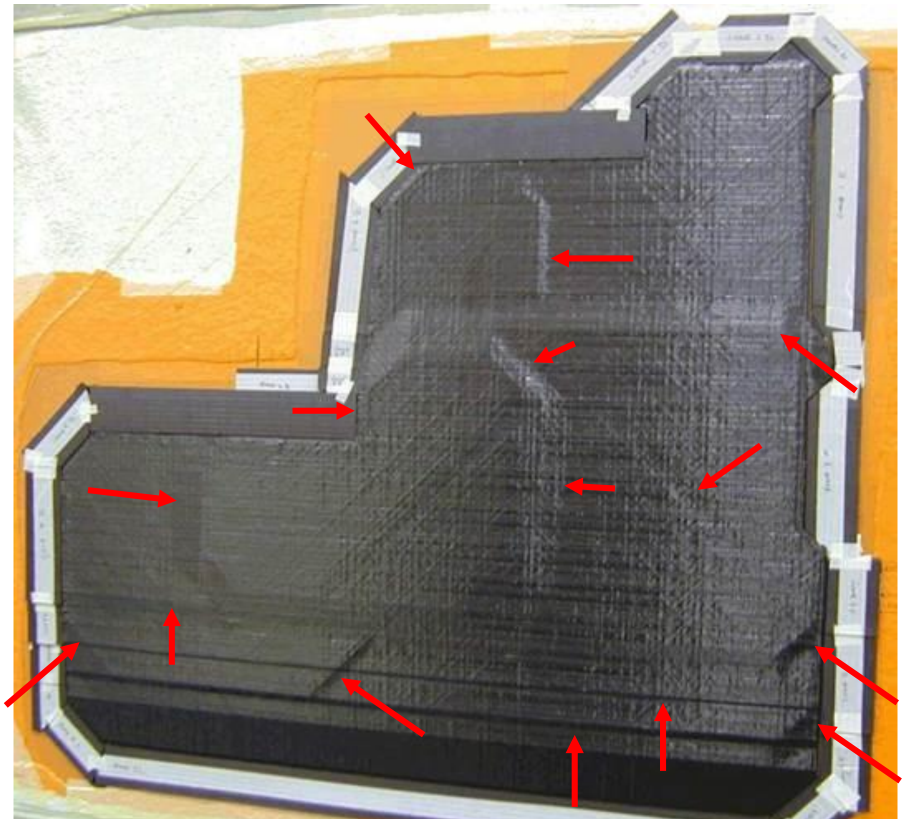
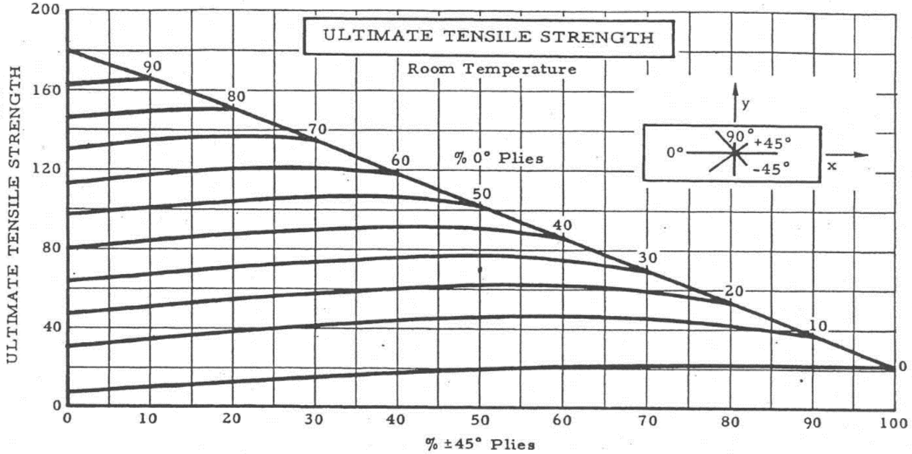


Image courtesy of BAE Systems

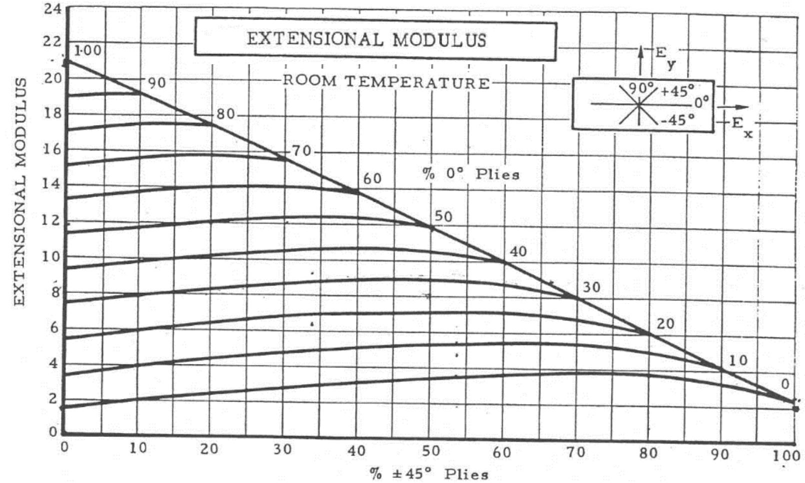
- Test panel representing small area of a skin
- Shows multiple changes thickness/ layup
- Large skin can easily have 150+ “zones”

Strain design

Tension strength



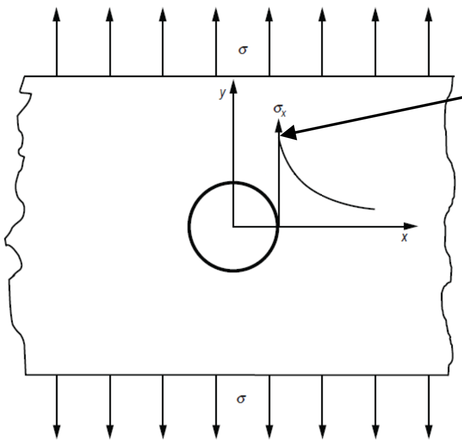
Modulus



- Carpet plots for strength and stiffness basically same shape
  - Strain to failure (Strength/ modulus) is approx. constant
  - For large area design, unnotched areas of skin
  - Measured in microstrain ($1\mu\varepsilon = 10^{-6}$)

- Unnotched tension strain to failure - typically 15 000$\mu\varepsilon$ (= 0.015)
- Unnotched compression strain to failure - typically 10 000$\mu\varepsilon$ (= 0.010)

Effect of holes in composites



Local stress concentration at edge of hole:

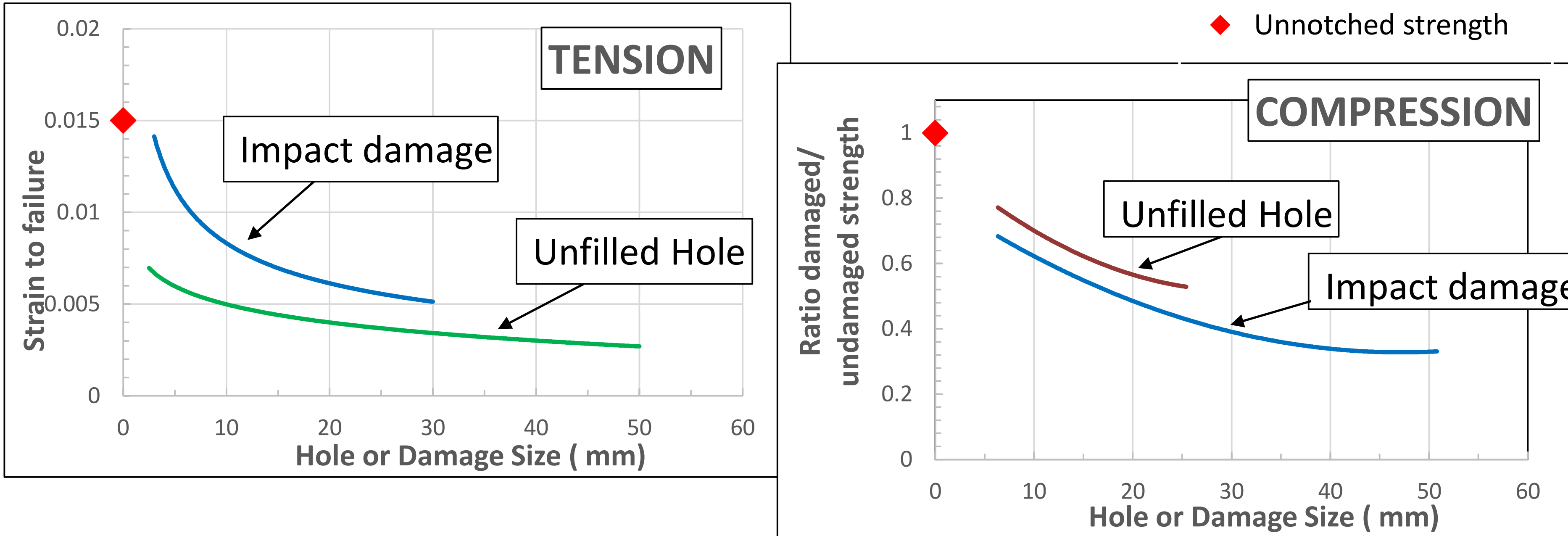
- theoretically 3.0 for isotropic material

	Metals	Composites
Statically	• Plasticity round hole • Eliminates stress concentration	• Elastic to failure • See full stress concentration
Fatigue	• See full stress concentration • Fatigue prone	• Already designed for stress concentration • Fatigue usually generally not an issue

- **Composites:**
- typically 2.5 in tension
- slightly less in compression
- due to slight local damage/ softening around hole

- Notched strain to failure
  - Tension - typically 5500με
  - Compression - typically 4500με
- **Always have to allow that hole may occur anywhere**

Effect of Holes and Impact Damage on Laminate Strength



Tension
- Holes larger effect than impact damage
- Design to “hole”

Compression
- Impact damage larger effect than holes
- Design to impact damage

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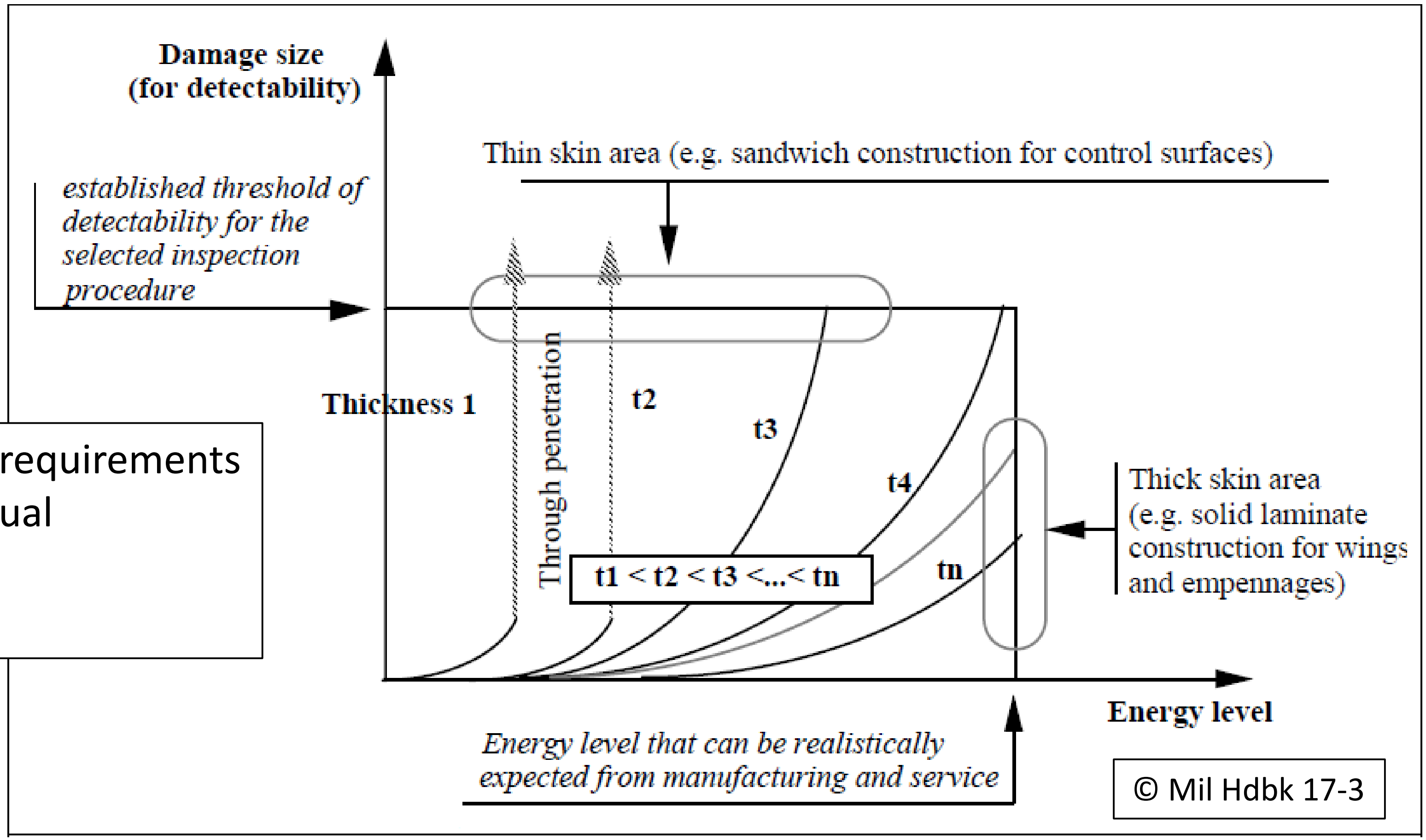
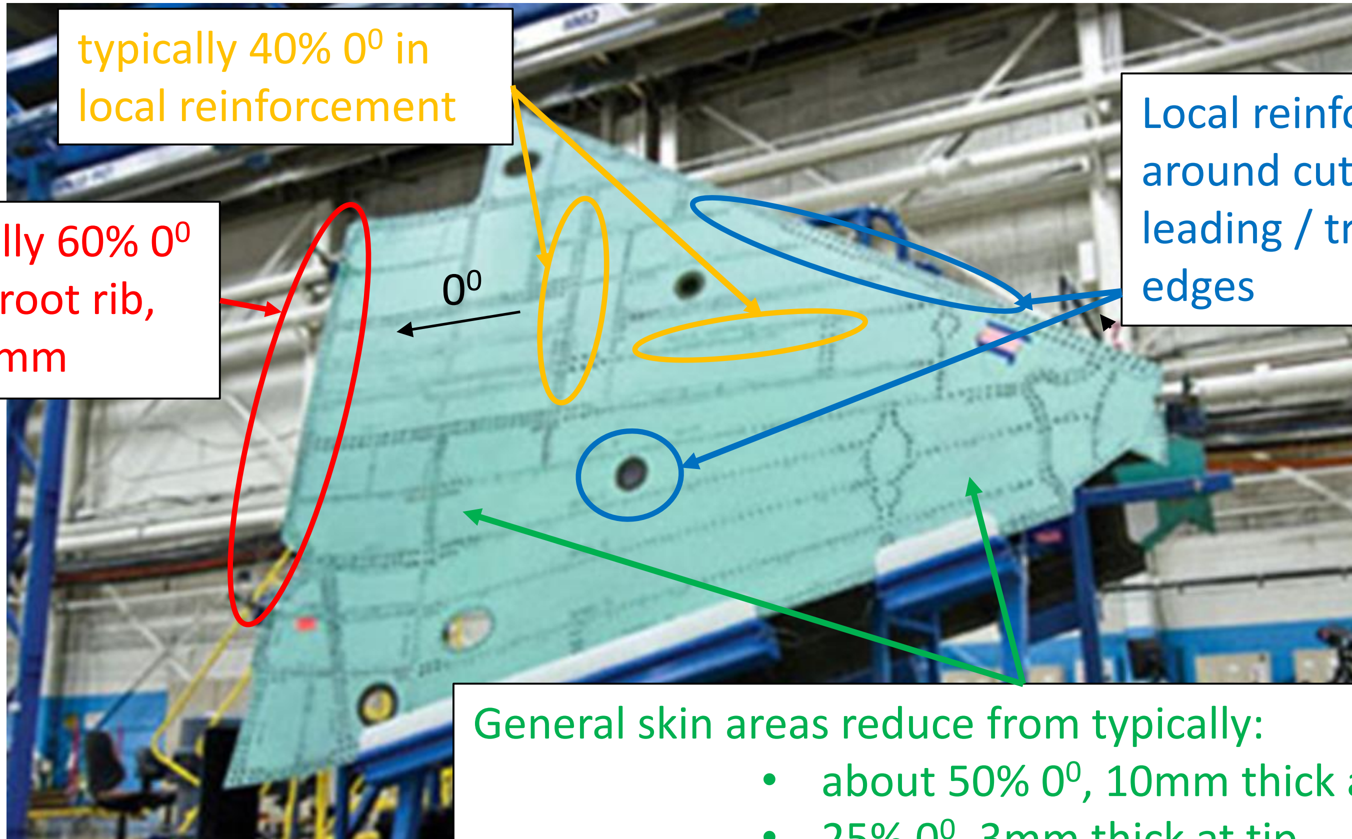
Impact – Effect of thickness

Detectability requirements

- usually visual
  - BVID
  - CVID



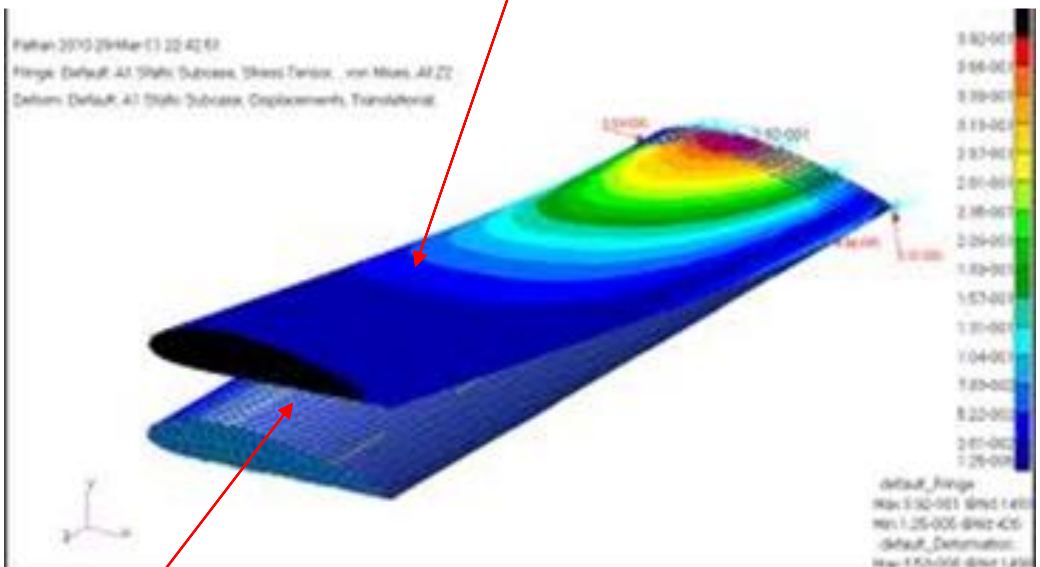
Typical Military Aircraft Wing skin



So what designs these areas/ determines these thicknesses?

Wing design

Upper wing skin – compression dominated



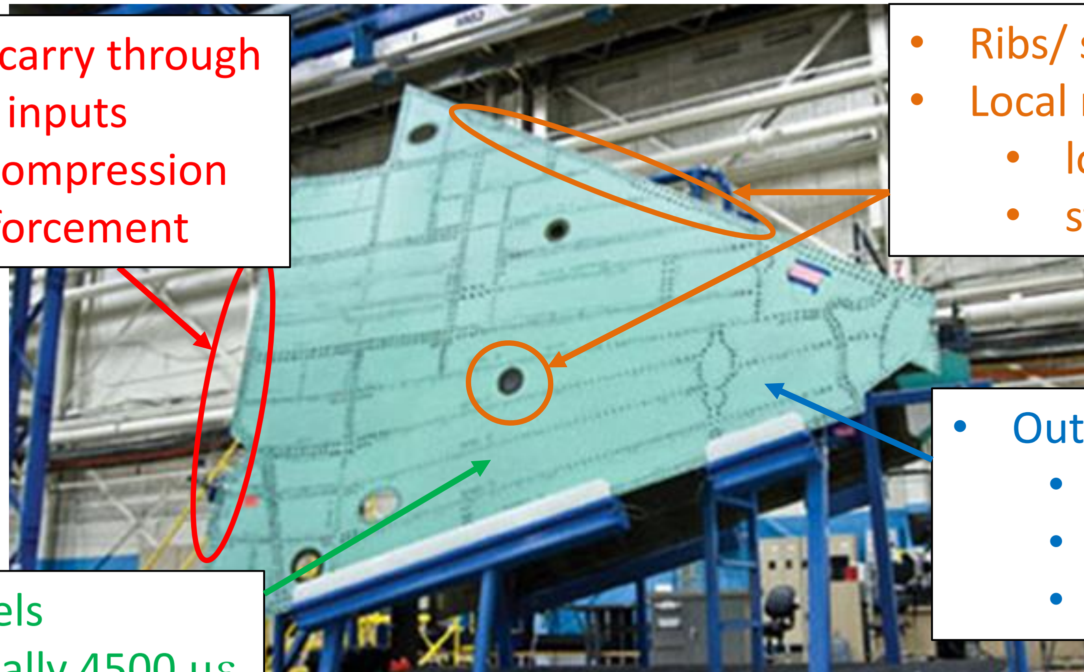
Lower wing skin – tension dominated (spectrum inverted)

- Different aspects dominate design of upper and lower skins

Upper wing skin
– compression dominated

- Wing pick up / carry through
  - Local load inputs
  - Bearing/ compression
  - Local reinforcement

- Ribs/ spars locations
- Local reinforcement
  - local load inputs
  - stress concentrations



- Outboard skin panels
  - thin
  - buckling designed
  - limits strains

- Other skin panels
  - CAI - Typically 4500 $\mu\varepsilon$

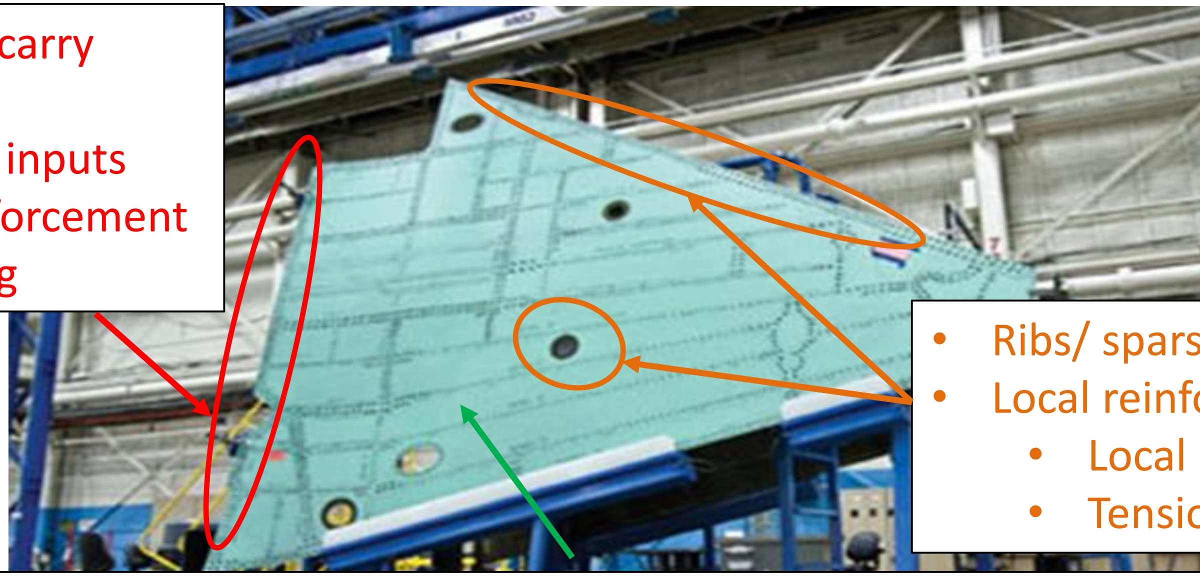
Designed typically:

- **40% bearing/ notched compression strength**
- **30% stiffness and buckling**
- **30% Compression after impact**

Other aircraft – different roles eg large civil- similar issues/ different percentages

Lower wing skin – tension dominated

- Wing pick up / carry through
  - Local load inputs
  - Local reinforcement
- Tension/bearing

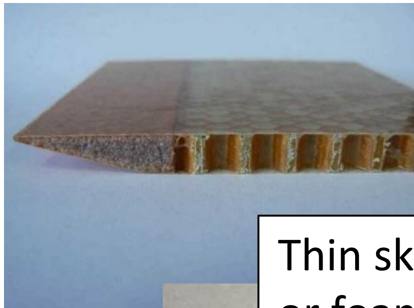


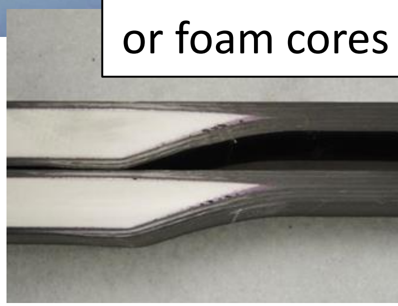
- Ribs/ spars locations
- Local reinforcement
  - Local load inputs
  - Tension/ bearing

- Skin panels designed
  - Allowable notched tension strain - typically 5500 $\mu\epsilon$
  - General allowable design strain to accommodate hole anywhere

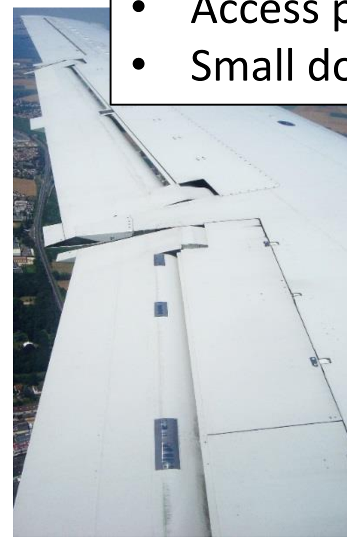
Designed typically:
- **40% bearing**
- **40% notched tension**
- **20% stiffness**

Thin skin stiffened panels

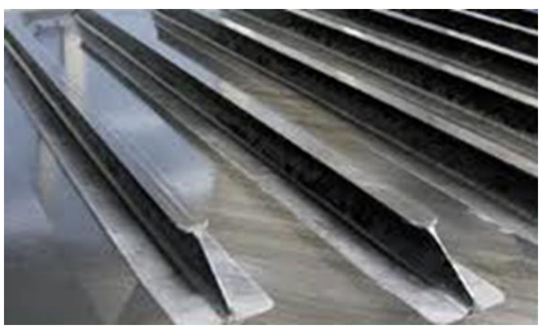




Thin skinned honeycomb or foam cores



- Smaller control surfaces
- Access panels etc
- Small doors



Bonded stiffeners

- Skin thicknesses maybe as low as 0.75mm
- Impact damage at low impact energies
- Allow impact on bondlines

- Design strains can be reduced to typically 2000$\mu\varepsilon$

Summary

- Holes and impact damage major reduction in strength
  - Generally holes more severe in tension
  - Impact more severe in compression
- Design to allow for 6mm hole anywhere
- Design around damage - visual detectability
  - Not worth chasing smaller and smaller defects
- Composite structure - multiple design criteria
  - Defects are not dominant design criteria in all areas