Overview

• Context and Background
  – Why is this an issue?

• Features and Parameters
  – What is the difference and why does it cause problems?
Begin at the beginning," the King said, very gravely, "and go on till you come to the end: then stop.”

— Lewis Carroll, *Alice in Wonderland*
Context & Background
Complex Machines – Complex Decisions
Fuselage Structure
barrel sections assembled to produce fuselage

panel segments welded to produce barrel sections

welded to produce panel segments

machined or extruded sub-panels
Structures
NOTES

1. ALL DIMENSIONS IN INCHES
2. ø = MINIMUM 1.00 DEG CSK RIVET
3. Φ = 38A BOLT
4. SKIN - 2624-T3 0.053 THK
5. FRAME SECTIONS - 7075-T6 0.05 THK
6. STRINGERS - 1004-T651 EXTRUSIONS
7. FRAME REINFORCING ANGLES - MILD STEEL 0.128 THK
Shear-Compression Test Rig

500kN Compression
400kN Shear
Panels 1.5mx1.5m
Virtual Testing

Advanced computer simulation allows virtual testing of the new concepts to quicken the selection of the most promising.
New manufacturing concepts such as laser beam and friction stir welding, and panel profiling, can result in lighter, cheaper airframes. (with Alcan France)
a) Laser beam welded section.  

b) Friction stir welded section.
a) Fully factored:

b) Parallel factored:
b) Friction stir welded (Specimen FS2)
Load-Displacement Curves
The devil in the detail!

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<th>Single frame bay specimen</th>
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Key Issue: Stiffener-Skin Interface

Different minimum weight solutions are found for each of these.
a) → Frame datums allow to translate axial in-plane
b) → Model axial loading & restraints
c) → Model rigid body motion restraints
Problem

• Design is about creating real products
  – Things that get made!
• Fundamentally it is defining geometry for manufacture
  – Of course also operations etc
• Sophisticated processes and tools
  – Systems engineering, CAD, CAE CAM…..
  – Powerful feature based modelling systems
Design Intent

“..a set of geometric and functional rules that the final product has to satisfy.”
(Mun)

or

“The set of functions which the system was designed to deliver in the anticipated operating environment”
(QUB)
Features and Parameters
The Face Off

• **The Process vs the Product**
  – How the model is built
  – How it looks in it’s final form

(a) (b) (c) (d) (e)
“..the designer’s choice of parameterisation and constraint schemes constitutes an important part of what is known as design intent” (Anderson)
Back to the Fuselage
• CAD Feature tools help the designer to create geometry (and features) quickly

• No account taken how it is to be manufactured…..
(a) Idealised Stiffener on plate

(b) Riveted Stiffener (assembled)

(c) Integral Stiffener (extruded or machined)

(d) Laser welded Stiffener (assembled)

(e) Friction Stir Welded Stiffener (assembled)
Why, sometimes I've believed as many as six impossible things before breakfast.”
— Lewis Carroll, *Alice in Wonderland*
Where does this all fit in a design process?

• Prediction using Newton…..

\[ \sum F_y = 0 \]
• But formula become more complex as we look deeper into problems

- E.g. beams
  
  $Load = W(x)$
  
  $S = \int W \, dx$
  
  $M = \int S \, dx$
  
  $\theta = \int M \, dx$
  
  $y = \int \theta \, dx$

Inside the material!
How do you eat an elephant?
Same for Complicated Machines

- Aircraft
  - Fuselage
  - Wing
  - Empennage
  - Engine
  - Undercarriage
Components can be complex in shape
Very challenging for complex shapes
Idealisation & Model Simplification

A typical narrow region in the model

Model Bounding Box: 872mm
Mini Edges <1mm = 1298 lines
26 lines can be replaced by 8 chains
“What I cannot create, I do not understand. Know how to solve every problem that has been solved.”

Richard Feynman
The fuselage is reinforced with frames and stiffeners.

The stiffeners are placed relative to the neutral axis of the fuselage.
Function (Intent) of the stiffener is to carry end load and a little (but preferably no) bending, supporting the skin.
Implications of assemblies

- Implies integration of manufacturing processes in design
- Consideration of cost, resourcing, planning, maintenance etc
- It is a problem with many dimensions
Integrated System Functions

\[ F(x, y, z, t, \text{cost, material, process...}) \]

What we can see in 3D

N-dimenions
Constraints limit the size & shape in 3D
Example of square showing cost & size in different areas

The physical shape may change due to other parameters, such as cost & weight.
Constraints impact shape

Projection of 5-D design space in 2D with and without uncertainty factor applied to constraints
Now think about manufacturing

Different minimum weight solutions are found for each of these.
Plate - Parameterisations

Machine from a block

Weld
New manufacturing concepts such as laser beam and friction stir welding, and panel profiling, can result in lighter, cheaper airframes. (with Alcan France)
C-Series Wing ~13,000 tests!
-> 1 vehicle, small number of material configurations

Stress and displacement patterns are different in composites

Failure locations are not always obvious
Questions!

• Identify the limitations of the CAD technology and integration of additional problem dimensions?

• A consistent parameter set representing the appropriate capability for design, analysis and manufacturing?

• A consistent modelling process for design, analysis and manufacturing?

• What is our confidence that validation testing is genuinely validating operational behaviour?

• What is the cost/confidence trade-off for testing new materials and structures in complex machines?
Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to get to.""

"I don't much care where –"

"Then it doesn't matter which way you go."

— Lewis Carroll, *Alice in Wonderland*
And remember……..

Imagination is the only weapon in the war against reality.”
— Lewis Carroll, *Alice in Wonderland*