APPENDIX A

Report on **AG 24** Bird Strikes Tolerant Structures
given by

M. Willows


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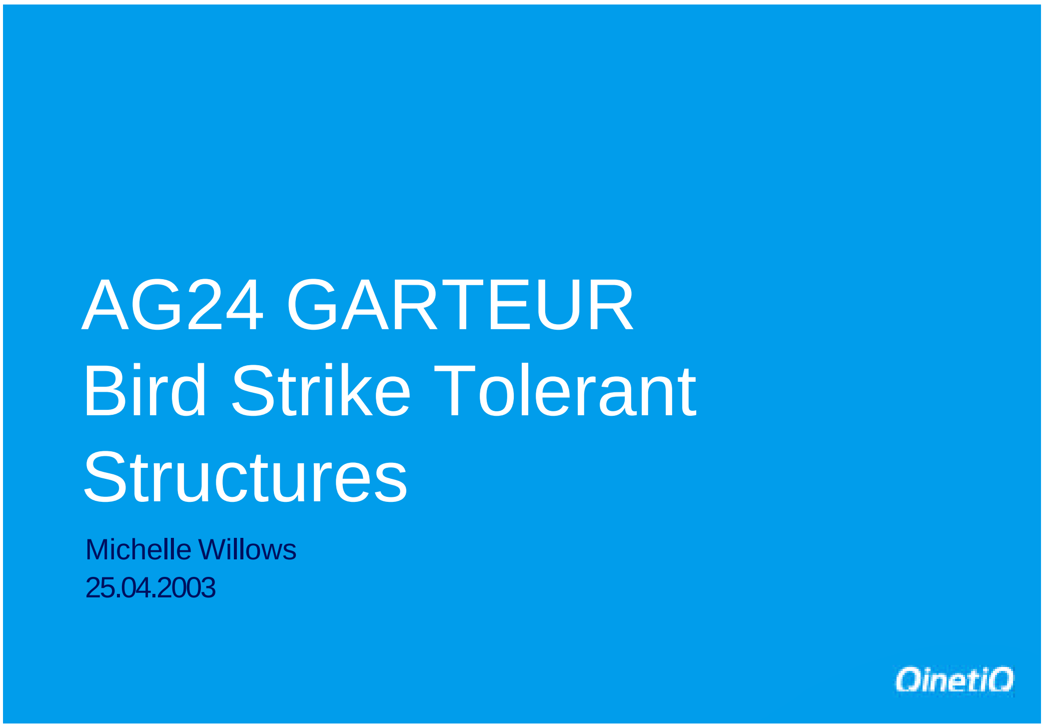
AG24 GARTEUR
Bird Strike Tolerant
Structures
Michelle Willows
25.04.2003
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Contents

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Main Objectives

- Round robin modelling activities to determine SOA
- Fabricate, test and model a bird strike tolerant structure
- Define an optimum bird strike numerical modelling methodology
- Gain acceptance of modelling techniques by Authorities

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Work Programme Status(1)

- PHASE 1: Participants use own bird strike modelling techniques (analytical/ numerical) to simulate bird strike onto :
  - Task 1: Rigid panel (compare bird models) - all partners
  - Task 2: Metallic panel - QQ, DLR, EADS, IC, ONERA
  - Task 3: Flat transparency - ONERA
  - Task 4: Composite panel - QQ, IC, *DLR, ONERA*

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Work Programme Status (2)

- PHASE 2: Participants to use revised techniques to model bird strike onto more complex shapes
  - Task 1: Metallic component (e.g. blunt & sharp LE) - QQ, EADS, *NLR*
  - Task 2: Composite component (e.g. blunt & sharp LE) - EADS, *DLR, IC, NLR*

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Work Programme Status (3)

- PHASE 3: Participants to use revised techniques to model bird strike onto a novel 'bird strike tolerant' design concept
  - Task 1: Fabricate novel leading edge design - NLR
  - Task 2: Perform bird strike test - BAe
  - Task 3: Simulate bird strike test - preliminary analyses by DLR

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Novel Bird Strike Tolerant LE Design

- Technical demonstrator for max. energy absorption (helicopter sub-floor)
- Fokker 100 shape
- 0.50m by 0.35m
- Novel tensor concept which effectively traps bird

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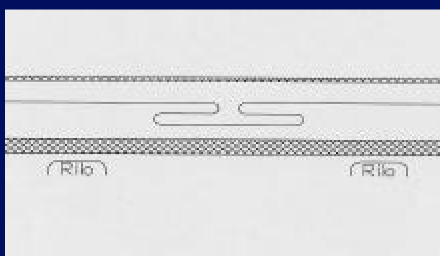
Ribs in Bird Strike Tolerant Design

- Aluminium ribs (1cm) bonded to ensure LE failure rather than buckling
- 6mm Aluminium bolts

Novel Tensor Concept

- LE is complex structure: 3 materials
  - glass cover face (woven aramid fabric, 0.25mm)
  - folded Dyneema (0.35mm, polyethylene fibre: high ductility, large deformations)
  - carbon epoxy laminate (0.28mm aramid carbon fabric/0.095mm UD carbon)



Deployment of Novel Tensor Concept

- Normal conditions tensor plies perform no function
- Aerodynamic loads on composite skin are transferred to ribs
- Under high lateral load all plies except tensor plies fail
- As bird hits tensor plies unfold (plastic hinges) and are loaded in tension (membrane) 'catching' the bird
- Once unfolded, ribs loaded in compression and controlled crush
- Sufficient KE absorbed to stop bird

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Design of Novel Tensor Concept

- Several LE design variables:
  - rib pitch, skin/rib attachment, composite material, stiffnesses, strengths, ply lay-up, laminate thickness
- Total bird KE must be absorbed within the LE volume/contour
  - limits unfolding depth
- Unfolding depth is a function of
  - tensor skin elongation
  - rib pitch (max. to reduce weight & no. fasteners)
- Max. allowable load 200kN: equates to 100kN vertical load to each rib once tensor unfolded

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Fabrication of LE Design

- Mid-section of a Fokker 100 stabiliser LE machined out & carbon epoxy mould produced
- Ply dimensions defined & cut, sub-laminates placed in mould & undergo cure cycle in autoclave of approx. 3.5 hrs
- Separated from mould
- Fastener holes drilled & edges machined to fit test rig
- Aluminium ribs attached

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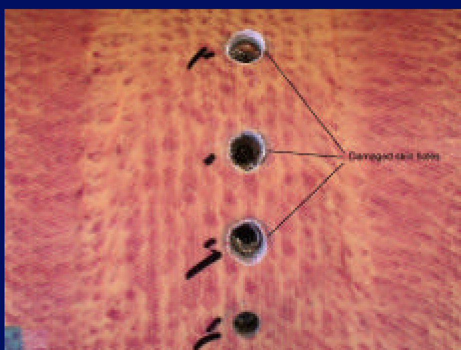
Preparation of LE for Testing

- When bolts removed from ribs, holes were found to be damaged
- Bolts repaired & 8mm titanium countersink bolts used



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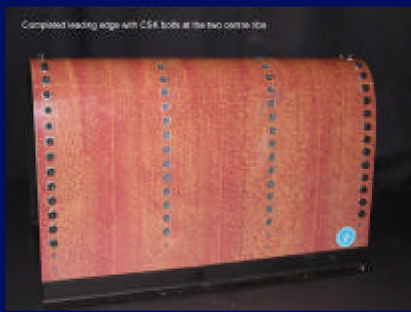
Preparation of LE for Testing

- Holes drilled along the edge to bolt the LE to test rig
- Intended to use tension bars/struts along side of LE for support (representing rest of the wing)
- But removed due to difficulty with modelling (preload)



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Test Specification

- Impact velocity subject of much debate:
  - Use impact speed during landing/takeoff approx. 100 m/s
  - Multiple bird impact at increasing velocities with detailed LE examination after each strike
- Latter option too difficult to model: damage accumulation
- Aim for complete LE failure & deployment of tensor to catch bird

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Bird Strike Tests

- Impact velocity of:
  - 117 m/s (227 knots)
  - 171 m/s (332 knots)
- Bird weight of:
  - 4lbs (1814g)
  - 4lbs (1811g)
- Impact location: centre line, midway between ribs
- Instrumentation: Laser beam deflection

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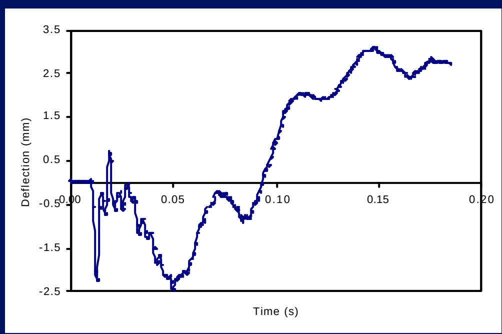
Bird Strike Test 1 Results

- No measurable damage (confirmed by NDT)
- LE deflected by approx 2.5mm before recovering after 0.09s



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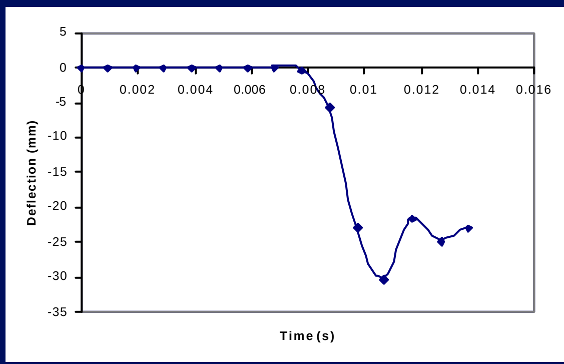
Bird Strike Test 2 Results (1)

- Bird penetrated
- Front spar torn away
- LE deflected by approx 30mm before failure



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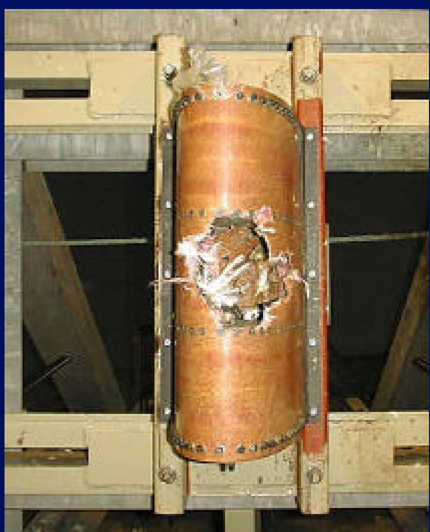
Bird Strike Test 2 Results (2)



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Bird Strike Test 2 Results (3)

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Bird Strike Test Conclusions

- Test 1: no visible damage & tensor concept was not activated
- Test 2: complete penetration by bird, tensor deployed but did not contain the bird which broke front spar (too severe for tensor containment)
- Both tests to be modelled

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Acceptance of Composite Modelling Predictions

- Main problem areas in modelling centre around:
  - joints, discontinuities & various types of bonding
  - new materials (hybrids) requiring new material models & incorporation of complex structures
- Currently modelling of composite structures is used as a first pass to determine design improvements
- No composite LE's in any civil aircraft although they are anticipated but there are composite fuselages
- It is the *structure* that is certified i.e. the material, manufacturing process and design

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Acceptance of Modelling Predictions

- New radical designs, inc. metallic structures, will not be accepted on the basis of modelling predictions alone without having evaluated those predictions against some test data
- Currently manufacturers do not use modelling techniques that are as sophisticated as those presented by the GARTEUR group, rather they employ empirical data and analytical methods

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Recommendations (1)

- Peloaded structures: representing aircraft in flight
- Inclusion of manufacturing defects
- Scope widened to include other debris e.g. concrete, bulk heads, wheel rims, etc. - > 60 m/s
- Scaling of impacts: manufacturers want to test higher impact weights at lower impact velocities (proof that straightforward scaling does not work)

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Recommendations (2)

- Synthetic bird:
  - Problem: Huge variations in impacting bird cause even more variation in damage to structure
  - Birds composed of gelatine/sawdust, agar/micro-encapsulation spheres, water & rags
  - Different birds: impact of structure/engine blade
  - Must generate *at least as much* damage as a real bird (hence manufactures prefer to use real bird as resultant damage less severe)
  - Allow easier comparison with numerical modelling predictions

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Recommendations (3)
• Synthetic bird development supported by International Birdstrike Research Group (IBRG)
– small-scale impact testing of substitute bird materials
• Bird biometric data collated by CSL
– inclusion of material variation within bird FE model
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