LOOKING AT LUSAKA'S LESSONS

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707-300

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Overview

- Accident description
- Design
- Certification
- Accident investigation findings
- Accident prevention assessment
- Lessons learned
- Rule/Policy changes?

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Lusaka Accident

- May 14, 1977
- Boeing 707-321C operated by Dan-Air
- UK registry G-BEBP on non-scheduled cargo flight
- 47,621 hours/16723 flights at failure
- Right hand horizontal stabilizer and elevator departed aircraft subsequent to selection of landing flap during approach to Lusaka Airport
- All six occupants killed

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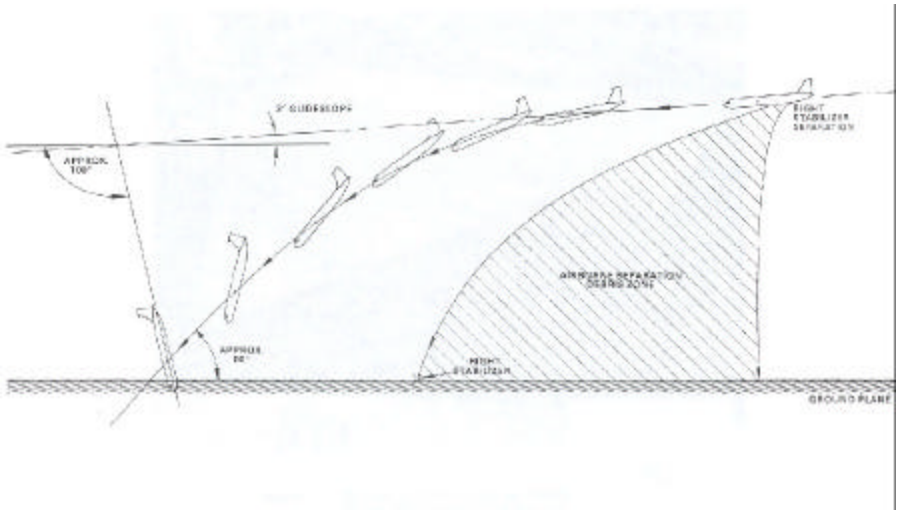
Final Flight Path



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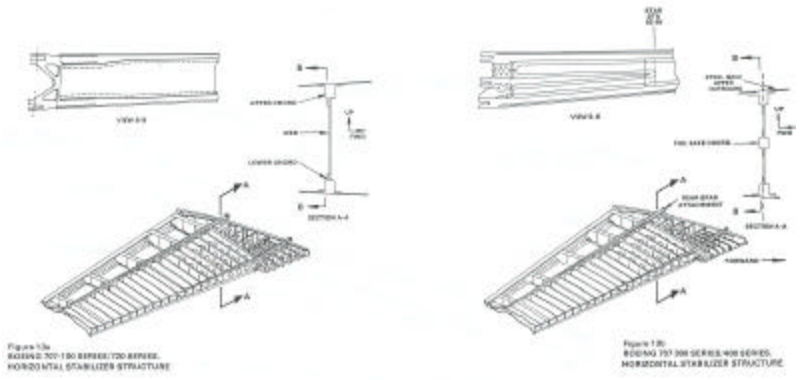
B707-300 Design

- Stabilizer extensively redesigned and enlarged relative to prior models
- "Waiting Fail safe" mid chord added to achieve fail safety with upper chord failed



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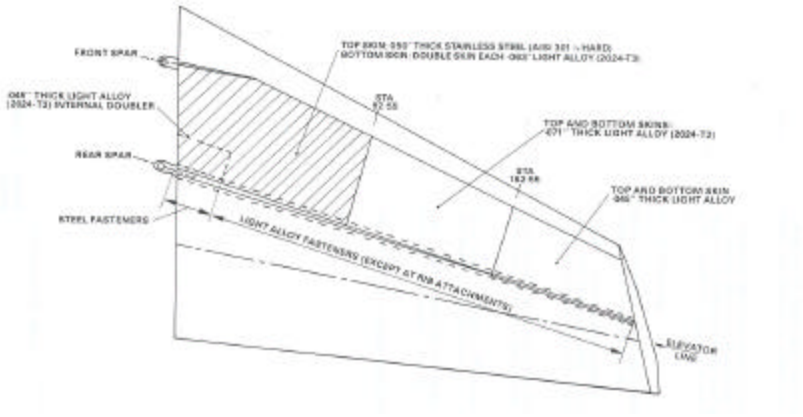
B707-300 Design (cont'd)

- Upper and lower cover skins beefed up after flight testing showed inadequate torsional stiffness



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B707-300 Certification

- Type certification on April 30, 1963
- 707-300/400 Design Service Goal (DSG) = 20,000 flights
- CAR 4b.270 failsafe option selected (same as –100)
- Full scale fatigue testing neither required or performed (although successful test conducted on –100)
- Failsafe capability with upper chord failed demonstrated by analysis only
  - -100 fail safety demonstrated by test with dynamic failure of upper attach pin

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B707-300 Certification (cont'd)

- UK certification based on FAA certification as fail safe and UK special conditions
  - Limit load residual strength
  - Submission of an inspection program designed to detect cracks before they reached dangerous proportions
- The recommended 'C' check was the only check found to contain inspections which cover the rear spar top chord and they were to occur at 1800 hour intervals starting at the first check

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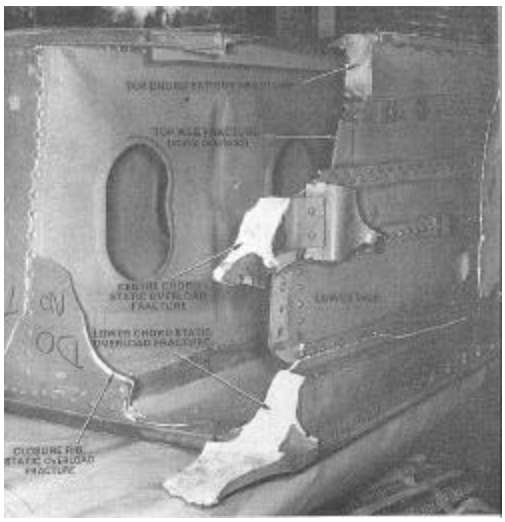
Accident Investigation Findings

- Top chord failed due to fatigue cracking leading to static down bending failure of remaining structure



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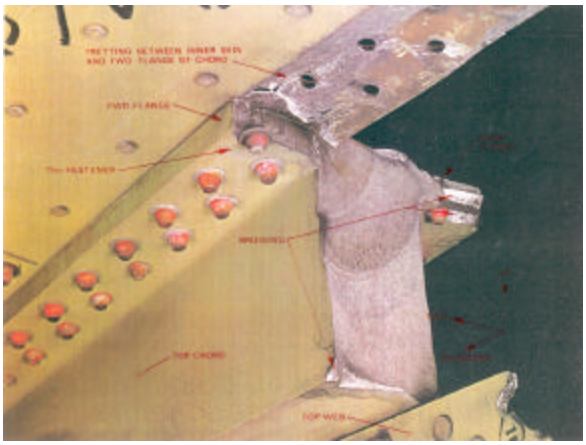
Accident Investigation Findings (cont'd)

- Crack origin at upper edge of 11th fastener hole in forward flange
- ? 7200 flights of crack growth from initiation to chord failure
- ? 100 flights from chord failure to stabilizer separation



Upper Chord Fracture Looking Outboard

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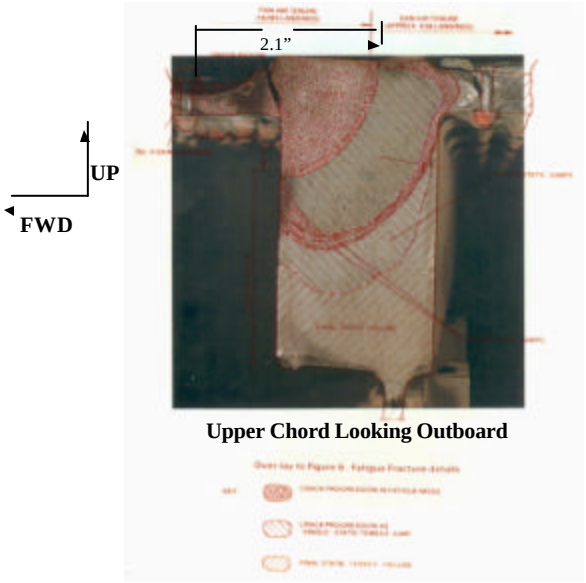
Accident Investigation Findings (cont'd)



Upper Chord Looking Outboard

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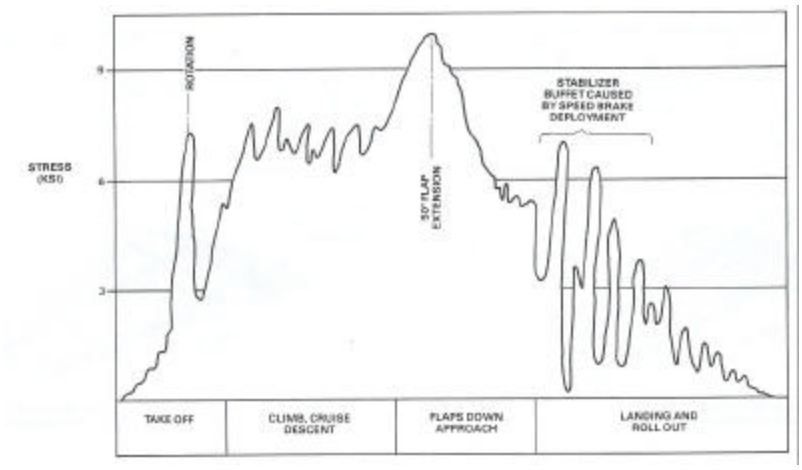
Accident Investigation Findings (cont'd)

- Post accident loads testing validated flight loads but revealed significant oscillating loads during normal landing roll due to speed brake deployment.



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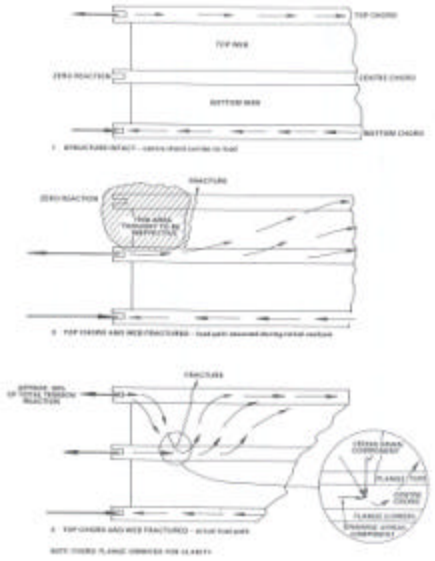
Accident Investigation Findings (cont'd)

- Post accident fail safe testing:
  - Showed structure not capable of residual strength loads with chord severed at 11th fastener hole.
  - Produced static overload failure mode very similar to G-BEBP.
  - Revealed that actual behavior of structure with chord failed at 11th fastener hole was significantly more complex than assumed for certification analysis



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Accident Prevention Assessment

- What inspection requirements might have prevented the accident?
- What knowledge base would have been required to establish the inspection requirements?
- What would have been required to develop the knowledge base?

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Inspection Requirements

(i.e. Where? When to start? How and how often?)

- Directed inspection at 11th fastener hole
- Inspection threshold not later than 75% DSG (i.e. 15000 cycles)
- NDI for cracking prior to chord failure at interval less than 3500 cycles

OR?

- Directed visual for failed chord at intervals less than 50 cycles

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Knowledge Base Assessment

INFORMATION NEEDED	REQUIRED ACTION
?? Fatigue Loading	?? Flight test measurement of fatigue loads
?? Critical location	?? Detailed FEM of intact structure and/or ?? Full scale fatigue test
?? Crack initiation life at critical location	?? Crack initiation analysis and/or ?? Full scale fatigue test
?? Crack growth scenario and life prior to chord failure	?? Crack growth analysis and/or ?? Full scale damage tolerance test
?? Residual strength behavior with failed chord	?? Complex FEM (e.g. nonlinear material and geometric behavior) and/or ?? Full scale residual strength test

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Lessons Learned

- Do pay extra attention to fatigue loading
  - Consider flight test validation
- Be wary of all design changes and their potential impact on fatigue and damage tolerance
  - Perform full scale tests unless there is compelling data which supports not doing it
- Don't assume where the most fatigue critical location is
  - Perform sufficient fatigue analyses and tests to identify where cracks are most likely to initiate and when

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Lessons Learned (cont'd)

- Do design in redundancy whenever practical
- Don't assume how the structure will behave with a large partial failure or complete failure of a major load path
  - Consider full scale testing to validate failure mode, residual strength and residual life of the structure if these attributes are fundamental to maintaining safety

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Lessons Learned (cont'd)

- Avoid complete reliance on safety-by-inspection strategies that are based on detecting nothing less than large partial failures and/or major load path failures
  - Post failure behavior has proven difficult to quantify and residual life, if any, is typically very short
- Do inspect for cracking prior to major load path failures or crack arrest

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Potential Rule Revisions

- Flight test validation of fatigue loads used for analyses and tests
- Fatigue life assessment of all PSEs
  - ARAC-GSHWG recommendation would, in effect, require this for MSD/MED susceptible structure in conjunction with LOV validation. (Need other PSEs!)
- Upper limit on inspection thresholds regardless of analysis results
  - Included in ARAC-GSHWG recommendation. (e.g. 50% DSG for single load path PSEs)

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Potential Rule Revisions (cont'd)

- Full scale fatigue test (FSFT) to demonstrate fatigue performance of all PSEs
  - Current rule only requires FSFT relative to MSD/MED susceptible structure
- Full scale damage tolerance testing (i.e. residual strength and residual life) to validate all 25.571(b) inspections that are premised on detection of nothing less than large partial failures or complete failures of major load paths

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Potential Rule Revisions (cont'd)

- Minimum level of redundancy supplemental to 25.571(b) requirements
  - Included in ARAC-GSHWG recommendation as "structural damage capability" (SDC)

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Acknowledgements

- This presentation was largely inspired by and incorporates material previously presented by Mr. Dan Cheney, ANM-100 (Ref: FAA Airframe Workshop 2002, Long Beach, CA, 22 August 2002.)
- Pictures and diagrams on slides 2, 5, 6, 7, 10, 11, 12, 13 and 14 were taken from "*Aircraft Accident Report 9/78, Boeing 707 321 G-BEBP, Report on the Accident Near Lusaka International Airport, Zambia, on May 1977*", HMSO, London, 1979.

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