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FEASIBILITY STUDY FOR C-141B REDUCTION OF WING LOADS BY UPRIGGI--ETC(U)
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REPORT NO.: LG80ER0144

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DATED: September 10, 1980

# LOCKHEED-GEORGIA COMPANY

## A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

MARIETTA GEORGIA

12 3

TITLE

FEASIBILITY STUDY FOR C-141B
REDUCTION OF WING LOADS
BY UPRIGGING THE AILERONS

10

S. Ja[illegible]ison

SUBMITTED UNDER

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MODEL C-141B

REFERENCE F09603-80-G-0417-[illegible]

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## i. SUMMARY

This report summarizes an investigation into the feasibility of uprigging the ailerons on the C-141B to reduce wing loads. The potential wing loads reductions were based on early wind tunnel data and were corroborated by recent flight test data at a mid-span location. Crack growth computations were made for four wing locations. Significant increases in structural safety limits for the two lower surface locations ranged from an improvement factor of 1.18 ($3^\circ$ uprig) to 2.731 ($6^\circ$ uprig) depending on location. Similar percentage increases could be expected in inspection intervals and structural durability. Two wing upper surface locations showed no significant change from aileron uprigging.

An examination of the potential impact on pitch trim requirements, roll response and dutch roll characteristics indicated only negligible effects from moderate aileron uprigging. A negligible degradation in the maximum lift at buffet onset was predicted. Drag increases for a range of uprig positions and lift coefficients were established from coordinated C-141/C-5A data. Two methods of uprigging were described which permit changing the uprig inflight if required. Flight tests to confirm predictions are recommended.

# 1.0 TABLE OF CONTENTS

## 2.0 LIST OF FIGURES

# 3.0 INTRODUCTION

This report presents the results of a feasibility study to reduce the C-141B wing loads by uprigging the ailerons.

Uprigging the ailerons will reduce the inner wing root bending moment. This reduction in the bending moments will reduce the stress level in the vicinity of the wing root and, depending on the magnitude of the load reduction, could change the recurring inspection requirements; any future local modification and possible local repairs could be reduced.

The primary objective of this study is to determine the effect on structural inspection requirements (calculated by fatigue crack growth analysis) on the inner wing caused by uprigging the ailerons. Structural durability enhancement factors will be reviewed and discussed. Secondly, all other aspects of uprigging the ailerons should be analyzed to determine if the program is feasible for incorporation into the C-141 fleet.

The items which are studied in this report to determine the effects of uprigging the ailerons are:

- <u>Aerodynamic Performance</u>

  Drag
  Mach Buffet
  Handbook Changes

- <u>Stability and Control</u>

  Pitch Trim Authority
  Roll Response and Power
  Dutch Roll

- <u>Wing Loads</u>

  Bending Moments
  Torsional Loads
  Shear

- <u>Stress Levels</u>

  Critical Locations

- <u>DADTA</u>

  Evaluate the effect of uprigging the ailerons on
  inspection intervals and wing durability factors

- <u>Prototype Method For Inflight Uprigging Of Ailerons</u>

  Trombone Slide
  Turnbuckle Arrangement

# 4.0 STUDY RESULTS

## 4.1 Performance

Aileron uprig has been studied in various applications for both the C-141 and C-5A aircraft. Flight test data exists for the C-5A aircraft as the entire fleet was modified with six degrees of uprigged ailerons. Results from these programs provide a reasonable level of confidence in predicting the aerodynamic changes.

The basic effect of uprigging the ailerons is to reduce the wing lift near the tip. The angle of attack must then be increased to restore the lost lift and to maintain level flight. The lift increase due to angle of attack is more concentrated at the wing root than at the tip. The net result of these changes is to reduce the wing root bending moment. This change to the load distribution causes an increase in the induced drag.

Increased drag estimates due to uprigged ailerons are shown on Figure 1. These data are coordinated analyses from C-141 and C-5A wind tunnel and flight test data.

C-141B AIRCRAFT
DRAG INCREASE DUE TO AILERON UPRIG

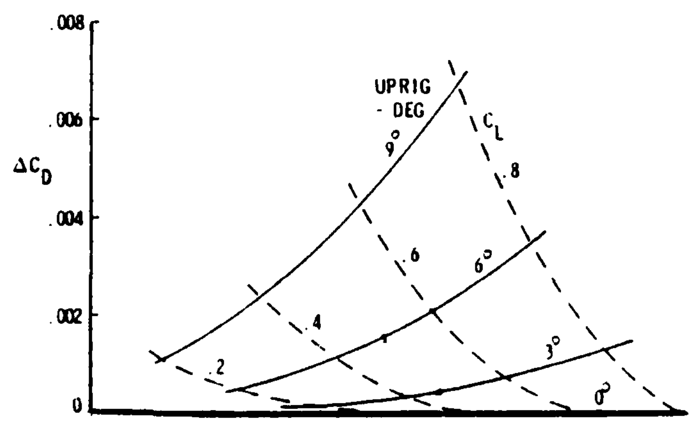



FIGURE 1

The following table illustrates the impact of these drag increases on the cruise performance of the C-141B aircraft.

| Aileron Uprig | Drag Increase | % Fuel Increase |
|---|---|---|
| $3^{\circ}$ | .0004 | 1.6 |
| $6^{\circ}$ | .0014 | 5.6 |

Increases in fuel consumption are applicable for all normal cruise operations of the airplane. Small increases in fuel consumption will also occur for climb, descent, and holding operations, but since they represent a small portion of the total mission fuel, the impact is small.

Since the aileron uprig results in an increased wing load in the center portion of the wing span (where flow separation begins) there will be a slight degradation in the maximum lift and in lift coefficient for buffet onset. Rough estimates of this effect indicate that $C_L$ changes of approximately 0.04 should be anticipated. Changes of this magnitude will not degrade any significant aircraft capability.

The aileron uprig will not be used during takeoff or landing, therefore, there will be no change in airport performance.

It is estimated that 80 pages of the Performance Handbook will be changed.

## 4.2 Stability and Control

Uprigging the ailerons will require an investigation into the following stability and control items:

Pitch Trim Authority

Roll Response and Performance

Dutch Roll

The results of these study investigations are:

4.2.1 Pitch Trim - The change in wing load distribution due to symmetric uprig of the ailerons produces a pitching moment which rotates the aircraft nose up and requires an increase in the aircraft nose down stabilizer setting to trim a given flight condition. For the $6^{\circ}$ uprig case it is estimated that about $0.5^{\circ}$ trim change will be required. Review of available flight test data, without aileron uprig indicates that the maximum trim required is about $2.0^{\circ}$. Since $4.5^{\circ}$ is available with the current trim limits, the trim change after aileron uprig will be within the range provided by the actuator.

4.2.2 Roll Performance - Flight tests of roll response with $3^{\circ}$ of aileron trailing edge uprigging were conducted during the initial flight testing of the C-141A. These tests show that $3^{\circ}$ uprigging has negligible effect on roll response as shown on Figure 2.

C-141 ROLL PERFORMANCE
EFFECT OF AILERON UPRIGGING

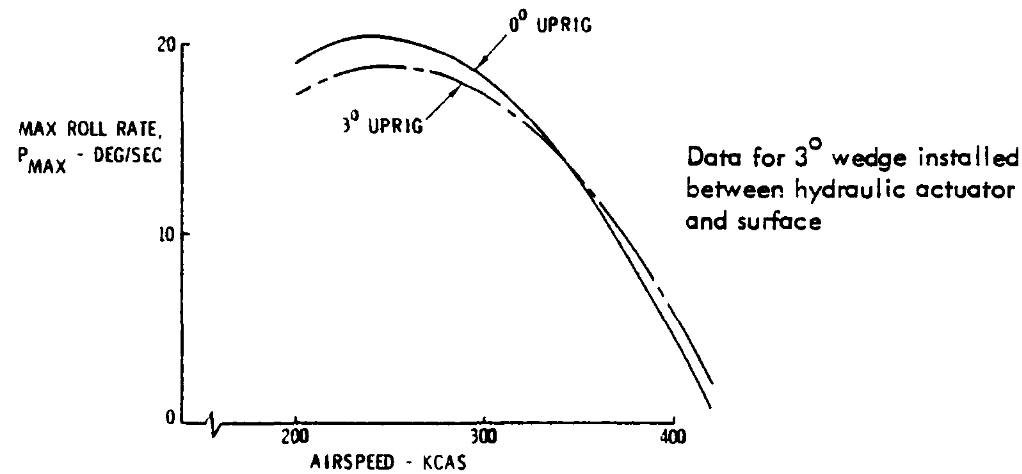



FIGURE 2

The data indicates less than a $1.5^{\circ}$ per second change in maximum roll rate. Roll power should not be affected as total aileron deflection (both left and right) is not changed. Similar results are expected for the $6^{\circ}$ uprig.

4.2.3 Dutch Roll - The effects of aileron uprig on basic dutch roll characteristics are expected to be minimal. The roll performance summary data indicate ample roll control is available for dutch roll recovery according to published procedures which should not require revision following uprig of the ailerons.

## 4.3 Loads

### 4.3.1 General

The C-141B baseline loads data and repeated loads spectra used in this study are the same as previously used in the C-141B Durability & Damage Tolerance Assessment (DADTA) of 1979. These loads data, along with the methods used to develop the repeated loads spectra, are discussed fully in Reference 1 for each of various load spectra (gusts, maneuvers, etc.) experienced during the operational lifetime of an average C-141B aircraft.

The repeated loads spectra are dependent upon the missions flown by the aircraft. The baseline aircraft usage data established for the DADTA study and presented in Reference 1 are also shown in this report as Table 1. The key parameters listed in Table 1 define the 18 different missions and their respective utilization for an average aircraft in the fleet. Those data are based on actual usage data from the C-141A fleet during a two-year period,October 1, 1969 to October 1, 1971. Subsequent revisions have been made to account for the higher weight of the C-141B and to provide for missions which utilize aerial refueling.

To develop the repeated loads spectra, each mission has been subdivided into a large number of mission segments. Each segment of the mission represents a period of time when the flight (or ground) conditions such as speed, cargo, and fuel weight are considered to be held constant at the average value for the duration of the mission segment. Thus each mission segment has an associated steady mean load about which the repeated loads fluctuate.

PREPARED BY: R.H. MILLER 8-15-77 CHECKED BY: J.C. DAVIS 8-15-77

# TABLE I

## SUMMARY OF MISSION PROFILES FOR C-141B DADTA ANALYSIS (SLA-IIB) PER 30,000 FLT HOURS (MAC)

| MISSION NO. | MISSION TYPE | FLT HRS PER SORTIE | SORTIES | FLT HRS | PERCENT UTILIZATION OF FLT HRS | RAMP GROSS WEIGHT | RAMP FUEL | RAMP PAYLOAD** | LANDING FUEL | SAG LDGS | TAG LDGS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Medium Range Logistics | 6.48 | *1336 | *8656 | *28.85 | 303,304 | 125,000 | 28,400 | 33,000 | | |
| 2 | Medium Range Logistics | 6.48 | * 399 | *2587 | * 8.62 | 327,804 | 125,000 | 52,900 | 33,000 | | |
| 3 | Short Range Logistics | 2.47 | * 535 | *1317 | * 4.39 | 234,304 | 76,500 | 7,900 | 38,500 | | |
| 4 | Short Range Logistics | 2.47 | *1166 | *2865 | * 9.56 | 259,804 | 85,000 | 24,900 | 46,500 | | |
| 5 | Short Range Logistics | 2.47 | * 535 | *1317 | * 4.39 | 283,304 | 93,500 | 44,900 | 54,000 | | |
| 6 | Short Range Logistics | 3.42 | * 373 | *1270 | * 4.23 | 295,304 | 120,000 | 25,400 | 66,000 | | |
| 7 | Long Range Logistics | 9.38 | * 294 | *2757 | * 9.19 | 335,304 | 153,352 | 32,048 | 20,752 | | |
| 8 | Position for Channel | 3.78 | * 297 | *1121 | * 3.74 | 256,104 | 106,200 | 0 | 61,500 | | |
| 9 | Training | 2.67 | *1349 | *3396 | *11.33 | 228,604 | 78,700 | 0 | 42,400 | * 456 | *4569 |
| 10 | Training with Airdrop | 4.50 | * 10 | * 45 | * 0.15 | 250,304 | 91,400 | 9,000 | 35,000 | * 10 | * 10 |
| 11 | Airdrop | 3.20 | * 201 | * 643 | * 2.14 | 257,304 | 99,000 | 8,400 | 59,500 | | |
| 12 | Flight Test | 0.90 | * 104 | * 94 | * 0.31 | 192,904 | 43,000 | 0 | 29,100 | | |
| 13 | Airborne Training | 1.17 | * 137 | * 160 | * 0.53 | 231,304 | 59,000 | 22,400 | 43,300 | | |
| 14 | Low Level Navigation | 0.95 | * 173 | * 164 | * 0.55 | 221,904 | 72,000 | 0 | 55,900 | | |
| 15 | Airlift (Aerial Refueling) | 13.97 | 54 | 754 | 2.51 | 259,904 | 80,000 | 30,000 | *20,000 | | |
| 16 | Contingency (A/R) | 14.25 | 21 | 299 | 1.00 | 334,904 | 115,000 | 70,000 | *20,000 | | |
| 17 | Exercise (A/R) | 13.93 | 54 | 752 | 2.51 | 297,904 | 96,000 | 52,000 | *20,000 | | |
| 18 | Training (A/R) | 6.00 | 300 | 1800 | 6.00 | 230,104 | 80,000 | 200 | *25,000 | | |
| | | | *7338 | *30,000 | 100 | | | | | * 466 | *4579 |

** Payload with an equipped weight empty of 149,904 lbs which includes 7,111 lbs MAC equipment & ECPs.

* Recommended change from original projection.

MAC recommended modified SLA-II profiles for C-141B DADTA

TOTAL LANDINGS 12,383

GA FORM 425-1

Uprigging the ailerons affects only the steady mean loads as described further in Section 4.3.2. The incremental repeated loads from gusts, maneuvers, etc. remain the same as described in Reference 1 whether the ailerons are uprigged or not.

### 4.3.2 Loads With Ailerons Uprigged

The incremental loads from incremental aileron deflections are based on the aerodynamic data obtained from wind tunnels in the early 1960's. Subsequent structural demonstration flight testing of rolling maneuvers in initial flight testing confirmed the predicted aileron effectiveness and its effect on wing design load conditions. Flight testing with the ailerons uprigged was also conducted in 1965 but a detailed loads analysis of that test data was not undertaken. A review of the limited data presently available from those early tests indicate that the overall wing loads are in agreement with predictions; however, it was not possible to isolate the incremental aileron loads from the limited amount of data available.

Flight test data were also collected in 1976 on a C-141A simulating an aerial refueling by flying behind a KC-135 tanker. This type of flight operation required a large amount of aileron activity to keep the aircraft properly aligned while in wake turbulence. A correlation of the wing bending moment at W.S. 479 with aileron deflection during one of the test runs is shown in Figure 3. There is a substantial amount of scatter of the test data which is reflective of the wake turbulence causing pitch and local angle-of-attack changes with superimposed dynamic oscillations of the wing. The trend of the data indicates that for $6^{\circ}$ of aileron deflection an incremental wing bending moment change of $3.0 \times 10^{6}$ inch-pounds would result at W.S. 479 with $V_E = 270$ knots.

C-141A SIMULATED AERIAL REFUELING
FLT 23, RUN 10B
GW = 242,800 LB, $V_E$ = 270K - 17 JUN '76

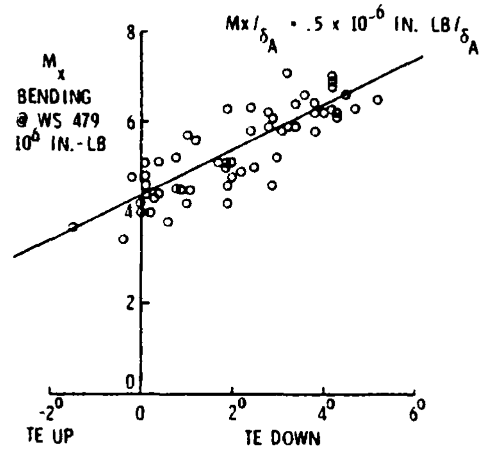



FIGURE 3

Figure 4 shows the effects of 6° aileron uprig on 1.0g trim wing loads with the above mentioned test point spotted on the bending moment plot at W.S. 479. The incremental changes in wing loads shown in Figure 4 were calculated by a computer program which accounts for the static aeroelastic effects from symmetric aileron deflections and "rebalances" the aircraft with changes in angle-of-attack and elevator deflection as required to maintain 1.0g steady, trim flight. The test data point (though it is an approximate value and for a slightly higher airspeed than the predicted data) is in reasonable agreement with the loads data used in this study.

An examination of data similar to that presented in Figure 3 was also conducted using 1977 test data from aerial refueling (dry hookups) of the YC-141B. Similar results to those in Figure 3 were obtained.

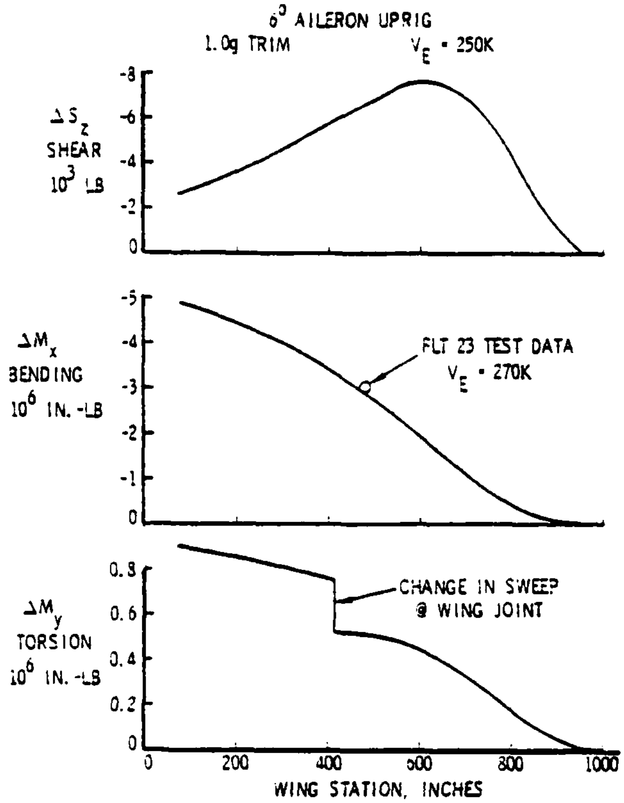



FIGURE 4

Incremental 1.0g wing loads from uprigging the ailerons are, in general dependent upon dynamic pressure and Mach number. The effect of Mach number on the incremental 1.0g loads was found to be small and did not exhibit a consistent trend across the dynamic pressure range. For this study, the variations with Mach number were eliminated by averaging the results at any given dynamic pressure (airspeed) over the Mach number range for each of several altitudes. The variations with airspeed of the wing load effects from aileron uprigging of 6° is illustrated in Figure 5 for the wing root station (W.S. 77).

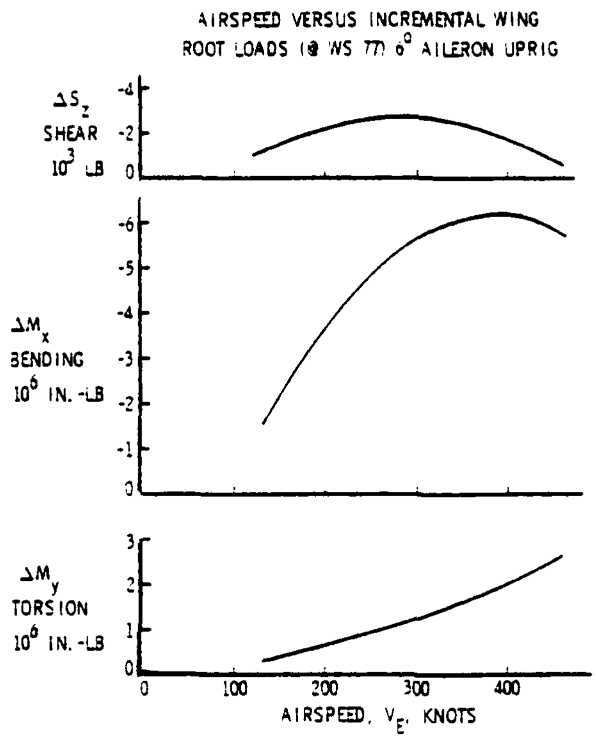



FIGURE 5

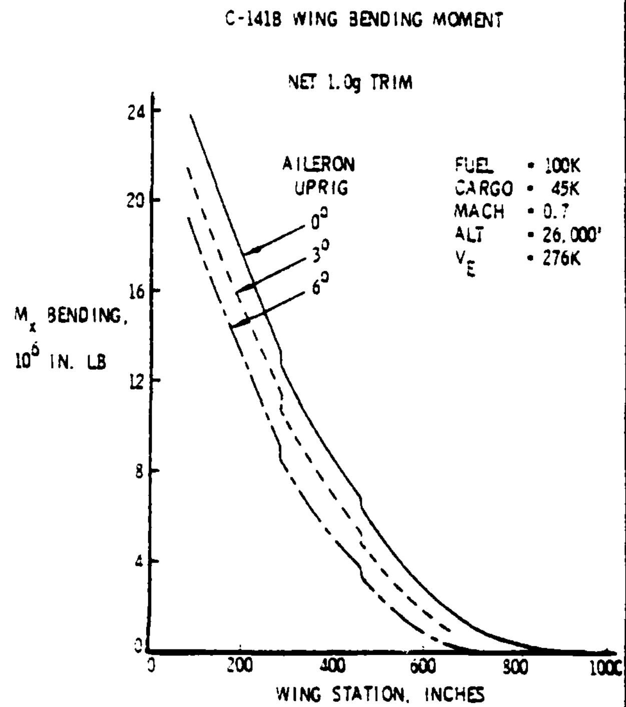



FIGURE 6

The wing bending moment distribution with and without aileron uprig is shown in Figure 6 for a sample 1.0g trim, mid-fuel, mid-cargo flight condition. It is clear from this figure that the uprigged ailerons provide relatively greater load relief in the outer wing than in the inner wing area.

## 4.4 Durability and Damage Tolerance Assessment

### 4.4.1 General

The Durability and Damage Tolerance Assessment (DADTA) has been limited to the calculation of safety limits which form the basis for establishing initial and recurring inspection intervals at suspected critical locations on the aircraft. The safety limit is based on the assumed presence of a "rogue" flaw, at time of manufacture, in a structural element from which structural cracks are propagated. The recommended initial inspection on an aircraft primary structural component or "zone" is one-half the time to grow the crack from the initial rogue flaw length to the critical crack length at which time the application of limit loads would cause unstable crack growth for the component.

Recurring inspection intervals after the initial inspection are calculated differently but the safety limit crack growth curve is also used. Each structural zone/area to be inspected is evaluated to determine which types of non-destructive inspection (NDI) techniques and equipment are required. With consultation and concurrence from WRALC, each particular NDI technique used for each analysis/inspection zone has been assigned a maximum non-detectable crack length which could be missed during an inspection. If no cracks are found on the initial inspection, then, to obtain the next inspection interval, it is assumed that a crack of length equal to the non-detectable value exists at that location; the amount of time to grow the crack from the NDI non-detectable length to the critical length is calculated and one-half that time period is the recommended recurring inspection interval.

The methods and parameters used in calculating crack growth to establish safety limits, initial inspections and recurring inspections are identical in all aspects except that recurring inspections presume the existence of a NDI non-detectable crack length which is larger than the "rogue flaw" length used for the safety limit and initial inspection.

The rogue flaw concept and the assumption that an initial flaw (crack) exists is a safety consideration and results in inspections which could detect unexpectedly early occurrences of cracks. The recurring inspections help insure that cracks present but not found on one inspection would be detected on the next inspection before they had reached their critical crack length.

When structural safety inspection programs are being established, an appraisal of the expected durability of the structure is also made. The durability "indicators" are based on initial flaws substantially smaller than the prescribed rogue length and are determined from calculations based on full-scale fatigue tests and other data sources. The durability calculations provide "indicators" of the ability of structural components of an "average" quality airframe to resist crack growth from very small microscopic initial flaw sizes. As discussed herein, the term durability indicator refers to the time for the very small initial flaw to grow to a functionally unacceptable length (such as to cause a fuel leak). It is obviously desirable for any structural component to reflect durability indicator times which equal or exceed the intended usage period of goal for the airframe.

Previous DADTA studies have generally shown that changes in the loads spectra which produce increases in the safety limits will also produce increases in the durability characteristics of the structure of a roughly proportional amount. Thus, the safety limit calculation results shown in this report, when expressed as an improvement factor change from their baseline values, may also be taken to reflect the improvement in the required initial and recurring inspection intervals; a similar improvement factor will be indicated for the durability characteristics.

## 4.4.2 Selection of Locations for Crack Growth Analysis

The primary purpose of uprigging the ailerons is to favorably affect the recurring inspection requirements and structural durability of the wing lower surface which generally has shorter safety limits than the wing upper surface. Two wing lower surface locations were selected for analysis which were considered to separately represent the general trend of influence of aileron uprigging on the inner and outer wings.

| | |
|---|---|
| W-36E | Located at IWBRS 191.6. Spanwise splice between panels 4 and 5. Representative of spanwise splices in the inner wing area. |
| W-47B | Located at OWBRS 62. Spanwise splice between panels 1 and 2. Representative of spanwise splices in inboard end of outer wing area. |

Two analysis locations were also selected on the wing upper surface in the inboard and outboard portions of the inner wing area. While those locations are mostly affected by ground loadings, it was considered possible that some degradation of safety limits could occur. The locations are identified as:

| | |
|---|---|
| W-23 | Located at IWBRS 80.6. Fuel pump hole in panel 1. |
| W-35F | Located at IWBRS 360. Spanwise splice between panels 1 and 2 |

The above locations are identified on the wing planform shown in Figures 7 and 8, respectively.

# C141B DADTA

## WING UPPER SURFACE ANALYSIS POINTS

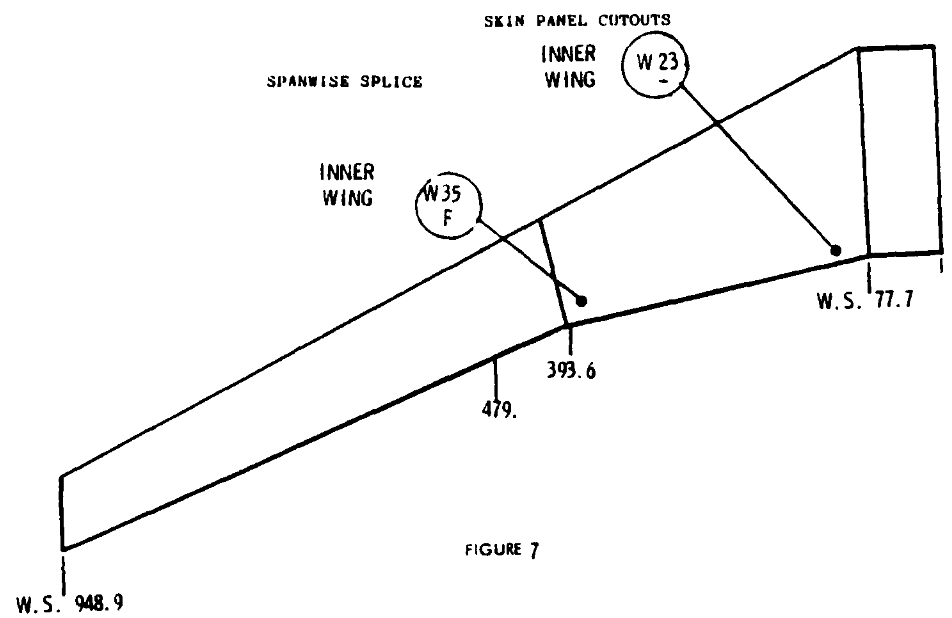



FIGURE 7

# C141B DADTA

## WING LOWER SURFACE ANALYSIS POINTS

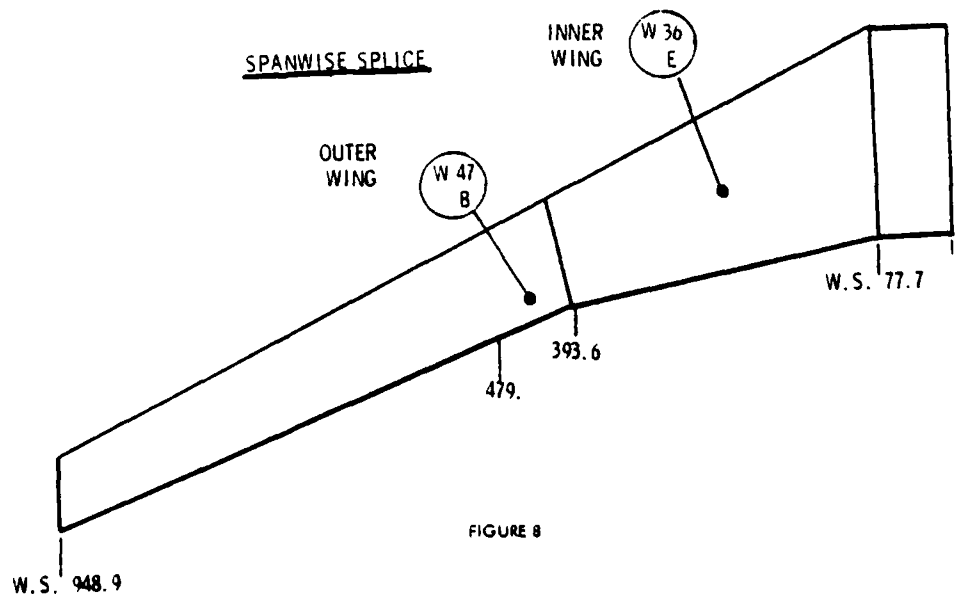



FIGURE 8

### 4.4.3 Crack Growth Methodology

Crack growth analyses require information on the following four basic analysis elements: (1) the applied load/stress spectrum, (2) the crack growth rate data for the material, (3) the applicable stress intensity factors, and (4) the load-interaction model.

The loads spectrum, consisting of many mission segments each having a set of variable loads which are cyclic about a given mean load, was briefly discussed in Section 4.3. The conversion from loads to stresses is made through the use of stress/load ratios which are obtained from a finite element model computer analysis of the wing structure. For loads which are applied slowly, or nearly so, such as 1.0g mean loads and banked turn maneuvers, the total stress (shear or axial) is the algebraic sum of the contributions from each of six different load components. For dynamic loads resulting from random inputs such as gusts or runway roughness, the total stress is obtained from statistical equations which reflect the average relationships predicted to exist between one loading component and all others.

The crack growth rate data for a given material/alloy is derived from laboratory tests and is usually collected under constant amplitude testing procedures. The crack growth rate data for this study is the same as used in the previous DADTA program of Reference 2 for safety limits calculations; it reflects the experimental test data under high humidity (90% Relative Humidity) conditions. As presented therein, the data is expressed in terms of the instantaneous crack growth rate (da/dn) for any applicable value of stress intensity range ($\Delta$ K).

The Hsu load-interaction model, as developed at Lockheed-Georgia, accounts for the fact that any given stress cycle may influence the crack growth from subsequent stress cycles depending on conditions established in the model. The principal effect evidenced by the model is the retardation of crack growth caused by high tensile stresses which delay subsequent crack growth from the following lower magnitude stress cycles. For this study, all interaction effects are fully accounted for within each flight; however, no crack retardation effects are permitted to carry-over to the suceeding flight. That treatment is compatible with the methods used in the development of the C-141 Fracture Tracking Program which is currently underway.

All of the above elements of the crack growth analysis are mechanized in a series of computer programs which include several other detailed considerations not mentioned here. For each structural location analyzed, however, it is necessary to prescribe the shape of the crack front and the path which the crack will follow.

### 4.4.4 Stress Levels at Analysis Locations

For the structural locations analyzed in this study, the axial stresses induced are largely governed by the magnitude of the wing bending moment with secondary influences from wing shear and torsion; shear stresses are largely governed by (vertical) shear and torsion. The incremental changes in the 1.0g stress levels from uprigging the ailerons are calculated from the incremental changes in those three load components. For the baseline configuration with no uprig, however, both shear and axial 1.0g stresses have been established using all six load components so that fore-and-aft shear and bending could be accounted for. The incremental cyclic stresses from gusts, maneuvers, etc., were also computed using six load components in previous DADTA studies and are utilized in this study unaltered.

### 4.4.5 Crack Growth Results

As referred to previously, percentage changes in crack growth safety limits also result in similar percentage changes in initial and recurring inspection intervals and are a fair approximation to the percentage changes in durability limits. The safety limits improvement factors, due to uprigging the ailerons, are illustrated on Figure 9 for the wing lower surface locations W-36E and W-47B, respectively, and tabulated below.

IMPROVEMENT FACTORS ON SAFETY LIMITS FOR WING LOWER SURFACE

| | AILERON UPRIG | |
|---|---|---|
| | $3^{\circ}$ | $6^{\circ}$ |
| Inner Wing W-36E | 1.18 | 1.465 |
| Outer Wing W-47B | 1.488 | 2.731 |

## C-141B
## AILERON UPRIG VS
## LOWER SURFACE SAFETY LIMIT IMPROVEMENT

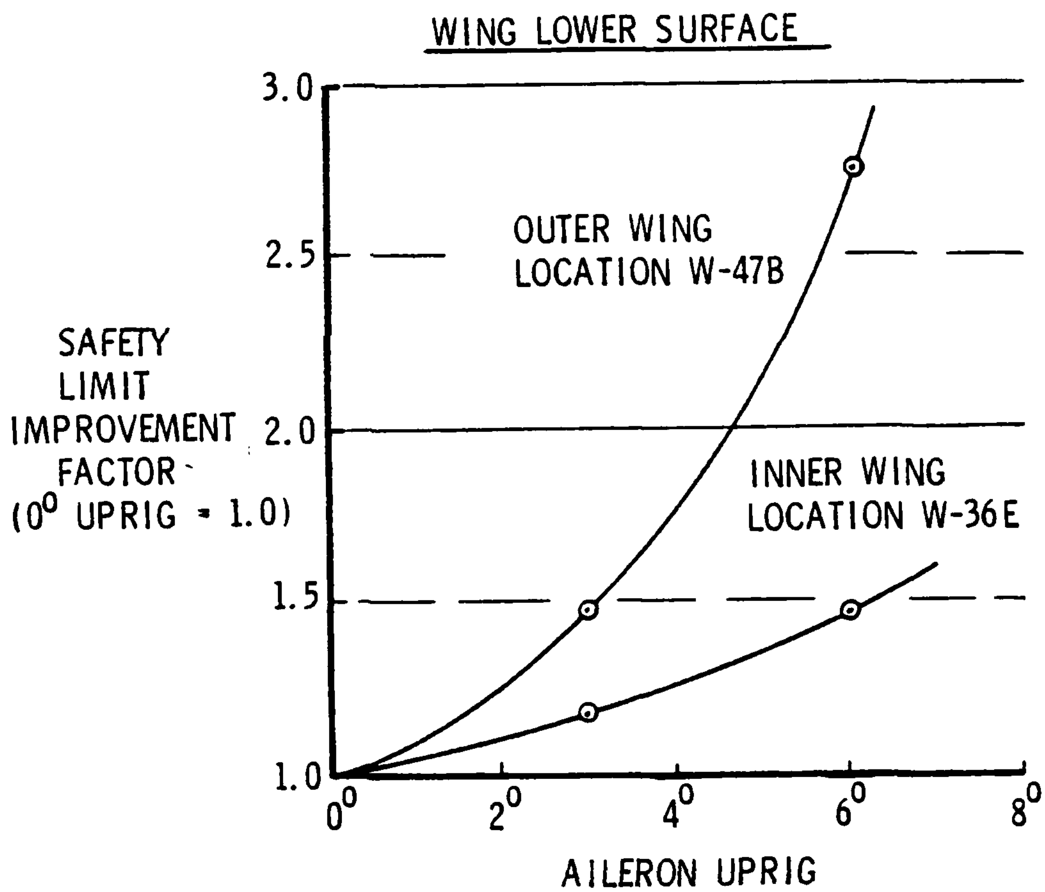



FIGURE 9

A review of the detailed crack growth rate information associated with the above improvements for W-36E was also conducted to assess which loading source contributed the most to the improvement. It was found that all flight load sources -- gusts, maneuvers, and aerial refueling -- were improved roughly uniformly in the same percentage as was the contribution from the ground-air transition cycles. The total percentage improvement from the above load sources averaged slightly higher than the values indicated in the table on page 19 since crack growth attributed to landing impacts was not changed by uprigging the ailerons. It should be noted that C-141 fatigue crack growth calculations of operational limits (safety and durability) on wing lower surface structural locations are influenced principally by gust and maneuver load sources.

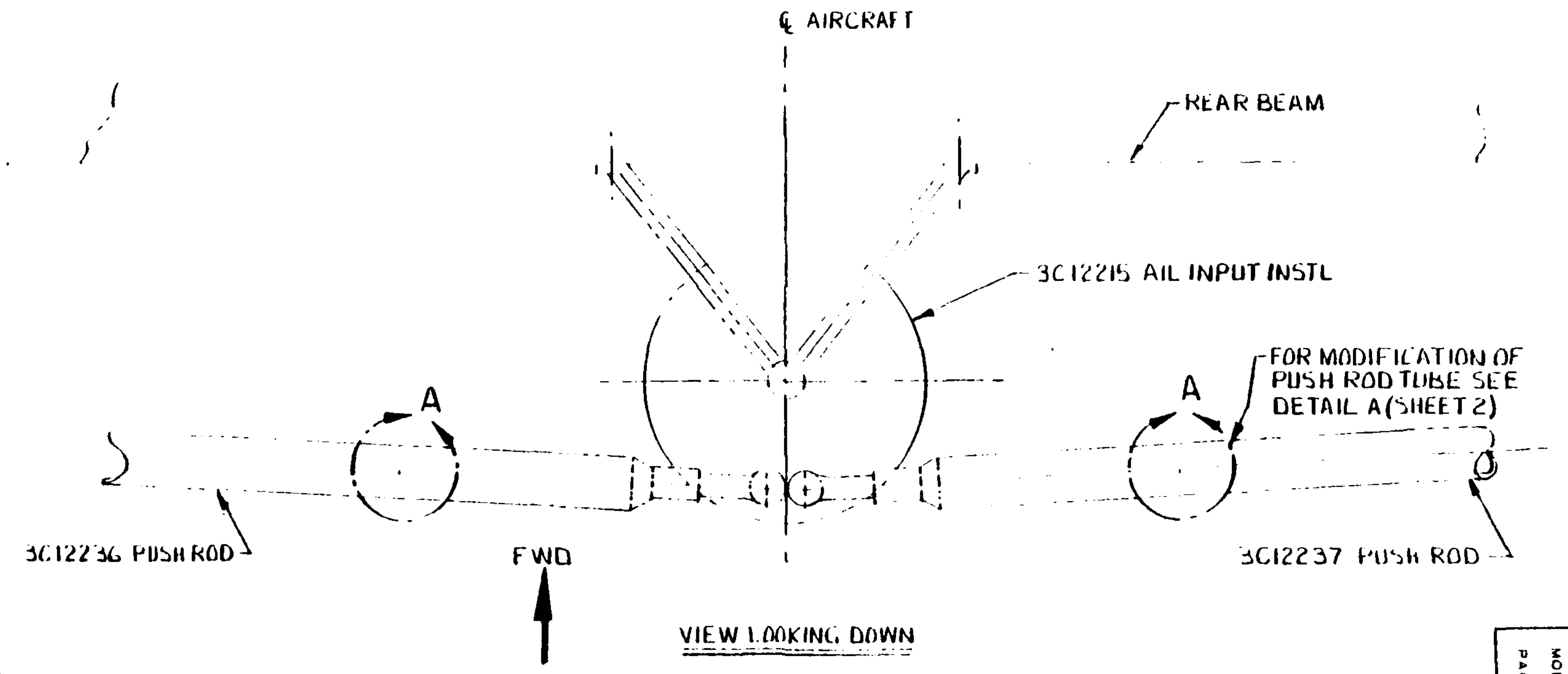
### 4.5 Prototype Uprigging Methods

Two safe and inexpensive methods of uprigging the ailerons from 0° to 3° or to 6° of uprig are shown on Figures 11 and 12. The rig positions can be safely changed inflight if required.

Figure 10 is a view looking down on the aileron input system at the aircraft ℄ and the aft side of the wing rear beam. The two push rods 3C12237 and 3C12236 are the rods to be replaced or modified.

Figure 11 is a concept which is like a sliding tube assembly. A detent is provided for the 0°, 3°, and 6° aileron position, once the assembly is in the desired position the adjusting bolt and nut is inserted and safety locked.

Figure 12 is another prototype concept to uprig the ailerons while the aircraft is inflight. This concept consists of an adjustable turnbuckle to uprig the ailerons.

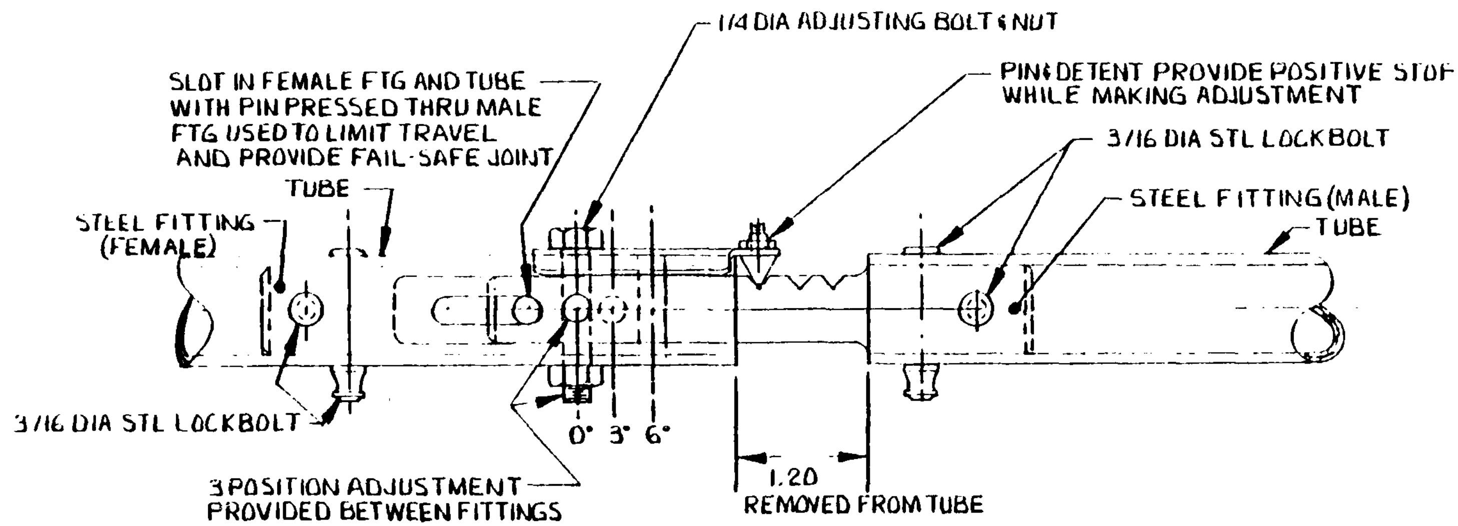



LOCKHEED-GEORGIA COMPANY

AILERON UPRIG ADJUSTMENT ROD (PROTOTYPE) C-141B

| SCALE | ENGINEER | APPROVED | |
|---|---|---|---|
| None (Notes) | W.C.H | | |
| DATE | CHECKED | APPROVED | |
| 7-18-80 | | | |

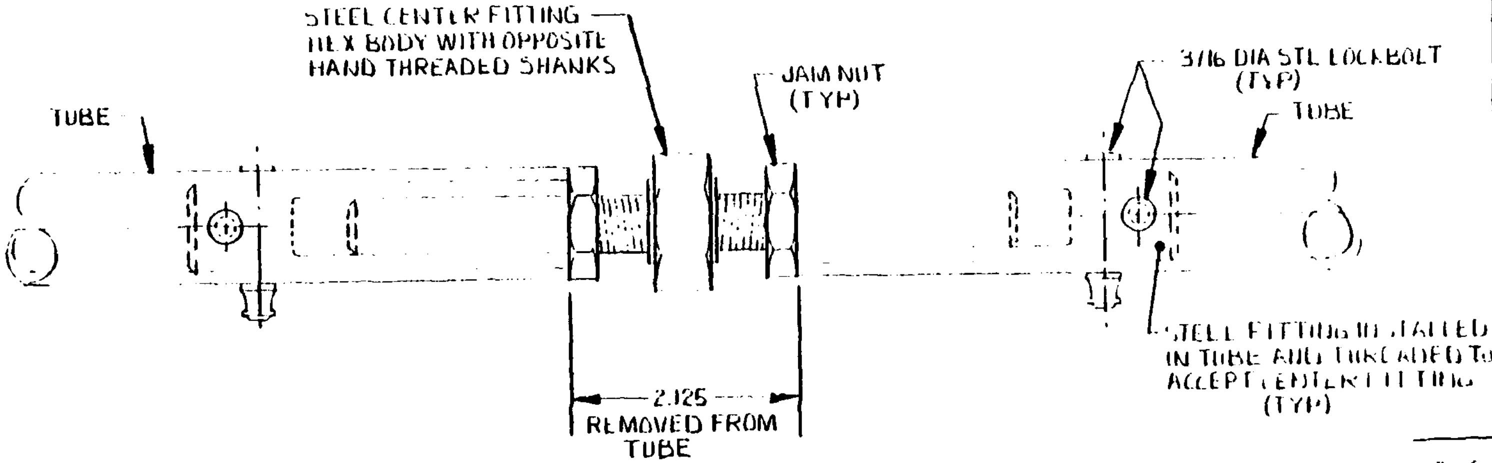
FIGURE 10




DETAIL A
(FOR LOCATION SEE SHEET 1)
SCALE - FULL

| LOCKHEED-GEORGIA COMPANY | AILERON UPRIG ADJUSTMENT ROD (PROTOTYPE) C-141B |
|---|---|
| SCALE: FULL | CHECKED: W.L.H. |
| DATE: 7-28-80 | |

FIGURE 11




LOCKHEED-GEORGIA COMPANY

AILERON UPRIG
JAM NUT ADJUSTMENT
(PROTOTYPE)
C-141B

FIGURE 12

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

This feasibility study supports the contention that aileron uprigging can significantly reduce wing loads and provide associated increases in safety limits, inspection intervals and structural durability. Although a limited corroboration of the incremental wing loads effect was indicated (Figure 3), additional flight testing would be required to more adequately confirm/refine predictions. Concurrently, the predicted drag increases from uprigging the ailerons could also be more accurately measured and assessed. Flight testing to determine those effects is therefore recommended if aileron uprigging is to be further considered.

The crack growth results indicate that as little as three degress of aileron uprig would provide significant increases in inner and outer wing safety limits but with a drag and fuel consumption penalty. The potential trade-off between increased fuel costs and reduced maintenance costs as a function of the amount of aileron uprig has not been established. It is recommended that dollar estimates for this trade-off be estimated for aileron uprig positions of $3^{\circ}$ and $6^{\circ}$ for reference in further evaluations.

## 6.0 REFERENCES

1. LG76ER0131, dated 15 August 1977, Rev. "A", dated 24 October 1979, C-141B Durability and Damage Tolerance Assessment, Vol. 1, Loads and Stress Tapes, Appendix "B"

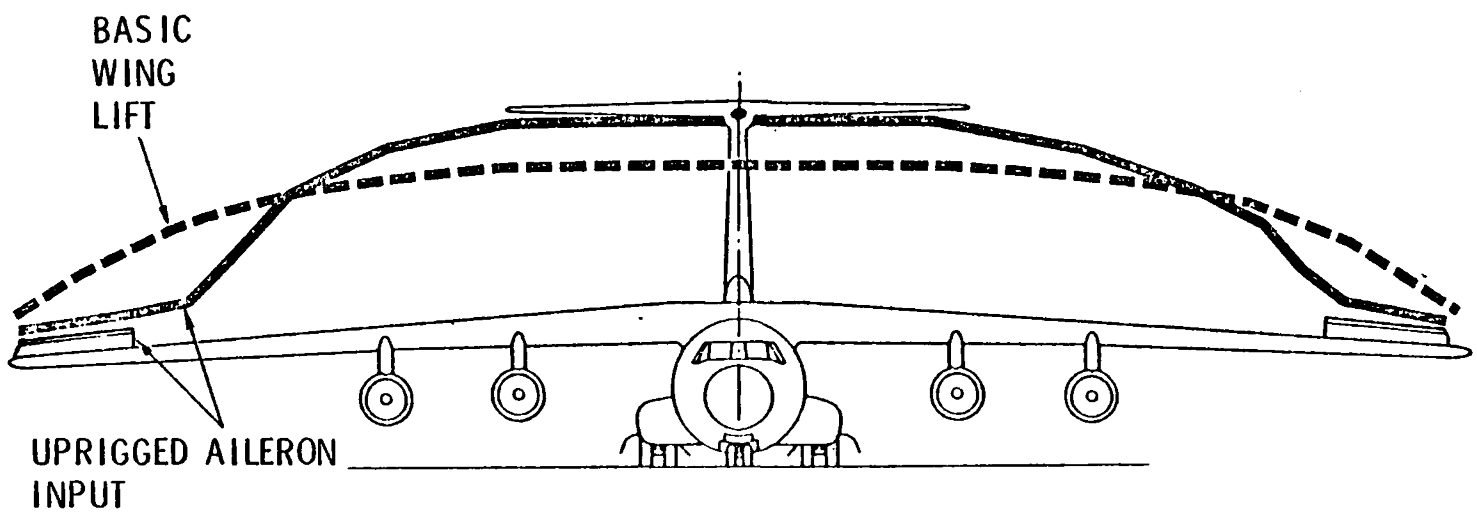
2. LG76ER0123, 30 September 1977, Rev. "C", dated 30 June 1980, C-141B Durability and Damage Tolerance Assessment - Crack Growth Analysis

# 7.0 APPENDIX

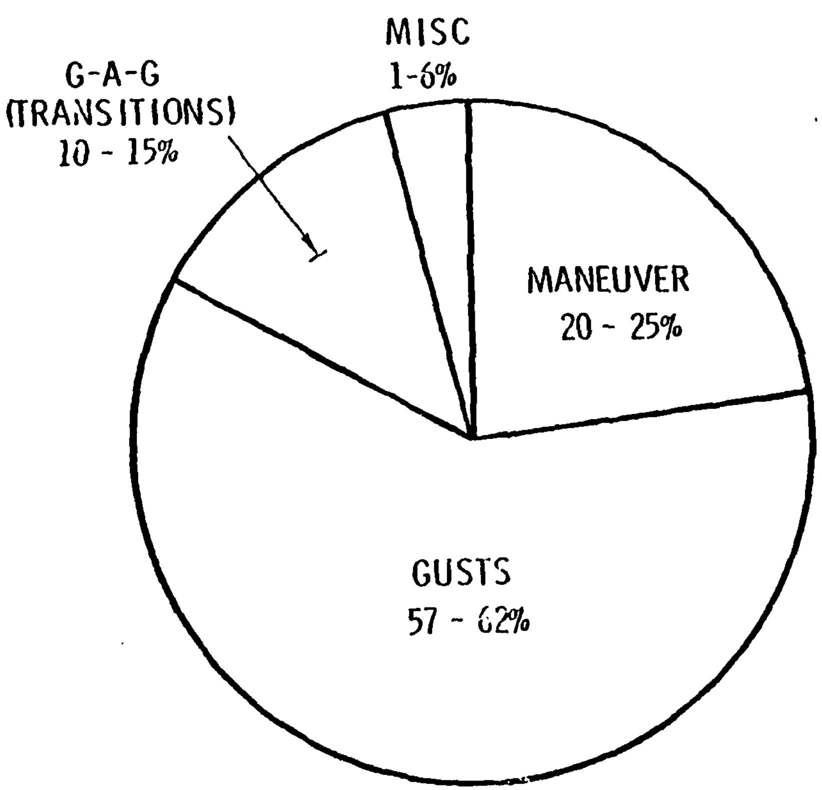
# METHODS TO REDUCE BENDING MOMENTS

1. ACTIVE CONTROLS
   - GUSTS 40 - 50%
   - MANEUVERS 30 - 50%
   - DESIGN LIMIT LOAD 10 - 15%
   - EXPENSIVE
2. UPRIGGED AILERONS
   - STATIC LOAD LEVEL 5 - 20%
   - LOW COST
   - SIMPLE DESIGN CHANGE

## LOAD REDISTRIBUTION WITH UPRIGGED AILERONS

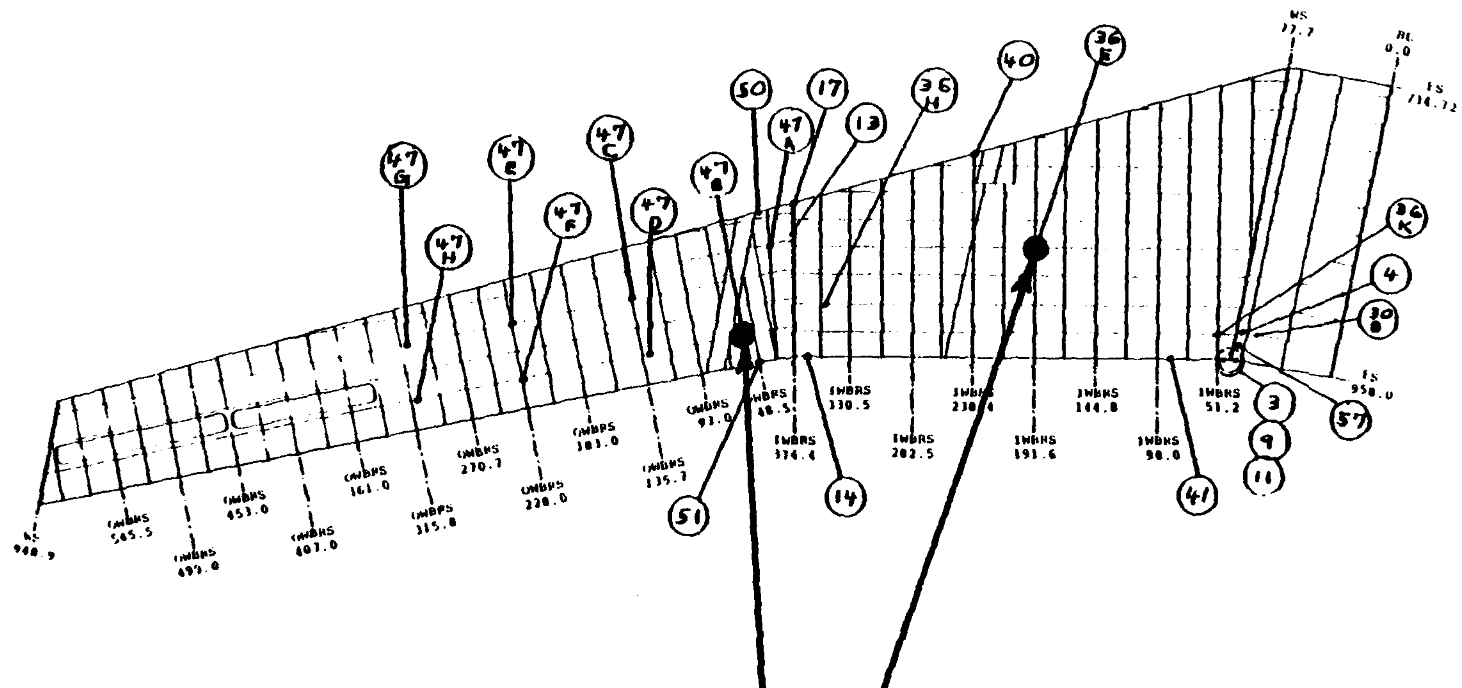


C - 141A FATIGUE - CRACK GROWTH BY LOADS SOURCE



REPARED BY: R. D. Jefferis CHEC...D BY: J. B. Cochran

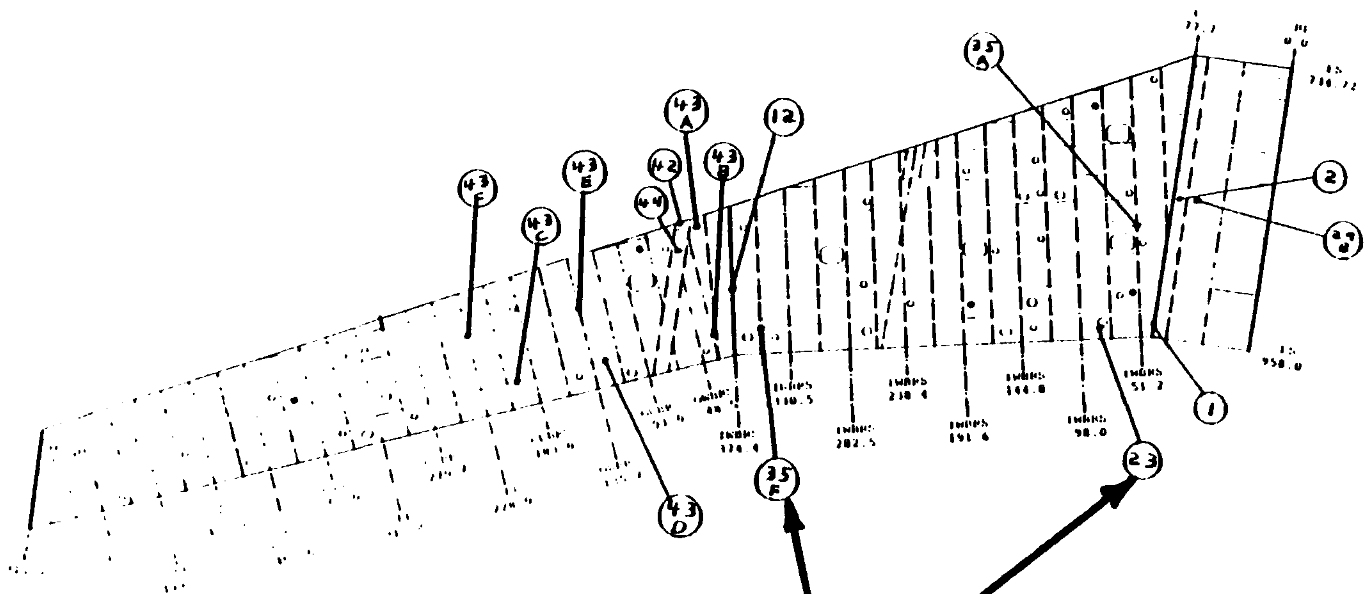
| TYPE OF STRUCTURE | CENTER WING | INNER WING | OUTER WING |
|---|---|---|---|
| CHORDWISE SPLICE | W-3 | W-13 | |
| SPANWISE SPLICE | W-30 | W-36 | W-47 |
| BEAM CAPS | W-9 | W-40<br>W-41 | W-50<br>W-51 |
| BEAM CAP SPLICES/ FITTINGS | W-11 | W-14<br>W-17 | |
| SKIN PANELS | W-4<br>W-57 | | |




Wing Lower Surface Analysis Points

PREPARED BY: R. D. Jeffers  CHECKED BY: J. B. Coleman

| TYPE OF STRUCTURE | CENTER WING | INNER WING | OUTER WING |
|---|---|---|---|
| CHORDWISE SPLICE | W-1 | W-12 | |
| SPANWISE SPLICE | W-29 | W-35 | W-43 |
| SKIN PANELS | W-2 | | W-42 |
| SKIN PANEL CUTOUTS | | W-23 | |
| INTERCOSTAL TO SKIN PANEL RISER RUNOUT | | | W-44 |




Wing Upper Surface Analysis Points

DATE
ILMED

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