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# III. NASTRAN ANALYSIS FOR THE AIRMASS SUNBURST MODEL "C" ULTRALIGHT AIRCRAFT


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# 1. PREFACE

This report was submitted to the aerospace engineering department of the University of Kansas. This report is to satisfy one credit hour in the course AE 592, special projects in aerospace engineering. The present research is a subset of project KU-FRL-6135 conducted under the supervision of professor Howard W.Smith.

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APPENDIX E (*): 2-D NASTRAN RESULTS

APPENDIX F(*): 3-D NASTRAN RESULTS

* APPENDIX E AND F ARE COMPUTER OUTPUT DATA WHICH ARE ATTACHED SEPARATELY.

## LIST OF SYMBOLS

| Symbol | Definition | Dimension |
|---|---|---|
| E | Modulus of Elasticity | ksi |
| Ec | Compression modulus of Elasticity | ksi |
| G | Modulus of Rigidity | ksi |
| Fcy | Compression Yield Strength | ksi |
| Fsy | Shear Yield Strength | ksi |
| Fty | Tensile Yield Strength | ksi |
| Ftu | Tensile Ultimate Strength | ksi |

| Acronyms | Definition |
|---|---|
| MAT | Material |
| NASTRAN | NASA Structural Program |

| Greek Symbols | Definition |
|---|---|
| $\rho$ | Poisson's Ratio |
| $\omega$ | Density $(lb/ft^3)$ |

# 1. INTRODUCTION

The purpose of this report is to create a three dimensional NASTRAN model of the Airmass Sunburst Ultralight comparable to one made for finite element analysis. A two dimensional sample problem will be calculated by hand and by NASTRAN to make sure that NASTRAN finds the similar results. A three dimensional model, similar to the one analyzed by the finite element program, will be run on NASTRAN. A comparison will be done between the NASTRAN results and the finite element program results. This study will deal mainly with the aerodynamic loads on the wing and surrounding support structure at an angle attack of 10 degrees.

## 2. 2-DIMENSIONAL MODEL

The purpose of this chapter is to create a two dimensional truss model similar to the Sunburst Ultralight front spar and the three flying wires. The static loads to be used are calculated from the aerodynamic loads at an angle of attack of 10 deg. The resultant element forces will be calculated manually and by use of NASTRAN. From these results, a comparative study will be made between the NASTRAN results the results achieved by manual calculation.

### 2.1 MODEL DESCRIPTION

The purpose of this section is to describe the major assumptions used to create the 2-dimensional model of the Sunburst Ultralight. It is assumed for this analysis that the root beam and the two wire nodes are fixed. The resulting model will be essentially a fixed cantilever beam attached to three truss elements in tension. The following Nodes will be fixed:

Node 1, Front Spar and Root Beam connection
Node 9, Cable end
Node 12, Cable end

Figures 2.1.1 and 2.1.2 show the dimensioned truss and the nodal data for the 2-dimensional model. The following subsections contain the information required for the NASTRAN program to be completed. The Sub-sections contain the following:

Node and Constraint identification
Element Description
Material Description
Wing Loading Calculations

With this information, the resulting NASTRAN program can be run on the University of Kansas VAX system.

SCALE 1" = 30"

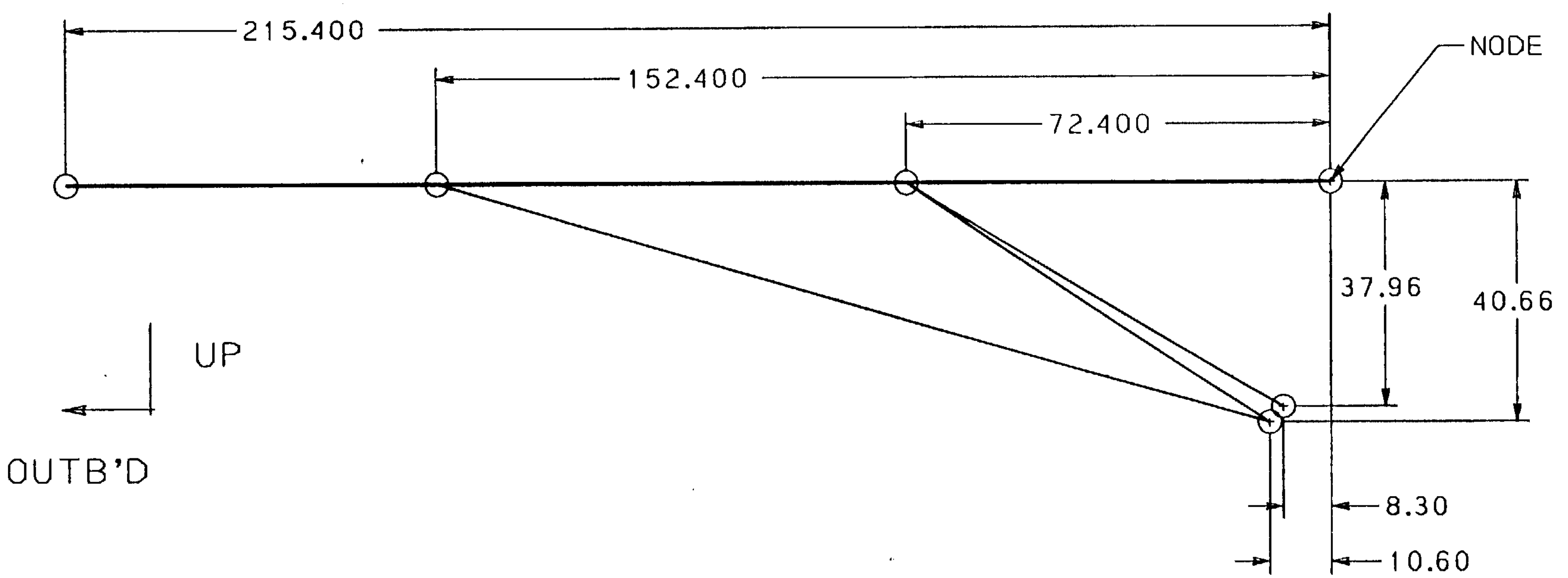


FIGURE 2.1.1: DIMENSIONED TRUSS MODEL

SCALE 1" = 40"

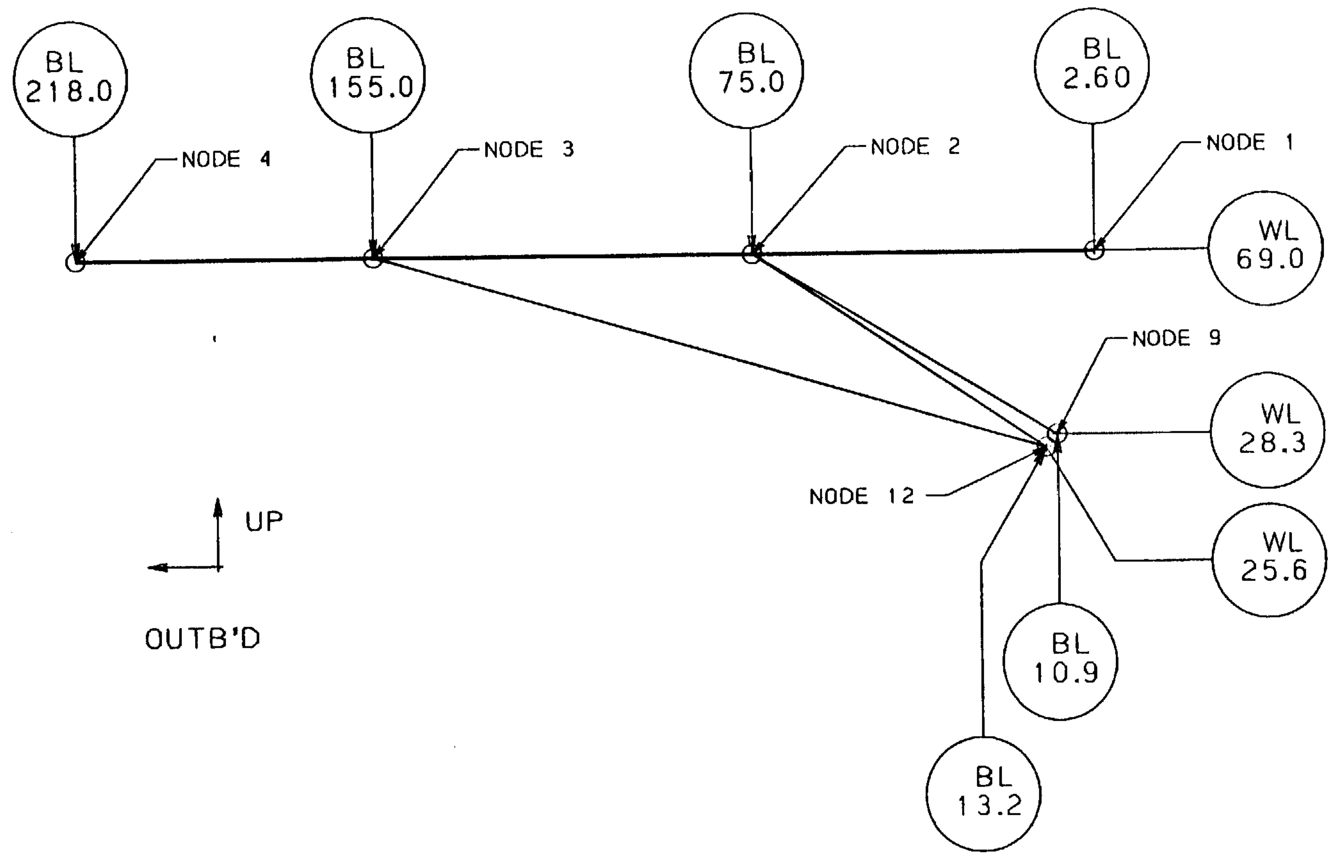


FIGURE 2.1.2: NODAL DATA FOR 2-D TRUSS

### 2.1.1 NODE POINT AND CONSTRAINT DEFINITIONS

The purpose of this section is to identify the grid points used and the constraint at each point. The constraints used by NASTRAN are as follows:

1 = Linearly constrained in the X-direction
2 = Linearly constrained in the Y-direction
3 = Linearly constrained in the Z-direction
4 = Constrained about the X-axis; Ox = 0 deg.
5 = Constrained about the Y-axis; Oy = 0 deg.
6 = Constrained about the Z-axis; Oz = 0 deg.

The following table contains the GRID cards used in the NASTRAN program for the 2-D model. Table 2.1.1 also includes the single point constraints for each point and the GRIDSET card for the default constraints.

**Table 2.1.1: GRID and GRIDSET Cards used in NASTRAN**

| NASTRAN CARD | X (AFT) (IN) | Y (OUTB'D) (IN) | Z (UP) (IN) | CONSTR-AINT |
|---|---|---|---|---|
| GRIDSET | | | | 1,4,5,6 |
| GRID #1 | 0.0 | 2.6 | 66.3 | 123456 |
| " #2 | 0.0 | 75.0 | 66.3 | |
| " #3 | 0.0 | 155.0 | 66.3 | |
| " #9 | 0.0 | 10.9 | 28.3 | 123456 |
| " #12 | 0.0 | 13.2 | 25.6 | 123456 |

### 2.1.2 ELEMENT IDENTIFICATION

The purpose of this section is to identify the elements used in the 3-dimensional NASTRAN model. The following table shows the elements used and their descriptions.

**Table 2.1.2: Element Descriptions**

| ELEMENT NUMBERS (EID) | DESCRIPTION |
|---|---|
| 1,2,3 (Fig.2.1) | Wing Spars; 1.75" Diameter Tubes, t = 0.049" |
| 4,5,6 (Fig.2.1) | Flying Wires;<br>(4) Diameter = 3/32"<br>(5,6) Diameter = 1/8" |

### 2.1.3 ELEMENT MATERIAL IDENTIFICATION

The purpose of this section is identify the materials used for each element of the ultralight model. The tube information is referenced from the ultralight model handbook. The cable information is experimental data taken from the analysis performed by students under the supervision of Dr. Howard W. Smith. The following are the material identifications for each element in the 3-dimensional model and pertinent material information:

Material ID = 1; EID = 1,2,3
6061-T6 Tube,
Spec = WW-T-700/6
Ftu = 42. ksi
Fcy = 34. ksi
Fsy = 27. ksi
E = 9.9+3 ksi
Ec = 10.1+3 ksi
$\mu$ = 0.33
$\omega$ = 0.098 lb/in^3
(Ref. 3, Table 3.6.1.0(b))

Material ID = 2; EID = 4,5
Alloy steel cables,
Experimental Data
Ftu = 864. psi
E = 29.0 +3 Ksi
$\mu$ = 0.33
$\omega$ = 0.283 lb/in^3

The materials used are assumed to be linear, temperature independent, isotropic materials. Therefore, MAT1 cards will be used in the NASTRAN program.

### 2.1.4 WING LOADING AND FORCE CALCULATIONS

The purpose of this section is to determine the forces on the wing nodes which must be equivalent to the wing loading. The wing loading was taken from test data in Reference 1, Table 3.3.2. The table and the calculations used to obtain the forces on the nodes can be found in Appendix A. The following are the results of these calculations:

Node 1, F1 = 56.1 lbs
Node 2, F2 = 55.6 lbs
Node 3, F3 = 30.2 lbs

These forces are considered static and thus Force cards will be used in the NASTRAN program. The forces are considered to act in the vertical, (z) direction.

## 2.2 MANUAL CALCULATION OF RESULTING FORCES AND MOMENTS

The purpose of this section is to calculate the resulting forces at each node for the 2-d model with the static loads. Manual calculations for the 2-dimensional truss model can be found in Appendix B. The following are the resulting element forces and stresses:

ELEMENT AXIAL FORCES AND STRESSES (APPENDIX B);

| ELEMENT | AXIAL FORCE (lbs) | AXIAL STRESS (psi) |
|---|---|---|
| 1-(TUBE) | -186. | 710. (COMP.) |
| 2-(TUBE) | -89.2 | 430. (COMP.) |
| 4-(CABLE) | +94.2 | 13600.(TENSION) |
| 5-(CABLE) | +0.70 | 101. (") |
| 6-(CABLE) | +103. | 8370. (") |

## 2.3 NASTRAN CALCULATION OF RESULTING FORCES AND MOMENTS

The purpose of this section is to use the NASTRAN program to calculate the forces at each node for the 2-D model with the static loads. Appendix C contains the NASRTAN program for two dimensional model to be analyzed. The program was run and the resulting output from NASTRAN can be found in Appendix C, attached separately. The following are the nodal displacements and the element forces calculated by NASTRAN:

NODAL DISPLACEMENTS (APPENDIX E);

| GRID POINT | X (in) | Y (in) | Z (in) |
|---|---|---|---|
| 1,9,12 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | -.00504 | +.0314 |
| 3 | 0.0 | -.00809 | +.173 |

ELEMENT AXIAL FORCES AND STRESSES (APPENDIX E);

| ELEMENT | FORCE (lbs) | AXIAL STRESS | SAFETY MARGIN |
|---|---|---|---|
| 1-(TUBE) | -180.5 | -689. (COMP.) | 4.8 |
| 2-(TUBE) | -98.7 | -377. (COMP.) | 8.9 |
| 4-(CABLE) | 103.2 | 8390. (TENSION) | -0.90 |
| 5-(CABLE) | 65.8 | 5350. (") | -0.84 |
| 6-(CABLE) | 33.2 | 4807. (") | -0.82 |

The displacements of the nodes 2,3 which are wing nodes are physically displacing in the correct direction. The wing, under the wing loading, will move in the up and inboard direction as if it were rotating about the root beam. It can be seen that for the experimentally calculated failure stress of the wire (Ftu = 842. psi) that all the safety margins are negative, as calculated by NASTRAN. This means that the wires are loaded beyond the experimental failure stress.

## 2.4 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this section is to comment on the results of the previous section and give some recommendations on the results.

### 2.4.1 Conclusions

The purpose of this section is to provide a summary of the previous chapter. The following are the element forces calculated manually:

ELEMENT AXIAL FORCES AND STRESSES (APPENDIX B);

| ELEMENT | AXIAL FORCE (lbs) | AXIAL STRESS (psi) |
|---|---|---|
| 1-(TUBE) | -186. | 710. (COMP.) |
| 2-(TUBE) | -89.2 | 430. (COMP.) |
| 4-(CABLE) | +94.2 | 13600.(TENSION) |
| 5-(CABLE) | +0.70 | 101. (") |
| 6-(CABLE) | +103. | 8370. (") |

The following are the forces calculated by use of the NASTRAN program:

ELEMENT AXIAL FORCES AND STRESSES (APPENDIX E);

| ELEMENT | FORCE (lbs) | AXIAL STRESS | SAFETY MARGIN |
|---|---|---|---|
| 1-(TUBE) | -180.5 | -689. (COMP.) | 4.8 |
| 2-(TUBE) | -98.7 | -377. (COMP.) | 8.9 |
| 4-(CABLE) | 103.2 | 8390. (TENSION) | -0.90 |
| 5-(CABLE) | 65.8 | 5350. (") | -0.84 |
| 6-(CABLE) | 33.2 | 4807. (") | -0.82 |

It can be seen that the results of the NASTRAN program and the manual calculations are compatible except for the values calculated for Element 5 and 6. The difference that does exist is due to NASTRAN taking into account the displacements of the wing root (Grid Points 2,3,4). It can be seen that the sum of the forces of elements 5 and 6 almost equals the sum of the same elements calculated by NASTRAN. The manually calculated values for element 5 and 6 must be off by a fraction of each. It is concluded that the NASTRAN program will produce correct results for the 3-dimensional model to be analyzed in Chapter 3.

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### 2.4.2 Recommendations

The purpose of this section is to give recommendations on the results of the chapter. It is recommended that the nodal displacements be included in the hand calculations to compare with the NASTRAN output.

# 3. 3-DIMENSIONAL ULTRALIGHT MODEL

The purpose of this chapter is to create a 3-dimensional ultralight model of the wing and surrounding structure to be used by the NASTRAN program. The forces, moments, and displacements of each node and the element stresses will be calculated by the NASTRAN program. These results are to be compared with those obtained by the finite element method calculated in Reference 1.

## 3.1 MODEL DESCRIPTION

The purpose of this section is to describe the major assumptions used to create the model. It is assumed for this analysis that the root beam is fixed. Therefore, the following nodes will be fixed:

Node 1; Front Spar and Root beam connection
Node 8; Rear Spar and Root beam connection
Node 10; Forward truss attachment point
Node 11; Aft truss attachment point

Nodes 1 and 2, however, are hinge attachments in which the front and rear spar are free to rotate about the Z-axis. This will be dealt with in the single point constraint for nodes 1 and 3. Figure 3.1 to 3.3 show the top views of the model with the Nodes and Elements identified. The figures show the wing internal cables (Fig.3.1), wing flying wires (Fig.3.2), and the truss members (Fig.3.3). Figure 3.4 shows an isometric of the complete model for visual purposes.

The following subsections contain the information required for the NASTRAN program to be completed. The Sub-sections contain the following:

Node and Constraint identification
Element Description
Material Description
Wing Loading Calculations

With the information calculated and identified in these sub-sections the NASTRAN program can be written.

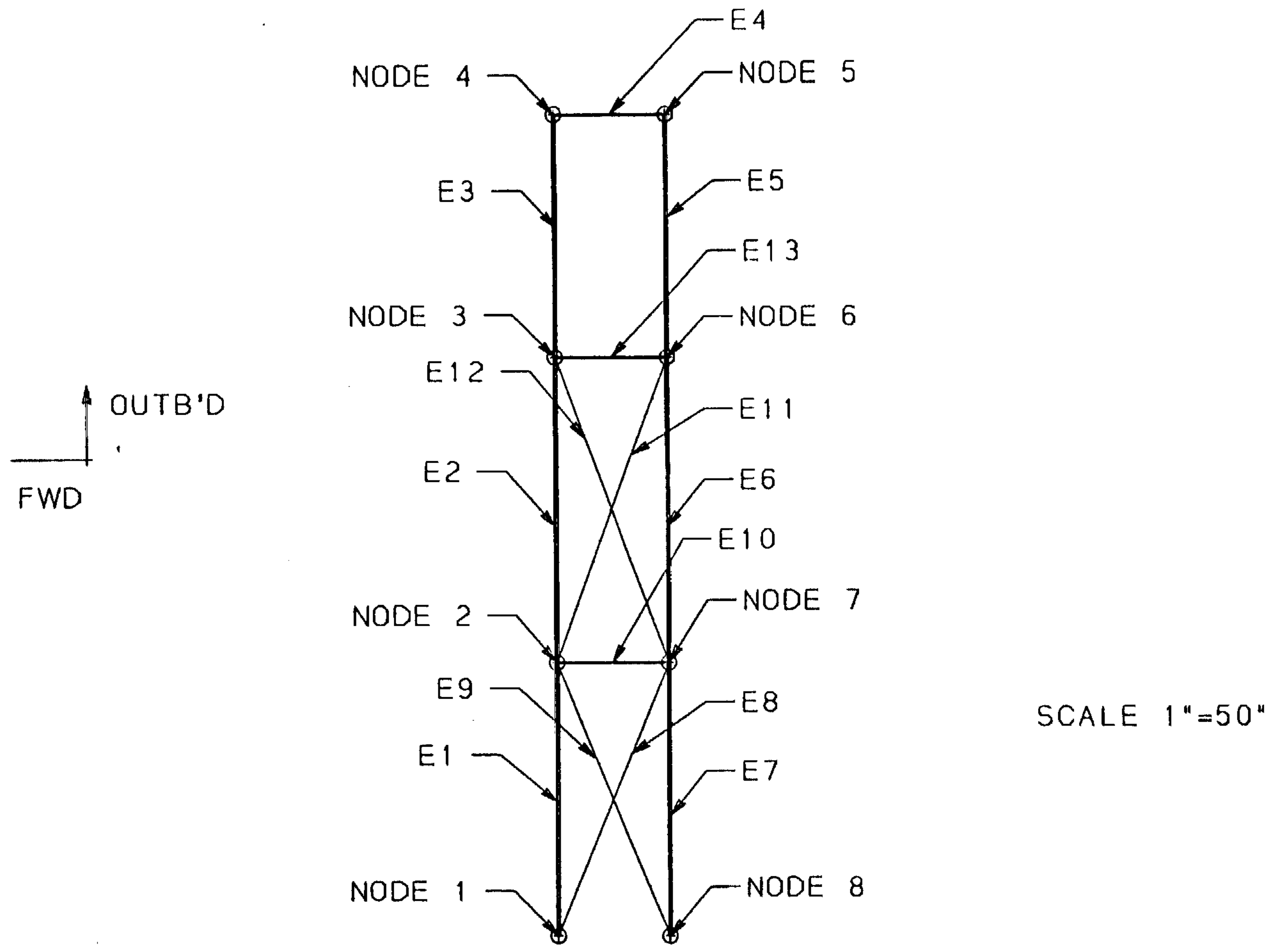


FIGURE 3.1: 3-DIMENSIONAL MODEL OF WING AND INTERNAL WING CABLES

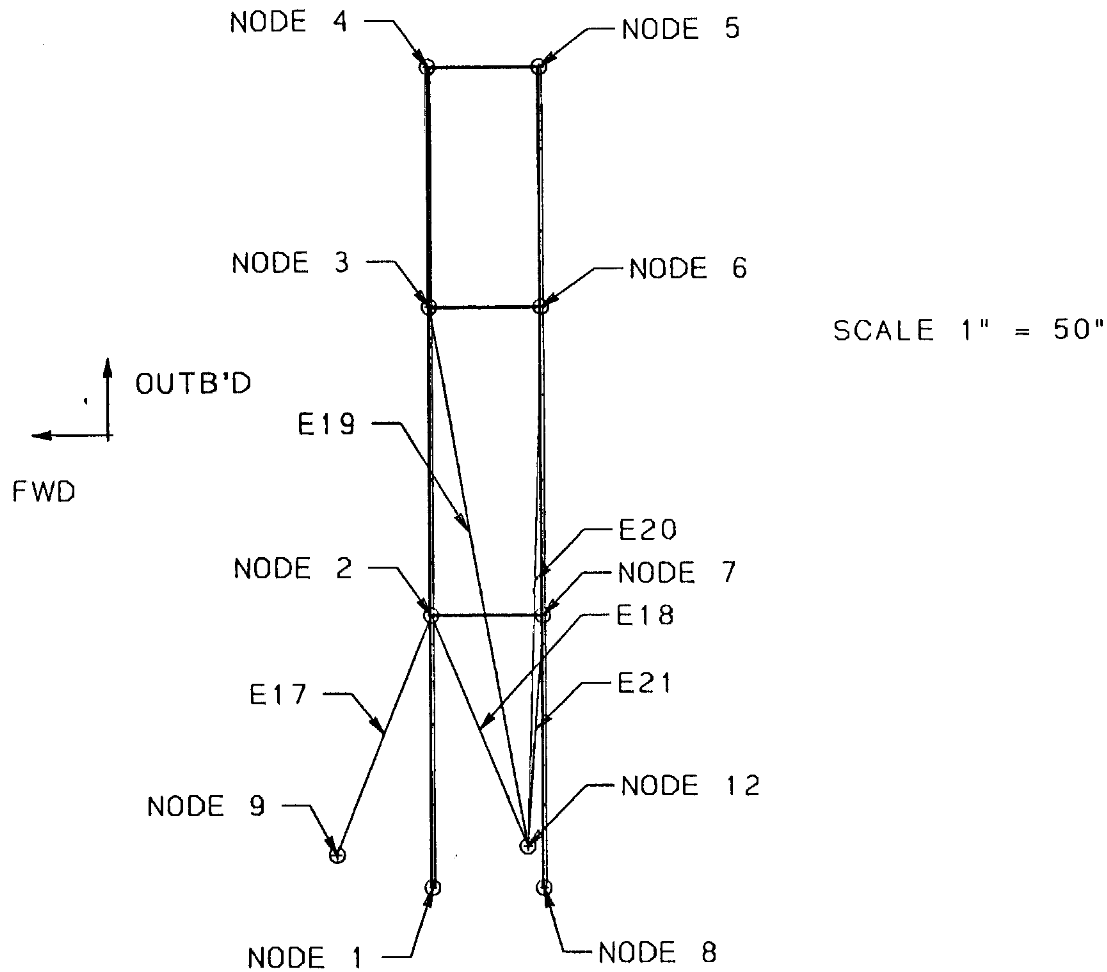


FIGURE 3.2: 3-DIMENSIONAL MODEL OF THE ULTRALIGHT WING
FLYING WIRES; TOP VIEW

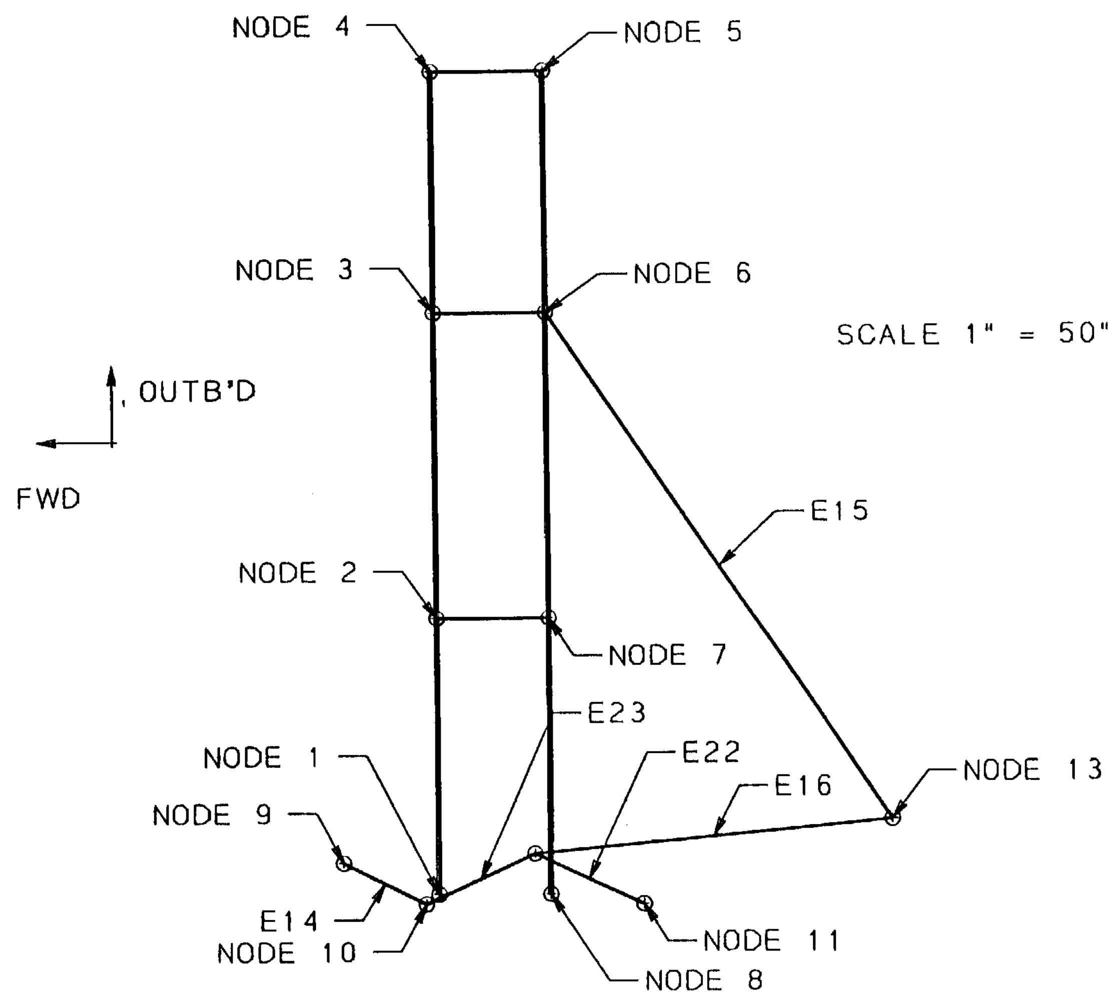

FIGURE 3.3: 3-DIMENSIONAL MODEL OF WING AND SURROUNDING STRUCTURE; TOP VIEW

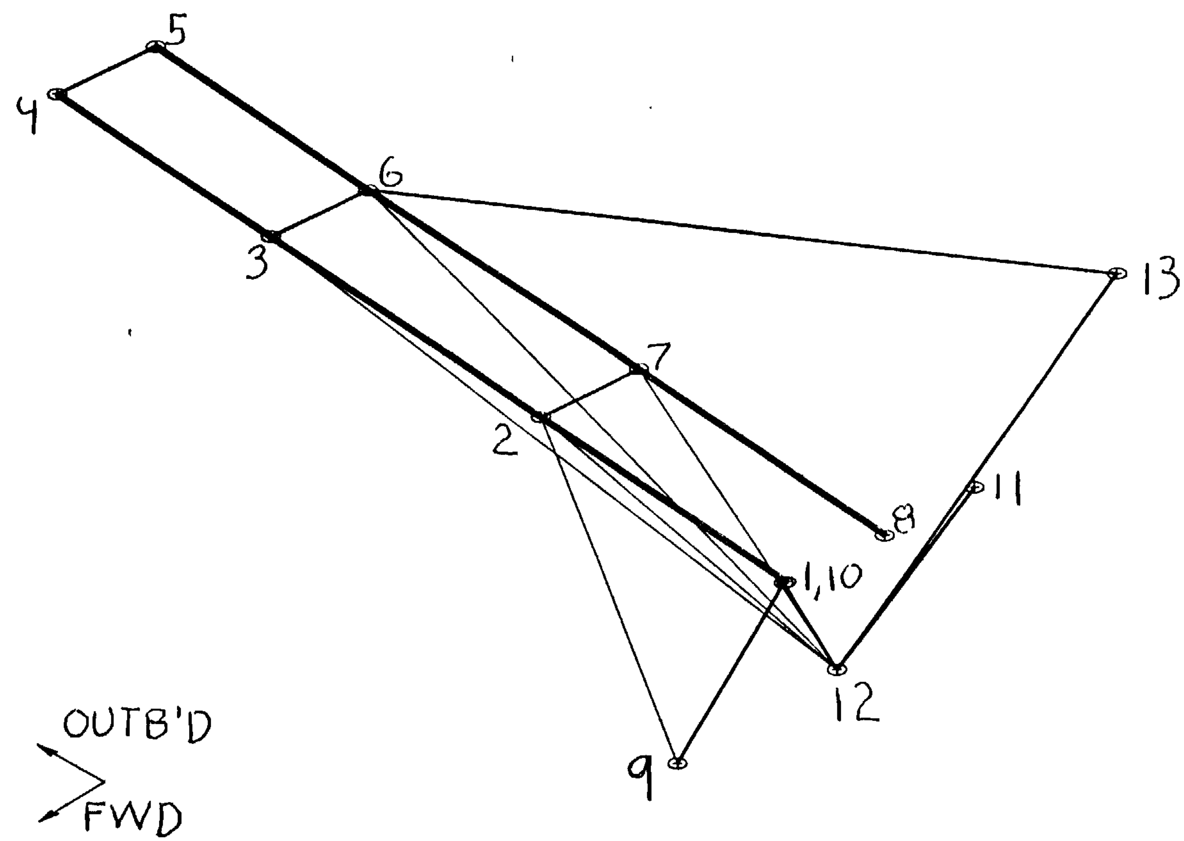


Figure 3.4; Isometric View of 3-D Model

### 3.1.1 NODE POINT AND CONSTRAINT DEFINITIONS

The purpose of this section is to identify the grid points used and the constraint at each point. The constraints used by NASTRAN are as follows:

1 = Linearly constrained in the X-direction
2 = Linearly constrained in the Y-direction
3 = Linearly constrained in the Z-direction
4 = Constrained about the X-axis; Ox = 0 deg.
5 = Constrained about the Y-axis; Oy = 0 deg.
6 = Constrained about the Z-axis; Oz = 0 deg.

The following table contains the GRID cards used in the NASTRAN program for the 3-D model. The table also includes the single point constraints for each point and the GRIDSET card for the default constraints.

**Table 3.1.1: GRID and GRIDSET Cards used in NASTRAN**

| NASTRAN CARD | X (AFT) (IN) | Y (OUTB'D) (IN) | Z (UP) (IN) | CONSTR-AINT |
|---|---|---|---|---|
| GRIDSET | | | | 4,5,6 |
| GRID #1 | 85.49 | 2.6 | 66.3 | 12345 |
| " #2 | 85.49 | 75.0 | 73.2 | |
| " #3 | 85.49 | 155.0 | 80.9 | |
| " #4 | 85.49 | 218.0 | 87.0 | |
| " #5 | 115.0 | 218.0 | 84.0 | |
| " #6 | 115.0 | 155.0 | 77.9 | |
| " #7 | 115.0 | 75.0 | 70.2 | |
| " #8 | 115.0 | 2.6 | 63.0 | 12345 |
| " #9 | 60.39 | 10.9 | 28.3 | |
| " #10 | 82.09 | 0.0 | 69.0 | 123456 |
| " #11 | 139.6 | 0.0 | 64.0 | 123456 |
| " #12 | 110.8 | 13.2 | 25.6 | 2456 |
| " #13 | 205.5 | 22.0 | 74.1 | 2456 |

### 3.1.2 ELEMENT IDENTIFICATION

The purpose of this section is to identify the elements used in the 3-dimensional NASTRAN model. The following table shows the elements used and their descriptions.

**Table 3.1.2: Element Descriptions**

| ELEMENT NUMBERS (EID) | DESCRIPTION |
|---|---|
| 1,2,3,5,6,7 (Fig.3.1) | Wing Spars; 1.75" Diameter Tubes, t = 0.049" |
| 4,10,13 (Fig.3.1) | Wing Ribs; 1.00" Diameter Tubes, t = 0.035 |
| 8,9,11,12 (Fig.3.1) | Wing Internal Cables; 1/8" Diameter |
| 14 (Fig.3.3) | Forward Root Tube Attachment Truss; 1.00" Diameter, t = 0.075" |
| 15,16 (Fig.3.3) | Tail Attachment Truss Tubes; 1.125" Diameter, t = 0.065" |
| 17,18,19,20,21 (Fig.3.2) | Flying Wires; (17) Diameter = 3/32" (18-21) Diameter = 1/8" |
| 22,23 (Fig.3.3) | Aft Root Tube Attachment Truss; 1.00" Diameter t = 0.049" |

### 3.1.3 ELEMENT MATERIAL IDENTIFICATION

The purpose of this section is identify the materials used for each element of the ultralight model. The tube information is referenced from the ultralight model handbook. The cable information is experimental data taken from the analysis performed by students under the supervision of Dr. Howard W. Smith. The following are the material identifications for each element in the 3-dimensional model and pertinent material information:

Material ID = 1; EID = 1-7,10,13,14,15,16,22,23
6061-T6 Tube,
Spec = WW-T-700/6
Ftu = 42. ksi

Fcy = 34. ksi
Fsy = 27. ksi
E = 9.9+3 ksi
Ec = 10.1+3 ksi
$\mu$ = 0.33
$\omega$ = 0.098 lb/in^3
(Ref. 3, Table 3.6.1.0(b))

Material ID = 2; EID = 8,9,11,12,17-21
Alloy steel cables,
Experimental Data (Ftu)
Ftu = 864. psi
E = 29.+6 psi (Ref. 3)
$\mu$ = 0.33 (")
$\omega$ = 0.283 lb/in^3 (")

The materials used are assumed to be linear, temperature independent, isotropic materials. Therefore, MAT1 cards will be used in the NASTRAN program.

### 3.1.4 WING LOADING AND FORCE CALCULATIONS

The purpose of this section is to determine the forces on the wing nodes which must be equivalent to the wing loading. The wing loading was taken from test data in Reference 1, Table 3.3.2. The table and the calculations used to obtain the forces on the nodes can be found in Appendix A. The following are the results of these calculations:

Node 1, F1 = 56.1 lbs
Node 2, F2 = 55.6 lbs
Node 3, F3 = 30.2 lbs
Node 6, F6 = 20.0 lbs
Node 7, F7 = 36.5 lbs
Node 8, F8 = 32.4 lbs

The forces calculated appear to be low. Since these forces are from the information from Reference 1, the results should still be consistent. These forces are considered static and thus Force cards will be used in the NASTRAN program. The forces are considered to act in the vertical, (z) direction.

## 3.2 PROGRAM DESCRIPTION

The purpose of this section is to describe the NASTRAN program created for analyzing the Sunburst Ultralight. The program was written with all the information identified in Section 3.1. The NASTRAN program output can be found in Appendix D.

The program is split up into three sections. The first section is the Executive Control Deck. This deck contains the user identification and administrative information. The second deck is the Case Control Deck. In this deck the codes identifying what type of analysis is to be performed is included. This lets NASTRAN identify what the program wants it to do. The final deck is the Bulk Data Deck. This deck contains all the model information identified in Section 3.1. The program is ready to be submitted at this point.

### 3.3 NASTRAN RESULTS

The purpose of this section is to document the NASTRAN program results. Appendix F contains the NASRTAN program results for the three dimensional NASTRAN model, attached separately. The reader is advised to look at Figure 3.1-2 to help locate visually the grid points and elements. The following are the nodal displacements and the element forces calculated by NASTRAN for the wing and flying wires:

NODAL DISPLACEMENTS;

| GRID POINT | X (in) | Y (in) | Z (in) |
|---|---|---|---|
| 1,8,10,11 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0192 | -0.00747 | 0.0440 |
| 3 | 0.0654 | -0.0281 | 0.232 |
| 6 | 0.0564 | -0.0236 | 0.146 |
| 7 | 0.0196 | -0.0114 | 0.0462 |
| 9 | -0.00184 | 0.0 | 0.0 |
| 12 | -0.00196 | 0.0 | 0.00404 |
| 13 | 0.0722 | 0.0 | -0.137 |

ELEMENT AXIAL FORCES;

| ELEMENT | AXIAL FORCE (lbs) | AXIAL STRESS (psi) | | SAFETY MARGIN |
|---|---|---|---|---|
| 1 (F.S.) | -114. | -436. | (COMP.) | 77. |
| 2 (") | -72.2 | -276. | (") | 120. |
| 6 (R.S.) | -81.8 | -312. | (") | 110. |
| 7 (") | -175. | -668. | (") | 50. |
| 10 (RIB) | +8.21 | +77.4 | (TENSION) | 540. |
| 13 (RIB) | -7.06 | -66.5 | (COMP.) | 510. |
| 14 (TUBE) | -38.3 | -176. | (") | 190. |
| 15 (") | 0.0 | 0.0 | | N/A |
| 16 (") | 0.0 | 0.0 | | N/A |
| 22 (") | -57.7 | -394. | (COMP) | 85. |
| 23 (") | +124. | -844. | (") | 39. |

CABLES;

| | | | | |
|---|---|---|---|---|
| 8 (Internal | SLACK | | | |
| 9 wing) | SLACK | | | |
| 11 | +14.5 | 1179. | (TENSION) | -.28 |
| 12 | SLACK | | | |
| 17 (Flying | +58.6 | 8486. | (TENSION) | -0.90 |
| 18 wires) | +51.8 | 5350. | (") | -0.80 |
| 19 | +112. | 9125. | (") | -0.91 |
| 20 | +72.8 | 5921. | (") | -0.86 |
| 21 | +81.2 | 6603. | (") | -0.87 |

The displacements of the nodes 2,3,6,7 which are wing nodes are physically displacing in the correct direction. The wing, under the wing loading, will move in the up and inboard direction as if it were rotating about the root beam. It can be seen that for the experimentally calculated failure stress of the wires (Ftu = 842. psi) that all the wire safety margins are negative, as calculated by NASTRAN. This means that the Ultralight flying wires, if this model is any indication, will fail in the 10 degree angle attack flight condition, if not before.

It can be seen that the highest cable stress is on Cable Element 19. This cable is the critical cable which will fail first. The cable runs from Node 12 to Node 3 (On Front spar). This can be seen on Figure 3.2. The reason for the high stress level for this wire is the angle at which the cable makes relative to the front spar in the X=0 plane. The force at node three must be countered by a very large cable load for the small angle.

## 3.4 COMPARISON BETWEEN FINITE ELEMENT METHOD RESULTS AND NASTRAN RESULTS

The purpose if this section is to compare the results obtained by the NASTRAN model used in this analysis and those achieved by the use of the Finite Element Method (Ref.1). Due to the different nodes and loading method used, only the cable axial stresses will be compared. The following are the resulting axial stresses for the flying wires calculated by each method:

| NASTRAN (3.3) | | | FINITE ELEMENT (Ref. 1) | | |
|---|---|---|---|---|---|
| ELEMENT | AXIAL FORCE (lbs) | AXIAL STRESS (psi) | ELEMENT | AXIAL FORCE (lbs) | AXIAL STRESS (psi) |
| 17 | +58.6 | 8486. | 34 | +76.7 | 10396. |
| 18 | +51.8 | 5350. | 35 | +44.3 | 3610. |
| 19 | +112. | 9125. | 37 | +222. | 18110. |
| 20 | +72.8 | 5921. | 38 | +145. | 11818. |
| 21 | +81.2 | 6603. | 36 | +65.4 | 5336. |

It can be seen that the values calculated by the finite element method are not very close to those by NASTRAN. This is due to the difference in models and loading scenarios used. The values, however, are comparable in that they follow the same trend. The critical wire is still Element 19 (NASTRAN) or Element 37 (Finite Element).

## 3.5 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this section is to comment on the results of the previous sections and give some recommendations on either the procedures used or the values assumed.

### 3.5.1 Conclusions

The purpose of this section is to provide a summary of the results calculated in this chapter.

It was found that the critical element in the structure is Element 19. This is the flying wire which runs from the pilot cage (Node 12) to the outboard location on the front spar (Node 3). The large force was primarily due to the very low angle that the cable makes relative to the front spar. The axial stress on the cable was much greater than the tested maximum stress of 842. psi (Experimental data from students under Howard W. Smith). From the comparison between the NASTRAN results the Finite Element Program results (Ref. 1), it was shown that Element 19 was critical in both. The values were not the same between both program results, but the calculated values did have common trends.

### 3.5.2 Recommendations

The purpose of this section is to present recommendations on the results obtained in this chapter. It is recommended that the 3-dimensional model be redone using more nodes so that a better idea of the actual stresses in all the elements can be found. A more enhanced model could use quadrilateral elements for the wing with the actual calculated wing loading. This would get much closer results than the concentrated static loads used in this analysis.

# 4. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this chapter is to comment on the results of the major parameters in this report that were to be calculated. Recommendations will also be written about the values obtained and the methodologies used.

## 4.1 Conclusions

The purpose of this section is comment on the results of this report. It was concluded in Chapter 2 that the results of the NASTRAN program and the manual calculations were comparable. The difference that did exist is due to NASTRAN taking into account the displacements of the wing root (Grid Points 2,3,4). It was concluded that the NASTRAN program will produce correct results.

The following are the resulting forces and displacements calculated in Chapter 3 for the 3-dimensional Ultralight Model:

NODAL DISPLACEMENTS;

| GRID POINT | X (in) | Y (in) | Z (in) |
|---|---|---|---|
| 1,8,10,11 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0192 | -0.00747 | 0.0440 |
| 3 | 0.0654 | -0.0281 | 0.232 |
| 6 | 0.0564 | -0.0236 | 0.146 |
| 7 | 0.0196 | -0.0114 | 0.0462 |
| 9 | -0.00184 | 0.0 | 0.0 |
| 12 | -0.00196 | 0.0 | 0.00404 |
| 13 | 0.0722 | 0.0 | -0.137 |

ELEMENT AXIAL FORCES;

| ELEMENT | AXIAL FORCE (lbs) | AXIAL STRESS (psi) | | SAFETY MARGIN |
|---|---|---|---|---|
| 1 (F.S.) | -114. | -436. | (COMP.) | 77. |
| 2 (") | -72.2 | -276. | (") | 120. |
| 6 (R.S.) | -81.8 | -312. | (") | 110. |
| 7 (") | -175. | -668. | (") | 50. |
| 10 (RIB) | +8.21 | +77.4 | (TENSION) | 540. |
| 13 (RIB) | -7.06 | -66.5 | (COMP.) | 510. |
| 14 (TUBE) | -38.3 | -176. | (") | 190. |
| 15 (") | 0.0 | 0.0 | | N/A |
| 16 (") | 0.0 | 0.0 | | N/A |
| 22 (") | -57.7 | -394. | (COMP) | 85. |
| 23 (") | +124. | -844. | (") | 39. |

CABLES;

| | | | | | |
|---|---|---|---|---|---|
| 8 | (Internal | SLACK | | | |
| 9 | wing) | SLACK | | | |
| 11 | | +14.5 | 1179. | (TENSION) | -.28 |
| 12 | | SLACK | | | |
| 17 | (Flying | +58.6 | 8486. | (TENSION) | -0.90 |
| 18 | wires) | +51.8 | 5350. | (") | -0.80 |
| 19 | | +112. | 9125. | (") | -0.91 |
| 20 | | +72.8 | 5921. | (") | -0.86 |
| 21 | | +81.2 | 6603. | (") | -0.87 |

It was found that the critical element in the structure is Element 19. This is the flying wire which runs from the pilot cage (Node 12) to the outboard location on the front spar (Node 3). The large force was primarily due to the very low angle that the cable makes relative to the front spar. The axial stress on the cable was much larger than the tested maximum stress of 842. psi (Experimental data from students under Howard W. Smith).

From the comparison between the NASTRAN results the Finite Element Program results (Ref. 1), it was found that Element 19 was critical in both. The cable stress values were not the same between the two program results, but the calculated values had common trends.

As a result of the analysis performed in this report it is concluded that the Ultralight Airmass Sunburst is unsafe. The outboard flying wire (Element 19) will fail due to the critically low angle it makes with the front spar.

## 4.2 Recommendations

The purpose of this section is to present recommendations on the results of this report. It is recommended that the nodal displacements be included in the hand calculations to obtain the same results. It is recommended that the 3-dimensional model be reworked using quadrilateral elements for the wing with the actual calculated wing loadings used. This would get much closer results than the concentrated static loads used in this analysis.

## 5. REFERENCES

1.) Muller de Almeida, Sergio F., Aerodynamic and Structural Analysis of an Ultralight Aircraft, May 6,1986.

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3.) Smith, Howard W. Phd., Aerospace Materials and Processes, The University of Kansas, January 1978.

4.) MCS/NASTRAN, Version 6.6.

5.) MCS/NASTRAN, Handbook of Linear Analysis.