AE 421 Final Design Project

Antarctic Explorer UAV Preliminary Design Report

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Component Design

1.0 WING Design

Vhy 10 pt font, nd such large nargins? I guess here is plenty of oom for me to omment over ere.

The following information of this section contains the current conceptual design and configuration summary for the wing of the Antarctic Explorer unmanned air vehicle. The wing skeletal structure is comprised of one type of material, which has been used over many years for aircraft construction, and that is 2024-T3 aluminum.

The wing was modeled using a computer aided drafting program called Unigraphics NX. Below is a screenshot of the wing concept proposed for this report.

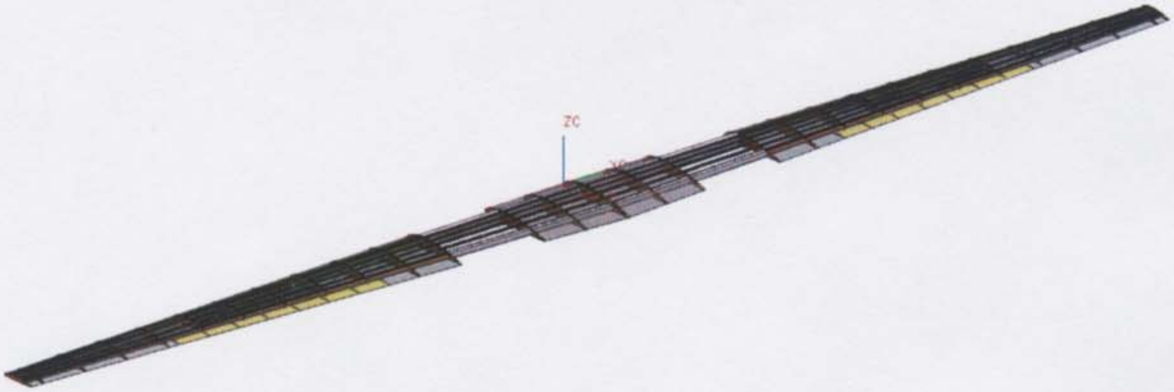


Figure 1.1 Tri-Metric View of the Antarctic Explorer UAV Wing

The structural implementation and integration of the wing to the rest of the aircraft is crucial as well as its performance parameters considering that it is the main lifting surface responsible for producing flight for the aircraft. The reason for the gap in the skins in the figure above is because they represent where the boom is integrated to the wing. The following table lists some of the general wing geometric characteristics.

Table 1.1 General Wing Characteristics

Wing Span (in)	Surface Area (in^2)	Aspect Ratio (~)	Taper Ratio (~)	LE Sweep (deg)	TE Sweep (deg)
430.32	9243.3	20	0.398	1.23	3.68

As can be seen from the figures in the table above, the wing concept introduces a very large aspect ratio (meaning a long and slender wing). From a flight performance point of view, the large aspect ratio allows for an increased value of lift as well as decreased value of induced drag (as well as overall drag). Because the ratio of lift to drag is on the higher end, the thrust (and therefore power) required to maintain flight is not nearly as high as it would be if the aspect ratio were lower. Thus, the amount of fuel required is not as high as compared to other types of aircraft of similar configuration but lower aspect ratios. Also, the increased amount in lift results in a lower stall speed at which the aircraft can fly at. This is an important parameter to meet for a UAV such as this. The concept of the vehicle centers around reconnaissance within the Antarctic (but is not limited to it), so a slower stall speed allows for being able to obtain increased resolution in autonomous imagery and produce and receive more fined-tuned signals for remote sensing (if needed).

Though the wing is nearly optimal for many performance characteristics (more advantages are discussed later in this section), the structural arrangement of it requires enough stiffness and resilience to withstand an assumed 3g loading at full weight of 1607 lbs (tips deflected up) from pressure distributions acting over the wing in flight as well as an assumed 1.5g loading (tips deflected down) from wind gusts. Due to its long and slender characteristics, the bending stress near the root of the wing connection to the boom is fairly high. The initial design, which is presented here and was originally based off of an analysis done in the AE 507 class in Fall of 2003 at the University of Kansas, was recently found to be too small structurally for skin, stringer, and spar cap sizes based on an analysis done on the wing in the AE 508 class at the University of Kansas of Spring 2004. This was due to sizing reductions of forward and aft spar height and overall wing torque box depth from one analysis to the next. Therefore, a second design iteration was done based on changing components and re-evaluating the weight of the wing. Actual drawing implementations were not completed in the integrated CAD model drawing for this due to time restraints. Yet, the second iterated design configuration is presented along with a weight analysis for the structural arrangement.of the wing. An important aspect to note is that the configuration used in the AE 508 class was slightly different based on stringer positions and aft spar cap position as well as rib placement and materials. Because of this, the AE 508 analysis cannot be taken as 100% accurate for the preliminary design presented for the wing in this report, but it is a good standard to base off of. Assuming the analysis within a 20% margin of error relative to this design, it is believed that the second iteration used for the wing design along with an innovative design for the wing-to-boom connection will keep the wing structurally sound having all positive margins of safety. Actual structural analysis would have to be preformed on the design, and this shall be left up to the structural analysis engineers of this project.

One interesting aspect to be noted about the wing design is that there is no need for flaps, only ailerons. One reason for this relates back to the high aspect ratio of the wing. Yet another reason has to do with the overall smaller relative size of the aircraft. The aileron also has a high aspect ratio, as it spans from 40% to 75% of the half-wing span location with its leading edge beginning at 80% of the airfoil cross-sectional cuts of the wing. This can be seen in the close-up view in the figure below.

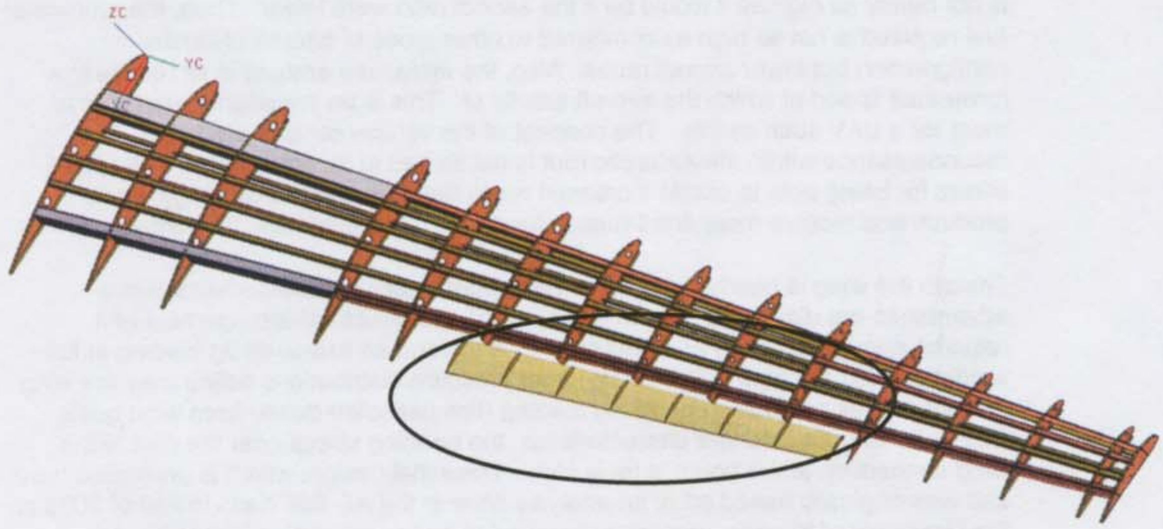


Figure 1.2 Aileron's Sizing Relative to the Wing Half-Span

In order to begin a generic concept design, a wing is generally sectioned into various parts and designed by each part. For this design, the wing was sectioned into three areas: an inboard, midboard, and outboard section. The section divide lines are bounded by rib locations throughout the wing. There are a total of 14 ribs in the wing spaced 15 inches apart (except for at the boom-to-wing intersection) and an end cap located at the wing tip. The airfoil used for the wing is depicted in the figure below.

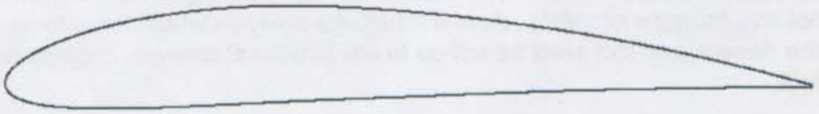
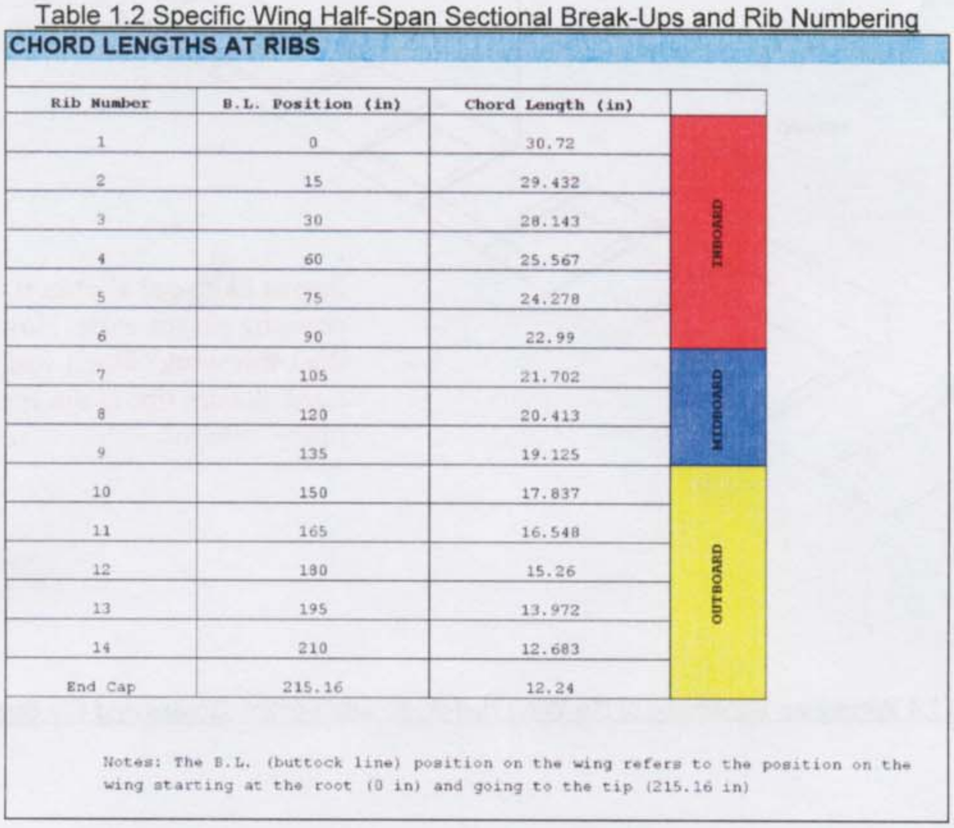


Figure 1.3 Wing Section Airfoil used for Preliminary Design (NACA 4412 Airfoil)

The following table depicts the specific section breaks as well as rib locations on the wing half span.

Table 1.2 Specific Wing Half-Span Sectional Break-Ups and Rib Numbering

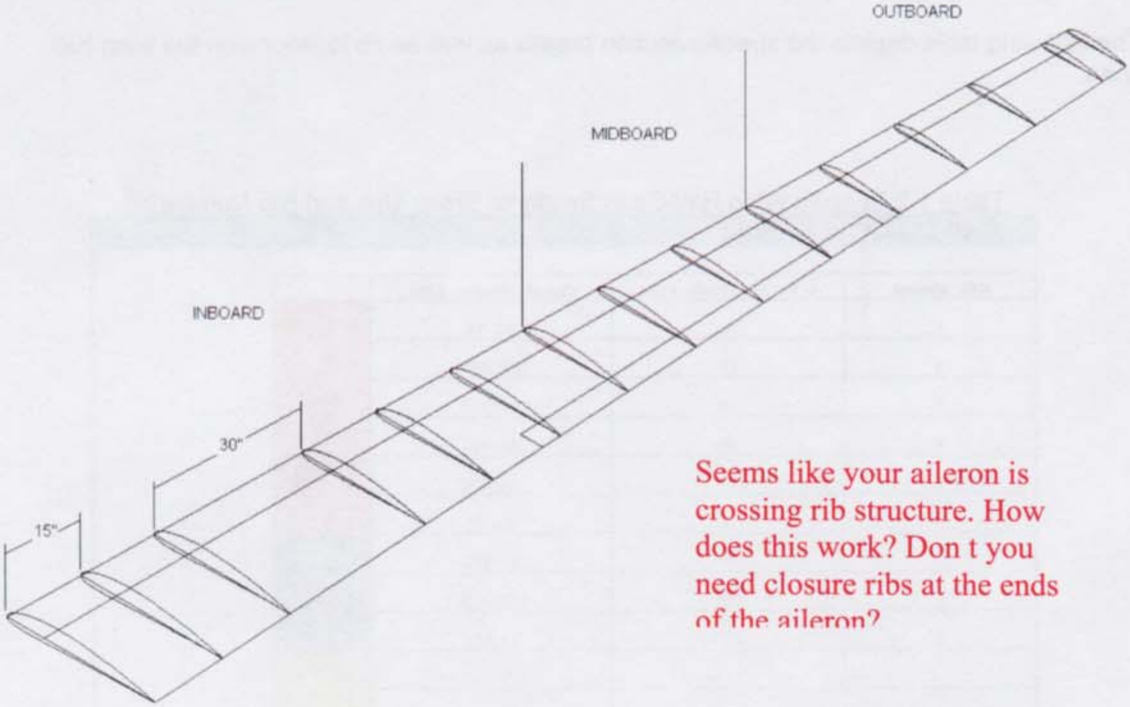


CHORD LENGTHS AT RIBS

Rib Number	B.L. Position (in)	Chord Length (in)	
1	0	30.72	INBOARD
2	15	29.432	
3	30	28.143	
4	60	25.567	
5	75	24.278	
6	90	22.99	
7	105	21.702	MIDBOARD
8	120	20.413	
9	135	19.125	
10	150	17.837	OUTBOARD
11	165	16.548	
12	180	15.26	
13	195	13.972	
14	210	12.683	
End Cap	215.16	12.24	

Notes: The B.L. (buttock line) position on the wing refers to the position on the wing starting at the root (0 in) and going to the tip (215.16 in)

Are you implying the need for 0.001 tolerance in chord length? Is this necessary? Can you afford it? Can you achieve it? Are skins continuous between ribs 3&4? This is a large unsupported length, even if within boom.

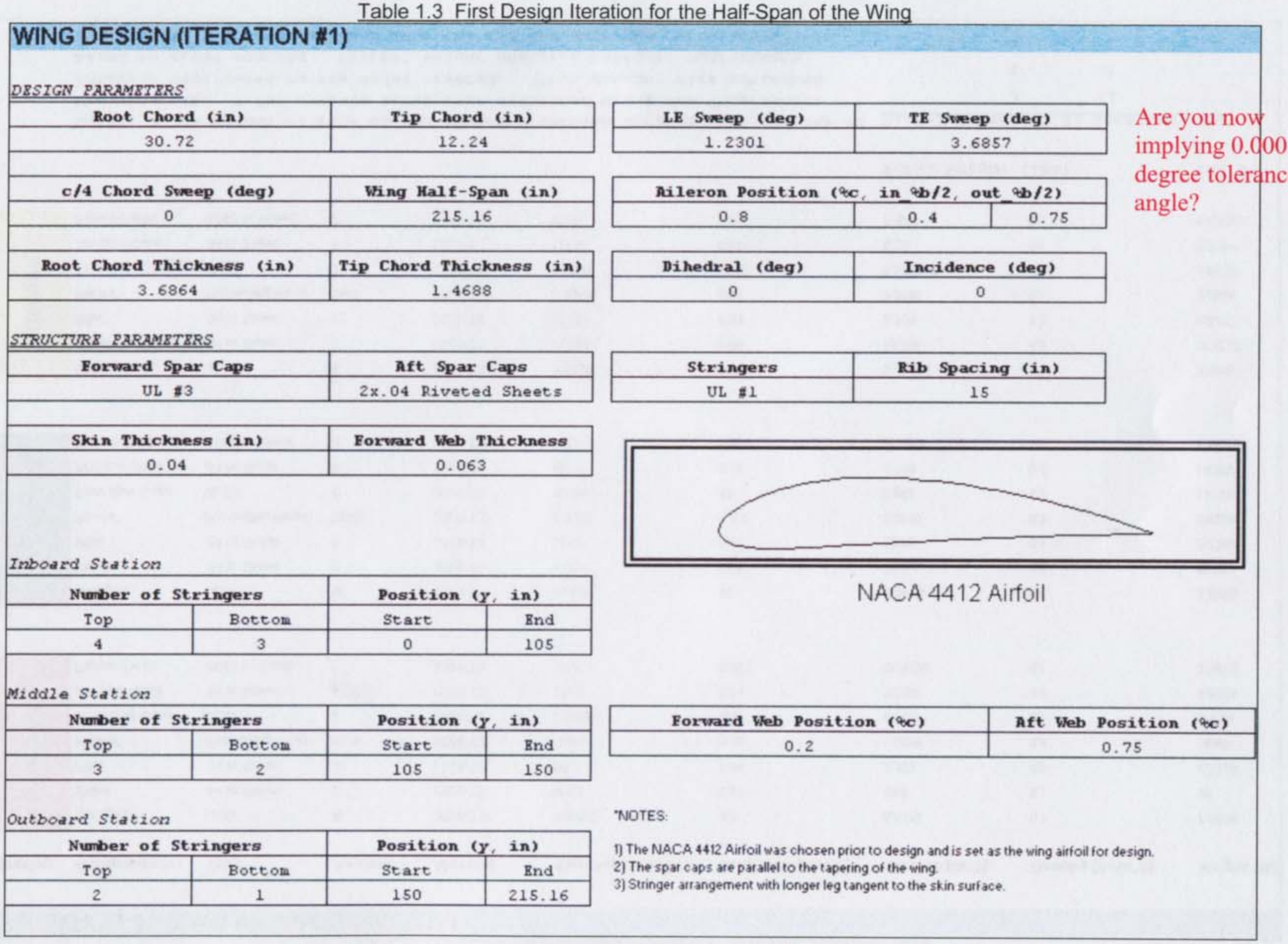


Seems like your aileron is crossing rib structure. How does this work? Don t you need closure ribs at the ends of the aileron?

Figure 1.4 Wireframe Schematic of the Wing Half-Span with Section Breaks and Rib Spacing

The following pages give a generic description of the general characteristics of the wing, its lifting surfaces (ailerons), and numbers for the skeletal structure arrangement of the wing. Both design iterations are given. NOTE: *The configuration summary of this report is based on conceptual design of iteration #1!*

Table 1.3 First Design Iteration for the Half-Span of the Wing



WING DESIGN (ITERATION #1)

DESIGN PARAMETERS

Root Chord (in)	Tip Chord (in)
30.72	12.24

LE Sweep (deg)	TE Sweep (deg)
1.2301	3.6857

Are you now implying 0.0001 degree tolerance on angle?

c/4 Chord Sweep (deg)	Wing Half-Span (in)
0	215.16

Aileron Position (%c, in_%b/2, out_%b/2)		
0.8	0.4	0.75

Root Chord Thickness (in)	Tip Chord Thickness (in)
3.6864	1.4688

Dihedral (deg)	Incidence (deg)
0	0

STRUCTURE PARAMETERS

Forward Spar Caps	Aft Spar Caps
UL #3	2x.04 Riveted Sheets

Stringers	Rib Spacing (in)
UL #1	15

Skin Thickness (in)	Forward Web Thickness
0.04	0.063

NACA 4412 Airfoil

Inboard Station

Number of Stringers		Position (y, in)	
Top	Bottom	Start	End
4	3	0	105

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Middle Station

Number of Stringers		Position (y, in)	
Top	Bottom	Start	End
3	2	105	150

Forward Web Position (%c)	Aft Web Position (%c)
0.2	0.75

Outboard Station

Number of Stringers		Position (y, in)	
Top	Bottom	Start	End
2	1	150	215.16

*NOTES:

1) The NACA 4412 Airfoil was chosen prior to design and is set as the wing airfoil for design.
2) The spar caps are parallel to the tapering of the wing.
3) Stringer arrangement with longer leg tangent to the skin surface.

Very nice.

Table 1.4 First Design Iteration Weight Analysis for the Full Wing

ITERATION #1 WING WEIGHT ANALYSIS

Section	Components	Type	Amount	Material	Avg. Area* (in^2)	Length/Depth (in)	Volume (in^3)	Density (lb/in^3)	Weight (lb)
Inboard	Stringers	UL#1	14	2024-T3	0.0535	105	5.6175	0.1	7.8645
	Skins	.04 in. Sheet	2	2024-T3	6000	0.04	240	0.1	48
	Ribs	.04 in. Sheet	12	2024-T3	56.3	0.04	2.252	0.1	2.7024
	Rivets*	Protruding Head	9328	2024-T31	0.0069	0.22	0.0015	0.1	1.4166
	Fore Spar Caps	UL#3	4	2024-T3	0.0818	105	8.589	0.1	3.4356
	Aft Spar Caps	.04 in. Sheet	4	2024-T3	281.4	0.04	11.256	0.1	4.5024
	Forward Web	0.063 in. Sheet	2	2024-T3	316.5	0.063	19.9395	0.1	3.9879
Midboard	Stringers	UL#1	10	2024-T3	0.0535	45	2.4075	0.1	2.4075
	Skins	.04 in. Sheet	2	2024-T3	1935	0.04	77.4	0.1	15.48
	Ribs	.04 in. Sheet	6	2024-T3	30.8	0.04	1.232	0.1	0.7392
	Rivets*	Protruding Head	3960	2024-T31	0.0069	0.22	0.0015	0.1	0.6014
	Fore Spar Caps	UL#3	4	2024-T3	0.0818	45	3.681	0.1	1.4724
	Aft Spar Caps	.04 in. Sheet	4	2024-T3	101.9	0.04	4.076	0.1	1.6304
	Forward Web	0.063 in. Sheet	2	2024-T3	102.3	0.063	6.4449	0.1	1.28898
Outboard	Stringers	UL#1	6	2024-T3	0.0535	65.16	3.48606	0.1	2.0916
	Skins	.04 in. Sheet	2	2024-T3	2215.4	0.04	88.616	0.1	17.7232
	Ribs*	.04 in. Sheet	12	2024-T3	17.65	0.04	0.706	0.1	0.8472
	Rivets*	Protruding Head	5680	2024-T31	0.0069	0.22	0.0015	0.1	0.8626
	Fore Spar Caps	UL#3	4	2024-T3	0.0818	65.16	5.330088	0.1	2.1320
	Aft Spar Caps	.04 in. Sheet	4	2024-T3	127.9	0.04	5.116	0.1	2.0464
	Forward Web	0.063 in. Sheet	2	2024-T3	112.7	0.063	7.1001	0.1	1.42002
							Total Weight (lbs)		122.65

NOTES: * The amount of ribs on the outboard section includes the end cap on the wing tip. * The average areas were collected using the Unigraphics Analysis tool based on the model created. Rivet amounts were estimated based on rivet spacing. Overall weight analysis based on approximate estimations. Aileron assumed into the mid and outboard calculations.

Global Approx. C.G. Location (in)

x	11
y	0
z	1

Table 1.5 Second Design Iteration for the Half-Span of the Wing

WING DESIGN (ITERATION #2)

DESIGN PARAMETERS

Root Chord (in)	Tip Chord (in)
30.72	12.24

LE Sweep (deg)	TE Sweep (deg)
1.2301	3.6857

c/4 Chord Sweep (deg)	Wing Half-Span (in)
0	215.16

Aileron Position (%c, in_%b/2, out_%b/2)		
0.8	0.4	0.75

Root Chord Thickness (in)	Tip Chord Thickness (in)
3.6864	1.4688

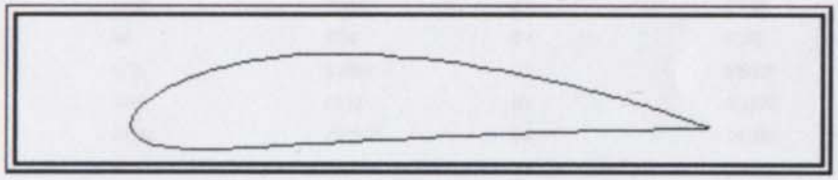
Dihedral (deg)	Incidence (deg)
0	0

STRUCTURE PARAMETERS

Forward Spar Caps	Aft Spar Caps
UL #6	2x.05 Riveted Sheets

Stringers	Rib Spacing (in)
UL #3	15

Skin Thickness (in)	Forward Web Thickness
0.063	0.063



NACA 4412 Airfoil

Inboard Station

Number of Stringers		Position (y, in)	
Top	Bottom	Start	End
4	3	0	105

Middle Station

Number of Stringers		Position (y, in)	
Top	Bottom	Start	End
3	2	105	150

Forward Web Position (%c)	Aft Web Position (%c)
0.2	0.75

Outboard Station

Number of Stringers		Position (y, in)	
Top	Bottom	Start	End
2	1	150	215.16

'NOTES:

1) The NACA 4412 Airfoil was chosen prior to design and is set as the wing airfoil for design.
2) The spar caps are parallel to the tapering of the wing.
3) Stringer arrangement with longer leg tangent to the skin surface.

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Table 1.6 Second Design Iteration Weight Analysis for the Full Wing

ITERATION #2 WING WEIGHT ANALYSIS

Section	Components	Type	Amount	Material	Avg. Area* (in^2)	Length/Depth (in)	Volume (in^3)	Density (lb/in^3)	Weight (lb)
Inboard	Stringers	UL#3	14	2024-T3	0.0818	105	8.589	0.1	12.0246
	Skins	.063 in. Sheet	2	2024-T3	6000	0.063	378	0.1	75.6
	Ribs	.04 in. Sheet	12	2024-T3	56.3	0.04	2.252	0.1	2.7024
	Rivets*	Protruding Head	9328	2024-T31	0.0069	0.22	0.0015	0.1	1.4166
	Fore Spar Caps	UL#6	4	2024-T3	0.184	105	19.32	0.1	7.728
	Aft Spar Caps	.05 in. Sheet	4	2024-T3	281.4	0.05	14.07	0.1	5.628
	Forward Web	0.063 in. Sheet	2	2024-T3	316.5	0.063	19.9395	0.1	3.9879
Midboard	Stringers	UL#3	10	2024-T3	0.0818	45	3.681	0.1	3.6810
	Skins	.063 in. Sheet	2	2024-T3	1935	0.063	121.905	0.1	24.381
	Ribs	.04 in. Sheet	6	2024-T3	30.8	0.04	1.232	0.1	0.7392
	Rivets*	Protruding Head	3960	2024-T31	0.0069	0.22	0.0015	0.1	0.6014
	Fore Spar Caps	UL#6	4	2024-T3	0.184	45	8.28	0.1	3.312
	Aft Spar Caps	.05 in. Sheet	4	2024-T3	101.9	0.05	5.095	0.1	2.038
	Forward Web	0.063 in. Sheet	2	2024-T3	102.3	0.063	6.4449	0.1	1.28898
Outboard	Stringers	UL#3	6	2024-T3	0.0818	65.16	5.330088	0.1	3.1981
	Skins	.063 in. Sheet	2	2024-T3	2215.4	0.063	139.5702	0.1	27.91404
	Ribs*	.04 in. Sheet	12	2024-T3	17.65	0.04	0.706	0.1	0.8472
	Rivets*	Protruding Head	5680	2024-T31	0.0069	0.22	0.0015	0.1	0.8626
	Fore Spar Caps	UL#6	4	2024-T3	0.184	65.16	11.98944	0.1	4.7958
	Aft Spar Caps	.05 in. Sheet	4	2024-T3	127.9	0.05	6.395	0.1	2.558
	Forward Web	0.063 in. Sheet	2	2024-T3	112.7	0.063	7.1001	0.1	1.42002
							Total Weight (lbs)		186.72

NOTES: * The amount of ribs on the outboard section includes the end cap on the wing tip. * The average areas were collected using the Unigraphics Analysis tool based on the model created. Rivet amounts were estimated based on rivet spacing. Overall weight analysis based on approximate estimations. Aileron assumed into the mid and outboard calculations.

Global Approx. C.G. Location (in)

x	10
y	0
z	0.8

In the next section, one will find the configuration summary of the wing design split into the following parts:

- Spars & Stringers
- Ribs
- Skins & Access
- Wing/Boom connection

a. SPARS

Iow can you be he primary tructure, and the ailsafe or edundant tructure?

Spars are the main internal structure of the wing and are meant to act as the fail-safe if other structure within the wing does not survive. They are generally comprised of either extrusions (called spar caps) with a sheet of metal with certain thickness (called a web), I-beams contoured to the shape of the wing sectional airfoil, or folded sheet metal contoured for the wing airfoil design and riveted together. There are two spars located within a wing – one forward and one aft relative to the aircraft wing and flight direction. (this is not your only option – and I suspect three may be preferred here)

1. Constraints

The airfoil used for the wing of this aircraft is a NACA 4412. The importance of that number designation is that the deepest that the cross-section of the wing ever gets is 12% of the chord length. This means that at the root, where the chord length is 30.72 inches, the deepest thickness it gets is 3.69 inches and at the tip, where the chord length is 12.24 inches, the deepest thickness it gets is only 1.47 inches. As was seen from the table for the first design iteration, the forward and aft spar positions are placed at the 20% and 75% chord positions, relatively. This corresponds to thicknesses of 11.5% and 6.4% of the chord, relatively, at their respective locations. This means that at the tip, the forward spar cap extrusions must fit within a 1.40 inch depth and the aft spar caps must fit within a .79 inch depth. Also, everything that is manufactured must be able to be manufactured at the University of Kansas.

2. Concept/Layout

Based on other aircraft design, it was chosen that the web positions of the forward and aft spars be located at the 20% chord line and 75% chord line, respectively. The placement of the aft spar relative to its chord-line percentage was to ensure that it would not interfere with the aileron or its control lines running inside of the wing.

ou re just crazy or these little lauses it was lecided or it was hosen. You tend o enter and end aragraphs with hem rather than nerely stating your lesign.

3. Sizing

Based on the constraints given above, it was decided that the forward spar caps (top and bottom) would be UL#3 extrusions in order to fit in at the wing tip location without interfering with one another and that the web thickness would be a 0.063 inch sheet of aluminum (in iteration #2, the design asks for UL#6 extrusions, which in fact would interfere with one another and would therefore have to be milled down in order to fit within the wing near the tip). Below gives the general schematic of the UL#3 extrusion with dimensions. (The figure below…)

Inches I presume? What tolerances are acceptable?

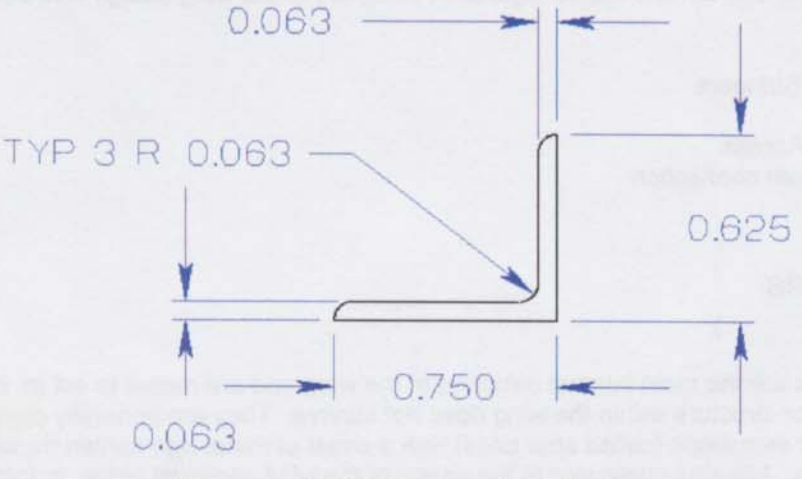

Figure 1.5 UL#3 Extrusion Cross-Section

The orientation of the longer leg of the extrusion mounts flush with the top and bottom skins of the wing and the web spans a height of 11.5% of the local chord line and is attached flush to the shorter leg faces of the UL#3 extrusions. Below shows the overall size of the web and the next figure shows the cross section of the web with the spar caps. Note that the web size does not extend the full length of the wing half span. The reason for this is because the spars are replaced with a different type of extrusion used for the wing-to-boom connection starting at the outer side of the boom and moving inboard. The actual connection and size arrangement will be discussed under the 'Wing/Boom Connection' section.

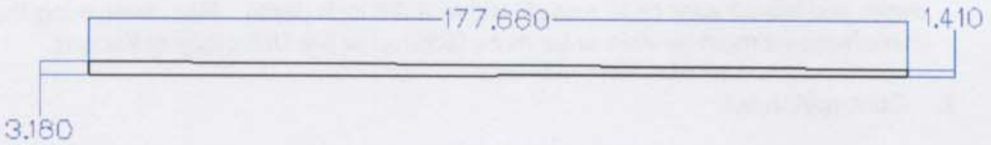

Figure 1.6 Forward Spar Web with Dimensions

Without arrowheads, at this scale, this took a moment to absorb

What is gap
between
spar cap
and skin
along
curved
airfoil?

Figure 1.7 Cross-Sectional Schematic of Forward Spar

One problem dealing with extrusions is that they come in certain length sections. It is assumed that the extrusion lengths obtainable for the University of Kansas are 8 ft. in length. With this in mind, it means that the spar extrusions must be spliced together so that the structure acts as one continuous member.

The idea for splicing the separate spar cap extrusions together is presented on the next page.
The principal idea behind splicing together the spar cap extrusions is backed by the attempt in creating a continuous spar cap. It is believed that the design shown below would help in simulating this and actually provide in structural support and rigidity.