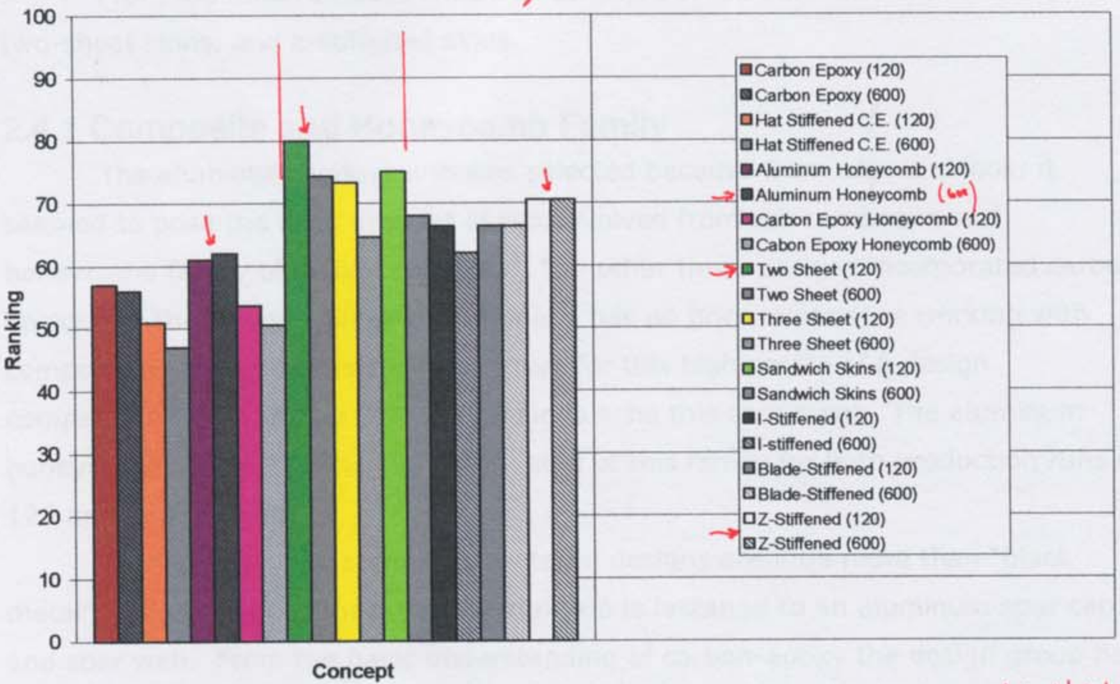
2.3 Evaluation of All Concepts

EASY TO DISTINGUISH RELATIVE PERFORMANCE, WHICH IS GOOD, BUT THEN YOU TELL ME THAT COMPARISONS SHOULD NOT BE CONSIDERED ACCURATE



IS HIGHER BETTER?

Figure 2.1 Evaluation of All Concepts

The ratings are based on a 100-point scale. In the case where a category was not applicable, (i.e. no die used in carbon epoxy honeycomb skins) the points for that category were left out and the score was scaled to a 100-point scale.

In figure 2.1 the red tones are the composites and honeycombs, the greens are the layered skins, and the blacks are the stiffened aluminum. Since the ratings are subjective, comparisons between families should not be considered accurate. Although team-wide discussion was held for each design concept, a different team member was responsible for rating each family of design concepts.

THESE SHOULD HAVE BEEN ADJUSTED BY COMMITTEE SUCH THAT THEY WERE UNIFORM. WERE ADJUSTMENTS MADE WITHIN EACH FAMILY? DO EACH REPRESENT ONE PERSONS JUDGMENT?

The actual ratings for each concept can be found in appendix B of this report.

NOTE: I'M LOOKING FOR INSIGHT ON HOW AND WHY YOU RATED CATEGORIES.

2.4 Selection of Three Best Concepts

From the initial evaluation, three concepts stood out: aluminum honeycomb, two-sheet skins, and z-stiffened skins.

2.4.1 Composite and Honeycomb Family

The aluminum honeycomb was selected because from an initial look, it seemed to pose the least amount of risk involved from the composite and honeycomb family of design concepts. The other three designs incorporated carbon-epoxy into the design. Since the company has no prior experience working with composite material the risk was too great for this high profile of a design competition. From figure 2.1, the rankings echo this sentiment. The aluminum honeycomb design has the highest ranking of this family for both production runs of 120 and 600 per year.

Furthermore, the composite material designs are little more than "black metal" designs. The composite material skin is fastened to an aluminum spar cap and spar web. From the basic understanding of carbon-epoxy the design group has, this is bad design. Also, due to corrosion concerns, carbon and aluminum should not be in contact with one another. Mere surface contact will cause galvanic corrosion and weaken the strength of the material. (which?) This means that either the spar caps that are in contact with the carbon-epoxy skin should be changed to a different metal like titanium or have a special coating added to the surface to act as a buffer between the two incompatible materials.

Composites do not carry loads in the same way as metals do. Composites like carbon-epoxy have excellent in-plane strength, but have very low through the thickness strength. This means the method by which ~~that~~ the skins are attached to the spars must be considered carefully. Fasteners such as rivets or bolts are not good options as they will induce point loads through the thickness of the skins. The only apparent fastening method is bonding. The aluminum and composite honeycomb concepts offer similar weights, but the acquisition cost of the carbon epoxy materials is higher than that of the aluminum.

TRUE IN SPIRIT – THOUGH WE DO USE FASTENERS IN COMPOSITES WITH DUE CONSIDERATION.

WHAT ABOUT LCC?
FATIGUE, CORROSION . . .

2.4.2 Layers Skins Family

From the layered skins family the two-sheet skin is the preferred manufacturing concept. The two-sheet skin was viewed as a less complex version of the three-sheet skin wing box because there are fewer layers to manufacture and assemble. The sandwich skin wing box is clearly the most complex of the layered skins family because of the intricate machining of the sandwiched material. This complexity both increases the cost of tooling and machining as well as assembly time not to mention the increase in technical risk and schedule risk.

2.4.3 Stiffened Skin Family

The z-stiffened skin wing box was found to have the smallest overall wing box material area of the stiffened skin family. Because of this, a reasonable assumption is that this concept will have the lowest weight. Additionally, z-stiffeners require only one row of rivets to attach them to the skin while blade and I-stiffeners need two rows. Additional fasteners add additional weight and assembly complexity. All other categories were essentially identical between the stiffened skins concepts.

WHY ARE YOU "ASSUMING" ANYTHING?
YOU HAVE DETAILED SIZING!

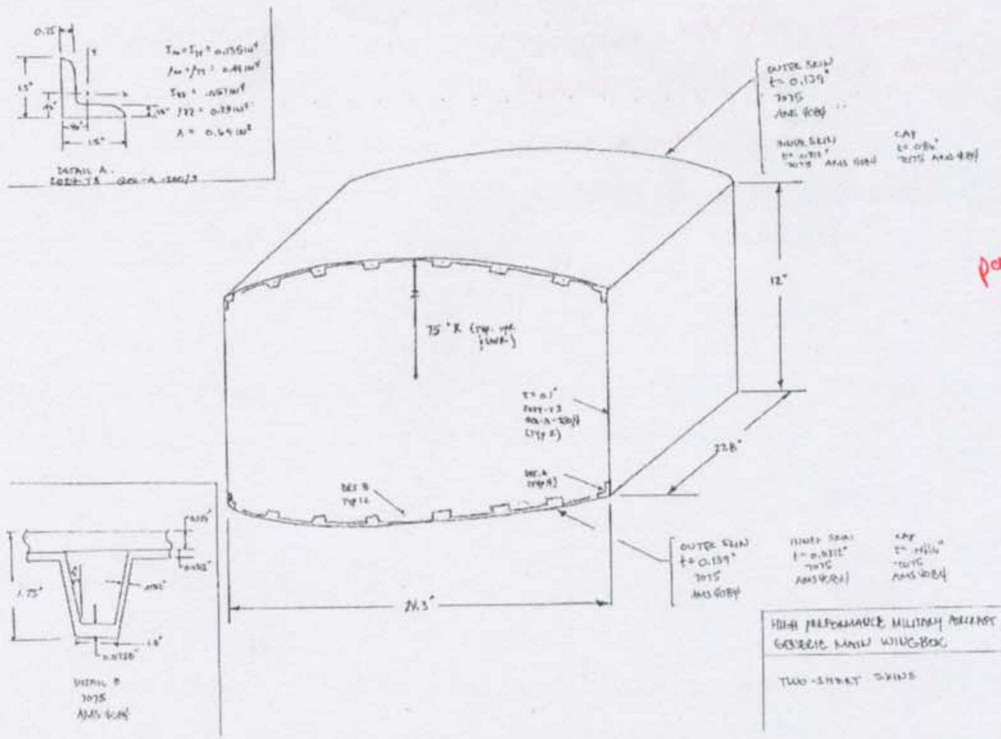
– I DON'T SEE THIS IN YOUR REPORT – THOUGH I SPECIFICALLY ADVISED ALL TEAMS AT THE INTERIM REVIEW TO HAVE ACTUAL WEIGHTS. →
GO TO YOUR PERFORMANCE RANKINGS IN APP B. ; I'LL LIST WEIGHTS.

– WHY WOULD I TRUST YOUR JUDGMENT ON REMAINING CRITERIA IF I DON'T BELIEVE WEIGHT?

Chapter 3: Two Sheet Concept

Written by Luke Thompson

From the sub-group including two-sheet, three-sheet and sandwich skins, the two-sheet skins were chosen to be the most desirable for this company. This section covers the possible processes that could be used to manufacture the specified wing box. Each process is discussed in depth and a decision as to which process to use will be made. The original part specification is included below in Figure 3.1.



poor figure.

Figure 3.1 Detailed Part Specification for Two-Sheet Skins

The top and bottom skins of the torque box will be constructed with the approach that the inner skin must be formed from 7475 AMS-4084 material prior to attachment of the outer skin. Note that this material is different from that shown on the drawing, which is believed to be erroneous. This forming will be done in the appropriate airfoil shape of the wing, so that no bending of the formed inner skin will be necessary. Possible forming operations for the inner skins are discussed in sub-sections 3.3.1 through 3.3.6. The outer skins will then ~~be~~ comprised ~~of~~ 0.139-inch thick 7475 AMS 4084 sheet metal that may be draped over and attached to the inner skin by bonding. This company prefers to purchase, rather than produce the sheet metal. The outer skin will likely be rolled into shape.

GOOD (T61 TEMPER)

NOT STANDARD CALL.

CAN YOU KNOW THIS?

The spar webs will be cut from 0.1-inch think 2024-T3 QQ-A-250/4 sheet metal. The 2024-T3 QQ-A-200/3 spar caps will be purchased in extruded form. This is because they are considered as standard geometry, and it should be more cost effective to buy them then develop tooling to form them within the company.

The overall torque-box assembly process is discussed following the options for inner skin forming.

NO. HAVE YOU CHECKED TOLERANCE AT CAP-SKIN INTERSECTION? IT'S TRUE THIS IS A STANDARD EXTRUSION – BUT IT WON'T WORK HERE.

3.1 Alternative Manufacturing Processes

3.1.1 Stamping

Process Description

The utilization of stamping for the creation of the inner skins is a rather practical idea. It would involve two opposing tools that would approach each other with the skin material in between. One tool would be the shape of the outer surface of the inner skin, and the other would be the shape of the inner surface of the inner skin. As the tools approached each other, they would form the skin into their respective shapes. This would induce some stress concentrations in the material, as well as some undesired thinning. Further, the width of the pre-formed metal would likely change by a small fraction as a result of forming. At this stage in the process, it is not necessary to enter that amount of detail. All of the aforementioned issues could be confronted and accounted for in detailed design of the manufacturing process.

Feasibility

Stamping would involve low risk, as it is a proven technology. It does require heavy expensive tooling, but compared to the processes to follow, it may prove to pail [pale] in comparison.

• Stamping was likely excessive for very gentle curvature of skins. Good for details at spar though.

3.1.2 Hydro-forming

Process Description

Hydro-forming follows the same principle of stamping. It just goes about in a completely different way. This process utilizes extremely high hydraulic pressures to form sheet around a tool. As a result of the use of fluid as a forming medium, the pressure is distributed evenly across the material to be formed. This results in much lower stress concentrations, and less thinning in critical areas.

In the case of the inner skins, a base tool would be created out of solid stock material to the shape of the outer surface of the inner skin. A reservoir would surround the other side. A sheet of pre-determined dimensions would be place over the tooling surface, and the top side of the material would be exposed to very high fluid pressure. This would force the sheet to conform to the tool, creating the final shape. The pre-formed dimensions may still vary from the post-formed dimensions, though, and that would have to be accounted for in detailed manufacturing process design. The 'as-modeled' specifications of Figure 3.1 call for non-uniform thickness. This would only be achievable with hydro-forming

Good.

NOTE: IF YOU MAKE DESIGN SUBSTITUTIONS - DO SO IN YOUR OWN RATING SCALE (ie CHANGE THE WT. RANKING ACCORDINGLY!)

if some sort of chemical milling process was completed prior to the forming operation to create the desired thickness distribution. A more likely approach would be to create a uniform thickness at the magnitude of the thickest specified region in Figure 3.1. This would cause a weight penalty, but our company is very concerned with successful completion of this project, and not necessarily willing to take large technical risks such as those associated with chemical milling.

Feasibility

Hydro-forming is also a proven technology, though the risk may be slightly higher than with pressure forming. The tooling may not need to be as heavy, but high-power hydraulic pumps and intricate valves will be involved. The tooling price will likely be higher than that of pressure forming. Hydro-forming delivers a better product than stamping, but it comes with a price.

3.1.3 Casting

Process Description

Casting of the inner skins would be relatively simple. Two opposing tools would have to be created. As with the pressure forming operation, they would be the shape of the inner and outer surfaces of the inner skin. These tools would be locked into position with the area between them enclosed with sidewalls. These two tools would be locked together, with what would be the span-wise axis vertical. The top end of this mold would have several inlet holes to allow the pouring of molten aluminum. After cooling, the removal of the mold would reveal the cast part. It would have seam lines around its edges that would likely require some after-working in order to create a smooth edge. The cast material would likely need some heat treatment after the casting operation to regain material properties lost in the process.

Feasibility

Casting does not lend itself well to the creation of thin sheets such as with this application. It is considered here only to be thorough. While the process of casting is relatively simple, the cost isn't necessarily reflective of this. The molding must be comprised of a material capable to withstand the molten temperature of aluminum. Further, one must have the equipment with which to bring the aluminum to its molten state. Dealing with molten aluminum carries with it some obvious environmental hazards as well. So, while there isn't much financial risk in casting, there is some safety risk that can result in financial risk, i.e. lawsuits. The necessary equipment and materials can be quite prohibitive as well. It is likely desirable to allow a sub-contracting specialist handle the casting if that route is taken.

3.1.4 Extruding

Process Description

Extruding again deals with the use of super heated (though not quite liquidous) metal. In this case, the molten aluminum for the inner skins would be contained in a reservoir behind an extrusion plate. This is a flat plate at the outlet of the reservoir which has a cut-out in it the exact shape of the inner skin cross-section. A large piston would apply a large amount of pressure to the reservoir, forcing it through the cut-out. This produces a long piece of material in the shape of the inner skin, meaning that post-processing in the form of cutting would be required. Individual skin pieces would have to be cut to length. The extruded material would likely need some heat treatment after the extrusion to regain material properties lost in the process.

PRACTICAL FOR SKIN?

Feasibility

As with casting, extruding carries the expense of heating the aluminum to a suitable temperature. There is no real technical risk, though as this is yet another well-proven technology. For similar reasons as discussed with casting, it may be wise to contract out any extrusion operations to a specialized metal-working company. Extrusion may prove very cost effective when making many pieces.

3.1.5 Milling

Process Description

Milling involves mechanically removing large amounts of material from a block to achieve a finished shape. In this case, both sides of the inner skin would have to be milled, adding a slight amount of complication to the operation. The process would likely, though not necessarily, be computer controlled.

Feasibility

A disproportionately large amount of metal would have to be removed in order to achieve the thin skin, which is desired. Tolerances may become an issue. Milling machines, especially computer controlled ones are very expensive. Since this process is not that well suited to the application at hand, it is not worth paying the high costs necessary for a milling operation.

I AGREE, BUT YOUR JUDGMENT SHOULD BE BACKED UP BY YOUR OWN RANKINGS. IT'S DANGEROUS TO JUST SAY THAT A PROCESS SHOULD BE AVOIDED DUE TO THE EXPENSIVE MACHINE.

3.1.6 Rolling

Process Description

Rolling, in this application, could be applied rather simply, using two pre-formed rollers with the shape of the inner skin in place. The cross section along the rotational axis of the wheels would look similar to the tool used for stamping, in that the two opposing tools fit together to form the material. It is to be noted that in order to create the skin in the jig shape, the rollers would not have constant diameters along their length. This is so that the curvature of the skin may be created. This process would allow the creation of non-uniform thicknesses in the 'as-modeled' torque box of Figure 3.1. There would be some stress concentrations, as with stamping. The material would have to be cut to length as with extruding, but there would be no need for heat treatment.

2 PULLEYS? – 1 FOR (INNER SKIN – CONTOURED); 1 FOR OUTER, FLAT?
– SINGLE PASS OPERATION (NOT LIKELY)
– TWO, THEN ATTACHMENT?

Feasibility

Rolling is, again, a proven technology. It does require heavy and possibly expensive tooling. Further, this tooling must be driven with a large amount of torque, which may imply large electrical bills. There is low technical risk here, though the before and after dimensions of the material would need to be looked at, since the rolling operation will obviously change them. Cold rolling the inner skins is a rather attractive approach.

3.2 Selection of Best Process

3.2.1 Brief Overall Torque-Box Assembly/Manufacturing Process

- **Inner Skins (Top & Bottom):** Pre-formed from 7475 AMS-4084 with "one of the processes" described in sub-sections 3.1.1 through 3.1.6. Note that contrary to the drawing in Figure 3.1, the inner skins extend to the edges of the torque box with the outer skins. Further, note that the inner skins will have to be produced from 0.09 inch thick sheet, as this is the closest gage to the specified thickest dimension of this part. — which? How does this affect wt. ratio?
- **Outer Skins (Top & Bottom):** Cut with shear from 0.190 inch thick 7475 AMS 4084 to pre-determined dimensions acquired from Figure 3.1 and bonded to outside of formed inner skins.
- **Spar caps:** Purchased in extruded form and cut to length (27.8 inches), then bonded or riveted to top and bottom skin assemblies. Note that the drawing in Figure 3.1 does not specify whether the spar webs are of identical dimensions. Due to lack of information, for the purposes of this project, they will be assumed identical. (TYP 2)
- **Spar Webs:** Cut from 0.125 inch thick 2024-T3 QQ-A-250/4 (already rolled down to 0.1 in)with shear to predetermined dimensions acquired from Figure 3.1, then bonded or riveted to respective spar caps, completing the torque box.

3.2.1 Selection of Inner Skin Manufacturing Process

This section deals with the selection of one process from sections 3.1.1 through 3.1.6 for the manufacturing of the inner skins. This selection is approached in an elimination manner, discounting those processes that are less attractive to our company one by one.

First of all, casting is ruled out. Casting thin sheets isn't easy, due to viscosity of the metal, and distribution problems within the mold. Any pockets at all in the material would mean scrapping it. Further, the material would need to be heat treated after casting. Achieving the jig shape after this heat treatment is very difficult, and involves severe technical risk.

Milling is the next to be ruled out. CNC equipment is very expensive, and relatively slow compared to some of the other processes to be considered. Additionally, one has to deal with recycling the large amounts of scrap.

Extruding is now excluded. While extruding is relatively cheap when subcontracting the operation out, as this company likely would, it is risky for the same reasons as casting. Heat-treating the material may change its net shape.

Hydro-forming is ruled out at this point, due to complexity and technical risk. While the process is relatively simple, our company has no expertise in this area. Further, the need to chemically mill the sheet prior to forming it adds another element of technical risk. We are a low risk company, and to that end are not willing to pursue this process in the forming of the inner skins.

Stamping is an attractive method in that it is simple, and does not require any finishing operations, as it is done cold. When compared to cold rolling the inner skins though, the equipment for stamping is larger, and potentially makes for a more dangerous work area. Also, this operation is discontinuous, and each article must be fed to the machine separately. Rolling the material is a continuous operation, which can be fed from a bulk quantity of sheet metal. Of course, the metal must then be cut to length, but this is not thought to be a serious problem.

Cold rolling is selected for the forming of the inner skins.

GOOD

BUT HOW WILL YOU ACHIEVE SIGNIFICANT VARIATION IN THICKNESS REQUIRED IN CAP?

3.3 Weight Estimation

For the weight estimation, dimensions are approximated. The top and bottom skins are assumed flat, and the spar caps are considered as the standard extrusion specified in the drawing of Figure 3.1. These same assumptions are made for the weight estimations of honeycomb and Z-stiffened skins, so that the comparison is valid. The purpose of the weight estimation at this point is solely for comparison with the other two processes, so approximating the dimensions to expedite the process seems an efficient engineering practice in this case.

Table 3.1 lists the component weight breakdown for the two-sheet skin torque box as drawn in Figure 3.1. Density for the 7475 AMS 4048 materials is 0.101 lb/in^3, and 0.1 lb/in^3 for the 2024 T3. These values are multiplied by their respective volumes for each part to arrive at a component weight in pounds. In order to calculate volumes, the dimensions were applied as specified in Figure 3.1. These values are very close to the exact volumes of the components, but are somewhat approximate, especially with the inner skins.

This data is used for comparison with the other two selected types of torque-box construction.

Table 3.1 Weight Breakdown for Two-Sheet Skins

Component Group	Volume (in^3)	Weight (lb)
Outer Skins	95.05	9.60
Inner Skins	104.36	10.54
Spar Webs	67.00	6.70
Spar caps	76.70	7.67
Entire Torque Box (minus attachment weight)	343.11	34.51

ABOUT RIGHT FOR 1 SKIN

BOTH UPR: LWR, OR JUST ONE?

AHH, HERE IT IS. UNFORTUNATELY, I DON'T AGREE WITH IT. I HAVE 44.4 lbs !

ASSUMING YOU DON'T MAKE SIGNIF. GEOM. CHANGES TO BE COST EFFECTIVE.

GOOD! MOST TEAMS USED 24.3"

3.4 Assembly Breakdown

Having decided upon the types of manufacturing processes to use for all of the torque box components, it is now possible to define a detailed manufacturing breakdown.

The outer skins are discussed first. Applying simple trigonometry to the drawing of Figure 3.1, it is possible to determine the actual (unfolded) width of the top and bottom skins as if they were laid flat. This is done using the specified radius of curvature of 75 in., and results in a width of 25.1 in. Note that this dimension is that of the skin after forming. The skin is to be cold rolled in an effort to minimize the necessary tooling of the entire torque box production, since the inner skin is also rolled. This operation will change the dimensions of the sheet it is fed, and this should be taken into account. It is recommended that this company hire an expert consultant in the area of cold rolling for a brief period to help it set up the line initially. This person's expertise would be used both for the inner and outer skin rolling operations.

SAME MACHINE, OR DIFFERENT?

The inner skins are too be cold rolled, as decided above. This will be a shape rolling operation, as complexities will be added to the cross-section of the sheet. The setup of a rolling line, which will produce the desired product can be quite complex. This is the reason for the aforementioned hiring of a rolling expert. While initial costs will be rather high, the risk is still relatively low, as the technology involved here is a proven one. The company is willing to bear the initial financial burden based on the belief that this rolling system will pay off in the long run. Note that this statement is based on the assumption that 600 articles will be produced each year. If only 120 are to be produced, we will likely subcontract the rolling out to a sub-contractor, as this production rate is not believed to be high enough to invest in a new technology base for the company.

On a technical note, there are some specific concerns, which will need to be addressed in conjunction with our consultant as the rolling line is designed. First, it is obvious that both the inner and outer skins are curved, not flat. This means that the opposing rollers must be of inversely variable diameter. In other words, from the center of the rollers along the axis to either end, one roller diameter will increase and the other will decrease. Further, the shape-rolling process of the inner skins involves fairly significant cross-sectional changes, and may require multiple rolling operations in order to achieve the desired shape. It should also be noted that since this is a cold-rolling operation, some load carrying capability would be given up in the form of residual stresses. These could be bought back with some heat-treating, but this involves possible shape changes. It is likely that this company will plan on the residual stresses, and potentially alters the design slightly in order to allow for them if necessary.

HOW WILL THIS AFFECT WEIGHT RATING?

Moving on with the assembly, once the inner and outer skins have been rolled, they will be cut to length, de-burred and bonded to one another adhesively. The cutting operation will likely be accomplished with a radial or chop saw. This should be a very efficient method of attachment, as adhesives are very strong in the shear modes, which will be encountered in this application. Further, to rivet the inner skins to the outer skins, effectively utilizing the strength of the inner skin would likely require a very large amount of rivets, as each channel would need to be riveted. This may significantly increase the weight of the torque box.

Next to be discussed are the spar caps. The standard angle extrusions, as the one shown in Figure 3.1 have an exterior angle of 90 degrees. It is obvious that this would leave a substantial gap between the skins and the spar caps. For this reason, this company believes it would be best to hire an extrusion company to extrude custom spar caps for us. The only real up-front cost is the development of the new extrusion plate. We may also incur costs from the sub-contractor for holding up one of their lines for our custom extrusions. This depends on volume. The more we order, the less likely we are to be additionally charged for the extrusions. If we only produce 120 torque boxes a year, it will probably be more expensive to order the extruded spar caps than if we made 600 per year. Upon arrival, the spar cap extrusions will need to be cut to length, de-burred, and attached to the upper and lower skin assemblies. This will likely be accomplished with rivets. The skin assemblies are thick enough that the riveting operation should not pose problems such as deforming it.

TRUE, BUT THEN YOU HAVE TO STORE THEM, WHICH COSTS ALSO.

Finally, the spar webs must be cut to dimensions. No forming is involved with these. They will then be riveted to the spar caps. Once again, the spar webs are thick enough (0.1 in.) that riveting should not deform their shape.

This completes the discussion of the manufacturing breakdown for a torque-box with two-sheet skins. The subsequent sections describe time, cost and risk for the selected process.

3.5 *Time Evaluation*

3.5.1 120 Articles Per Year

At a production rate of 120 torque boxes per year, allowing for holidays, an average of 5 would need to be turned out every two weeks. This rate is not very demanding, and frankly would not offer much more than a supplement to the companies profit. This rate can be satisfied with ease. It is likely that the rolling line would be run once every week, producing inner skins one week, and outer skins the next. This would likely be a Monday. The interim time could be used for maintenance or roller changes for different operations. Using this method, there would always be a reserve of formed skins, though not a large enough on to pose a risk or waste. The skins would obviously already have been cut to width. At the same time, the spar webs could be cut to width and length. These cutting operations would take place on Tuesdays, and the necessary articles, i.e. inner or outer skins would be cut, depending on the week. Thursday could be used to cut the spar caps and skins to length, and preparing them for assembly. Friday, the skins would be bonded together, and all the riveting would take place the following Monday. Note that all the aforementioned processes were carried out on an average of 5 articles at once, delivering all the items for a week at one time, rather than continuously.

So you need floor space for storage.

Most of the described tasks listed above do not require but a fraction of the day even with minimal (1-5) workers. Additional time would be used to support this companies other projects.

3.5.2 600 Articles Per Year

At a production rate of 600 torque boxes per year, allowing for holidays, an average of 12 would need to be produced every week. That's a little more than 2 per day. This rate is obviously more demanding than the lower 120/year discussed above. It also carries with it the potential for more profit, so our company is willing to invest more time to satisfy the desired rate, making this one of our larger projects. The same schedule as discussed in section 3.5.1 will be used. A larger fraction of the day will be spent on this task than before. Additionally, 1 or 2 more employees may be hired. In short, rather than increase the size of the company to accommodate this production rate, our time will simply be re-budgeted. If the project is successful, and looks like it will last, than the company may take on more employees to run the line and accommodate our various other projects. This goes along with our low-risk approach to this new contract.

3.6 Cost Evaluation

In this section, the cost per torque box will be assessed. Where discrepancies between the 120/year and 600/year production rates occur, they will be mentioned. For the most part this is based on a cost per article approach. Note that in the short time that these analyses have been performed, many of the finite costs listed below have not been possible to locate. Only the major material costs have been accounted for in Table 3.2. Table 3.3 shows the equipment cost for the two-sheet concept. (Material costs are from references 5 & 6. Tool costs are from reference 4.)

Table 3.2 Material Cost Estimation for Two-Sheet Skins

Component	Cost	120	600
Inner Skin	$56.50/ft	$2,619.60	$13,098.00
Outer Skin	$56.50/ft	$3,084.00	$15,420.00
Spar Webs	$84.75/ft	$1,356.00	$6,780.00
Spar cap	$3.85/ft	$4,296.60	$21,483.00
Rivets	$6/lb	$1,612.80	$8,064.00
Adhesive	$1.50/ft^2	$1,680.00	$8,400.00
Total		**$14,649.00**	**$73,245.00**

Table 3.3 Tooling Cost Estimation for Two-Sheet Skins

Equipment	Cost	Maintenance	Total
Cold rolling	$475,000.00	$1,000.00	
Slitting Equipment	$5,000.00	$500.00	
Riveting Equipment	$2,000.00	$500.00	
Chop Saw	$400.00	$500.00	
Total	**$482,400.00**	**$2,500.00**	**$484,900.00**

3.7 *Final Risk Estimation*

Most of the risk involved with the production of the torque box as specified in Figure 3.1 lies with the initial purchase and setup of the cold-rolling mill. It is believed that if thorough and correct engineering practices are exercised in this step, the decision to cold-roll the skins will pay off in the end. It should take relatively low time, and it will be a simple, low cost process once it is all setup. Obviously, this risk is increased if the production rate is only 120 per year. In the event that this low rate might be the one to be completed, it may be wise to contract out the rolling of the skins, rather than purchase the equipment in-house. Virtually all of the costs pose a higher risk with lower production, as the ability to meet the rates does not appear to be an issue. It would be much preferred in the interest of the company to produce 600 articles per year rather than 120.