

Front Suspension Design Report

- MANY comments inside - and on the drawings
- You are "close" to being done -
- You must do an assy dwg of the front upright / Axle / hub / Brake / wheel to identify interferences & and examine other upper A-arm
- Mike's calculations need to be verified - use your 5140 steering mount - other analysis to check it

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ME-5190 Vehicle Dynamics
December 9, 1998

- ASSY dwgs of all connecting pieces are needed to verify clearances at full bump / rebound / left / right turns

Front Suspension Components

- 1) **Upright Assembly**
 - a) Upright
 - b) Upper A-arm Bracket
 - c) Steering Link
 - d) Brakes
 - e) Brake Mounting Bracket
 - f) Brake Line Mounting Brackets
 - g) Speedometer Sensor Bracket

- 2) **Lower A-Arm Assembly**
 - a) Front Tube
 - b) Rear Tube
 - c) Inserts
 - d) Spherical Bearing Housing
 - e) Rod Ends
 - f) Spherical Bearing

- 3) **Upper A-Arm Assembly**
 - a) A-Arm
 - b) Rod Ends
 - c) Spherical Bearings

- 4) **Hub Assembly**
 - a) Hub
 - b) Hub Nut
 - c) Axle
 - d) Axle Nut
 - e) Bearings
 - f) Bearing Spacers
 - g) Brake Rotor
 - h) Speedometer Magnet

- 5) **Chassis Brackets**
 - a) Upper A-Arm Front Bracket
 - b) Upper A-Arm Rear Bracket
 - c) Lower A-Arm Front Bracket
 - d) Lower A-Arm Rear Bracket
 - e) Spring Bracket

- 6) **Springs**

- 7) **Wheel & Tire**

- Upright -

The current upright design has been designed for 1G cornering, 1G Braking and 4G Bump loading. It also has a safety factor of four on top of these loadings. The maximum loading that have been calculated and are using for our design are 2359-lbs radial load and 935-lbs vertical load at the lower a-arm, 632-lbs radial load and 935-lbs vertical load at the axle, and 1727-lbs radial load at the upper a-arm. The moment we have calculated at the axle is 4441lb-in, at the lower a-arm 7223lb-in, and no moment on the upper a-arm mount. We have chosen to use 7075-T6 Aluminum for the upright. The shape of the upright has been designed but there are still many calculations that are being done to finalize the dimensions of the upright.

Some of the issues we are still working on are the mounting technique we will use on the upper a-arm and on the steering link bracket. The current design has a one-piece bracket that will connect the upright to both the upper a-arm, and the steering rod.

We have not finalized the upright because some of the component placements are still unknown. Some of these components are the brake mounts, brake line mounts and the speedometer sensor. These components will be finalized over the month of December.

The plan for machining the upright is to have Pat Nelson do it in the machine shop down stairs.

we should see Bob Nelson with your finished Days ASA

- Lower A-Arm -

The lower a-arm design calls for .049 inch wall thickness, 1.0-inch diameter 4130 steel tube. The maximum force in the lower a-arm front tube without any safety factor is 1951-lbs in tension. The rear tube maximum force is 2703-lbs in compression. The spring bracket will also be welded onto the lower a-arm so that the direction of the force goes through the center of the spherical bearing. The rod ends we will be using are PRM-6T for the rear tube and a PRM-5T for the front tube. The spherical bearing we will be using on the upright mount is a HAB-7T. Aurora makes all of the rod ends specked above. Another manufacturer option for the rod ends is National Rod Ends. They have identical sized rod ends with similar strength characteristics.

The a-arm tubes will be made here by solar car members and welded together by Dale in the machine shop.

we'll need a jig

- Upper A-Arm -

The upper a-arm will be made of machined 7075-T6 Aluminum. There will be a spherical bearing at the upright attachment point and rod ends attached to the other two ends of the a-arm. The rod ends we will be using are PRM-5T for both ends and a HAB-5T spherical bearing for the upright attachment. The maximum force in the upper a-arm

front tube without any safety factor is 1321-lbs in compression. The rear tube maximum force is 1866-lbs in tension.

Mike Becker or Travis Lange will machine the a-arm.

- Hub Assembly -

The hub will also be ^{made} ~~make~~ from 7075-T6 Aluminum. The hub design is not finished and not much time has gone into its design. The current design choices that have been made are to use a 30mm diameter 4130 steel axle and try to also reduce the weight by removing extra material from the outside ring and to incorporate built in spacers to reduce set up time for brake rotor assembly. There is also a magnet being designed into the brake rotor for the speedometer sensor.

The choices we for the hub which will be solved over Christmas break is the bearing manufacturer and the manufacturer for the axle nut which Dan Timmerman is pursuing.

*Must only load
growments
in shear*

- Chassis Brackets -

Chassis brackets have been design to support the a-arms in their correct position but no force analysis has been done. The lower a-arm brackets are designed to use shoulder bolts. The upper a-arm brackets are using "AN Bolts". The spring bracket has not yet been designed.

*Need
dimensions*

- Springs -

The spring selection for the front suspension has been narrowed down to a 0.5-lb bike shock made by Fox or RockShox.

The shocks we have ruled out are Noleen and RST because of their poor performance ratings. During the December break, we will explore further shock-spring unit options by visiting local bike shops. We will also continue our contacts with representatives for Fox and RockShox.

*could
treatments*

- Wheel and Tire -

The wheel and tire selected for Aurora 4 are the same as used in 1997. The wheel is made by NGM. It is a 14inch diameter Al 6061-T6 rim weighing 3.5-lbs. The tire is the Bridgestone Ecopia. The tire is 19.09 inches in diameter, and has a load capacity of 350-lbs.

- Selected Analysis -

Suspension Geometry

The suspension geometry was developed based upon the given specifications for the car's physical dimensions. The main dimensions were as follows:

- 1) 9 inches: inside dimension of top and bottom plane of chassis
- 2) 10.8 inches: allowable vertical movement from bottom chassis plane to top point of upright at full bump
- 3) 13.4 inches: ground to bottom plane of car
- 4) 45 inch: front track.

Another specification for the front suspension is low scrub. To analyze the suspension, we treat it as a four bar, two-dimensional linkage. Using a spreadsheet developed by Mike Greminger, we found the optimized location of the four suspension points. Using the "Solver" function in Excel, the spreadsheet found the four points by minimizing the scrub value.

As a check to the previous method, we used the Lincages software package to analyze the four bar linkage and scrub calculations. For this method, Lincages outputs coordinates which we analyze in a spreadsheet. The way we analyzed scrub in this situation is by comparing the lateral movement of the center of the tire at each increment to the amount of arc distance traveled by the tire during the same increment. This is the same argument about scrub that we have previously discussed at Solar Car meetings.

Our initial goal was to limit scrub to 0.010 inches for 2 inches of travel, 1.5 up and 0.5 down. In our analysis, we found the scrub for 4 inches of travel, 2.5 up and 1.5 down. Using Mike Greminger's spreadsheet, the scrub was calculated to be 0.016 inches. Using Lincages, the scrub value was 0.024 inches. We felt that these numbers would suffice for low scrub. On a following page is the result sheet to Mike's spreadsheet, which shows the scrub value and the scrub radius (which falls close to our goal of 1.0 inch).

Another design goal for the front suspension was to have a suspension with the roll center at, or below the ground. From Mike Greminger's spreadsheet, we can plot the location of the roll center versus the increment value of the travel. This is based upon looking at one side of the front suspension only. On the following plot, the zero line on the vertical scale is ground level. On the horizontal axis, zero is full droop, and 100 is full bump. You can see that our roll center is always near ground.

FBD's, Forces, and Moments

Once the geometry was developed, we analyzed the forces and moments on the suspension members and upright by creating free body diagrams. A following page shows the free body diagrams used, along with the labeling scheme. Once the equations from the FBD's were found, they were entered into a spreadsheet that calculates all of the forces and the moments at given locations. The spreadsheet is capable of switching the

DIAGRAM needed
why different?
Explain this

how do you know his work is correct?
check it with your homework on Roll Center placement

the equations are also useful to identify which params to make by small => should show this & cannot

By simply placing the eqns into the spread sheet, you have provided a tool to analyze whatever set of dimensions you choose -

However, by looking at the equations, you get some insight as to what parameters you'd like to make big & small to reduce certain forces -

You could do cut & try on the spread sheet, but there are dozens of parameters - the eqns direct you to some "good ones" or "sensitive ones"

MIKE GREMINGER'S SCUB SHEET

130

distance

Ax Ay Bx By Cx Cy Dx Dy
 11.196 10.6 22.5 14.2 22.7 19.88 11.25462 18.93658

R1 8.606486
 R2 11.38563
 L1 5.667892
 L3 14.40678
 intermediate calc x 0.45
 intermediate calc y 5.65
 camber 0.079478
 camber(degrees) 4.553768

x3 -10.9 y3 6.55 x1 -2.34538 y1 5.606585
 rad deg theta/100
 theta 1 total 0.435065 24.92739 0.004351
 Theta 5 0.156818 8.985032
 Theta 4 0.07734 4.431264

Enter new x1,y1 values here:
-2.34538 5.606585


*need to reference 54 mm bolts
 to ~~reference~~ 1/2
 reference the
 54 mm bolts*

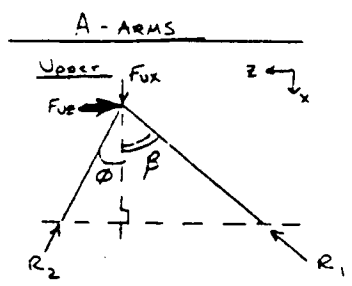
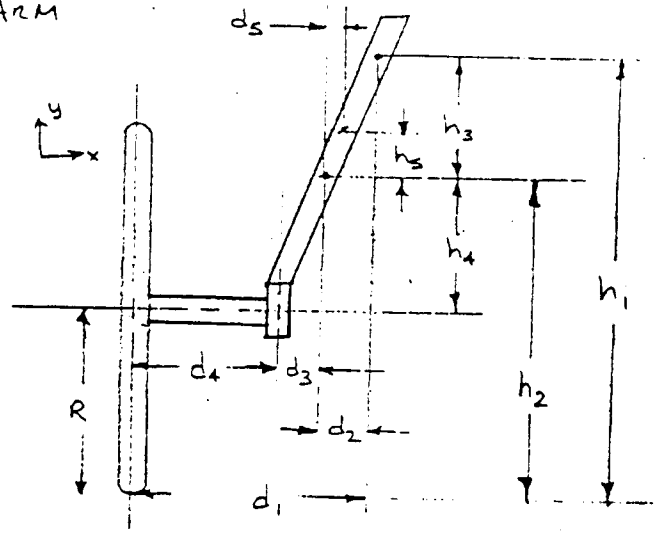
first theta 0.06458 3.700187
 Scrub Radius 1.116637
 Scrub 0.015658
 0.015645

length of lower arm (front view) 11.38563 Front Link Back link
 length of upper arm (front view) 8.606486

Spring ON

FBD'S - Spring ON LOWER ARM

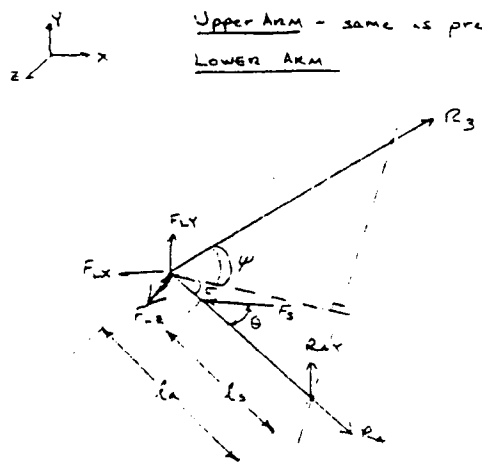
 Output Variables



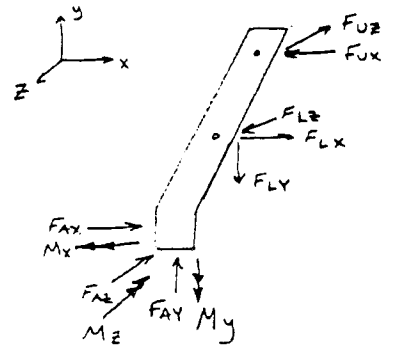
SPRING FORCE ON A-ARM

A-ARMS

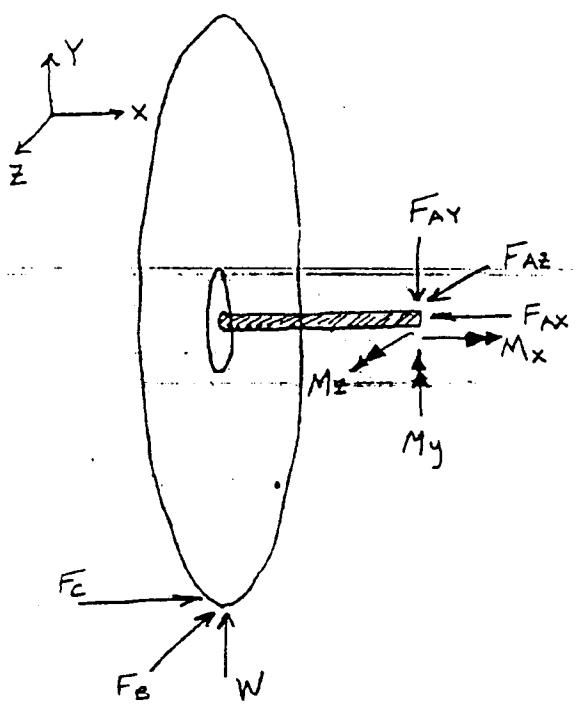
Upper Arm - same as previous
Lower Arm



UPRIGHT



Wheel & Axle



bump, brake, and cornering loads to analyze the forces at different conditions. A sample of this spreadsheet is shown on a following page. Tables 1, 2, and 3 show the maximum forces acting at the various locations for various loading conditions.

Table 1. Forces at the Upper and Lower Arm Pivots on the Upright for Various Loading
All forces in Lbs.

Bump, Break, Corner g's	4	4	4	0	0	4	0	Radial Force
	0	1	0	1	0	1	1	
	0	0	1	0	1	1	1	
Fuz	0	1162	0	1162	0	1162	1162	
Fux	372	372	-906	0	-1278	-906	-1278	1727
Flx	372	372	-1374	0	-1746	-1374	-1746	
Fly	935	935	935	0	0	935	0	935
Flz	0	1587	0	1587	0	1587	1587	2359

Table 2. A-Arm Forces and Upright Moments for Various Loading
(t = tension, c = compression) Forces in Lbs., Moments in Lb-in.

Bump, Break, Corner g's	4	0	0	4	4	4	0
	0	1	0	1	0	1	1
	0	0	1	0	1	1	1
R1	82c	1239c	282t	1321c	200t	1039c	957c
R2	332c	726t	1140t	394t	800t	1534t	1866t
R3	125t	1825t	176c	1951t	50c	1776t	1650t
R4	1180t	1051c	1651c	129t	470c	1522c	2703c
Mfront axle	-1870	0	4441	-1870	2571	2571	4441
Mfront lower arm	-2104	0	7223	-2104	5119	5119	7223
Mside axle	0	4038	0	4038	0	4038	4038
Mside lower arm	0	6566	0	6566	0	6566	6566

Table 3. Maximum Forces and Moments at the Axle
Forces in Lbs., Moments in Lb-in.

Fax	Fay	Faz	Fa-radial	Ma-front view	Ma-side view
467.5	935	425	632	4441	4038

This is Good -

A-Arm Sizing

Using the forces found for the arms, we were able to begin sizing suspension arms. We found the required size for Aluminum arms with square cross sections, and for Chro-moly tubing. A spreadsheet was developed to help in sizing the arms. First, for a square aluminum arm the required size was found by multiplying the given loading by a safety factor of four. The square size was found by dividing the force by the yield strength. Next, the arm was analyzed in compression, again with a safety factor of 4. If the column was too short for Euler column theory, Johnson buckling theory was used, and the square arm dimension was calculated.

For Chro-moly tubing, we found the required area for tension in the same manner as before. Then we selected a tubing size to meet those requirements. Next we applied column-buckling theory by calculating the required inertia for the tube. We then checked to see if our tube selection was adequate. Next we proceeded to determine if the column fell into the Euler range or Johnson theory range. Different tube sizes were selected until all the criteria were met. Examples of all the calculations are shown in following pages.

The lower arm back link calculations were also completed to ensure bending strength in the arm due to the spring mounting. Simple stress calculations were performed based on a 1.0-inch offset of the spring from the end. The moment and stress were calculated. The 1.0-inch, .049 tubing does not quite meet a safety factor of 4, but with aiming the spring at the pivot, we should not realize the full moment in the arm.

Not shown

For the upper arm, we have decided to machine it out of aluminum. The size required is 0.596 inches, from the front link. We will probably make them 0.625 inches square, then machine ribs into the sides to reduce weight, especially in the back link. Further stress calculations would be done to ensure the new cross section met the buckling requirements.

For the lower arm, the back link requires the 1.0-inch, 0.049 thick tubing. The front link will also be 1.0-inch diameter, but we can get by with a thinner wall. The front does not require the same diameter, but we chose this to make the spring mount easier to weld across a flat area.

Upright Analysis

Using the force spreadsheet the moments on the upright were calculated. The following page shows the worst case moments on the upright. Using these moments, and a spreadsheet for analyzing different cross sections, we determined the dimensions for the upright. In all cases, the moments are used to calculate stress, which is then compared to the yield strength. The current upright has a safety factor of at least 4.0 at all locations.

One of the main challenges was finding a cross section to fit with our steering system. The current cross section at the lower arm has 21 degrees of turning angle when the upright moves toward the forward arm, and 25 degrees of turning angle when the upright moves toward the rear arm.



Safety Factor

Aluminum Props
7075-T6
E (psi)
Yield (psi)

5/8 tubing
O.D. [in]
Thickness [in]
Area [in²]
Rad. of gyration [in]
Inertia [in⁴]
wg/ft [lb]

0.3668

0.3014

Steel Props
4340
E (psi)
Yield (psi)

1/2 tubing
O.D. [in]
Thickness [in]
Area [in²]
Rad. of gyration [in]
Inertia [in⁴]
wg/ft [lb]

0.4977

0.236

Aluminum calcs. Use square arms

Steel calcs. Use tubing

100E+6
700E+3

30.0E+6
100.0E+3

Upper Arm Forward Link (rt)

Length [in]
Compression [lbf]
Tension [lbf]

14
1321
282

same as equivalent length for buckling
Comp. Pcrit 5284
Tension--Pcrit 1128

Aluminum
Tension--Req'd Size

Area [in²]
Square size [in]
Req'd Inertia [in⁴]
Square size [in]

Steel

Tension--Req'd Size

Area [in²]

0.0161
0.127

0.0113

Buckling --Req'd Size

Req'd Inertia [in⁴]
Square size [in]

Buckling--Req'd Size

Req'd Inertia [in⁴]

0.0034978

Tangent Point
Le/rho
Area--Johnson
Square size--Johnson [in²]

53.1
81.321447
-0.4374
#NUM!

Tube Selection

O.D. [in]
Thickness [in]
Area [in²]
Rad. of gyration rho[in]
Inertia [in⁴]
Tangent Point
Le/rho

76.95299
68.493151

Euler Pcr 5589.419
Johnson Pcr 5356.525

Johnson Criteria--if Le/rho < Tangent point, then use Johnson theory
Area--Johnson 0.08750

135

Upper Arm Rear Link (r2)

Length [in] **7.63** same as equivalent length for buckling
 Compression [lbf] 1328
 Tension [lbf] 7464

7.63
332
1866

Aluminum
 Tension--Req'd Size Steel

Area [in²] 0.1066
 Square size [in] 0.327
 Req'd Inertia [in⁴] 0.0007833
 Square size [in] 0.311

Tension--Req'd Size 0.0746
 Buckling--Req'd Size 0.0002611

Tangent Point 53.1
 Le/rho 84.78998
 Johnson Criteria--if Le/rho < Tangent point, then use Johnson theory
 Area--Johnson #NUM!
 Square size--Johnson [in²] -0.0690



Tube Selection
 O.D. [in]
 Thickness [in]
 Area [in²]
 Rad. of gyration rho[in]
 Inertia [in⁴]
 Tangent Point
 Le/rho

Euler Pcr 18818.01
 Johnson Pcr 7826.41

Johnson Criteria--if Le/rho < Tangent point, then use Johnson theory
 Area--Johnson 0.01505

Lower Arm Forward Link (r3)

Length [in] **16.74** same as equivalent length for buckling
 Compression [lbf] 704
 Tension [lbf] 7804

16.74
176
1951

Aluminum
 Tension--Req'd Size Steel

Area [in²] 0.1115
 Square size [in] 0.334
 Req'd Inertia [in⁴] 0.0019989
 Square size [in] 0.394

Tension--Req'd Size 0.0780
 Buckling--Req'd Size 0.0006663

Tangent Point 53.1
 Le/rho 147.18595
 Johnson Criteria--if Le/rho < Tangent point, then use Johnson theory
 Area--Johnson #NUM!
 Square size--Johnson [in²] -0.0035



Tube Selection
 O.D. [in]
 Thickness [in]
 Area [in²]
 Rad. of gyration rho[in]
 Inertia [in⁴]
 Tangent Point
 Le/rho

Euler Pcr 3909.415
 Johnson Pcr 3846.669

Johnson Criteria--if Le/rho < Tangent point, then use Johnson theory
 Area--Johnson 0.01623

Lower Arm Rear Link (r4)

Length [in]	9.6	same as equivalent length for buckling
Compression [lbf]	2703	Comp. Pcrit 10812
Tension [lbf]	1180	Tension--Pcrit 4720

Steel

Aluminum
 Tension--Req'd Size [in²] 0.0674
 Buckling --Req'd Size [in⁴] 0.010096
 Square size [in] 53.1
 Tangent Point 56.304213
 Le/rho 0.3527
 Johnson Criteria--if Le/rho < Tangent point, then use Johnson theory 0.5939
 Area--Johnson Square size--Johnson [in²]

Euler Pcr 53331.85
 Johnson Pcr 13635.12

Moments on Lower Back Link

Location	distance	V [lbf]	M [in-lbf]
outboard end	0	935	0
spring location	1	-108.7209	3740
inboard mount	9.6	0	0

Steel

Aluminum
 Stress [psi]--calc at spring loc. using square compressive data 109.3E+3
 Yield strength 70.0E+3
 Req'd square size [in] 76.95299
 Tangent Point 28.512029
 Area--Johnson

Johnson Criteria--if Le/rho < Tangent point, then use Johnson theory

Stress [psi]--calc at spring loc. using square compressive data

Yield strength

112.7E+3

100.0E+3

While performing the analysis, one of the main goals was to move the neutral axis toward the center of the upright cross section. This would help reduce stress by reducing the distance the edge was from the neutral axis. To achieve this, a small flange was placed along the inside edge of the upright.

Another means of reducing stress is to increase the web depth of the upright. We want to keep the upright below 1.5 inches thick to reduce wheel-fairing width. Because of this constraint, increasing the web depth is not an option for us. Resisting bending also depends on web thickness. Various wall thickness combinations were used at different locations. We have come to the conclusion that we can use varying wall thickness if it will reduce weight. Since the final design of the upright is not complete, this is still to be determined.

Maybe
hard to
achieve
our shop
do it
smoothly w/o
stress
risers

Analysis was also performed to find the thickness of the lower arm mounting rib sections in the upright. The rib was modeled in three different situations. The first failure mode was shear through the rib in a horizontal direction towards the inside of the car. The second analysis treated the rib as a cantilever beam off of the upright back wall. Finally, the rib was analyzed as a beam fixed on both ends. Several variations of rib thickness have been calculated, and will be used pending the finalizing of other dimensions on the upright.

Near the axle, analysis was performed on the axle cross section to determine the depth and width of the upright at that location. Again, shear through the side was first analyzed. Then, bending in two different directions was analyzed. The axle suffers from the same bending direction as the upright at the lower arm mounting position. Adding web depth would be a solution, but we want to keep the depth around 1.0-inches for packaging constraints with the hub and rotor.

Taking all these calculations into consideration, first iteration values for the upright dimensions are shown in the upright component drawing. These dimensions give a very good idea of the final shape and size of the upright. All dimensions will be refined as more hard constraints are received from the rest of the team.

Hub-
Brake-
wheel-
axle
attachment
fasteners

Moments on Upright

Location		M front view	M side view	
Axle	M4	0		lb-in
Lower	M3	5.95		lb-in
Upper	M1	11.6		lb-in

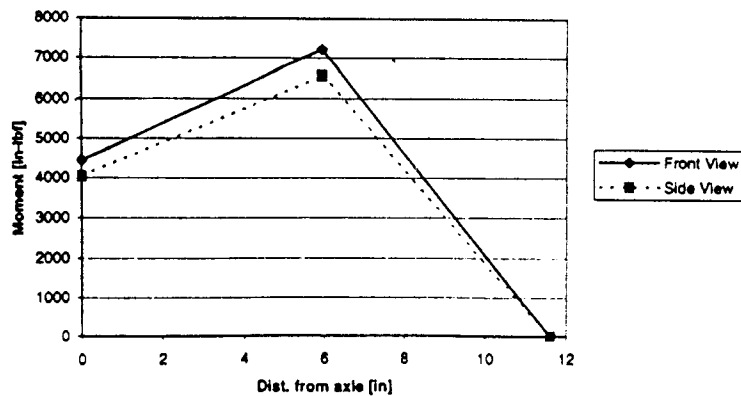
Front View Moments

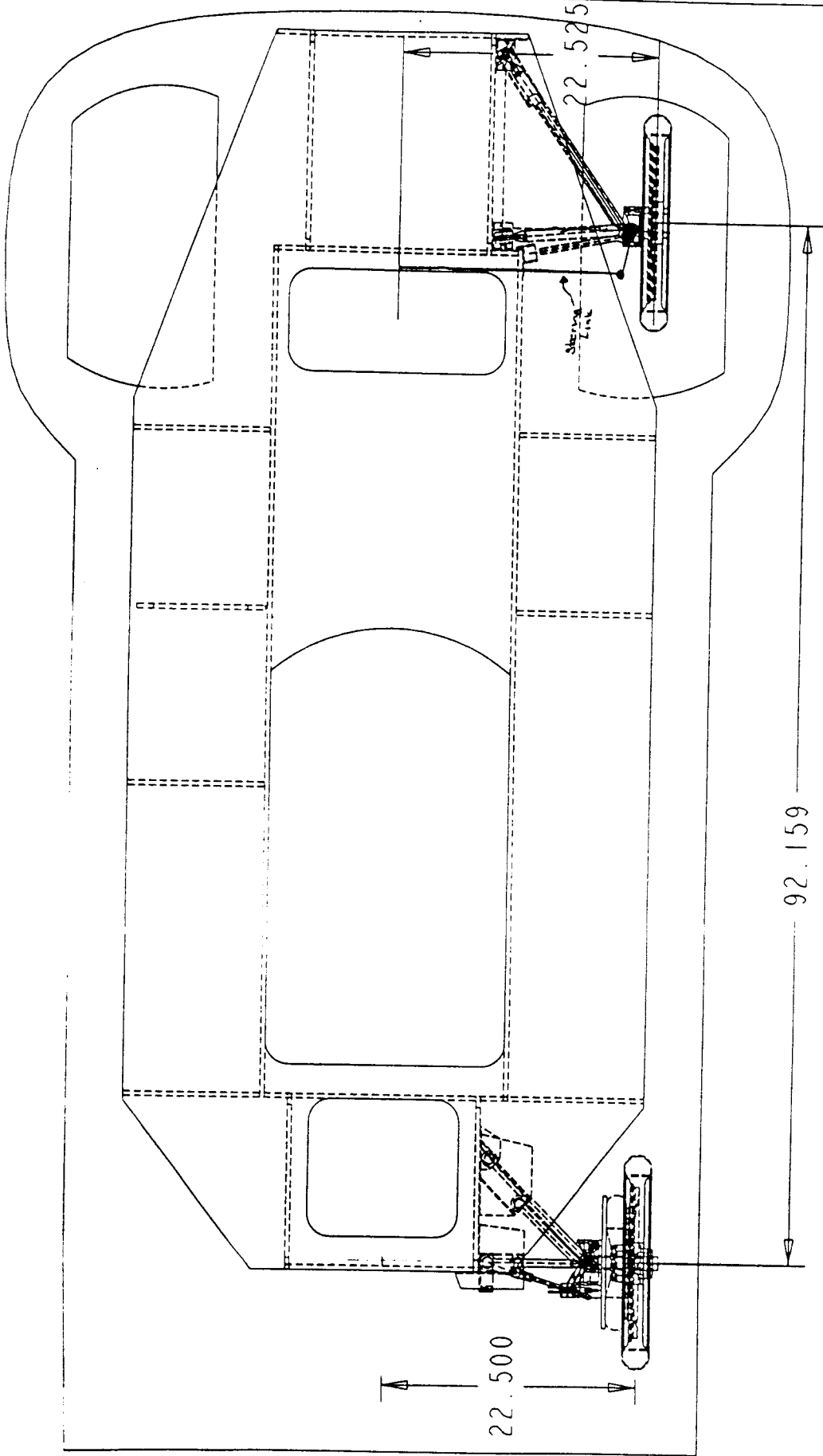
X dist	Moment [in-lb]	m1
0	4441	
0.25	4558	
0.5	4675	
0.75	4792	
1	4909	
1.25	5026	
1.5	5143	
1.75	5259	
2	5376	
2.25	5493	
2.5	5610	
2.75	5727	
3	5844	
3.25	5961	
3.5	6078	
3.75	6194	
4	6311	
4.25	6428	
4.5	6545	
4.75	6662	
5	6779	
5.25	6896	
5.5	7013	
5.75	7129	
5.95	7223	
5.95	7223 m2	
6	7159	
6.25	6839	
6.5	6520	
6.75	6200	
7	5881	
7.25	5561	
7.5	5241	
7.75	4922	
8	4602	
8.25	4283	
8.5	3963	
8.75	3643	
9	3324	
9.25	3004	
9.5	2685	
9.75	2365	
10	2045	
10.25	1726	
10.5	1406	
10.75	1087	
11	767	
11.25	447	
11.5	128	
11.6	0	

Side View Moments

X dist	Moment [in-lb]	
0	4038	
0.25	4144	
0.5	4250	
0.75	4356 m1	425
1	4463	
1.25	4569	
1.5	4675	
1.75	4781	
2	4888	
2.25	4994	
2.5	5100	
2.75	5206	
3	5313	
3.25	5419	
3.5	5525	
3.75	5631	
4	5738	
4.25	5844	
4.5	5950	
4.75	6056	
5	6163	
5.25	6269	
5.5	6375	
5.75	6481	
5.95	6566	
5.95	6566	
6	6508	
6.25	6218	
6.5	5927 m2	-1162.17
6.75	5637	
7	5346	
7.25	5055	
7.5	4765	
7.75	4474	
8	4184	
8.25	3893	
8.5	3603	
8.75	3312	
9	3022	
9.25	2731	
9.5	2441	
9.75	2150	
10	1859	
10.25	1569	
10.5	1278	
10.75	988	
11	697	
11.25	407	
11.5	116	
11.6	0	

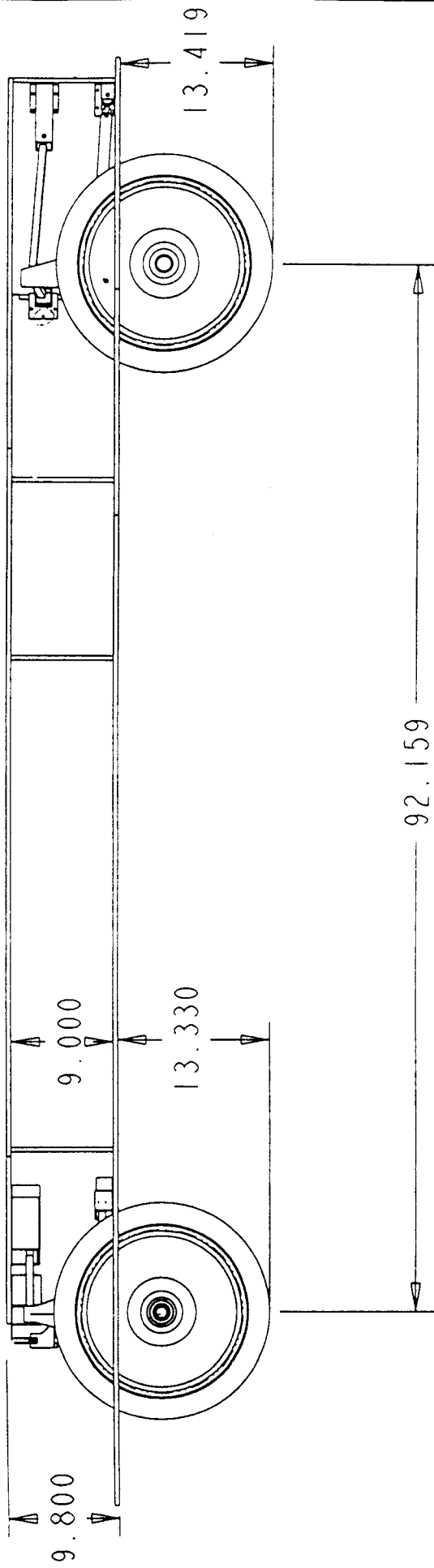
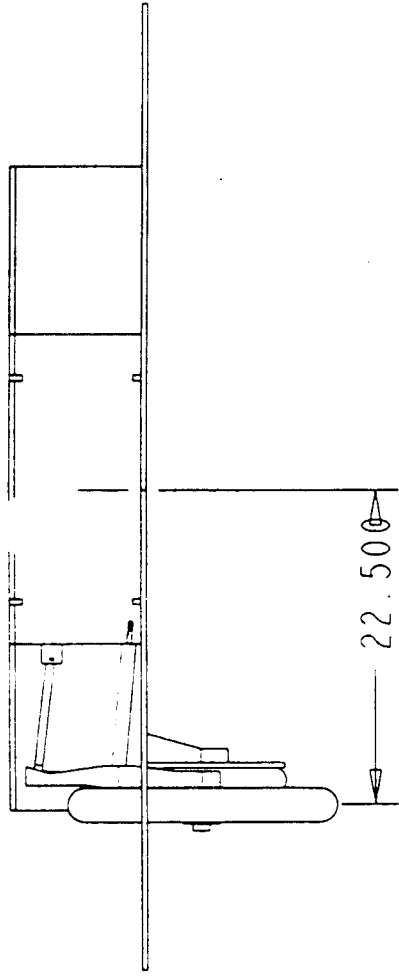
Upright Moments





Title:	
Designed for: Sunrayce 99	
UNIVERSITY OF MINNESOTA	
Solar Vehicle Project	
Aurora 4	Date
Scale:	Drawn by
	Res.

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Title	
Aurora 4	Designed for: Sunrayce 99
Scale	UNIVERSITY OF MINNESOTA Solar Vehicle Project
Date:	Drawn by: Rev.

(42)

Handout 12

Front Suspension Design Report

Excellent
work -
a few comments inside -

PSM
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ME-5190 Vehicle Dynamics
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The detailed design of the front suspension has been 99 percent completed. The only items left in the design are spacers and selecting fastener lengths. Both of these items will be completed very shortly. Fabrication is under way. The "on wheels" date is scheduled for April 4th. My major tasks for the quarter were:

- complete the upright design and coordinate its fabrication, along with all attached components
- complete the detailed design of upper and lower arms, coordinate fabrication of upper arms
- select and order shock and springs
- schedule and coordinate hub and rear upright fabrication
- coordinate fabrication of EDM parts for front and rear suspensions
- coordinate purchase of rod ends for all mechanical teams
- create detail drawings of components for fabrication
- complete detailed design and fabricate spherical bearing housings.

The following is a summary of the status of each component.

Upright Assembly

The upright detailed design was completed, along with the upper arm bracket and the steering links. Currently, the uprights are being fabricated in the ME Research Shop. The steering links have been made in the student shop. The upper arm bracket is being made by the AEM Research Shop using wire EDM. The bracket will be finished in the student shop. That is scheduled to be completed by the end of the current week.

Brakes have been in hand since last quarter. The mounting bracket design for the brakes has been completed. They will be rough cut using abrasive water-jet cutting. They will be finished milled by students. The speedometer will be placed on a bracket that extends off of the bottom fastener of the brake mounting bracket. Further details of its design will begin when the Electrical Team gives us further information about placement and spacing.

Lower A-Arm Assembly

The model of the lower arm is completed. Detailed drawings of the components are currently being completed. Threaded tube inserts were ordered and machined to reduce weight. The spherical bearings and rod ends were purchased and arrived from Aurora Bearing. The spherical bearing housings have nearly been completed in the student shop. The retaining rings remain to be ordered. A possible vendor is McMaster-Carr, or Industrial Supply, depending on the quantities available.

The plan is to fabricate the arm components in the student shop in the next week. Then, we will need to figure out jigs for welding the arms. This is all scheduled to be completed by the end of March.

Upper A-Arm Assembly

Design of the upper arm has been completed. Drawings are included. Spherical bearings and rod ends were ordered and have arrived. Retaining rings still need to be ordered. The upper arms will be machined by the shop that can get them to us by March 31. I have contacted the ME shop, the Physics shop, and Travis Lange. Dan Timmerman has also tried to outsource the arms, but has been unsuccessful finding a shop to complete them in time.

Hub Assembly

The hub design was completed by Dan Timmerman. He also selected bearings and is in the process of obtaining more sets of bearings for testing. The hub threading and the corresponding hub nut were designed to be compatible with the new motor and hub being developed. Work was completed in conjunction with Mike Becker. Currently, the hubs and hub nuts are being machined in the ME Research Shop.

The axle design is close to being finished. No detailed drawings exist yet. Brake rotors have been designed. They will be rough cut by abrasive water-jet and finished by students. The EE team has purchased the speedometer magnets. They will be glued into the brake rotors. Rotor spacers and hub bearing spacers are still being designed.

Chassis Brackets

Chassis brackets have all been designed. Shock brackets are finished, with a few possible tweaks to yet be completed. Drawings have been included. The rear attachment of the lower arm and shock to the chassis was completed by introducing a rear tower. This also involved changing the angle of the lower arm rear tube. All forces were checked and verified to be within original design specifications.

Fabrication of the towers and brackets pieces has begun. Most of the brackets should be completed by early next week. We will then proceed to welding up the tower assemblies.

Shocks and Springs

We selected a Risse coil over shock unit that has 2.4 inches of travel. They have been purchased and should be here in the next few days. Analyses of shock location and motion ratio were completed using analytical displacement analysis techniques from ME 3203. Using this spreadsheet, I verified roll center height and low scrub performance of our suspension geometry. Springs were also ordered based upon analysis completed in the homework exercises. We ordered two rates for the front, 150 lb/in and 190 lb/in. They should arrive in the next week.

Reference the attached figures —

Front Spring Static Analysis

Design Variables

Ws	775 lb	sprung weight of car
Wc-f	213 lb	front corner sprung weight
Wc-r	174	rear corner sprung weight
tr-f	45.2 in	front track
tr-r	45 in	rear track
CG height	17.5 in	
roll ctr hgt	0.72 in	
n	1.40 ft	distance, CG to roll ctr height
MR-f	1.63	front motion ratio
del wb	2.5 in	amount wheel moves from static to bump
del wd	1.5 in	amount wheel moves from static to droop
f	n/a	frequency of suspension

*Highlight
The important
conclusions and refer to
them in the text*

Calculations for Front Springs

	1.6	2	Hz	Desc	Eqn
f	1.8	2	Hz	frequency	
kw-f	70.44	55.66	lb/in	front wheel rate	$=Wc \cdot (f/3.13)^2$
kw-r	57.54	45.47	lb/in	rear wheel rate	
RS	189.41	149.66	ft-lb/deg	roll stiffness	$=(kw \cdot tr^2 / 1375)_{front} + (kw \cdot tr^2 / 1375)_{rear}$
BRA/g	5.72	7.24	deg/g	body roll angle per g	$=Ws \cdot n / RS$
w.t./g	2.26	2.86	in/g	wheel travel/g	$=(BR/g) / 57.3$
	0.3	0.3		avg lateral g's expected	
w.t.	0.677	0.857	in	wheel travel	
	1.823	1.643	in	travel left in bump	
	0.823	0.643	in	travel left in droop	$=del \cdot wb \cdot w.t.$

Spring Rate

	187.2	179	231	lb/in	Spring rate
fstat	347.2	347.2	347.2	lb	static spring force
del stat	1.855	2.348	1.503	in	static spring deflection
del sd	0.920	0.920	0.920	in	spring travel, static to droop
del sb	1.534	1.534	1.534	in	spring travel, static to bump
del sp	0.935	1.428	0.582	in	spring preload dist
del total	3.389	3.882	3.036	in	total spring movement

select a spring with free length - del total > coil bind length

[Redacted]

[Redacted]

Ws 775 lb sprung weight of car
 Wc-f 213 lb front corner sprung weight
 Wc-r 174 rear corner sprung weight
 tr-f 45.2 in front track
 tr-r 45 in rear track
 CG height 17.5 in
 roll ctr hgt 0.72 in
 n 1.40 ft distance, CG to roll ctr height

MR-r 1.64 rear motion ratio
 del wb 2 in amount wheel moves from static to bump
 del wd 1.5 in amount wheel moves from static to droop

f n/a Hz frequency of suspension

[Redacted]

f 1.8 1.6 2 Hz frequency

kw-f 70.44 55.66 86.97 lb/in front wheel rate
 kw-r 57.54 45.47 71.04 lb/in rear wheel rate
 RS 189.41 149.66 233.85 ft-lb/deg roll stiffness
 BRA/g 5.72 7.24 4.63 deg/g body roll angle per g
 w.t./g 2.26 2.86 1.83 in/g wheel travel/g

[Redacted] 0.3 0.3 avg lateral g's expected
 w.t. 0.677 0.857 0.548 in wheel travel
 1.323 1.143 1.452 in travel left in bump
 0.823 0.643 0.952 in travel left in droop

[Redacted]

Fslat 285.4 285.4 285.4 lb static spring force
 del stat 1.506 1.906 1.220 in static spring deflection
 del sd 0.915 0.915 0.915 in spring travel, static to droop
 del sb 1.220 1.220 1.220 in spring travel, static to bump

del sp 0.592 0.992 0.305 in spring preload dist
 del total 2.726 3.126 2.439 in total spring movement

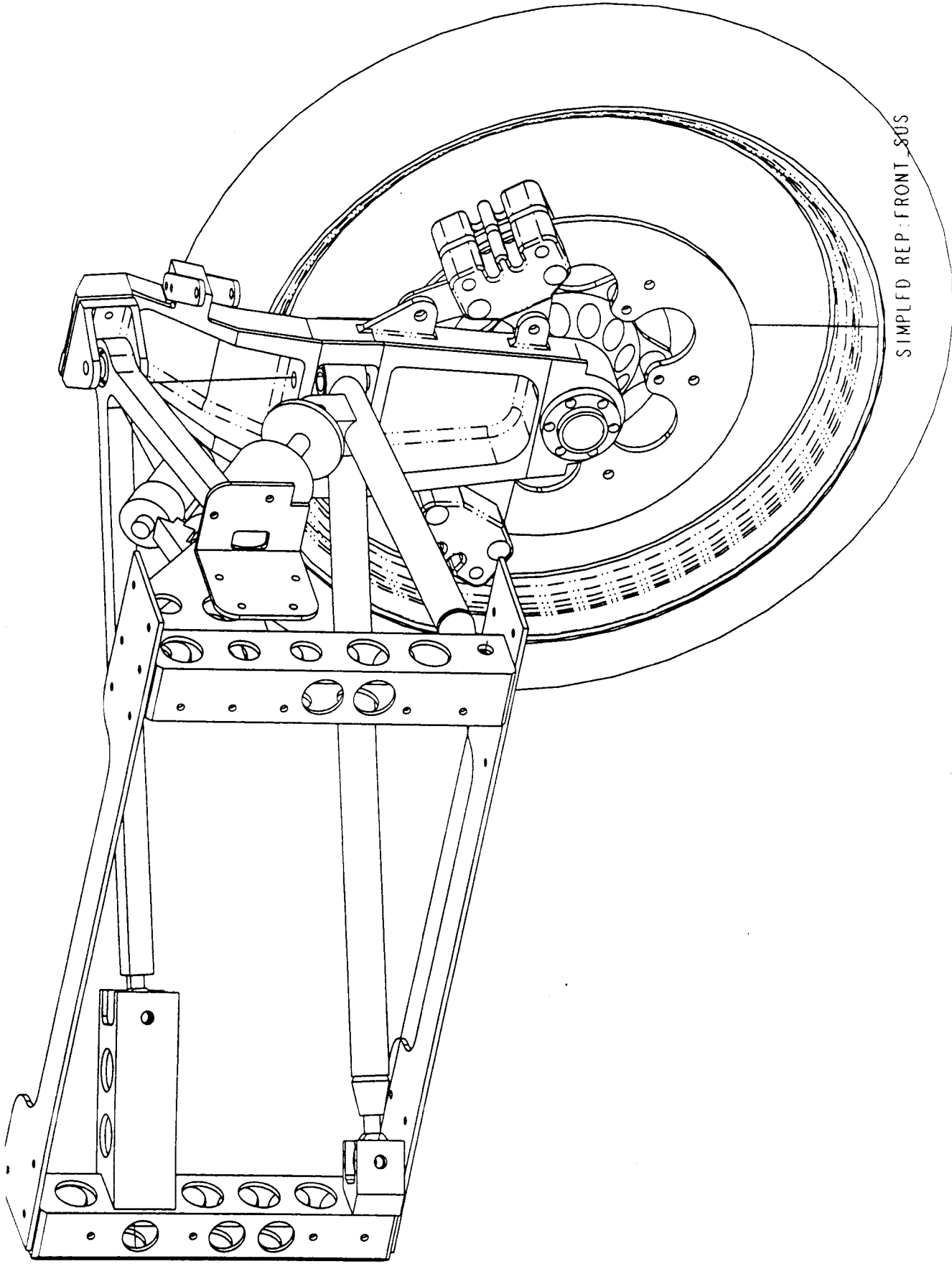
select a spring with free length - del total > coil bind length

$= Wc \cdot (f/3.13)^2$
 $= (kw \cdot tr^2 / 1375) \text{ front} + (kw \cdot tr^2 / 1375) \text{ rear}$
 $= Ws \cdot n / RS$
 $= (W/2) \cdot (BRA/g) / 57.3$

$= \text{del wb} \cdot w.t.$

$= kw \cdot MR^2$
 $= Wc \cdot MR$
 $= Wc \cdot MR / Ksp$
 $= \text{del wd} / MR$
 $= \text{del wb} / MR$

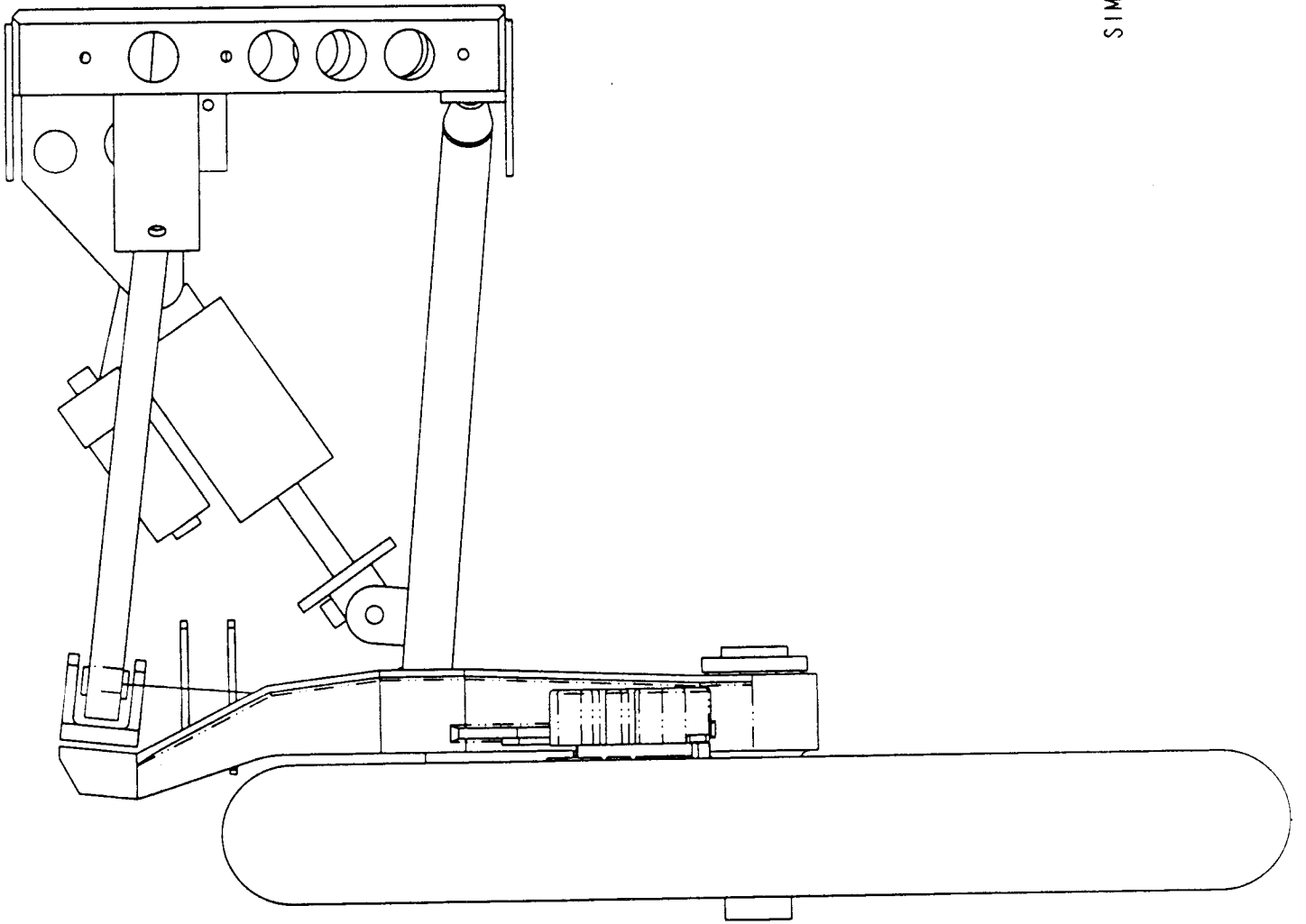
$= \text{del stat} - \text{del sd}$
 $= \text{del sp} + \text{del sd} + \text{del sb}$

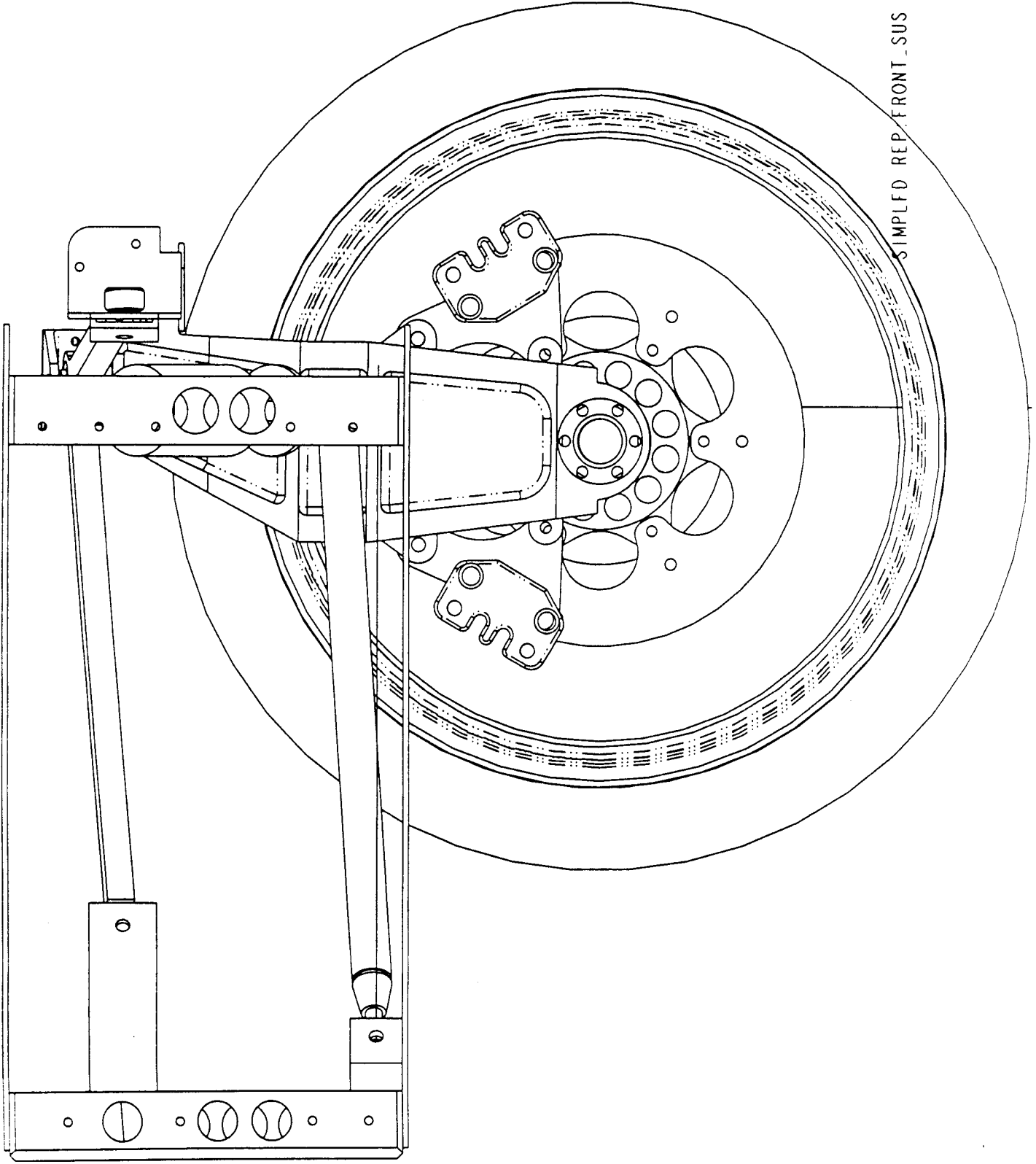


SIMPLFD REP: FRONT SUS



SIMPLFD REP: FRONT_SUS





SIMPLFD REP FRONT SUS

SIMPLFD REP: FRONT .SUS

