Handout 12 Evolution of BII Rear Swing Arm

This handout deals with the evolution of the BII swing arm rear suspension. We had been trying to modify the BI rear-facing double A-arm arrangement with its long-stroke spring shock unit mounted vertically above the rear axle line. This gave a motion ratio (MR) equal to one, but required the chassis to have raised "ears" for mounting the spring bracket. We were trying other spring arrangements (see page 3 of the 12/3/02 memo) when it dawned on me that we had not examined the forces upon the chassis properly when BI was designed. The purpose of the 12/3/02 memo was to point out that error – which explained why the rear portion of the BI chassis would visibly twist in bump motion (!).

The 12/7/02 memo suggests we reconsider a swing arm suspension, like Aurora II. A side view drawing of the evolving Aurora II swing arm is on the last page of the 12/7/02 memo.

The 12/10/02 memo shows the concept where the supporting A-arm attaches to the cross tube with pivots. This allows the height adjustment to occur in the link from the chassis to the spring: that is, no spring/shock travel is used up when the rear ride height (which changes the body angle of attack) is adjusted. A weight estimate is included, using steel members at 0.28 Lb/cu. inch.

The drawings dated 12/19/02 by Al Majkrzak implement the sketches in the 12/10/02 memo, but do not have the spring link. The side view drawing is in the next memo.

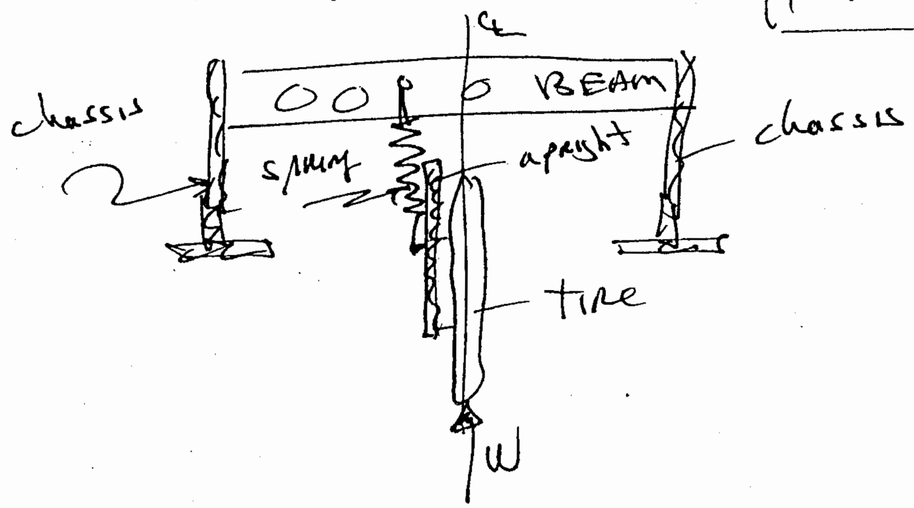
The 12/23/02 memo estimates the Motion Ratio of the 12/19/02 drawings from the side view on the second page of the memo as 3.2, which is about double the desired value of 1.6. The memo suggests a more detailed layout on page 4, with estimated dimensions. (These were “close” to the finalized values).

See the comments on Aiming the Spring Force, Arm Mounts on the Chassis and Rear Bulkhead location and mounting tabs. Note that fairly detailed concepts for the mounting bracketry must be considered here.

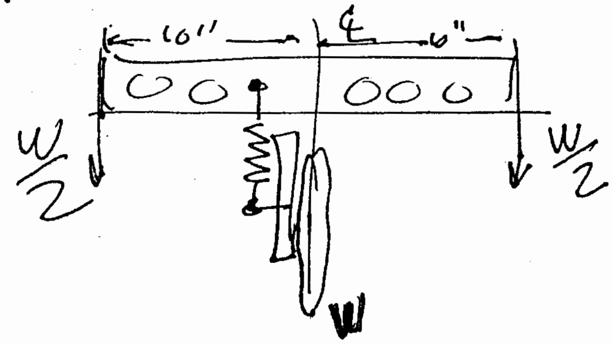
TO: SVP MECH / REAR SUSP TEAM
FROM: Prof Starr
Re: Rear susp layout

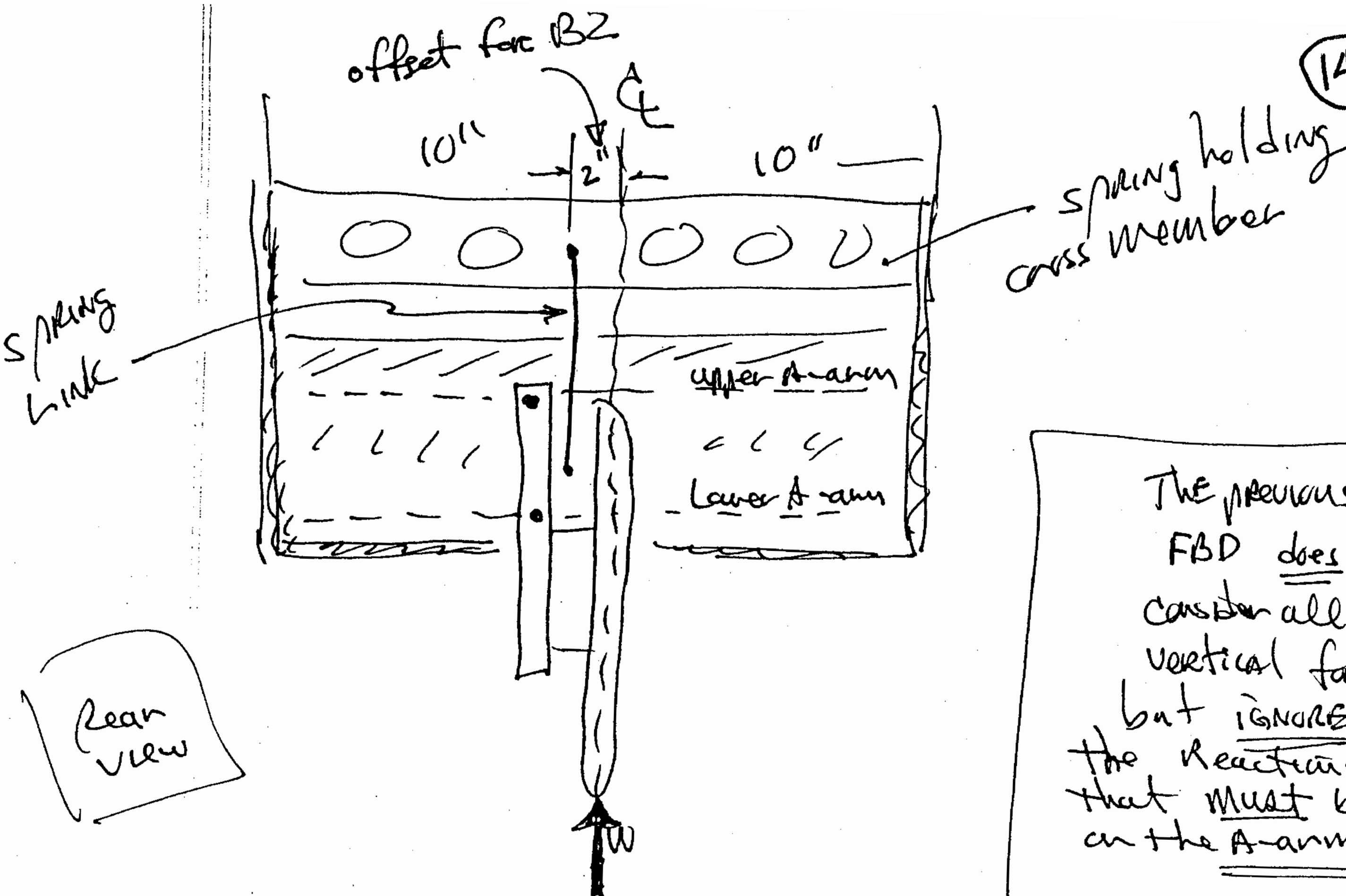
I was fooling around with alternate spring set-ups on the crossbeam, and alternate cross beams and discovered a misconception we had about the loads on Borealis — or at least, something we ignored —

We had looked at the rear susp system & chassis FBD as — (Rear view)



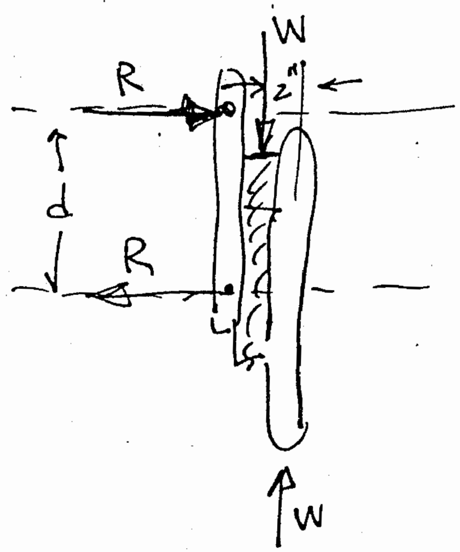
If we consider this whole system FBD, then all forces are internal, so if the Beam was separated from the chassis, then — it appears that W/2 act at each side of the chassis — causing NO moment. This is NOT correct





The previous FBD **does** consider all the vertical forces but **IGNORES** the Reactions that **must** be on the A-arms

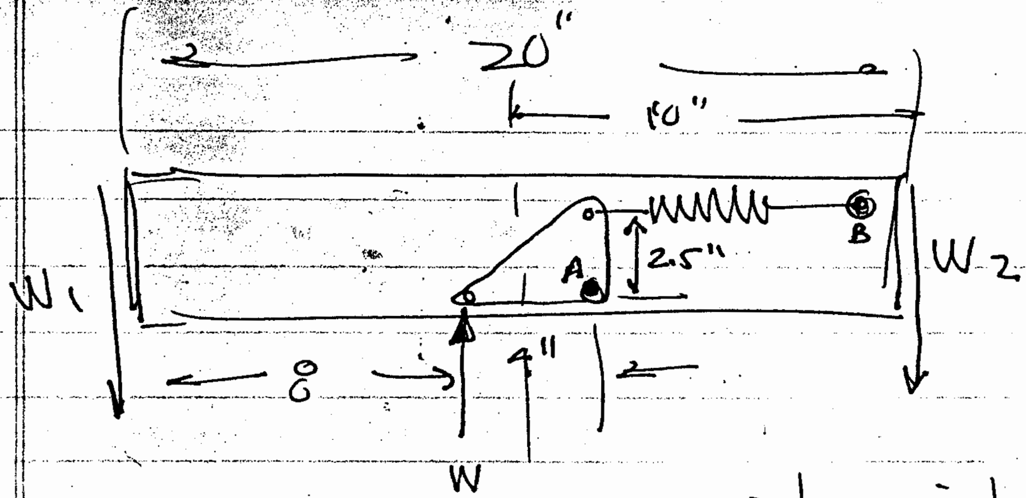
Trace load W to the chassis via FB Diagrams



the 2" offset of the tire load & spring link load causes moment 2W in-lb which is reacted by the a-arms as (d)R = 2W

(the offset was $4\frac{3}{8}$ for Borealis

<u>Now</u> Trace the spring link force to the chassis



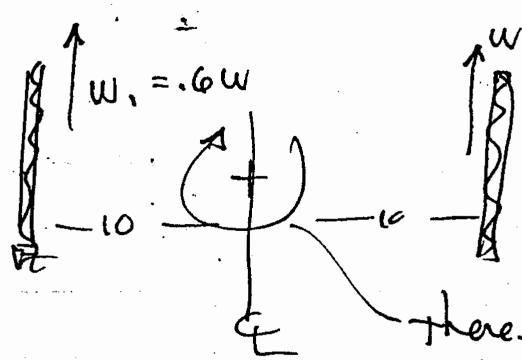
The pivots at A & B have internal forces.

Assume the Beam is stiff, so there's only shear at each end —

so $W_2 = \left(\frac{8}{20}\right)(W) = .4\,W$
$W_1 = .6\,W$

from $\Sigma T = 0$, $\Sigma F_Y = 0$

on the chassis where the cross Beam attaches

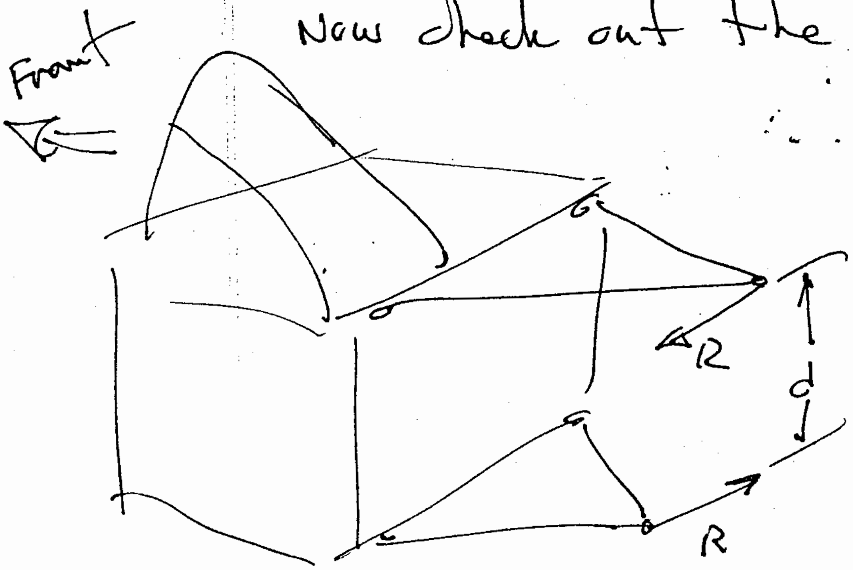


theres a net Moment at this plane of the chassis of amount

$M = 10(.6W) - 10(.4W) = 10(.2)W = 2W$

if we say a Bump is 4g with 180 lbs static, $2W = 2(4)(180) = 1440$ inch-lb $= 120$ ft-lb

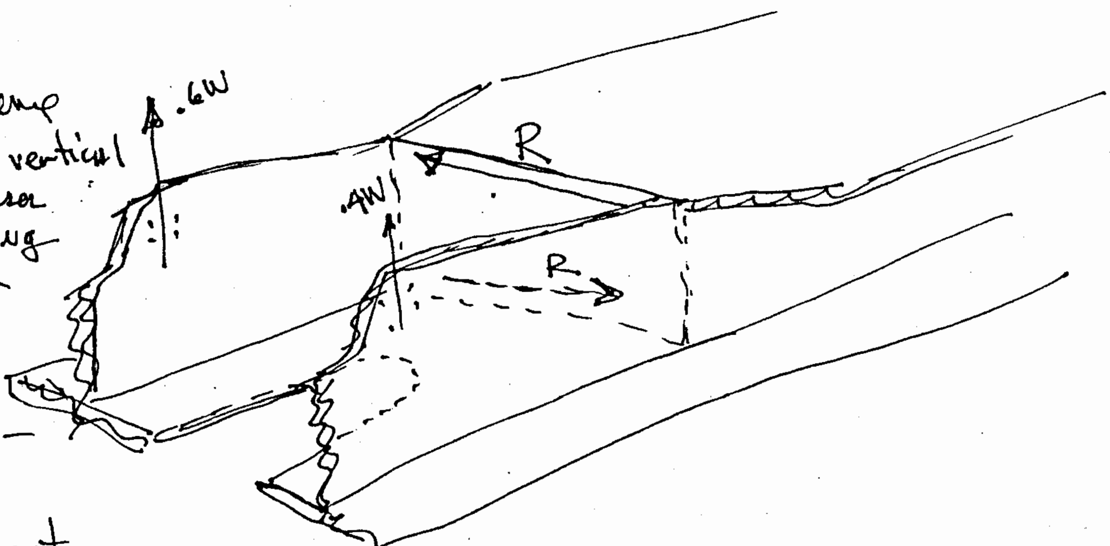
Now check out the A-Arm moments



This applies moment Rd = 2W to the Rear of the chassis where the A-arms mount

so we have

the difference in these vertical forces causes the twisting moment on the rear of the chassis –



the moments
$2W = Rd \approx 120$ lb-ft (max) cause twisting of the chassis between the cross member & the rear plane where the A-arms attach –

ISSUE – should we examine ways to stiffen the rear chassis

– IGNORE this (NOTE cornering loads are reacted through the a-arms and apply to the rear chassis plane)

– Reconsider the A^3 type link

Note on Borealis, $d \doteq 4\frac{3}{8}''$

on B2, $d \approx 2''$, so for Borealis, whatever effect this had, it will be halved with B2

12/7/02

TO: SUP Mech TEAM / REAR SUSP
FROM: Prof STARR
Re: Rear susp type – Reconsider a SWING ARM –

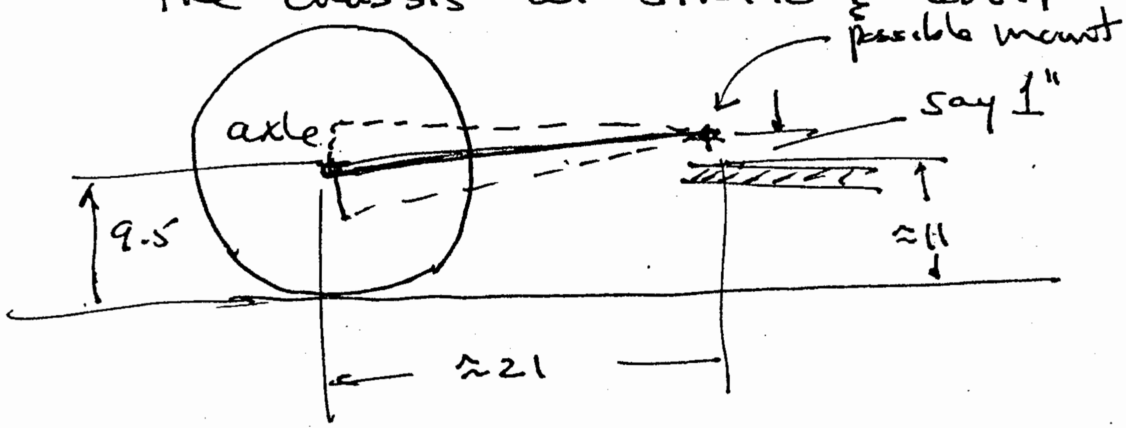
My recent 12/3/02 memo outlined some previously UNRECOGNIZED forces upon the rear of the chassis caused by the vertical spring (ala Borealis) on the vertical spring link (ala B2) not being placed along the centerline of the tire (vertical)

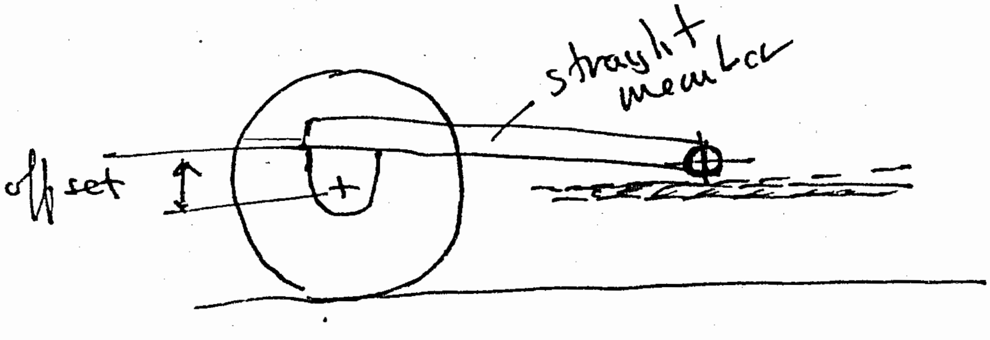
I suggested that we could
- stiffen the rear frame to resist a torsional load
- use an AURORA 3 type spring attachment and link set-up

However – since we have lowered the rear of the chassis for aero purposes, I think we should re-consider the simple swing arm suspension. We used one on Aurora 2 along with a separate spring link and horizontal spring set-up. The lowered rear end means that the ~~xxxx~~ severe anti-squat, which raises the rear of the vehicle under "hard" acceleration, should not be any more of a "problem" than it was on Aurora II. — Aurora II raised the rear end of the body about 0.5" upon take off → not a concern —

The main problem with a swing arm is accomodating the arm-body interference —

If arm connects the axle & mount with a "straight member", it will be below the chassis at static & droop

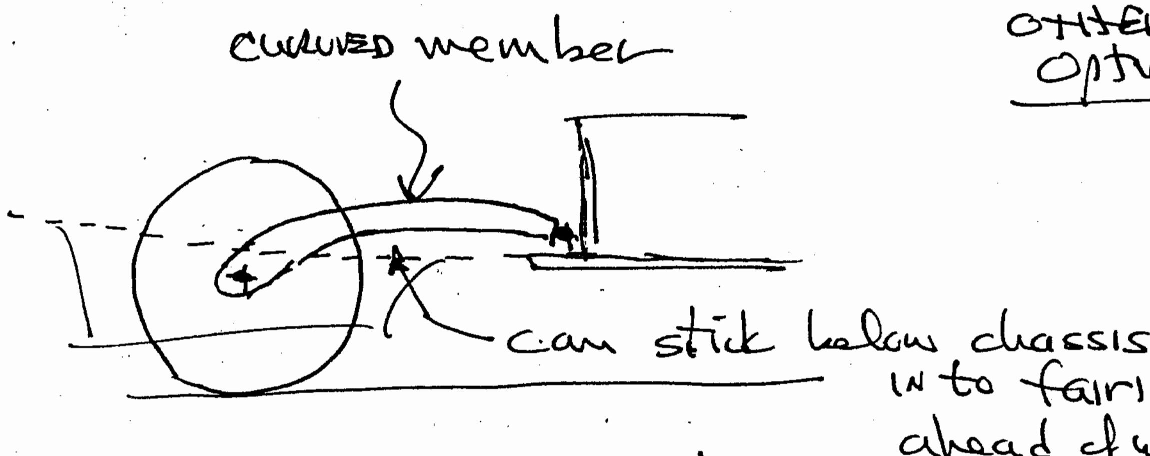


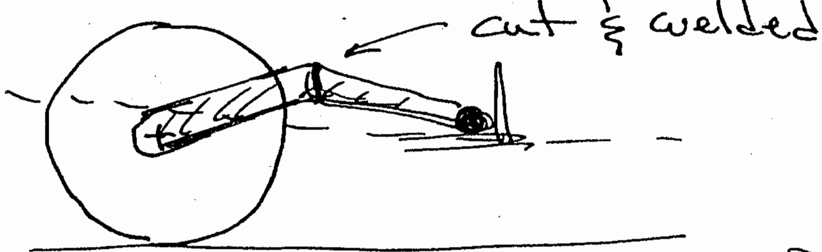


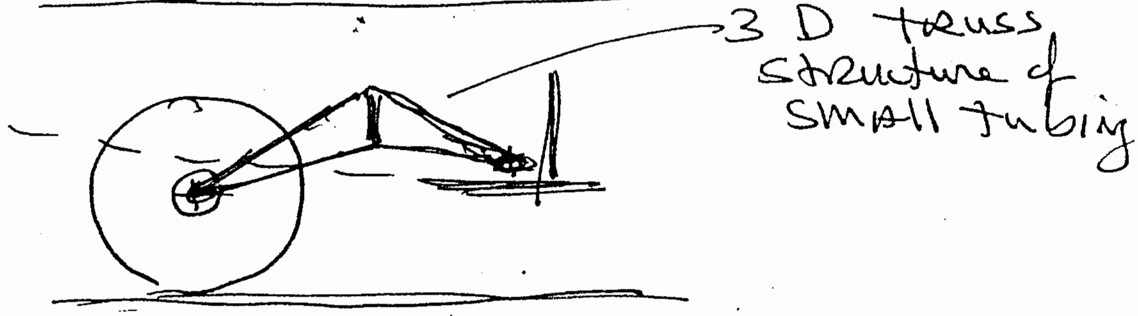
"Aurora II soln"

use a straight member with an offset Bracket for the axle

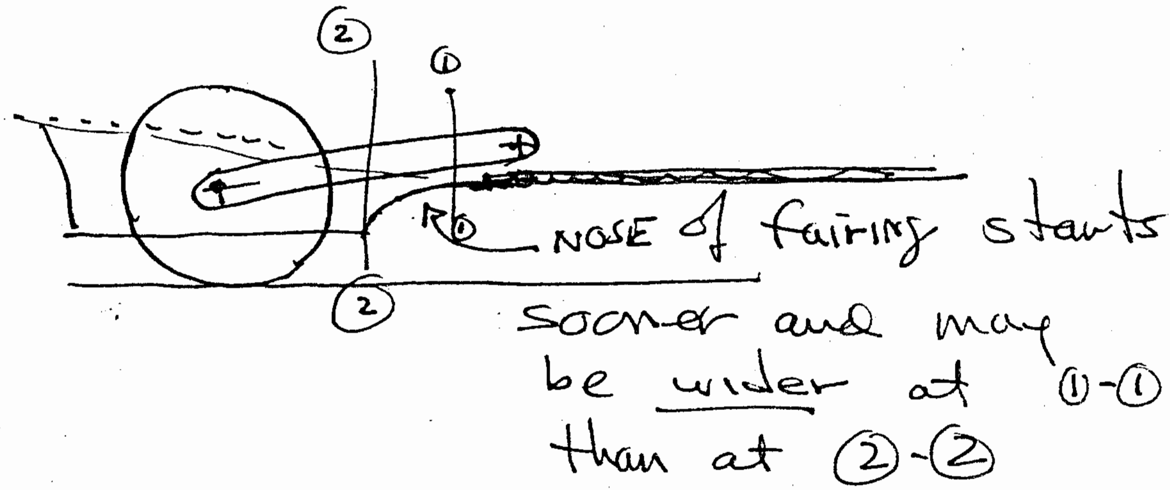
SOME OTHER Options





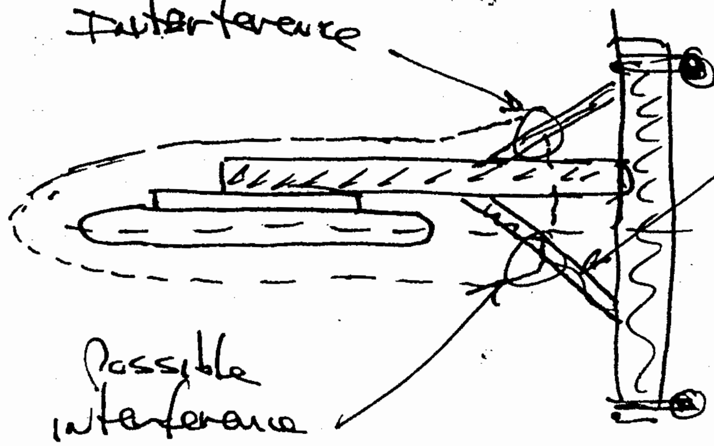


A common "Aero option" is to alter the bottom of the vehicle ahead of the fairing —



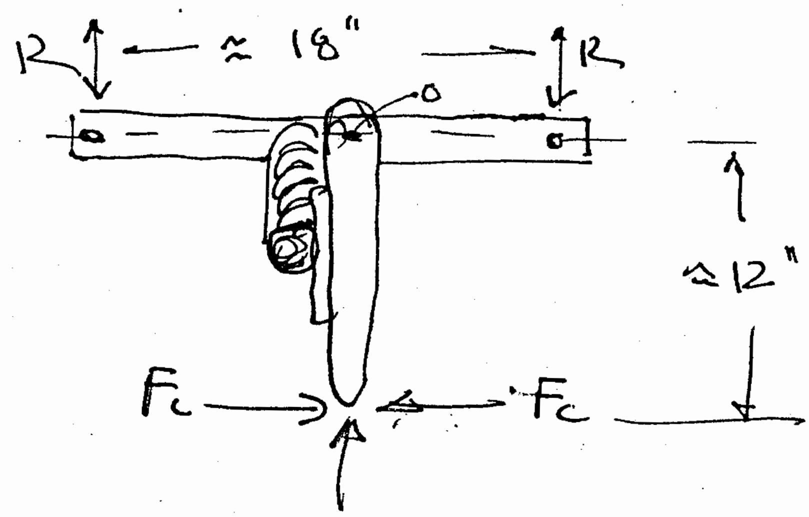
why wider?

Top view — showing why fairing may need to start "wider" if we use a straight ~~tube~~ member



Force considerations / spring mounts

Rear view cornering — F_c forces



ΣT_0: $18R = 12 F_c$

$R = \frac{12}{18} F_c$

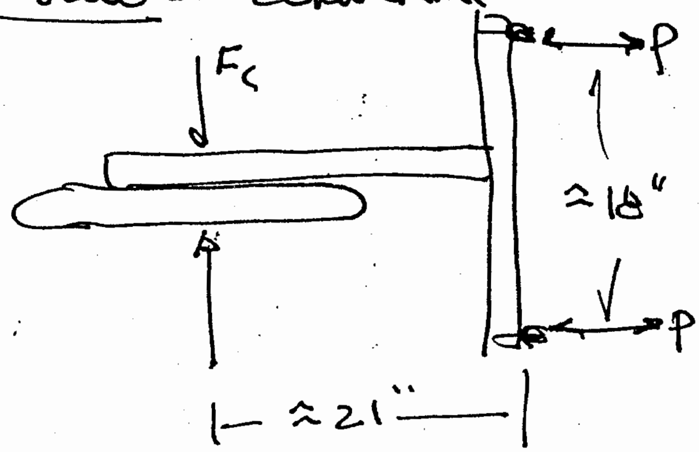
$R = \frac{2}{3} F_c$

F_c max ≈ 200 lb

$R \approx 133$ lb

add bump loads on page ___

top view – cornering



$$21 F_c = 18 P$$

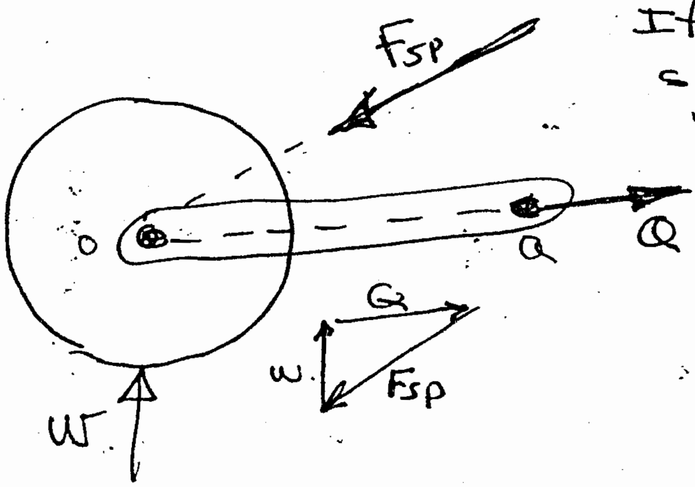
$$P = \left(\frac{18}{21}\right)^{-1} F_c$$

$$P = \left(6/7\right)^{-1} F_c$$

$$P < F_c = 180\ \text{lb}$$

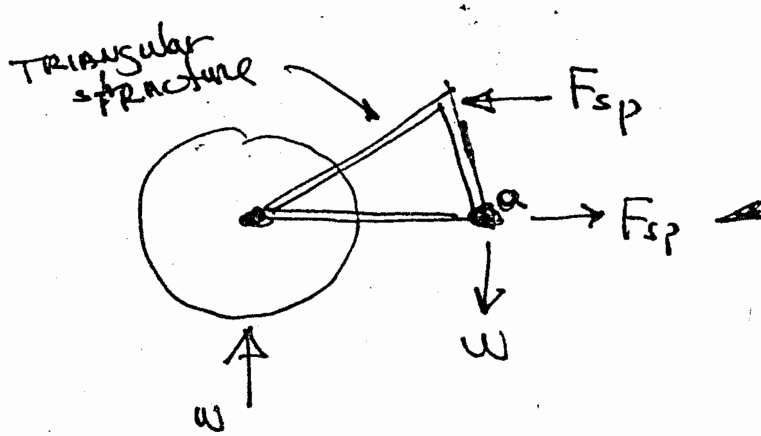
$$P \approx \left(\frac{7}{6}\right) F_c = \underline{210}$$

Spring attachments – options



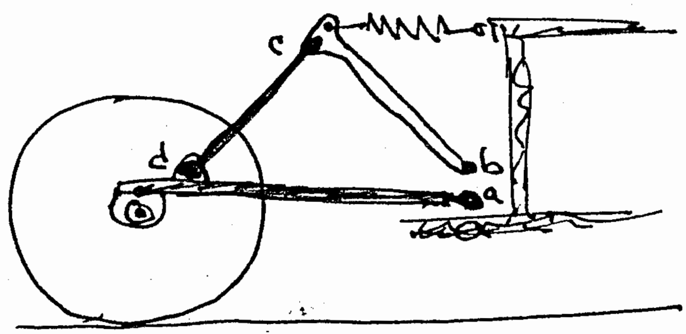
If we aim spring or spring link at the axle, then force Q is along the line between the axle & the mounting pivots (a)

a common arrangement is:



Here, the mounting pivot a also supports weight/bump load W

ON AURORA II we used rod ends for pivots and we wanted the springs to be horizontal, so we created an arrangement with a separate spring actuation that behaved like the previous sketch, but had two pivots near point a –

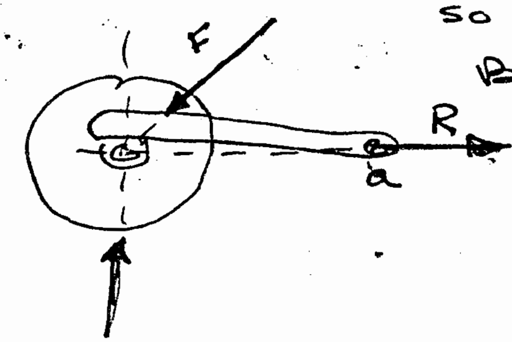


pivots at
a, b, c, d

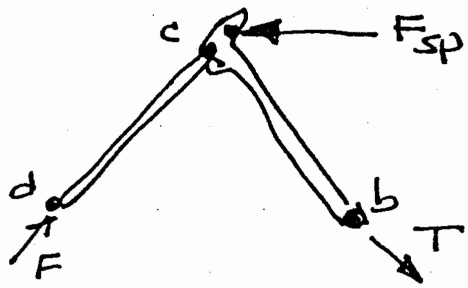
Link c-d was a straight 2 force member with left/right handed rod ends to adjust Ride height – and was aimed at the axle

Link c-b was an A-ARM with Rod ends at b on each side of the car.

THE FORCES on the swing arm were then:

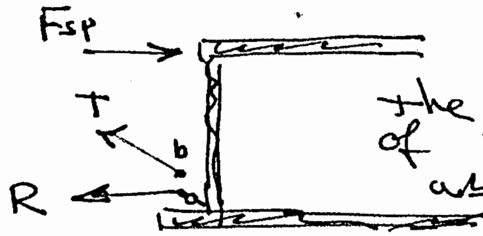


so there was little or no Bending on the rod End at Point a the other forces were —



Rod ends at b, c, d were all loaded in TENSION/compression (axially)

so on the chassis the loads were



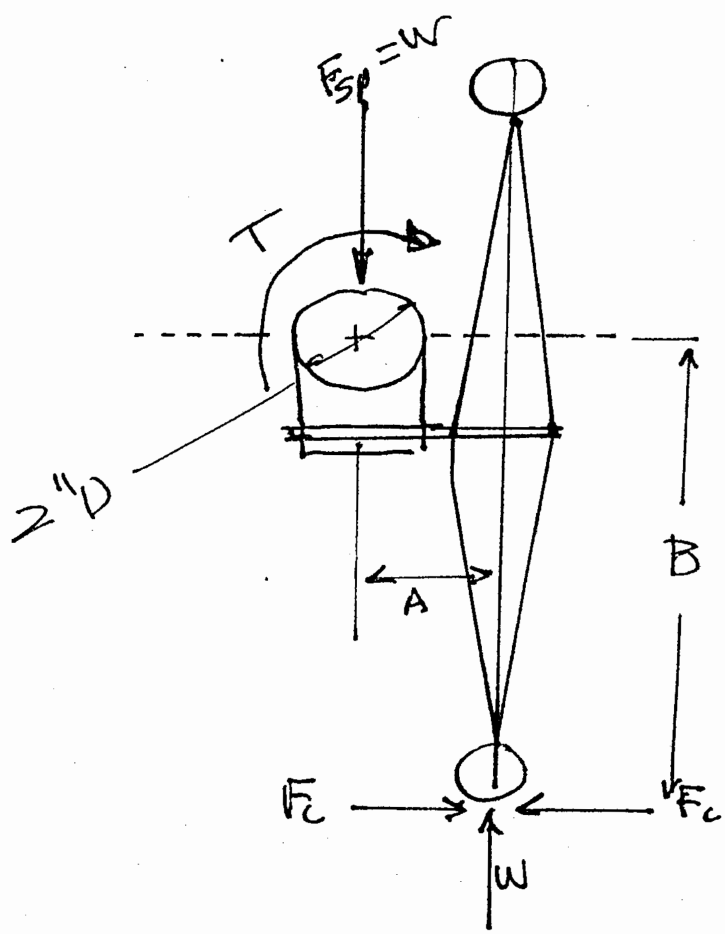
the vector sum of T & R are about the same as forces on a for the "common arrangement" on page 5, but NO rod ends are in Bending)

Note that if we did not use rod ends at a on the "common arrangement", it would be fine —

Torsional load on the arm — Bump & cornering

The Aurora II arm was 2" O.D. × 0.065" wall chrome-moly steel — weighing about 1.34 Lbs/ft (P.234, Mech Team Notes)

Rear view (Aurora 2 Approx)



F_{SP} = spring link vertical component = W

maximum torsional load on arm

$T = (B)F_c + (A)(W)$

where $B \simeq 13"$
$A \simeq 2.5"$

max $T = 13 F_c + 2.5 W$

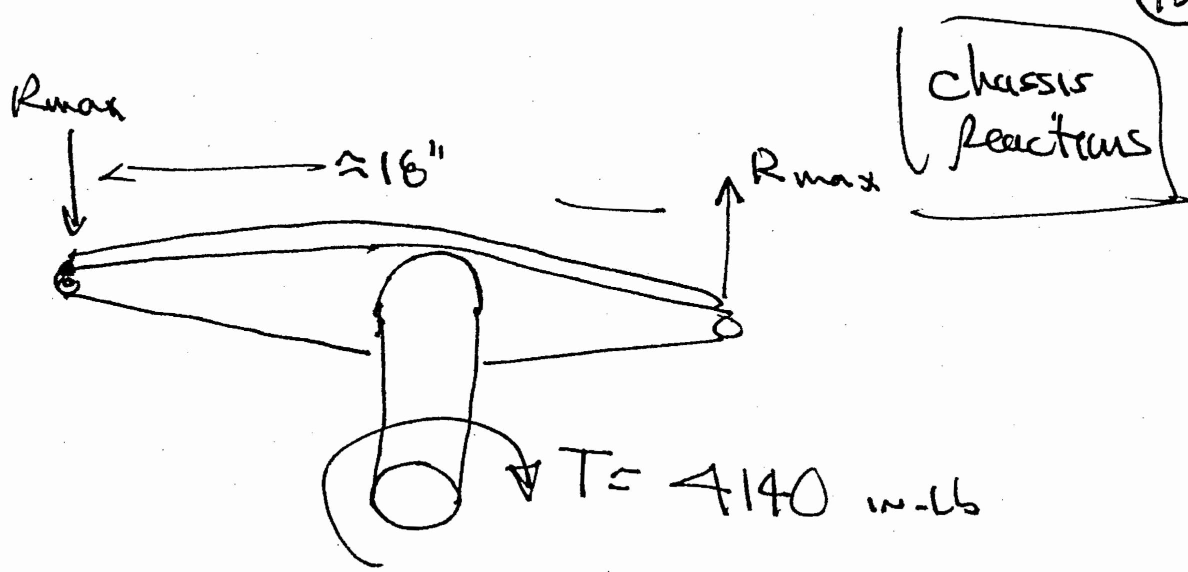
$F_c \simeq 180$ for Borealis
$\simeq 270$ for A II

max T ⇒ A2 ⇒ (13)(270)+(2.5)(4)(270) ↑4G

$T_{(A2)}$ = 6210 inch-lb

W ≅ 180 for Borealis
= 270 for A II
at 1 G Bump

for Borealis ~ assume B & A are about same as Aurora 2, $T_{(B2)}$ = 4140 in-lb



$$R_{max} \approx \frac{4140}{18} = 230 \text{ lb}$$

<u>usual</u> <u>Rmax</u> – <u>static</u> – 1g, no corner

$$\frac{T}{18} = \frac{2.5\,W}{18} = \frac{2.5(160)}{18} = 25 \text{ lb!}$$

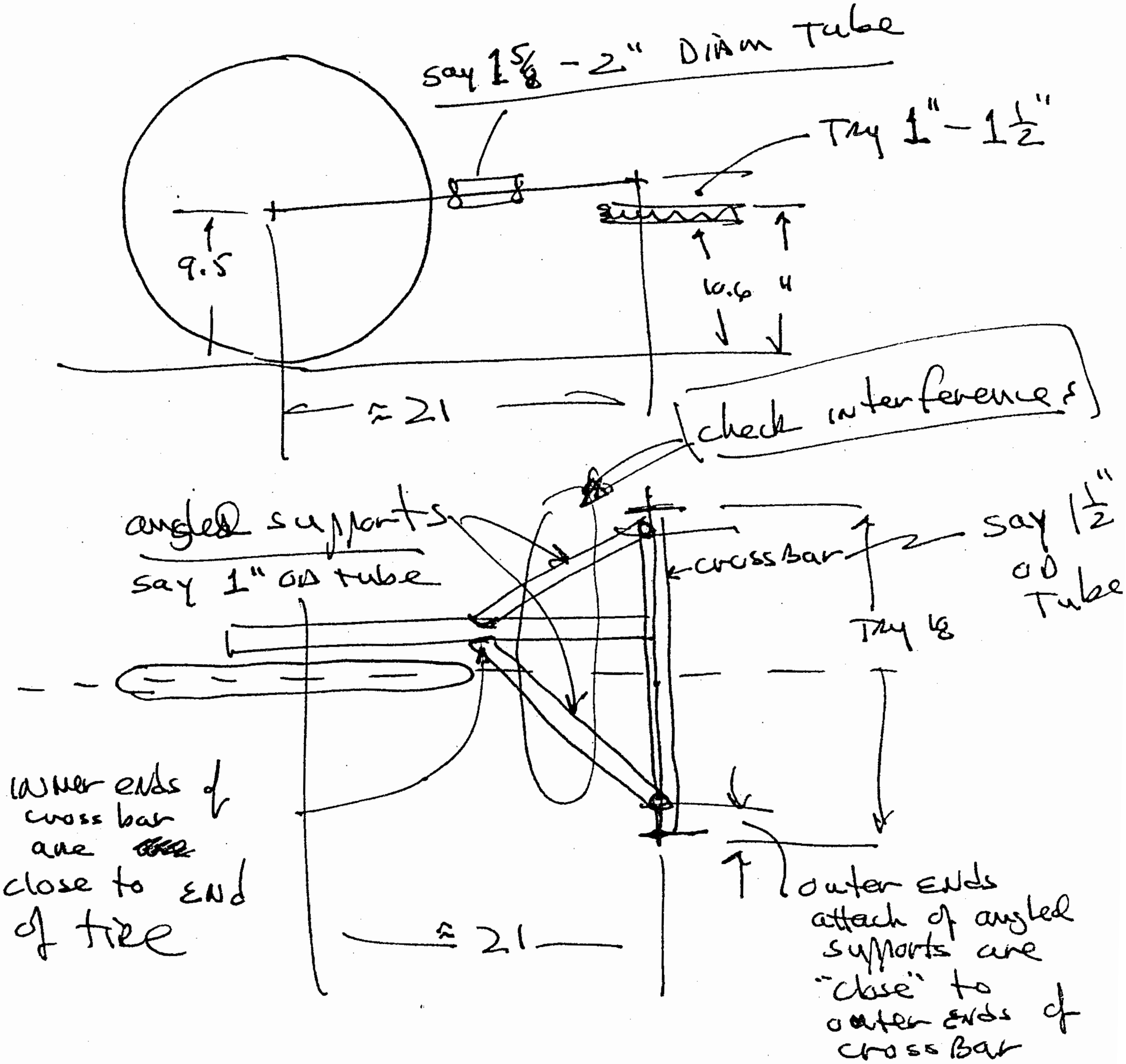
NOTE – this offset will be a bit bigger in B2.

<u>Point</u> – we can use a design similar to A2 as a very SAFE starting point

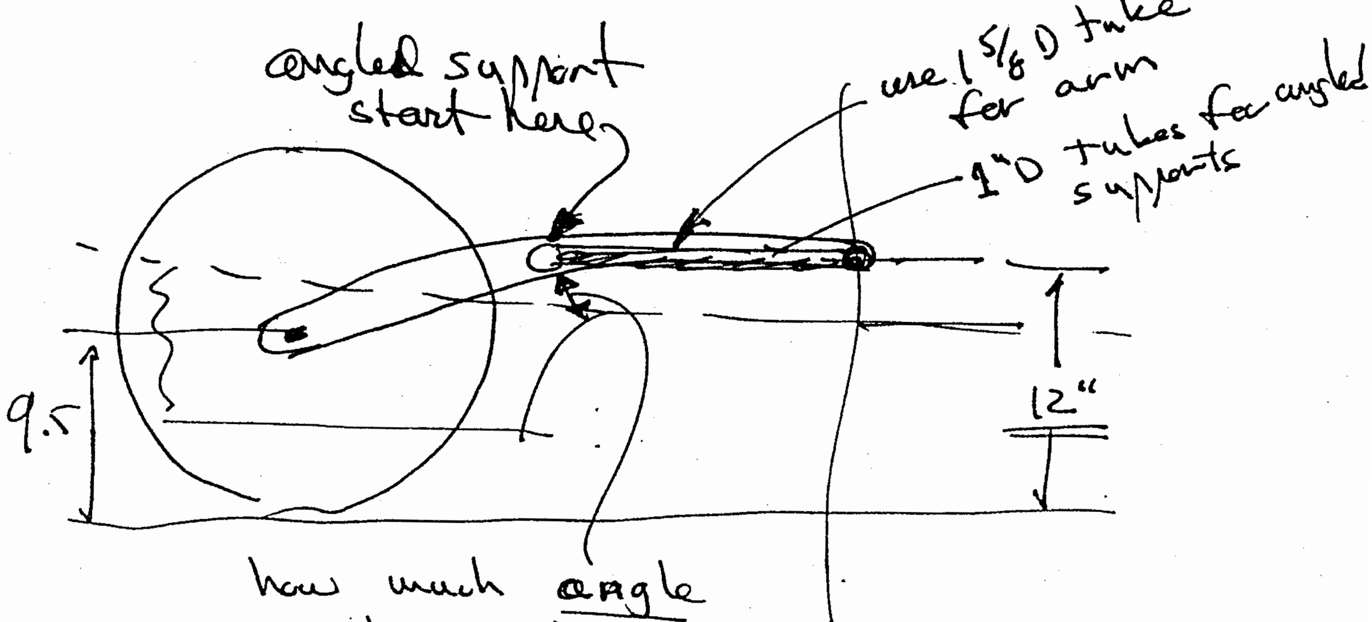
(A2 DRAWING IS ATTACHED)

SOME DESIGN ISSUES –

(A) can we use a "straight Bar" between pivots?



BENT ARM - where & how much



how much angle in the ~~arm~~ arm do we need to always have clearance?

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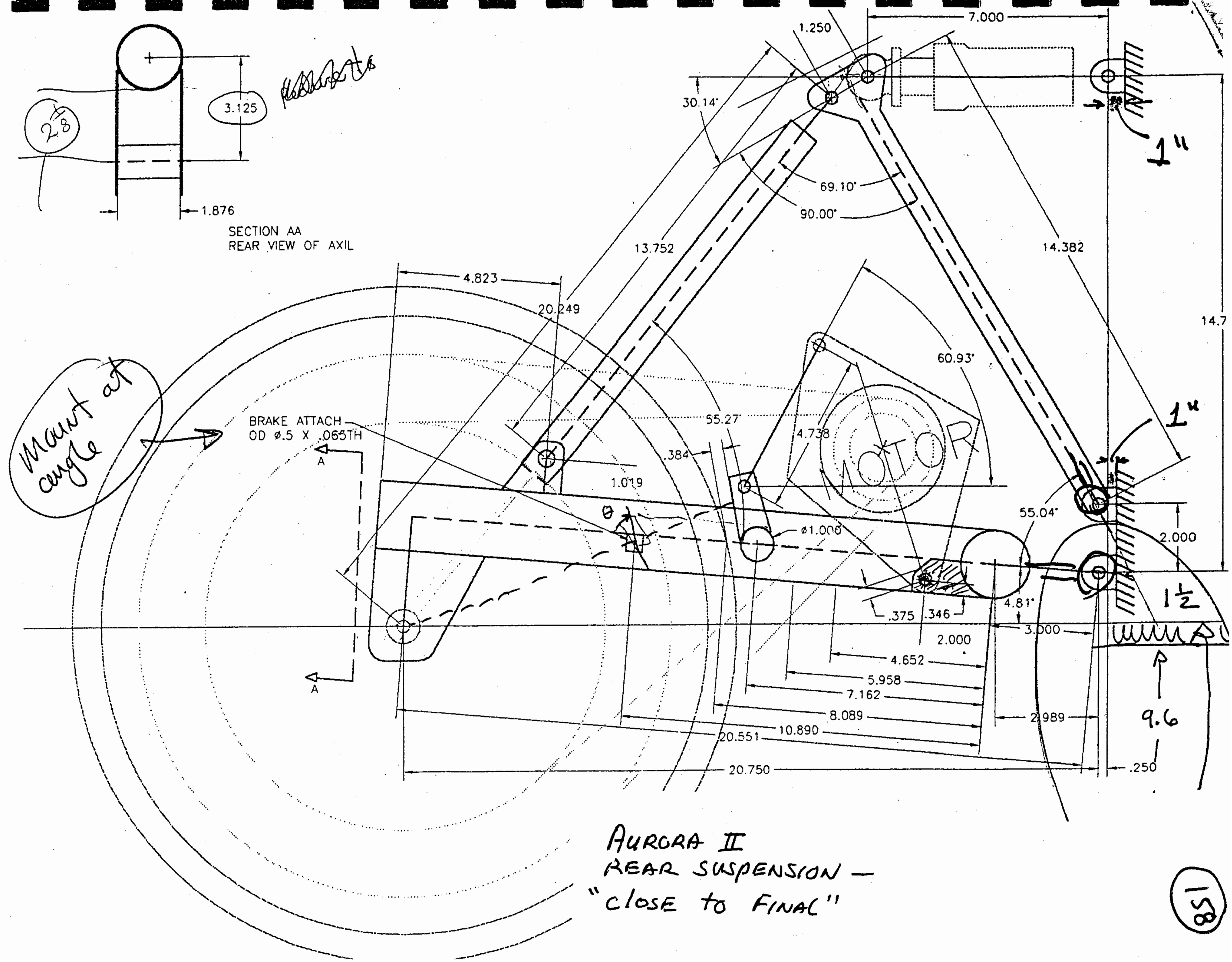
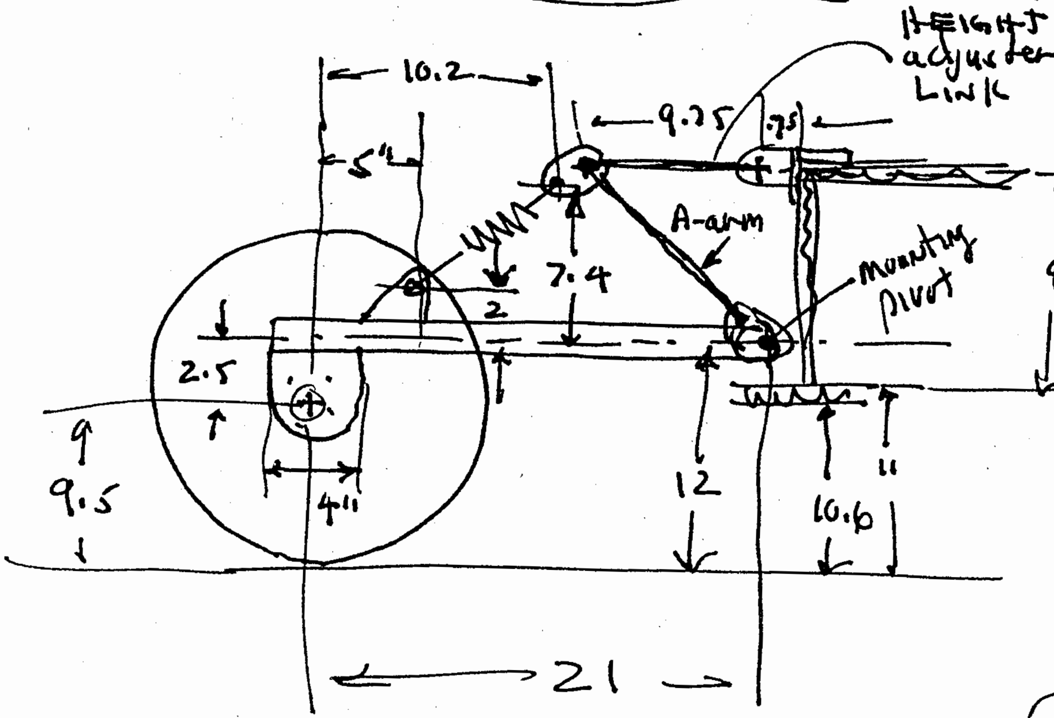
other issues - spring mount options ⇒ arm pivots
- TOE adjustment options
- camber adjustment options
- motor mount to ARM options & details -



AURORA II
REAR SUSPENSION —
"CLOSE TO FINAL"

Possible Swing arm Layout

Prof draw 12/10/02

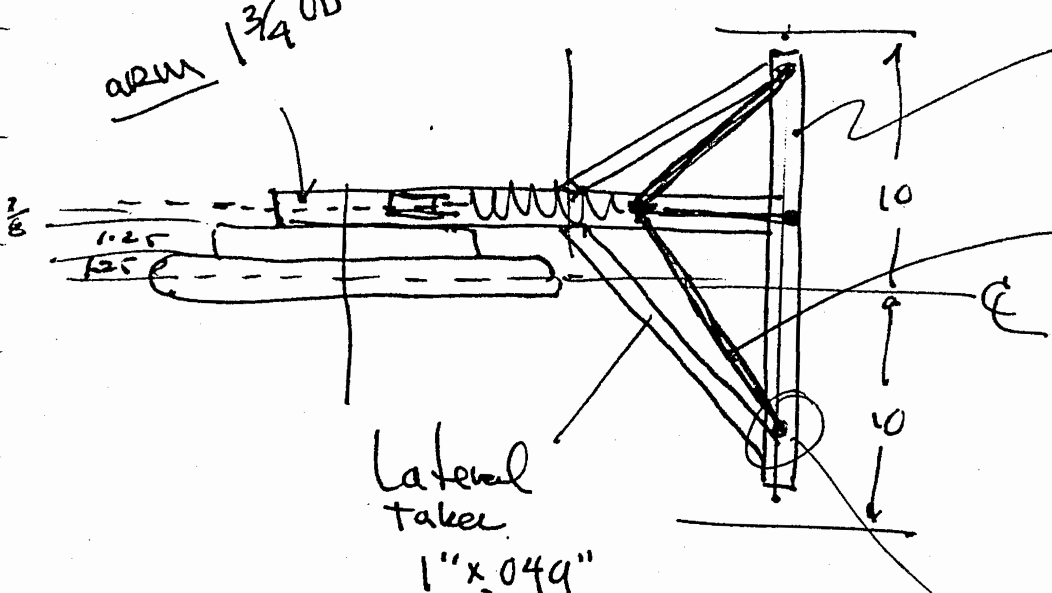


[arm is Horizontal at static]

9.4 to middle of Top panel at Rear

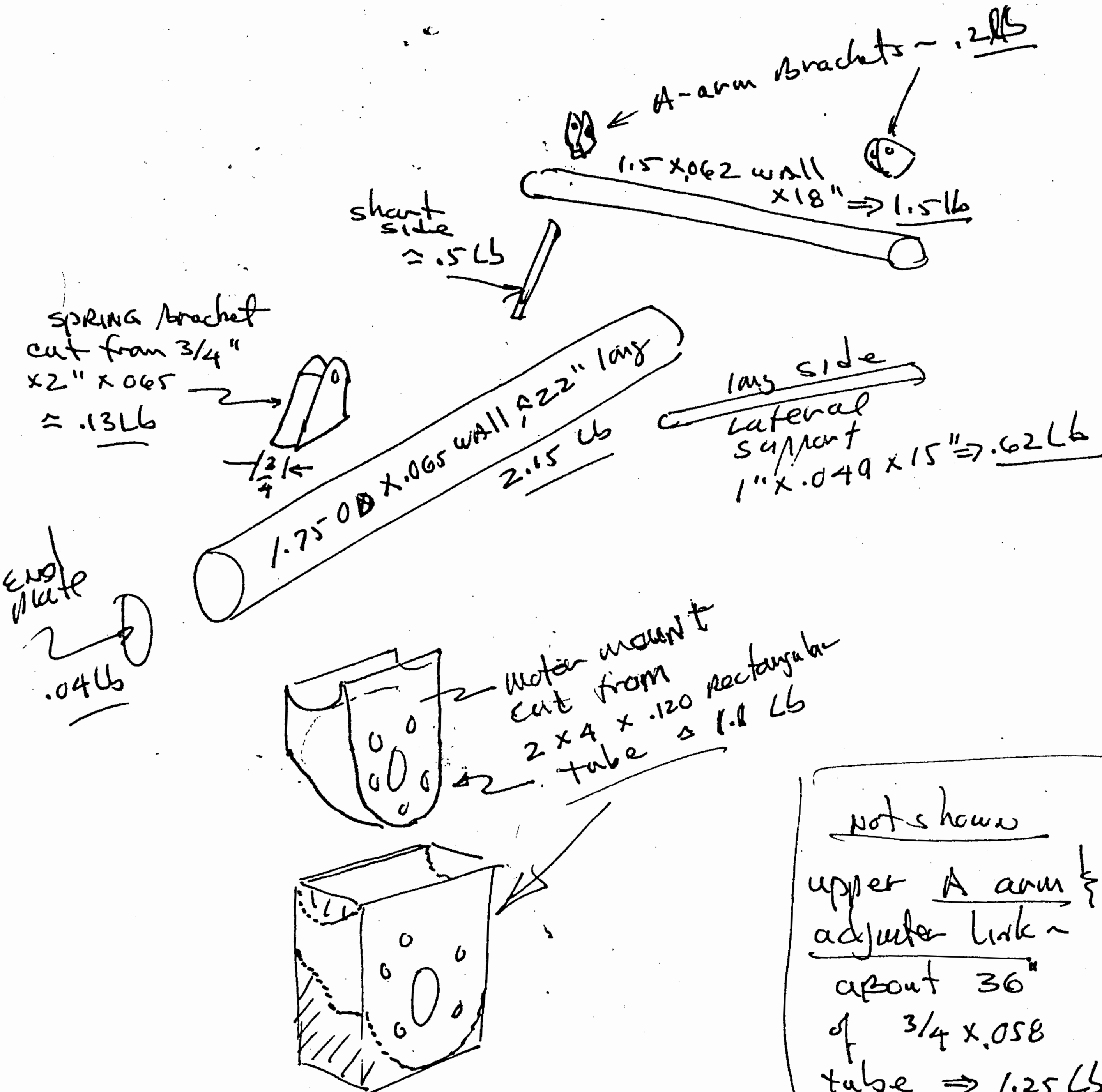
[HEIGHT Adjuster is Horizontal at static]

[Fox shock 8.5" fully Extended 2.5" travel]



A-arm mounts to cross tube on Rod ends

wt Estimate

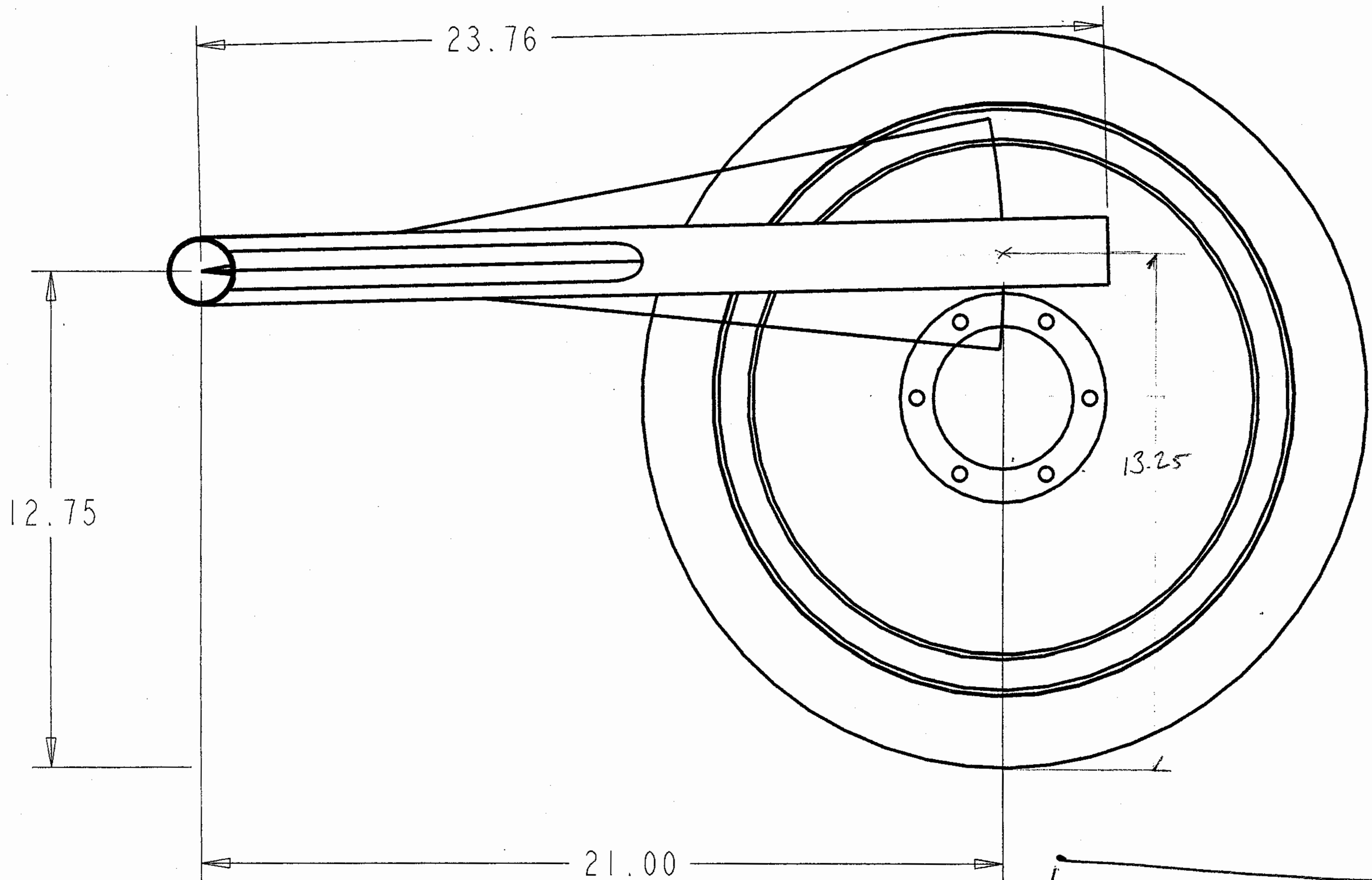


not shown

upper A arm & adjuster link ~ about 36" of 3/4 x .058 tube ⇒ 1.25 Lb

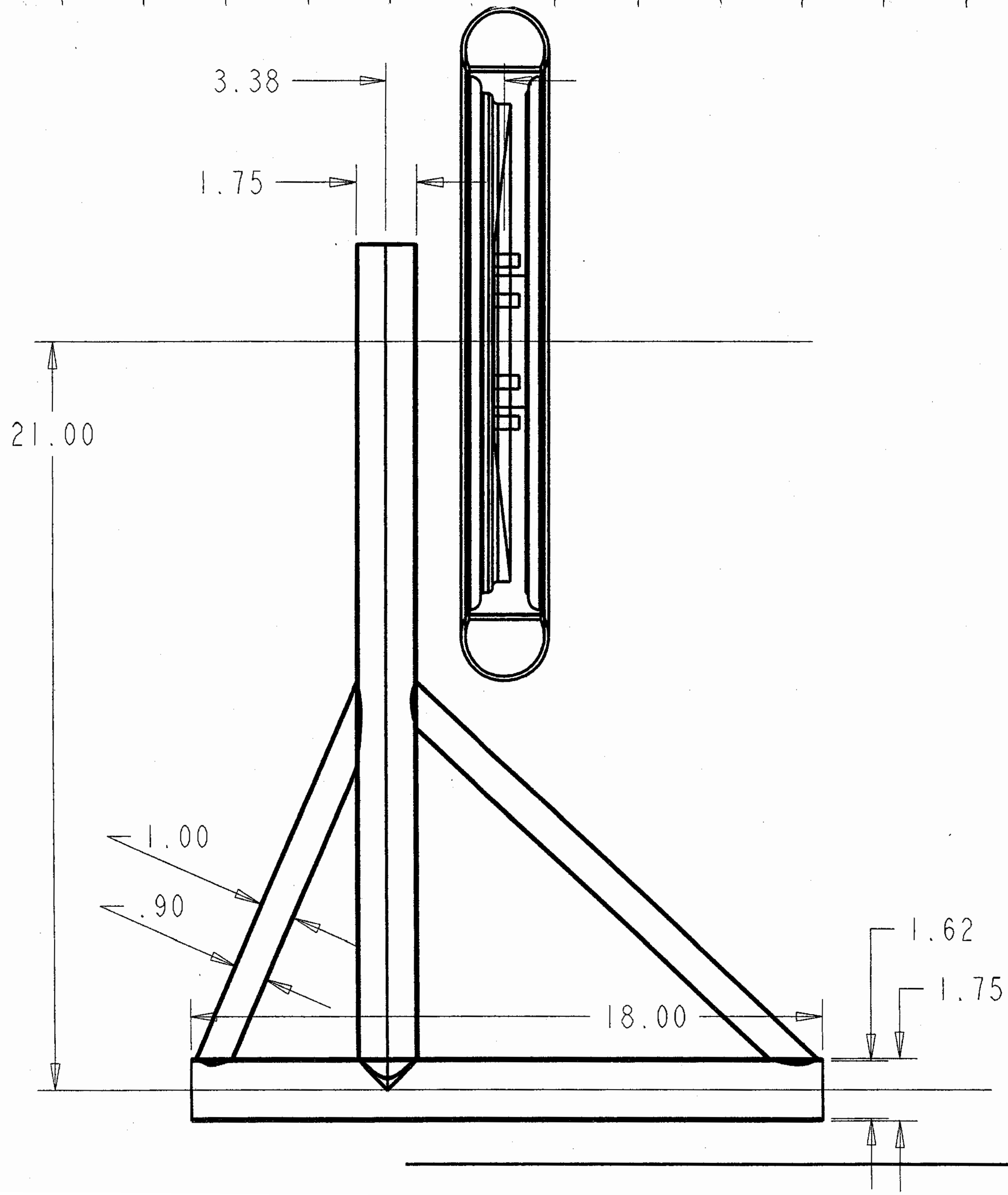
4 PRU-5T Rod ends ≈ .3 Lb

wt so far: 7.8 Lb without
- spring/shock
- mounting method
- Bolts



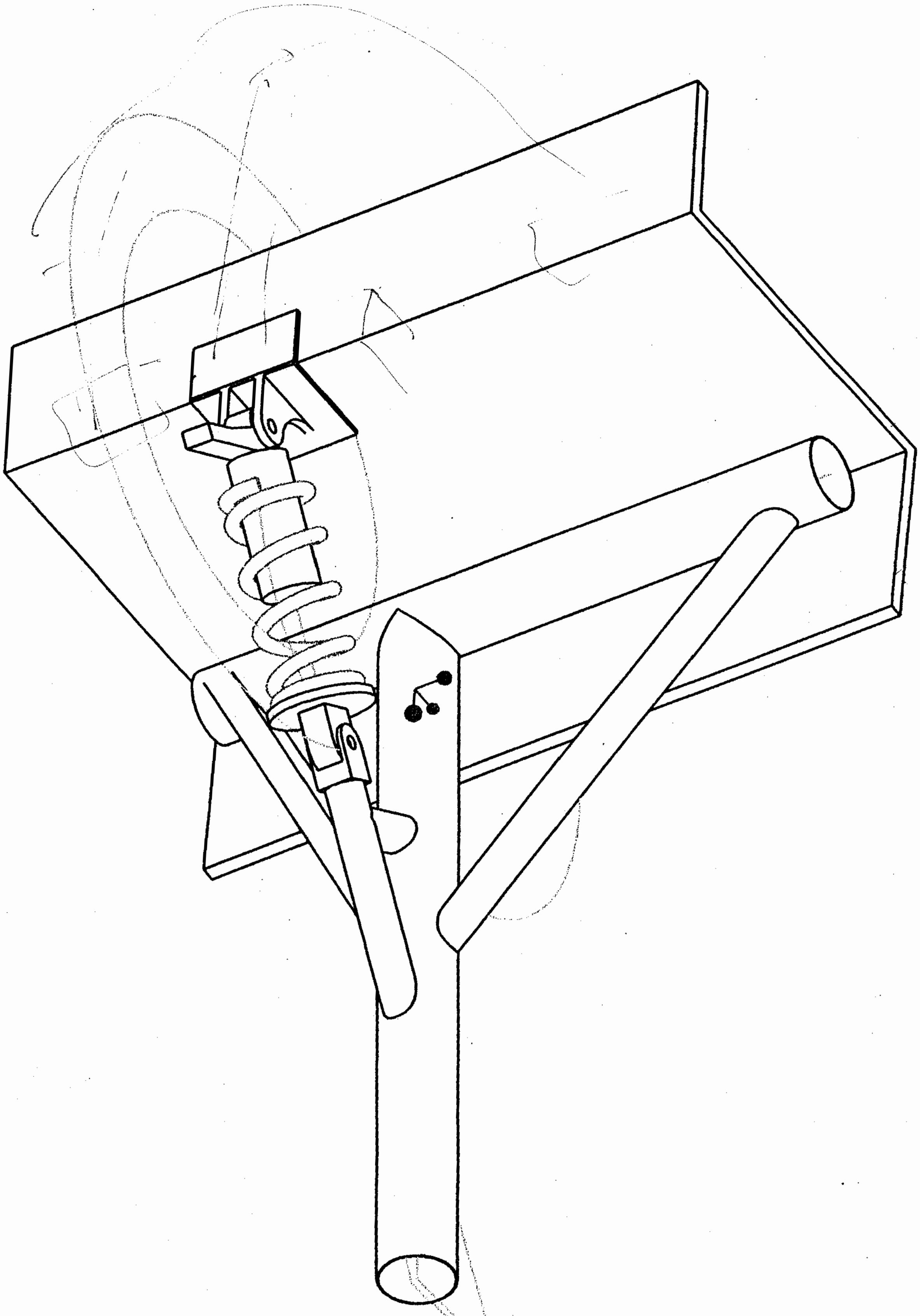
Borealis 2
Rear Swing Arm-Straight
Al Majkrzak
12-19-2002
SCALE 0.250

161



Borealis 2
Rear Swing Arm-Straight
Al Majkrzak
12-19-2002
SCALE 0.250

162



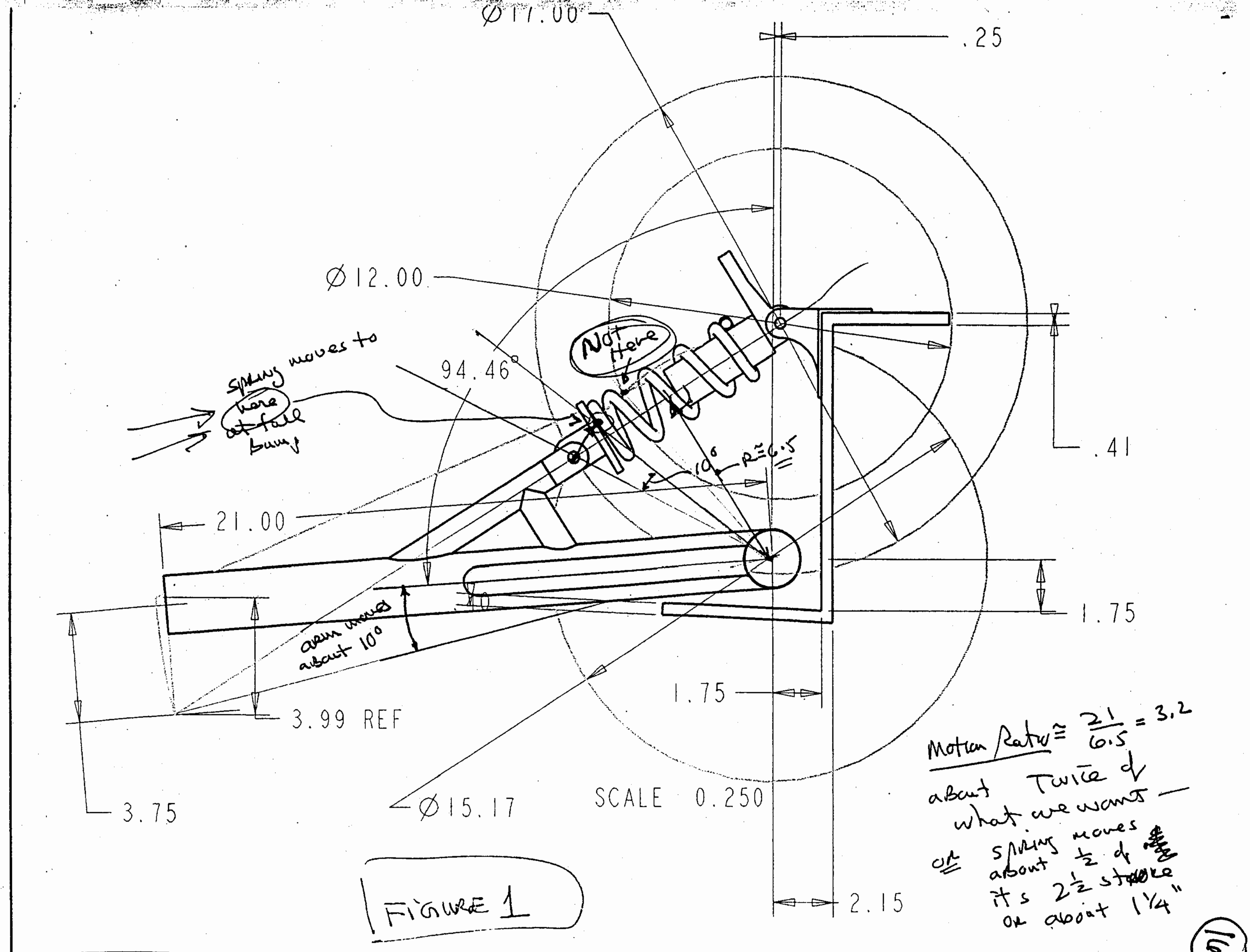
TO: SUP MECH TEAM 12/23/02
FROM: Prof Starr
Re: Rear Suspension AND CHASSIS

I cannot make tonight's meeting, but I have been fooling with the rear suspension layout – THE following DESCRIBES some "points" AND RECOMMENDS what WE should do –

1. Treure & Al came in last thursday and showed me a swing arm layout with the spring attached to the swing arm and chassis.

The motion analysis was done incorrectly. (SEE FIGURE 1, from TREURE) when the axle moves 4", the spring compresses only about 1.25", Not its available 2.5", for a gross motion ratio of $4''/1.25 = 3.2$ = MR.

A HIGH motion ratio doesn't use all the shock travel and produces large loads in the shock – we could use smaller shocks, but with the 40+ Lbs of unsprung weight at the rear, I don't think we want a real small oil Reservoir in the shock – we KNOW these shocks with Motion ratios of about 1.6 work O.K. at the front from Borealis I – So we should keep the MR ≈ 1.6



Ø17.00
.25
Ø12.00
.41
94.46°
Not Here
spring moves to here at full bump
10° R≅6.5
21.00
1.75
arm moves about 10°
1.75
3.99 REF
3.75
Ø15.17
SCALE 0.250
2.15
Motion Ratio ≅ 21/6.5 = 3.2
about Twice of what we want —
or spring moves about ½ of its 2½ stroke or about 1¼"

FIGURE 1

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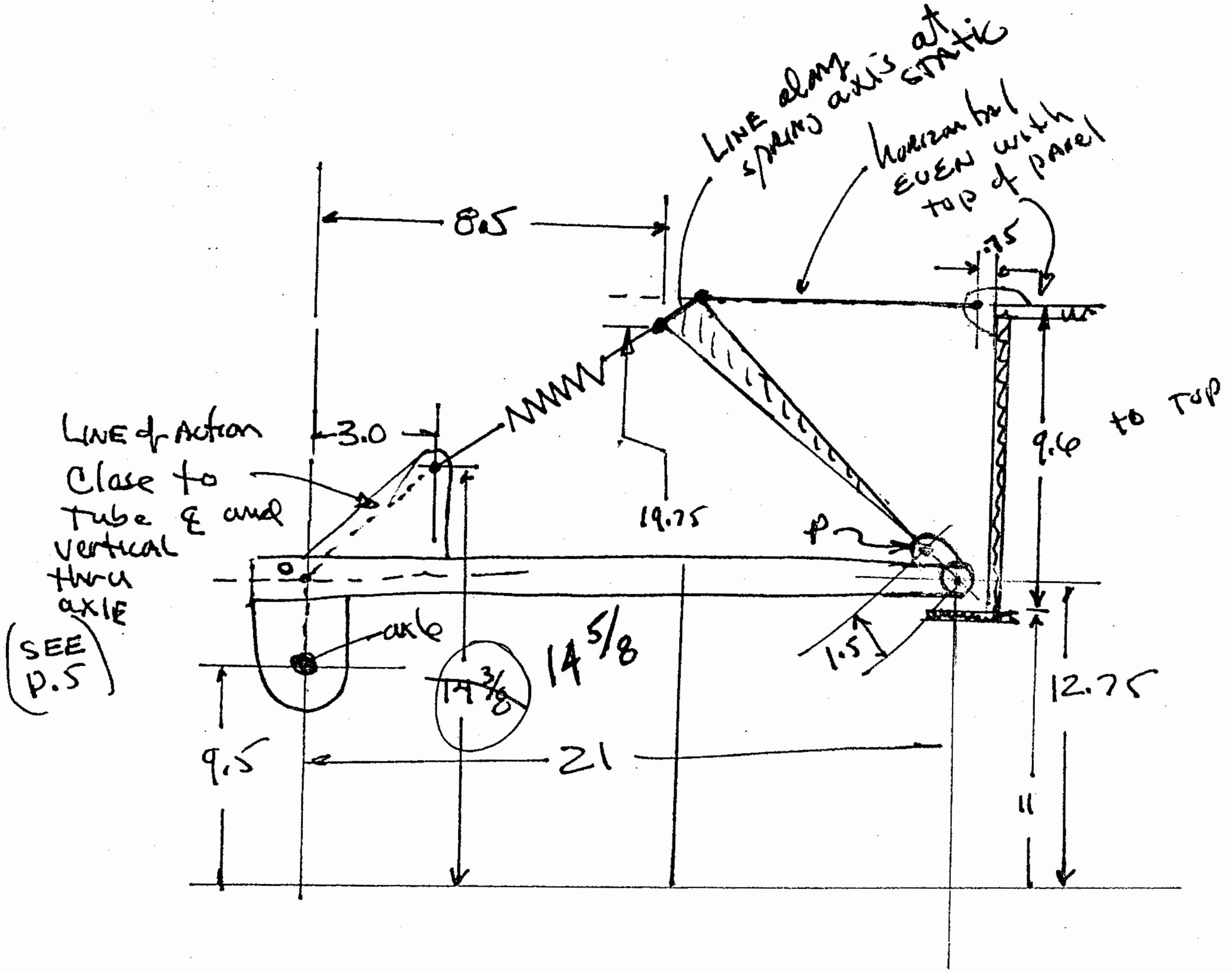
To have MR ≈ 1.6, then the shock travel should be about:

$$MR = \frac{\text{wheel travel}}{\text{shock travel}} \approx 1.6 = \frac{4''}{2.5''}$$

└ DESIRED shock travel

2. To achieve this, we need to utilize the spring & link type of layout that I described in the 12/10/02 memo. I am working out a slightly different geometry from that memo that uses a fox shock with 2.75" of travel (which is 8.75" long fully extended). The figure 2 shows some key preliminary dimensions with respect to ground & motor/axle.

The drawing I got from Al on Thursday showed the front pivot of the swing arm at 12.75" above the ground, with a straight swing arm, and a 21" horizontal arm length — Figure 2 uses these, though it would be good to decrease the 12.75" and 13.25" tube ℄ height at the axle if possible, via discussion with the <u>Aero team</u> — regarding the nose of the fairing —



(SEE P.5)

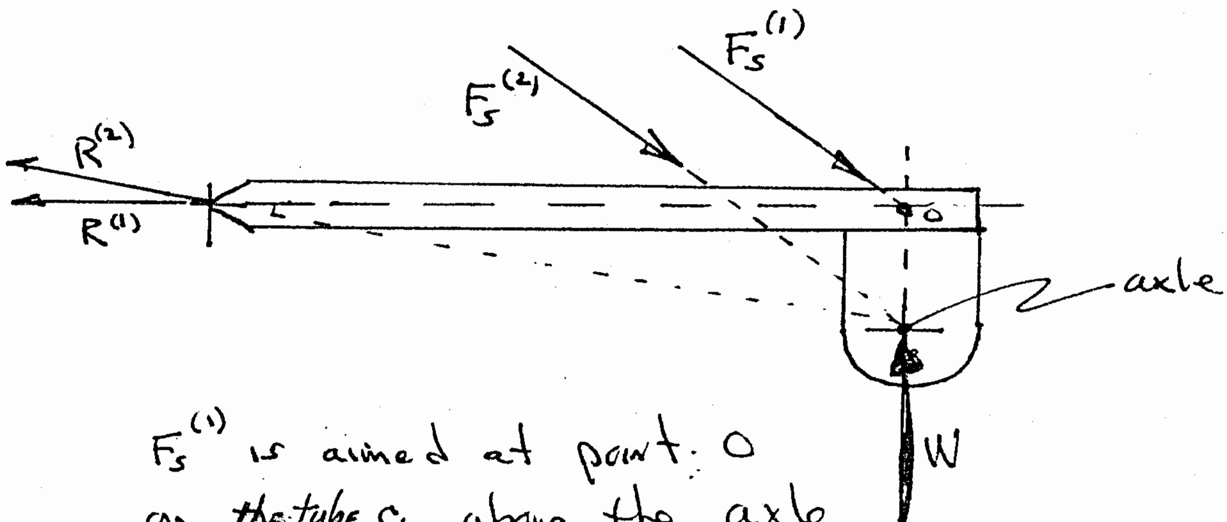
FIGURE 2 Layout of proposed link system — static position

uses Fox shock with 2.75" stroke, 8.75 center to center length fully extended —

DRAW this and check the motions & pick a height for point O — (nominal 13.25" (Point P is a pivot attached to the cross tube) check shock motion at +2.5" Bump, -1.5" REBOUND at axle

3. Comment on Aiming the Spring Force —

My 12/7/02 memo regarding "Reconsidering a swing arm", had comments about aiming the spring force at the axle as a favorable arrangement. This is O.K if the axle is on the ℄ of the straight swing arm, but in our case, the axle is below the straight swing arm — the following shows two cases:



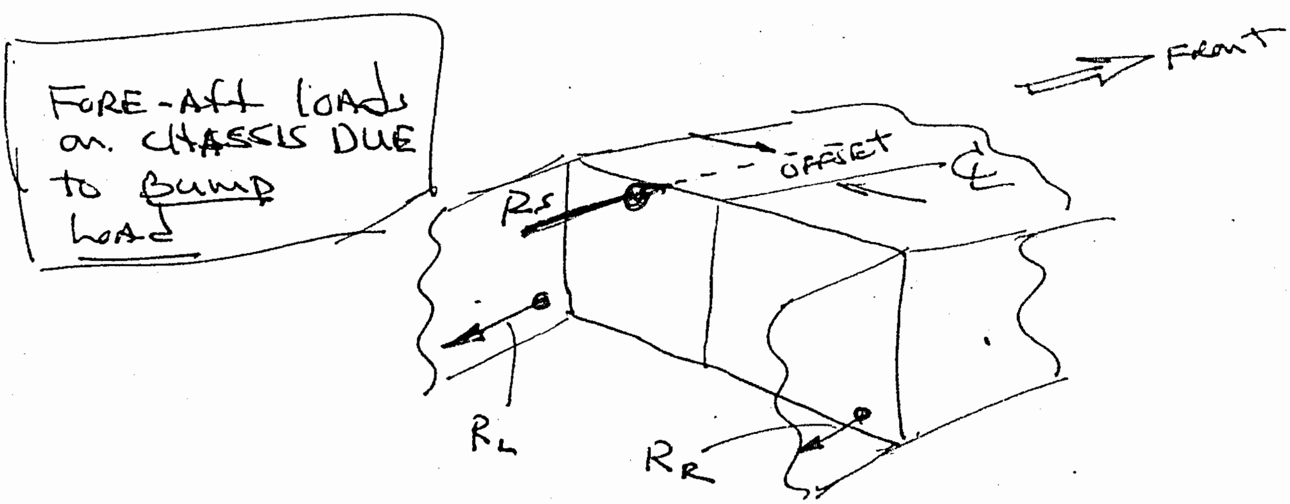
$F_s^{(1)}$ is aimed at point O on the tube ℄ above the axle, and produces Reaction $R^{(1)}$ which loads the swing arm in TENSION, and $R^{(1)}$ has NO component that adds to the spring force

$F_s^{(2)}$ is aimed at the axle, and produces reaction $R^{(2)}$ which produces some bending in the swing arm in addition to tension, and $R^{(2)}$ has a vertical component that the spring must overcome in addition to W.

⟹ Aiming F_s at point O is BETTER

4. Arm Mounts on Chassis

I'VE DEVELOPED A FEW mounting options with adjustments, USING TRAVIS' IDEA of The pivot Bolt BEING REMOVEABLE, AND ADJUSTMENTS MADE by changing the BRACKET. Since the spring link is horizontal, the force on the chassis will produce NO moment when viewed from the rear, but since it is offset from the centerline, in the same line as the swing arm axis (when viewed from the top, there will be a difference in the fore-aft reactions on the chassis at the pivots:



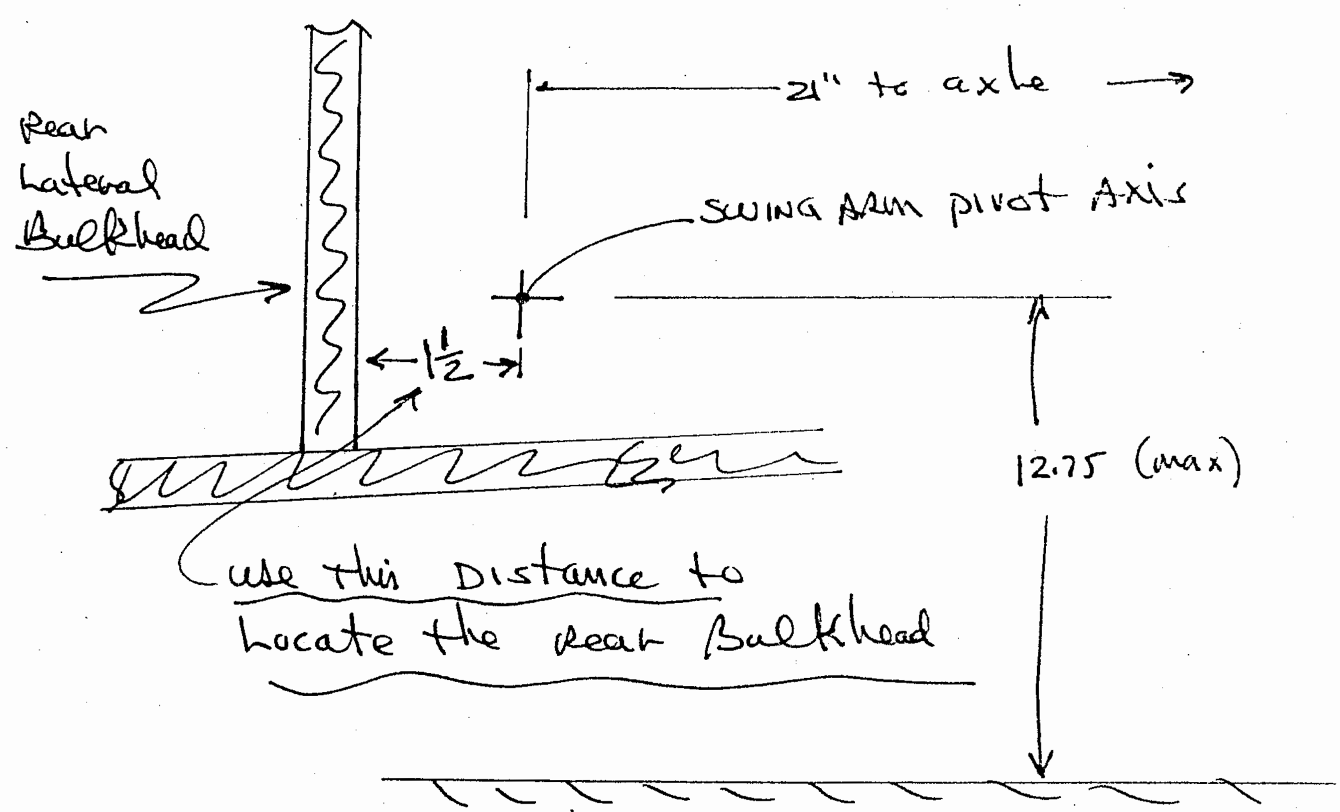
$R_L > R_R$

R_S = spring link force = $R_L + R_R$

since the vehicle is doing bump loads all the time, (vs. CORNERING loads) we could have the more heavily loaded mount be "not-adjustable" and the less loaded one "adjustable" — more on this soon —

5. REAR Lateral Bulkhead Location

For the chassis mounts of the swing arm, which locates the BACK lateral Bulkhead and the tabs, consider the following — SIDEVIEW



Placement of Locking Tabs in Rear lateral panel