

PROGRAM REPORT

SUBJECT: Revised Stability Index for Utility

Objective:

Review alternatives to increase stability index.

Background:

The stability index of Ranger vehicles is generally at or below median levels to comparable vehicles (Attachment I). A study of methods to improve stability index for the Bronco II has resulted in several design alternatives to achieve an improvement of Bronco II stability index from 1.85 to a maximum achievable of 2.25 without a totally new concept vehicle.

Summary:

The study revealed that increased mass or revised component center of gravity locations resulted in small increases in stability index. These types of improvements were not adopted as part of the final proposals. However, if these revisions were adopted, they would be additive. Attachment II provides details of these effects. One adverse effect found was a reduction in stability index of 0.10 by adding 130# of luggage with the RPO roof mounted rack.

In order to improve stability index substantially, the following are required:

- .Widened track width
- .Lower center of gravity achieved by raising the wheel center lines with the respect to body with trade-off's in ground clearance and vehicle package.

Discussion:

Attachment III describes five (5) alternatives to increase the stability index. All proposals assume the maximum tire will be restricted to a P205 x 15. These proposals are summarized as follows:

Proposal 1

Increases front track to 55.9" by reducing wheel offset 0.5". Increase rear track to 56.6" by increasing rear axle length 1.5" and use the revised offset wheels. The vehicle height will be reduced 0.5" in the front by restricting jounce and the rear ride to curb will be reduced 0.5" by increasing spring rates. This proposal provides a stability index of 2.02. The offset wheels and front vehicle height revisions can be used on the current P/U 4x4. The rear height of the P/U 4x4 will be reduced 0.5" by revising the spacer height. This proposal results in a unique rear axle for the Utility. The P/U 4x4 stability index is 2.01 with this proposal.

<u>Model</u>	<u>Investment</u>	<u>Piece Cost</u>	<u>Weight</u>	<u>Timing</u>
Ranger 4x4	-	\$(1.50)	2.0#	1983
Bronco II	\$(4.0 million)	4.00	(10.0)	1983½

Proposal 2

Increases front track to 56.4" by lengthening front axle 0.25" per side and using the revised offset wheels in Proposal I. All other changes are the same as Proposal I. This results in a stability index of 2.03 on the Bronco II. The increased front track in this proposal will result in a 1.3" "dog track" in the P/U 4x4. The P/U 4x4 stability index is 2.02 with this proposal.

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Plaintiff's Exhibit

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<u>Model</u>	<u>Investment</u>	<u>Piece Cost</u>	<u>Weight</u>	<u>Timing</u>
Ranger 4x4	-	\$42.00	2.0#	1983
Bronco II	\$(4.0 million)	\$3.50	(11.0#)	1983½

Proposal 3

This proposal maximizes the vehicle track with a small reduction in height. Thus, providing maximum ground clearance and only minor body sheet metal tear-up. This alternative results in an index of 2.09. The change described in this proposal would be unique to the Utility and could not be incorporated into the 4x4 for Job #1, 1983. The required revisions in this proposal are widen frame siderails, revise front radius arm and axle length, and revise front axle carrier position to widen track on both axles to 58.0". Investment (\$10.1 million); piece cost (\$11.09); weight (41.0#); timing - Job #1, 1983½ (potential risk on release and samples).

Proposal 4

This utilizes the same track increase in Proposal 3 and a 1.36" height reduction. The resulting stability index is 2.19. This proposal has rear body and seating package revisions as well as increased frame vertical offset of 1.36" at the front and increased rear frame height by 1.36". The rear spring will have 2" of negative camber. These changes could not be incorporated into the P/U 4x4 for Job #1, 1983. Investment (\$13.1 million); piece cost (\$54.00); weight (113.0#); timing - Job #1, 1983½ (potential risk on release and samples).

Proposal 5

Reduces vehicle height an additional 1.0" from Proposal 4 for a stability index of 2.25. This proposal has major front and rear sheet metal revisions and results in a vehicle height only 0.5" higher than a 4x2 pick-up due to 15" vs. 14" tires on 4x4 vs. 4x2. This requires increased frame vertical offset of 2.36" at the front and 1.36" at the rear but with a 3" negative camber of the rear spring. These changes could not be incorporated into the P/U 4x4 for Job #1, 1983. Investment (\$13.8 million); piece cost (\$54.00); weight (113.0#); timing - Job #1, 1983½ (potential risk on release and samples).

Open Issues:

General Open Issues:

Attachment IV provides an open issues list for the five proposals and identifies the open problems requiring detail study and resolution. Proposal 1 and 2 have the fewest issues with the wheel durability prove-out and sign-off timing being the most critical.

Ground Clearances:

Attachment V compares ground clearances for various proposals and shows the primary trade-off's in approach and departure angles with the extremes of lowering the vehicle center of gravity.

Commonality:

Proposal 1 or 2 can be incorporated in the P/U 4x4 for Job #1, 1983. These proposals will result in a unique rear axle for the Utility.

All other proposals result in significant vehicle tear-up to incorporate them into the P/U 4x4 and cannot be contained within Job #1, 1983 P/U 4x4 timing.

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Recommendations:

- Proceed with Proposal 2 revisions to the Utility and the P/U 4x4 to maximize stability index and meet reasonable cost and timing constraints.
- Delete the roof mounted luggage rack as an RPO due to adverse effect on stability index.
- Establish and initiate a joint Design/Development work plan to achieve desired lateral acceleration gains in the Utility vehicle.

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CENTER OF GRAVITY AND STABILITY INDEX COMPARISON

Vehicle	LD	Tread		Curb Wt.	Center of Gravity		Stability		Standard/ Cut. Tire
		Frnt.	Rear		Horis. 1/	Vertical Base/Ovt.	Index Base/Ovt.	Envelope	
<u>Pickup 4x2</u>									
- Ranger 2/	114.0	54.9	54.6	2559	46.0	24.8/25.6	2.21/2.14	6242	P185R14/205
- Ranger	114.8	54.8	54.4	2730	47.3	25.5	2.14	6260	P215/75R14
- Courier	112.9	52.5	54.5	2710	50.6	20.8	2.57	6040	6.00x14
- Toyota	101.5	52.5	52.3	2493	44.2	19.0	2.76	5319	7.00x14
- F100	133.0	64.6	64.6	3028	59.2	25.9	2.49	8592	P235/75R15
<u>Pickup 4x4</u>									
- Ranger 2/	114.0	54.9	54.1	2051	44.5	27.1/28.5	2.01/1.91	6213	P185M5/LT215
- Pickup	111.0	52.8	51.0	3046	44.9	20.4	1.83	5761	G78-15
- Toyota	101.8	56.3	55.1	2942	39.0	25.1	2.23	5691	H78-15
- Toyota	110.2	56.3	55.1	2942	46.7	24.9	2.24	6130	H78-15
- F150	132.2	65.2	64.8	4282	55.9	27.7	2.35	8593	P215/75R15
<u>Utility</u>									
- Bronco II 2/	94.0	54.9	54.1	3002	43.7	28.2/29.3	1.93/1.86	5123	P185R15/LT215
- Jeep CJ5	83.4	52.3	50.6	2636	47.4	23.5	2.19	4791	H78-15
- Jeep CJ7 Reno.	93.6	54.1	52.1	2775	49.2	26.0	2.04	4965	L78-15
- IH Scout	100.0	61.6	60.4	4285	44.1	27.5	2.22	6100	10.00x15
- Pre-78 Bronco	92.0	57.4	57.4	3498	40.0	26.8	2.14	5200	G78-15
- 80 Bronco	104.7	65.1	64.4	4206	50.0	26.7	2.43	6779	L78-15
- 80 Bronco	104.9	64.8	64.3	4406	55.4	27.6	2.34	6761	L78-15

1/ Horizontal CG is measured rearward from front axle.

2/ Calculated data.

Weight Control Engineering/
January 20, 1981

Revised/ February 5, 1981

BRONCO II High UTILITY
(With Driver)

<u>Action</u>	<u>Vertical CG</u>	<u>Stability Index</u>
<u>Base</u> Updated vehicle with current weights and vertical CGs of all components, including wrap-over glass and updated interior trim; 54.5 average track, maximum optional tire LT215/15.	29.40	1.85
<u>Proposal 1</u> • Revised front ride height by restricting jounce 0.5", reduce rear rise-to-curb by 0.5"; increase front track by 1.0" with 0.5" offset wheels change to obtain a front track of 55.9"; increase rear track by 1.0" with 0.5" offset wheel change and increase axle width by 1.5" to obtain a rear track of 56.6" for an average track of 56.25". • Restrict maximum option tire from LT215/15 to P205/15 M-S.	28.56 27.85	1.97 2.02
<u>Proposal 2</u> • Same as the first proposal except widen front axles 0.25" per side to obtain a front track of 56.1" for an average track of 56.5". • Restrict maximum option tire from LT215/15 to P205/15 M-S.	28.56 27.85	1.98 2.03
<u>Proposal 3</u> • Revised front ride height by restricting jounce 0.5", reduce rear rise-to-curb by 0.5", increase track by 3.07" front and 3.86" rear to 58.0" average track. • Restrict maximum option tire to P205/15 M-S.	28.56 27.85	2.03 2.09
<u>Proposal 4</u> • Same as first proposal except lower front and rear ride height 1.36" additionally (1.86" front and 1.36" rear). • Restrict maximum option tire to P205/15 M-S.	27.20 26.49	2.13 2.19
<u>Proposal 5</u> • Same as second proposal except lower front and rear ride height 1.00" additionally (2.86" front and 2.36" rear). • Restrict maximum option tire to P205/15 M-S.	26.44 25.73	2.19 2.25

Weight Control Engineering/
February 5, 1991

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RANGER (4x4) PICKUP (LLB)
(With Driver)

	<u>Vertical CG</u>	<u>Stability Index</u>
<u>Base</u> Vehicle with 2.3L/144 with maximum optional tires, optional GVW springs, and average track of 54.5".	28.76	<u>1.89</u>
<u>Proposal 1</u> • Restrict ride height front and rear 0.5" and increase track by 1.0" front and rear with 0.5" offset wheel change to obtain a front track of 55.9" and a rear track of 55.1" for an average track of 55.5".	28.26	1.96
• Restrict maximum optional tire from LT215/15 to P205/15 M-S.	27.55	<u>2.01</u>
<u>Proposal 2</u> • Same as Proposal 1 except widen front axles by 0.25" per side to obtain a front track of 56.4" for an average track of 55.75".	28.26	1.97
• Restrict maximum optional tire from LT215/15 to P205/15 M-S.	27.55	<u>2.02</u>

Weight Control Engineering/
February 5, 1981

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BRCMCO II 4x4 UTILITY

<u>Action</u>	<u>Stability Index Variance</u>
• Replace front aluminum differential housing with cast iron.	0.01
• Replace powertrain light weight material with cast iron components (clutch housing, transmission case and extension, transfer case).	0.02
• Lower engine CG one inch (pivot about transfer case output shaft).	0.01
• Restrict maximum option tire from LT215/15 to P205/15.	0.06
• Restrict tires and wheels from 15" to 14".	0.03
• Delete wrap-over glass (13 lbs.) and interior trim update (25 lbs.).	0.01
• Stow high pressure spare flat on floor.	0.01
• Variance per 0.5 inch change in track.	0.02
• Add 130 lbs. luggage in roof mounted rack (5 lbs.).	(0.10)

WEIGHT INCREASES FOR CAST IRON COMPONENTS

Differential Housing	22 lbs.
Clutch Housing	18 lbs.
Transmission Case	24 lbs.
Transfer Case	22 lbs.

Weight Control Engineering/
February 5, 1981

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Summary of Proposed Changes for Stability Study Development

ETA TII-4

Current Program	Proposed 1	Proposed 2	Proposed 3	Proposed 4	Proposed 5	
STABILITY INDEX	1.85	2.02	2.03	2.09	2.19	2.25
VEHICLE CHANGES						
FRONT TRAIL	54.9°	55.9° Increased 1.0° via reducing wheel offset by 0.5" (from 1.12" to 0.62").	56.4° Same as Proposed 1 plus additional 0.5" in axle width increase.	58.0° Increased 3.07° via axle width increase and redesign of front suspension and frame.	58.0°	58.0°
REAR TRAIL	54.1°	56.6° Increased 1.0° via reducing wheel offset by 0.5" (from 1.12" to 0.62") and an additional 1.5" in axle width incr.	56.6°	58.0° Increased 3.86° via axle width increase.	58.0°	58.0°
VERTICAL CG	28.6"	27.9" Reduction of front ride height by 0.5" thru jounce restriction (from 3.8" to 3.3") and reduced rear rim to curb by 0.5" (from 3.17" to 2.67") Maximum tire restricted to F205/15 10AS.	27.9°	27.9°	26.5° Same as Proposed 1 plus additional ride reduction of 1.36" achieved by raising and redesigning the frame and floorpan revisions.	27.7° Same as Proposed 4 plus further ride height reduction of 1.0" resulting in front center revisions.
PERFORMANCE PARAMETERS						
• Floor Cost	Base	\$4.00	\$3.90	(\$11.00)	(\$9.00)	
• Tooling	Base	(\$1.5 NTL)		(\$8.1 NTL)	(\$10.7 NTL)	(\$12.4 NTL)
• Engineering	Base	(\$2.5 NTL)		(\$2.0 NTL)	(\$ 2.4 NTL)	
• Total Investment	Base	(\$4.0 NTL)		(\$10.1 NTL)	(\$13.1 NTL)	(\$13.8 NTL)
• Weight	Base	(70.0 lbs.)	(11.0 lbs.)	(41.0 lbs.)	(113.0 lbs.)	
• Ground Clearance	Base	Reduced by 0.5" (front)			Reduced by 1.86" (front) and 1.36" (rear)	Reduced by 2.56" (front) and 2.36" (rear)
• Timing	Base	Containable for Job #1 1983 with potential risk on body-side panel sample (6-1 wks.) and late production wheel availability will delay durability sign-off by approx. two months and will not support the 1-29-82 sample at source date for Job #1, 1983.		Containable for Job #1 1983 with potential risk on body-side panel sample (6-1 wks.) late-to-lead drawings on frame require immediate release and on the transfer case by 5/81.	Same as Proposed 3 with floorpan revisions requiring immediate body design kick-off.	Same as Proposed 4 with front lower a potential risk for sample (6-8 wks.)

1/17/82

LF Vehicle Engineering/
February 5, 1981

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BRONCO II/RANGER Lx4
Recommended Stability Index Improvement Proposal

	<u>Bronco II</u>	<u>Ranger Lx4</u>
<u>STABILITY INDEX</u>	2.03	2.02
<u>VEHICLE CHANGES</u>		
• FRONT TREAD	56.4" Increased 1.0" via reducing wheel offset by 0.5" plus an additional 0.5" in axle width increase.	56.4"
• REAR TREAD	56.6" Increased 1.0" via reducing wheel offset by 0.5" plus an additional 1.5" in axle width increase.	55.1" Increased 1.0" via reducing wheel offset by 0.5".
• VERTICAL CG	27.9 Reduction of front ride height by 0.5" thru jounce restriction; reduced rear rise to curb by 0.5"; and restrict maximum tire to P205/15 M&S.	27.6 Reduction of front ride height by 0.5" thru jounce restriction; reduced rear ride height by 0.5" via reduced spacer height; and restrict maximum tire to P205/15 M&S.
<u>PROGRAM PARAMETERS</u>		
• Piece Cost	\$3.50	(\$2.00)
• Tooling	(\$1.5 MIL)	Included
• Engineering	(\$2.5 MIL)	Included
• Total Investment	(\$4.0 MIL)	Included
• Weight	(11.0 lbs.)	2.0 lbs.
• Ground Clearance	Reduced by 0.5" (Front)	Reduced by 0.5" (Front & Rear)
• Timing	Containable for Job #1, 1983 $\frac{1}{2}$ with potential risk on body-side panel sample (6-8 weeks)	Containable for Job #1, 1983, however, late production wheel availability will delay durability sign-off by approx. two (2) months and will not support the 1-29-82 samples at source date.

LT Vehicle Engineering/
February 5, 1981

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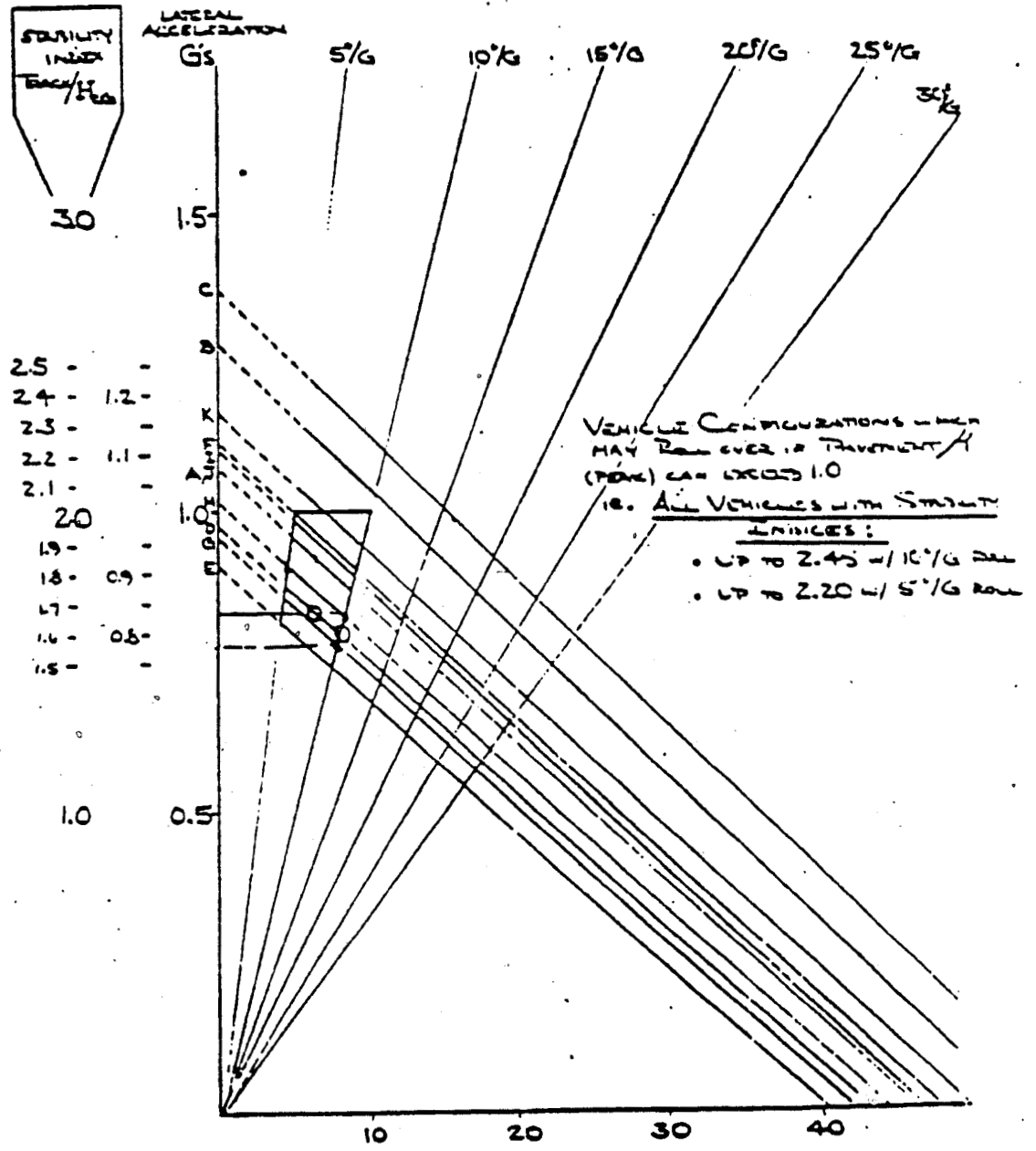
Open Issues for Revised Stability Proposals for Spruce II

<u>ISSUES</u>	<u>Proposal 1</u>	<u>Proposal 2</u>	<u>Proposal 3</u>	<u>Proposal 4</u>	<u>Proposal 5</u>
. AID - Increased track effect on assembly line at tee set equipment	-	-	X	X	X
. Axle commonality/timing	-	-	X	X	X
. ϕ 1 Crossmember package	-	-	-	X	X
. Steering gear/intermediate shaft package (clearance to power steering belt and fuel pump).	-	-	-	X	X
. Intermediate shaft to ϕ 1 crossmember	-	-	-	X	X
. Frame stacking	-	-	X	X	X
. Oil pan clearances and removal	-	-	-	X (minor)	X
. U-Joint to oil pan (assumes substandard clearance deviation acceptable)	-	-	-	X	X
. Front driveshaft plan view angle (transfer case)	-	-	X	X	X
. Assess crashworthiness of frame	-	-	X (minor)	X	X
. Rear axle with 58.0° track (shaft mix-up)	-	-	X	X	X
. Negative rear spring camber (acceptability)	-	-	-	X (minor)	X
. 0-1 clearances (approach and departure)	-	-	-	X (minor)	X
. suspension forward shock bracket clearance to rear floor pan/passenger's seat	-	-	-	X	X
. Spare tire package and effect on liftgate	-	-	-	X	X
. Rear body sills/body mounts (structural impact of moving outboard)	-	-	X (minor)	X	X
. Emission Certification of 2.3L engine	-	-	X	X	X
. Revised rear floor pan and rear seat construction	-	-	-	X	X
. Rear seating package	-	-	-	X	X
. Impact on (4x4) pick-up (commonality of parts) and pick-up program timing	-	-	X	X	X
. Durability sign-off timing of offset wheels	X	X	-	-	-
. Frame Timing	-	-	X	X	X
. Dog Track (P/U 4x4)	-	X (minor) ✓	-	-	-

g/ Note Proposal 2 requires 1.3" wider front than rear track, the front track can be increased from 56.4" to 57.1" which increases dog track to 2.0" and is not recommended for appearance reasons

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ROLL OVER STABILITY FOR VARIOUS CONFIGURATIONS
 STABILITY INDEX / LATERAL ACCELERATION -vs- ROLL ANGLE



VEHICLE LEGEND
 RANGE 42
 RANGE 44
 RANGE 46
 RANGE 48
 RANGE 50
 RANGE 52
 RANGE 54
 RANGE 56
 RANGE 58
 RANGE 60
 RANGE 62
 RANGE 64
 RANGE 66
 RANGE 68
 RANGE 70
 RANGE 72
 RANGE 74
 RANGE 76
 RANGE 78
 RANGE 80

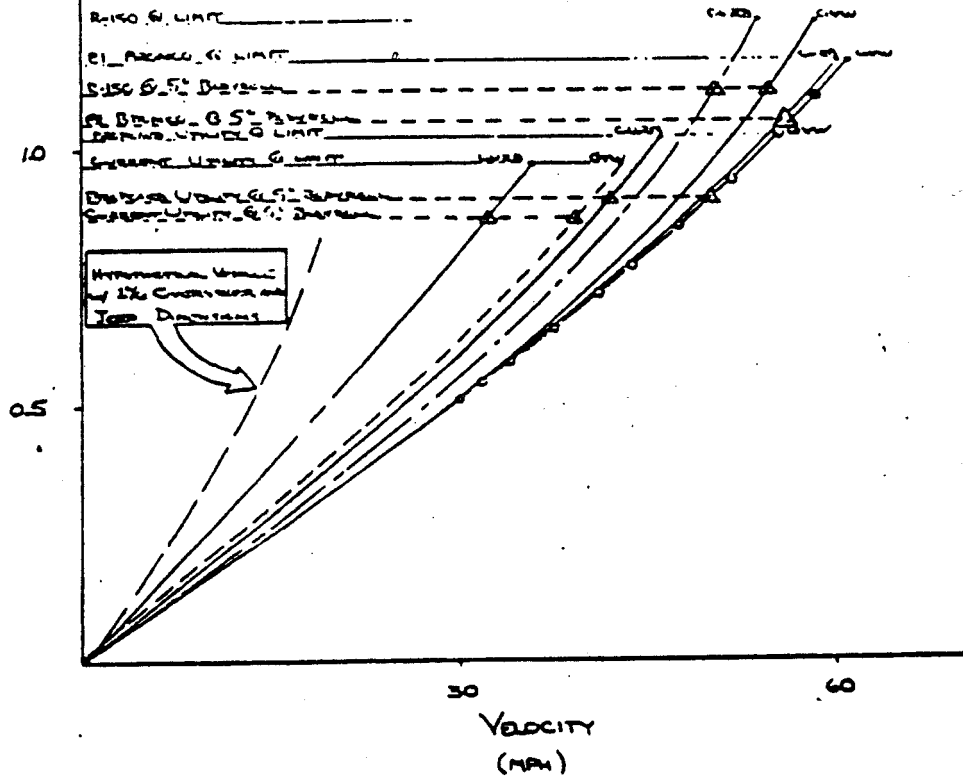
ROLL ANGLE (DEGREES)

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LT-73
 2-7-71

LATERAL ACCELERATION -VS- VELOCITY FOR 100° STEERING WHEEL INPUT

LATERAL ACCELERATION
FOR 100° SWA INPUT
(G's)



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2-5-81

Bronco II Vehicle Dynamic Properties Revisions

<u>Baseline:</u>	<u>Stability Index</u>	<u>Roll Gradient</u>	<u>U/S Ccef.</u>	<u>Steering Gain</u>	
				<u>30 MPH</u>	<u>60 MPH</u>
Curb	1.86	5.81	-0.42	0.79	3.82
GVW	1.93	5.29	1.37	0.63	1.72

Vehicle Revisions:

.Lower Rr. Spg.
Frt. Hanger Bracket
0.50"

.Revised Pitman Arm
Offset (Raise 1.26")

.Reduce Pitman Arm
Length 5% (Overall
Steering Ratio in-
creases from 18:1
to 18.9:1)

Curb	2.06	5.68	1.32	0.60	1.66
GVW	2.28	3.97	2.89	0.51	1.11

Additional Actions:

.Revise Overall Steering
Ratio from 18.9:1 to
22.0:1

Curb	2.06	5.68	1.32	0.52	1.43
GVW	2.28	3.97	2.89	0.44	0.95

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MECHANICS OF ROLLAGE

EXHIBIT I-1

Fig 1. Body Roll on Chassis
Sub-limit normal cornering

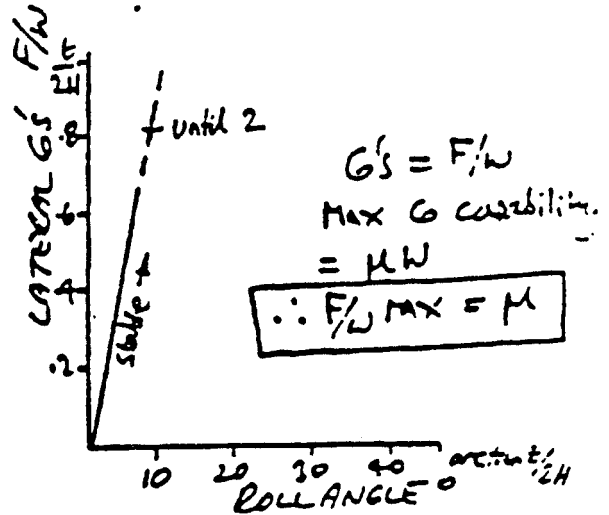
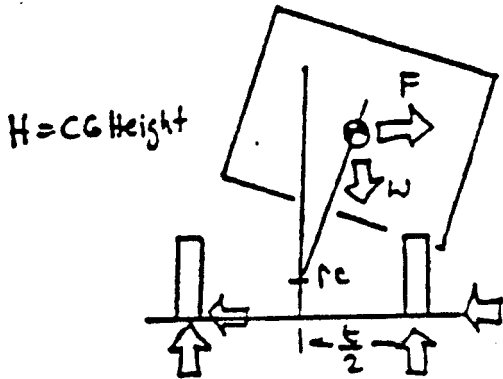


Fig 2. Rigid Body Mechanism
to roll over

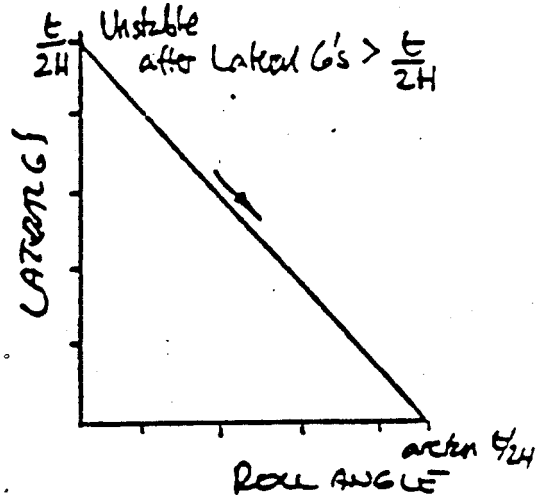
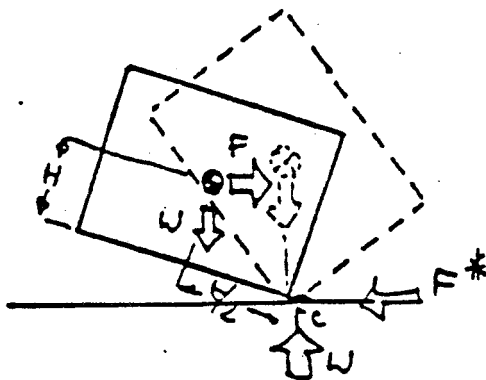
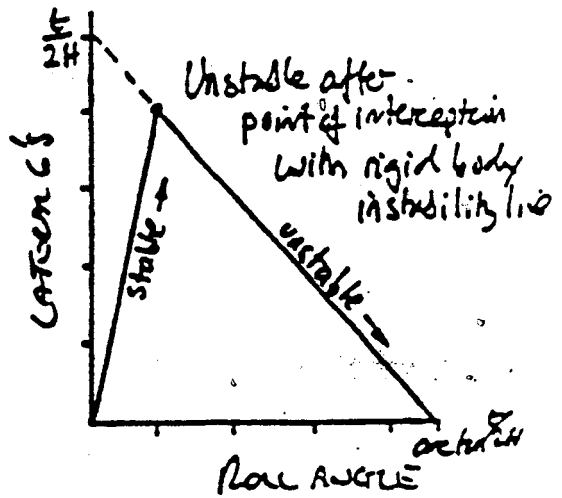
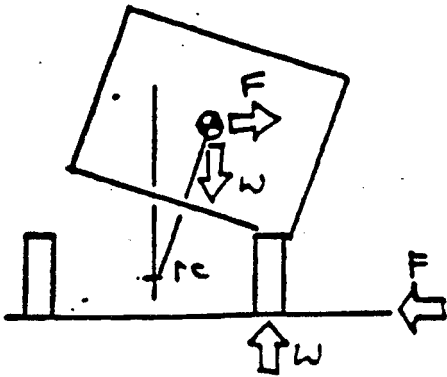


Fig 3. Roll Over Mechanism
for overall vehicle



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