FC044
3/29/71

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 15

LUNAR ROVING VEHICLE SYSTEMS HANDBOOK

REV A

JUNE 22, 1971

PREPARED BY

FLIGHT CONTROL DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Dgt-66535

APOLLO

LUNAR ROVING VEHICLE SYSTEMS HANDBOOK

LRV-1

REV A

PREFACE

This document has been prepared by the Flight Control Division, Manned Spacecraft Center, Houston, Texas. This document is a complete reissue which replaces the Lunar Roving Vehicle Systems Handbook, dated March 29, 1971. Information contained within this document represents the lunar roving vehicle systems as of June 22, 1971.

This document is intended for specialized use by the LRV flight controllers in real-time and near-real-time operations. This document, in conjunction with the Boeing Company's LRV Operations Handbook, LS006-002-2H, will provide the LRV flight controllers with a thorough knowledge of the LRV.

Comments regarding this handbook should be directed to the Lunar Surface Experiments Section of the Lunar/Earth Experiments Branch, Flight Control Division. Revisions or PCN's will be issued as required prior to the flight date.

Approved by:

James E. Saultz, Sr.
Chief, Lunar/Earth Experiments Branch

Eugene F. Kranz
Chief, Flight Control Division

APOLLO

LUNAR ROVING VEHICLE SYSTEMS HANDBOOK

LRV-1

REV A

JUNE 22, 1971

TABLE OF CONTENTS AND ITEM EFFECTIVITY

TABLE OF CONTENTS AND ITEM EFFECTIVITY JUNE 22, 1971 (CONCLUDED)

SECTION 1

INTRODUCTION

1.1 LRV ACRONYMS AND ABBREVIATIONS

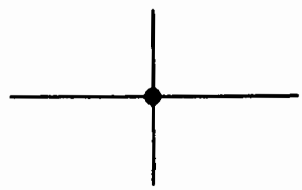
ac	alternating current
Adc	ampere(s) dc
amp	ampere(s)
ant	antenna
assy	assembly
CB	circuit breaker
CDC	control and display console
dc	direct current
DCE	drive control electronics
DGU	directional gyro unit
F	fuse, Fahrenheit
fld	field
fwd	forward
gnd	ground
HS	heat sink
inhib	inhibit
insul	insulation
IPI	integrated position indicator
instl	installation
km	kilometer(s)
LCRU	lunar communications relay unit
LM	lunar module
LRV	lunar roving vehicle
max	maximum
mde	mode
MOCR	Mission Operations Control Room
ms	millisecond
MSFN	Manned Space Flight Network
MSS	mobility subsystem
mtr	motor
N/A	not applicable
neg	negative
norm	normal
oper	operate
out	output
pct	percent
PLSS	portable life support system
pos	positive
posn	position
pri	primary
PWM	pulse width modulator
pwr	power
ref	reference
reg	regulator
rev	reverse
rly	relay
rst	reset
sci	scientific
sig	signal
snsr	sensor
SPU	signal processing unit
sw	switch
sup	supply
sys	system
T	temperature
temp	temperature
therm	thermal
V	volt(s)
Vac	volt(s) ac
Vdc	volt(s) dc
W	watt(s)
WH	walking hinge

1.2 DRAWING SYMBOL STANDARDS

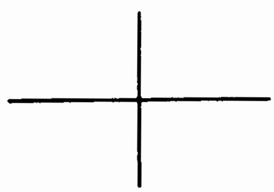
1.2.1 Line Legend

1.2.1.1 Electrical line, power and control.-

A. Electrical connected



B. Electrical crossover



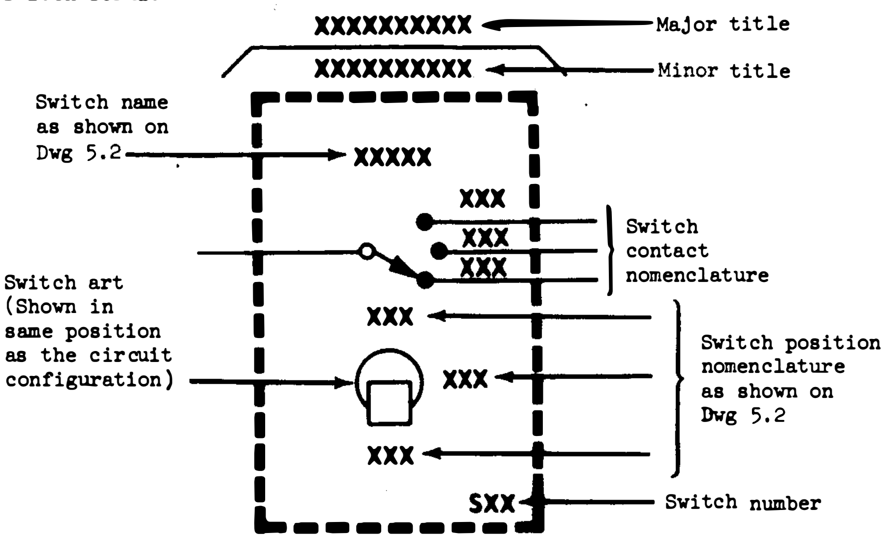
1.2.1.2 Directional flow arrows.-

1.2.1.3 Mechanical linkage.-

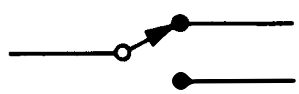
1.2.2 Electrical Symbols

1.2.2.1 Switches.-

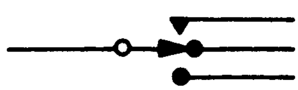
A. Switch format



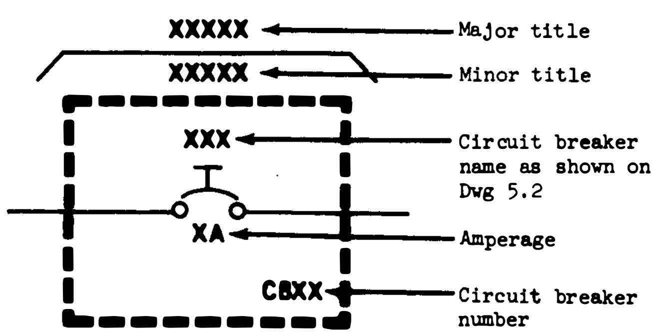
B. Two-position switch



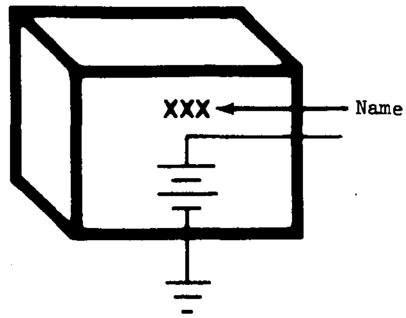
C. Three-position switch



1.2.2.2 Circuit breaker.-

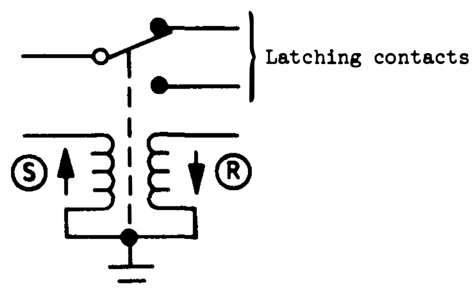


1.2.2.3 Battery.-

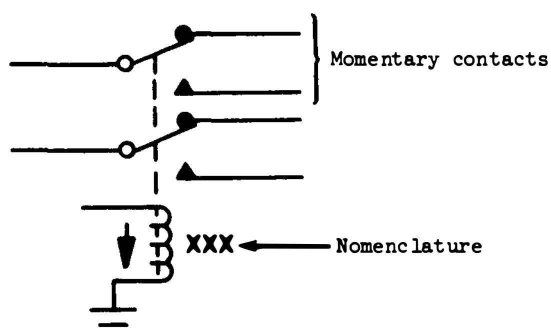


1.2.2.4 Relays.-

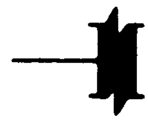
A. Latching relay



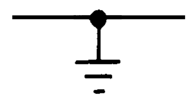
B. Non-latching relay



1.2.2.5 Bus.-



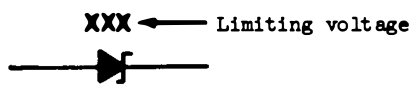
1.2.2.6 System ground.-



1.2.2.7 Diodes.-

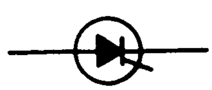
A. General

B. Zener

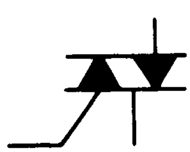


C. Tunnel

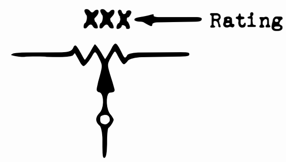
D. Control rectifier (SCR)



E. Triac



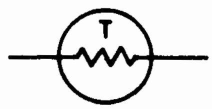
1.2.2.8 Potentiometer.-



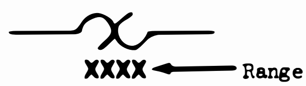
1.2.2.9 Resistors.-

A. Fixed

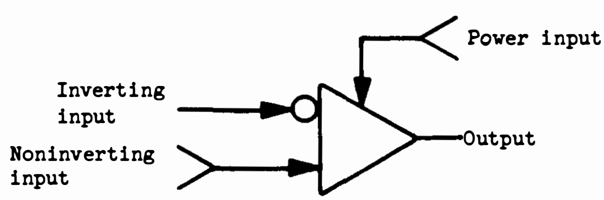
B. Thermistor or resistance thermometer (any element whose sensing resistance varies with temperature regardless of polarity)



1.2.2.10 Thermostat.-

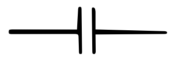


1.2.2.11 Amplifier.-



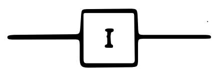
1.2.2.12 Capacitors.-

A. Fixed

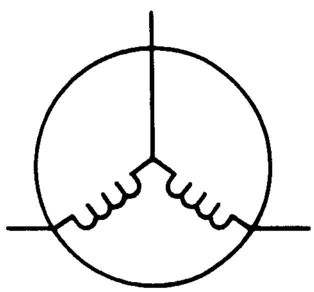


B. Variable

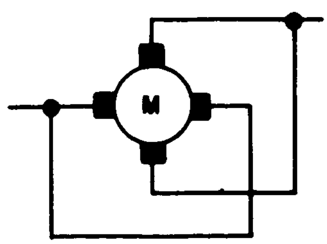
1.2.2.13 Digital inverter.-



1.2.2.14 Synchro transmitter.-

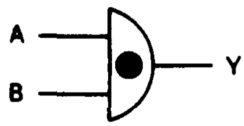


1.2.2.15 Motor.-

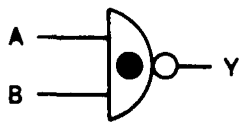


1.2.2.16 Gates.-

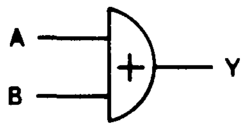
A. And



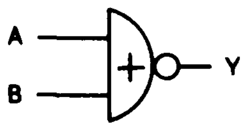
B. Nand



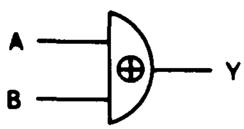
C. Or



D. Nor



E. Exclusive or



Truth table

A	B	Y
1	1	1
1	0	0
0	1	0
0	0	0
1	1	0
1	0	1
0	1	1
0	0	1
1	1	1
1	0	1
0	1	1
0	0	0
1	0	0
0	1	0
1	1	0
0	0	1
1	1	0
1	0	1
0	1	1
0	0	0

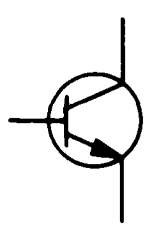
NOTE

Open circle indicates an inverter.

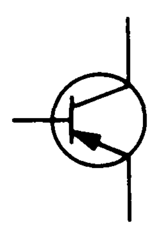
1.2.2.17 Electrical filter.-

1.2.2.18 Transistors.-

A. NPN



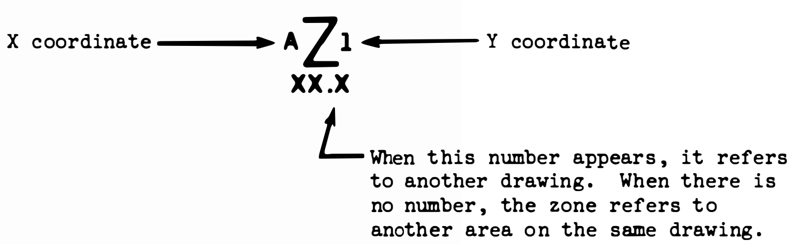
B. PNP



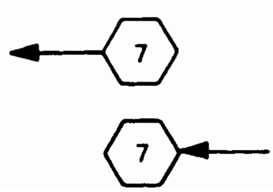
1.2.3 Miscellaneous Symbols

1.2.3.1 Drawing notes.- Notes are of two types: general and specific. General notes do not apply to a specific area on the drawing. Specific notes do apply to a specific area or areas of the drawing and are indicated with a note flag (shown below) which appears in the area or areas referenced.

1.2.3.2 Technical zone references.- Zone references direct attention from one area to another in the same or another drawing. The "Z" shown below, with appropriate zone locators, indicates the exact area referenced.



The hexagon ("hex"), shown below, is used to connect one line to another line on the same or on another drawing. The appropriate "Z" appears next to the "hex" to direct attention to the location of the corresponsing reference.



SECTION 2
GENERAL INFORMATION

2.1 LRV DESCRIPTION

The LRV is a four-wheeled, electrically propelled, manually controlled vehicle to be used for transporting crewmen and equipment on the lunar surface. The vehicle has accommodations for two crewmen and has the stowed auxiliary equipment designed for a particular mission.

Either crewman may control the LRV by utilizing the hand controller installed midway between the two seats. All controls and displays are located on one panel for easy use from either seat. These controls and displays include switches for drive motors, steering motors, main batteries, and redundant systems selection. Displays of battery parameters, navigation data, and temperatures of critical components are provided. Circuit breakers are located in groups on the same control panel.

The LRV consists of the following major subsystems and components: structure, mobility, crew station, electrical, navigation, and stowed payload.

3.1 SUBSYSTEM DESCRIPTION

The LRV structure subsystem consists of the chassis (Drawing 3.1), passive and active thermal control devices, and dust control devices.

3.2 THERMAL CONTROL

Thermal control (Drawing 3.2) is incorporated into the LRV to dissipate excessive heat from operating equipment in the forward chassis, to maintain operating limitations of instruments on the control and display console, and to relieve excessive heat from the crew station. Thermal control is provided in the forms of surface finish, insulation, radiative surfaces, thermal mirrors, thermal straps, and fusible mass heat sinks. A warning flag is provided to indicate battery or traction drive overtemperatures.

3.2.1 Foward Chassis Thermal Control

Thermal control on the forward chassis is provided by straps, thermal mirrors, thermal blankets, fusible mass heat sinks, and dust covers. These protect the drive control electronics (DCE), signal processing unit (SPU), directional gyro unit (DGU) and batteries 1 and 2 from overheating. Thermal blankets are composed of 15 layers of aluminized mylar with 14 layers of interspersed nylon net.

Aluminum thermal straps connected to the DCE, SPU, and DGU transfer heat away from these electronic components and store it in the batteries and/or the fusible mass heat sinks.

Fused silica thermal mirrors are incorporated on top of batteries 1 and 2, the SPU, and the DCE and operate to dissipate heat from the batteries and fusible mass heat sinks when the dust covers are opened.

Fiber-glass dust covers over both batteries and the SPU are opened manually and close automatically by means of a bimetallic closing actuator (Drawing 3.2). The SPU cover is linked with the battery 1 cover, and, as such, will open and close at the same time. Temperature limits are described in the subsystem descriptions.

3.2.2 Crew Station Thermal Control

3.2.2.1 Control and display console (CDC).— All instruments on the CDC are mounted to an aluminum plate which is isolated by multilayer insulation and fiber-glass mounts. The external surfaces of the CDC are coated with heat resistant paint (Dow-Corning 92-007), and the faceplate is black-anodized.

3.2.2.2 Center chassis.— Handholds, footrests, tubular sections of seats, and center and aft floor panels are anodized.

3.3 DUST CONTROL

Dust control is incorporated into the LRV to minimize the effect of lunar dust on the equipment and crew. Dust control is provided by means of fenders, boots, covers, seals, and caps.

Fiber-glass fenders control the dust created by the wheels. The fenders consist of a fixed section and a sliding section which must be extended by the crew upon deployment on the lunar surface.

A boot around the base of the hand controller grip provides control against dust entering the mechanism.

The steering sectors in the forward and aft chassis are enclosed with structure, beta cloth, and boots for dust control.

All working joints of the suspension system are protected from dust by seals and dust caps.

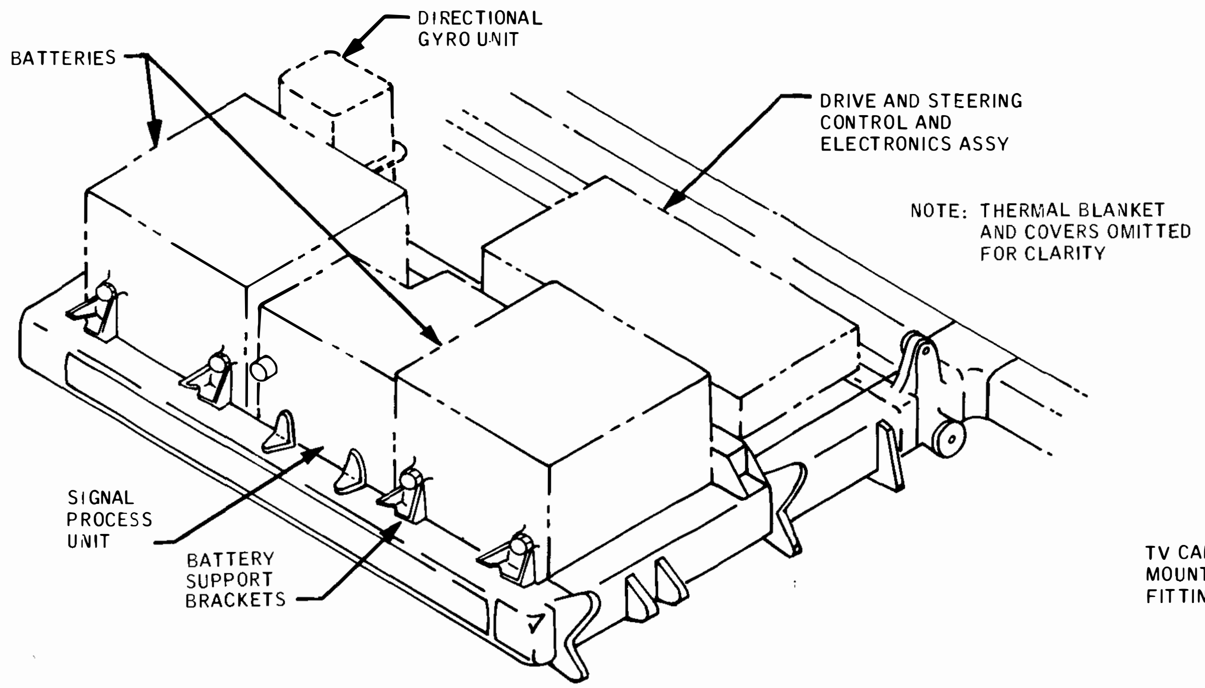
The traction drive assemblies are hermetically sealed thus preventing entry of lunar dust.

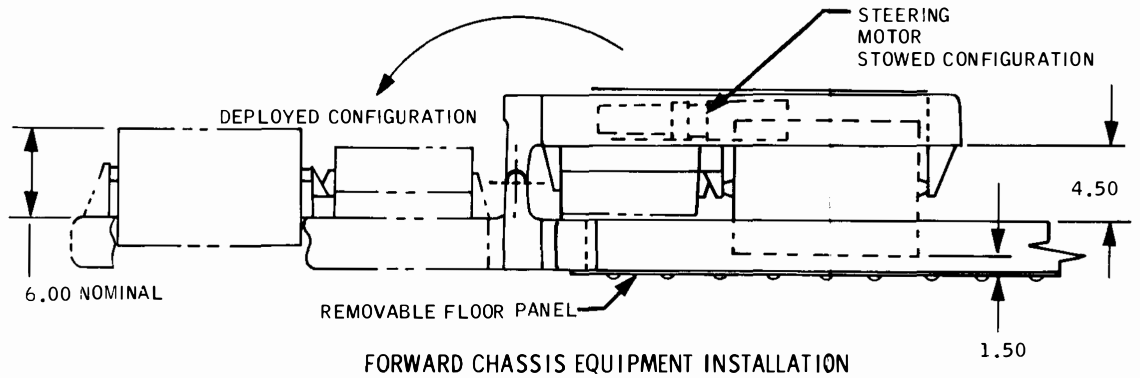
Dust control for the brakes is provided by circumferential shields around the drums and boots around the brake levers.

The piston rod of the linear damper is protected from dust by a cylindrical sleeve and by seals.

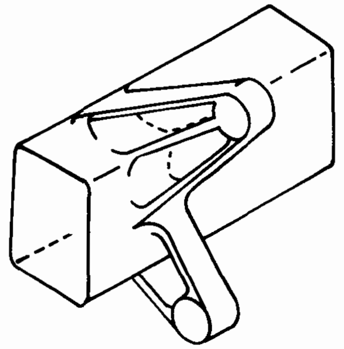
Fiber-glass covers over the batteries and SPU provide dust protection for the thermal mirrors while closed.

FOLDOUT FRAME 1

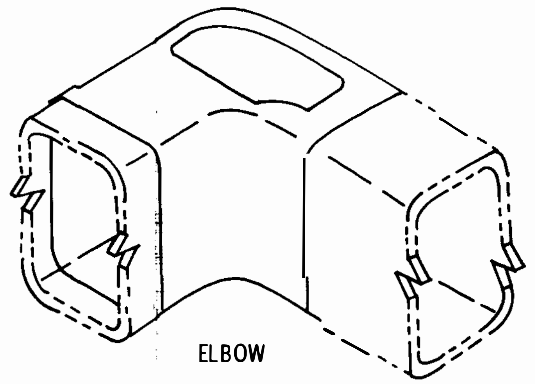




FORWARD CHASSIS EQUIPMENT INSTALLATION



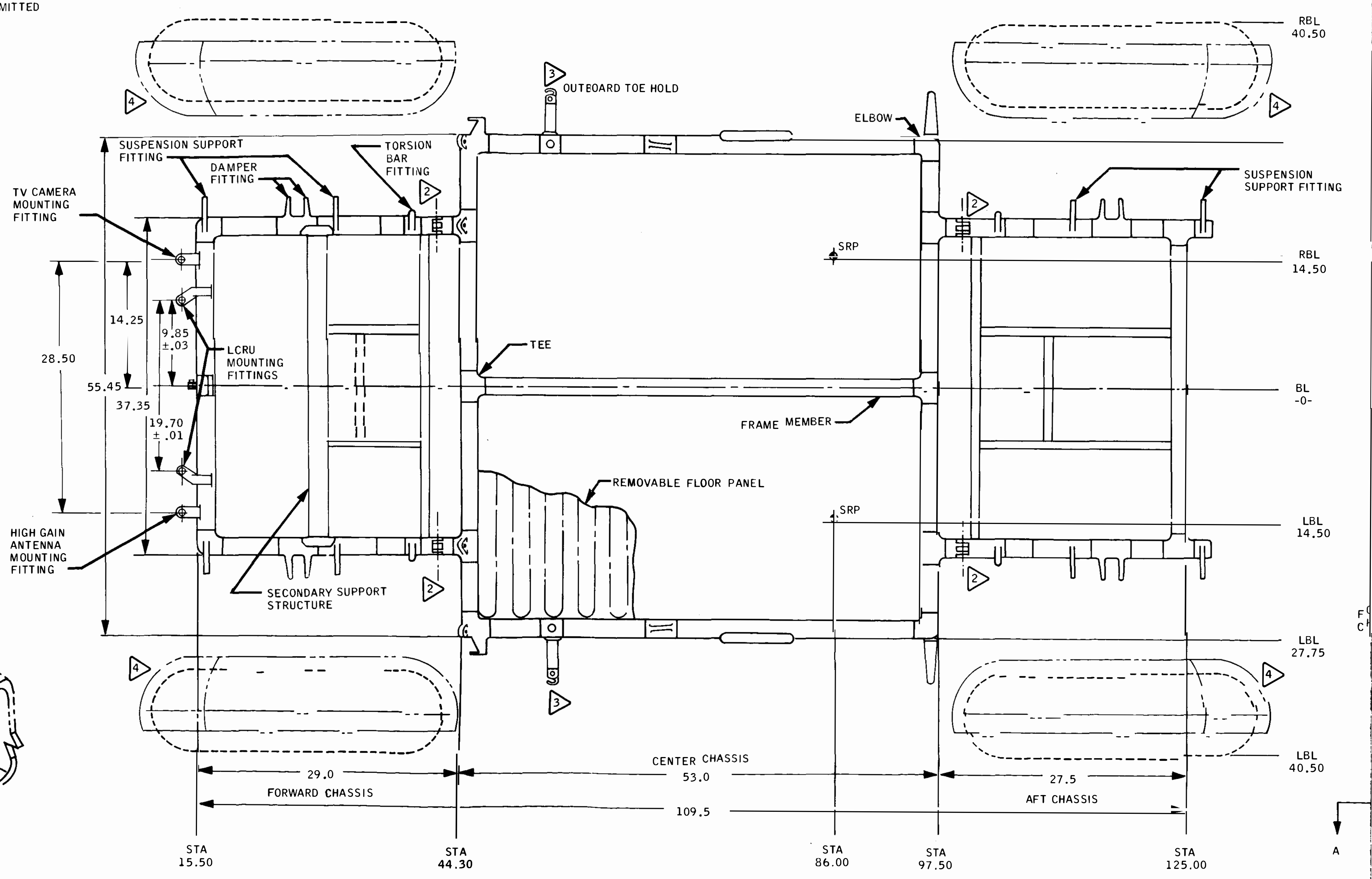
TYPICAL SUSPENSION SUPPORT FITTING



ELBOW

FOLDOUT FRAME 2

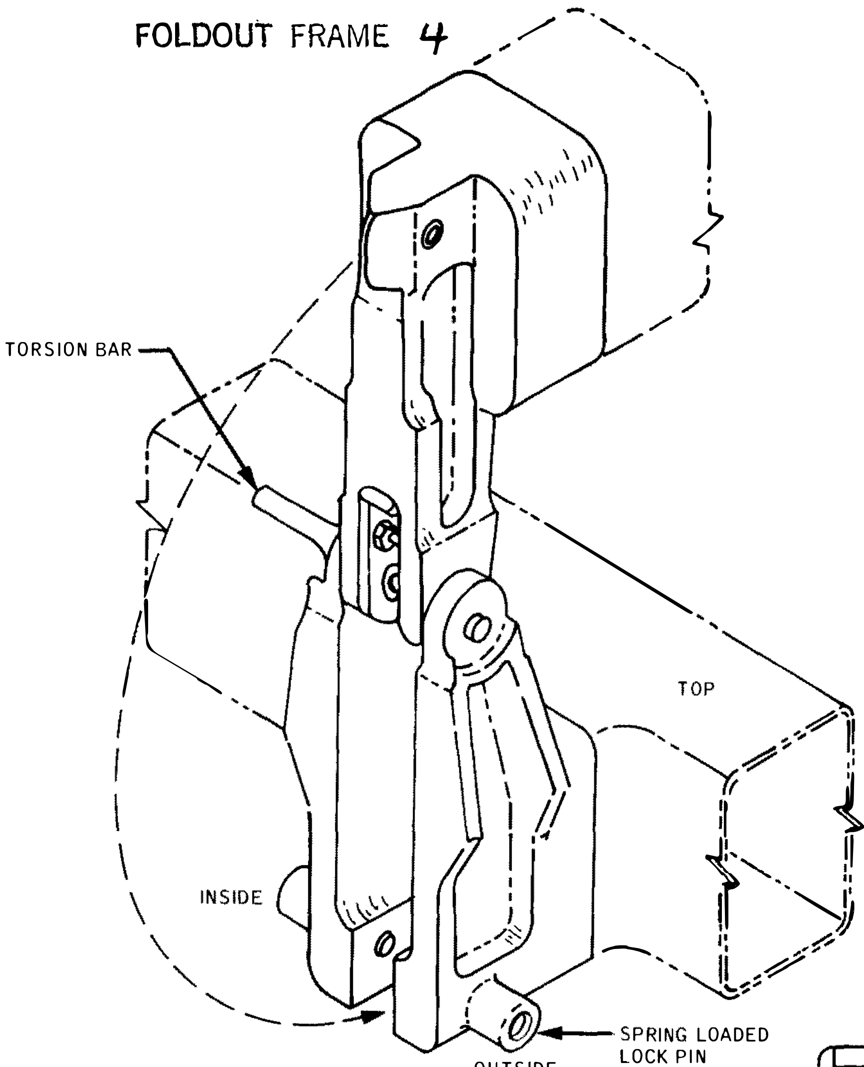
FOLDOUT FRAME 3



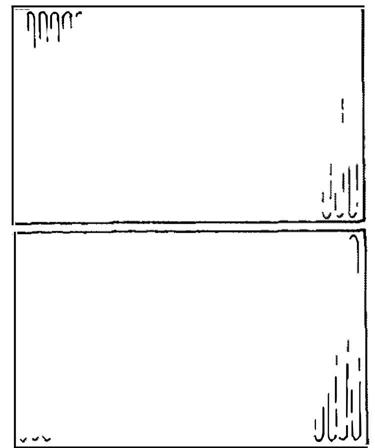
LTR	PCN	DR	ENG	DATE	APPROVAL
A					

COMMENTS:

FOLDOUT FRAME 4



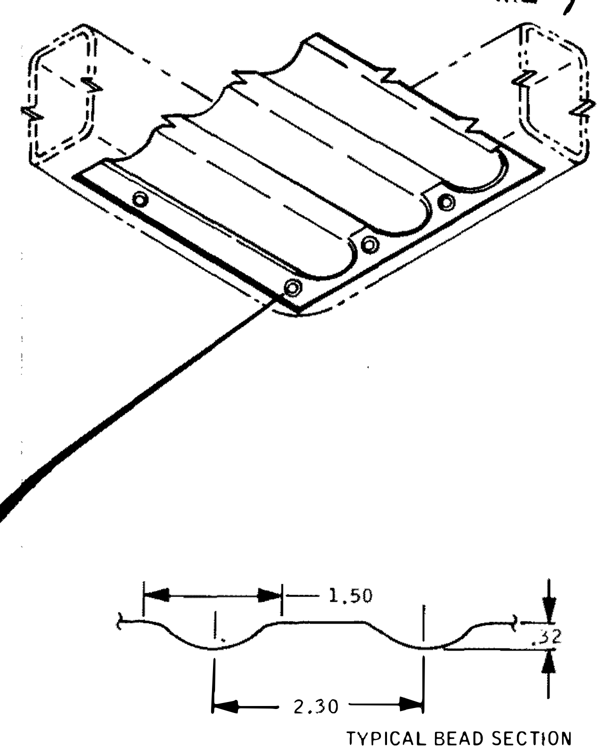
HINGE

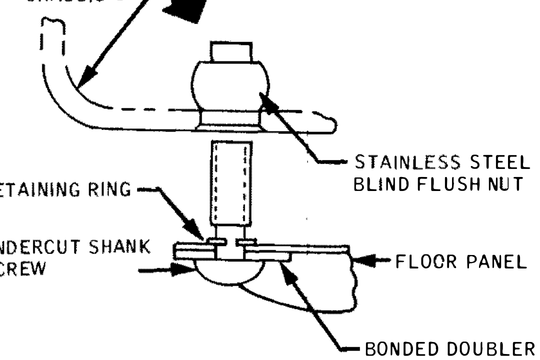


CENTER SECTIONS .020 X 27.65 X 52.00

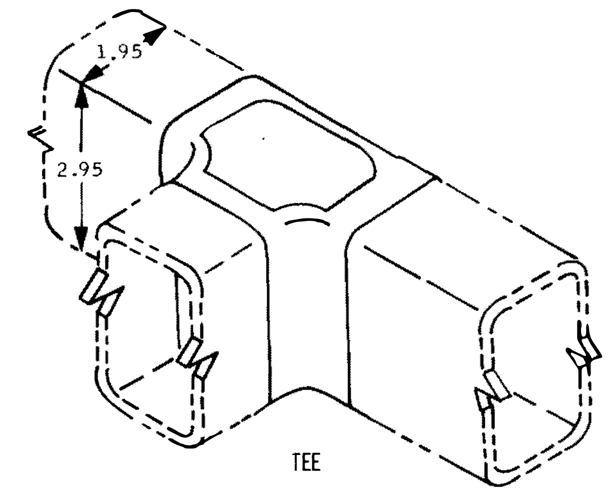
LOOKING FROM UNDERSIDE OF VEHICLE

FOLDOUT FRAME 5





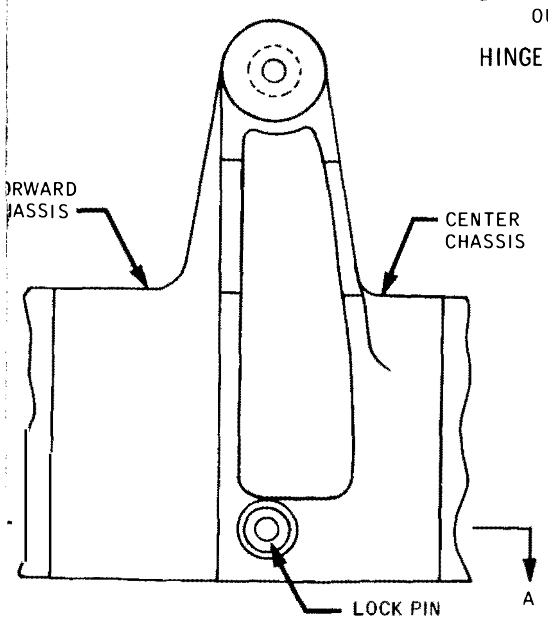
FLOOR PANELS



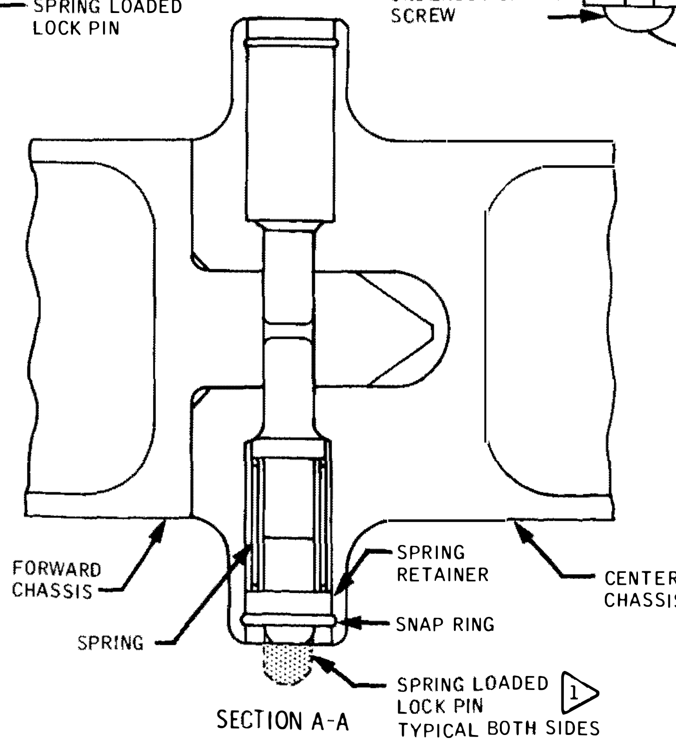
TEE

NOTES:

4. FENDER EXTENSIONS DEPLOYED BY CREW
3. OUTBOARD TOE HOLD IS THE CENTER MEMBER OF THE DEPLOYMENT TRIPOD AND IS INSTALLED BY THE CREW AFTER LRV IS ON THE LUNAR SURFACE
2. HINGES
1. HINGE IS LOCKED IN DEPLOYED POSITION WHEN LOCK PIN IS FLUSH WITH CHASSIS.



HINGE IN DEPLOYED POSITION (SIDE VIEW)



SECTION A-A

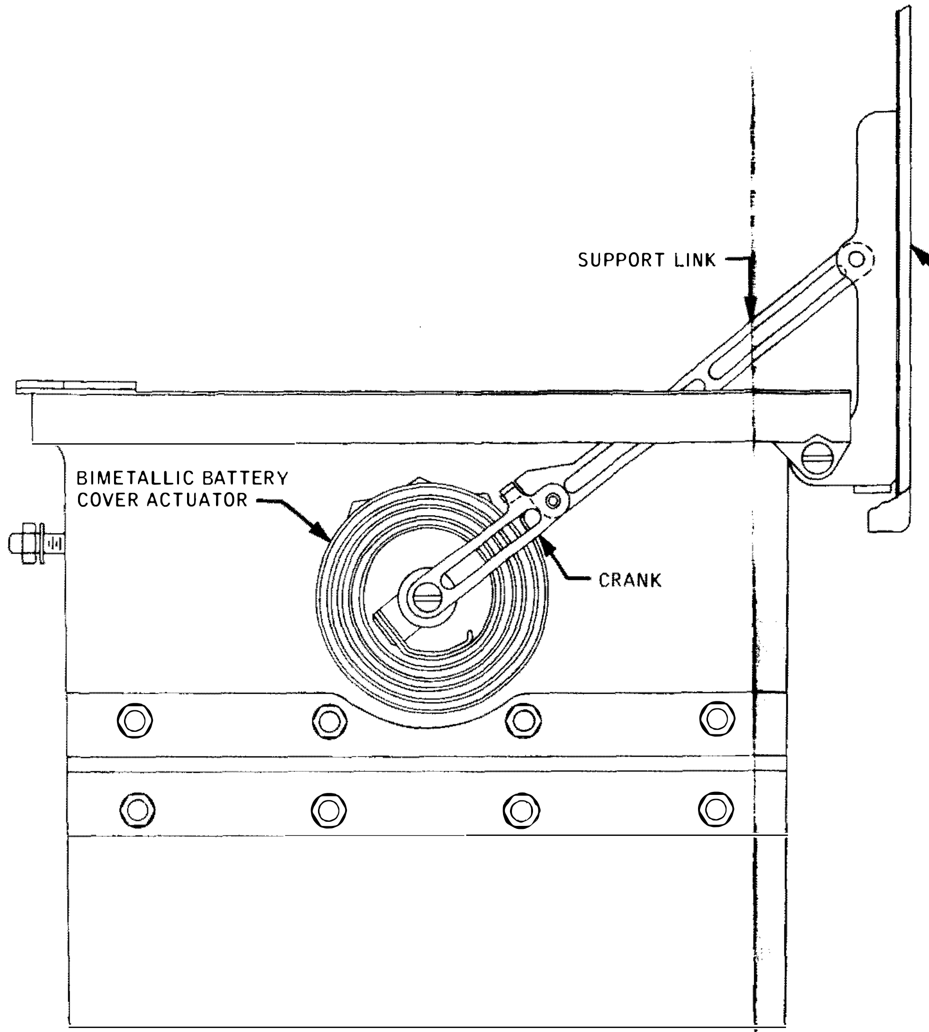
SIGNATURES	DATE	
DR L. Stewart	8/3/70	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER · HOUSTON, TEXAS
DSGN Bill L. Cornelius	3-30-71	
QC Betty M. Taylor	3-30-71	CHASSIS
ENGR John H. Cooper	3-29-71	
APP Gerald D. Griffith	3-29-71	
FEC Dean B. Kisler	3-30-71	LRV — DWG NO 3.1
AUTH		55 X 17 — PAGE 3-3 — SHEET 1 OF 1

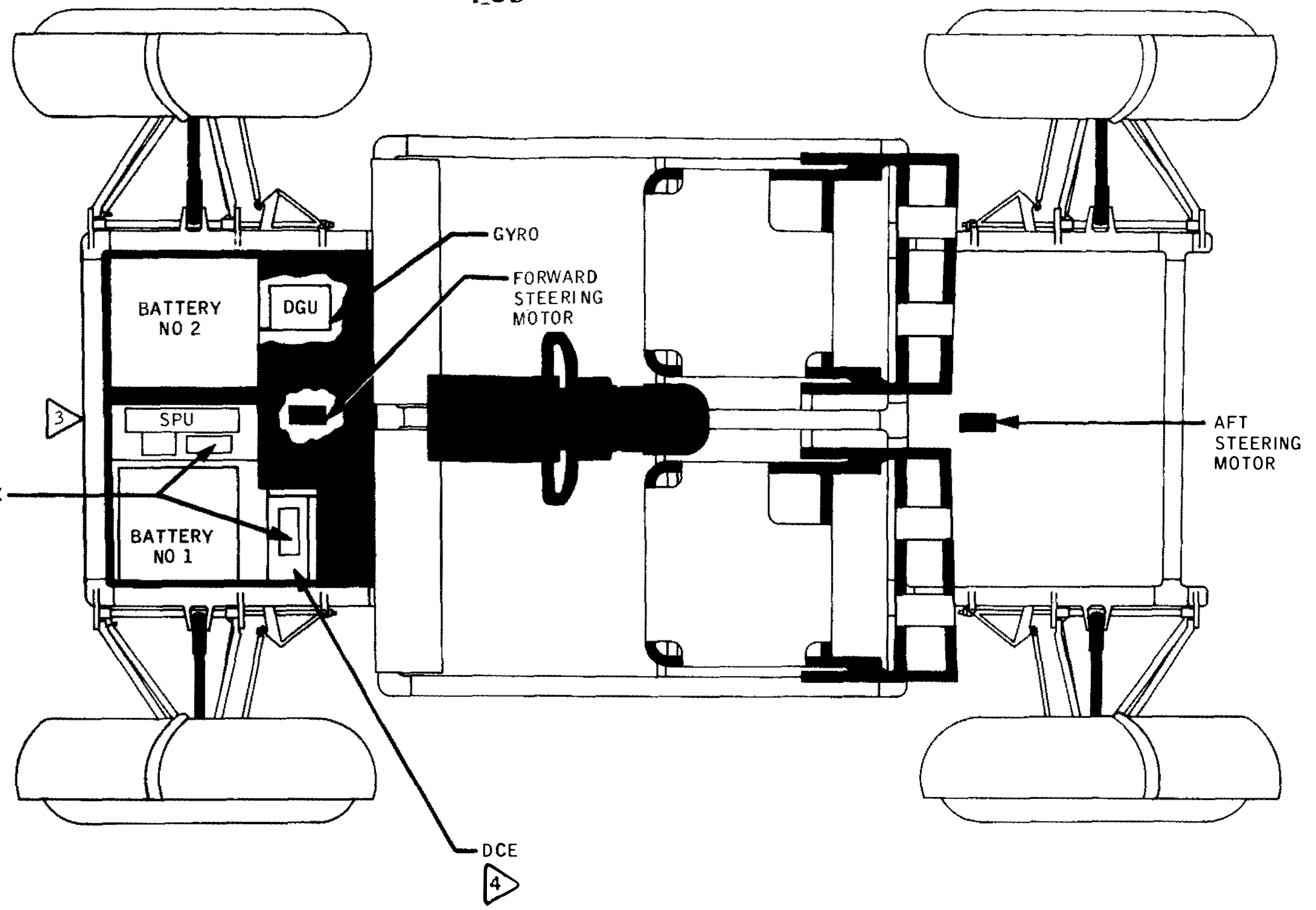
LTR	PCN	DR	ENG	DATE		APPROVAL
A		[illegible]	[illegible]	6/23/71	[illegible]	[illegible]

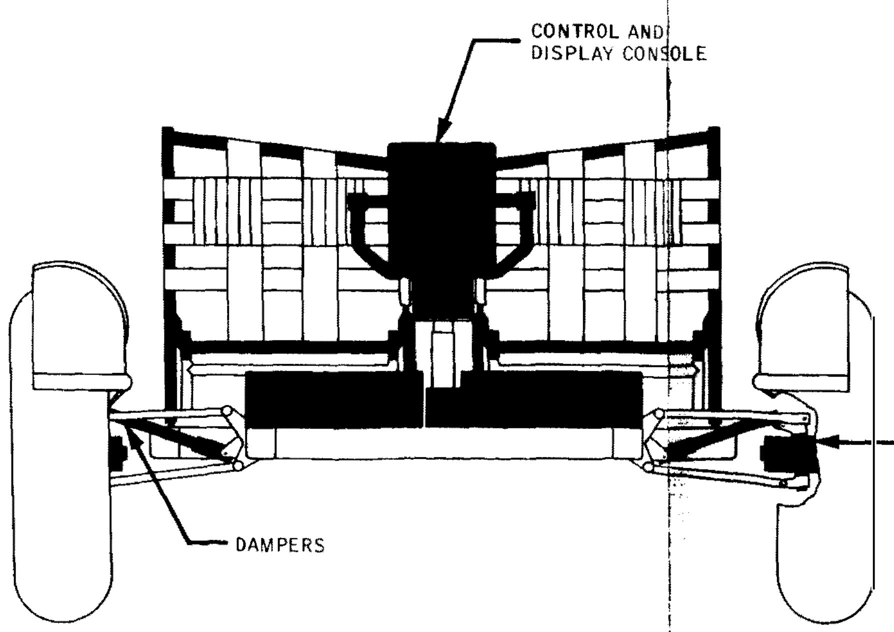
COMMENTS:

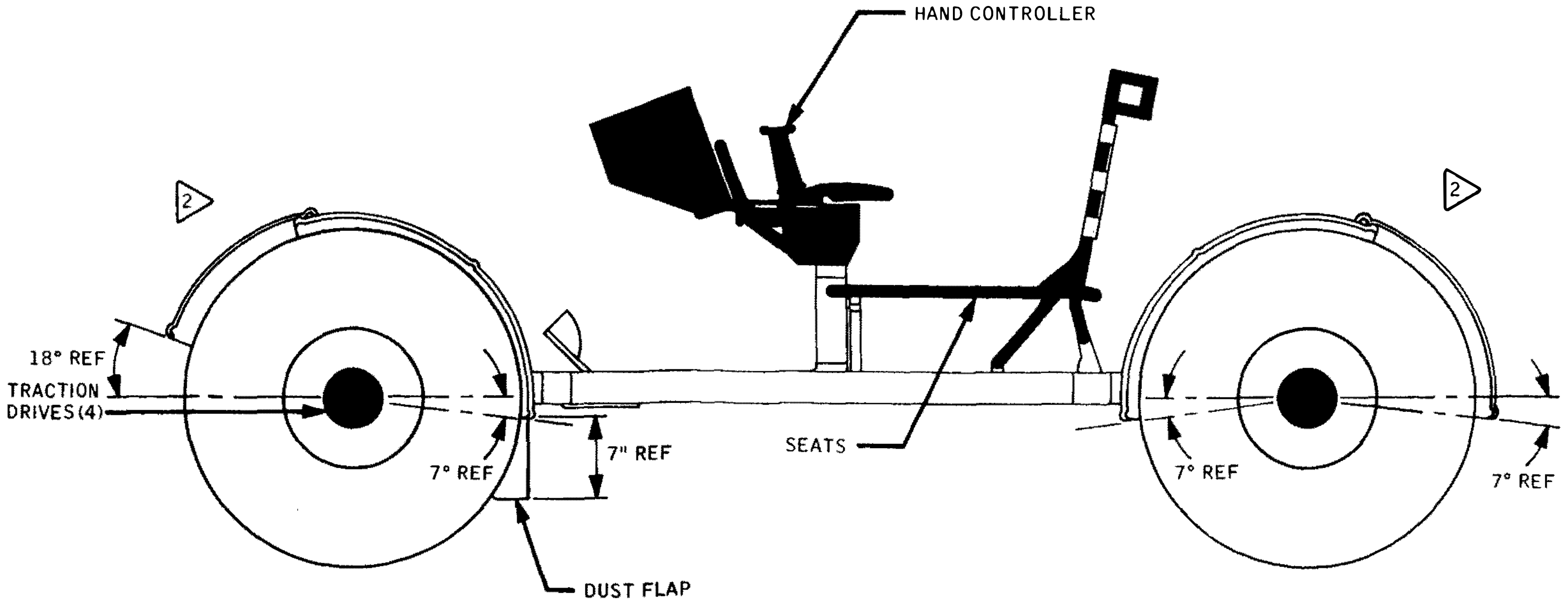
FOLDOUT FRAME 2

FOLDOUT FRAME 3









NOTES:

1. AT 50° BATTERY TEMPERATURE, THE COVERS WILL CLOSE
2. FENDER SHOWN DEPLOYED
3. SPU USES 2-1/4 LB EICOSANE WAX FOR PARTIAL THERMAL CONTROL WITH THERMAL STRAP TO BATTERY NO 1
4. OPERATING LIMITS FOR DCE: 460° R TO 619° R DCE USES 3-1/2 LB OCTADECANE WAX FOR PARTIAL THERMAL CONTROL
5. BLACK INDICATES AREAS HAVING THERMAL CONTROL BY SURFACE FINISH

SIGNATURES	DATE
DR Malcolm G. Smith	9-2-70
DSGN Bill J. Cornelius	3-30-71
QC Betty M. Taylor	3-30-71
ENGR John H. Cooper	3-29-71
APP Gerald D. Griffith	3-29-71
FEC Dean B. Fisher	3-30-71
AUTH	

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

THERMAL CONTROL

LRV | DWG NO 3.2

33 X 17 | PAGE 3-4 | SHEET 1 OF 1

SECTION 4
MOBILITY

4.1 SUBSYSTEM DESCRIPTION

The LRV mobility subsystem consists of the wheels, suspension, traction drive, steering mechanical, steering electrical, and drive control electronics.

4.2 WHEEL

Each wheel (Drawing 4.1) consists of an open wire mesh tire with chevron thread covering 50 percent of the surface contact area. The tire inner frame (bump stop) prevents excessive deflection of the outer wire mesh frame under high impact load conditions. Each tire is capable of maintaining full operations with 10 percent of the wire elements broken.

Each wheel can be uncoupled from the traction drive by operation of the two decoupling mechanisms (Drawing 4.2), which allows the wheel to "free-wheel" about a bearing surface independent of the drive train for up to 100 km of lunar operation. The decoupling mechanism can also be used to re-engage the wheel with the traction drive. Either outboard toehold can be used as the wheel decoupling tool. Decoupling a wheel results in a nonfunctional brake and odometer for that wheel.

4.3 SUSPENSION

The chassis is suspended from each wheel by a pair of parallel triangular arms connected between the LRV chassis and each traction drive. (See Drawing 4.3 for the suspension system.) Loads are transmitted to the chassis through each suspension arm to a separate torsion bar for each arm. The upper torsion bars are used primarily to deploy the wheels from the stowed condition. Deployed, they carry about 15 percent of each wheel load, with the lower torsion bars carrying the remaining 85 percent. Wheel vertical travel and rate of travel is limited by a damper connection between the chassis and each upper suspension arm. The damper limits wheel vertical travel to 6 inches of jounce and 4 inches of rebound under nominal load conditions. The combination deflection of the suspension system/tires combines to allow 14 inches of chassis ground clearance when the LRV is fully loaded and 17 inches when unloaded.

Damping energy heat is transferred to the silicone oil (47 cc) in the damper. The heat is then conducted from the oil to the damper walls for dissipation.

The suspension assembly is rotatable approximately 135 degrees to allow LRV stowage in the LM.

4.4 TRACTION DRIVE

Each wheel is provided with a separate traction drive assembly (Drawing 4.4) consisting of harmonic drive reduction unit, drive motor, and brake assembly. Each traction drive is hermetically sealed to maintain a 7.5 psia internal pressure for optimum thermal control. Decoupling a wheel also decouples that traction drive assembly.

4.4.1 Harmonic Drive

The four harmonic drive reduction units transmit torque to each wheel. Input torque to the four harmonic drives is supplied by the four electric drive motors. The harmonic drives reduce the motor speed at the rate of 80:1 and allow continuous application of torque to the wheels at all speeds without requiring gear shifting. Each traction drive also contains an odometer pickup which transmits pulses to the navigation system signal processing unit at the rate of 9 pulses per wheel revolution.

4.4.2 Drive Motor

The drive motors are direct-current series, brush-type motors which operate from a nominal input voltage of 36 Vdc. Speed control for the motors is furnished by pulse width modulation from the drive controller electronics package. Each motor housing also forms the kingpin for the LRV steering system. Each motor is instrumented for thermal monitoring. An analog temperature output from a thermistor located in the field winding is transmitted for display on the control and display panel. In addition, each motor contains a thermal switch which closes at excessive temperatures and provides an input signal to the caution and warning system to actuate the warning flag.

4.4.3 Brakes

Each traction drive is equipped with a mechanical brake (Drawing 4.5) actuated by a cable connected to a linkage in the hand controller (Drawing 5.4). Braking is accomplished by moving the hand controller rearward. Brakes are effectively locked at 12° of hand controller aft movement. Drive power inhibit is actuated by a switch at 15° of hand controller aft movement. Decoupling a wheel also decouples the brake for that wheel.

4.5 STEERING

4.5.1 Steering Mechanical

LRV steering (Drawing 4.6) is accomplished by Ackerman-geometry steering of both the front and rear wheels allowing a wall-to-wall turning radius of 122 inches. Steering is controlled by moving the hand controller left or right from the nominal position. This operation energizes separate electric motors for the front and rear wheels and provides through a servosystem a steering angle proportional to the position of the hand controller.

Each steering motor is connected to a speed reducer which drives a spur gear sector which, in turn, actuates the steering linkage to accomplish the change in steering angle. Maximum travel position of the sector provides an outer wheel angle of 22° and inner wheel angle of 50°. The steering rate is such that lock-to-lock steering can be accomplished in 5.5 ± 0.5 seconds.

The front and rear steering assemblies are mechanically independent of each other. In the event single Ackerman steering is desired or for a motor/speed reducer failure, the steering linkage can be disengaged from a sector, the wheels can be manually centered and locked, and operations can continue using the remaining active steering assembly. Forward steering re-engagement cannot be accomplished by a crewman. The aft steering can be re-engaged using the special tool stowed on the aft chassis. This tool is used to retract the locking pin from the steering sector.

4.5.2 Steering Electrical

The steering electrical system (Drawing 4.7) is a servosystem. A signal generated by deflection of the hand controller is coupled to the input servoamplifier as an error signal across a bridge. This error signal is amplified and applied to the steering motor field coils in a direction determined by polarity of the input error signal (determined by the direction that the hand controller is deflected). The feedback pot is driven by the steering motor to a position that exactly cancels the original input error signal by balancing the bridge. Angular displacement of the wheels will then remain constant until the hand controller is moved to a new position.

The two steering motors are supplied power through separate circuit breakers from selectable electrical buses to provide redundancy.

Single Ackerman steering can be selected by centering the wheels and turning off either aft or forward steering power. This procedure may require occasionally recentering the disabled steering by turning on its drive power momentarily with the hand controller in the straight ahead position.

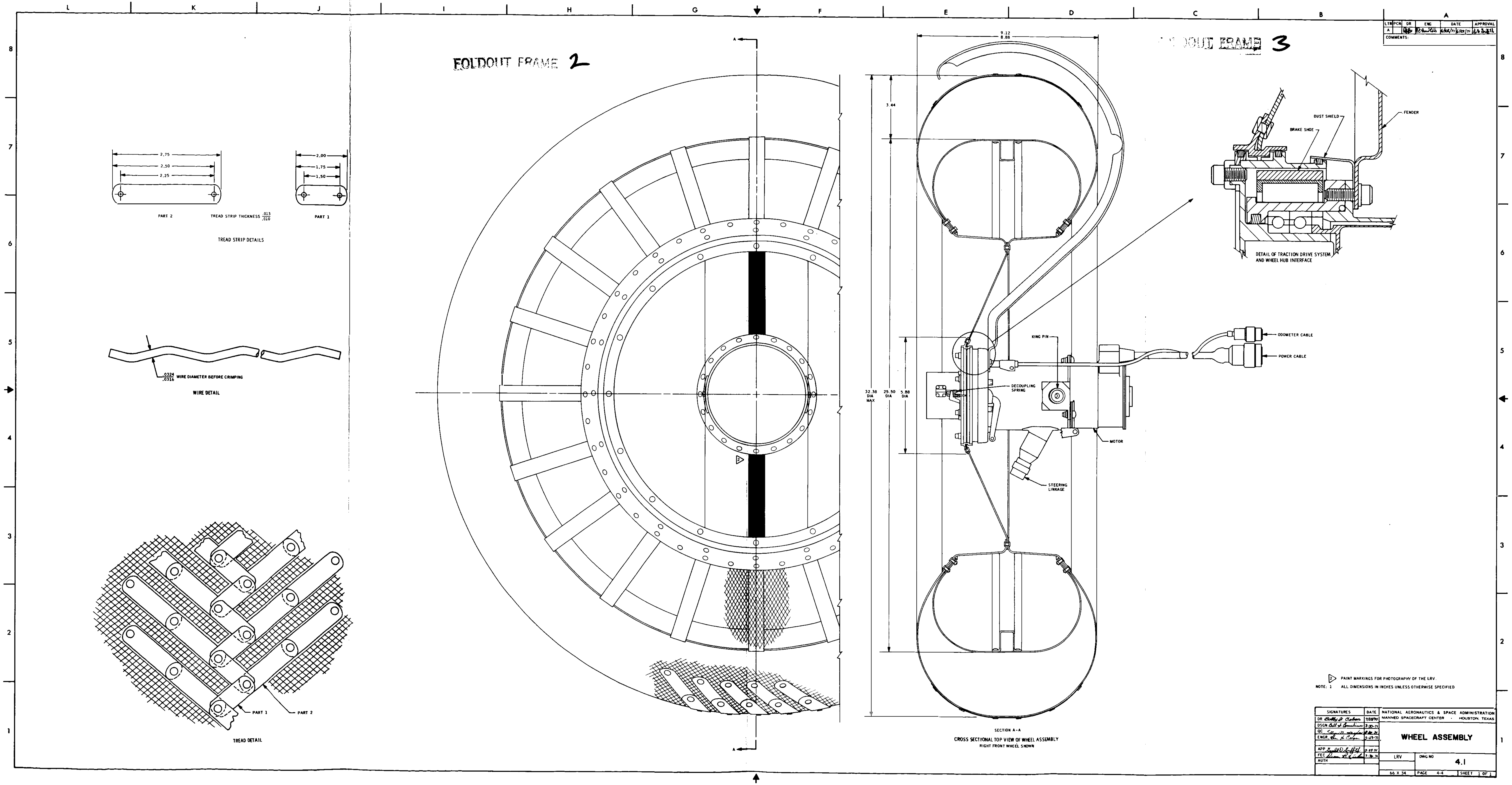
4.6 DRIVE CONTROL ELECTRONICS (Drawing 4.8)

A forward or rearward motion of the hand controller about the palm pivot point closes switches which select forward or reverse drive direction. This same movement causes a signal to be generated by the wiper of the traction drive pot. This signal controls the duty cycle modulation of the pulse width modulator (PWM). The pulse width of the PWM is proportional to the amount of hand controller deflection (throttle). This signal is then coupled through an inhibit gate to current-limited power transistors which in turn modulate 36 Vdc power to the drive motor field coils. The direction of current flow through the drive motor is determined by motor control relays which are normally controlled by the hand controller select switches.

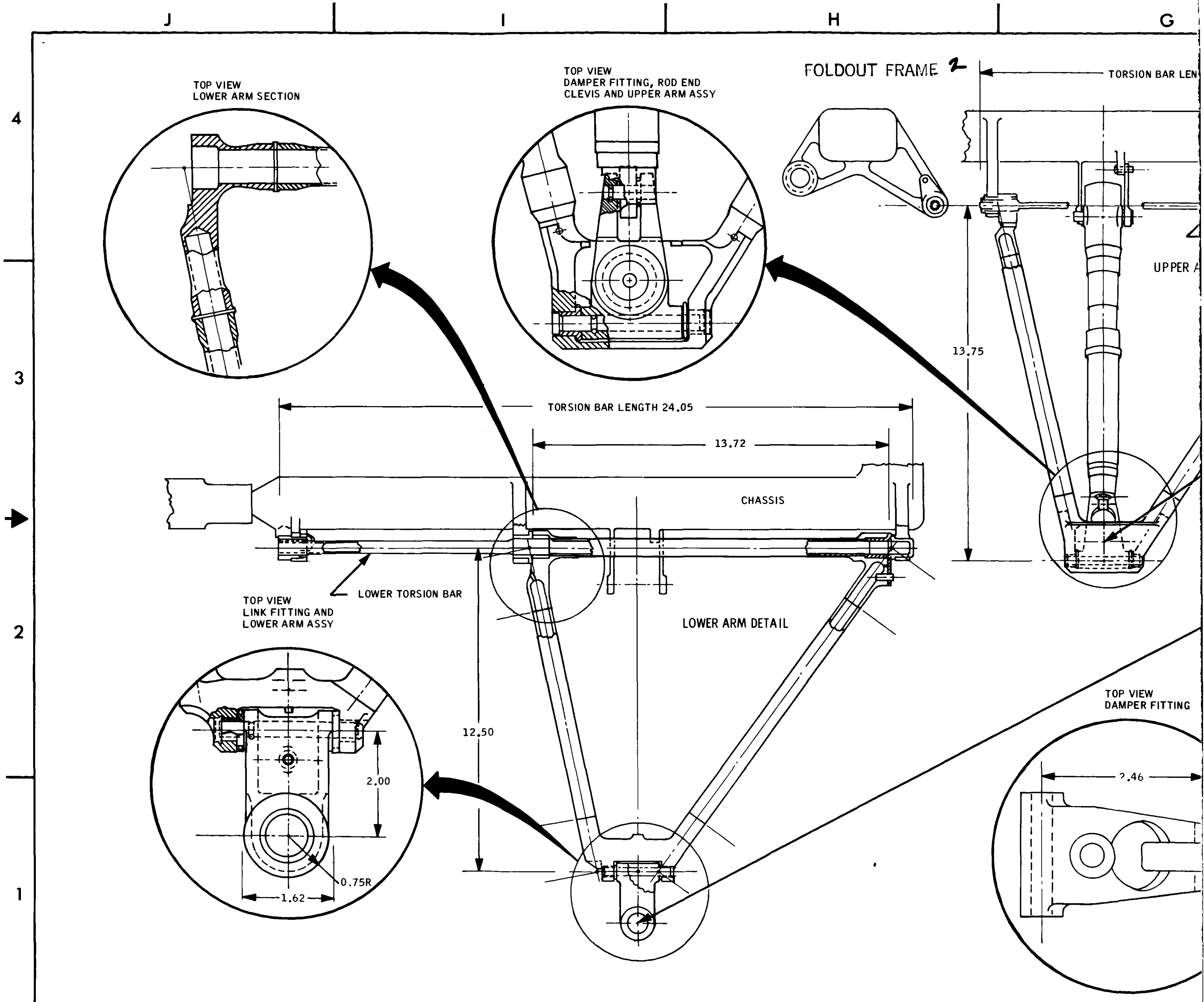
Signals generated by the odometer reed switches in the traction drive prevent application of reverse drive motor power while moving forward or vice-versa if the LRV speed is greater than 1 km per hour. The vehicle should be completely stopped before attempting to change direction as the odometer inhibits are unpredictable between 1 km per hour and stopped.

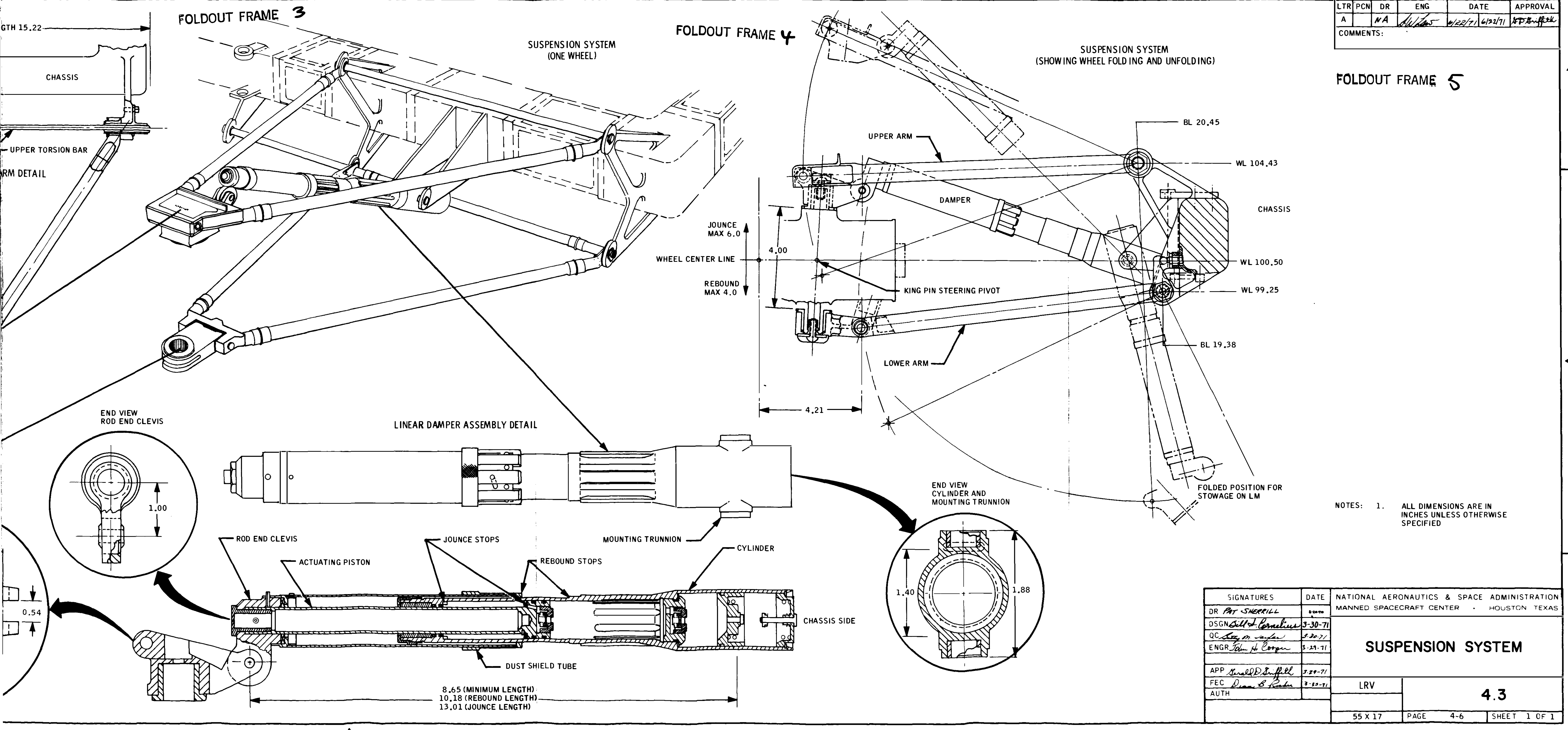
Drive power is also inhibited by a drive power inhibit switch which closes at the hand controller aft 15° position (brakes nominally lock at 12° aft) or by getting a current overload signal from the current limiting circuits. Also, drive power is temporarily inhibited while changing directions to prevent switching the motor control relays under load.

Application of motor drive power when applying brakes is possible since the brakes lock at approximately 12° aft hand controller movement, and the brake inhibit logic is set at 15° aft hand controller movement. This is true for both forward and reverse drive power.


FOLDOUT FRAME 2
FOLDOUT FRAME 3
PART 2
TREAD STRIP THICKNESS .013/.010
PART 1
TREAD STRIP DETAILS
2.75
2.50
2.25
2.00
1.75
1.50
.0324/.0316 WIRE DIAMETER BEFORE CRIMPING
WIRE DETAIL
PART 1
PART 2
TREAD DETAIL
9.12
8.88
3.44
32.38 DIA MAX
25.50 DIA
5.88 DIA
KING PIN
DECOUPLING SPRING
MOTOR
STEERING LINKAGE
ODOMETER CABLE
POWER CABLE
DUST SHIELD
BRAKE SHOE
FENDER
DETAIL OF TRACTION DRIVE SYSTEM AND WHEEL HUB INTERFACE
SECTION A-A
CROSS SECTIONAL TOP VIEW OF WHEEL ASSEMBLY
RIGHT FRONT WHEEL SHOWN
PAINT MARKINGS FOR PHOTOGRAPHY OF THE LRV
NOTE: 1 ALL DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
WHEEL ASSEMBLY
LRV
DWG NO 4.1
66 X 34
PAGE 4-4
SHEET 1 OF 1

FOLDOUT FRAME 1





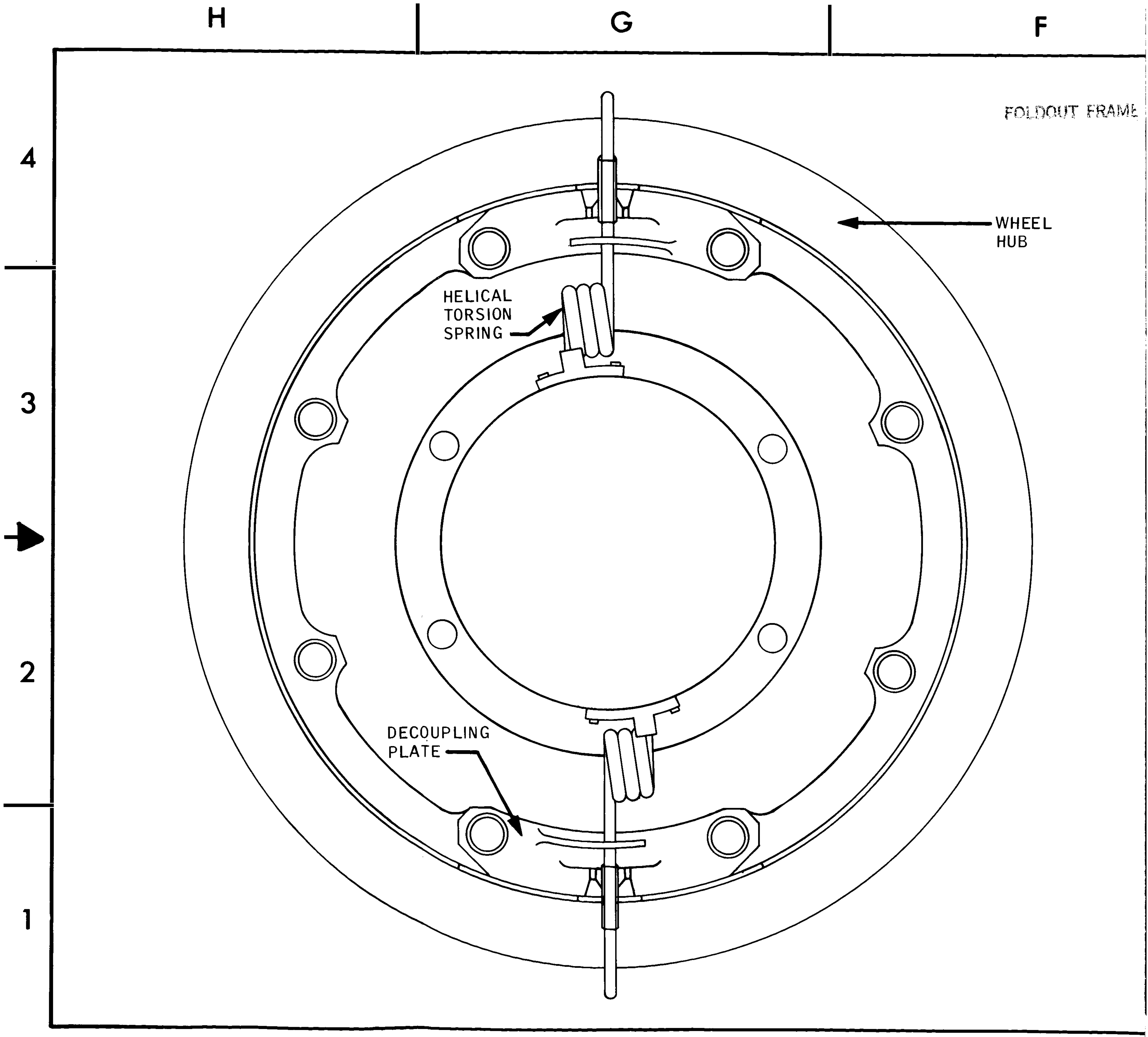
LTR	PCN	DR	ENG	DATE		APPROVAL
A		NA		6/22/71	6/22/71	

COMMENTS:

NOTES: 1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER · HOUSTON TEXAS
DR PAT SHERRILL		
DSGN Bill J. Cornelius	3-30-71	
QC	3-30-71	SUSPENSION SYSTEM
ENGR John H Cooper	3-29-71	
APP Gerald D. Griffith	3-29-71	
FEC	3-30-71	LRV / 4.3
AUTH		
		55 X 17 / PAGE 4-6 / SHEET 1 OF 1

FOLDOUT FRAME 1

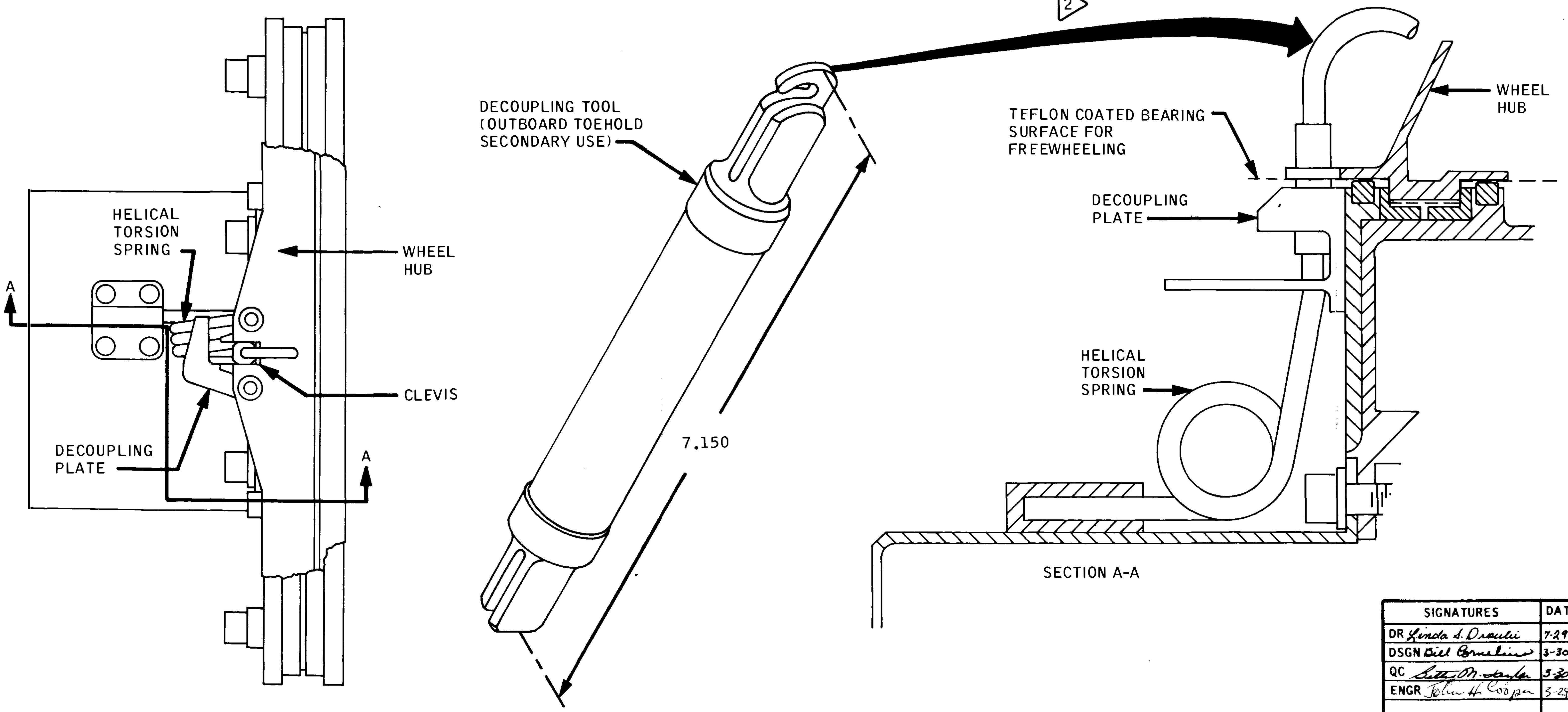


FOLDOUT FRAME

LTR	PCN	DR	ENG	DATE		APPROVAL
A		NA	Sl[illegible]	6/22/71	6/22/71	[illegible]

COMMENTS:

FOLDOUT FRAME 3



6. RECOUPLING IS ACCOMPLISHED BY ALIGNING THE CLEVISES AND RETURNING THE PINS

5. DECOUPLING RIGHT REAR WHEEL DISABLES SPEEDOMETER

4. DECOUPLING ANY TWO WHEELS DISABLES THE NAV SUBSYSTEM RANGE AND DISTANCE DISPLAYS (SPU LOGIC SELECTS THIRD FASTEST WHEEL FOR DISTANCE COMPUTATIONS)

3. DECOUPLING DISABLES BRAKES, DRIVE POWER, AND ODOMETER TO THAT WHEEL

(2) TO DECOUPLE WHEEL, PULL SPRING OUT AND ROTATE ABOUT WHEEL CENTERLINE

1. ALL DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED

SIGNATURES	DATE
DR Linda S. Drauli	7-29-70
DSGN Bill Cornelius	3-30-71
QC [illegible]	3-30-71
ENGR John H. Cooper	3-29-71
APP [illegible] Griffith	3-29-71
FEC [illegible]	3/30/71
AUTH	

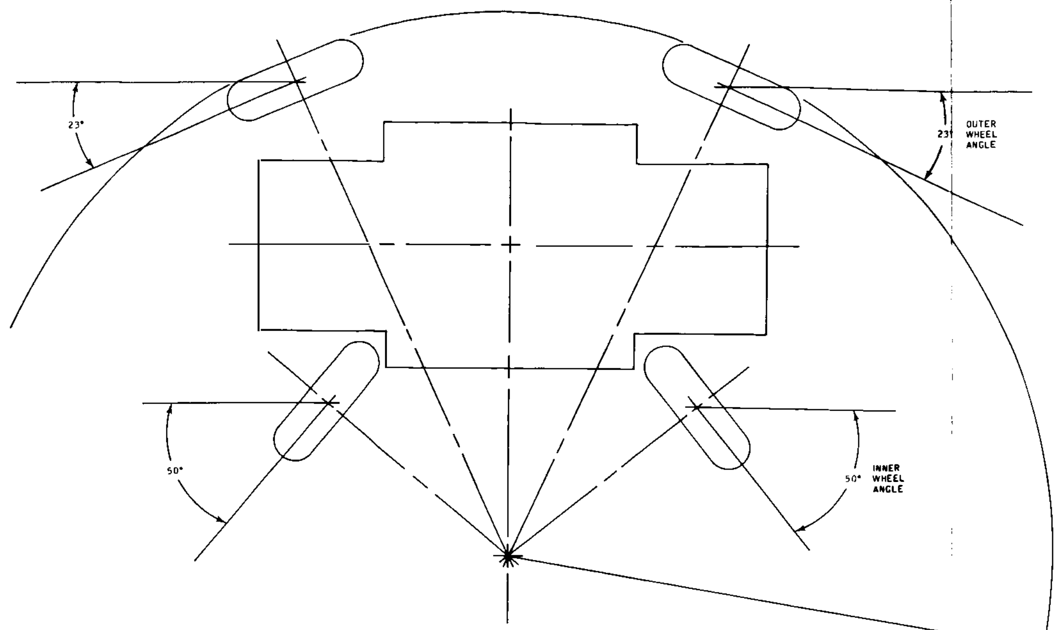
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER • HOUSTON, TEXAS

DECOUPLING ASSEMBLY

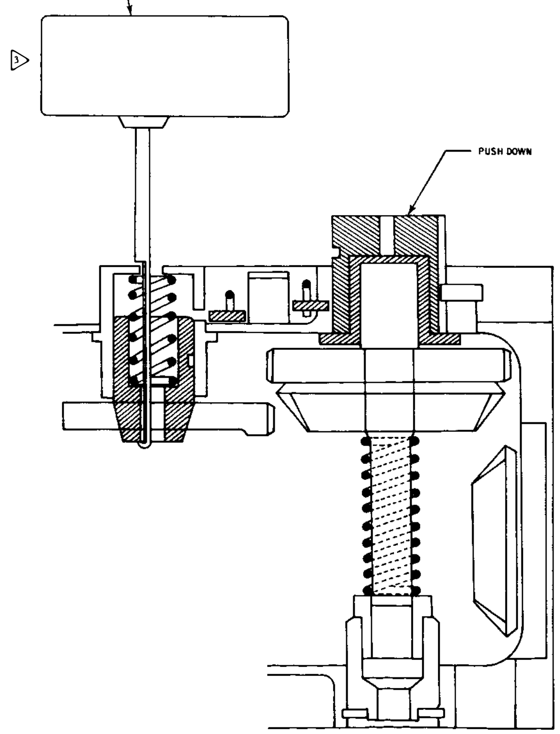
LRV NO. 4.2

34 X 10.5 PAGE 4-5 SHEET 1 OF 1

FOLDOUT FRAME 1

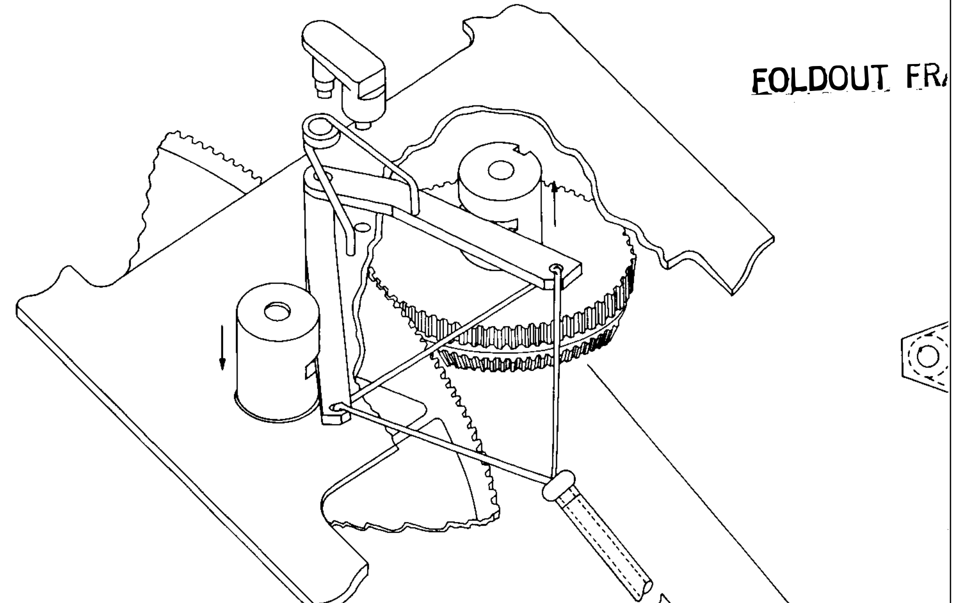


DOUBLE ACKERMANN

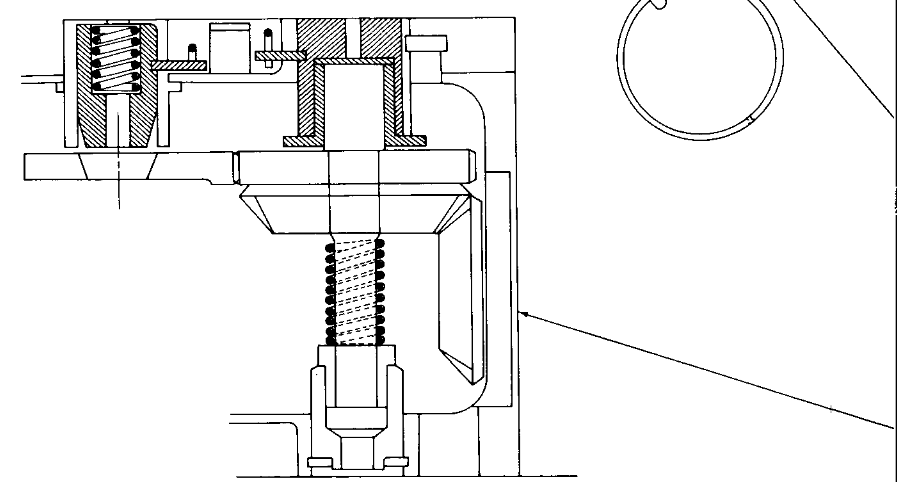


STEERING RECOUPLING
(REAR ONLY)

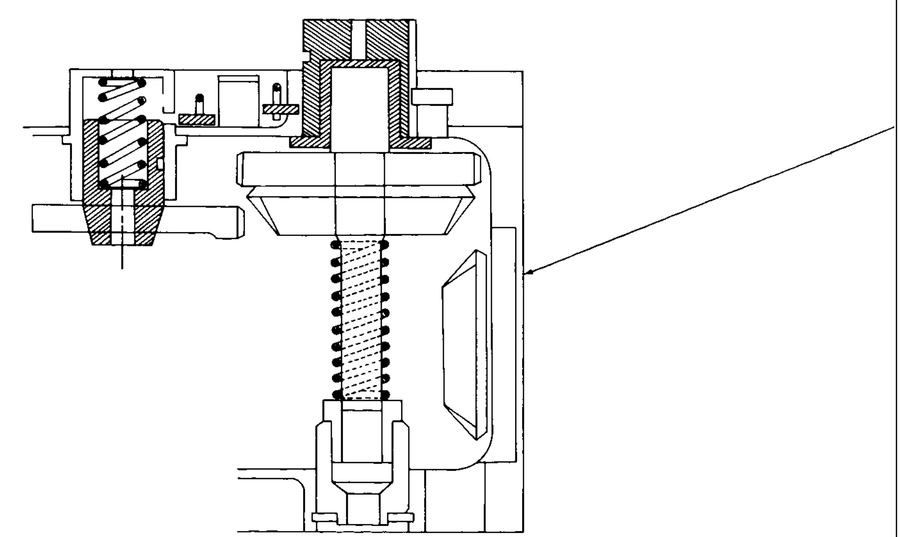
FOLDOUT FRA



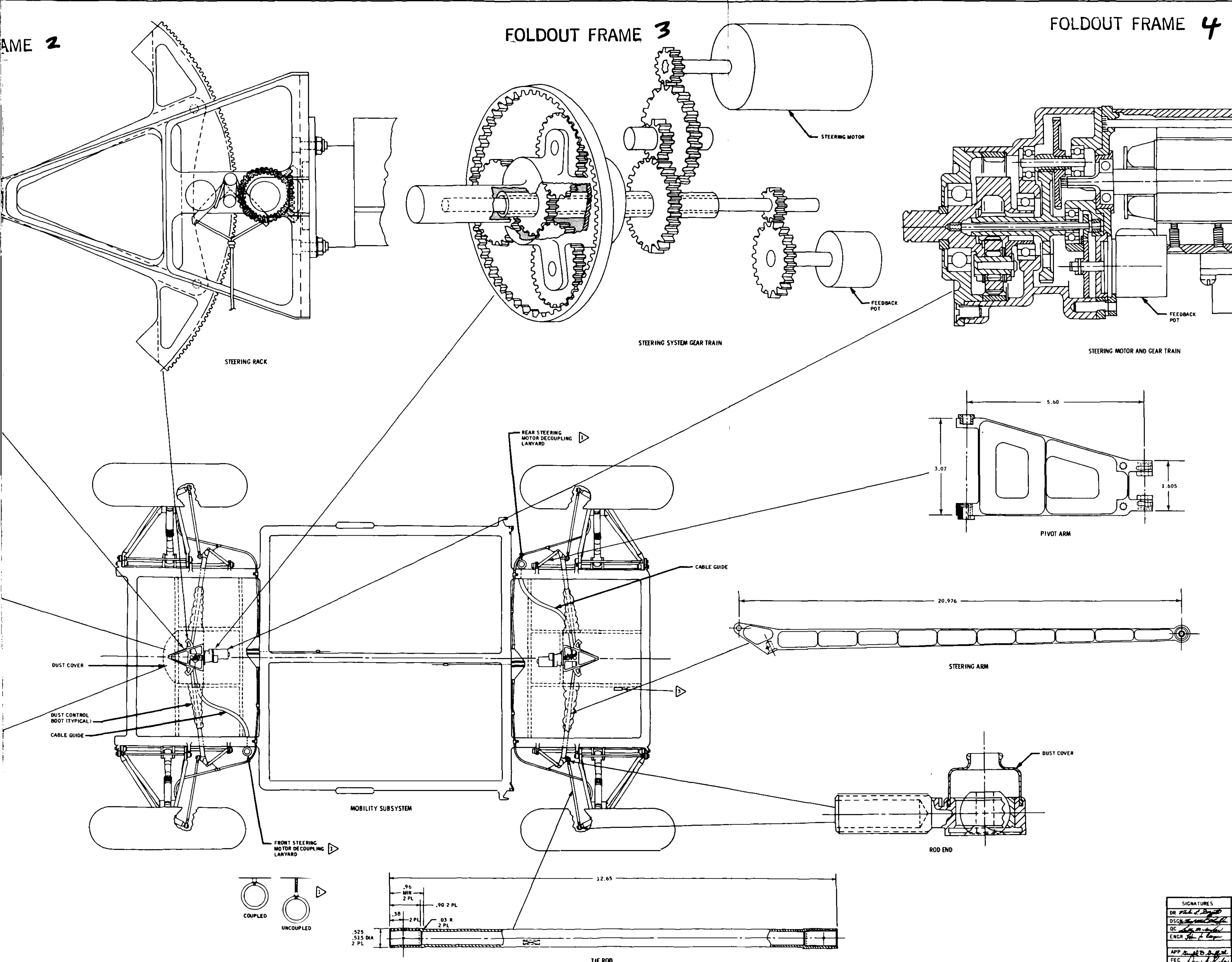
STEERING DISCONNECT ASSEMBLY



BEFORE STEERING DISCONNECT



AFTER STEERING DISCONNECT



NOTES:

1. YELLOW PAINT SHOWS WHEN STEERING IS DECOUPLED
2. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE INDICATED
3. STEERING REENGAGEMENT TOOL, STOWED ON AFT CHASSIS

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

STEERING SYSTEM MECHANICAL

LRV

DWG NO: 4.6

93.5 X 34 | PAGE 4-9 | SHEET 1 OF 1

H	G	F	E	D

FOLDOUT FRAME 1

FOLDOUT FRAME 2

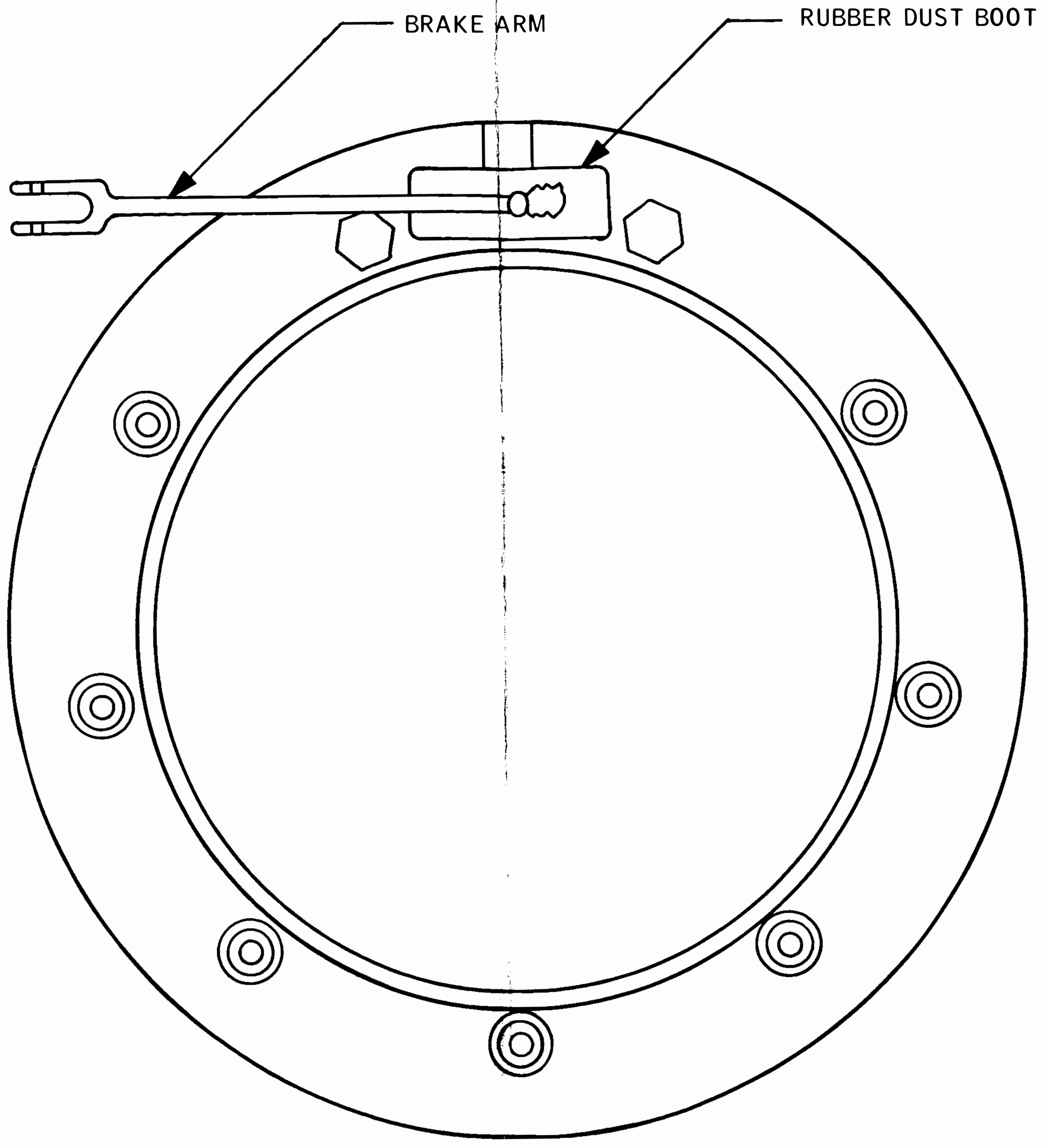
FOLDOUT FRAME 3

4

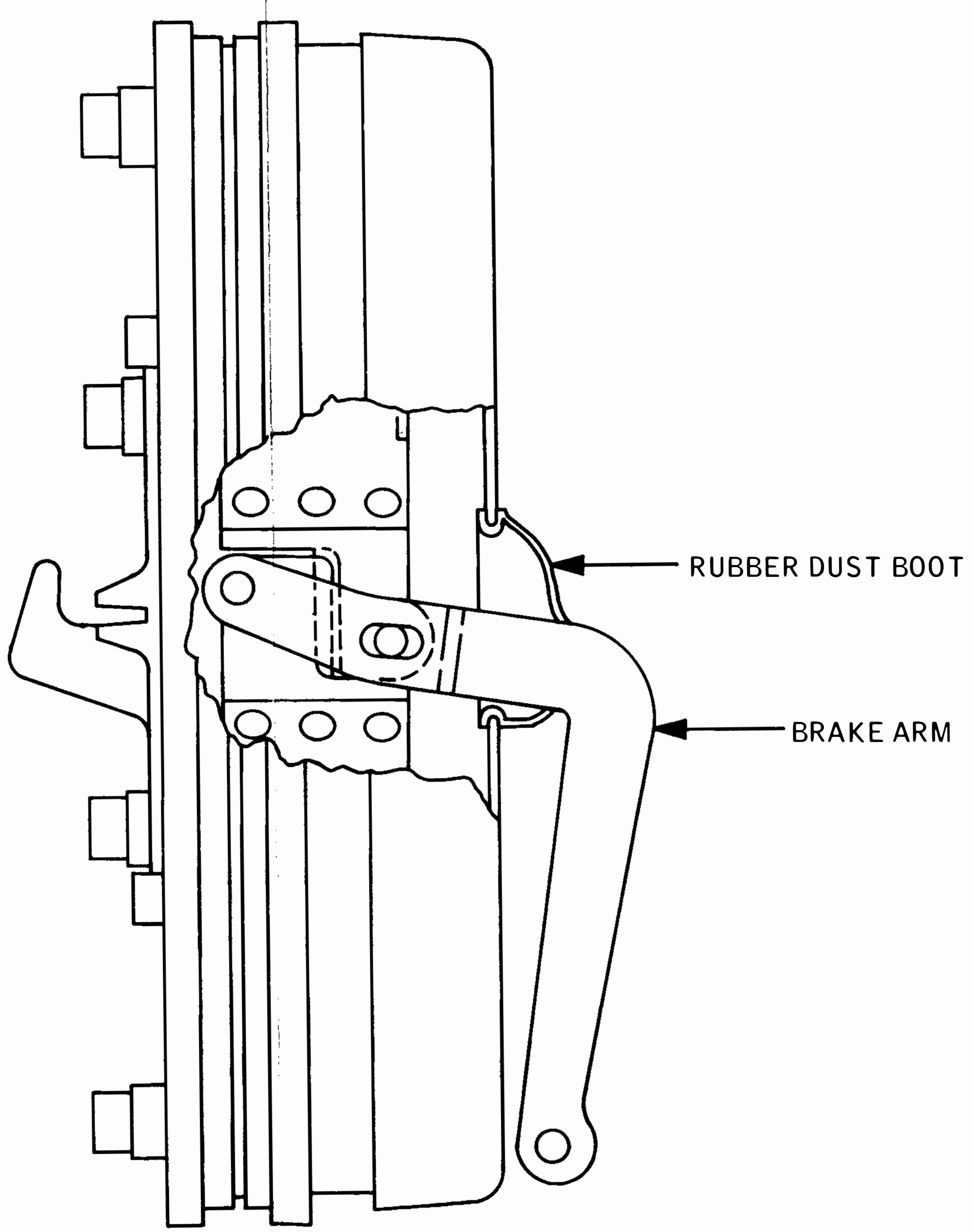
3

2

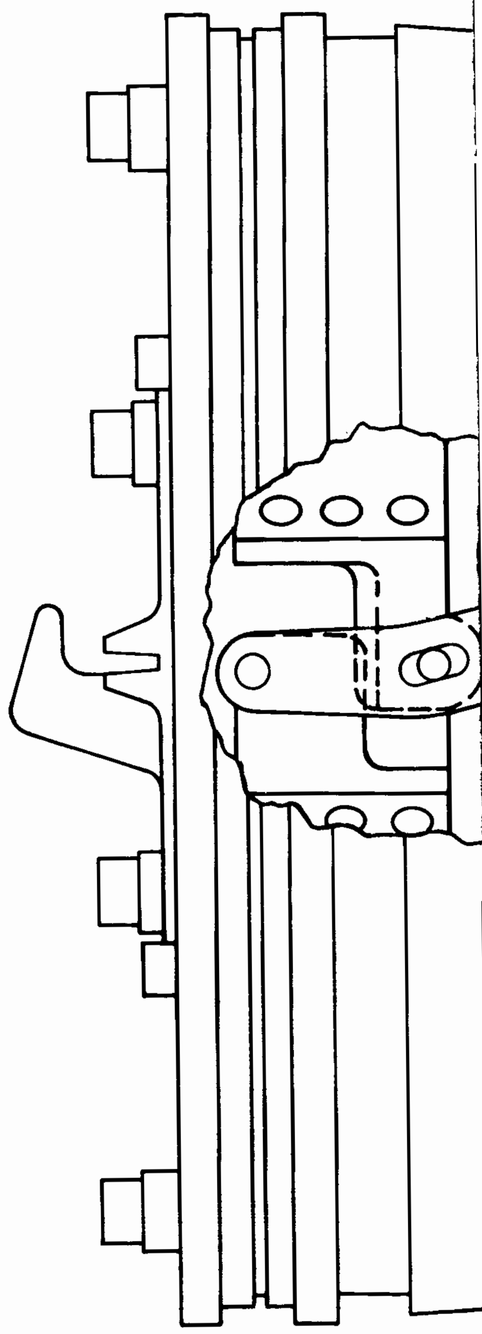
1



REAR VIEW



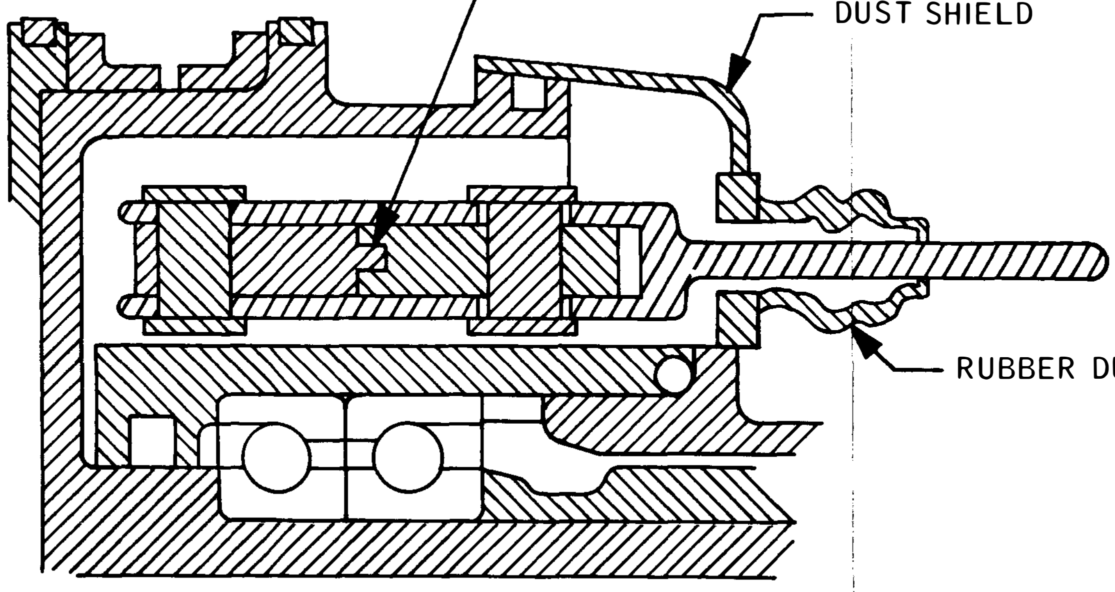
TOP VIEW
(NORMAL POSITION)



TOP VIEW
(BRAKING POSITIO

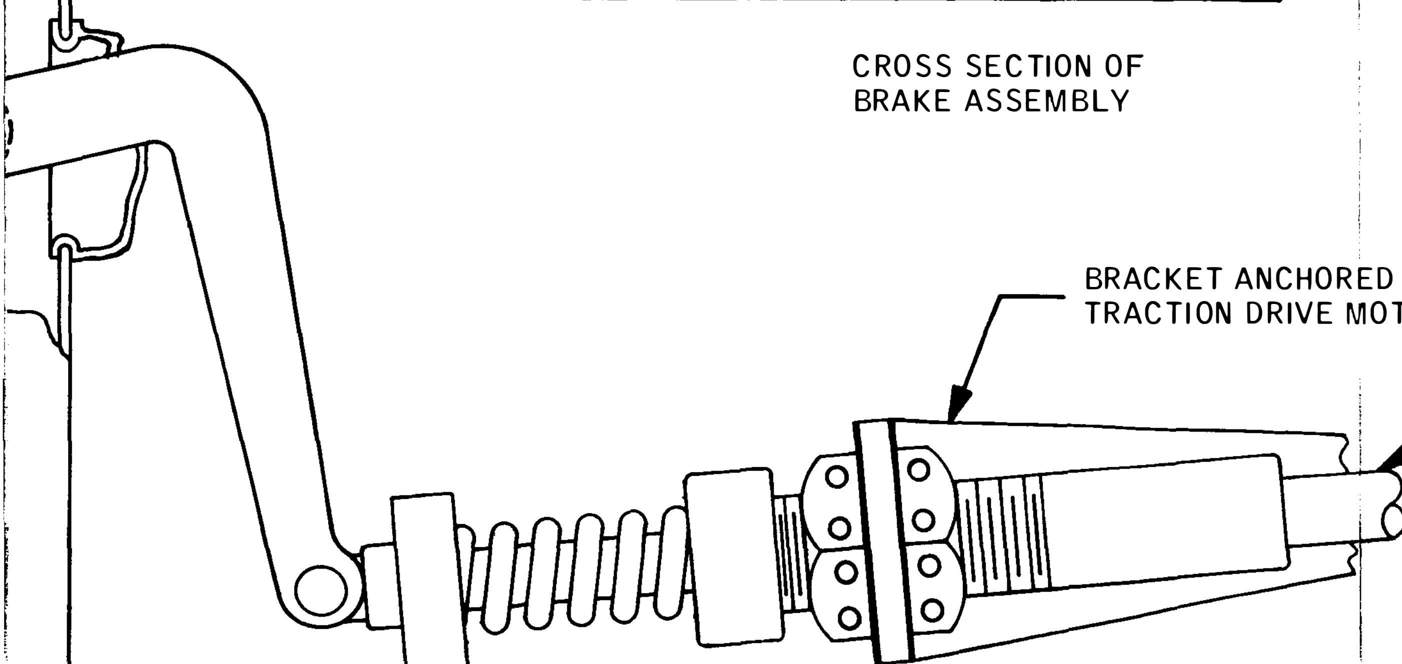
LTR	PCN	DR	ENG	DATE		APPROVAL
A		NA	SW Law	6/22/71	6/22/71	GD Griffith

COMMENTS:



CROSS SECTION OF
BRAKE ASSEMBLY

NOTE: 1. BRAKE BAND LINING THICKNESS 0.115 INCHES, WIDTH 0.735 INCHES



BRAKE CABLE CLEVIS

H Z 1
5.4

N)

SIGNATURES	DATE
DR Malcolm D. Smith	9-3-70
DSGN Bill Cornelius	3-30-71
QC Betty M. [illegible]	3-30-71
ENGR John H. Cooper	3-29-71
APP Gerald D. Griffith	3-29-71
FEC Dennis B. Rinker	3/30/71
AUTH	

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

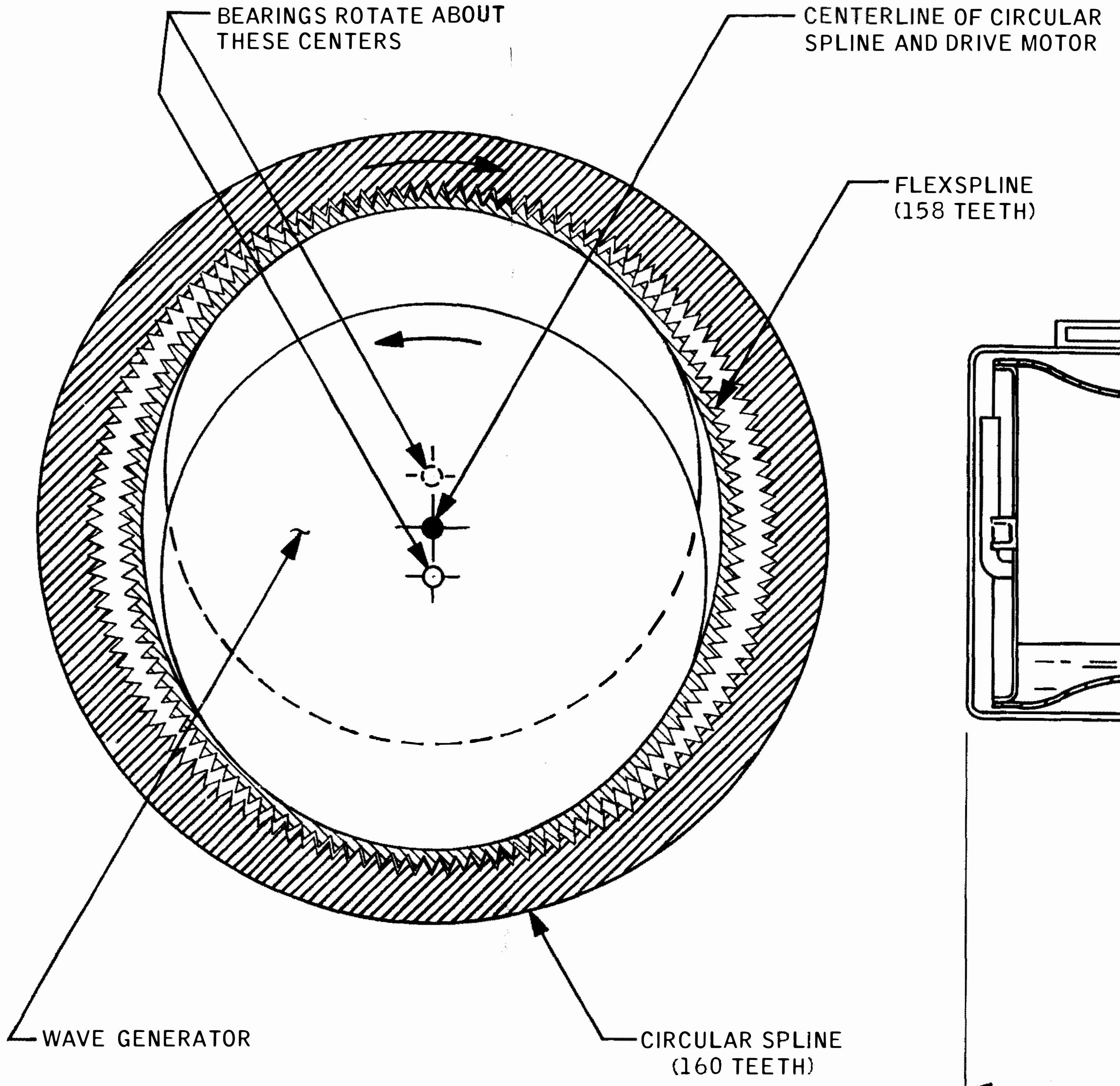
BRAKE ASSEMBLY

LRV | NO. 4.5

34 X 10.5 | PAGE 4-8 | SHEET 1 OF 1

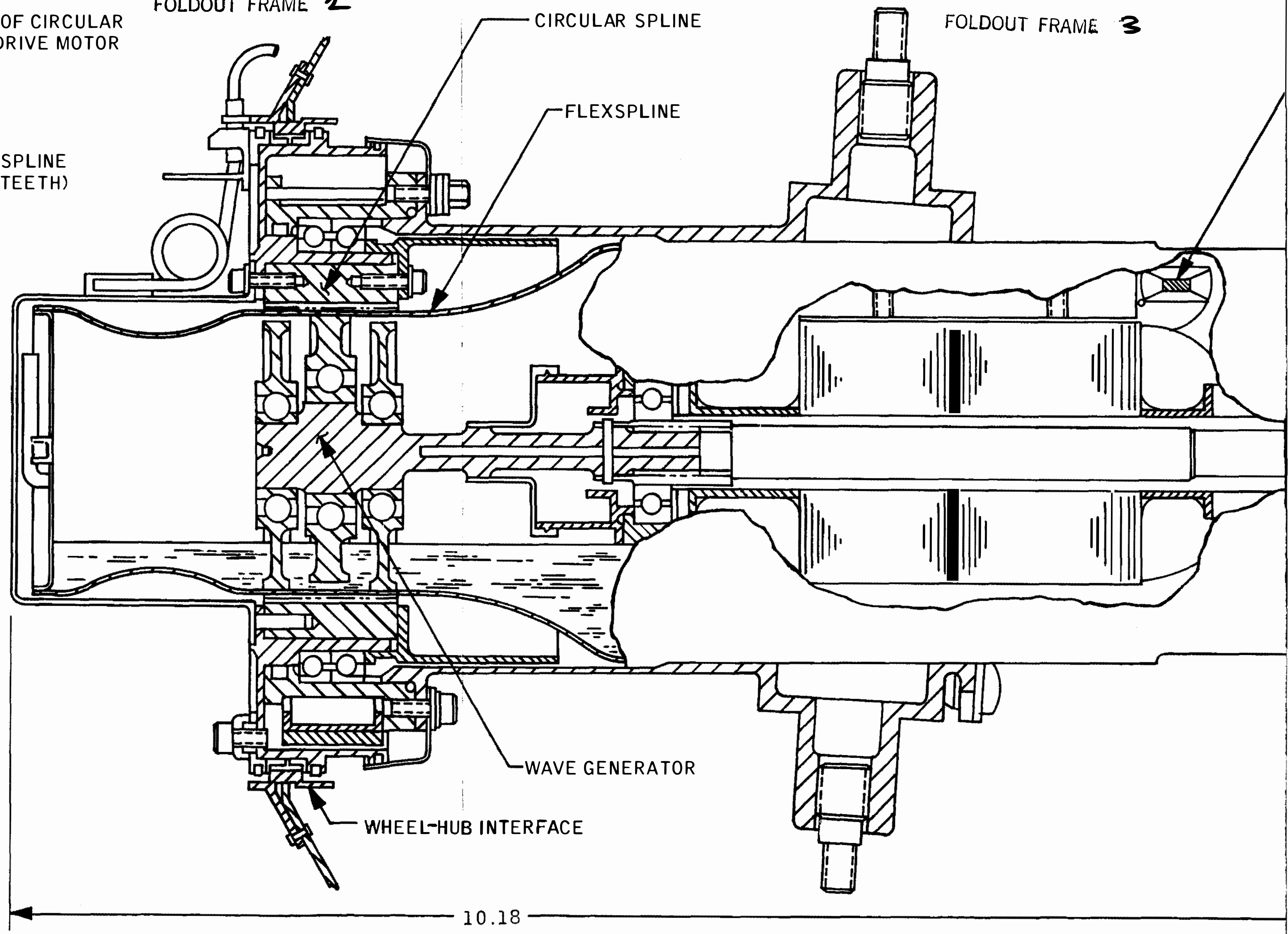
FOLDOUT FRAME 1

H G F E D



END VIEW OF HARMONIC DRIVE ASSY
FUNCTIONAL DIAGRAM
(NOT TO SCALE)

FOLDOUT FRAME 2



FOLDOUT FRAME 3

4 3 2 1

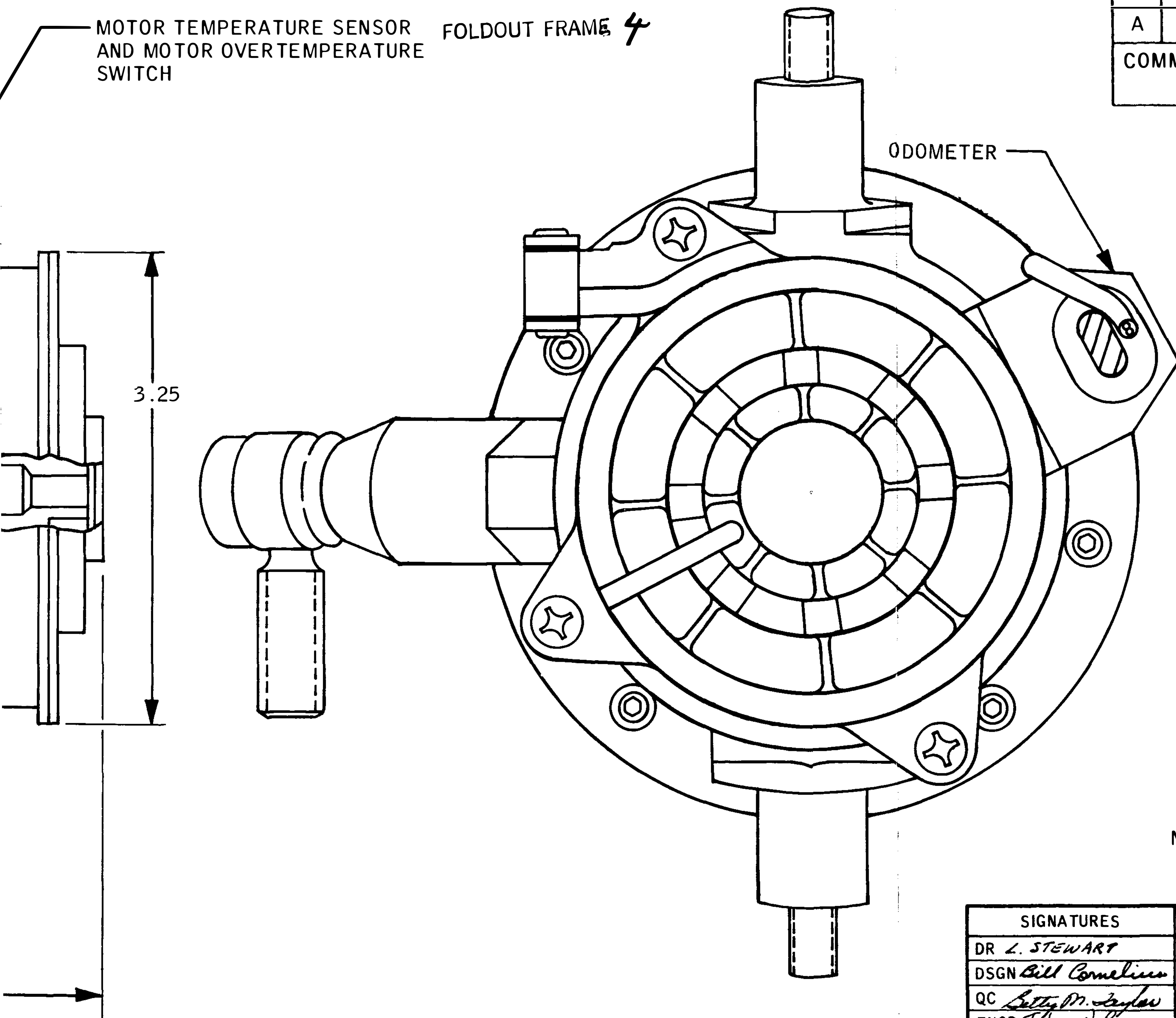
C	B	A

LTR	PCN	DR	ENGR	DATE		APPROVAL
A		NA	S W Law	6/22/71	6/28/71	G D Griffith

COMMENTS:

FOLDOUT FRAME 4

FOLDOUT FRAME 5



NOTE: 1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

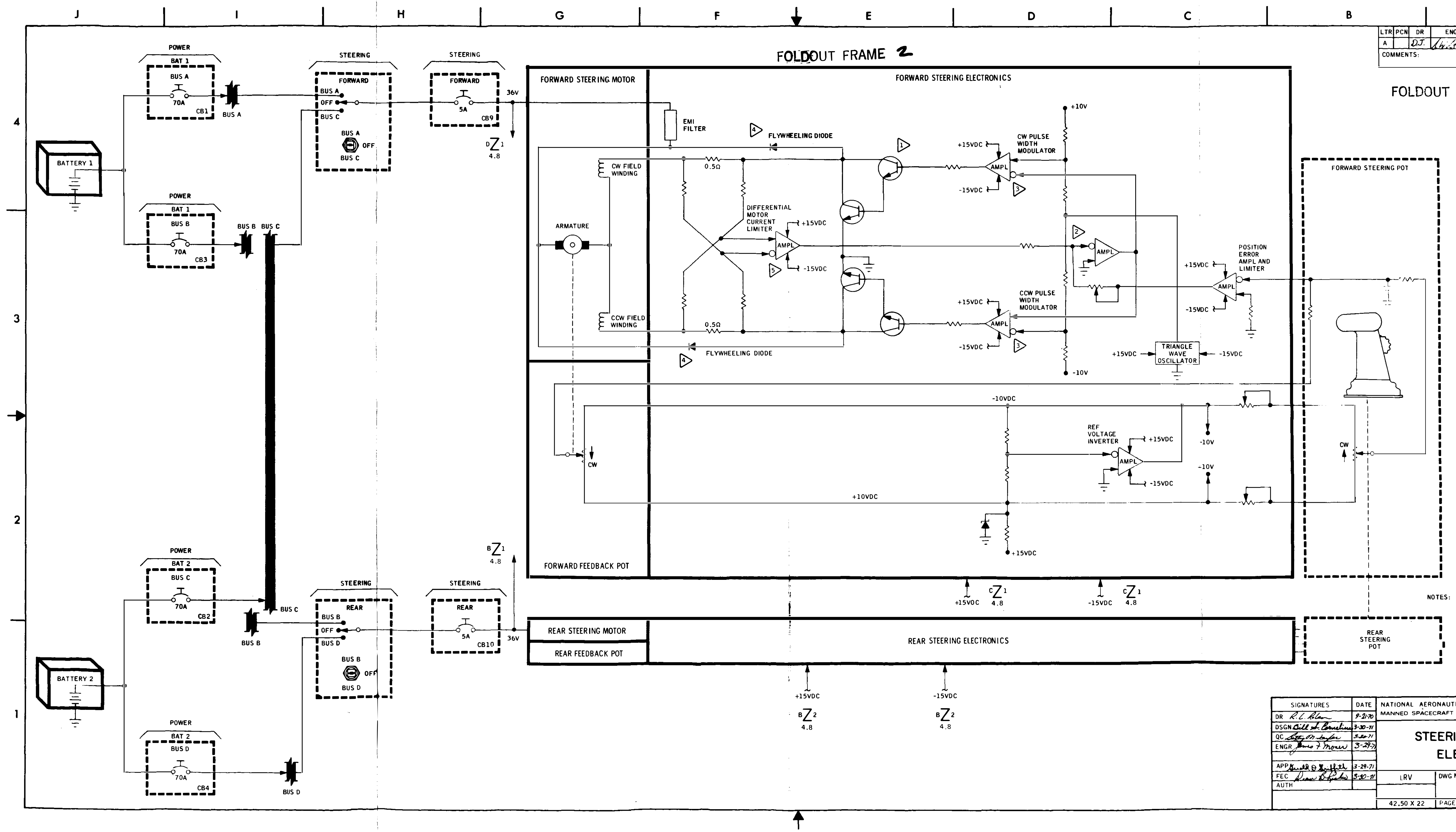
SIGNATURES	DATE
DR L. STEWART	9-1-70
DSGN Bill Cornelius	3-30-71
QC Betty M. Taylor	3-30-71
ENGR John H. Cooper	3-29-71
APP Gerald D Griffith	3-29-71
FEC Dean B Fisher	3-30-71
AUTH	

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

TRACTION DRIVE ASSEMBLY

LRV	NO. 4.4
34 X 10.5	PAGE 4-7 · SHEET 1 OF 1

4 3 2 1



NOTES:

1. A PLUS VOLTAGE TURNS TRANSISTOR ON
2. AMPLIFIES ERROR SIGNAL LESS OUTPUT OF CURRENT LIMITER AND APPLIES MIXED OUTPUT TO THE PULSE WIDTH MODULATORS
3. AMPLITUDE MODULATED ERROR SIGNAL AND TRIANGLE WAVE OSCILLATOR RESULT IN PULSE WIDTH MODULATION DRIVING SIGNAL TO MOTOR TRANSISTORS
4. FLYWHEEL DIODES ALLOW MOTOR FIELDS TO COLLAPSE AFTER EACH PULSE PROVIDING ADDITIONAL POWER
5. CURRENT LIMITING IS HELD TO 1.8 AMPS IN EITHER FIELD WITH RESPECT TO THE OTHER

LTR	PCN	DR	ENG	DATE	APPROVAL
A		DJ.			

COMMENTS:

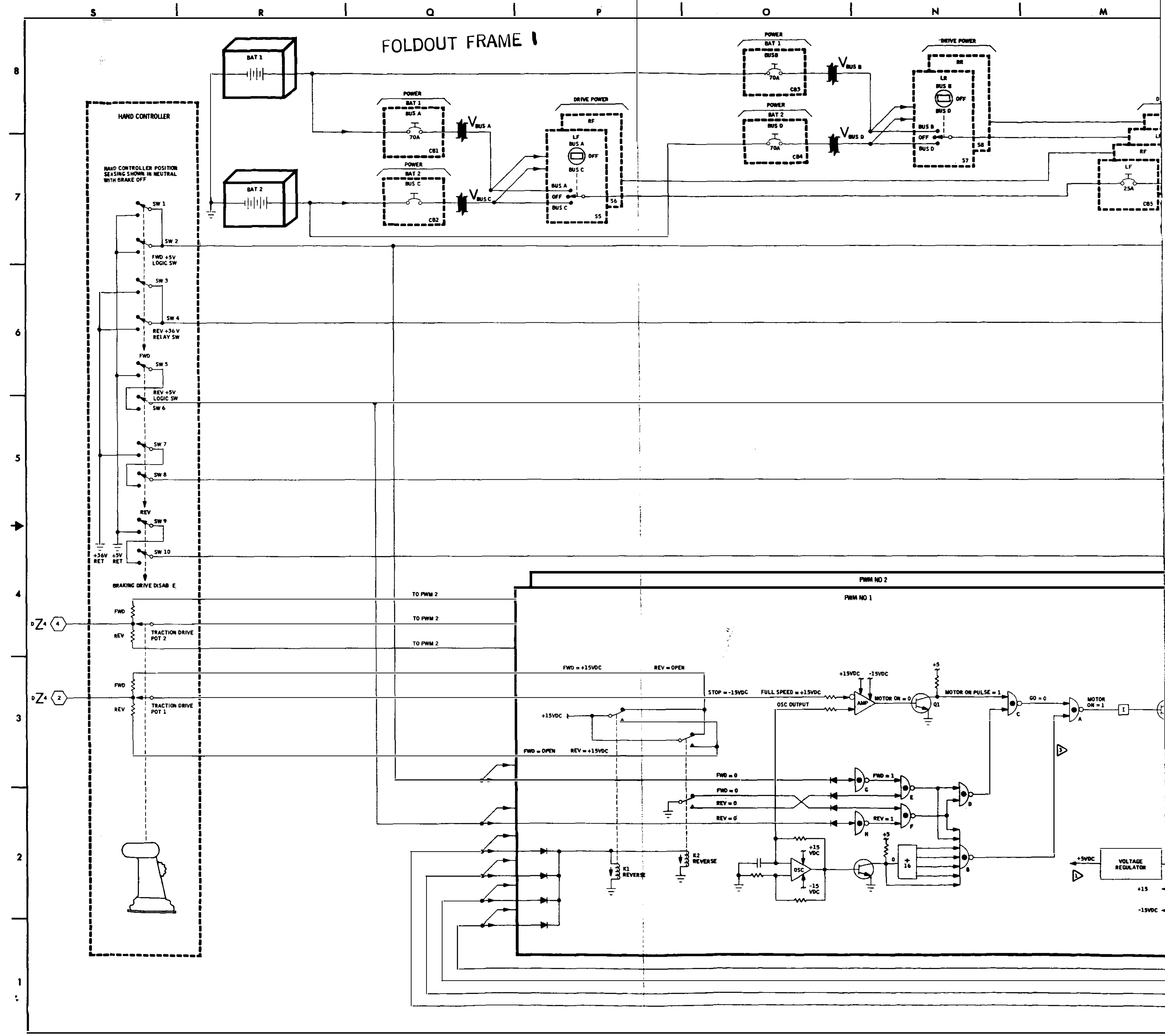
SIGNATURES	DATE
DR R. L. Rolan	9-21-70
DSGN Bill L. Cornelius	3-30-71
QC	3-30-71
ENGR James F. Moser	3-29-71
APP	3-29-71
FEC	3-30-71
AUTH	

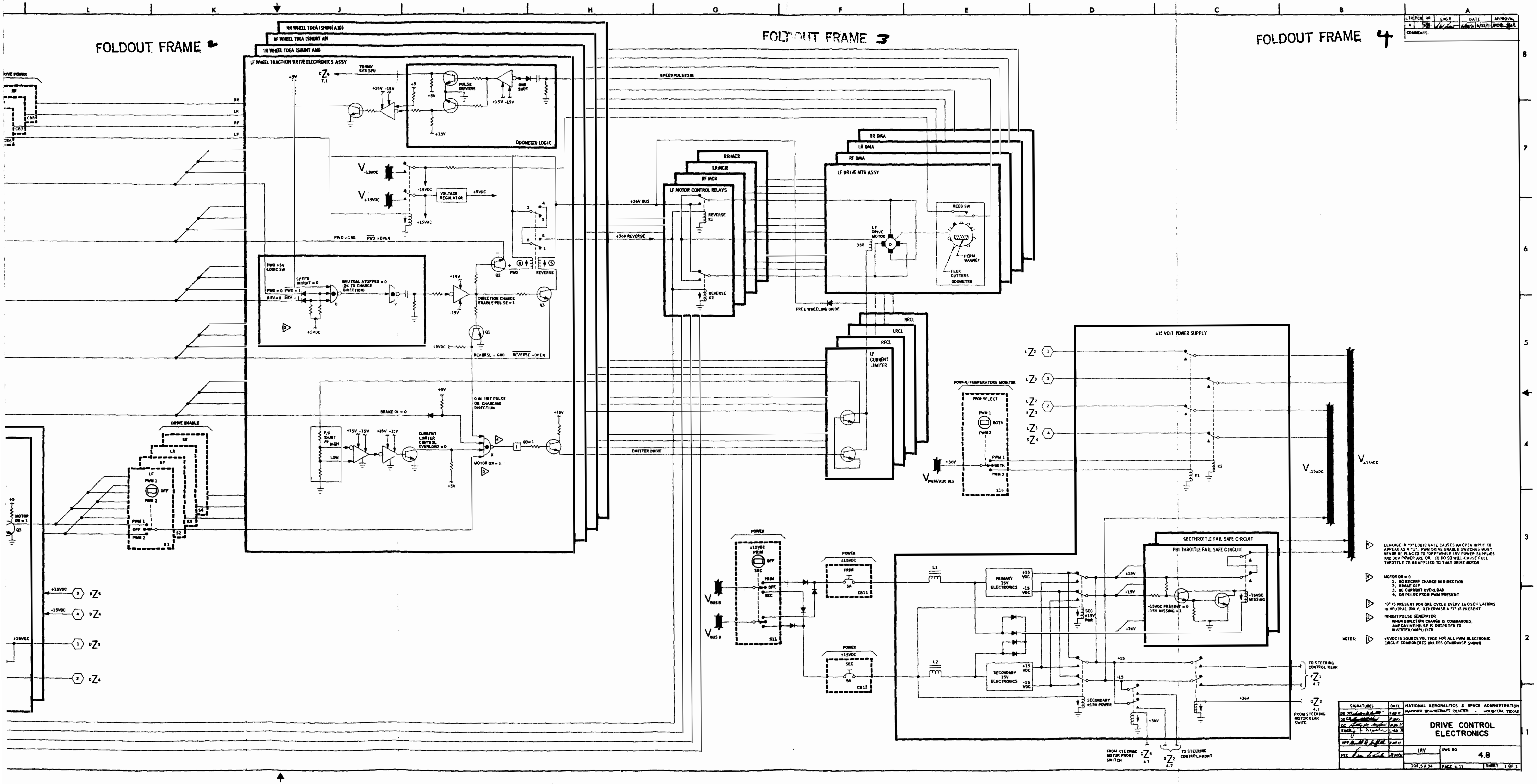
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

STEERING SYSTEM ELECTRICAL

LRV | DWG NO 4.7

42.50 X 22 | PAGE 4-10 | SHEET 1 OF 1


FOLDOUT FRAME 1
S
R
Q
P
O
N
M
8
7
6
5
4
3
2
1
BAT 1
BAT 2
POWER
BUS A
70A
CB1
CB2
BUS C
DRIVE POWER
RF
LF
OFF
S5
S6
BUSB
CB3
BUS D
CB4
LR
RR
S7
S8
25A
CB5
HAND CONTROLLER
HAND CONTROLLER POSITION SENSING SHOWN IN NEUTRAL WITH BRAKE OFF
SW 1
SW 2
FWD +5V LOGIC SW
SW 3
SW 4
REV +36 V RELAY SW
FWD
SW 5
REV +5V LOGIC SW
SW 6
SW 7
SW 8
REV
SW 9
SW 10
+36V RET
+5V RET
BRAKING DRIVE DISABLE
TRACTION DRIVE POT 2
TRACTION DRIVE POT 1
TO PWM 2
PWM NO 2
PWM NO 1
FWD = +15VDC
REV = OPEN
FWD = OPEN
REV = +15VDC
+15VDC
STOP = -15VDC
FULL SPEED = +15VDC
OSC OUTPUT
AMP
MOTOR ON = 0
Q1
MOTOR ON PULSE = 1
GO = 0
MOTOR ON = 1
FWD = 0
FWD = 1
REV = 0
REV = 1
K1 REVERSE
K2 REVERSE
OSC
+15 VDC
-15 VDC
VOLTAGE REGULATOR
+5VDC
+15
-15VDC


FOLDOUT FRAME 2
FOLDOUT FRAME 3
FOLDOUT FRAME 4
RR WHEEL TDEA (SHUNT A10)
RF WHEEL TDEA (SHUNT A9)
LR WHEEL TDEA (SHUNT A10)
LF WHEEL TRACTION DRIVE ELECTRONICS ASSY
ODOMETER LOGIC
PULSE DRIVERS
ONE SHOT
VOLTAGE REGULATOR
SPEEDPULSES
+36V BUS
+36V REVERSE
FWD
REVERSE
DIRECTION CHANGE ENABLE PULSE = 1
EMITTER DRIVE
DRIVE ENABLE
RR MCR
LR MCR
RF MCR
LF MOTOR CONTROL RELAYS
RR DMA
LR DMA
RF DMA
LF DRIVE MTR ASSY
REED SW
PERM MAGNET
FLUX CUTTERS ODOMETER
FREE WHEELING DIODE
RRCL
LRCL
RFCL
LF CURRENT LIMITER
±15 VOLT POWER SUPPLY
POWER/TEMPERATURE MONITOR
PWM SELECT
SEC THROTTLE FAIL SAFE CIRCUIT
PRI THROTTLE FAIL SAFE CIRCUIT
PRIMARY 15V ELECTRONICS
SECONDARY 15V ELECTRONICS
SECONDARY ±15V POWER
TO STEERING CONTROL REAR
FROM STEERING MOTOR REAR SWITC
FROM STEERING MOTOR FRONT SWITCH
TO STEERING CONTROL FRONT
NOTES:
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS
DRIVE CONTROL ELECTRONICS
LRV
4.8
PAGE 4-11
SHEET 1 OF 1

SECTION 5

CREW STATION

5.1 HARDWARE

The crew station hardware consists of seats, footrests, inboard handholds, outboard handholds, armrest, floor panels, seat belts, fenders, and toeholds (Drawing 5.1).

5.1.1 Seats

The two LRV seats are tubular aluminum frames spanned by nylon. The seats are folded flat onto the center chassis for launch and are erected by the crew after LRV deployment on the lunar surface. The seat back is used to support and restrain the portable life support system (PLSS) from lateral motion when the crew members are seated. The seat erection sequence is shown on Drawing 5.1. The seat bottom contains a cutout to allow the crew access to the PLSS flow control valves and includes vertical supports for the PLSS. A stowage bag is provided under each sheet.

5.1.2 Footrests

For launch, the footrests are stowed against the center chassis floor where they are held by a Velcro pad. The basic footrest is deployed by the crew on the lunar surface and is adjustable prelaunch to accommodate various size crewmen.

5.1.3 Inboard and Outboard Handholds

The inboard handholds are constructed of 1-inch o.d. aluminum tubing and are used to aid the crew in ingress of the LRV. These handholds also contain identical payload attach receptacles for the 16-mm data-acquisition camera and the lunar communications relay unit (LCRU) low-gain antenna.

The outboard handholds are integral parts of the chassis. These handholds are used to provide crew comfort and stability when seated on the LRV. They are also used for seatbelt attachment.

5.1.4 Armrest

The armrest is used to support the inboard arm of both crewmen when seated to prevent arm fatigue and to support the arm of the operator during hand controller operation.

5.1.5 Floor Panels

The floor panels in the crew station area are beaded aluminum panels. The floor is structurally capable of supporting the static full weight of standing astronauts.

5.1.6 Seatbelts

Nylon webbing seatbelts are provided for each seat. The belt end terminates in a hook which is used to attach and remove the belt to the outboard handhold. Length of the belt is adjusted by a buckle. A spring-loaded stretch section (2.5-inch stretch) in the belt eliminates the necessity of belt length adjustments while fastening or releasing the belt.

5.1.7 Fenders

The retractable portion of each fender is deployed by the astronaut during LRV activation on the lunar surface.

5.1.8 Outboard Toehold

The outboard toeholds are used to aid the crew in egressing the LRV in one-sixth gravity operations. Each toehold is formed by dismantling the left and right LRV/LM interface tripods. The leg previously pinned to the center chassis longitudinal member is used as the toehold. The tripod member is inserted into the chassis receptacle where it is secured with a ball pin to form the operational position of the toehold. It is also the tool used to decouple the wheel, to release the telescoping tubes and saddle fitting on the forward chassis, and to free the steering decoupling rings from the stowed position. Either toehold may be used as a tool.

5.2 CONTROL AND DISPLAY PANEL

The control and display panel (Drawing 5.2) is separated into two functional parts: navigation on the upper part of the panel and monitoring/controls on the lower part. The function of each device on the panel is explained below.

5.2.1 Navigation Displays

A. Attitude indicator - This instrument provides indications of LRV pitch and roll. It indicates PITCH upslope (U) or downslope (D) within a range of plus 25 to minus 25 degrees in five-degree increments. The damper on the side of the indicator can be moved to the right in order to damp out oscillations. To read roll angles, the indicator is rotated forward which exposes the ROLL scale to the left-side crewman. The ROLL scale is graduated in one-degree increments 25 degrees either side of zero.

B. Integrated position indicator (IPI) - The IPI consists of the heading compass card, range- and bearing-to-LM digital indicators, and a total-distance-traveled indicator. The indicators are described individually.

C. HEADING (M6) - This compass rose indicator displays the LRV heading with respect to lunar north. The initial setting and updating of the heading indicator is accomplished by operating the GYRO TORQUING switch LEFT or RIGHT. The indicator is calibrated in two-degree increments.

D. BEARING (M6) - This digital indicator displays bearing to the LM. This indicator reads in one-degree digits. In the event of power loss or undervoltage to the navigation system, the BEARING indication will remain intact. Restoration of normal power may cause loss on the indications.

E. DISTANCE (M6) - This digital indicator displays distance traveled by the LRV in increments of 0.1 km. This display is driven from the navigation signal processing unit which, in turn, receives its inputs from the third-fastest traction-drive odometer. Total digital scale capacity is 99.9 km. Power loss will freeze the reading but restoration of normal power may cause the indicator to assume random values.

F. RANGE (M6) - This digital indicator displays the distance to the LM and, like the BEARING display, will remain intact in the event of power failure with possible loss of information after restoration of power. Total digital scale capacity is 99.9 km, graduated on 0.1-km increments.

NOTE

Operation in reverse adds to the distance-traveled display and will bias the range and bearing values.

G. Sun shadow device - This device is used to determine the LRV heading with respect to the sun. The scale length is 15 degrees either side of zero with one-degree divisions. The sun shadow device can be utilized at sun angles up to 75° (zenith).

H. SPEED (M5) - This indicator shows LRV velocity from 0 to 20 km/hr. This display is driven from the odometer pulses from the right rear wheel, through the SPU.

NOTE

There is no speed indication when the NAV POWER circuit breaker is open or the right rear wheel is decoupled.

5.2.2 Navigation Switches and Circuit Breaker

A. GYRO TORQUING (S15) - This switch is used to slew the navigation gyro at the rate of 1.5°/sec to adjust the HEADING indication during navigation updates. Placing the switch in LEFT moves the HEADING scale clockwise. With the switch in RIGHT, the scale rotates counterclockwise. There is a 2-minute torquing limit with a 5-minute cooldown period afterwards. This allows 180° of gyro torquing per cycle.

B. NAV POWER (CB13) - This circuit breaker is used to route power from the main buses B and D to the navigation subsystem. The navigation and power distribution system is designed to provide power for the navigation system from either battery simultaneously to preclude power loss in the event of failure of one battery. With this circuit breaker in the open position, the SPU will not function, causing loss of speed indication and allowing no changes in the navigation displays. Restoring navigation power may cause the navigation displays to assume random readings.

C. SYSTEM RESET (S14) - This switch is used to reset the BEARING, DISTANCE, and RANGE digital displays to zero. This switch requires pulling the toggle out, then placing it in the operating position. This feature is designed to prevent inadvertant actuation of the switch.

5.2.3 Power Section Circuit Breakers and Switch

A. AUX (CB14) - This circuit breaker is used to route power to the auxiliary connector at the forward end of the LRV. This circuit breaker receives input power from both batteries via buses A and C.

B. BAT 1 BUS A (CB1) - This circuit breaker is used to energize bus A with power from battery 1.

C. BAT 1 BUS B (CB3) - This circuit breaker is used to energize bus B with power from battery 1.

D. BAT 2 BUS C (CB2) - This circuit breaker is used to energize bus C with power from battery 2.

E. BAT 2 BUS D (CB4) - This circuit breaker is used to energize bus D with power from battery 2.

F. ±15 DC PRIM/OFF/SEC switch (S11) - This switch is used to route 36 Vdc power from buses B and D to the ±15 DC PRIM (CB11) or ±15 DC SEC (CB12) circuit breakers.

G. ±15 DC PRIM (CB11) - This circuit breaker is used to route 36 Vdc power from the ±15 DC PRIM/OFF/SEC switch to the input of the primary ±15 volt dc power supply.

H. ±15 DC SEC (CB12) - This circuit breaker is used to route 36 Vdc power from the ±15 DC PRIM/OFF/SEC switch to the input of the secondary ±15 volt dc power supply.

5.2.4 Power/Temperature Monitor Switches and Meters

A. AMP-HR meter (M1) - This double-scale indicator is used to monitor remaining battery capacity in battery 1 and battery 2. At full charge, both the "1" and "2" reading should be 121 amp-hrs. These readings are not redundant.

B. VOLTS AMPS meter (M2) - This double-scale indicator is used to monitor the voltage or current being supplied from battery 1 and battery 2. Selection of which parameter (volts or amps) to monitor is controlled by the BATTERY SELECT switch. In order to use the same scale for accurate current and voltage, the scale is graduated from zero to 100. When the VOLTS X 1/2 position of the BATTERY SELECT switch is selected, the meter indication will be twice the value of the actual battery voltage (i.e., the indicator will read 72 for a voltage of 36 Vdc at the battery). The allowable excursion of battery voltages, 66 to 82 (2X volts), is bracketed on the scale.

C. MOTOR TEMP SELECT (S13) - This switch is used to select the FORWARD or REAR drive motor temperature sensors to be monitored on the MOTOR °F indicator.

D. BATTERY SELECT (S12) - This switch is used to select either voltage or current of each battery on the VOLTS AMPS indicator.

E. BATTERY °F meter (M3) - This double-scale indicator is used to monitor the internal temperature of each battery. The allowable battery temperatures are bracketed on the meter.

F. MOTOR °F meter (M4) - This double-scale indicator is used to monitor the temperature of each drive motor. Either the front or rear wheels are monitored at any particular time. Both left and right wheels of either the front or rear set are monitored concurrently. Selection of which set of wheels to monitor is made by placing the MOTOR TEMP SELECT switch to either FORWARD or REAR position. The allowable motor temperatures are bracketed on the meter.

G. PWM SELECT (S16) - This switch is used to energize pulse width modulators in the motor controller. With the switch in the BOTH position, PWM 1 and PWM 2 are both energized, and selection of either PWM 1 or PWM 2 can be made for control of any of the four drive motors. Placing the switch in the "1" position inhibits power from energizing PWM 2 and all the DRIVE ENABLE switches must be placed in the PWM 1 position to achieve motor control. Similarly, if the "2" position is selected, power to PWM 1 will be inhibited and all DRIVE ENABLE switches must be placed in the PWM 2 position to control the drive motors. If this switch is placed in PWM 1 or PWM 2 position with the corresponding DRIVE ENABLE switches in an opposite position, those traction drives which are so set will have full on drive power applied to them. This condition may be intentionally introduced as a contingency means of controlling the vehicle. It is known as the "jackrabbit" mode.

5.2.5 Steering Switches and Circuit Breakers

A. FORWARD steering switch (S9) - This switch is used to select either bus A or bus C to supply power to the forward steering motor. Power is routed from bus A or bus C through this switch to the input side of the FORWARD steering motor circuit breaker (CB9).

B. FORWARD steering circuit breaker (CB9) - This circuit breaker is used to protect the forward steering motor. Electrical power is routed from bus A or bus C through the FORWARD steering switch (S9) to the input side of the FORWARD steering circuit breaker. With the circuit breaker closed, power is then routed directly to the steering motor armature and to the DCE power supply where it energizes a relay routing ±15 dc power to the forward steering electronics.

C. REAR steering switch (S10) - This switch is used to select either bus B or bus D to supply power to the rear steering motor. Power is routed from bus B or bus D through this switch to the input side of the REAR steering motor circuit breaker (CB10).

D. REAR steering circuit breaker (CB10) - This circuit breaker is used for the rear steering motor in the same manner as described for the FORWARD steering circuit breaker.

5.2.6 Drive Power Switches and Circuit Breakers

A. LF (CB5), LR (CB7), RF (CB6), and RR (CB8) circuit breakers - These circuit breakers are used to protect the four drive motors from overload damage. The right rear (RR) and left rear (LR) circuit breakers receive power from bus B or bus D, depending on the drive power switches. The right front (RF) and left front (LF) circuit breakers receive power from bus A or C, depending on the setting of the drive power switches.

B. LF (S5), LR (S7), RF (S6), and RR (S8) switches - These switches are used to select the appropriate bus to supply power to a specific drive motor. The left front (LF) and right front (RF) drive motors are powered from bus A when the LF and RF switches are in the BUS A position. With the switches in the BUS C position, the left front and right front motors are supplied power from bus C. In the OFF position, the switch prevents power from reaching the drive power circuit breakers. The rear drive motors are similarly powered by selecting the BUS B, BUS D, or OFF positions of the switches. These switches also energize a relay in the DCE which applies ±15 Vdc power to the selected electronics.

5.2.7 Drive Enable Switches

LF (S1), LR (S3), RF (S2), and RR (S4) switches - These switches are used to select either pulse width modulator 1 or 2 for control of a specific drive motor. With any switch in the PWM 1 position, pulse width modulator 1 will be used to control the drive motor of the appropriate switch (i.e., left rear, right rear, left front, or right front). In the OFF position, full drive power is continuously applied to the applicable drive motor. Thus, the "OFF" position should only be used during contingency modes of operation. These switches have guards placed around them. This is a second method of configuring the contingency "jackrabbit" mode (see Paragraph 5.2.4.G).

5.2.8 Caution and Warning System

The caution and warning system is shown schematically as an entity in Drawing 5.3. The normally open temperature switches in the batteries and drive motors close on increasing temperatures. When either battery reaches 125 ± 5° F or any drive motor reaches 400 ± 12° F, the temperature switch closes, energizing the OR logic element and the driver. The driver then sends a 10-millisecond, 36-V pulse to the coil of the electromagnet which releases the magnetic hold on the indicator at the top of the console and a spring-loaded flag flips up. The astronaut resets the flag by pushing it down.

5.3 HAND CONTROLER

The hand controller (Drawing 5.4) provides the steering, speed, and braking commands. Forward movement of the hand controller about the palm pivot point proportionally increases forward speed. Right and left movements provide inputs to the two steering motors allowing directional control. Moving the reverse inhibit switch down and moving the hand controller 14° rearward past the neutral palm pivot point provides reverse power. Bringing the controller rearward about its lower pivot point inititates braking. The parking brake is engaged by moving the controller fully rearward. To release the parking brake, move the hand controller to a steer left position. (In event of malfunction of the brake release, the contingency parking brake release ring, shown in Drawing 5.4, can be pulled to release the brake.)

It is possible for either forward or reverse power to be applied while braking since the hand controller must be moved through about 50 percent of its brake travel before the drive power inhibit logic is energized.

TABLE 5-I.- CIRCUIT BREAKER TRIP LEVELS

CB	Nom amp	Maximum trip current (trip 1 hr)				Minimum trip current (no trip 1 hr)				Time in sec (min-max) no preload current @77°F % of nominal current	
		0°F	+77°F	+180°F	+180°F @10^{-4}mm Hg	0°F	+77°F	+180°F	+180°F @10^{-4}mm Hg	200%	400%
CB1 CB2 CB3 CB4	70	105.0	101.5	80.0	77.0	84.0	73.5	59.0	45.9	15-70 sec	2-10 sec
CB5 CB6 CB7 CB8	25	40.0	37.5	31.5	27.0	36.3	28.75	17.5	15.0	15-40 sec	3-7 sec
CB9 CB10 CB11 CB12 CB13	5	8.75	7.5	5.0	4.7	7.4	5.75	3.0	2.5	15-40 sec	1.5-4 sec
CB14	7.5	12.38	11.2	7.5	7.12	11.1	8.63	4.5	3.8	15-40 sec	1.5-4 sec

TABLE 5-II.- METER DATA - NAVIGATION DISPLAYS

Data displayed	System 3σ accuracy	Display range	Display resolution
Heading[a]	±6°	0 to 360°	1 degree
Bearing to LM[a]	±6°	0 to 360°	1 degree
Range to LM	600 m at 5 km	0 to 30 km	0.1 km
Total distance traveled	2%	0 to 99 km	0.1 km
Velocity	1.5 km/hr	0 to 20 km/hr	1 km/hr
Sun angle	±2°	±15°	1°
Attitude			
Pitch	±3°	±25°	5°
Roll	±2°	±25°	1°
Fixed compensation 0.245 meters/pulse Attitude to ±45° Latitude to ±45°		Longitude - All Steering rates 50°/sec maximum	

[a]Ref to lunar north

TABLE 5-III.- METER DATA - ENGINEERING PARAMETERS

Meter	Units of measurement	Display range	Display resolution	Meter accuracy[b]
Amp-hour meter	Amp-hours	-15 to +120 A-h	10 A-h	2.8% full scale
Volts-amps meter	Volts:	0 to 100 V (divided by 2)	10 V (divided by 2)	2.8% full scale
	Amps:	0 to 100 A	10 A	2.8% full scale
Battery temp meter	Degrees Fahrenheit	0 to 180° F	20° F	2.8% full scale
Drive motor temp meter	Degrees Fahrenheit	200 to 500° F	50° F	2.8% full scale

[b]Meter accuracy is for meter only, not electronics.

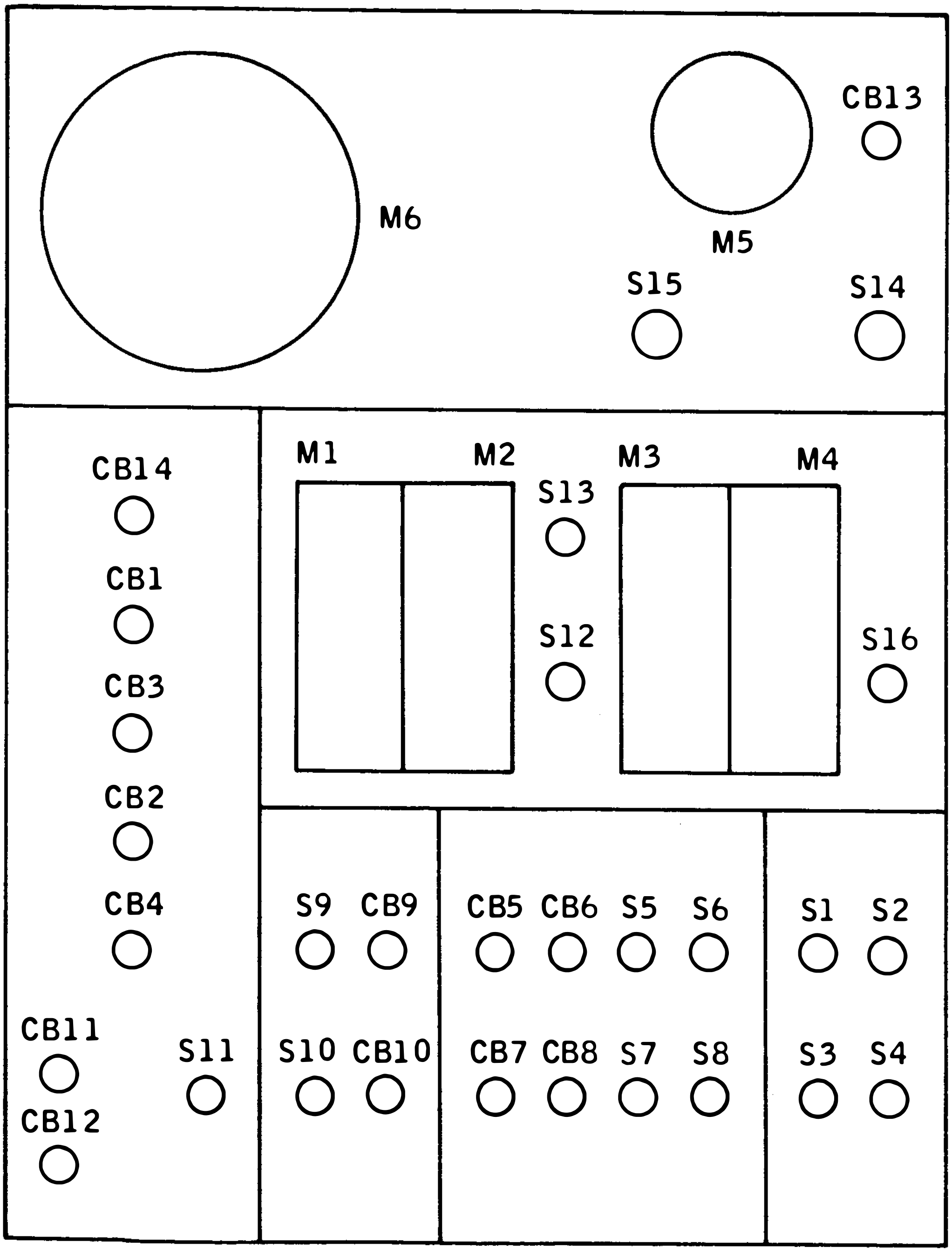
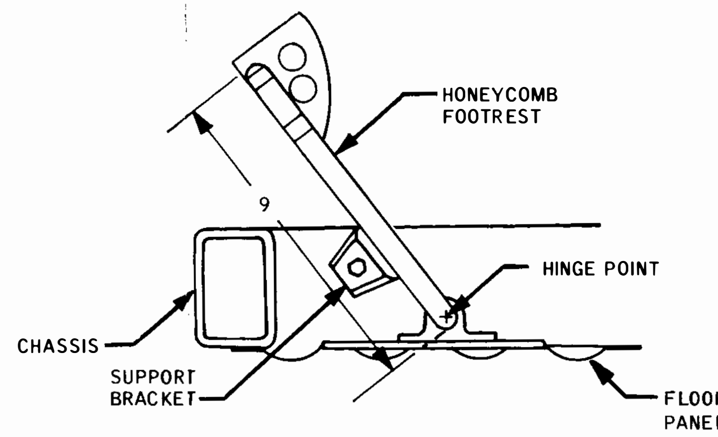


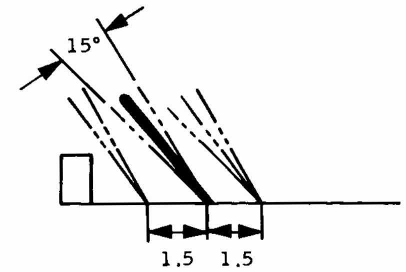
Figure 5-1. - Meter, switch, and circuit breaker numbering.

H G F E

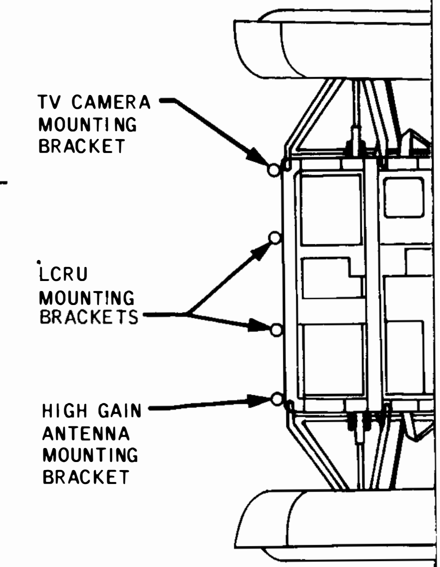
FOLDOUT FRAME 1

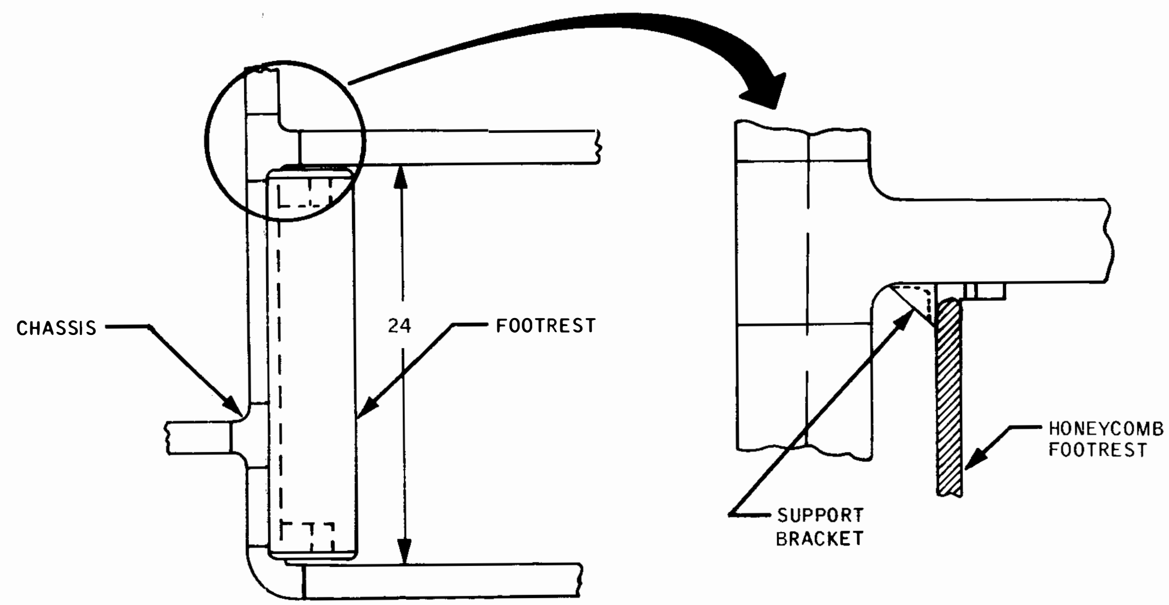


SIDE VIEW



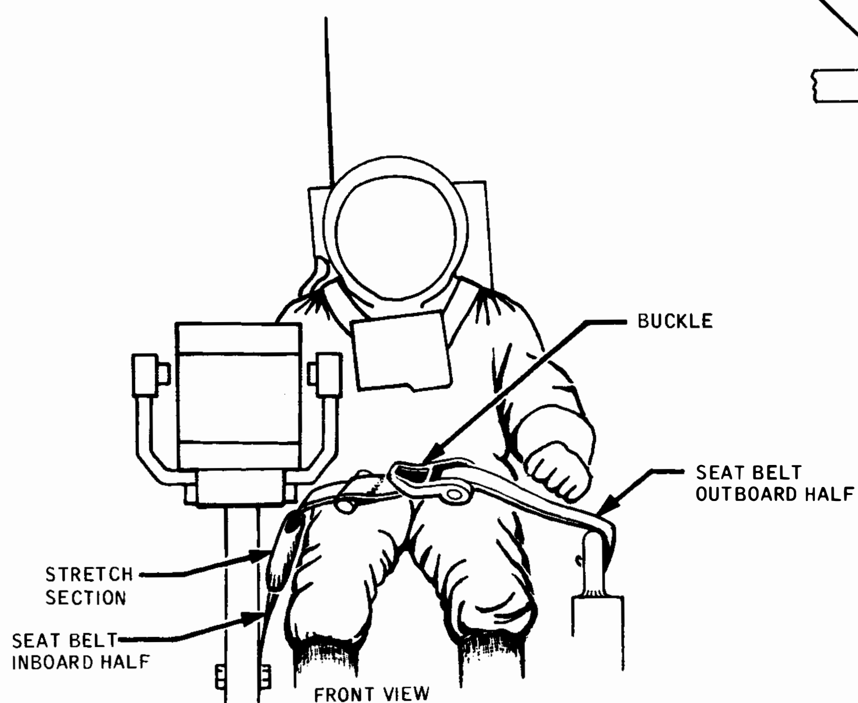
FOOTREST ADJUSTABILITY RANGE





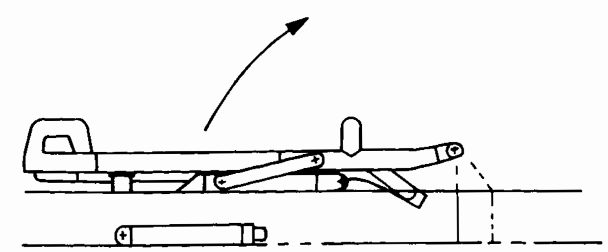
PLAN VIEW

FOOTREST DETAIL

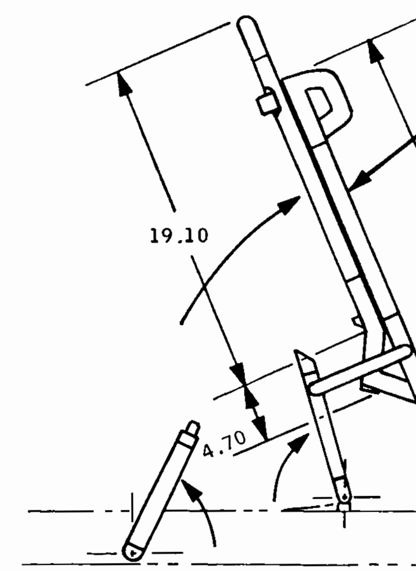


FRONT VIEW

SEAT BELT DETAIL



STEP 1

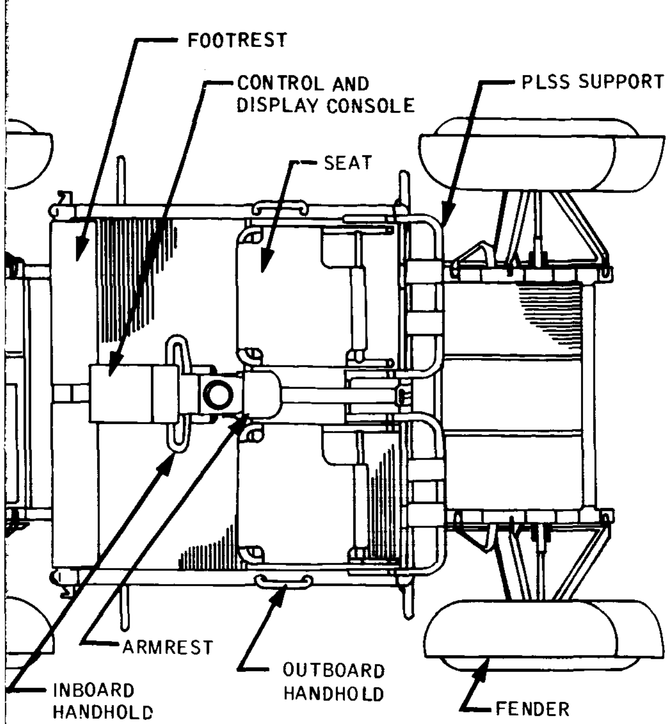


STEP 2

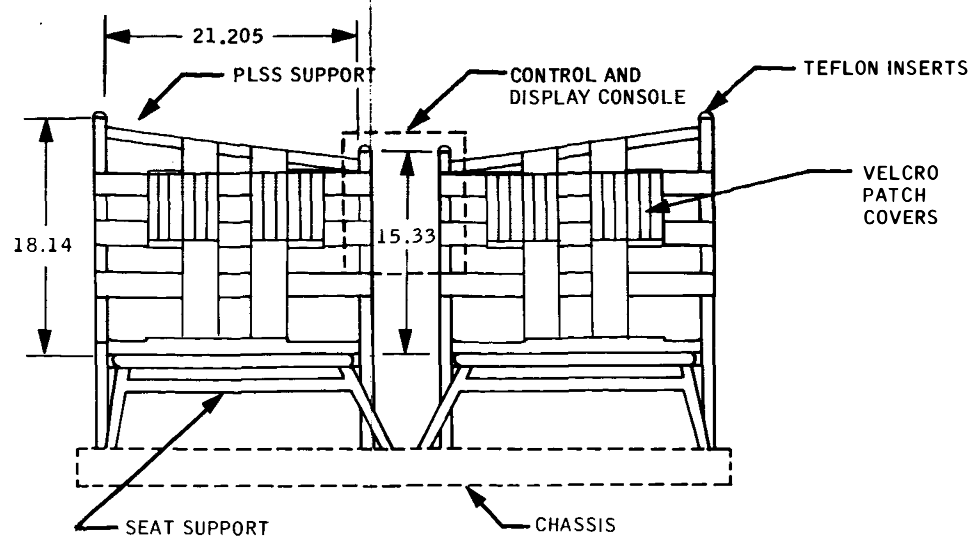
FOLDOUT FRAME 2

LTR	PCN	DR	ENG	DATE		APPROVAL
A		RHB	T C Newton	6/22/71	6/22/71	G. D. Griffith

COMMENTS:

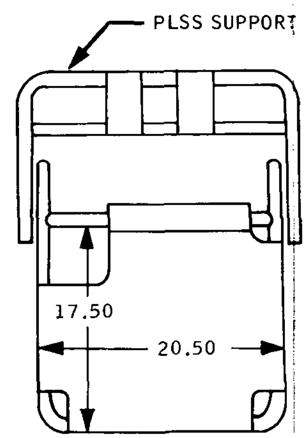


LRV PLAN VIEW



SEAT DETAIL - FRONT VIEW

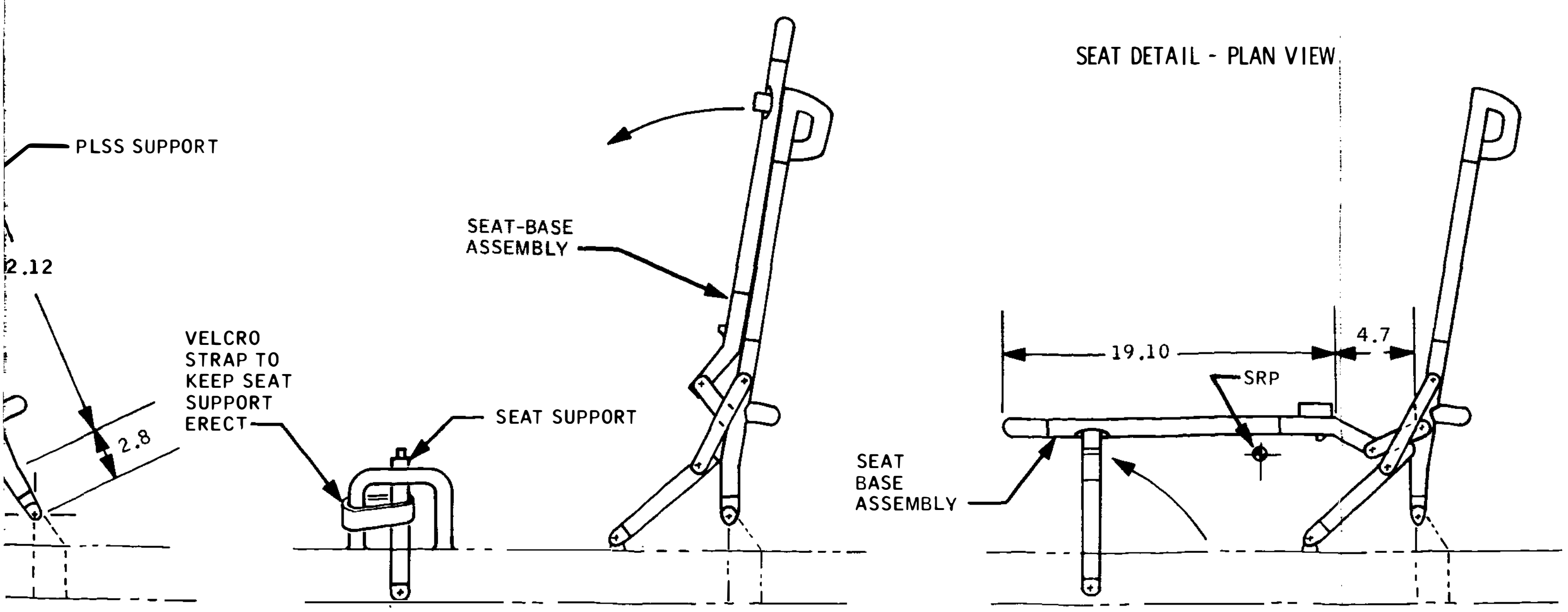
FOLDOUT FRAME 3



SEAT DETAIL - PLAN VIEW

2. STOWAGE BAGS ARE LOCATED BENEATH BOTH SEATS AND CONNECTED TO THE SEAT SUPPORT AND PLSS SUPPORT CHASSIS MOUNTS

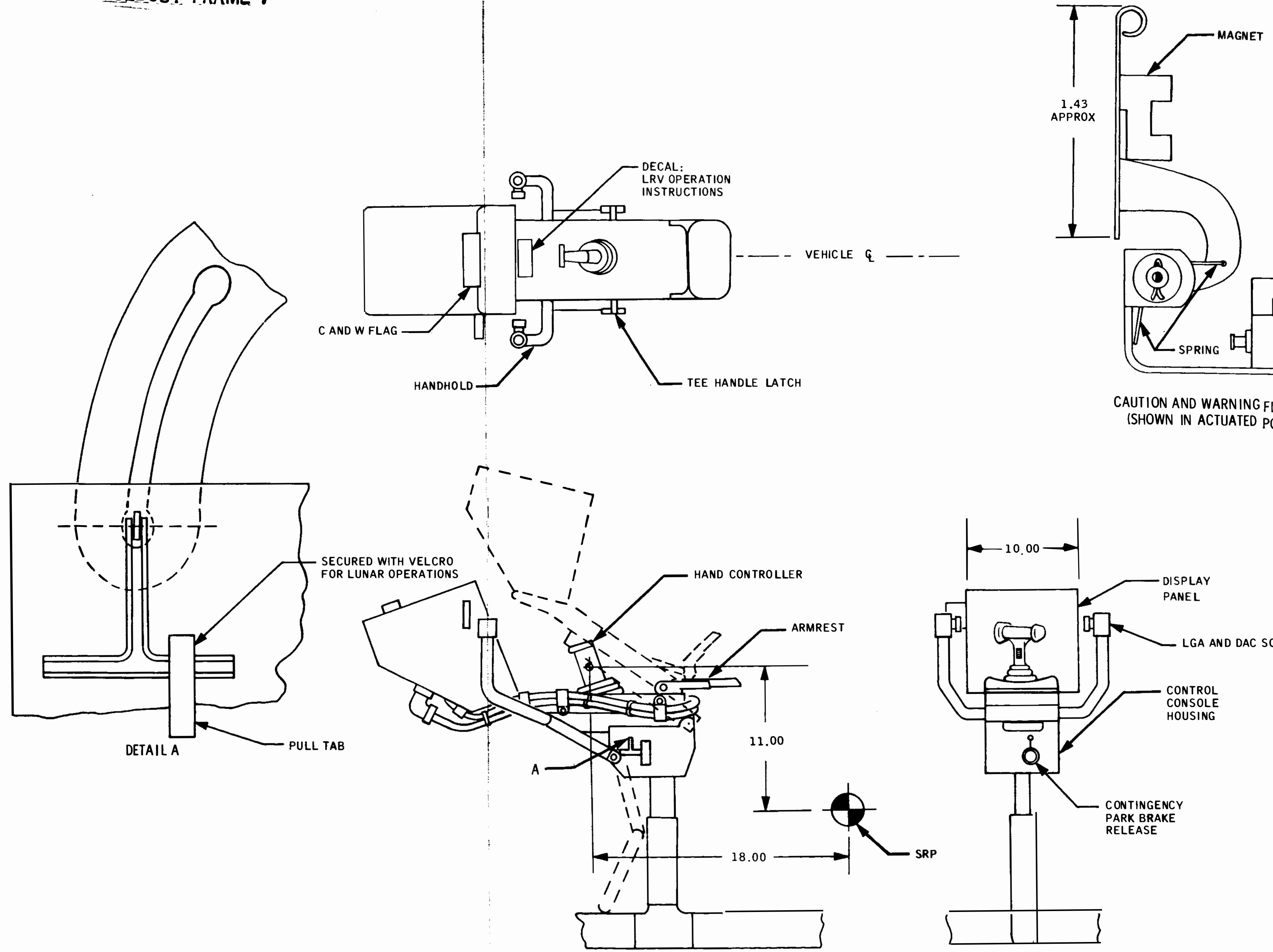
NOTES: 1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE INDICATED



SEAT ERECTION SEQUENCE

SIGNATURES	DATE	
DR L. Stewart	6/10/70	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER · HOUSTON, TEXAS
DSGN Bill S. Cornelius	3-30-71	CREW STATION HARDWARE
QC Betty M. Taylor	3-30-71	
ENGR John H. Cooper	3-29-71	
APP Gerald D. Griffith	3-29-71	
FEC Dean B. Kuhn	5-30-71	LRV — DWG NO 5.1
AUTH		44 X 17 — PAGE 5-10 — SHEET 1 OF 1

FOLDOUT FRAME 1



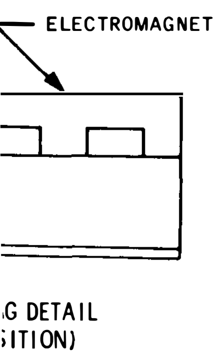
CONTROL AND DISPLAY CONSOLE - MECHANICAL

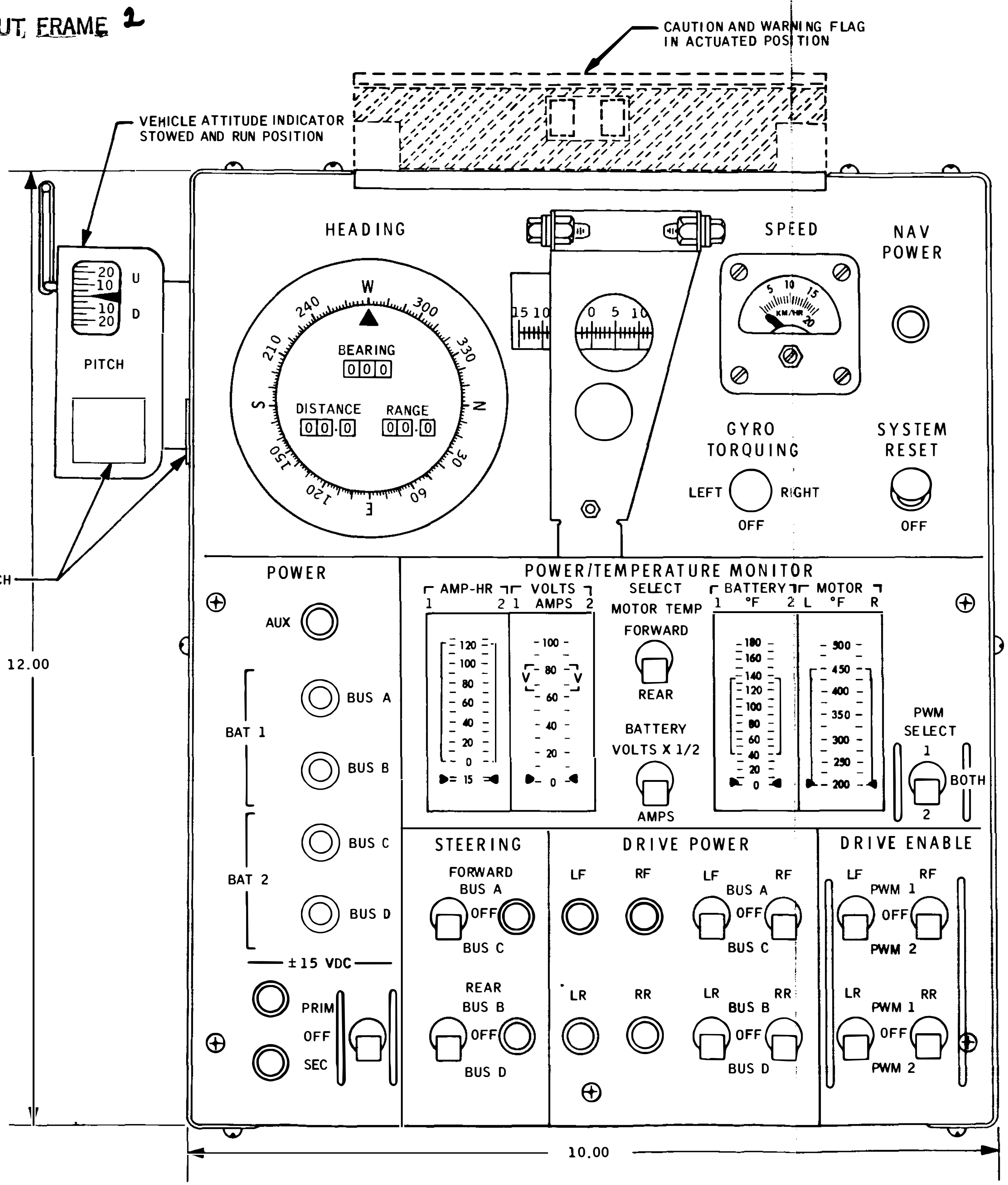
FOLDOUT FRAME 2

FOLDOUT FRAME 3

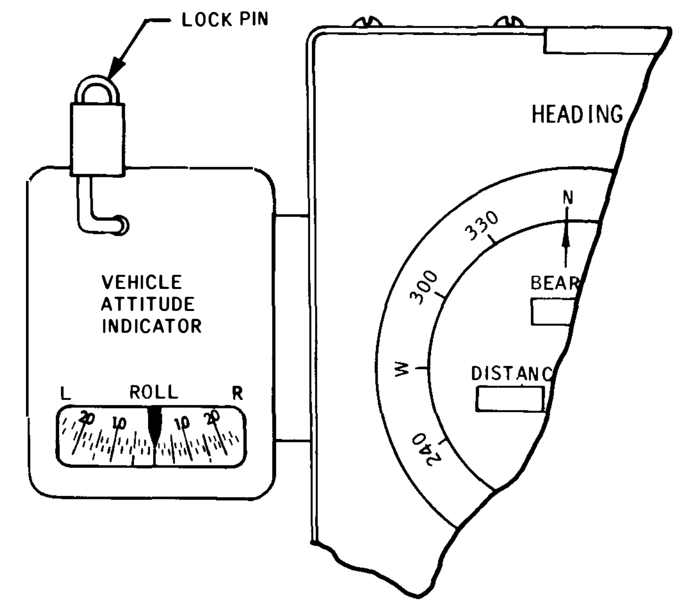
LTR	PCN	DR	ENG	DATE		APPROVAL
A		R.B.	[signature]	6/22/71	6/23/71	[signature]

COMMENTS:





CONTROL AND DISPLAY PANEL



VEHICLE ATTITUDE INDICATOR NAV UPDATE POSITION

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
2. C AND W FLAG LOCKING PIN AND ATTITUDE INDICATOR LOCKING PIN NOT SHOWN.
3. SSD SHOWN IN STORED POSITION ONLY.

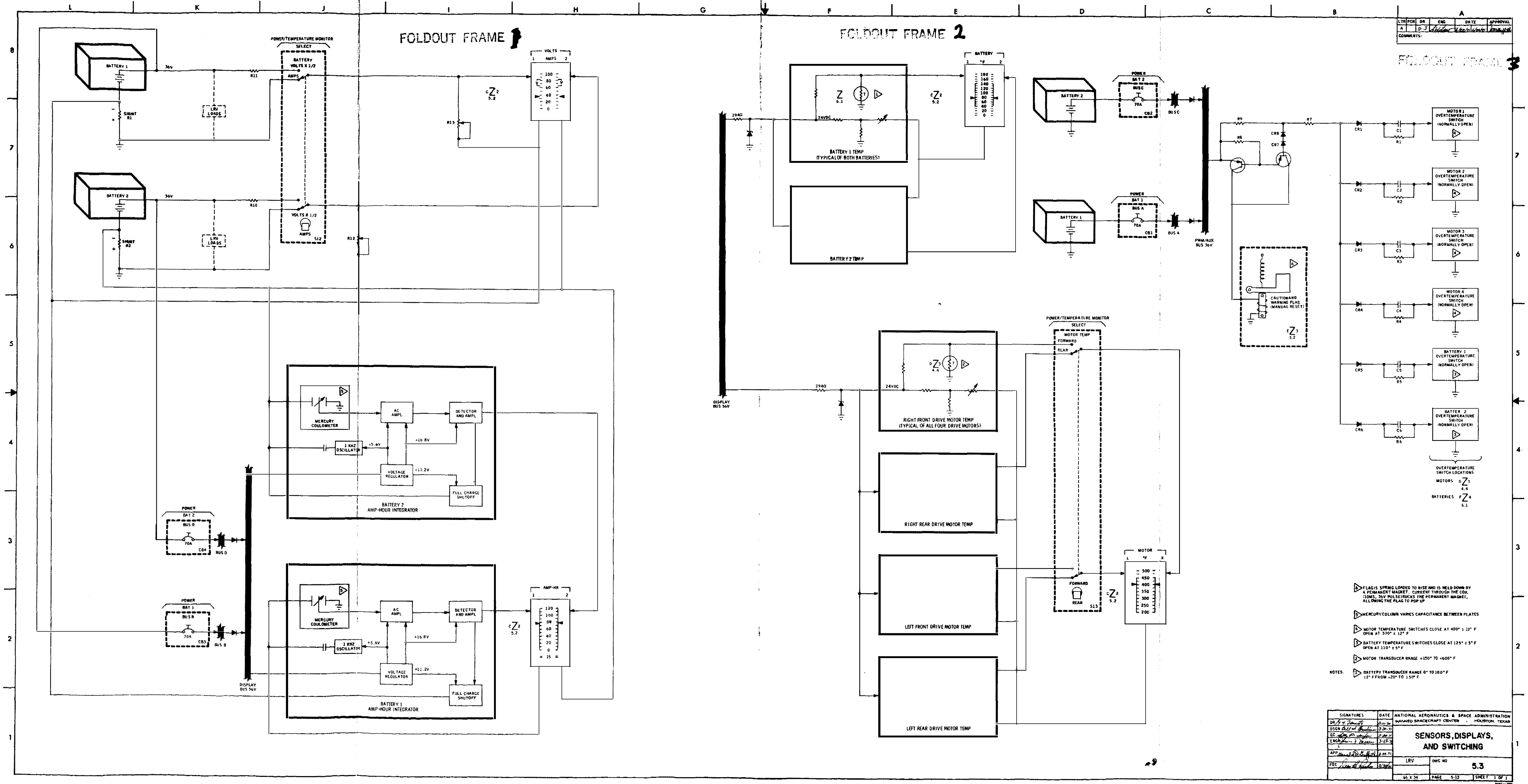
SIGNATURES	DATE
DR [signature]	8/13/70
DSGN Bill S. [signature]	3-30-71
QC [signature]	3-30-71
ENGR John H. Cooper	3-29-71
APP Gerald D. Griffith	3-29-71
FEC [signature]	3-30-71
AUTH	

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

CONTROL AND DISPLAY CONSOLE

LRV | SIZE | DWG NO 5.2

44 X 17 | PAGE 5-11 | SHEET OF


FOLDOUT FRAME 1
FOLDOUT FRAME 2
FOLDOUT FRAME 3
POWER/TEMPERATURE MONITOR
SELECT
BATTERY VOLTS X 1/2
AMPS
VOLTS X 1/2
S12
BATTERY 1
BATTERY 2
SHUNT R1
SHUNT R2
36V
R11
R10
R12
R13
LRV LOADS
VOLTS
AMPS
MERCURY COULOMETER
AC AMPL
DETECTOR AND AMPL
1 KHZ OSCILLATOR
VOLTAGE REGULATOR
FULL CHARGE SHUTOFF
+16.8V
+5.6V
+11.2V
BATTERY 2 AMP-HOUR INTEGRATOR
BATTERY 1 AMP-HOUR INTEGRATOR
POWER
BAT 2
BUS D
70A
CB4
BAT 1
BUS B
CB3
DISPLAY BUS 36V
AMP-HR
BATTERY
°F
BATTERY 1 TEMP (TYPICAL OF BOTH BATTERIES)
BATTERY 2 TEMP
24VDC
294Ω
BUS C
CB2
BUS A
CB1
PWM/AUX BUS 36V
R9
R8
R7
CR8
CR7
CAUTION AND WARNING FLAG (MANUAL RESET)
MOTOR 1 OVERTEMPERATURE SWITCH (NORMALLY OPEN)
MOTOR 2 OVERTEMPERATURE SWITCH (NORMALLY OPEN)
MOTOR 3 OVERTEMPERATURE SWITCH (NORMALLY OPEN)
MOTOR 4 OVERTEMPERATURE SWITCH (NORMALLY OPEN)
BATTERY 1 OVERTEMPERATURE SWITCH (NORMALLY OPEN)
BATTER 2 OVERTEMPERATURE SWITCH (NORMALLY OPEN)
OVERTEMPERATURE SWITCH LOCATIONS
MOTORS
BATTERIES
MOTOR TEMP
FORWARD
REAR
S13
RIGHT FRONT DRIVE MOTOR TEMP (TYPICAL OF ALL FOUR DRIVE MOTORS)
RIGHT REAR DRIVE MOTOR TEMP
LEFT FRONT DRIVE MOTOR TEMP
LEFT REAR DRIVE MOTOR TEMP
MOTOR
6 FLAG IS SPRING LOADED TO RISE AND IS HELD DOWN BY A PERMANENT MAGNET. CURRENT THROUGH THE COIL (10MS, 36V PULSE) BUCKS THE PERMANENT MAGNET, ALLOWING THE FLAG TO POP UP
5 MERCURY COLUMN VARIES CAPACITANCE BETWEEN PLATES
4 MOTOR TEMPERATURE SWITCHES CLOSE AT 400° ± 12° F OPEN AT 370° ± 12° F
3 BATTERY TEMPERATURE SWITCHES CLOSE AT 125° ± 5° F OPEN AT 110° ± 5° F
2 MOTOR TRANSDUCER RANGE +150° TO +600° F
NOTES: 1 BATTERY TRANSDUCER RANGE 0° TO 180° F ±2° F FROM +20° TO 150° F
SIGNATURES
DATE
DR
DSGN
QC
ENGR
APP
FEC
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS
SENSORS, DISPLAYS, AND SWITCHING
LRV
DWG NO
5.3
66 X 34
PAGE 5-12
SHEET 1 OF 1

P | O | N | M | L | K

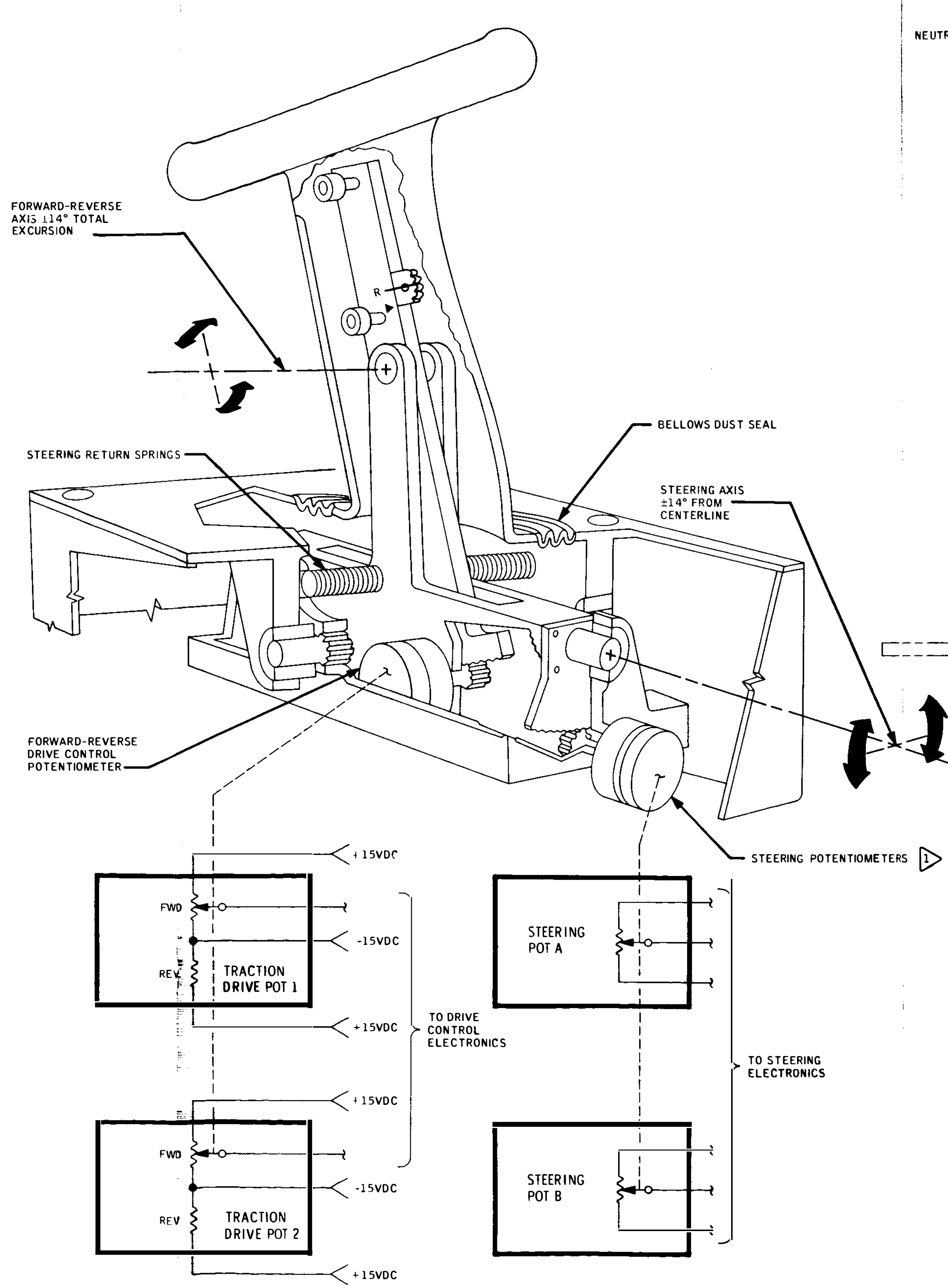
FOLDOUT FRAME 1

4

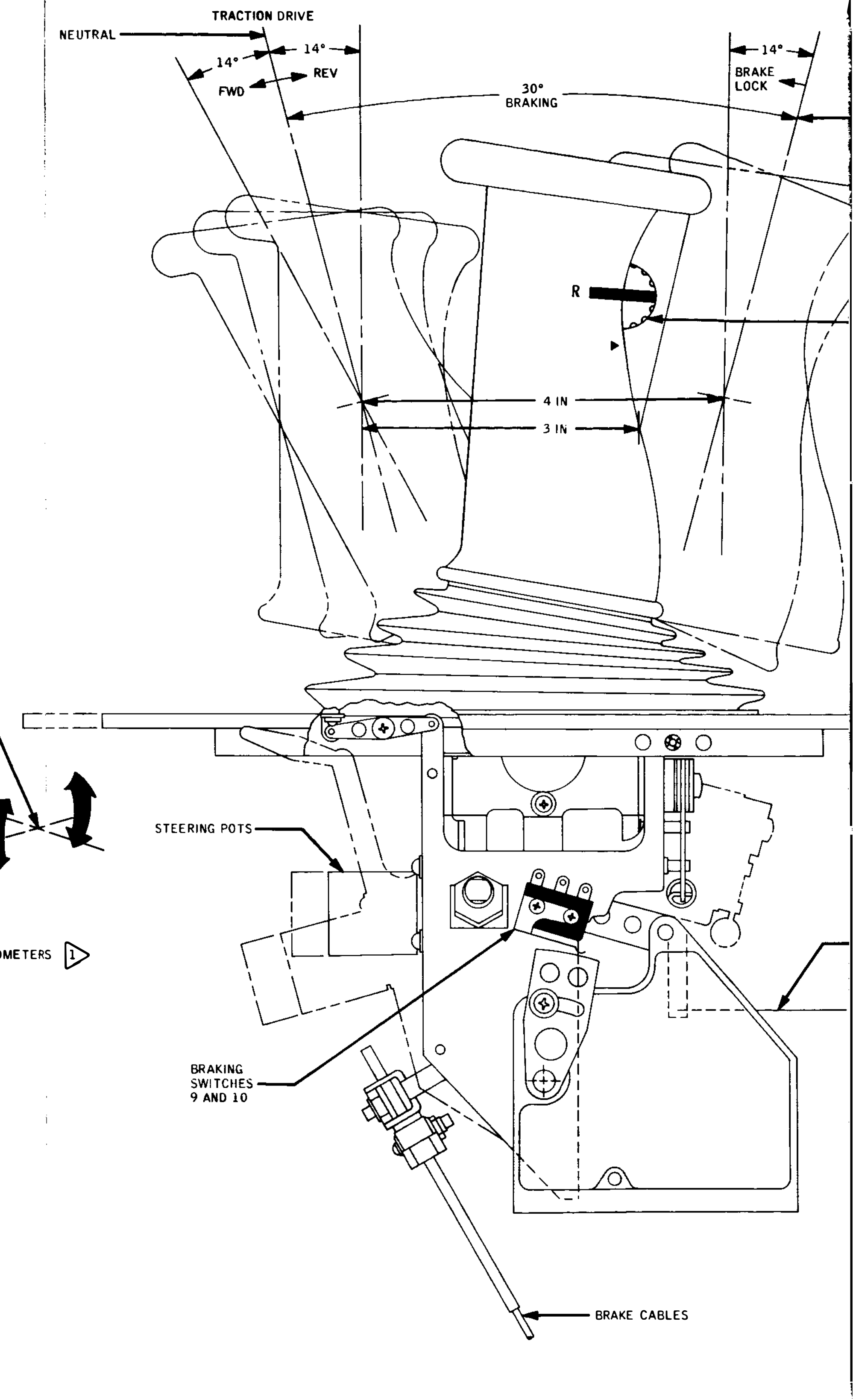
3

2

1

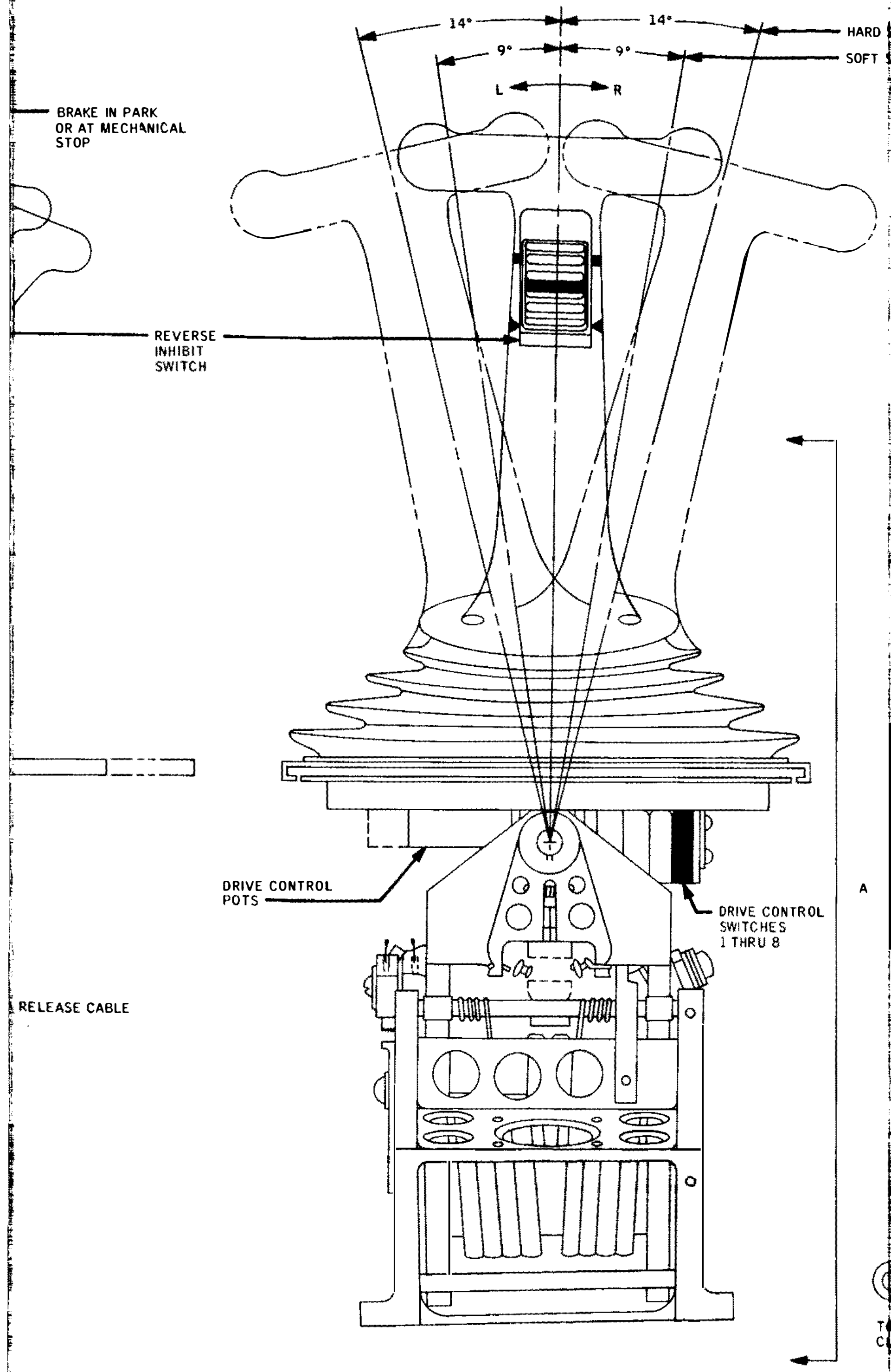


HAND CONTROLLER



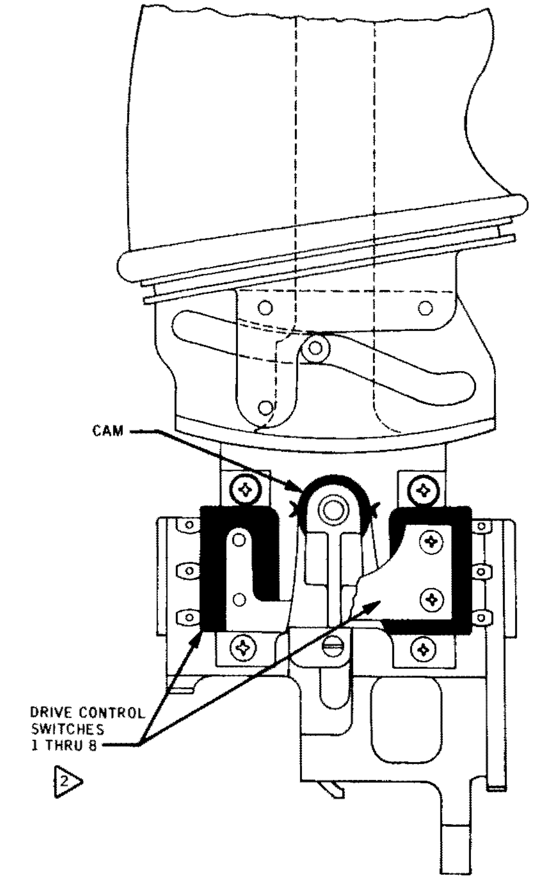
HAND CONTROLLER TRACTION DRIVE AND BRAKING

FOLDOUT FRAME 2

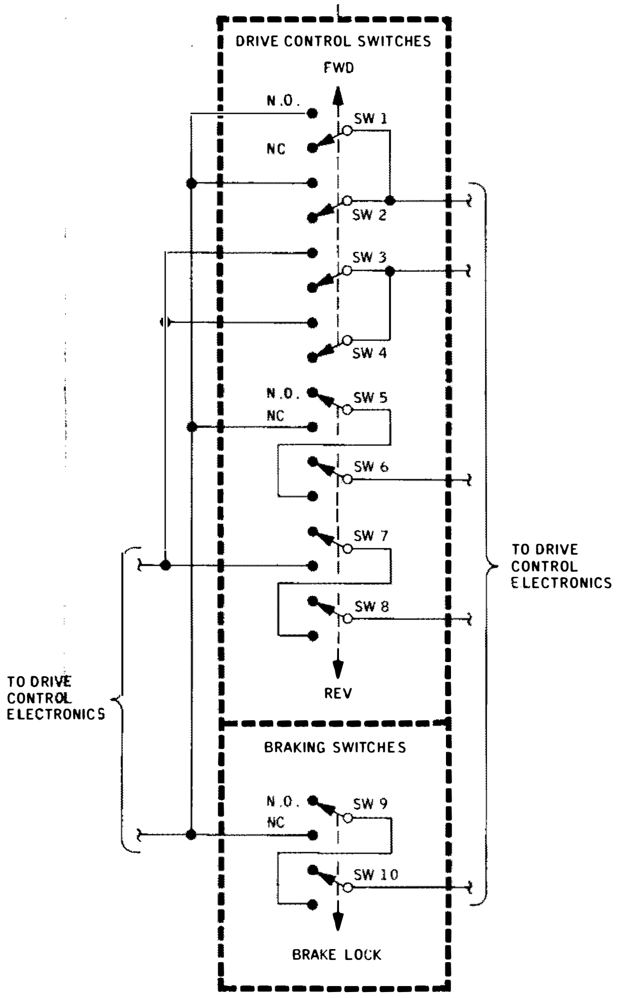


HAND CONTROLLER
STEERING

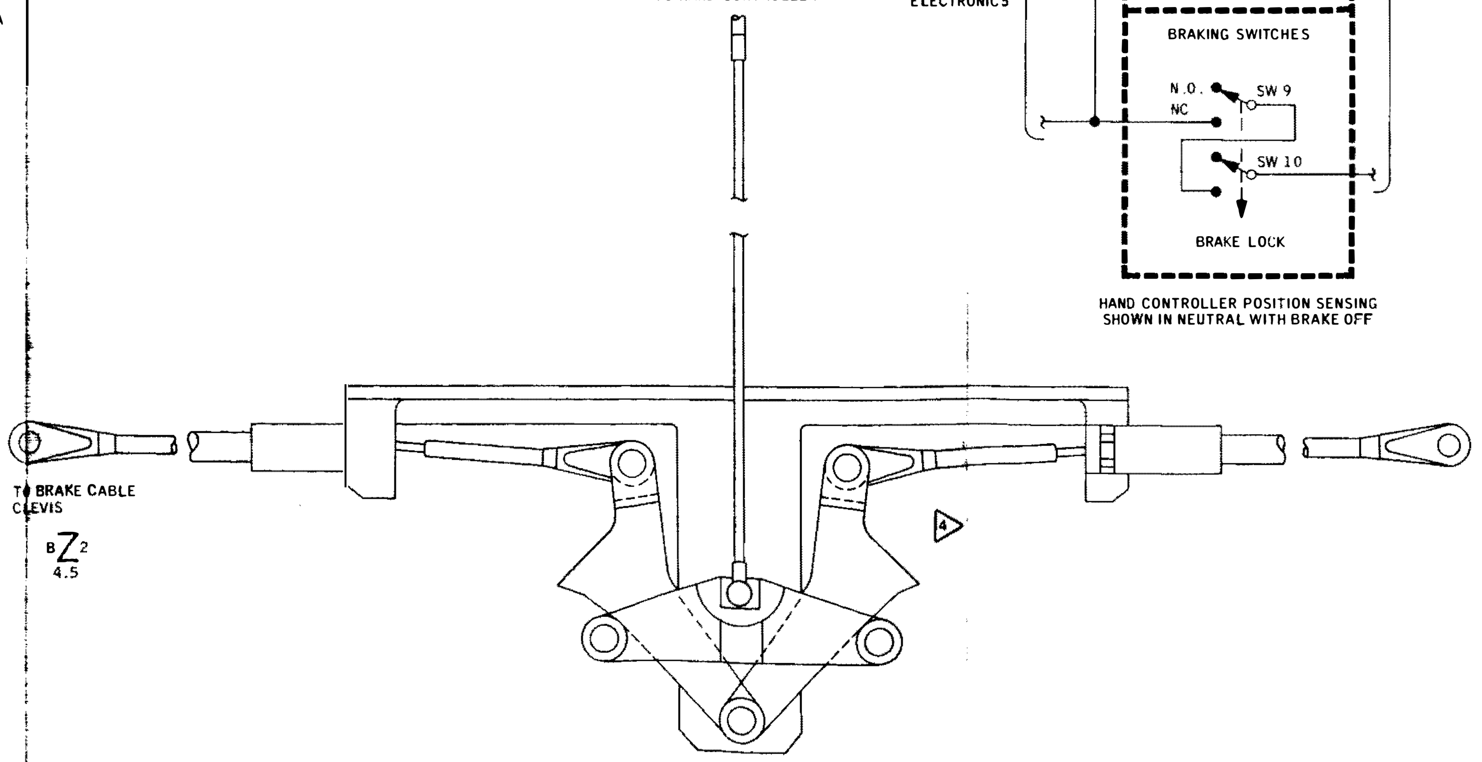
FOLDOUT FRAME 3



VIEW A



HAND CONTROLLER POSITION SENSING
SHOWN IN NEUTRAL WITH BRAKE OFF



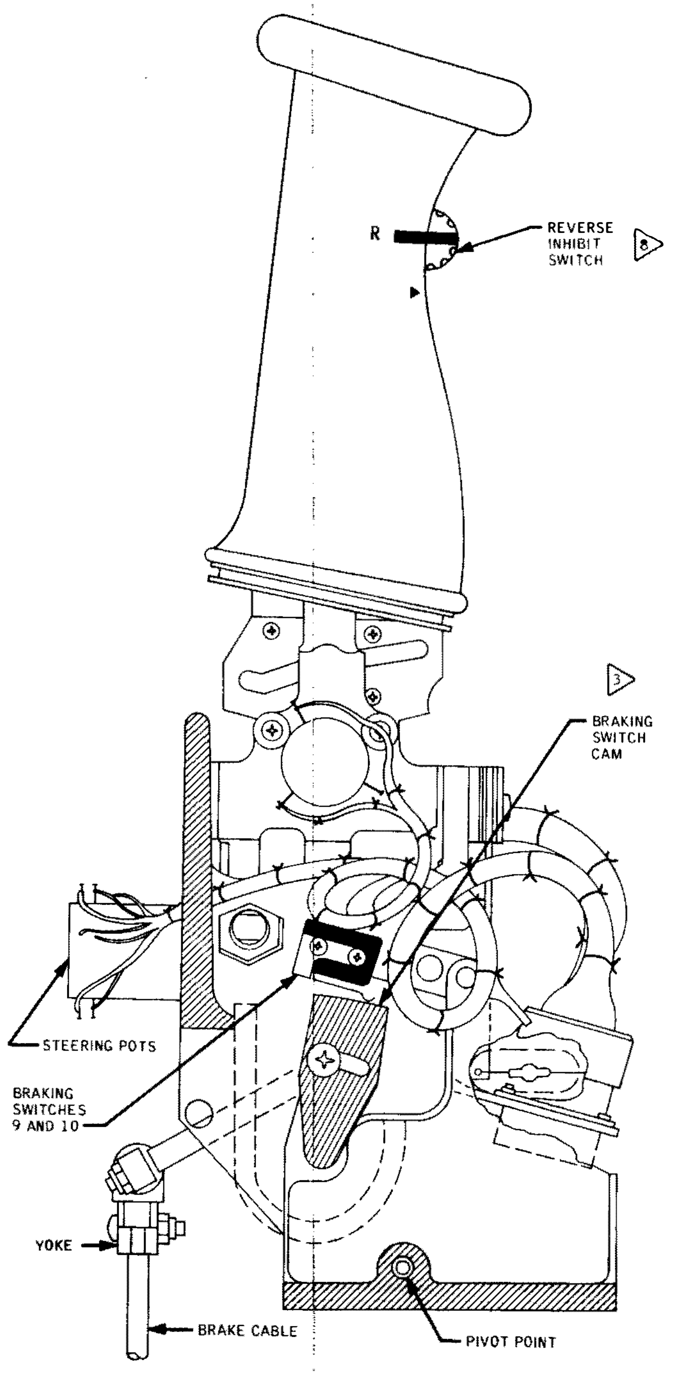
B Z 2
4.5

BRAKE CABLE LAYOUT (TYPICAL FRONT AND REAR)

FOLDOUT FRAME 4

LTR	PCN	DR	ENG	DATE		APPROVAL
A				6/22/71		

COMMENTS:



8 REVERSE INHIBIT SWITCH:
DOWN - INHIBITS REARWARD MOVEMENT PAST NEUTRAL OF THE PALM PIVOT BY MECHANICAL BLOCKING
UP - ALLOWS FREE MOVEMENT ABOUT PALM PIVOT

7. TO ENGAGE REVERSE POWER AFTER BRAKING, HAND CONTROLLER MUST BE RETURNED TO NEUTRAL, THEN REVERSE

6. PARKING BRAKE IS SET BY PIVOTING HAND CONTROLLER FULLY REARWARD. IT IS RELEASED BY STEERING LEFT

5. HAND CONTROLLER WILL REMAIN IN THE SELECTED FORWARD OR REVERSE POSITION AND MUST BE MANUALLY RETURNED TO NEUTRAL DRIVE POSITION

4 BRAKE EQUALIZER HAS STOP TO ALLOW FOR CABLE FAILURE BRAKING

3 HAND CONTROLLER, INCLUDING THE BRAKING SWITCHES, MOVES WITH RESPECT TO THE STRIPED FRAMES. SWITCH CAM FOLLOWER RIDES OFF THE CAM ALLOWING SWITCH TO OPEN

2 SWITCHES 1 THROUGH 8 ARE DRIVE CONTROL SWITCHES. SWITCHES ARE SHOWN IN OPEN (NEUTRAL STICK) POSITION. SWITCHES ARE CLOSED BY CAM ACTION WHEN STICK IS MOVED FORWARD OR AFT 1 DEGREE ± 0.5 DEGREES

NOTES: 1 STEERING POTS LOCATED FORWARD OF HAND CONTROLLER AND OPERATE FUNCTIONALLY AS SHOWN

SIGNATURES	DATE
DR Linda J Braulee	12-17-70
DSGN Bill J. Cornelius	3-30-71
QC	3-30-71
ENGR James F Moser	3-29-71
APP Gerald D Griffith	3-29-71
FEC	3/30/71

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

BRAKE CABLE LAYOUT AND HAND CONTROLLER MECH/ELEC

LRV | DWG NO 5.4

68 X 22 | PAGE 5-13 | SHEET 1 OF 1

SECTION 6
ELECTRICAL POWER

6.1 GENERAL

The electrical power subsystem consists of two batteries and distribution wiring, connectors, switches, circuit breakers, and meters for controlling and monitoring electrical power.

6.2 BATTERIES

The LRV contains two primary silver-zinc batteries (Drawing 6.1). Both batteries are used simultaneously on an approximate-equal-load basis during LRV operation by selection of various load-to-bus combinations through circuit breakers and switches on the control display console.

The batteries are located on the forward chassis enclosed by the thermal blanket and dust covers. Battery 1 (on the left side facing forward) is connected thermally to the navigation signal processing unit and serves as a partial heat sink for the SPU. Battery 2 (on the right side facing forward) is thermally tied to the directional gyro unit and serves as a heat sink for the DGU.

The batteries are installed in the LRV on the pad at Kennedy Space Center in an activated condition and are monitored for voltage and temperature on the ground until T-18 hours in the countdown. On the lunar surface, the batteries are monitored for remaining amp-hours, temperature, voltage, and output current.

Each battery is capable of carrying the entire LRV electrical load, and the circuitry is designed such that in the event one battery fails the entire electrical load can be switched to the remaining battery.

6.3 DISTRIBUTION SYSTEM

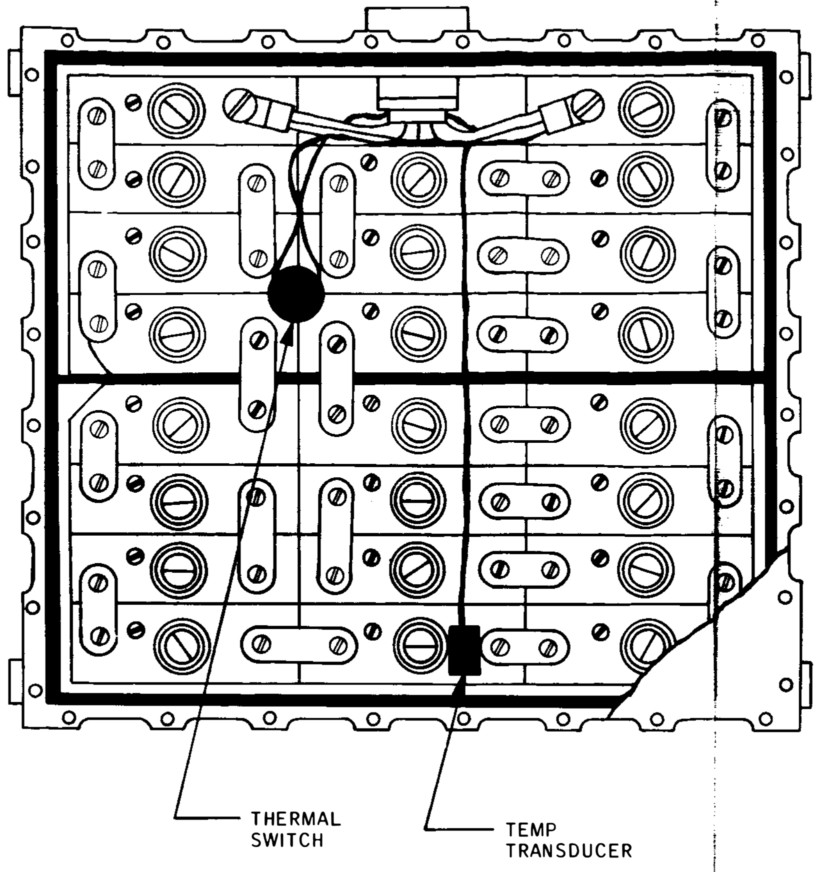
The electrical schematic for the LRV is shown in Drawing 6.2. The switch and circuit breaker arrangement is designed to allow switching any electrical load to either battery.

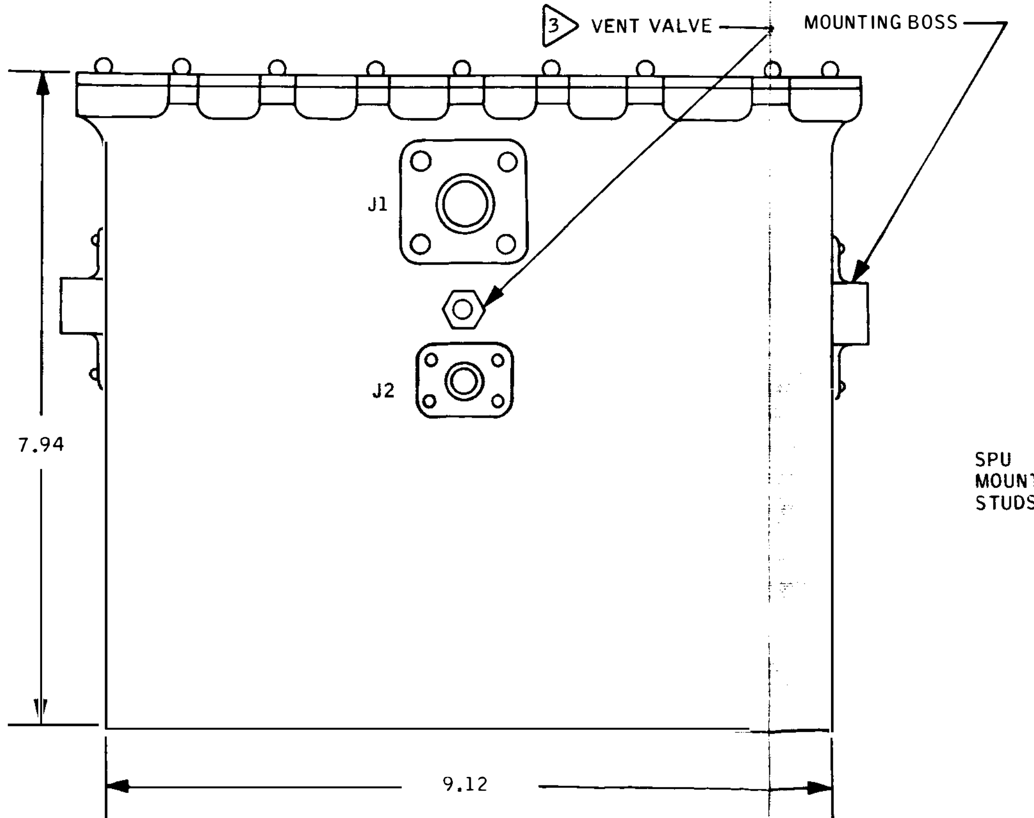
During normal LRV operation, the navigation system power must remain on during the entire sortie. To conserve power, all mobility elements (i.e, traction drives, steering motors, drive control electronics, and ±15 Vdc power supplies) may be turned off at a stop.

TABLE 6-I.- BATTERY DATA

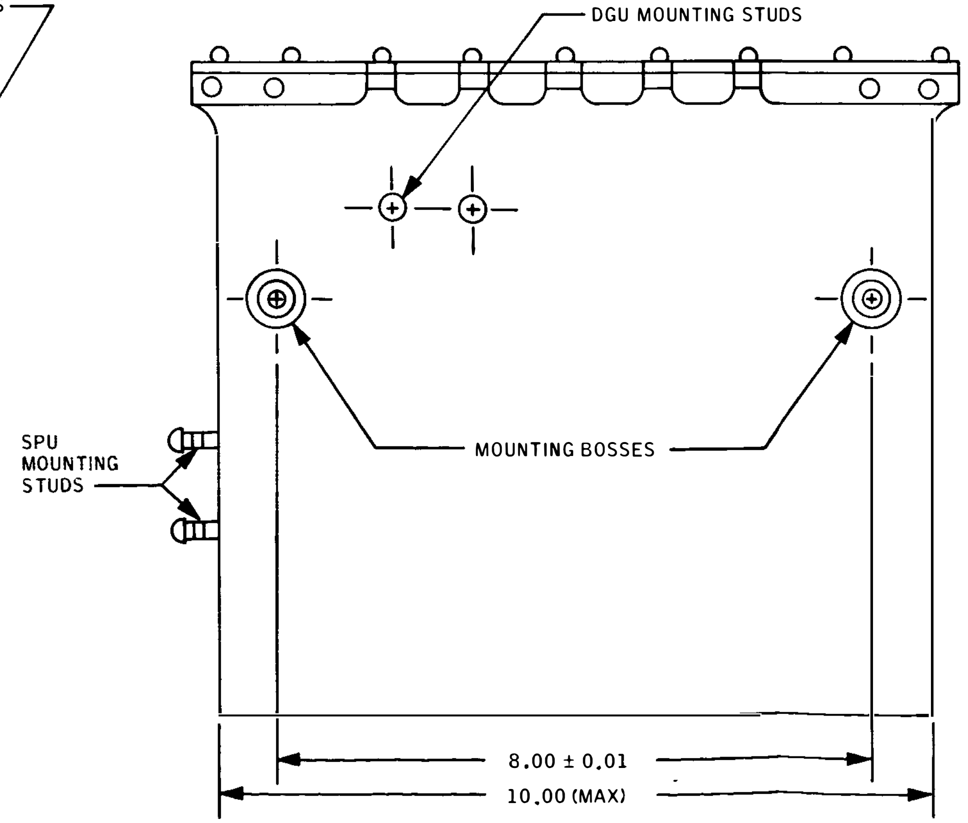
Voltage:	Nominal 36^{+5}_{-3} Vdc, Transient 36^{+8}_{-4} Vdc
Current:	47 A, max peaks to 90 A
Capacity:	121 amp-hours (4356 watt-hours) at 36 Vdc nominal 115 amp-hours (4140 watt-hours) at 36 Vdc minimum
Thermal dissipation:	High thermal conductance between cell blocks and surfaces of battery case
Personnel safety:	Pressure relief valve opens at 3.1 to 7 psid, closes when differential pressure is below valve's relief pressure Case designed to withstand 9 psi (without deformation)

FOLDOUT FRAME I



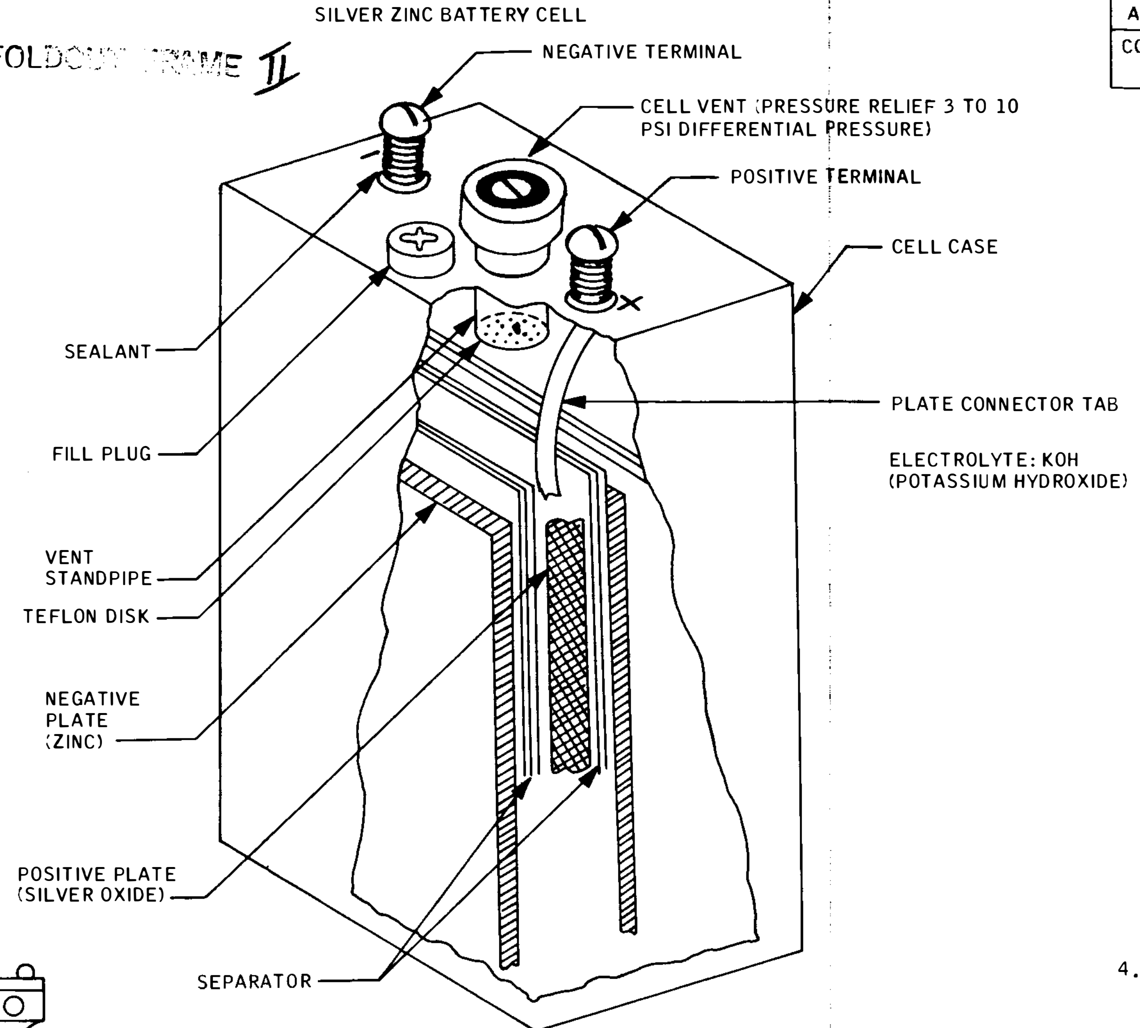


VIEW A-A



VIEW B-B

FOLDOUT FRAME II



CELL DETAIL

ELECTROLYTE: KOH (POTASSIUM HYDROXIDE)

FOLDOUT FRAME III

LTR	PCN	DR	ENGR	DATE		APPROVAL
A		BVC	[illegible]	6/24/71	7/12/71	[illegible]

COMMENTS:

4. EACH CELL HAS A NOMINAL VOLTAGE BETWEEN 1.5 AND 1.8V

3. BATTERY CASE RELIEF VALVE OPENS AND CLOSES AT 3.1 TO 7 PSID

2. EACH BATTERY CONTAINS 23 CELLS CONNECTED IN SERIES

NOTES: 1. ALL DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED

SIGNATURES	DATE
DR Vicki Doggett	1/12/71
DSGN Bill [illegible]	3-30-71
QC [illegible]	3-30-71
ENGR James F Moser	3-29-71
APP Gerald D Griffith	3-29-71
FEC Dean B [illegible]	3-30-71

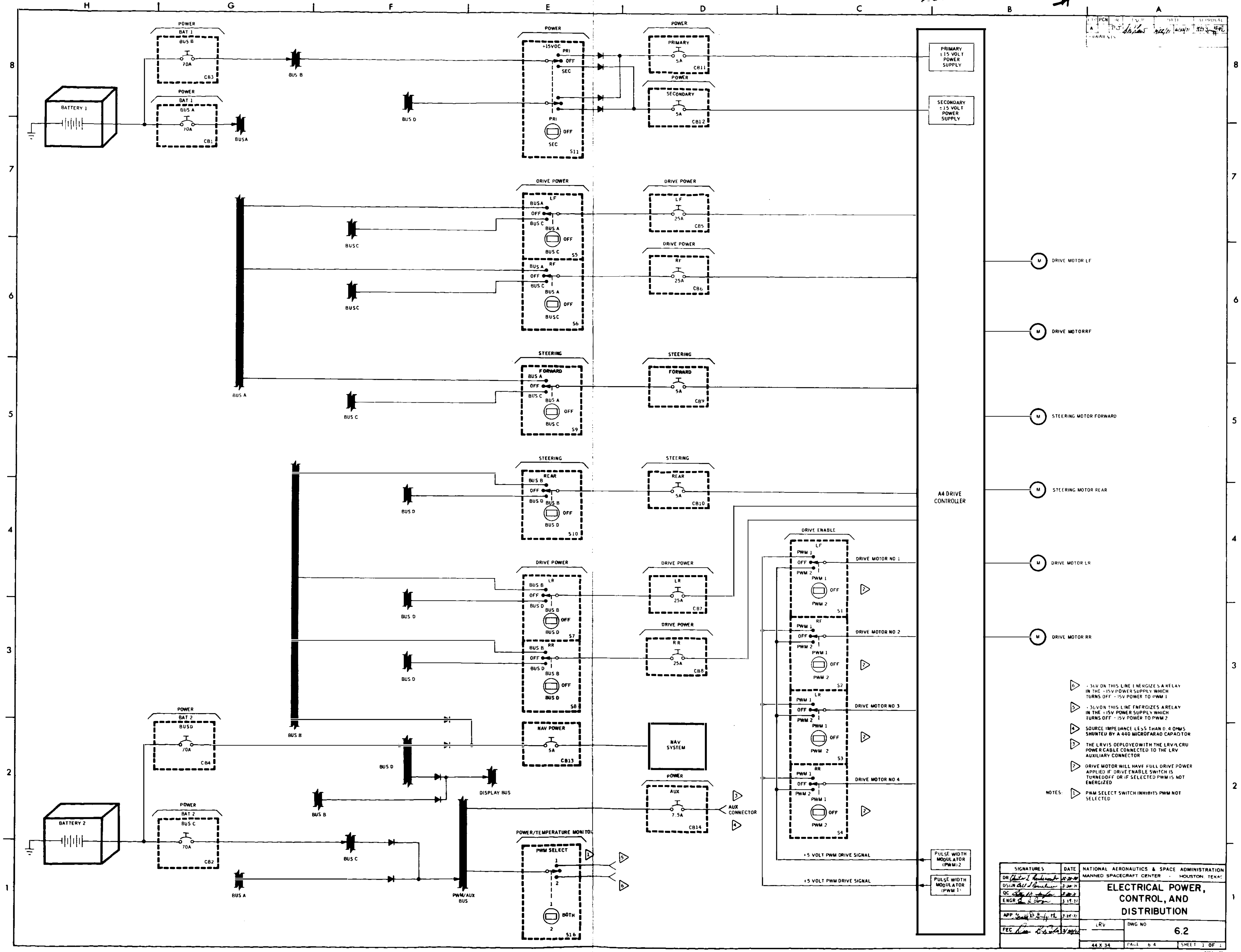
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

BATTERY

LRV	DWG NO 6.1
33 X 17	PAGE 6-3 · SHEET 1 OF 1

FOLDOUT FRAME II

FOLDOUT FRAME I



SECTION 7
NAVIGATION

7.1 GENERAL

A block diagram of the navigation subsystem is shown in Figure 7-1. Hardware locations are shown in Figure 7-2.

The power supply converts the LRV battery voltage to the ac and dc voltages required for operation of the navigation subsystem components. Signal inputs to the subsystem are heading with respect to lunar north (which is obtained from a directional gyro) and odometer pulses corresponding to a fixed distance (which are obtained from each traction drive unit).

These signals are operated upon by the navigation subsystem which displays the results as bearing back to the LM, range back to the LM, total distance traveled, and velocity. The heading with respect to lunar north is displayed directly.

7.2 HEADING

The directional gyro is erected (case leveled) and torqued until it is aligned with lunar north. Alignment is accomplished by measuring the inclination of the LRV in pitch and roll using the attitude indicator (Drawing 5.2) and the sun angle using the sun shadow device (Drawing 5.2). This information is relayed to earth where a heading angle is calculated. The crew then torques the gyro until the heading indicator matches the calculated value. Gyro torquing can only be done continuously for 2 minutes with a 5-minute cooldown period following. This enables up to 180° azimuth change per cycle. The system is initialized by using the SYSTEM RESET switch, which resets all digital displays and internal registers to zero. Initialization is performed at the start of each traverse.

The heading angle of the LRV is derived directly from the output of the gyro, which is generated by a three-wire synchro transmitter and is independent of computed data. The heading indicator in the integrated position indicator (IPI) contains a synchro control transformer and an electromechanical servosystem which drives the control transformer until a null is achieved with the inputs from the gyro.

7.3 ODOMETER

There are four odometers in the system, one for each traction drive unit. Nine odometer pulses are generated for each revolution of each wheel. These signals are amplified and shaped in the motor controller circuitry and enter the line receiver in the SPU. The odometer pulses from only the right rear wheel enter the velocity processor for display on the LRV SPEED indicator.

Odometer pulses from all four wheels enter the odometer logic via the SPU line receivers. This logic selects the third-fastest wheel for use in the distance computation. This insures that the odometer output pulses will not be based on a wheel which is locked, nor will they be based on a wheel that is spinning.

NOTE

The odometer logic cannot distinguish between forward and reverse wheel rotation. Therefore, reverse operation of the LRV adds to the odometer reading.

The SPU odometer logic sends outputs directly to the digital distance indicator in the IPI and to the range/bearing processor in the SPU. Upon entering the range/bearing processor, the outputs initiate holding selection and conversion of heading sine and cosine to digital numbers. Low voltages (<30 volts) can cause the distance indicator to assume a random value upon resuming normal (>30 volts) voltage.

7.4 RANGE AND BEARING

The effect of conversion of heading sine and cosine at distance increments is equivalent to entering distance increment times sine heading and distance increment times cosine heading into the ΔE and ΔN registers in the digital part of the bearing and range processor. The digital processor then adds the new ΔE and ΔN numbers to the components of the east (E) and north (N) accumulators. The E and N accumulators, therefore, contain the east and north vector components of the range and bearing back to the LM. The digital vectoring process then does a vector conversion on the N and E numbers to obtain range and bearing, which are displayed on digital counters in the IPI. Each distance increment from the odometer logic initiates the entire sequence described, and results in the updating of bearing and range. Range and bearing displays will be retained in the event navigation system power is less than 30 volts, but may be lost upon return of normal power.

7.5 SUN SHADOW DEVICE

The sun shadow device is used to determine LRV heading with respect to the sun. Scale length is 15 degrees either side of zero in one-degree increments. The sun shadow device can be used at sun elevation angles up to 75°.

TABLE 7-I.- POWER REQUIREMENTS

Initialization and warmup (1.5 minutes max from closing of navigation CB)			92 watts
Operating:	DGU	12 watts	
	SPU	28	
	Display electronics	5	
	Total		45 watts

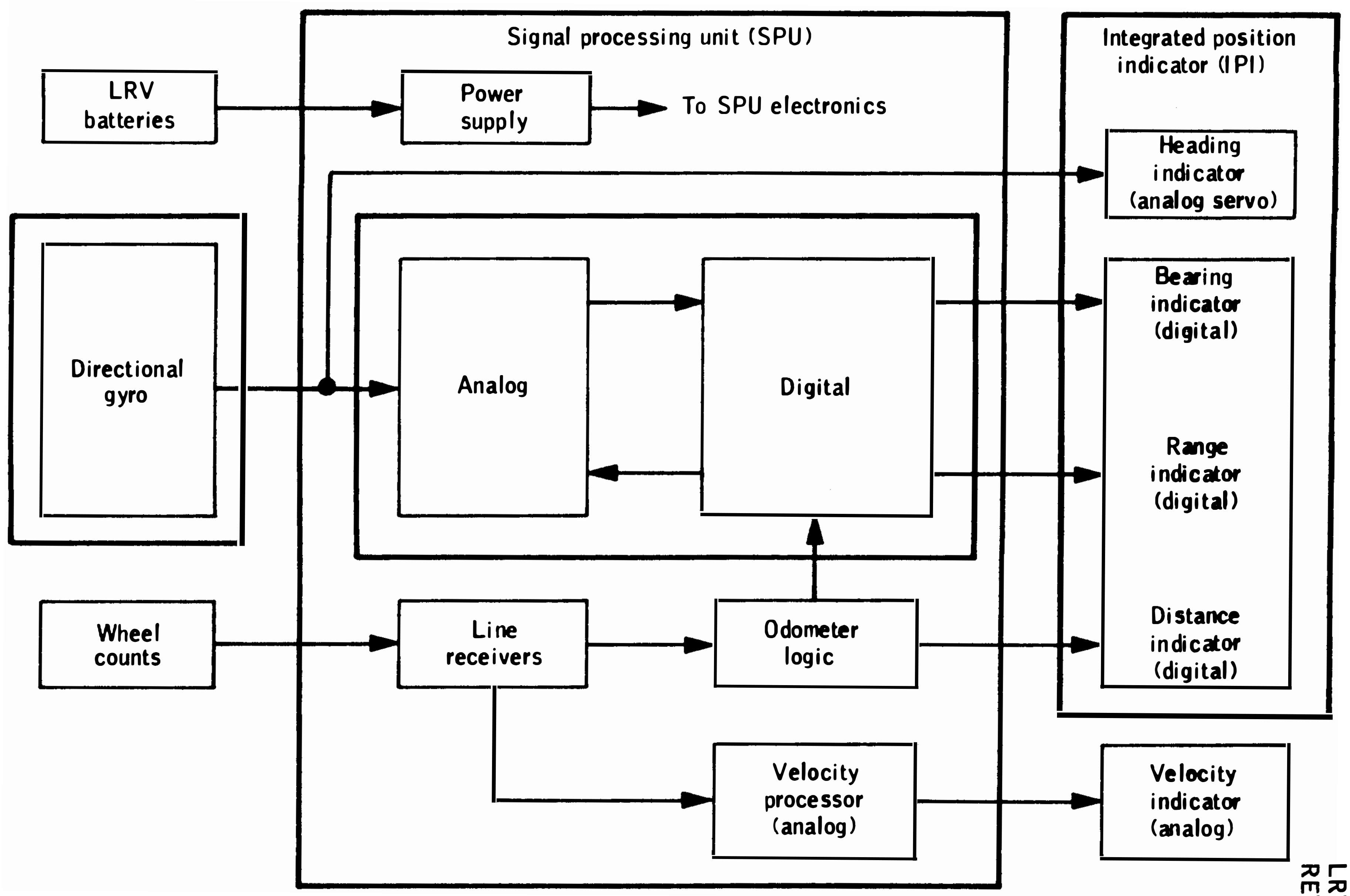


Figure 7-1. - Navigation subsystem block diagram.

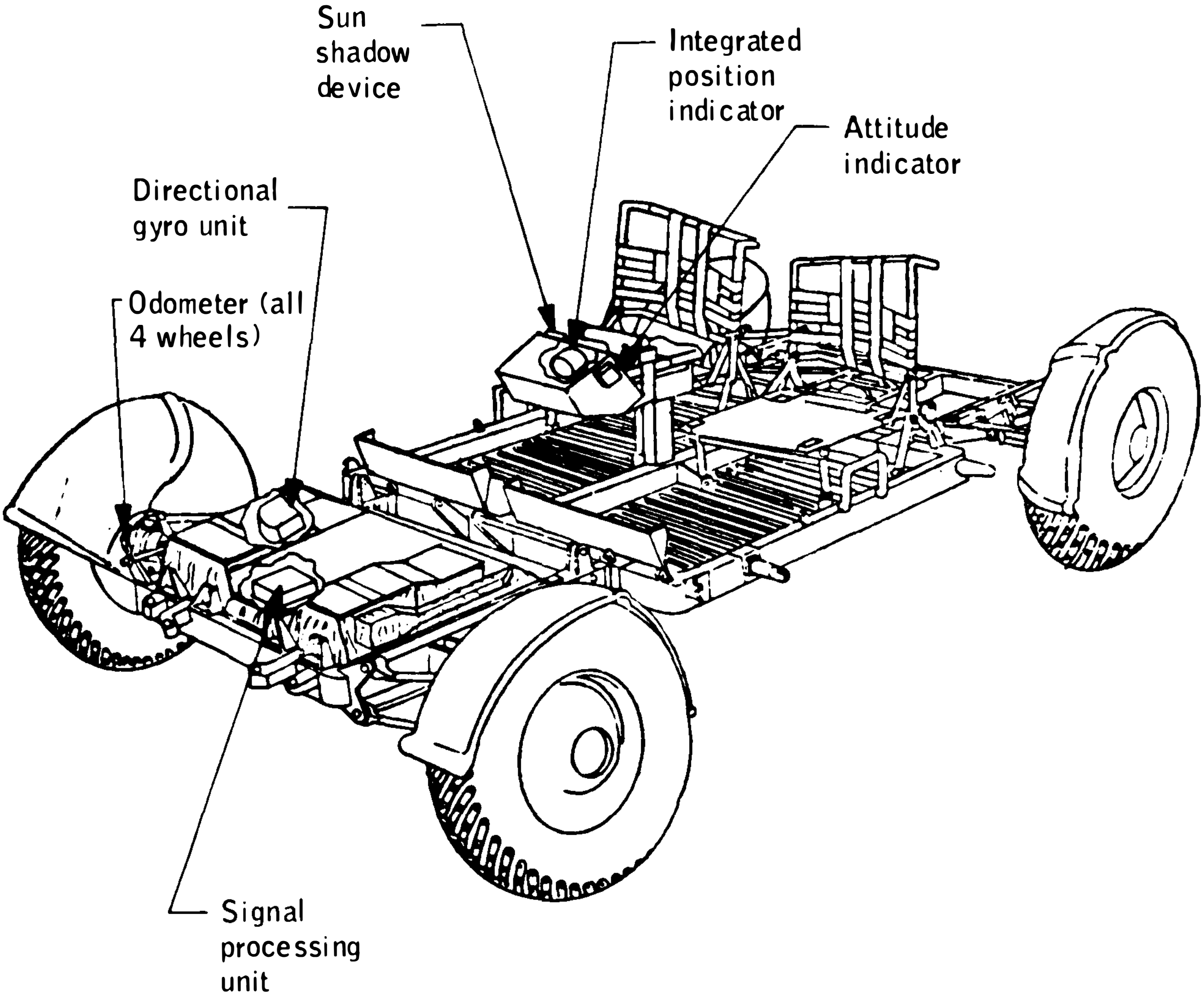
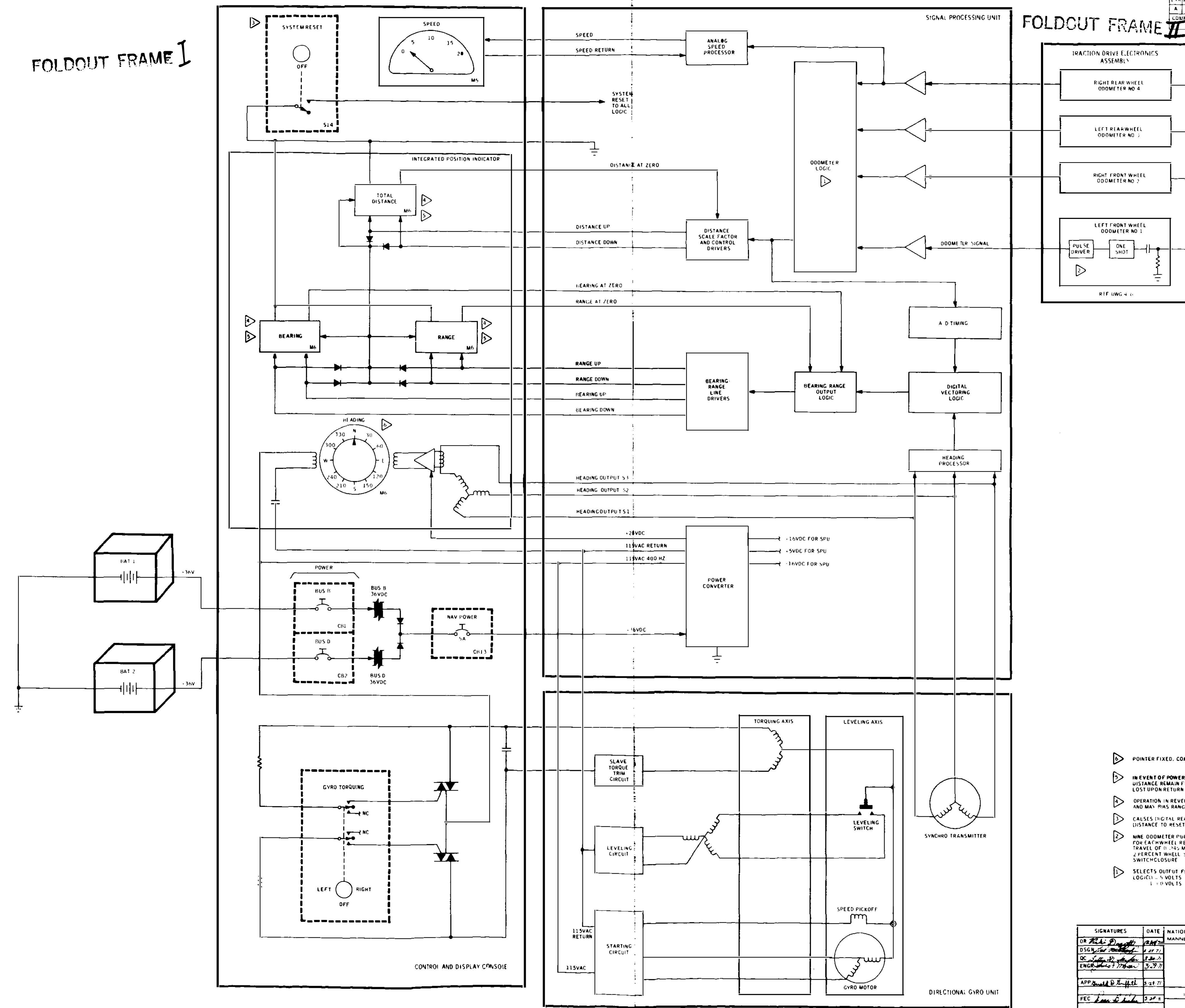


Figure 7-2. - Navigation components.

FOLDOUT FRAME I

FOLDOUT FRAME II



6. POINTER FIXED, COMPASS ROSE ROTATES
5. IN EVENT OF POWER LOSS RANGE, BEARING, AND DISTANCE REMAIN FIXED BUT READINGS MAY BE LOST UPON RETURN OF POWER
4. OPERATION IN REVERSE ADDS TO TOTAL DISTANCE AND MAY BIAS RANGE AND BEARING
3. CAUSES DIGITAL READOUTS IN RANGE, BEARING, AND DISTANCE TO RESET TO ZERO
2. NINE ODOMETER PULSES (10 MS WIDTH) ARE GENERATED FOR EACH WHEEL REVOLUTION GIVING AN EFFECTIVE TRAVEL OF 0.245 METERS PER PULSE (INCLUDING 2 PERCENT WHEEL SLIP). PULSE RESULTS FROM REED SWITCH CLOSURE
1. SELECTS OUTPUT FROM THIRD FASTEST WHEEL LOGIC 0 = 5 VOLTS, 1 = 0 VOLTS

SIGNATURES	DATE
DR	3-24-71
DSGN	3-27-71
QC	3-30-71
ENGR	3-29-71
APP	3-29-71
FEC	3-30-71

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

NAVIGATION SYSTEM

DWG NO 7.1

44 X 34 | PAGE 1/5 | SHEET 1 OF 1

SECTION 8

EQUIPMENT STOWAGE

8.1 INTRODUCTION

This section contains the LRV auxiliary equipment which includes provisions for transporting miscellaneous equipment for support of lunar activities, including experiments, communications, and photography. Detailed stowage provisions can be found in the Apollo 15 Lunar Roving Vehicle (LRV), Lunar Surface Equipment Stowage Location and Criteria, MSC-03991 Revision A, dated April 15, 1971.

8.2 FORWARD CHASSIS PAYLOAD PROVISIONS

The LRV forward chassis contains the equipment necessary to transport the lunar communications relay unit (LCRU), the high-gain antenna, and the color TV camera with remote command azimuth-elevation control unit.

8.2.1 Lunar Communications Relay Unit

The LCRU is mounted in the two inboard receptacles on the LRV forward chassis forward frame member. The two LRV support posts are installed in these receptacles prior to LRV delivery to Kennedy Space Center. The LRV/LCRU power cable is connected to the LRV auxiliary connector before launch. The LCRU support posts and LRV/LCRU power cable are carried on the LRV during launch and translunar flight.

8.2.2 High-Gain Antenna and Ground-Controlled Television Assembly

The high-gain antenna is secured to the left outboard receptacle on the forward chassis forward frame member. This receptacle is identical to the one on the right outboard side for the television camera/azimuth-elevation unit. To rotate antenna azimuth setting, grasp handle, push down to unlock, turn to desired setting and release. Staff locks in last position. The GCTA is a 525-line, sequentially scanned, color television camera. When mounted to the LRV it has ground remote command capability in azimuth, elevation, zoom, and iris.

8.2.3 Auxiliary Connector

The auxiliary connector provides power for the LCRU. Power at the connector is furnished at 36^{+5}_{-3} Vdc at a power level not exceeding 150 watts through the AUX POWER CB on the C&D panel. Source impedance at the connector is less than 0.4 ohms shunted by 600-microfarad capacitance. Prior to launch the LCRU power cable is attached to the auxiliary connector.

8.3 CENTER CHASSIS PAYLOAD PROVISIONS

The center chassis has provisions to carry auxiliary equipment on the inboard hand-holds, under the crew seats, and on the chassis floor.

8.3.1 Inboard Handhold Payload Receptacle

The inboard handholds are provided with receptacles for supporting the 16-mm data acquisition camera and low-gain antenna. In addition, a map holder clip is attached to the right-hand inboard handhold during lunar surface preparation.

8.3.2 Under-Seat Stowage

One collapsible stowage bag is provided under each seat for transporting miscellaneous payload items. These bags are installed on the LRV before launch. The forward end of each bag is secured to the LRV seat support frame. The bags are erected when the seat support frames are raised during LRV activation. The aft ends of the bags are held in place by springs attached to the rear member of the center chassis. Raising the seat off the seat support gives access to the stowage bags.

8.3.3 Floor Payload Stowage

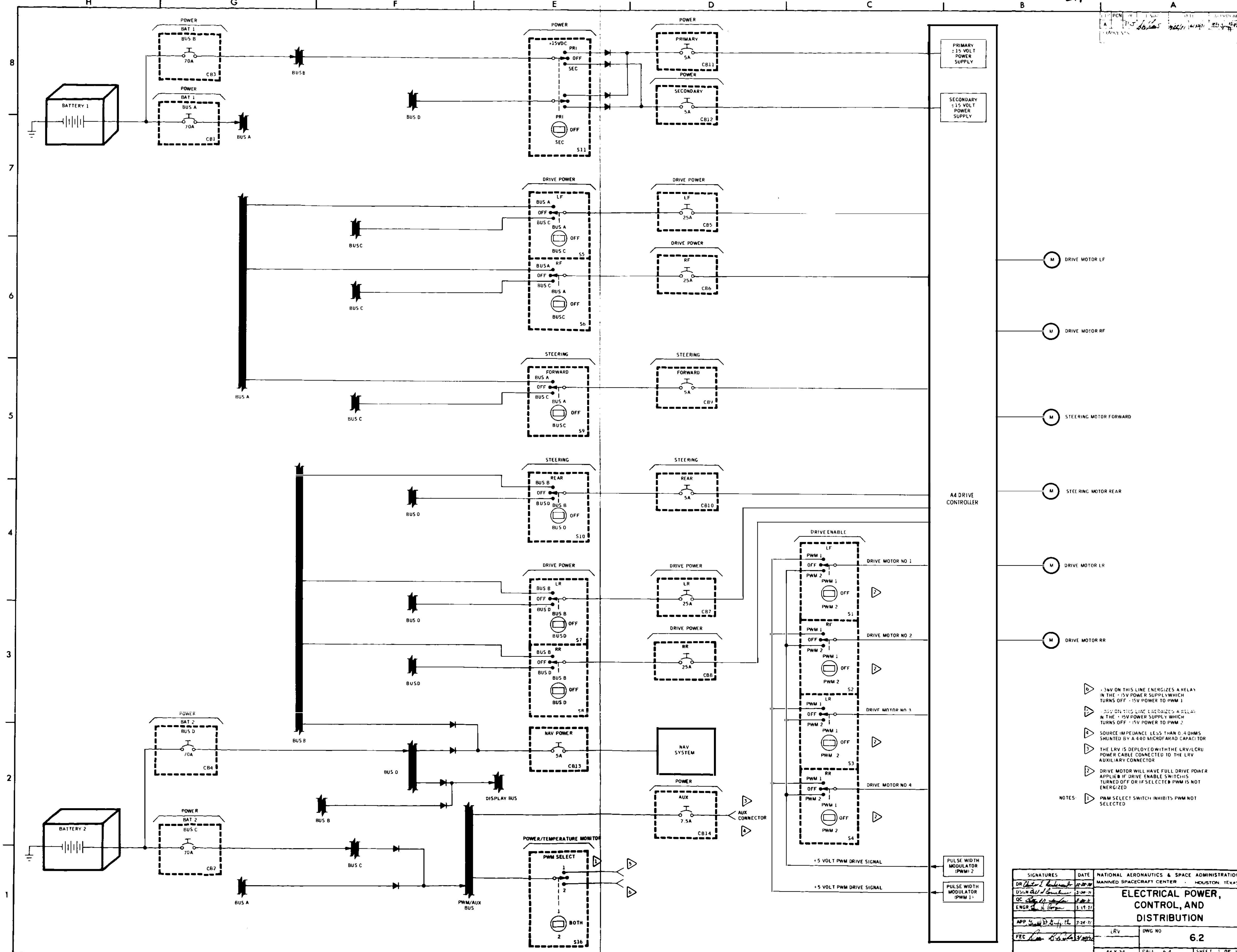
When only one astronaut is operating the LRV, the area normally used by the second crewman may be used for payload stowage. The seat can be placed in the operational stowage position secured by Velcro straps or payload can be placed on the seat and secured by the seatbelt. The under-seat stowage bag must be removed to use the floor area as a stowage area.

8.3.4 Back-of-Seat Payload Stowage

The buddy PLSS umbilical is carried in a bag attached to the back of the LRV right seat.

4 MOBILITY

FOLDOUT FRAME II



FOLDOUT FRAME I

7 NAVIGATION

6 ELECTRICAL POWER

5 CREW STATION

2 GENERAL INFORMATION

3 STRUCTURE

1 INTRODUCTION