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FINAL REPORT

AN INVESTIGATION OF TV MOBILE TERMINAL REQUIREMENTS FOR THE CTS COMMUNICATIONS EXPERIMENTAL PROGRAM

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FINAL REPORT

AN INVESTIGATION OF TV MOBILE TERMINAL REQUIREMENTS FOR THE CTS COMMUNICATIONS EXPERIMENTAL PROGRAM

prepared for

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by

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Contract: PL.3600-1-2208, Serial No. OPLI-0148
Date: July, 1972.

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SECTION A

GENERAL

A-1 Introduction

This report summarizes the results of a study entitled "An Investigation of TV Mobile Terminal Requirements for the CTS Communications Experimental Program" and performed by RCA Limited for the Communications Research Center at Shirley Bay, Ontario under contract PL-36001-1-2208. The defined objective of this program was: "To obtain a technical description of a TV Mobile Terminal intended for:-

1) Transmission of television broadcast signals from remote locations via the SHF transponder of the CTS spacecraft.

2) Interfacing with other experiments such as the use of wideband modems, etc.

3) Use as a back-up terminal to the main CTS Communications Control Terminal to be established near Ottawa."

The work was performed between November, 1971 and June 1972.

A-2 Terminal Concepts

The need for a ground terminal fitted with transmitting and receiving equipment and capable of being rapidly moved from one place to another was recognized many months before the start of this study by the communication system planners (Ref. A-2). In line with Canada's unique geographical characteristics and population distribution, the need for the terminal to be moved within the more sparsely settled Northern regions was noted.

From this, and other lofty considerations, the idea for a wide ranging mobile terminal was born, and the effort necessary to translate the idea into a practical concept was begun. This study is part of that effort.

The lack of extensive surface transportation facilities and reliance upon air traffic through the North was recognized early in the program as being the single most influential factor bearing upon the terminal development. Too large a terminal severely restricts the aircraft available for transportation; too small a terminal denies adequate experimental facilities.

We have considered the aspects of transportability very carefully and have come to the conclusion that either one of two basic terminal concepts may be employed depending upon the most likely remote operating destination for the terminal and the frequency of "tours of duty" at these locations.

The first concept is termed "the domestic trailer concept" and utilizes a modified streamlined domestic trailer shell to which an antenna pedestal and platform frame work is attached. This is the most economical type of terminal and is recommended if the experimental program does not call for extensive use in the north, or if the services of a large aircraft such as the "Hercules" are available. Figure A-1 is an artist's conception of the domestic trailer type.

The second concept is termed "the modular concept" and it utilizes the principle of modular construction so that the terminal can be disassembled into small units, or modules, for shipment by air in a Boeing 737 class aircraft and reassembled following shipment. This is the most flexible type of terminal and is recommended if the experimental program calls for extensive service in the north, as originally planned. It is also the most expensive. Figure A-2 is an artist's conception of the modular trailer on the site.

Regardless of which concept is chosen, the communications equipments will not be affected. The equipment capacity of either concept is such that the recommended communications systems can be installed in either, although the domestic trailer concept provides a larger floor area and would therefore be the more comfortable.

In the development of the concepts we have kept these points in mind:

1) A primary use for the terminal is the transmission of television broadcast signals from remote locations via the CTS spacecraft to Ottawa.

2) The mobile terminal must be capable to be used as a back-up terminal for the main communications control terminal to be established at CRC near Ottawa.

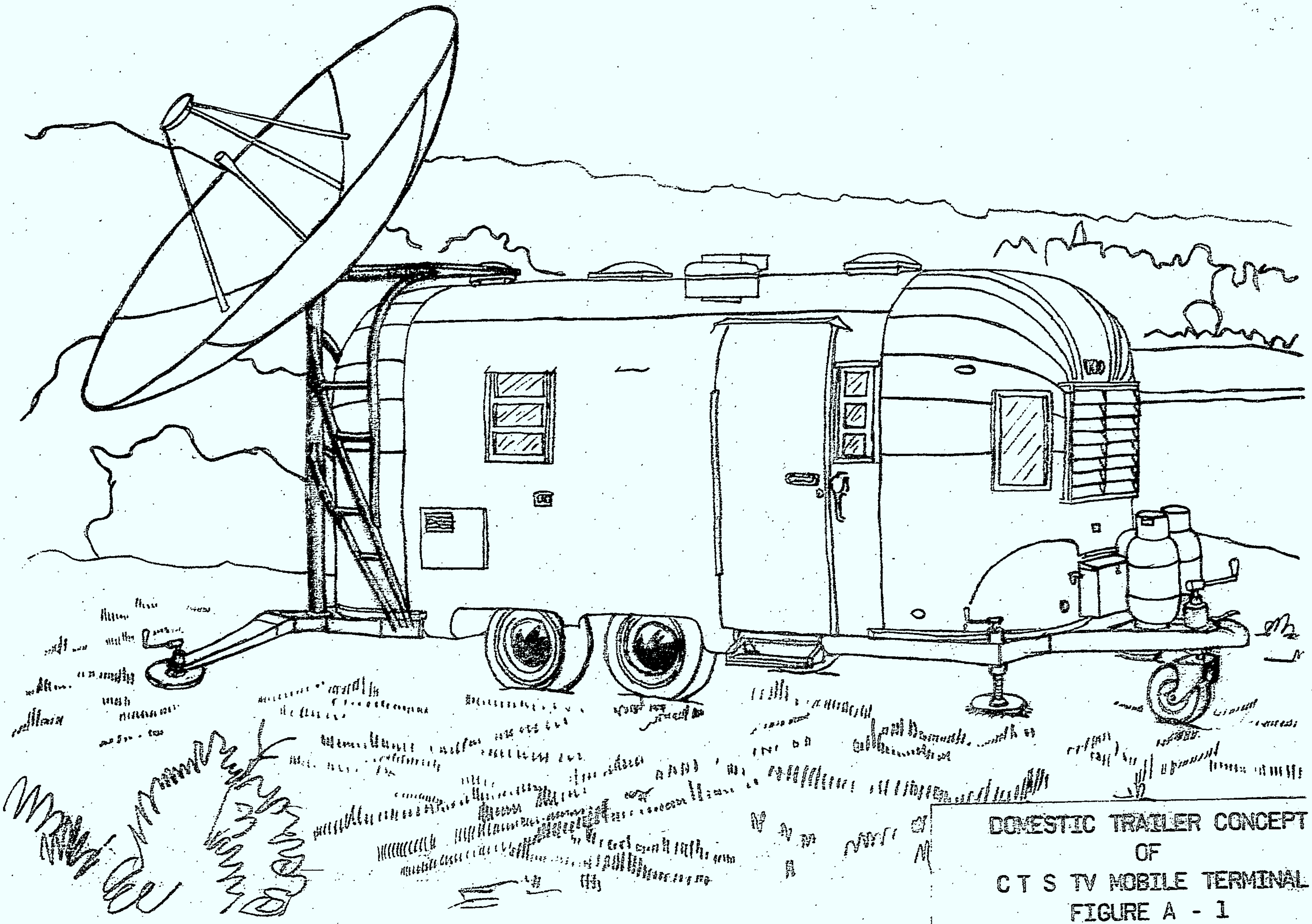
3) The terminal must be capable of interfacing with other experiments such as the use of wideband modems, TDMA signals, facsimile, etc.

4) The terminal should have a portable self contained primary power supply so that local hydro power need not be a limitation.

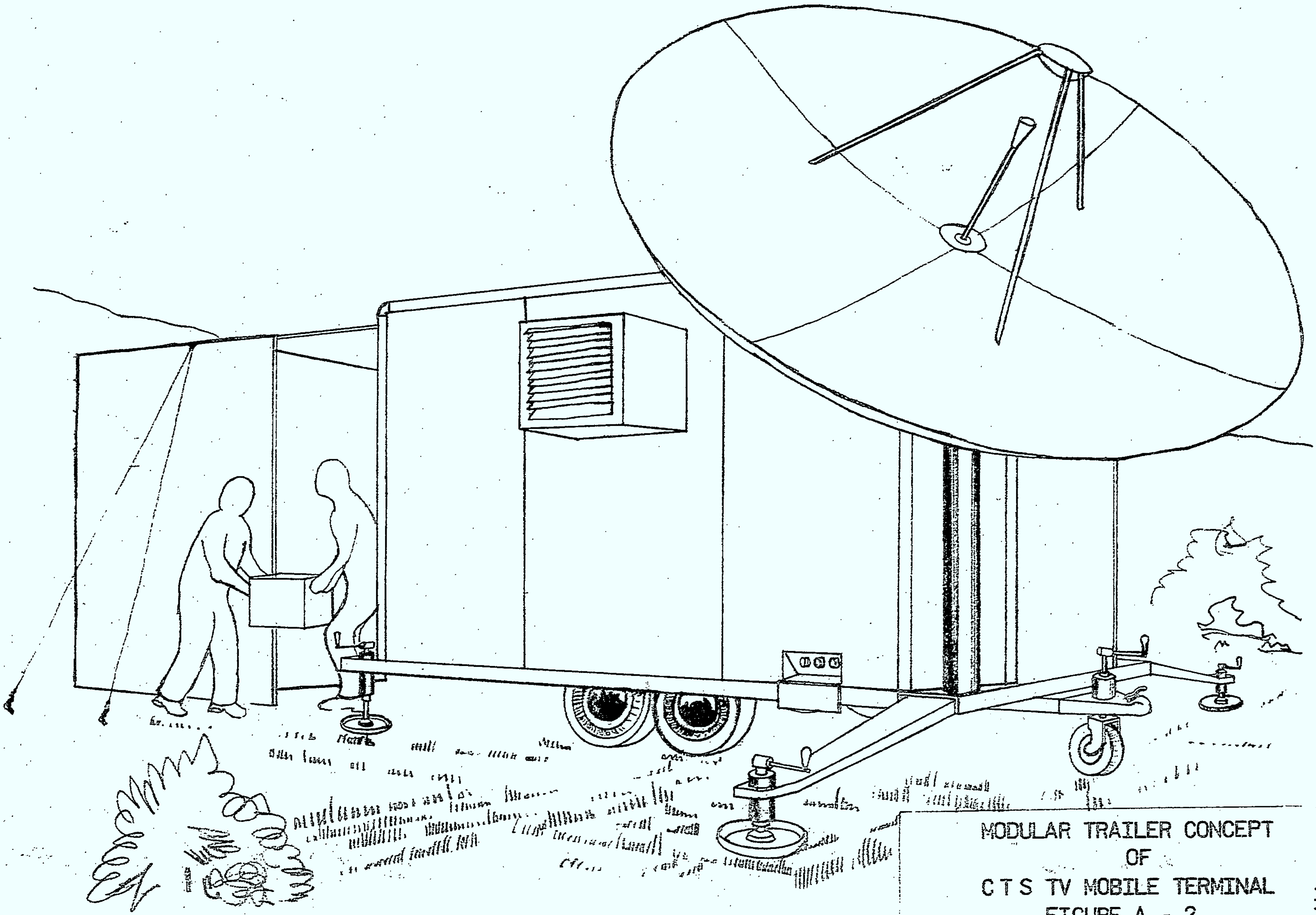
5) The operating crew size should be a minimum consistent with the requirements of the experimental program and the needs of safety.

6) The time and effort needed for assembly and disassembly should be minimized.

7) The needs dictated by operational procedures must be considered.



DOMESTIC TRAILER CONCEPT
OF
C T S TV MOBILE TERMINAL
FIGURE A - 1



MODULAR TRAILER CONCEPT
OF
C T S TV MOBILE TERMINAL
FIGURE A - 2

A-3 Options in Terminal Characteristics

Table A-1 lists the different options that were considered for the terminal, and includes the identification of the chosen options. As used here, an option is defined as a fundamental and important characteristic which must be selected between possible candidates and which constitute a readily identifiable visual or operational portion of the terminal. Thus, a specific shelter "style" is an option. So, too, is the IF conversion technique used in the communication subsystem.

Some options are mutually exclusive, such as trailer styles. Others are not. In Table A-1 we have separated mutually exclusive option groups by horizontal lines. Only one selection in such a group can be made for each concept.

A-4 Technical Description

In Table A-2 we list the major parameters which, taken together, constitute a technical description of the two terminal concepts as currently visualized. Several points may be worthy of special note or repetition.

1) The antenna and mount are identical for both concepts.

2) The communications equipment and capabilities are identical for both concepts.

3) The modular trailer may be flown as regular commercial air freight by airlines using Boeing 737 or equivalent aircraft whereas the domestic trailer requires larger aircraft such as the Hercules.

4) The modular concept will require a significant amount of development effort, both for the modules and chassis of the trailer itself, and for the module handler which must be used for rotational manipulation of the modules.

5) Costs are based on 1972 labor rates and equipment costs.

Considering costs, we note that the modular trailer concept estimated costs are about $115,000 higher than those for the domestic trailer concept. The basic advantage of this concept, which is air transportable at commercial rates, must be balanced against the disadvantage of high transportation costs.

TABLE A-1

BASIC OPTIONS IN TV MOBILE TERMINAL CONFIGURATION

CHARACTERISTIC	DESCRIPTION	SELECTED Domestic	SELECTED Modular
SHELTER STYLE	Domestic Trailer	X	
	Military Expandable Trailer		
	Modular Trailer		X
	Commercial Trailer		
	Modular Shelter		
	Prefabricated Shelter		
	Helicopter Hut		
TRANSMITTER	Parallel Existing TWT (350W-500MHz BW)	X	X
	Existing Klystron (500W-40MHz BW)		
	Modified Parallel TWT (500W-500MHzBW)		
	Modified Klystron (500W-60MHzBW)		
	New, Single TWT (500W-500MHzBW)		
	New, Single TWT (1000W-500MHz BW)		
	New, Klystron (2000W-85MHzBW)		
RECEIVING SYSTEM	Mixer Front End		
	TDA Front End	X	X
	Paramp Front End		
	Single IF Down conversion		
	Double Down conversion	X	X
ANTENNA	Cassegrain	X	X
	Horn Fed		
	Offset Parabola		
	One Piece Reflector		
	Folding Rim Segments		
	Sectional Reflector	X	X
	Aluminium Reflector		
	Magnesium Reflector		
	Fiberglass Reflector	X	X

TABLE A-1 (Cont'd)

CHARACTERISTIC	DESCRIPTION	SELECTED Domestic	Modular
TRACKING	Manually adjustable Manual servo controlled Programmed Auto-Track (monopulse) Step-Track	 X	 X
MOUNT	2 Axis Polar 2 Axis AZ-EL 3 Axis AZ-EL Track Angle	 X	 X
	Manual Movement (Gear and Crank Electric Motor and Gear Drive Hydraulic Linear Actuator Drive Electric Linear Actuator Drive	 X	 X
PRIMARY POWER	DC 60 HZ 400 HZ	 X	 X
	115V Single Phase - 2 wire 115V/230V Single Phase - 3 wire 230V Three Phase - 3 wire 115/200V Three Phase - 4 wire	 X	 X
BACK-UP POWER SOURCE	Diesel Engine/Alternator Gasoline Engine/Alternator Fuel Cell /Inverter Storage Battery/Inverter Thermoelectric/Inverter	X	X

TABLE A-2

TECHNICAL DESCRIPTION OF THE TV MOBILE TERMINALS

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
A. General			
1. Configuration	3 modules placed on a folding chassis. Antenna and mount on column in one corner. (See figure A-2)	Commercial streamlined domestic trailer fitted with antenna and mount on a column in one corner (See Figure A-1)	
2. Overall Dimension	Approximately 8 ft high, 8 ft wide, 15 ft long (less tow bar) without antenna installed.	Approximately 8 ft high, 8 feet wide, 22 ft long (less tow bar) without antenna installed.	
3. Shipping Configuration (Road)	Assembled trailer with antenna, engine generator set and module handler stowed inside. Miscellaneous equipment and stores stowed inside. Shipping panels stowed on top or ar rear.	Antenna and engine generator set stowed inside. Carries miscellaneous equipment and stores stowed inside.	
4. Shipping Configuration (Air)	3 separate 5'x7'x8'6" modules (approx.) folding chassis, module handler, antenna and positioner shipping cases, miscellaneous shipping cases placed on pallets.	Same as road configuration	
5. Air Transportable by	Boeing 737, Electra C46, cargo helicopter, Lockheed Hercules	Lockheed Hercules, high capacity cargo helicopter.	

TABLE A-2 (CON'T)

6. Special Handling equipment	Module handler required	None
7. Shipping Wt.	7000 lbs approx (not including fuel)	6500 lbs. approx (not including fuel)
8. Conveniences	Toilet, with holding tank, running water, propane furnace, electric heaters, ventilators, air conditioner, work bench wall cabinet.	Toilet with holding tank, running water, propane furnace, electric heaters, ventilators, air conditioner work bench, wall cabinets, 2 desks.
9. Environmental	- 40°F to + 90°F. Operational capability (minimum range) capable of sustaining salt spray, sand and dust rain etc., incident Canada wide	Same as Modular
10. Human factors engineering	As a design aim to meet requirements of Mil Std 1471A as applicable to a ground workshop except as restricted by limitations in working space (See Appendix A-3)	Limits of MilStd 1472A to be essentially complied with, as applicable to a ground workshop. (See Appendix A-3)
11. Reliability and Maintainability	Operational reliability such that probability of successful 3 week operational period is better than 90%. Modular electronic equipment to be used where possible to improve maintainability and reduce down time to less than ½ hour for most failures that are field repairable	Same
12. Usefullness after Experiments Completed	Possible use for experiments in logistics or other communications programs.	Possible use for experiments in other communications programs.

TABLE A-2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
13. Estimated Cost	$441,675.	$325,780.	

NOTES:

1. Loss of one transmitter TWT may require a longer period than ½ hour, depending upon output waveguide configuration.

2. Includes development and acceptance testing; excludes test equipment.

TABLE A-2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	Notes
B. Communications			
(a) Transmit IF and RF			
Configuration	Double IF Upconversion		
Deviation	Adjustable to ± 20 MHz Peak		
1st IF	70 MHz basic		1
2nd IF	735 MHz nominal		
Basic IF Bandwidth Capability	Up to 85 MHz		
IF Bandwidth Adjustment	IF Filter replacement		
RF Frequency range	14 to 14.5 GHz		
Instantaneous RF Bandwidth	500 MHz		2
RF Driven Output Level	1 watt Typical maximum		
RF Output Level Adjustment	By adjustment at driver input		
RF Transmitter tubes	Parallel, phased TWT's		
RF Transmitter Output Level	350 Watts minimum		
RF Line Losses	1 dB nominal		
EIRP	+74.8 dBW minimum at maximum output		
Interfaces - at IF	70 MHz and 735 MHz		3
Interfaces - at RF	input for order wire transmitter		3
Test Loops - at IF	to 70 MHz main IF circuitry		
Test Loops - at RF	to 12 GHz receive RF circuitry via test loop translator		
Equalization	Linear and Parabolic group delay as required		

NOTES:

1. Other IF frequencies may be used as necessary with the range 40 to 100 MHz.

2. Bandwidth covers entire frequency range.

3. External interface.

TABLE A-2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
Communications (continued)			
(b) Receive IF and RF			
Configuration		Double IF Down conversion	
Front End type		Tunnel Diode Amplifier	
Input Line Losses		0.7 dB nominal	
G/T ratio		18.5 dB/°K	
Front End Frequency Range		11.7 to 12.2 GHz	
Front End Instantaneous Bandwidth		500 MHz	1
1st IF frequency		580 MHz	
2nd IF frequency		70 MHz nominal	2
Band Selection		By tuning 1st local oscillator	
Basic IF Bandwidth Capability		85 MHz minimum	
IF Bandwidth selection		Second IF filter replacement	
Dynamic Range to A G C		40dB typical	
Discriminator range		Up to $\pm$ 20 MHz peak deviation	
Interface at IF		580 MHz and 70 MHz	3
Interface at RF		output to order wire receiving	3
Test Loops at IF		from 70 MHz transmit IF circuitry	
Test Loops at RF		from 14 GHz transmit RF circuitry via test loop translator	
Equilazation		Linear and Parabolic Group Delay as required	

NOTES:

1. Bandwidth covers entire frequency range.

2. Other IF frequencies can be used as necessary within the range 40 to 100 MHz

3. External interfaces.

TABLE A-2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
Communications (continued)			
(c) Baseband (Receive and Transmit Directions)			
Basic Bandwidth Capability		Up to 10 MHz	
Signal Processing For		1-525 line NTSC color video channel	
		1- audio channel on 4.5 MHz subcarrier	1
		1- audio channel on 6.74 MHz subcarrier	2
		1-audio channel on 7.50 MHz subcarrier	2
		1-audio channel on 7.80 MHz subcarrier	2
		1-audio channel on 8.21 MHz subcarrier	2
		1-sound channel for FM Broadcasting	
Video Bandwidth		4.2 MHz	
Audio Channel Bandwidth		Either 10 KHz or 15 KHz as required	3
Pre-emphasis and De-emphasis		CCIR standards for video	
		75 sec for audio and sound	
		All signals may be handled simultaneously	
Interfaces - for video		1 volt peak to peak across 75 ohms, unbalanced	4
" for audio		+9 dBm across 600 ohms, balanced	4
" for sound		+9 dBm across 600 ohms, balanced	4
Interface Adustments for video		Equalization and level correction	
for audio and sound		Isolation and level correction	

NOTES:

1. Deviation $\pm$25 KHz for compatability with broadcast standards.

2. Deviation $\pm$100 khz

3. Type "A" broadcast quality circuits require 10 kHz. FCC specifications for broadcast transmitters specify 15 kHz capability.

4. External interfaces to other program sources.

TABLE A-2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
C. Trailer			
1. Inside Body Dimensions	Approx 8' wide 6'6" high 14'6" long	Approx 7'6" wide 6'6" high and 21' long	
2. Weight (less operational equipment)	3500 lbs approx.	3,500 lbs approx.	
3. Roadability at highway speeds	Safe towing characteristics up to 50 M.P.H. minimum speed required. Shape will increase drag and cross wind effects	Safe towing characteristics at highway speeds. Good aerodynamically.	
4. Towing speed, off highway on firm terrain	5 M.P.H.	5 M.P.H.	
5. Type of Body Construction	Welded aluminium extrusion frame, aluminium inner and outer skins with urethane insulation; modules connected by fasteners with sealing gaskets and EMC metal gaskets.	Rivetted aliminium innner and outer skins with formed aluminium ribs and stringers, in aerodynamic monocoque shape. Screening to be provided for EMC.	
6. Type of chassis Construction	Folding or telescoping steel frame with elastomeric or air ride suspension, with tandem walking beam axle and 4 wheel electric brakes.	Conventional steel frame with 3 main members and cross members approx. 2 ft apart. Elastomeric or air ride suspension, with tandem walking beam axle and 4 wheel electric brakes.	
7. Tow Bar	Compatible with frame equalizer type hitch. 10 to 15% of gross vehicle weight to be carried at hitch ball	Same	

TABLE 2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
C. Trailer (continued)			
8. Susceptibility to damage	Module handling implies some risk to electronic equipment and possibility of damage to seals flanges etc of modules.	Less structural strength but less possibility of damage to trailer or to contents.	
9. Ease of Repair	Skin damage easily repairable using kit provided. Structural damage should be repaired by trailer manufacturer. Close tolerances required.	Relatively simple to repair, including minor structural damage, using rivetted doublers and formed sheet.	
10. Suitability for antenna positioner installation	Rigid structure and mitred corners should permit direct attachment	Tubular struts and platform added to support pedestal. Aerodynamic shape reduces wind forces.	
11. Suitability for electronic racks installation	Separate modules constrain layout possibilities. For module shipping, racks on sides require shock mounts and special pads.	Strengthened floor to be provided. Shock mounting not required may require addition of doublers to provide suitable attachment points on walls and ceiling.	
12. Ease of equipment relocation	Difficult because of modular constraints and possible incompatibility with structural members.	Many layouts are possible subject to possible structural problems noted above.	
13. Approximate cost	including module handler		

TABLE A-2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
D. Engine Generator Set			1
1. KVA Rating	15 intermittent, 12.5 continuous		
2. Power Rating	12 intermittent, 10 continuous		
3. Frequency	60 Hz		
4. Voltage	115 - 230V single phase		
5. Dimensions	Approx. 50" long, 26" high, 20" wide		
6. Weight	800 lbs approx.		
7. Cooling means	Direct driven blower		
8. Fuel Consumption	1 Imperial gallon per hour at rated continuous load		
9. Environmental Capability	- 50°F to + 100°F, with winterization kit or high temperature kit used, if required, and appropriate fuel type. Suitable enclosure to protect against rain, snow sand and dust and permit use of combusion type pre-heater.		
10. Starting system	Electric starter motor, glow plugs, intake air preheat, remote start control provided.		
11. Protection	Automatic shutdown due to low oil pressure or excessive engine temperature. Overload protection on generator output and on other wiring of set. Automatic fire protection with rate of temperature change sensor.		

TABLE A-2 (CON'T)

PARAMETER	MODULAR CONCEPT	DOMESTIC CONCEPT	NOTES
D. Engine Generator Set (continued)			
12. Indication		Watt/VA meter, volt meter, A.C. Ammeter, frequency meter, D.C. charge-discharge ammeter, oil pressure gauge, cylinder head temperature gauge, fuel contents gauge and elapsed operating time meter.	
13. Control (local)		Choke (manual and automatic), starter switch, generator field switch, generator output switch, engine preheat switch, glow plug switch, cooling air control, fuel valves.	
14. Control (Remote)		Start switch, engine preheat switch (switches glow plugs on), generator output switch.	
15. Indication (Remote)		Watt/VA meter, frequency meter, A.C. volt meter, fuel contents gauge, engine temperature and oil pressure gauges. Warning lights for oil pressure, temperature and battery charger.	
16. Log book and Operating Instructions		To be housed in readily accessible waterproof enclosure.	
17. Tool Kit		Box with any special tools, fittings, wrenches etc. used on a routine basis.	

NOTE: 1. Applicable to diesel prime mover set for either terminal concept.

A-5 Discussion

In Table B-2, we have estimated transportation costs for various modes and distances. Extracting from this table the case for a 1600 mile air lift from Edmonton to Inuvik, we note that basic round trip transportation costs are:-

(a) $7,800. by commercial freight for the modular trailer, and

(b) $28,500. by air charter for the domestic trailer.

Therefore, costs are roughly $6. per mile more to air transport the domestic trailer. We can therefore charter Hercules aircraft for flights totalling about 17,200 miles before the excess transportation costs for the domestic trailer exceeds the excess procurement costs for the modular trailer.

The above "break-even" point has not considered all factors. If a really detailed analysis were to be performed, it would require consideration of at least the following:-

(a) assembly and disassembly times for the modular trailer.

(b) time value of money (excess procurement costs occur earlier than excess transportation costs).

(c) availability of aircraft * and its effect on the routing of the terminal.

The uncertainty of the travel requirements for the terminal, the lack of bona-fide cost proposals for developments, and many other factors negate any additional benefits which might otherwise accrue from such a detailed analysis.

Nevertheless, the trend is clear: on a purely economic basis, we must have an experimental program which includes over 17,000 miles of air lift in order to justify the increased costs and greater problems of the modular concept.

But there are other considerations, not necessarily direct economic ones. We shall pose a few of them as questions.

1. Is the "proving out" of the modular concept itself, a desirable aim?

2. Since the modular concept permits transportability virtually anywhere in Canada, is this an advantage and will it become part of an experiment?

3. Can the inherent adaptability in size and use of the modular concept form the basis for join experiments comprising several agencies and several mobile units connected together?

Perhaps these questions lie outside the strict guidelines established for the terminal. However, we feel we must raise them as they do have valid implications on the ultimate selection of a concept and which cannot be solved on purely economic or engineering considerations.

---

* For example, no Hercules aircraft for charter out are known to be currently based in Montreal.

A-6 Study Development

In this section we have dealt with the general descriptions and considerations of the terminal concepts. In the following sections we develop the rationale that has led us to the concepts. Each section is devoted to a particular aspect of the study. The study development proceeds as follows:-

Section B	-	discussion of transportation, site selection, operation and back-up service.
Section C	-	communication description and capability.
Section D	-	antenna description.
Section E	-	antenna positioner requirements.
Section F	-	trailer concepts and description.
Section G	-	module handling description and requirements.
Section H	-	heating and ventilation facilities.
Section I	-	primary power system, both AC and DC.
Section J	-	system reliability, availability and maintenance.
Section K	-	suggested procurement plan.
Section L	-	basic testing requirements.
Section M	-	estimates and sources of estimates.

Appendices providing background information relating to most of the sections then follow.

A-7 Recommendation

While we have developed two terminal concepts in this study we may make the following conditional recommendations:-

Recommendation 1 If the C.T.S. experimental program requirements include significant air transportation by commercial carrier of the terminal and for an experiment to check out the modular terminal concept, then the modular trailer concept is recommended.

Recommendation 2 If the C.T.S. experimental program requirements do not include significant air transportation by commercial carrier, then the domestic trailer concept is recommended.

In the event that the Modular Trailer concept is chosen, then the following additional recommendations are made:-

Recommendation 3 A more detailed evaluation of the methods to provide adequate sealing between modules should be made prior to issuing any RFP's.

Recommendation 4 A more detailed evaluation of the module handler should be made prior to issuing any RFP's.

With respect to the communication equipment, the terminal contractor should be responsible for all activities except for one possibility relating to transmitter procurement. This exception arises because the same type of transmitter equipment may be installed in both the terminal and the Ottawa control station. Therefore:

Recommendation 5 If the transmitter equipment is obtained as part of a common procurement, then either the terminal contractor or CRC may assume procurement responsibility as is most advantageous. In this case there must be joint approval of the equipment acceptablity and schedule.

SECTION B

OPERATIONAL ASPECTS

B-1 **General**

In this section we examine the fundamental operational aspects that bear upon the two mobile terminal concepts. We examine some of the reasons for the selection of certain physical parameters and limitations in facilities, particularly in relation to the mode of transportation. In fact, transportation aspects are perhaps the most influential factors governing the terminal's physical concepts. We also consider the operational aspects relating to a remote "tour of duty".

Let us begin by briefly examining transportation. The following assumptions are made:

a) tours will begin and end at CRC.

b) a two-man crew will operate the terminal.

c) the modular terminal will be transported by air for at least part of its journey.

d) the domestic terminal will be transported by rail (or road) for at least part of its journey.

e) RF signals will be transmitted.

f) no electrical power service is available at the remote site.

g) accomodation for personnel is available at the remote site.

B-2 **Transportation**

The mobile terminal should be capable of being transported over as much of Canada's territory as possible. This follows from the basic guidelines established for the Communications Technology Satellite Program: that one of the major purposes of this program is to examine communications capabilities and requirements throughout Canada's northland. It is this requirement which poses the greatest challenge to the operation of the terminal.

By transportation we include:

a) movement by air - winged aircraft
- helicopter

b) movement by road - towing
- flat bed

c) movement "off-road" - tracked vehicles
- air cushion vehicles
- sled

d) movement by rail - piggyback

e) movement by water - ocean vessel
- lake vessel
- river barge

Transportation throughout much of Canada's northland lacks comprehensive road, water and rail facilities, except for restricted regions* and therefore the major mode of transportation is by air. For some communities, however, road and rail transportation can be used for at least part of a tour.

Transportation throughout Southern Canada will be entirely by surface means, unless time is a factor.

Table B-1 lists a representative sampling of possible tours to indicate the difference in distance and transportation modes. We will use this sampling to estimate transportation costs later in this section.

B-3 Air Transportation

We do not assume that military or government aircraft will be used to transport the terminal. The availability of such aircraft will be conditional upon specific priorities or needs which cannot be assessed at this time and in any case are unknown to the writers. The analysis is therefore restricted to commercial aircraft in freight service.

Considering the requirements for terminal we have concluded that the minimum practical size of winged aircraft is one which falls in the Boeing 737 jet range.**

* The MacKenzie River system, using river barge, is an example of one such "restricted" region.

** A smaller aircraft such as an "Otter" could be considered, but the total payload would be too small to be practical.

TOUR	ROUTE	CLASS	APPROX. DISTANCE TRAVELLED (MILES) PER LEG	TOTAL
1	Ottawa - Toronto	Short Haul Road (or Rail)	260	260
2	Ottawa - Prince Rupert	Long Haul Rail	3,105	3,105
3	Ottawa - Montreal	Short Haul Road	120	
	Montreal - Frobisher Bay	Medium Haul Air	1,301	1,421
4	Ottawa - Montreal	Short Haul Road	120	
	Montreal - Resolute Bay	Long Haul Air	2,289	2,409
5	Ottawa - Edmonton	Long Haul Rail	2,049	
	Edmonton - Yellowknife	Medium Haul Road	963	
	Yellowknife - Inuvik	Medium Haul Air	680	3,692
6	Ottawa - Maniwaki	Helicopter	50	50

TABLE B-1

REPRESENTATIVE SAMPLING OF POSSIBLE REMOTE "TOURS OF DUTY"

This aircraft is currently in regular commercial and charter service throughout a large part of nothern Canada by such airlines as Nordair and Pacific Western Airlines. Therefore, it has been chosen as a standard.

This selection immediately places a limitation on the maximum size of the terminal's shipping units as shown in Figure B-1. The permissible unit size does not mean a limit to the size of the terminal. However, it imposes the necessity of assembling units to form the terminal and therefore dictates the modular concept.

A larger aircraft, "The Hercules" can be chartered from Pacific Western Airlines (and others). It is the only commercial aircraft capable of transporting the assembled modular terminal or the domestic trailer. As we shall see, however, costs for charters can be very high.

The load capacity of this aircraft is 23 tons, much higher than the estimated weight of either terminal concept. Thus the utility of a Hercules solely to transport the terminal is rather low. Figure B-2 shows the freight space available.

One restrictive aspect of air transportation is that flammables, such as gasoline, cannot fly on the same flight with passengers except in the case of the Hercules carrying no more than two passengers in the cockpit. However, conventional fuel, such as the terminal will require, is available at Resolute and Frobisher (for example) for less cost than if it is flown in, although empty drums may be required.

Transportation by Helicopter is an attractive method when short distances to relatively inaccessible locations are involved. Costs, however, would be very high (as we shall see) so that the use of helicopters would be restricted to tours where either there is no other means of transportation or where the consequences of using other means is unacceptable. The latter situation may occur, for example, if the terminal is to be set up (say, for relay of line TV pictures) on an island during the spring ice-break up period.

B-4 <u>Road Transportation</u>

Order in Council Number 3142 of the Province of Quebec dated September 1971, governs permissible weights and dimensions for highway vehicles in that province. It is related to the Highway Code, which is essentially similar for other provinces, because highway vehicles operate interprovincially. For this reason, we consider Quebec regulations are similar to other provinces and the regulation is summarized, as it relates to the mobile terminal's trailer and towing vehicle, in Appendix B attached to this report.

Also summarized in Appendix B is Section 29 of the Highway Code concerning required lights and reflectors for highway operated vehicles, another part of the Order in Council #3142 concerning combinations of motor vehicles and part of Order in Council #1993 concerning safety devices for trailers.

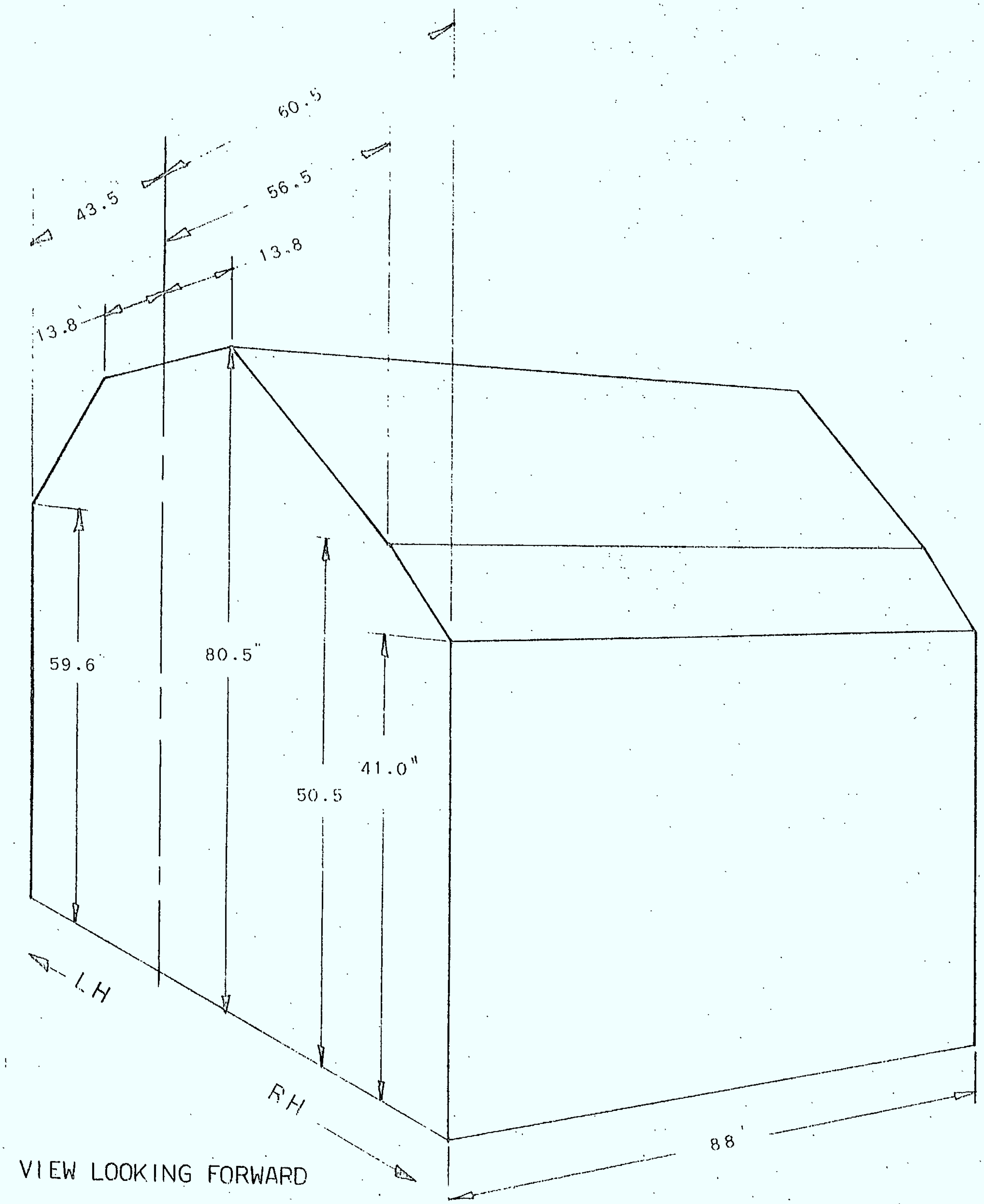
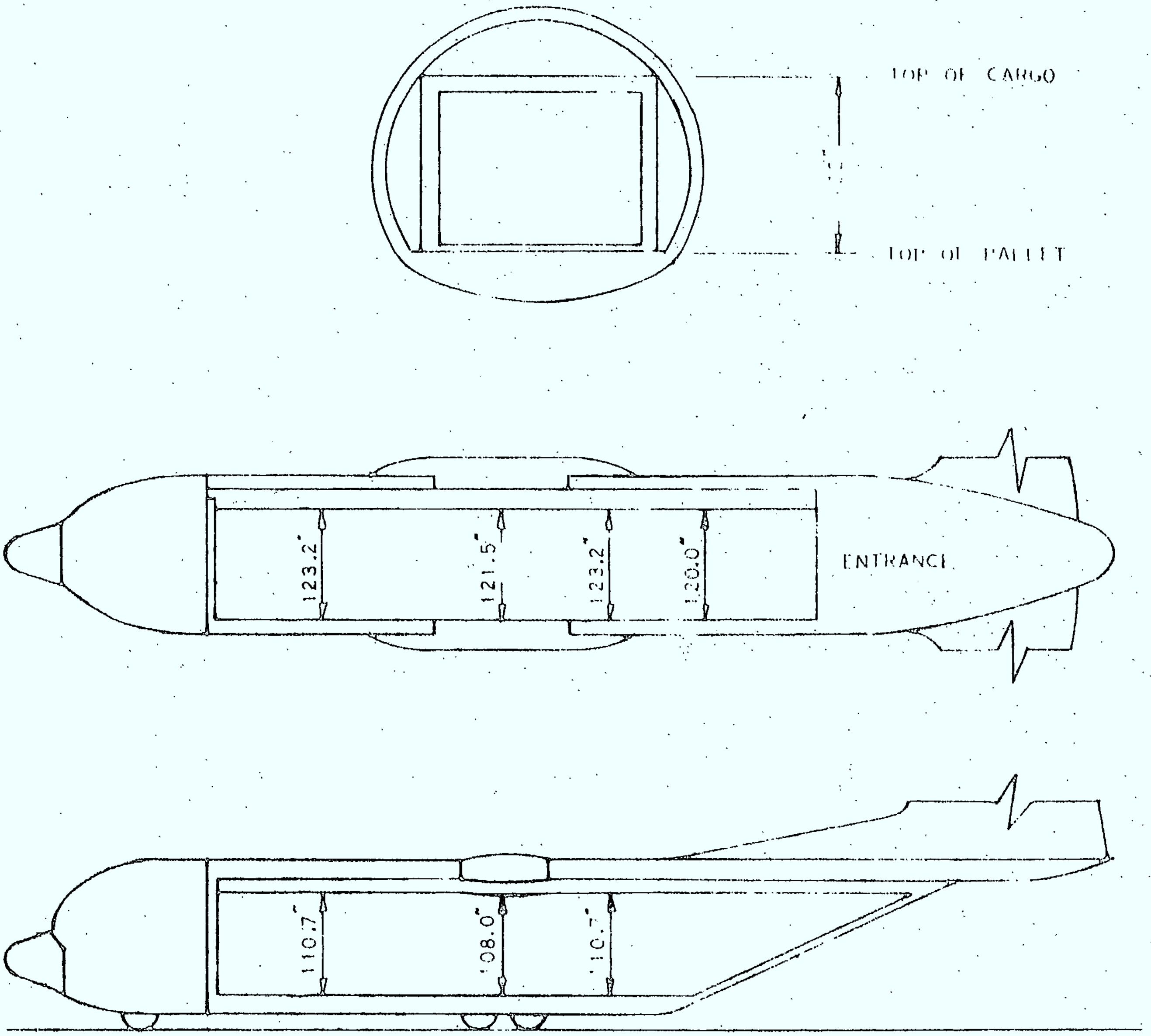


FIGURE B-1

PALLET ENVELOPE BOEING 737

LOCKHEED HERCULES



CHARACTERISTICS.

LOADING DOOR: 10 FT WIDE x 9 FT HIGH

MAXIMUM CUBE UNIT CARGO DIMENSIONS: 47 FT x 9 FT 6 IN x 8 FT 9 IN
(WITHOUT ROLLERS)

DESIRED CUBIC UNIT: 46 FT x 9 FT x 8 FT

CARGO CAPACITY: 5,307 CUBIC FT (BULK) AND 4,138 CUBIC FT OF PALLETIZED CARGO WITH A WEIGHT CONCENTRATION FACTOR OF 7,000 LB PER SQ. FT.

FIGURE B-2 - CARGO COMPARTMENT - LOCKHEED HERCULES

Certain comments can be made about the regulations as they affect the mobile terminal application:-

a) Permissible gross vehicle weights are not restrictive.

b) No more than two vehicles in combination shall be considered.

c) The maximum trailer width should be 8 1/2 feet or less, so that special permits are not required.

d) Three amber lights should be located at the front of the trailer, at the top.*

e) The trailer should be fitted with electric or hydraulic brakes which would have a break-away switch to apply them in the event of break-away from the towing vehicle. In addition, two strong chains should be fitted to connect the trailer to the towing vehicle.

Both the domestic and modular trailers may be towed or transported by truck. When transported by truck, the modular trailer can travel assembled. For normal operational use where sites are serviced by roads, the terminal may be towed directly to the site, with the antenna and positioner and the generator set either stowed in the trailer or carried by the tow-vehicle on a flat bed. In the latter case, the clearance from the top of the trailer to the road surface must be checked. Trucking and towing costs are compared later in Table B-2 and tend to favor trucking.

B-5 Off-Road Transportation

Ground transportation away from roads will often be required around Northern Communities as well as in the south. Some advance assessment of conditions prevailing around remote sites will be required so that prior arrangements can be made to have an appropriate "off-road" vehicle meet the trailer at a convenient time and place. It may not always be possible to have a suitable carrier available at the desired time and place since these vehicles will frequently be rented from agencies such as mining and exploration groups who make full-time use of their specialized equipment and are not in the vehicle-rental business.

Tracked vehicles are commonly used in the North for off-road travel; they are capable of remarkable performance in that few terrains are impassable to them. Heavy loads can be carried up fairly steep and rocky slopes. Of course, relatively inaccessible sites that will require tracked vehicles, are expected to be the exception rather than the rule. Seasonal variations of surface conditions must be anticipated but in most cases travel over snow and ice by tractor-vehicles is straight-forward. However, it may be preferable to charter a helicopter to transport the terminal rather than subject

* This is standard practice to meet the Highway Code, should the towing vehicle not be equipped with these lights.

equipment to the severe shocks likely to be encountered with off-road travel exceeding, say, 5 or 10 miles. Helicopters can accomplish in hours what might take days for a tractor to accomplish. Helicopters may also be more generally available in the north than off-road transportation. Advoidance of damage to the tundra by tracked vehicles will also favour the helicopter.

Wheeled vehicles suitable for off-road transportation are equipped with large, low pressure tires. These have been used in the north with some success; however, their availability may not be too extensive so that their usefulness in this regard is rather limited.

Air cushion vehicles do not appear to be practical machines for transportation. The requirements of surface smoothness and slope severely limit their capabilities. (ref. B1).

B-6 Rail Transportation

Transportation by rail is attractive because it is convenient, reliable and frequent. In addition, CP rail offers a towing service in connection with its piggyback service; Canadian Pacific could tow either trailer by tractor from any convenient location directly onto a flat car. At the destination, another tractor would simply tow the trailer off the flat car to an airport or whatever locations is desired.

Rail transportation should be seriously considered, where feasible, and where transportation distance exceed, say, 500 miles.

B-7 Water Transportation

Transportation by water includes the possibility of using an ocean route to the Arctic coastline. The Ports of Montreal and Halifax would be the most likely embarkation points. However, as the northern shipping season is rather short (early July until late October for the Hudson Bay region; one month for the Norwegian Bay region) and since such voyages take a relatively long time to complete, the use of an ocean route is not recommended. Dock facilities at Northern Ports would also have to be examined.

Transportation by water also includes lake and river routes using ferries and barges. Such routes are most normally extensions of overland routes where the costs of bridges, tunnels, or by-pass roads, prohibits their construction. We recommend that if a proposed tour includes a ferry, or barge route, that the vessel's load capacity be checked for maximum dimensions and weight limits.

In the Northwest Territories, the MacKenzie River system forms a waterway in which an extensive river barge system has been developed. The minimum average sailing time between Hay River and Tuktoyaktuk (1,122 miles) during the shipping season* is

	Continuous Sailing	With Stops & Relays
Northbound:	4 1/2 - 5 1/2 days	9 days
Southbound:	7 1/2 - 9 1/2 days	12 days

Dock facilities and load capacity seem to be satisfactory to handle both terminal concepts but this should be checked if use of the waterway is contemplated.

B-8 Transportation Costs

Table B-2 summarizes estimated direct costs applicable to the representative tours discussed.

Calculation of air transport costs is based upon information supplied by Nordair in Montreal and the Pacific Western Airlines (PWA) Freight Office in Calgary. The air freight rates apply to scheduled flights only but we are advised that if the total freight load exceeds the capacity of the scheduled services, then extra sections are added to the service to "mop up" the back log.

With respect to charter services the following notes are applicable:

1) Hercules aircraft charter costs are calculated on the basis of $4.00 per mile for airline distance exceeding 500 miles. Charter costs for a Boeing 737 aircraft would be $3.15 per mile.

2) If an aircraft is not based at the point where transportation commences, then the costs of flying the aircraft from its base must be added.

3) No Hercules aircraft are based at Montreal or Ottawa at the present time.

4) PWA has no restrictions on unloading times. Nordair charges $500/hr for unloading times in excess of one-half hour.

5) Passengers may be carried on charter flights at no additional cost, although the airline must be advised prior to flight time so that seats may be installed. However, if more than one passenger is to be flown, then regulations require that an airline stewardess or steward be on board (a delightful situation to contemplate).

Calculation of truck and towing costs include rates for drivers.

* The actual shipping season varies with weather conditions and latitude but typically lasts from late May until late October.

TABLE B-2

ESTIMATED TRANSPORTATION COSTS FOR REPRESENTATIVE TOURS

TOUR	ROUTE	MODE	ESTIMATE SOURCE	APPLICATION	COSTS ($) OUT	RETURN	ROUND	NOTES
1	Ottawa - Toronto	Road by Towing	National	Both concepts	160	160	320	1
		Road by Flatbed	Kingsway	Both concepts	206	206	412	
		Rail by Piggyback	CP	Both concepts	120	120	240	2
2	Ottawa-Prince Rupert.	Road by Towing	National	Both concepts	1,576	1,576	3,152	1
		Road by Flatbed	Kingsway	Both concepts	1,180	1,180	2,360	1
		Rail by Piggyback	CP	Both concepts	1,300	1,300	2,600	2
3	Ottawa-Montreal	Road by Towing	National	Both concepts	115	115	230	1
	Montreal-Frobisher Bay	Air Freight-Boeing 737	Nordair	Modular concept	3,780	2,100	5,880	
	Montreal-Frobisher Bay	Air Charter-Boeing 737	Nordair	Modular concept	8,000	8,000	16,000	3,4,5
4	Ottawa - Montreal	Road by Towing	National	Both concepts	115	115	230	1
	Montreal-Resolute Bay	Air Freight-Boeing 737	Nordair	Modular concept	4,200	2,100	6,300	
	Montreal-Resolute Bay	Air Charter-Boeing 737	Nordair	Modular concept	14,000	14,000	28,000	3,4,5
5	Ottawa-Edmonton	Road by Towing	National	Both concepts	1,306	1,306	2,612	1
		Road by Flatbed	Kingsway	Both concepts	1,010	1,010	2,020	1
		Rail by Piggyback	CP	Both concepts	1,080	1,080	2,160	2
	Edmonton-Inuvik	Air Freight-Boeing 737	Pacific	Modular concept	5,200	2,600	7,800	
		Air Charter-Electra	Pacific	Modular concept	8,920	8,920	17,840	3,5
		-Boeing 737	Pacific	Modular concept	11,040	11,040	22,080	3,5
		-Hercules	Pacific	Both concepts	14,250	14,250	28,500	3,5

TABLE B-2 (cont'd)

TOUR	ROUTE	MODE	ESTIMATE SOURCE	APPLICATION	COSTS (S) OUT	RETURN	ROUND	NOTES
	Edmonton-Yellowknife	Road by Flatbed	Pacific	Both concepts	17,250	17,250	355	
	Yellowknife-Inuvik	Air Freight-Boeing 737	Pacific	Modular concept.	3,465	2,100	5,565	
6	Ottawa-Maniwaki	Bell 204 -B Helicopter Charter	Northern	Modular concept	3,750	3,750	7,500	3,5,6

NOTES:

(1) Includes Driver

(2) Towing service available at destination at
S10.00/hr for Eastern Canada
S11.00/hr for Western Canada
includes drivers.

(3) Costs for returning aircraft to base included.

(4) Charter costs include 1/2 hour allowance for unloading at destination. Costs for additional unloading time if necessary, at pro rated charge of S500/hr.

(5) Availability of aircraft when needed must be checked beforehand. Many aircraft leased for long periods at a time.
Basic rate is S500/hr.

(6) About 5 return trips of 1 1/2 hours duration are estimated necessary to transport modular trailer. Larger helicopters (Skycrane) may serve some areas but availability may be difficult to obtain because of lease arrangements with construction companies, etc.

(7) National - National Trailer Convoy
Kingsway - Kingsway Freight Lines
CP - CP Rail
Pacific - Pacific Western
Northern - Northern Wings Helicopter

Calculation of rail costs are for basic transportation if the service of a towing vehicle are required at either end of the journey then additional costs (including driver) of $10.00 per hour in Eastern Canada, or $11.00 per hour in Western Canada, must be added.

Costs for transportation to Inuvik* assumes that Edmonton and Yellowknife are interim locations where the modes of transportation are changed. The route is therefore by rail to Edmonton, by road from Edmonton to Yellowknife, and from Yellowknife to Inuvik by air.

B-9 Preparation and Travel to the Remote Site

The key to any remote operation is the organization and planning operations prior to the tour. Basic guidelines specifically related to the terminal operation should be spelled out in some detail in an Operations Manual, and blank checklists should be provided which would form part of the service log. We assume that the above is provided and that the terminal crew is thoroughly familiar with the procedures.

The preliminary organizational routines to be followed include:

a) experiment definition and time table and time duration estimate.

b) investigation to the extent necessary regarding facilities, land, power availability, supplies, etc., at the remote site.

c) listing and gathering of special equipment required.

d) gathering and checking of spares, maintenance tools, shipping containers, etc.

e) requisitions of expendibles, fuel, special clothing, etc.

f) dummy run(optional) of experiment, particularly if new techniques are to be tested.

g) arrangements with carriers for receiving, loading and unloading the mobile terminal.

h) arrangements for accomodations for the crew at or near the place of remote operations.

The extent to which these preparations are made will depend, of course, upon the nature of the experiment, the remote location, and the familiarity of the crew with the remote location. A typical schedule for an operational 2 week "Tour of Duty" to Resolute Bay is given in Table B-3.**

* This table was prepared prior to the announcement by the Canadian Government of plans to construct an all-weather road to Inuvik from the south.

** Regular scheduled flights by Nordair were assumed in preparing this schedule.

TYPICAL OPERATIONAL RETURN 2 WEEK TOUR OF DUTY TO RESOLUTE BAY

TASK	ACTIVITY	WEEKDAY	START	STOP	DURATION	NOTE
Station Set-up						
A	Transportation to Montreal	Wednesday	8:30	12:15	3 hrs. 45 min.	
B	Trailer Disassembly	Wednesday	13:30	16:15	2 hrs. 45 min.	
C	Aircraft Loading	Thursday	By carrier as necessary			
D	Flight to Resolute Bay	Thursday	11:00	16:05	6 hrs. 5 min.	Regular Nordair Schedule.
E	Aircraft unloading	Thursday	By carrier as necessary			
F	Trailer assembly	Thursday	16:45	19:30	2 hrs. 45 min.	
G	Transportation to site	Friday	8:30	11:30	3 hrs.	
H	Set-up on site	Friday	12:30	16:30	4 hrs.	
I	Satellite Aquisition	Friday	16:30	16:40	10 min.	
J	Operational Preparations	Friday	16:40	17:10	30 min.	confirm status
Experimental Period						
	Start experiments ↓	Friday ↓	17:10 ↓	- ↓	As required	Soonest possible Includes operational check
	Stop experiments and sign off	Sunday	-	15:00	As required	Latest possible.
Return to Ottawa						
A	Dismantling on site	Sunday	15:00	17:00	2 hrs.	
B	Transportation to Airport	Monday	8:00	11:00	3 hrs.	
C	Trailer Dissassembly	Monday	12:00	14:45	2 hrs. 45 min.	
D	Aircraft loading	Monday	By carrier as necesssry			
E	Flight to Montreal	Monday	16:50	23:40	5 hrs. 50 min.	Regular Nordair Schedule.
F	Aircraft unloading	Tuesday	By carrier as necessary			
G	Trailer Assembly	Tuesday	10:00	12:45	2 hrs. 45 min.	
H	Transportation to Ottawa	Tuesday	13:45	17:30	3 hrs. 45 min.	

TOTAL TOUR TIME - 13 days, 9 hours - AVAILABLE OPERATIONAL TIME - 8 days, 22 hrs. 50 min.

TABLE B-3

A summary of the steps necessary to prepare the terminal for transportation is given in Table B-4. Reusable shipping containers for all miscellaneous supplies as well as for the antenna components are recommended.

If information regarding the remote location is sketchy or not available, it would be a good policy to send one of the crew members to the location at least one or two days prior to transporting the terminal to survey the area and to select an appropriate operating spot.

Transporting the Domestic Trailer is quite conventional, be it by road, rail or air (in a Hercules) and need not be discussed in detail. However, the modular trailer, if transported by air, deserves some additional comments.

If the intended remote location for the terminal is, say, near Resolute, then the steps necessary for transporting the modular trailer from Ottawa to Resolute are as outlined in Tables B-5 and B-6. Here, we assume one crew member is already in Resolute. Figure B-3 shows the trailer being disassembled, Figure B-4 shows the trailer stored as freight in a Boeing 737 fuselage.

Current commercial air schedules list two regular flights per week to Resolute from Montreal* departing on Mondays and Thursdays at 11:00 A.M. The scheduled flight duration is 5 1/2 hours. A reasonable procedure would thus specify that the mobile terminal would be delivered to the carrier in Montreal a day prior to the flight date by the second crew member who would then remain in Montreal overnight to oversee the aircraft loading the following day and then travel on the same aircraft. Following arrival at Resolute, both crew members would re-assemble the terminal and, if time permits, tow it to its operating location. Terminal set-up and satellite aquisition could commence in the morning after the flight.

We have assumed roughly normal 8 hours-a-day for the activities of the crew members, although it is quite impractical to adhere to a 8:00 hours to 17:00 hours work day. Additional time would be required whenever unforeseen difficulties arises, or if the experiment schedule dictates the necessity. A detailed examination of such requirements is both premature and beyond the scope of this report.

B-10 Site Selection and Preparation

Sites accessible by road very near or within communities will normally present a few surface difficulties unless permafrost is present. With no permafrost, it is sufficient to choose hard and level soil making use of footpads** where necessary under the jacks to reduce the bearing loads and prevent settling. A site should have ample space to permit set-up operations. Operations on top of permafrost is undesirable: if necessary, however, special techniques exist for supporting the terminal (ref. F-7).

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* Nordair schedule effective April 30, 1972.

** Footpads should be sized to suit the expected bearing capability of the ground.

TABLE B-4
TYPICAL PREPARATION ACTIVITIES FOR THE MOBILE TERMINAL

STEP	ACTIVITY	COMMENT	NOTE
1.	Plan Operations appropriate to type of experiment.	1) Determine any special equipment requirements	1
		2) Determine spare needs	
		3) Determine expendables needed	2
		4) Determine routing	
2.	Obtain special equipment and checkout total system.	If necessary.	
3.	Check terminal's tool kit, spare parts compliment, shipping containers, etc.	Include special equipment requirements in this step.	
4.	Ensure that all batteries are fully charged and that electrolyte levels are satisfactory.	Charge and/or maintain as necessary.	
5.	Obtain expendable materials.	Expendables may also be procured at destination. This possibility should be examined.	2
6.	Check antenna system for accuracy and operation.	Include mount in this examination. Correct and/or align as necessary.	
7.	Dismantle and pack antenna components into shipping containers.		
8.	Pack tool kit, spare parts, expendable material.	Consider sequence of accessibility in this step. For example, access to the tool kit may be required during transit. Therefore, it should be clearly marked and be easily available.	

TABLE B-4 (cont'd)

TYPICAL PREPARATION ACTIVITIES FOR THE MOBILE TERMINAL

STEP	ACTIVITY	COMMENT	NOTE
9.	Check trailer hitch, suspension, chassis, etc.	Ensure that lubricating, maintenance, etc. has been performed as required.	
10.	Stow shipping containers in trailer.		
11.	Stow module handles in trailer.		

Notes:

1. A check list will be very useful. The operations manual should include blank check-sheets containing check-lists of regular equipment and provision for check-lists of special equipment.

2. Expendables are considered to be fuel (for both heating and power), oil, water, etc.

3. Time, schedule not shown. This will depend upon experiment capability and extent and efficiency of support facilities.

TYPICAL PROCEDURE TO TRANSPORT TERMINAL FROM OTTAWA TO MONTREAL

STEP	ACTIVITY	COMMENTS	ESTIMATED TIME DURATION
1	Towing vehicle arrives at CRC	Preparations completed	-
2	Connect towing vehicle to trailer	Ensure compatibility of hitches	15 min.
3	Tow trailer to Nordair Freight Terminal at Dorval, Quebec.	Pre-arrange with carrier for space to dissassemble terminal	3 hours.
4	Install and set jacks, and disconnect towing vehicle.	Return towing vehicle to Ottawa	30 min.
		Total elapsed time - -	3 hrs. 45 min.

TABLE B-5

TABLE B-6

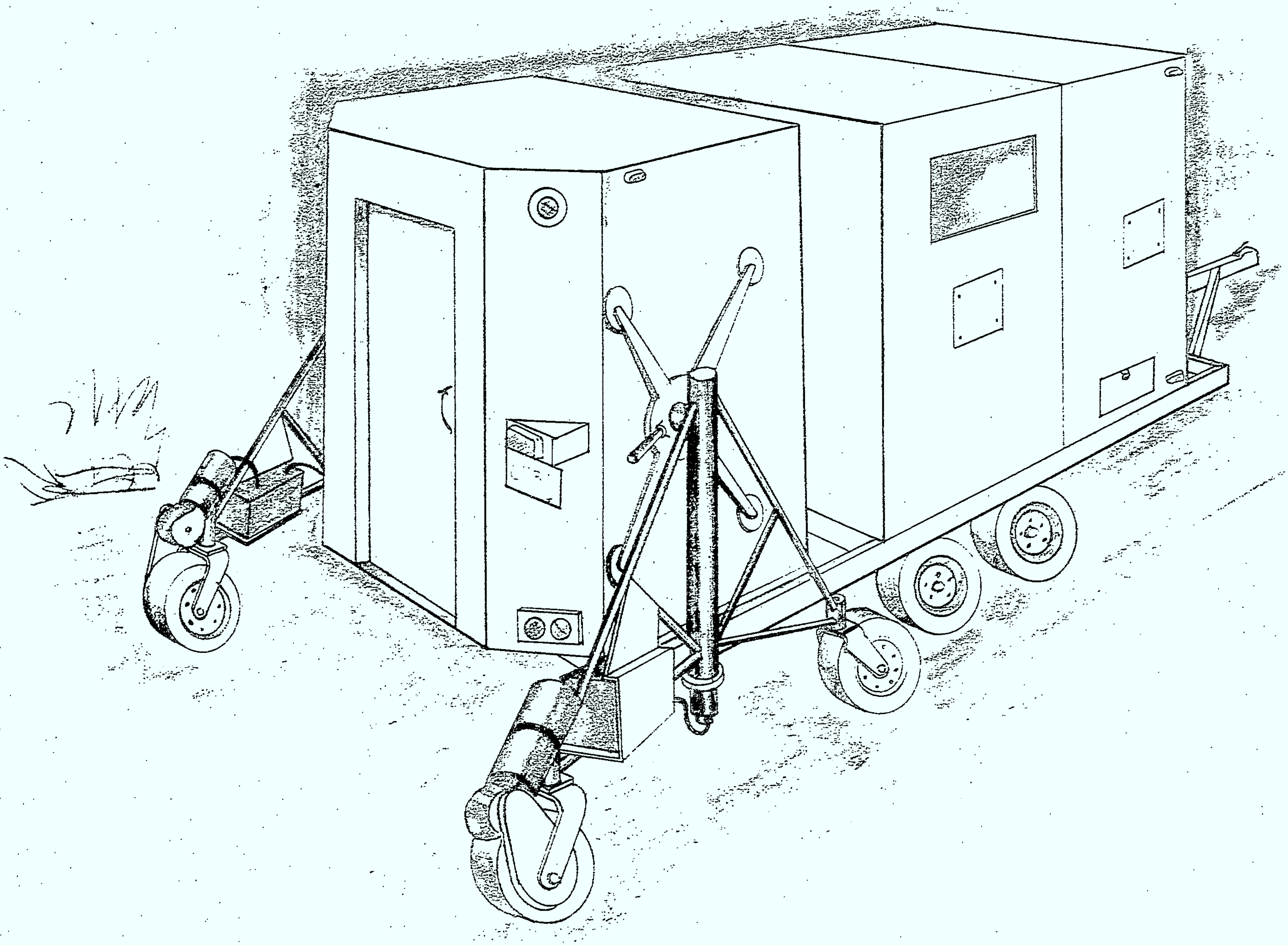
TYPICAL PROCEDURE TO TRANSPORT MODULAR TRAILER FROM MONTREAL TO RESOLUTE BAY

STEP	ACTIVITY	COMMENTS	ESTIMATED TIME DURATION	NOTE
1.	Remove module shipping covers		10 min.	
2.	Remove antenna shipping cases, auxiliary cases and load auto pallet 2.	Use fork lift truck	10 min.	1
3.	Remove motor generator set and load onto pallet 1.	Use fork lift truck	10 min.	1
4.	Release fasteners linking module 3 to module 2, and module 3 to chassis.	Quick release fastener	10 min.	
5.	Lift module 3 off chassis and move away about 3 feet.		5 min.	
6.	Attach shipping covers to opened sides of modules 3 and 2.		15 min.	
7.	Move module 3 clear of chassis, rotate through 90° and lower until module is about 6" off ground.		10 min.	
8.	Move module 3 and set onto pallet 5.		5 min.	1
9.	Release fasteners linking module 2 to module 1, and module 2 to chassis.		10 min.	
10.	Lift module 2 off chassis and move away about 3 feet.		5 min.	
11.	Attach shipping covers to opened sides of modules 2 and 1.		15 min.	
12.	Move module 2 clear of chassis, rotate through 90° and lower until module is about 6" off ground.		10 min.	

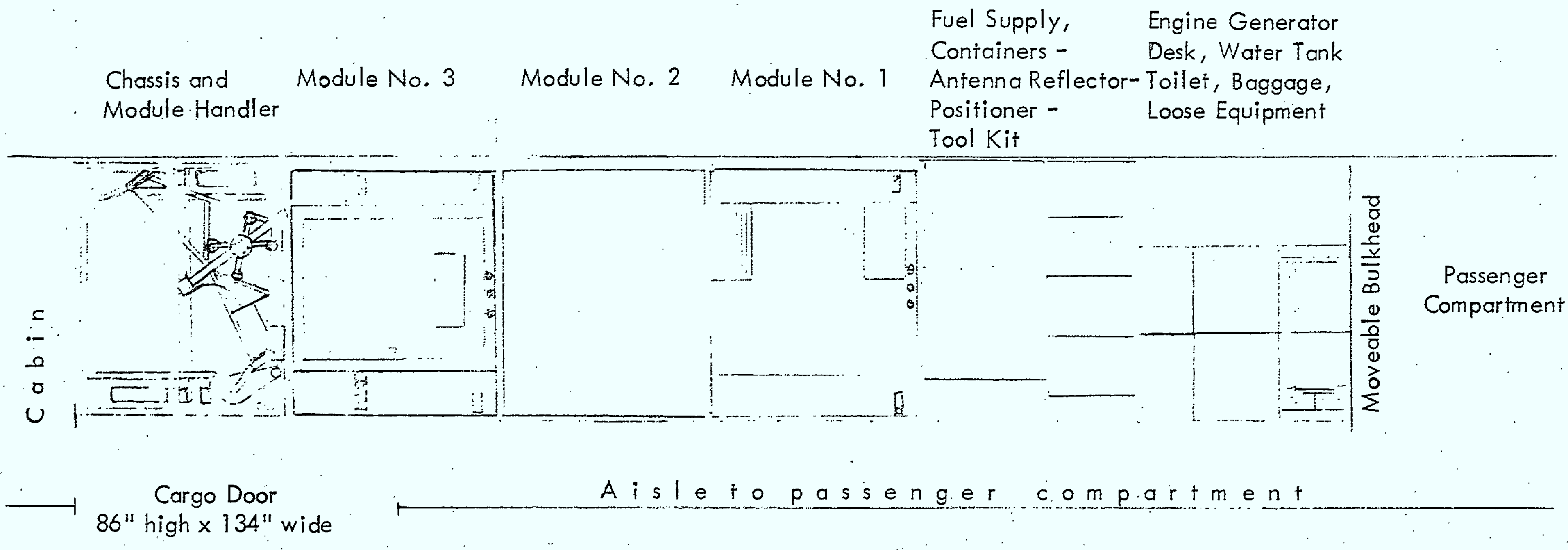
TABLE B-6 (cont'd)

STEP	ACTIVITY	COMMENTS	ESTIMATED TIME DURATION	NOTE
13.	Move module 2 and set onto pallet 4.		5 min.	1
14.	Release fasteners linking module 1 to chassis.		5 min.	
15.	Lift module 1 off chassis and move clear.		5 min.	
16.	Rotate through 90° and lower until module 1 is about 6" off ground.		10 min.	
17.	Move and set onto pallet 3.		5 min.	1
18.	Lift ends of chassis and fold inwards to compact		5 min.	
19.	Load module handler onto chassis.		10 min.	
20.	Set chassis onto pallet 6.	Use fork lift truck	5 min.	1
21.	Advise carrier disassembly completed.		-	1
		TOTAL ELAPSED TIME	2 hrs. 45 min.	

Note: (1) These activities must be co-ordinated with the carrier.



DISASSEMBLY OF MODULAR TRAILER
FIGURE B - 3



Notes:

1. Max. no. pallets = 7
2. For mixed cargo & passenger configurations
   Passenger Capacity - 6 pallets = 10
   5 pallets = 28
3. Payload - 23,000 to 28,000 lbs. (depending on fuel carried)

FIGURE B-4

MODULAR TERMINAL LOADED INTO BOEING 737

In Northern communities, antenna elevations will be small, hence high-ground with a clear unobstructed view of the horizon is desirable in the direction of the spacecraft. Low antenna elevations present a possible safety hazard for personnel entering the transmitter beam; warning signs should be posted. Power from a 500 watt transmitter radiating from a 10 foot dish will result in beam flux densities of approximately 7 to 20 mw/cm^2. The current recommended maximum flux levels to which personnel should be exposed is commonly taken to be 10 mw/cm. However, this figure is considered by many (and particularly Russian investigators) to be too high.

B-11 Set-up Procedures and Interface

The terminal must be located such that the "V" formed by its corner containing the antenna mount points approximately to the satellite. Local landmarks or other information can be used to determine this. The steps to be followed in preparing the terminal for service are essentially identical for both the domestic trailer and modular trailer concepts. Table B-7 summarizes the steps and includes a time duration estimate for each of the steps. Figure B-5 shows the antenna erection in progress.

For the particular tour under discussion, interface requirements for the terminal involves only a power connection from the motor generator. If externally generated baseband or IF signals are involved, then appropriate connections to the interface panel are also required. These connections use standard impedance levels of 50 ohms unbalanced for IF, 75 ohms unbalanced for video, and 600 ohms balanced for audio. Further details are given in Section C.

Figure B-6 is a plan view of a typical set-up for a remote terminal and shows optional connections to local hydro if sufficient power with the correct voltage characteristics is available*, and interface with an assumed broadcasting crew for transmission of broadcast television signals.

B-12 Satellite Acquisition

One operationally important part in the operations manual should be a set of tables relating the elevation and azimuth angles of the line-of-sight between the satellite at its specified parking spot in the equatorial plane to points on the earth in a grid network specified by latitude and longitude. Included in the tables should also be the nominal angle, called the tracking angle, at which the N-S motion of the satellite would appear to an observer at the grid points.

We assume that we have such a set of tables and that we know the latitude and longitude of our terminal. However, our ability to set true elevation and azimuth are dependent upon the accuracy with which we can define as references true horizon and true north (or south). Provided the spirit levels with which we align the trailer are accurately placed and calibrated, there is no problem with defining

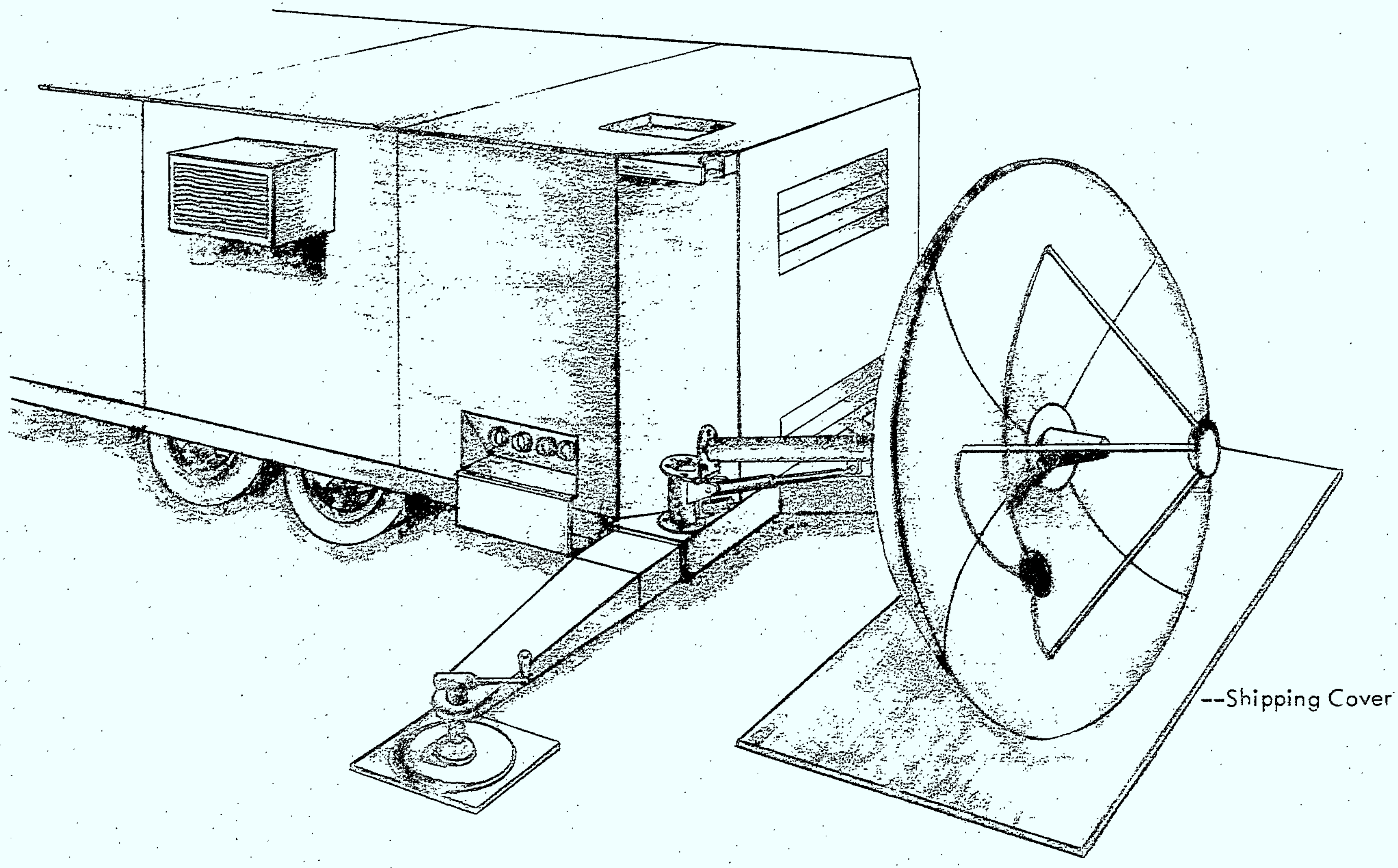
* Details for such connections must be pre-arranged.

TABLE B-7
TYPICAL SITE SET-UP PROCEDURE

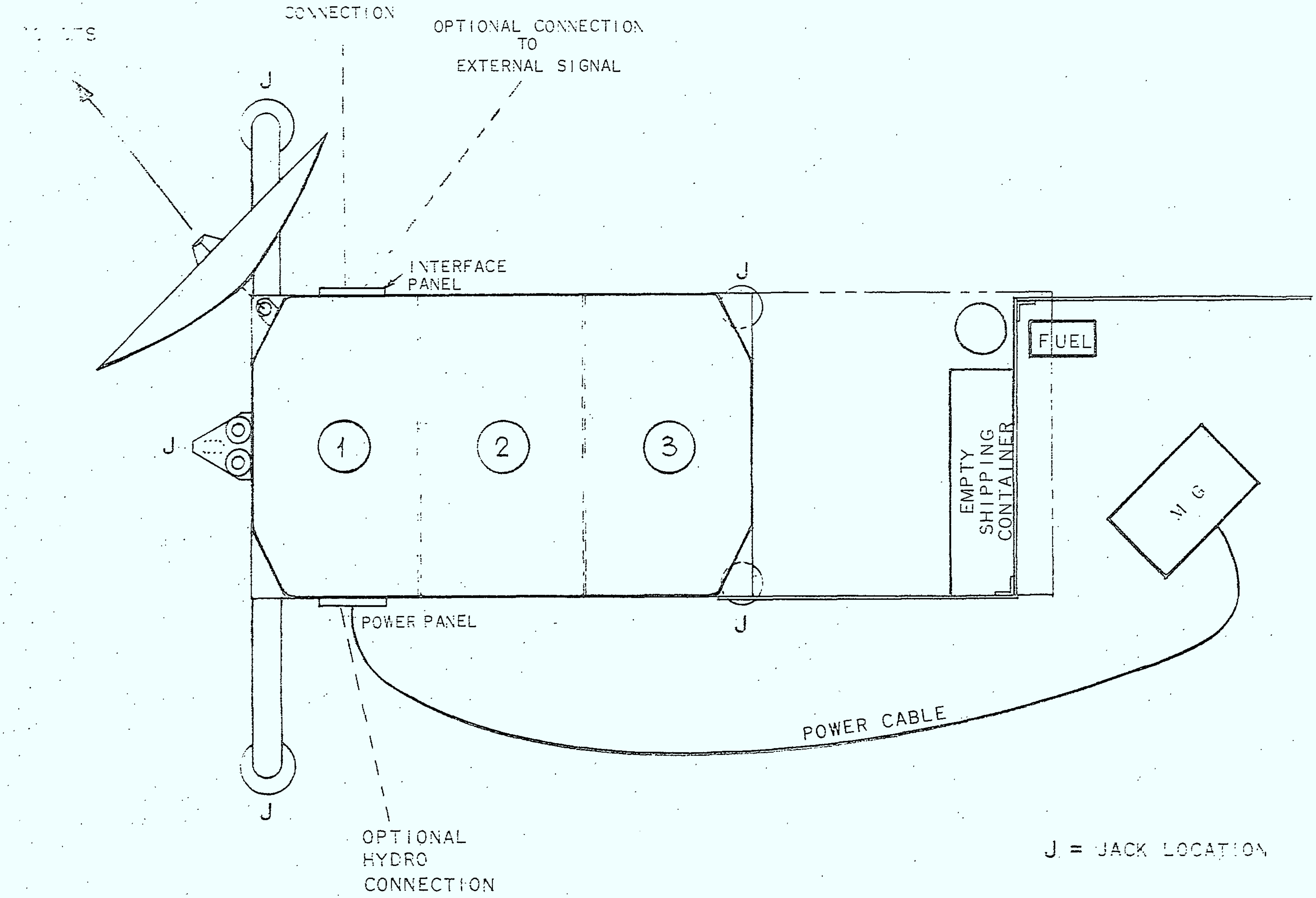
STEP	ACTIVITY	COMMENTS	ESTIMATED TIME DURATION
1	Clear site area.		15 min.
2	Locate trailer on site.	Corner with antenna mount column to point south.	5 min.
3	Install and set jacks, and disconnect towing vehicle.	Return towing vehicle to source; use appropriate foot pads.	20 min.
4	Pull antenna shipping cases, auxiliary cases, and module shipping covers from trailer.	Use modular handler if necessary.	5 min.
5	Pull motor generator set from trailer and locate conveniently.	See set-up	5 min.
6	Unpack antenna components and miscellaneous equipment.	Do not destroy packing material.	15 min.
7	Install and connect MG fuel tanks.		15 min.
8	Connect power cable between trailer and MG set.		5 min.
9	Start and warm up MG set	If advisable or necessary.	5 min.
10	Rough level trailer	Use body mounted spirit levels.	10 min.
11	Lay one module shipping cover on ground and drop antenna mount column and antenna mounting ring.	Position so that top of antenna mount column, when dropped, is above centre of cover.	
	Install and check antenna.	See Table D-5. Position antenna mount column suitably.	85 min.
12	Fine level trailer.		15 min.

TABLE B-7 (cont'd)

STEP	ACTIVITY	COMMENTS	ESTIMATED TIME DURATION
13	Check MG operation; check all cable connections and interfaces; place heating and ventilating equipment into operating mode.	Use check list.	15 min.
14	Energise communications equipment, warm up.		5 min.
15	Use module shipping covers to build shelter area.		15 min.
16	Clean up and store empty shipping cases and materials.		5 min.
			4 hours.



ANTENNA ERECTION
FIGURE B - 5



PLAN VIEW OF SITE SET - UP

FIGURE B - 6

the true horizon. However, with respect to the azimuth, we have a problem. Magnetic compasses throughout much of the north, are of limited accuracy.

An azimuth reference can be roughly obtained by use of landmarks and maps, the position of the sun or stars* and the time of day. But even so, the accuracy of obtaining the azimuth reference is considerably less than that of obtaining an elevation reference.

The possibility that the satellite's orbital tilt may be as much as 2° off the equatorial plane introduces uncertainty in the location of the satellites along the tracking axis. Thus, even though we have a relatively accurate horizon reference, we have a uncertainty slightly larger than $\pm 2^{\circ}$ as measured along the tracking path, in the actual elevation angle to the satellite.

The antenna positioner is adjustable about three axes (see Section E-4). One axis is preset perpendicular to the tracking angle at the site, or at Ottawa, in accordance with the remote site coordinates. This adjustment would make the second axis (elevation) parallel to the earth's equatorial plane so that rotations about this axis would be perpendicular to the equatorial plane. The third, or azimuth axis, is perpendicular to the local horizon.

To initiate the search we point the antenna along the nominal line-of-sight given in the table for our particular location using our established azimuth and elevation references.

Because of the uncertainties in the reference and in the elevation angle of the satellite, the true-line-of-sight to the satellite will lie within a solid angle centered along our assumed line of sight. In the Appendix we show that this solid angle may be $\pm 30^{\circ}$ in azimuth and $\pm 5^{\circ}$ in elevation. We therefore off-set the antenna in azimuth -30°, and, starting at the extreme left of the solid angle, sweep to the right at a rate of approximately 1° per second. At the end of the sweep, the elevation angle should be increased by an antenna beam width followed by a second sweep from right to left. The elevation angle should now be decreased by 2 beamwidths followed by a third sweep from left to right. The process is repeated until aquisition is made. Figure B-7 illustrates the search pattern.

A further uncertainty must be considered. If the beacon is used as a locking signal, then uncertainties in the beacon frequency as well as uncertainties in the terminal local oscillator frequency coupled with a narrow band receiver will cause frequency misalignments. Thus the receiver will have to sweep over the expected range of frequency misalignment at least once for every search element**. In defining the above azimuth sweep rate we have considered this factor (see Appendix E). If a wideband signal is used as a locking source, then frequency search will probably not be needed.

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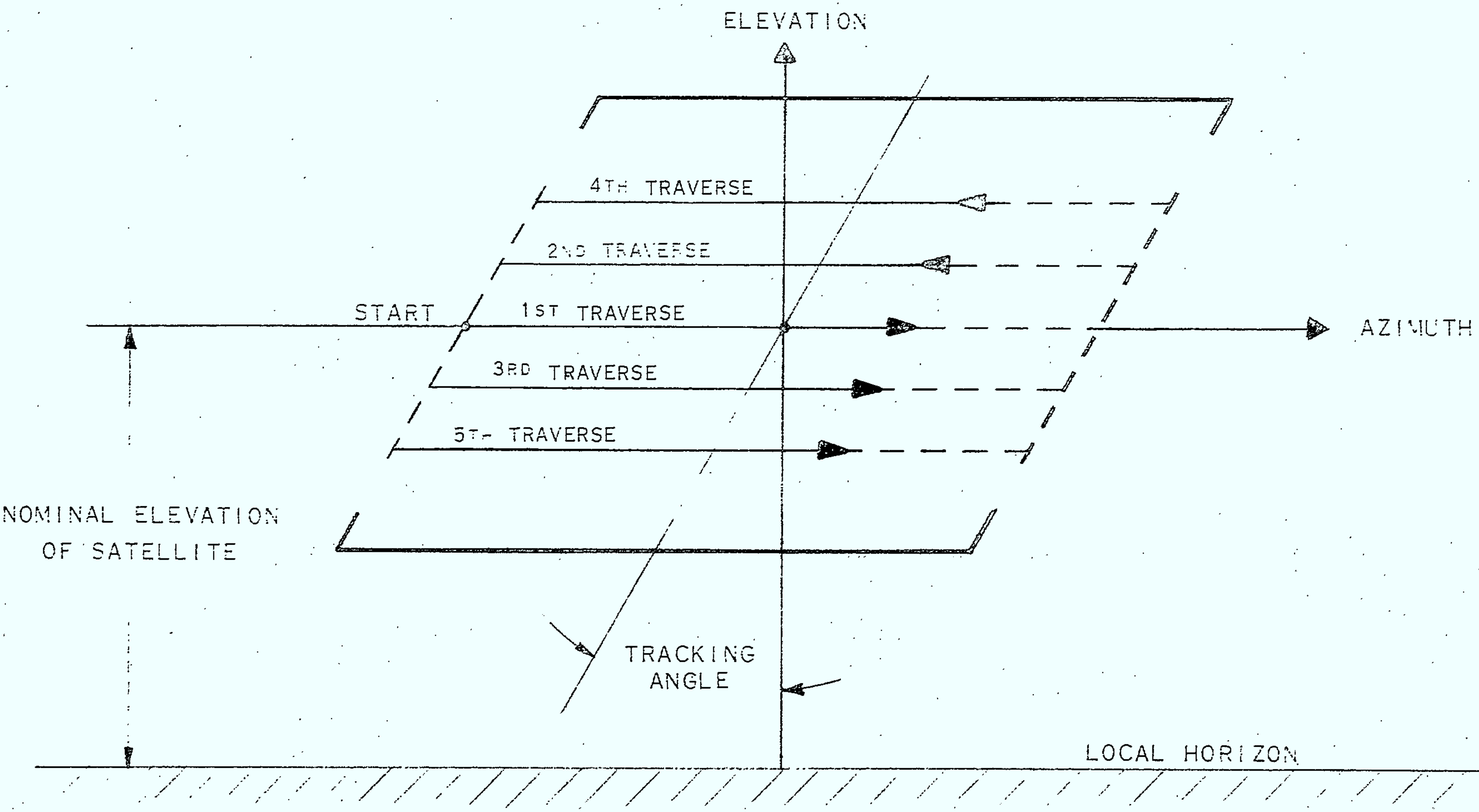
* Depending on the weather and the season.

** A search element is defined as the antenna beamwidth in which the carrier-to-noise ratio resulting from the received signal exceeds the defined threshold.



SEARCH PATTERN

NOMINAL-AZIMUTH-ANGLE

FIGURE B-7

B-13 Terminal Operation

We can do no more than touch terminal operation, for details depend largely upon the experiment. In most cases, however, requirements are straightforward and generally comparable with earth terminal operation anywhere. We assume that satellite aquisition has been made and that either the beacon or a communications signal provides the reference.

Two-way voice facilities via the satellite to the Ottawa Control terminal should be established first on a pre-assigned channel preferably at pre-arranged times, although this latter restriction may not be necessary. The mobile terminal design should be such that operation of two-way voice channels need not require energizing the main transmitter. In fact, two-way voice equipments should have the capability of battery operation so that information of a failure or malfunction in either the motor generator set, or the main transmitter, can be transmitted to the main control terminal.

A comprehensive station log should be kept to record, with reference to operations,

a) nature of the experiment

b) system configuration

c) equipment turn on time (except transmitter)

d) transmitter turn-on-time

e) transmitter radiate interval

f) all instrument readings

g) experiment readings

h) primary power readings

i) observed malfunctions or failures

j) turn off times

The capability of two men to carry out a comprehensive set of measurements will be limited and must be considered when preparing the operations plan. Their capabilities can be extended through use of recording equipment such as paper strip recorders or multi-channel pen recorders. Connected to a suitable clock, these devices provide useful and dated records.

Often, however, the terminal would be used simply as a relay for signals generated externally, say, from a remote broadcasting unit, or a computer terminal. The tasks of the operators would then be much simpler and could consist of simply monitoring input and output signals to ensure their qualities with reference to some specified standards. The operators would have to ensure that grounding problems between themselves and the external sources do not exist, or must take steps to minimize them or eliminate them if they do exist.

Long hours are often required of field personnel. This is not a serious situation unless the nature of the activities leads to fatigue because of boredom, excessive hours without breaks, or overly demanding tasks. These aspects must be considered for any tour of operation because incapacitation of one man by illness or injury is a relatively more serious matter here than it would be for a larger crew.

B-14 Completion and Return

The last operational field act of the crew should be to sign "off-the-air" using two-way voice communication to Ottawa indicating the expected itinerary for return. Flight schedules for Nordair from Resolute to Montreal indicate flights on Mondays and Thursdays, both leaving at 16:50 hours. Therefore, preparation of the terminal for towing transportation to Resolute airport, and disassembly of the terminal for air shipment, can easily be done on the day of the flight. However, since arrival time in Montreal is scheduled at 23:40 hours, reassembly of the terminal and towing to Ottawa should be carried out the following day after a reasonable rest period. The operational steps to be followed are in reverse order to those taken when starting out on the tour.

The condition of the remote site should be left as close as possible to the state it was in before arrival. In particular, waste material, garbage, empty bottles, etc. should not be left at the site. This is as much an act of necessity as it is of courtesy, for one of the characteristics of the north is the extreme length of time that it takes the forces of nature to repair the damage or to disintegrate the debris left by man.

When the terminal is returned to Ottawa, it can either be left in the towing configuration if another tour of duty is imminent, or set-up as the standby system for the main communications control terminal. Such repairs or replenishment of supplies as are necessary should be performed as soon as practical after return. Lubrication, removal of rust, paint "touch-up", etc., are recommended activities to be carried out on a routine basis after each tour.

B-15 Standby Operation at Ottawa

When not in the field, the terminal may profitably be used as a standby for the main communications control terminal at Ottawa. Thus, in the event that portions of the main terminal fail, or malfunction, then use of the mobile terminal can prevent the loss of many experiments or operations.

Since the mobile terminal antenna is smaller and its receiver is noisier* than those for the main terminal, both its G/T ratio on receive, and its EIRP on transmit are significantly less. Table B-8 compares these parameters.

As transmitting stations, the standby and main terminal are interchangeable and no signal parameter changes are needed, as long as the required EIRP for a given experiment is less than 76.4 dBW. If this is not the case, then an investigation of possible signal parameter changes should be initiated to see if EIRP requirements can be decreased. (This latter investigation should in any case be made as a contingency plan for any experiment).

As a receiver terminal, the lower G/T ratios for the mobile terminal compared to the main terminal means that the spacecraft must transmit more power in the carrier. Incidentally, increasing the transponder power by transmitting more power from the transmitting terminal shifts the system noise budget towards a greater downpath contribution, therefore for otherwise similar parameters in the signal we need not increase transponder power as much as the receiving terminal G/T ratio might seem to indicate.

The capabilities of the other transmitting equipments and the spacecraft gain setting must therefore be checked to see if an experiment can be handled by the remote terminal, and, if not, to determine what parameter changes are necessary or possible. Again, this should be carried out as a contingency plan.

With the exception of two-way voice services, none of the proposed baseline terminals for CTS experiments will be capable of transmission. Therefore, the use of the mobile terminal as standby will be more likely as a transmitter than as a receiver. With respect to two-way voice operations, the current 4 foot terminal with a 1 watt transmsitter capability may be operationally marginal in a standby situation. However, even here communications may still be possible, albeit more noisy.

What we have considered up to now is a comparison of the capabilities of front ends, transmitters and antennas. Operationally, we must also consider interfacing between the two terminals.

* We are informed that a room temperature parameter amplifier is contemplated for the main control terminal.

COMPARISON OF MAJOR PARAMETERS OF MOBILE AND MAIN COMMUNICATIONS TERMINALS

PARAMETER	MAIN COMMUNICATIONS CONTROL TERMINAL.	MOBILE TERMINAL	UNIT
Antenna Diameter	30	10	Feet
Front end	Parametric Amplifier	TDA	
Noise Figure	3.5	6.5	d B.
Transmitter Power	350 (Note 1)	350	watts (min)
EIRP	89.4	74.8	dB W (max)
G/T ratio	32.2	18.4	dB/
Antenna Gain (Tx)at 14 GHz	59.9	50.4 dB	dB
Antenna Gain (Rx)at 12 GHz	58.6	49.1	dB

Note: (1) This assumes that the transmitters in the control and mobile terminals are identical.

TABLE B - 8

A most convenient interface would be at IF for the following reasons:-

1) operational duties are easier performed in the main control terminal than in the remote terminal because of space limitations.

2) interface at IF means that the RF amplifiers, up converters and down converters are in the mobile terminal while IF filters, modulators, demodulators and baseband processing equipments are in the control terminal.

3) most operational duties are performed on the IF filters, modulators, demodulators and baseband equipments.

The location of the receiver remote from the operating area should not cause any operational difficulty, since wideband receivers commonly operate for long periods of times unattended.

There are, however, two problems that must be resolved. First, limited antenna tracking is required, and second, transmitter operation must be controlled.

To resolve the first problem, the mobile terminal should be fitted with an interface socket connecting the tracking actuators and the antenna pointing readout devices. A remote control panel interface plug and interconnecting cable should be provided for the main control terminal so that control and monitoring of the mobile terminal's antenna in the main terminal is possible. Interface to the main terminal's computing facilities may be added for a programmed track capability.

To resolve the second problem, a similar remote facility for remote control of the mobile terminal's transmitter radiate/standby operation, and remote monitoring of transmitter power, voltage, etc., in the main control building should be provided. Remote adjustment of transmitter power level would be a useful, but not essential feature. It should not be necessary to turn the transmitter on or off remotely as long as the physical separation of the remote and main terminals is not too great.

Interface at baseband is also quite possible, and sufficient facilities for such interfacing are part of the terminal's complement. All that is needed is to ensure compatibility of signal levels, polarity (for video) and impedance characteristics.

Interface at RF is not recommended in view of the high frequencies involved and the rather significant losses that would be incurred using 12 GHz and 14 GHz transmission lines.

A primary power service at the main building should be provided to which the mobile terminal can connect. In the event of loss of hydro power, the motor generator set can be used to provide primary power.

If a particular experiment has a high enough priority, both stations should operate in parallel, but the mobile terminal should draw primary power from the motor generator set. Thus, in the event of a loss of hydro power, or other failures affecting the control terminal, the remote terminal would be unaffected and could easily assume the responsibility for the experiment.

SECTION C

COMMUNICATIONS SYSTEM

C-1 General

The communications system for the mobile terminal is configured to satisfy:

a) the experimental requirements while the terminal is in field service

b) the back-up requirements for the main control terminal near Ottawa.

We have assumed that these requirements are established by the baseline description given in reference C-1 . However, the probability that other as yet undefined experiments will be performed has been noted and suitable interface facilities have been provided to allow for this in the most flexible manner.

The baseline system permits experiments in the following services:

1) 525 line NTSC color signals with from 1 to 4 associated audio channels.

2) conventional FM sound broadcast signals.

3) Single-channel-per-carrier two-way voice signals.

and the terminal is equipped with the appropriate baseband processing equipment. In addition, other experiments may include:

4) TDMA signal transmission.

5) wideband PCM signal.

6) facsimile.

7) remote computer terminal services,

to mention just a few.

Both single conversion and double conversion IF system can be used. Single conversion is the least costly; double conversion is the most flexible. Both are briefly examined.

We begin this section with discussion of terminal capabilities, EMC considerations, IF frequency selection and frequency plans, and discuss optional aspects. Table C-1 lists the general specifications for the communication system.

TABLE C-1
COMMUNICATIONS SYSTEM - GENERAL SPECIFICATIONS

PARAMETER	VALUE	UNIT	NOTES
GENERAL			
Antenna Type	Parabolic		Sectional
Feed	Cassegrain		
Diameter	10	feet	
Receiver Front End	TDA		
Transmitter	Parallel TWT's		Air Cooled
TRANSMIT			
Frequency Range	14.0-14.5	GHz	
Tuning Range	14.0-14.5	GHz	2nd LO Tuning
RF Bandwidth Capability	85	MHz	
1st IF	70	MHz	
2nd IF	735	MHz	Nominal
Deviation Capability	± 20	MHz	Peak, Max.
IF Bandwidth	40	MHz	Video signals
Antenna Gain	50.4	dB	at 14.5 GHz
Transmit Output Power	350	Watts	Minimum
Line Losses	1.0	dB	Typical
EIRP	+74.8	dBW	Boresight
RECEIVE			
Frequency Range	11.7-12.2	GHz	
Tuning Range	11.7-12.2	GHz	1st LO Tuning
RF Bandwidth Capability	85	MHz	
1st IF	70	MHz	
2nd IF	580	MHz	Nominal
Discriminator Capacity	± 20	MHz	Peak, Maximum
IF Bandwidth	38	MHz	Nominal
Antenna Gain	49.1	dB	
Line Losses	1.0	dB	
Receiver Noise Figure	6.5	dB	
G/T Ratio	18.5	dB/°K	
BASEBAND			
Bandwidth Capability	10	MHz	Maximum
Response Variation	± 0.5	dB	Max. over BW
Gain Stability	± 0.5	dB	max. 10 hr interval
Interface Levels - video	1.0	V	p-p
- audio & sound	+9	dBm	max. signal
Interface Impedance -video	70	ohms	unbalanced
- audio and sound	600	ohms	balanced

C-2 Capabilities

The practices followed in developing the terminal's communications system are similar to those used in current earth station designs, for that is precisely what the mobile terminal is. "Off-the-shelf" equipment design has been selected in most cases to minimize costs. The basic television performance to be expected should, in most cases, be equivalent to the quality standard established by Intelsat. Up to 4 high fidelity audio channels may be handled as subcarriers. FM sound broadcast quality can be as high as conventional local services, except that RF satellite power limitations will probably preclude conventional 2 channel stereophonic transmission.*

Considering the above factors, and the basic needs that the terminal must satisfy, the terminal's capabilities have been specified to include:

1) Transmission and reception of 525 line NTSC color video signals.

2) Transmission and reception of from 1 to 4 audio signals as subcarrier of the main video signal, or 1 audio signal as a separate carrier.

3) Transmission and reception of 1 compatible FM sound signal.

4) Transmission and reception of 2 two-way voice signal operation and order wire circuits for:

   a) remote terminal operation
   b) other experimenters making use of the terminal.

5) Interface at IF to permit

   a) connection of special experimental signals such as PCM signals, etc.
   b) connection to the main terminal at Ottawa as a back-up unit.

6) Interface at baseband for television, sound, and order wire circuits.

7) Back-to-back loop testing using a test loop translator.

IF filters similar to those established for Intelsat are recommended for the terminal. If these are used, and assuming that signal parameters are suitably adjusted, then performance equivalent to that provided by Intelsat may be expected.

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* For equal carrier powers, the output signal-to-noise ratio for a conventional stereophonic signal is about 22 dB lower than that of a conventional monophonic signal.

C-3 EMC Considerations

EMC considerations are covered in detail in Appendix C-5. Here we summarize the approach taken and the preventive measures recommended.

Coupling of wanted and unwanted signals can occur at the RF frequencies via the antennas, but in the 12 and 14 GHz bands the aspects of sharing and co-ordination that are problems of considerable magnitude in the 4 and 6 GHz common carrier bands are not yet too significant and can usually be handled on a specific "case-by-case" evaluation if necessary. The trailer's operating site can easily be changed if interference into, or by, another system threatens to be a problem.

The antenna's side lobe characteristics have been specified to be some 30 to 40 dB down. These characteristics are compatible with relatively economical antenna design and good EMC characteristics, considering the total environment.

The trailer's EMI characteristics should be similar to that of a screened room. Special gasketing techniques are recommended for the modular trailer while additional EMI screening is suggested for the domestic trailer. By these means, both the emission of spurious signals from the trailer's equipment and the susceptability of the equipment to external signals will be minimized.

The concept of the "screened room" assists at the IF frequencies which, at least for the first IF equipment of the receiver chain, is potentially susceptible to interferences.

General engineering considerations include the use of "good engineering practice" with regard to connectors, grounding, shielding, installation power line filtering, etc. If this is followed, we feel that electromagnetic compatibility is assured.

C-4 IF Frequencies

Figures C-1 and C-2 are block diagrams of the communication system using single conversion and double conversion techniques respectively. Single conversion, as illustrated by Figure C-1 is potentially the most economical since only one frequency converter per signal path is required. However, signal selectivity and bandwidth capability is more restrictive. The IF frequency is 70 MHz for compatibility with current communications equipment parameters as recommended by CCIR and other committees.

The greater selectivity of double conversion methods, as illustrated in Figure C-2 makes it the desirable choice for the mobile terminal. The equipment complexity is not increased significantly. Additional costs are also reasonable, providing currently available equipment is chosen. The choice of what the secondary IF frequencies should be is complicated by the lack of standardization between equipment suppliers; each one uses his own criteria for selection.

FIGURE C-2.
BLOCK DIAGRAM
DOUBLE IF CONVERSION COMMUNICATIONS SYSTEM

FIGURE C-1.
BLOCK DIAGRAM
SINGLE IF CONVERSION COMMUNICATIONS SYSTEM

As an example, RCA Limited offers double down-conversion for frequency conversion from 4 GHz (nominal) to 589 MHz to 70 MHz and double up-converters for frequency conversion from 70 MHz to 735 MHz to 6 GHz (nominal) in their standard earth station line. The selection of frequency steps is based purely on considerations of the interaction of the harmonics that are generated as mixing products. The fact that simple loop back-to-back testing cannot be done in the 735 to 580 MHz IF loop is not considered serious from an operational point of view, since back-to-back testing may be done at the 70 MHz IF directly, or at RF using a test loop translator to represent the satellite.

For the CTS Program, although RF signals are in the 12 GHz and 14 GHz bands, the middle IF frequencies of 735 to 580 MHz are still a reasonable choice. The higher IF to RF frequency ratio means that harmonic interactions can be kept quite low.

There is another consideration, however, that merits some attention. The CRC simulation program for communications experiments calls for the procurement of suitable equipments to simulate the ground-satellite-ground link. The IF frequencies for this simulation facility are specified at 70 MHz and 500 MHz. This suggests that, for the most representative simulation, the Ottawa communications control terminal might be similarly equipped.* If this is the case, then perhaps the mobile terminal should be similarly equipped, so that interface between the control and mobile terminals at either IF frequency would be possible.

Finalization of the higher IF frequencies is one area which should be determined by consideration of the total CTS communications system. We will assume, for the purpose of illustration, that IF frequencies of 70 MHz, 580 MHz, and 735 MHz are used in the mobile terminal. Figure C-3 shows a typical rack layout for a double conversion communication system packaged for mobile terminal service.

C-5 Frequency Plans

The frequency assignments for the baseline signals are not yet finalized. Nevertheless, we have made some assumptions with respect to a potential assignment which permits:

a) simultaneous transmission or reception of all baseband signals

b) fixed tuning of receivers or convertors so that service selection is obtained by equipment switching rather than adjustment.

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* At the time of writing, the authors are not aware of any decision by CRC on the Control terminal communications equipment parameters.

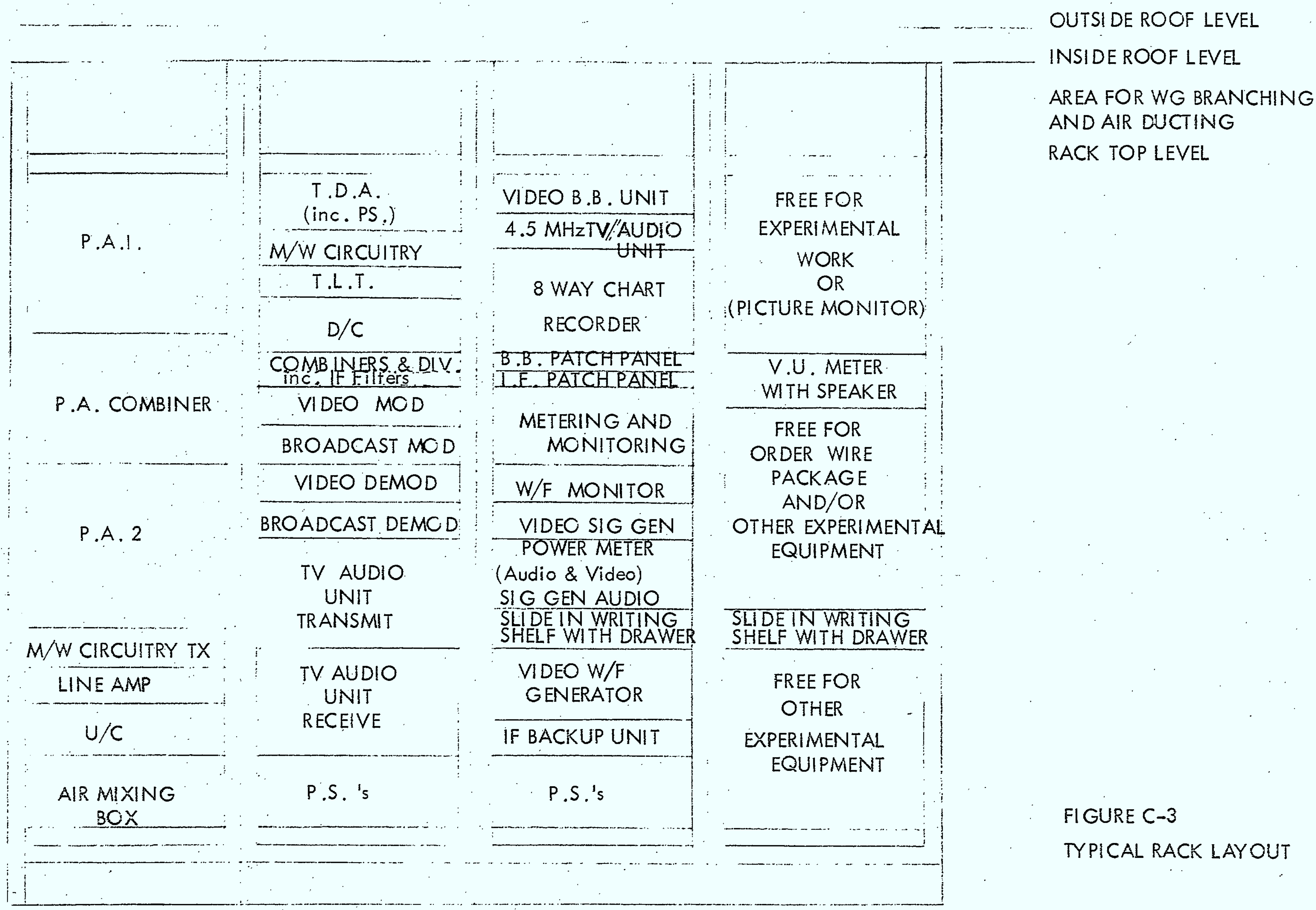

FIGURE C-3

TYPICAL RACK LAYOUT

Figure C-4 illustrates the assumed frequency assignments in the 70 MHz IF band. The consideration used in arriving at the assignments are that

a) each service has a clear spectrum "slot"
b) wideband modulated video IF signals should be centered on 70 MHz
c) the sound signals' IF frequencies should be in the conventional FM band (88 to 108 MHz)
d) order wire IF frequencies should be below the video IF
e) the second or 3rd harmonic of the order wire signals should not fall in the sound IF slot.

C-6 RF Transmission Lines

For antenna tracking, three degrees of freedom are considered to be desirable: azimuth, elevation, and rotation about the antenna boresight. Rotation about these axes is generally less than 45 degrees, which permits several possible methods of waveguide runs. It is essential that these should minimize losses in transmit and receive sections because of their effects on transmitter power requirements and on noise temperature. Figure C-5 shows a possible configuration, whose calculated losses would be about 0.9 dB in each of transmit and receive directions.

C-7 Transmitter

For economic reasons, the recommended transmitter concept is to use two TWT's operating in parallel, and phased and balanced by suitable phase shifters and attenuators. At present, 350 watts minimum or +25.45 dBW* is available although 500 watts (or +27 dBW) is quite possible with extra engineering effort. Alternatives such as higher power klystrons are possible but require considerable development at considerable cost. (See Appendix C-6).

The drive for the transmitter would be a TWT amplifier assembly giving nominally 1 watt of output. However, solid state amplifiers of this capability are just becoming state of the art and by the time the equipment is required they may be a feasible alternative, giving space and weight savings.

C-8 Receiver - Front End

The receiver front end would be a room temperature T. D. A. (tunnel diode amplifier) with a basic noise figure of less than 6 dB. To allow for implementation and time degradation, we are assuming a worst case noise figure of 6.5 dB.

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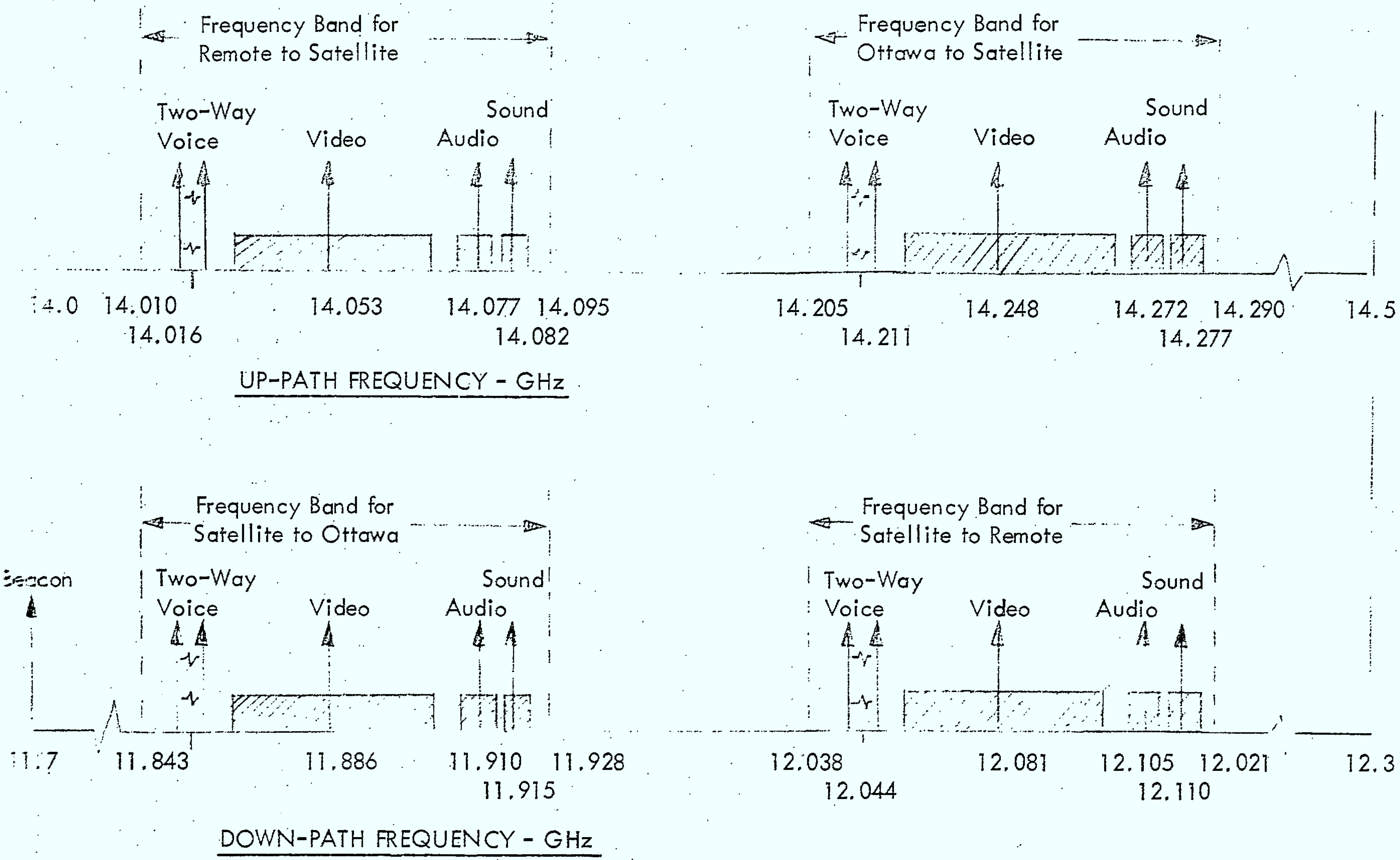
* Current performance calculations, indicate that this power is just sufficient for the baseline signals. Further refinements may be in order if the experimental program expands to include experiments requiring increased bandwidth, transmitter powers, etc.



Notes: Frequency assignments are for illustration only. An overall Frequency Plan for communications experiments is still to be developed.

FIGURE C-4
ASSUMED FREQUENCY ASSIGNMENTS

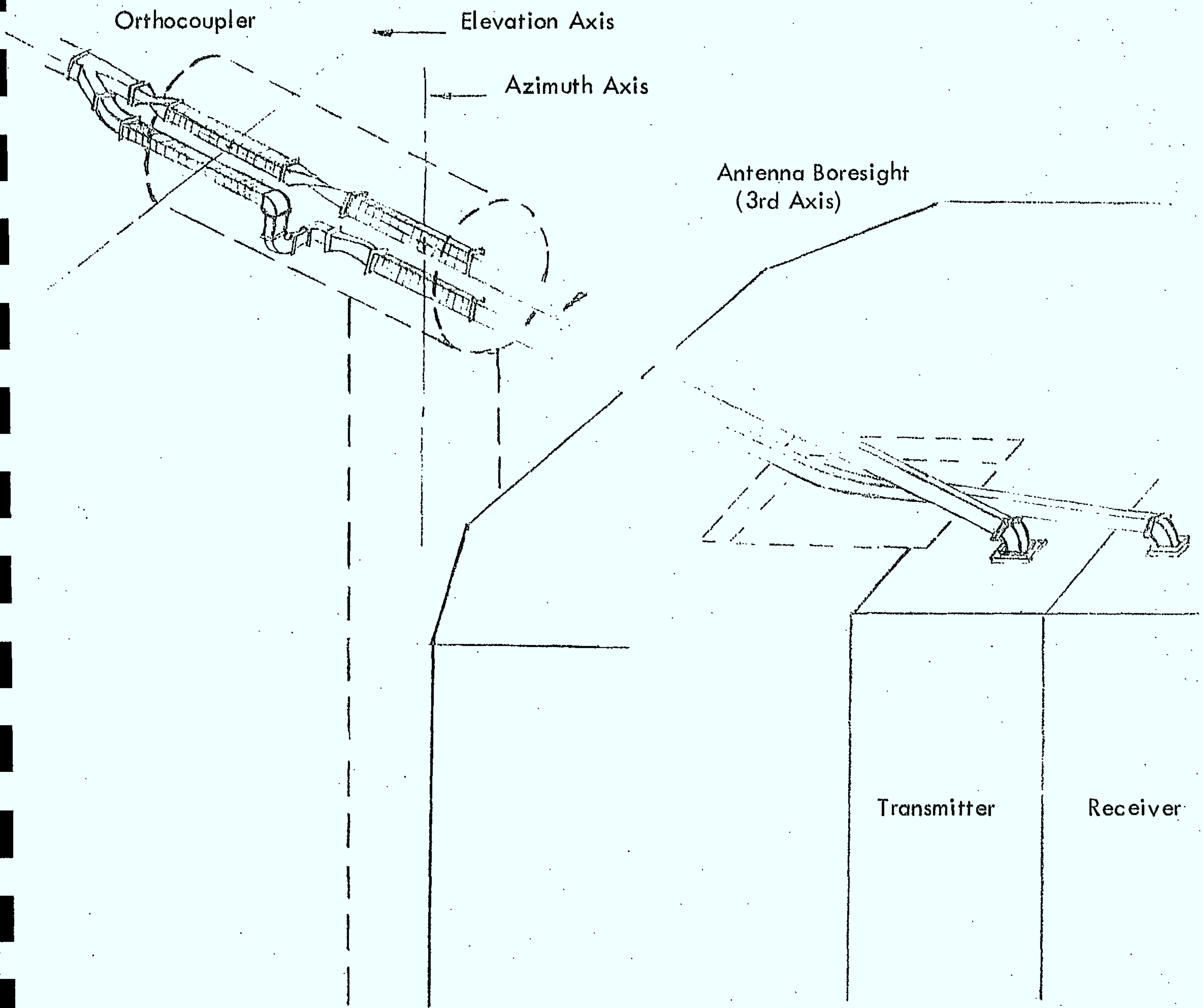


FIGURE C-5

RF TRANSMISSION LINES

Mounting the low noise receiver on the antenna structure has been considered. In view of the small advantage to be gained (perhaps 0.2 dB) and the complications of design, operation, and maintenance, we have discarded this possibility.

The dual up and down converters would use balanced mixers with conversion loss of about 10 dB and be driven by solid state sources readily available of +8 dBm and a frequency stability of $\pm$ 50 kHz. Filtering of output and IF amplification in wideband IF amplifiers would be part of the up and down converter packages.

C-9 RF Interconnections

All interconnecting should be heliax between the low noise amplifier and down converter, and between the low power amplifier and main amplifier.

Switches and heliax interconnections would be made available for connecting an order wire unit (see C-15) either through some of the active equipment or directly to the antenna feed for emergency or standby operations.

C-10 Modulators

Separate modulators are suggested for the video, audio, and sound signals. The video modulator is a wideband unit with an adjustable deviation capability of 20 MHz peak, centered on 70 MHz. "Off-the-shelf" modulators are available with the performance needed.

Audio modulators provide sub-carriers which are added above the baseband. Five such modulators are recommended so that either a single sound signal on a 4.5 MHz sub-carrier can be generated and added to the video signals for subsequent reception using conventional receiver circuits (following the video detection) or four sub-carriers at 6.74 MHz, 7.5 MHz, 7.86 MHz, and 8.74 MHz respectively can be generated for broadcast use.*

The sound modulator provides an output at 99 MHz nominal thereby enabling sound loop tests to be made, or checking of the modulator with a high quality, but conventional "off-the-shelf" FM tuner.

C-11 Demodulators

Facilities for demodulation provide the same flexibility for signal handling in the receive direction as the facilities for modulators does in the transmit direction.

The video demodulator is capable of handling FM signals with deviations up to 20 MHz peak. The output baseband capabilities must be 10 MHz to cover the combined spectrum of the video baseband and the audio sub-carrier spectrum.

* These frequencies are chosen to avoid interference from its second harmonic of the color sub-carrier (3.58 MHz nominal).

The five audio sub-carrier demodulators differ primarily in the discrimination center frequency adjustments.* Either the conventional audio sub-carrier at 4.5 MHz can be processed, or sub-carriers at 6.74 MHz, 7.50 MHz, 7.86 MHz, or 8.24 MHz can be demodulated.

The sound demodulator consists of a down converter from 99 MHz to the conventional FM IF frequency of 10.7 MHz. From this point on, conventional FM circuit components can be used. Alternatively, the high quality FM tuner may be used in place of the described system.

C-12 Baseband

Baseband equipment is standard. Pre-emphasis and de-emphasis, in accordance with North American standards, are suggested for the video, audio, and sound signals. The amplifiers, attenuators, and patching facilities are all "off-the-shelf" and specific details may depend upon the manufacturer, particularly in the case of patching equipment. Figure C-6 shows a typical patch panel layout.

C-13 Interface with External Signal Sources

The trailer specifications call for the provision of a weatherproof interface panel, accessible from the outside. Weatherproof video and audio bulkhead connectors are mounted on this panel to which external video, audio, sound, or other wire cables may be connected. When no such connections are required, the bulkhead connectors should be capped with "termination caps" containing appropriate line terminators. These caps should be chained to the panel to prevent loss when disconnected.

The uncertainty of the length of external signal cable, and therefore its attenuation, means that the level of the signals at the terminal may be less than standard. Further, in the case of video signals the attenuation may be frequency sensitive, a rather serious aspect for color. Variable equalizers and line correction amplifiers should be provided where necessary to correct for these problems.

In the case of audio or sound signals, a potential "hum" problem exists, since the power sources and the earth potential of the signal sources between external signals and the terminal may be different. For that reason, line isolation transformers should be provided, and grounding should be so arranged, that the shields of the balanced interconnecting cables are grounded at one end only. Figure C-7 shows a typical interface circuit.

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* For compatibility, the 4.5 audio sub-carrier peak deviation should be set to 25 kHz. The four "broadcast" sub-carriers typically use deviations set to 100 kHz.

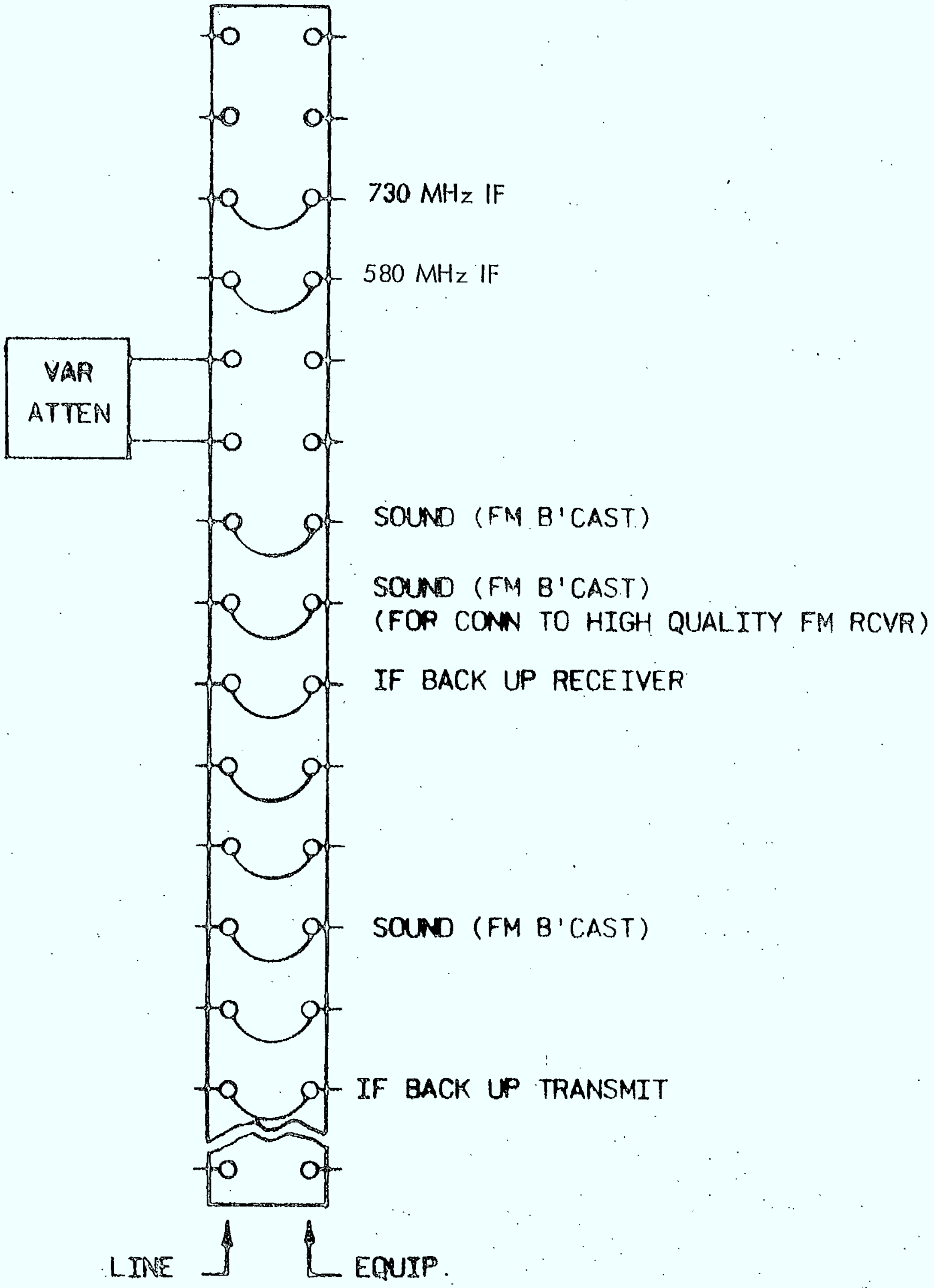


FIGURE C-6-A

I F PATCH PANEL

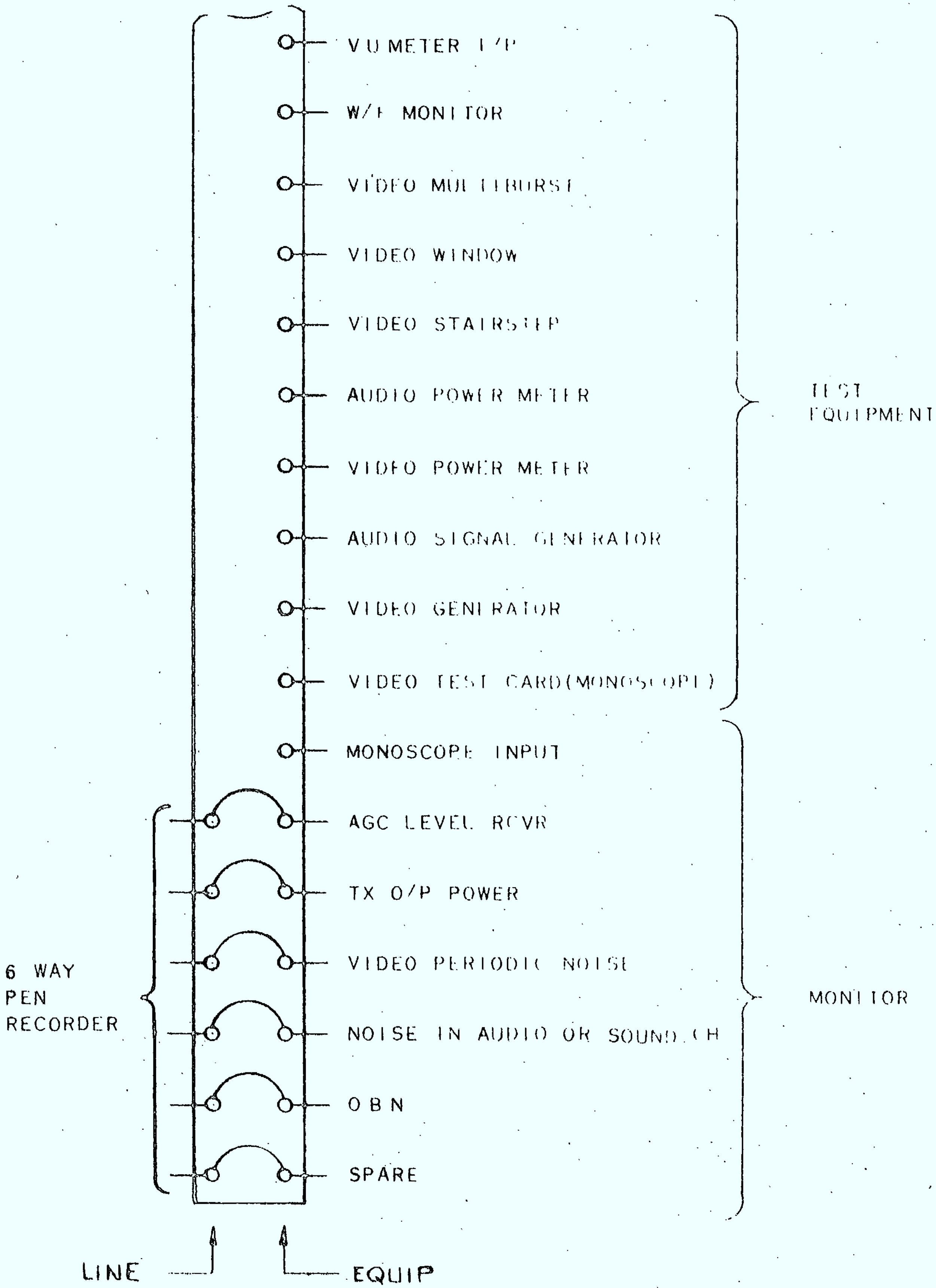


FIGURE C-6-B TEST PATCH PANEL FACILITY

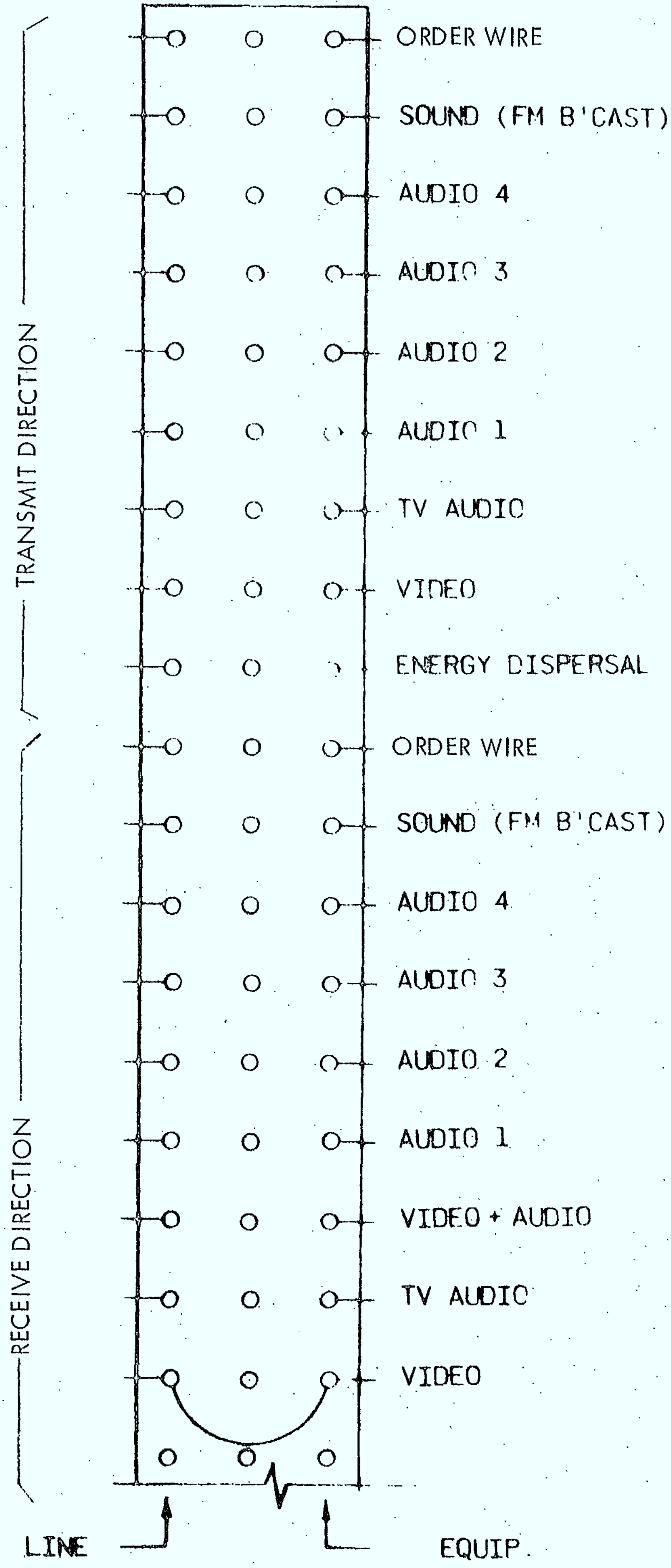


FIGURE C-6-C BASEBAND PATCH PANEL NO. 1

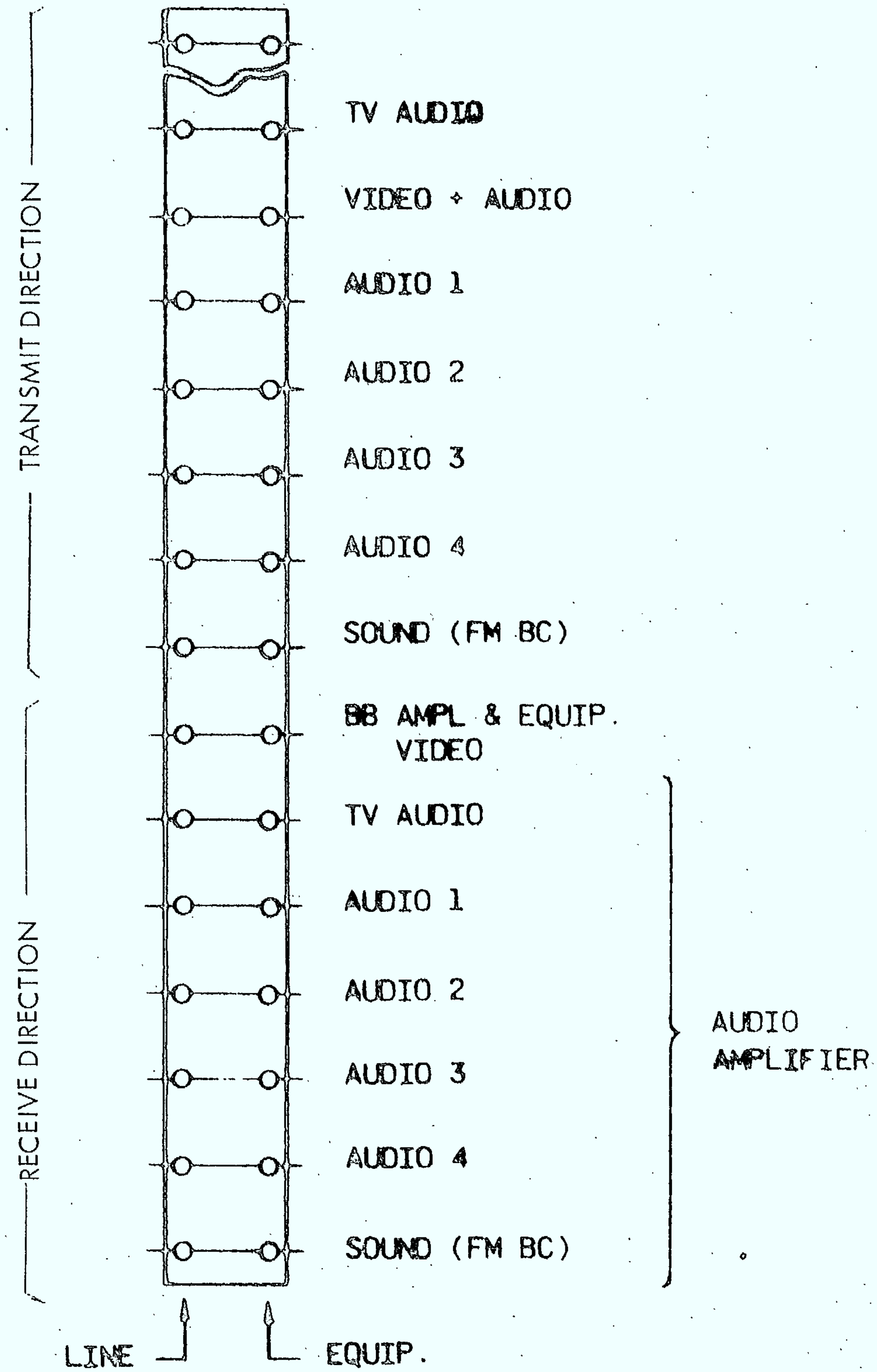
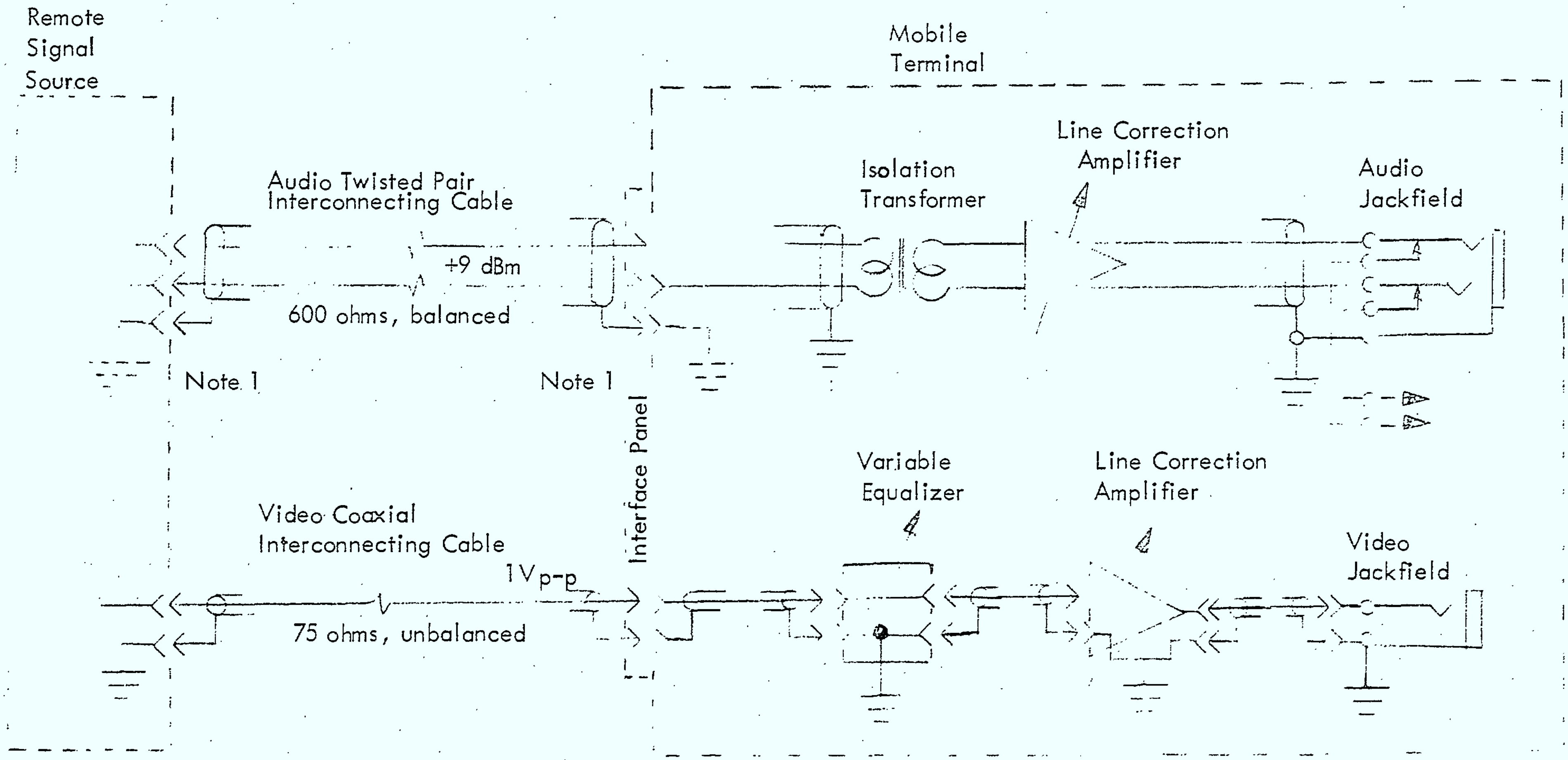


FIGURE C-6-D - BASEBAND PATCH PANEL NO. 2



Note 1: Ensure that shield of audio connecting cable is grounded at one end only.

FIGURE C-7

TYPICAL INTERFACE CIRCUIT

C-14 Test Loops

Some back-to-back testing may be performed at audio and at the 70 MHz IF points by suitable patching. Somewhat more extensive back-to-back tests are also possible by cross-connecting equipment using jumper cables between the equipment connectors. Specific details and capabilities depends upon the equipment.

Back-to-back testing at RF is accomplished using a "test loop translator" which frequency converts the transmission signals in the 14 GHz band to reception signals in the 12 GHz band. Except for the local oscillator circuitry, the equipment in the test loop translator is passive.

Access ports and signal levels in the RF part of the communications system are sufficiently flexible so that RF loopscan be made at a number of points. A variable RF attenuator at the 14 GHz input of the translator permits control of RF levels.

Test loops across the 735 MHz to 580 MHz IF bands is not possible, but this limitation is not serious and in the event of failure, or malfunction, the isolation of the problem to one or the other of the dual frequency conversion circuits is relatively easily accomplished using conventional diagnostic procedures.

C-15 Order Wire

Order wire facilities are not considered in this study except that interface facilities are provided so that the order wire unit may connect into the system at both the RF and the baseband points. We have assumed that order-wire facilities will be provided via the two-way voice circuits and that the equipment would be developed as part of the two-way voice program.

Note, however, that any of the four audio sub-carriers provided for the television service can be assigned for use as an order wire, or "service channel".* Further, the sound channel itself could also be used as an order wire channel.

C-16 Operation

Some operational comments have already been made in sections B-13 and B-15. We offer a few more here, including some on transmitter energization, since parallel operation of TWT's calls for a more cautious procedure because of the additional requirement to "balance" the outputs of the two power tubes. Bear in mind that these comments are preliminary and are subject to change or elaboration.

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* Sometimes referred to as "cue and control" channel, particularly by broadcasters.

The point at which "operation" begins is subject to interpretation. We say that it begins after the terminal has been set up, levelled, and checked out, the motor generator set has been warmed up, the heating and ventilating equipment, or air-conditioning equipment, has been adjusted, and packing containers have been stowed.

Normal operation begins at the patch panels. The system configuration is set up by patching according to the experimental needs of equipment and test facilities.

After the configuration is established, the equipment may be energized and the transmitter put through its warm-up cycle into the standby state.

The satellite may now be acquired following the procedure of B-12. Contact with Ottawa via a two-way voice circuit used as order wire may now be made and the experimental program details may be confirmed or changed as required.

A typical procedure is outlined in table C-2 where transmission of a video test signal is required. The basic procedure assumes that the two signal paths through the transmitter are not balanced.

A field operations manual is recommended wherein detailed procedures, summarizing manufacturer's recommendations, system considerations, and equipment features are described in detail. This manual could very well be prepared by the terminal supplier but in this case would not include material of which the experiment planners are more intimately aware of. Such additional material, however, could be included as an addenda.

TABLE C-2

TYPICAL OPERATING PROCEDURE FOR A VIDEO TRANSMISSION

Step	Task	Notes
1	Warm up equipment	Follow suppliers recommendations
2	Acquire satellite beacon	See section B-12
3	Adjust video signal generator for standard output	1 volt peak-to-peak (max) at video jackfield for all video signals, either test or program
4	Adjust deviation	No pre-emphasis
5	Connect receiver	Test loop at 70 MHz; no de-emphasis
6	Adjust receiver and check	Observe waveform
7	Insert emphasis and re-check	Re-adjust levels if required
8	Connect test loop translator from driver TWT Output hybrid to receiver input	Set levels as required. Set equalizers as necessary
9	Check signal over system loop	Observe waveform
10	Place transmitter output on dummy load	Waveguide switch
11	Reduce transmitter driver output level to minimum	Attenuator at driver input
12	Turn on transmitter	Parallel TWT configuration

...con't

TABLE C-2 CON'T

Step	Task	Notes
13	Increase transmitter drive until unbalance indicator reads 6dB lower than maximum permitted unbalance	Assumes that phase and amplitude adjustments not set properly
14	Adjust phase and amplitude balance controls on transmitter for minimum reading of unbalance indicator	
15	Repeat steps 13 and 14 until required RF output level from transmitter is reached	Required output level depends upon experiment to be performed
16	Place transmitter on standby	
17	Re-check antenna pointing using beacon signals from spacecraft	
18	Connect transmitter output to antenna line	Waveguide switch
19	Energized transmitter	
20	Confirm that signal is received at receiving end	Use order wire

SECTION D

ANTENNA

D-1 General

This section provides details on electrical performance, mechanical construction, assembly, alignment considerations and alignment procedures for the antenna.

A nominal antenna size of 10' is chosen for the mobile unit on the basis of the reasonable compromise between antenna gain and handling ability. A larger antenna would be more difficult to handle and, since its beam would be narrower, it would require a much more rigid foundation. Even the 10' antenna will require a stability such that shelter distortions under all normal operating conditions cannot be permitted to exceed approximately 0.1 in. (sec. F-8). A reduction in antenna size would permit some relaxation of structural stability in proportion to the ratio between the reduced antenna size and the antenna diameter. Thus if an 8' antenna were found to be satisfactory, the rigidity required could be reduced to about 0.125 inches.

D-2 RF Configuration

The obvious choice for the aperture is an illuminated paraboloid reflector. Either of two basic feed arrangements, namely the Cassegrainian feed or the focal point feed, can be utilized. (See Figures D-1 and D-2*.) On the basis of a comparison of electrical and mechanical parameters, and cost we recommend the Cassegrain. The more important parameters are discussed under the following sub-sections.

D-3 Gain

Both feed arrangements (i.e. Cassegrainian or focal point feed) deliver the same gain performance within ± 0.2 dB when using a symmetrical paraboloid reflector (see Tables D-1 and D-2). An additional approximately 0.5 dB gain could be achieved by constructing a shaped Cassegrain antenna. Proper shaping of the reflectors to provide an uptapered illumination characteristic in the Cassegrain optics to compensate for some of the normal downtaper in the primary illumination pattern should be performed. The resulting more uniform illumination characteristic provides additional gain. The shaping requirements need not be difficult to determine.**

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* For the focal point feed antenna, a circular feed similar to that being used on the satellite could be considered.

** RCA Limited, for example, has an existing computer program for such calculations.

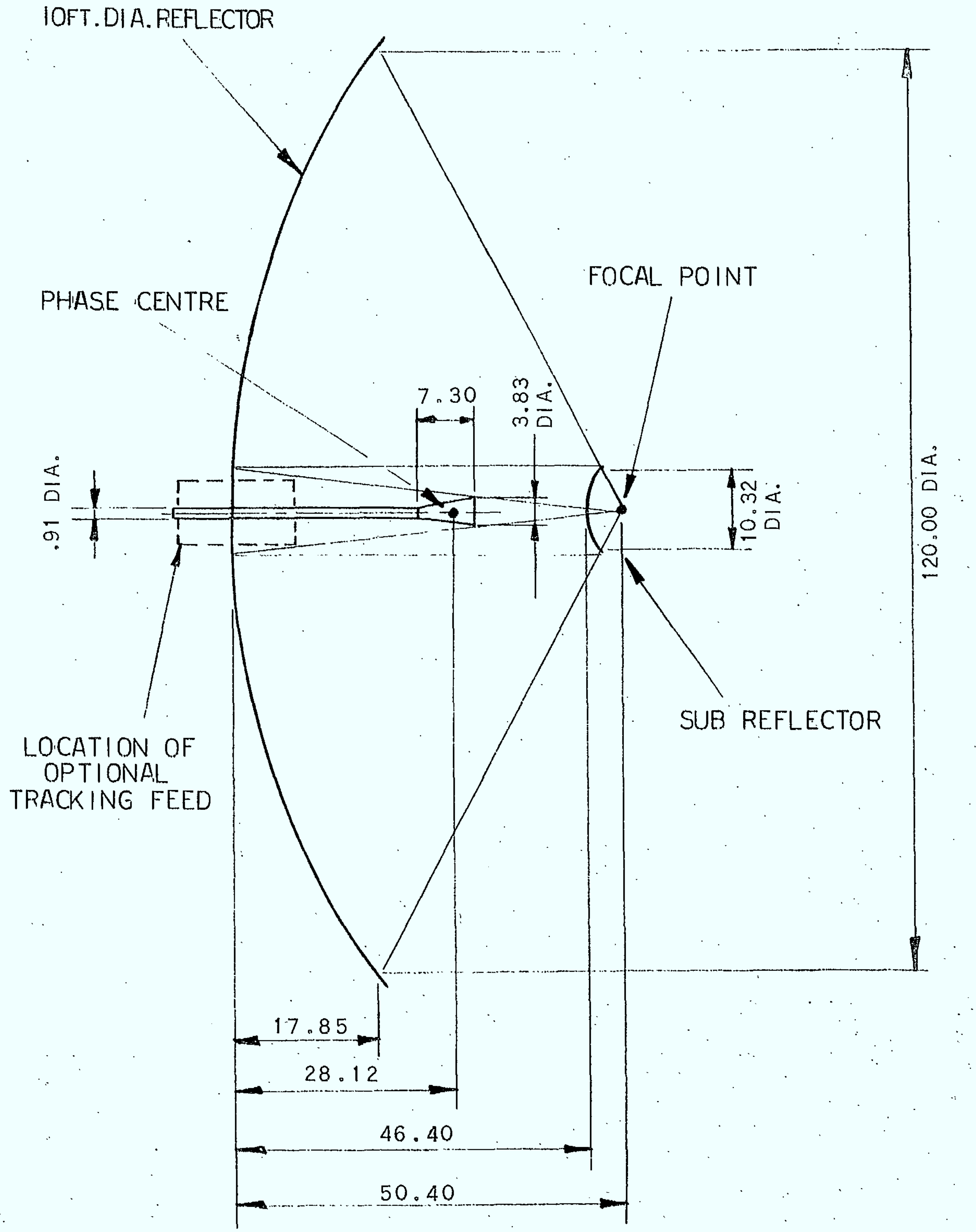

FIGURE D-1 CASSEGRAIN ANTENNA GEOMETRY

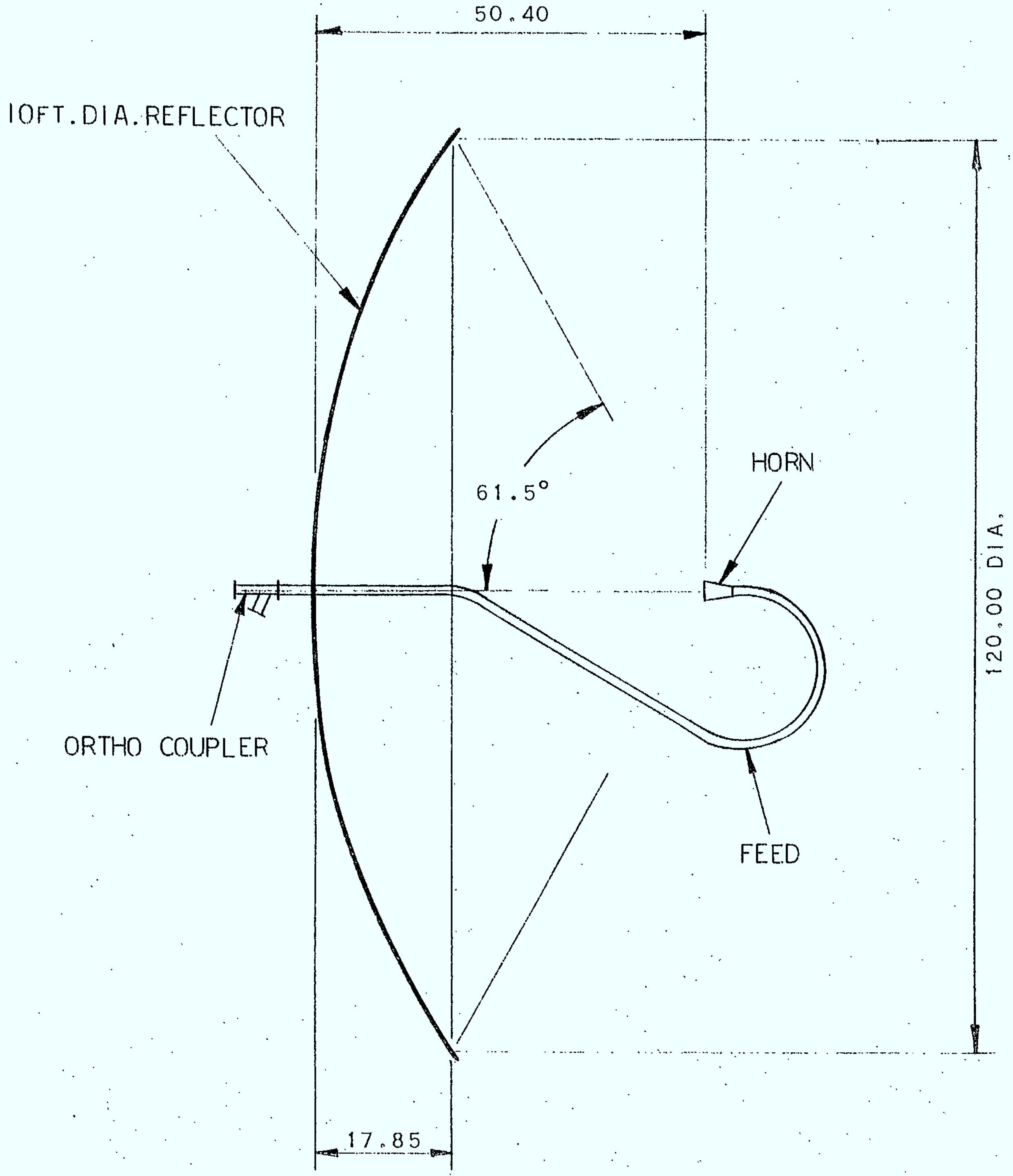

FIGURE D-2 FOCAL POINT FEED ANTENNA GEOMETRY

TABLE D-1

CASSEGRAIN ANTENNA GAIN PARAMETERS SUMMARY

Parameter		Value (dB) for Operating Frequencies 11.7 GHz	12.2 GHz	14.0 GHz	14.5 GHz
1.	Gain of ideal 120" circular aperture	51.44	51.81	53.00	53.31
2.	Aperture illumination losses for main reflector	0.84	0.84	1.00	1.00
3.	Spillover loss for main reflector	0.05	0.05	0.05	0.05
4.	Spillover loss for subreflector	0.84	0.84	0.63	0.63
5.	Blocking loss due to subreflector	0.12	0.12	0.12	0.12
6.	Blockage loss due to subreflector supports (0.5" Dia.)	0.28	0.28	0.28	0.28
7.	Power loss due to optical system inaccuracy (± 0.015" RMS)	0.15	0.17	0.22	0.24
8.	Power loss due to primary pattern phase error	0.10	0.10	0.10	0.10
9.	Power loss due to feed horn losses	0.07	0.07	0.07	0.07
10.	VSWR loss	0.04	0.04	0.04	0.04
11.	Orthocoupler loss	0.05	.05	.05	.05
12.	Antenna losses at input of orthocoupler	2.54	2.56	2.56	2.58
13.	Antenna gain at input of orthocoupler	48.9	49.25	50.44	50.73

TABLE D-2 — FOCAL POINT FEED ANTENNA GAIN PARAMETERS SUMMARY

Parameter		Value (dB) for Operating Frequencies 11.7 GHz	12.2 GHz	14.0 GHz	14.5 GHz
1.	Gain of ideal 120" circular aperture	51.44	51.81	53.0	53.31
2.	Aperture illumination losses	0.77	0.77	1.26	1.26
3.	Spillover loss	0.44	0.44	0.24	0.24
4.	Blockage loss due to feed horn and supports	0.4	0.4	0.4	0.4
5.	Power loss due to optical system inaccuracy (± 0.015" RMS)	0.14	0.17	0.22	0.24
6.	Power loss due to primary pattern phase error	0.10	0.10	0.10	0.10
7.	Power loss due to feed horn losses	0.01	0.01	0.01	0.01
8.	VSWR loss	0.04	0.04	0.01	0.01
9.	Orthocoupler loss	0.05	0.05	0.05	0.05
10.	Feed Circular loss (6 ft.)	0.24	0.24	0.27	0.27
11.	Antenna losses at input of orthocoupler	2.19	2.22	2.56	2.38
12.	Antenna Gain at input of orthocoupler	49.25	49.59	50.44	50.73

D-4 Pointing Error Budget

The total assigned pointing error budget for the antenna optics is ± 0.05 degrees. For the two optical configurations, the breakdown of this budget is given in Table D-3. Details of the pointing error calculations are given in Appendix D-1.

D-5 Sidelobe Level

The focal point feed antenna offers a somewhat better sidelobe level performance (26 to 30 dB) than does the Cassegrain antenna (20 to 22 dB). This is due to the reduced blockage at the center of the aperture.

D-6 Cross-Polarized Levels

The Cassegrain antenna offers better cross-polarized sidelobe level performance. (i.e. 30 to 35 dB versus 20 to 25 dB). This is due to the inherent symmetry of the Cassegrain feed structure and due to the fact that the surface currents on the small feed horn in the focal region of a focal point feed antenna tend to contribute to the cross-polarized level at angles off the antenna's axis.

D-7 Mechanical Considerations

The Cassegrain antenna offers the exclusive advantage of being able to accommodate a tracking feed. It also offers the possibility of polarization adjustment by means of incorporating two phase shifters connected in series, one fixed and one rotable, in the feed assembly*. This approach would eliminate the need for rotating the entire antenna assembly. This means of adjustment may, however, at these frequencies cause a slight group delay problem.

For the Cassegrain optics we recommend that the vertex of the reflector contain the necessary interfaces for a possible future changeover to a tracking feed. Figure D-1 shows the approximate location that the tracking feed housing would occupy.

An interesting design approach might be to design the antenna assembly to accommodate either the Cassegrain or the focal point feed optics so that a field comparison of the two approaches could be made. For instance, one of the two configurations may offer a shorter set up time.

An offset fed parabolic antenna has a lower center of gravity which would be advantageous but we do not recommend it because of the greater development and fabrication costs and difficulty in providing a feed, for the relatively large angles through which the antenna must be capable of traversing.

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* The antenna positioner proposed (reference E-4) provides inherent polarization correction.

TABLE D-3

POINTING ERROR BUDGET

CASSEGRAIN OPTICS

Main reflector deflections due to gravity and wind-load		$\pm 0.025^\circ$
Lateral displacement of the subreflector		$\pm 0.015^\circ$
Rotation of the subreflector about its vertex		$\pm 0.01^\circ$
	TOTAL	$\pm 0.05^\circ$

FOCAL POINT FEED OPTICS

Main reflector deflections due to gravity and wind-load		$\pm 0.025^\circ$
Lateral displacement of the feed horn		$\pm 0.025^\circ$
	TOTAL	$\pm 0.05^\circ$

D-8 Construction

The antenna reflector, feed and positioner should be considered as a subsystem. In addition to electrical and mechanical positioning accuracy, a very important requirement is to be able to quickly and easily assemble and disassemble this subsystem and to facilitate requirements for storage and shipping. This suggests that several easily handled subassemblies should be used, with simple interfaces, and not requiring great assembly accuracy.

The proposed reflector would comprise 4 removeable segments shaped like slices of a pie. These segments would be joined together using quick release latches and accurately machined V joints to form the parabolic reflector surface. Segments would be a convenient size for storage in a relatively small shipping container (approximately 5 feet x 7 feet x 2 feet).

The dish segments would be manufactured from fibreglass with a metallic reflective surface provided on their faces. To achieve the necessary rigidity the fibreglass would be laid up on the mold to include ribs and reinforcing rings and a flanged ring to which the dish would attach to the antenna positioner. A lighter weight dish could be achieved using a honeycomb or foam sandwich technique.

Fibreglass has advantages such as strength, resistance to denting and to distortion and ease of repair. One disadvantage is the poor thermal conductivity which would make de-icing a more difficult problem, however heating elements could be molded in place just behind the front surface.

Spun aluminum dishes are commonplace but for this application where a surface tolerance of 0.010" r.m.s. will result in 0.1 dB gain reduction, at 14 GHz, the required accuracy could be difficult to achieve for a segmented assembly. Obtaining the segments by cutting up a spun reflector would relieve internal stresses and cause distortion. The segments could be reshaped by hammering but it would be difficult to achieve the accuracies required. An alternate approach might be to stretch form segments individually over an accurate form.

Stretch forming could be impractical because the aluminum sheet would have to be relatively thick to provide the required rigidity, and only a few manufacturers would have large enough machines. Another approach could be to machine the segments out of solid aluminum and employ chemical milling to provide ribs to make a light weight structure. These techniques are well proven but would require further investigation to determine comparative costs and possible limitations.

A summary of the required construction and set-up accuracies which are calculated in Appendix D-1 is given in Table D-4. A typical sectional reflector configuration is given in Figure D-3.

TABLE D-4

ANTENNA MECHANICAL TOLERANCE REQUIREMENTS

CASSEGRAIN ANTENNA

Parameter	Allowable Tolerance
Min. reflector deflections due to wind-load and gravity	± 0.020" maximum at the periphery
Reflector surface errors	± 0.015" rms
Axial displacement of the subreflector	± 0.141"
Axial displacement of the feed horn	± 0.1"
Lateral displacement of the subreflector	± 0.030"
Rotation of the subreflector about its vertex	± 0.14°

FOCAL POINT FEED ANTENNA

Parameter	Allowable Tolerance
Reflector deflections due to wind-load and gravity	± 0.020" maximum at the periphery
Reflector surface error	± 0.015" rms
Lateral displacement of the feed horn	± 0.025"
Axial displacement of the feed horn	± 0.160"

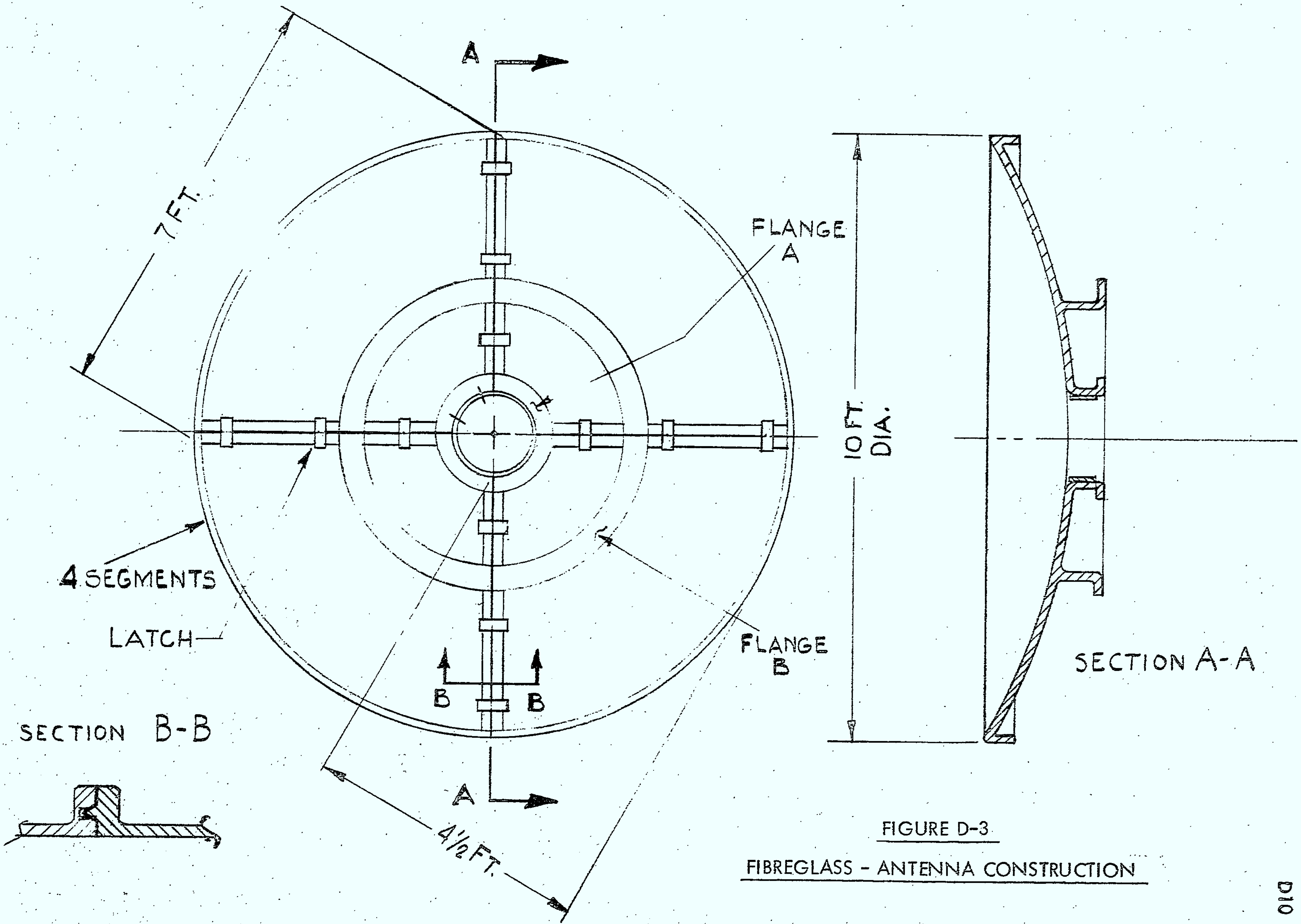


FIGURE D-3

FIBREGLASS - ANTENNA CONSTRUCTION

D-9 RF Coupling from the Orthocoupler to the Outside of the Elevation Axis

The antenna location selected, on the corner of the trailer, permits a very short feed, which is essential at SHF transmission frequencies.

RF coupling losses are very significant factors and the mechanical design of the antenna positioner must be dictated to a large extent by this constraint.

Layout drawings, using the antenna positioner concept which we are recommending (reference E-4) have shown the feasibility of employing waveguide twists and flexible waveguide as shown in Figure D-4, to provide direct waveguide connections to the transmitter and receiver.

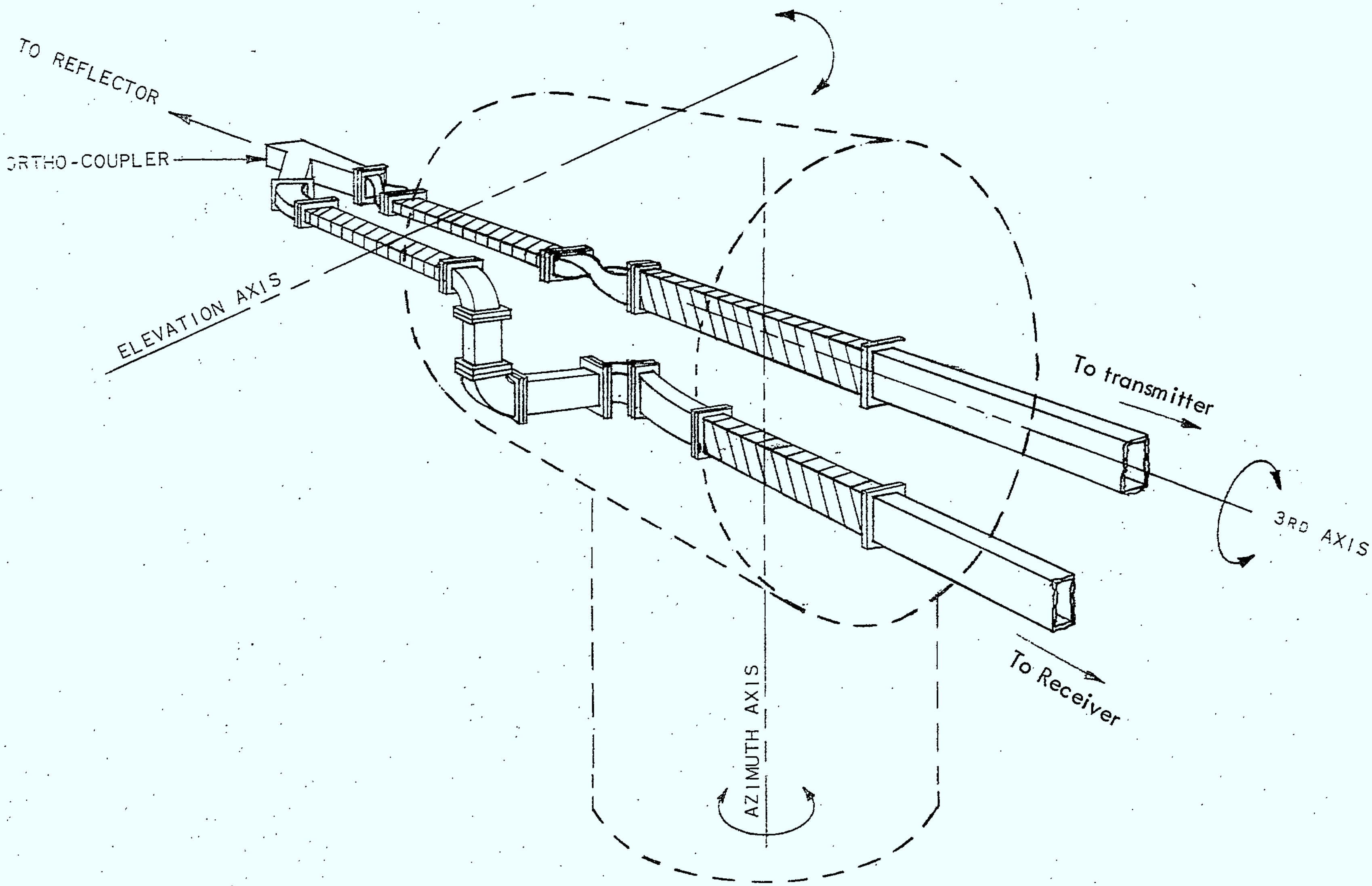
The twists serve two functions, first to rotate the waveguide through 90° between the elevation and azimuth axes and secondly to restrict the amount of twist imposed on the waveguide by rotation of the antenna about the third axis of the positioner (reference E-4). For various degrees of rotation required the twists could be made in 10 or 15 degree increments.

Other approaches requiring rotary joints might permit somewhat simpler assembly procedures at the operating sites and might be required should a different type of positioner be selected to that recommended, however they would certainly be more expensive and have larger losses.

D-10 Pressurization

Two approaches for pressurizing the system can be used. The first involves the use of a motor-driven pump and dehydrator. The second utilizes a simple gas bottle. The first approach has the advantage of allowing the use of a fairly leaky system since the pump will always start whenever the pressure drops below a certain preset minimum. It has the disadvantage, however, (at least for a portable station) of requiring an AC or DC power mains. The second approach is much simpler and simply uses dry nitrogen compressed in a standard gas bottle. The drawback is that the system must be perfectly leak-proof, (i.e. as good as a car tire) or the supply in the bottle will be depleted very rapidly, perhaps within a day.

It should be assumed that use of the gas bottle will necessitate the use of O-ring seals at all points. This is in keeping with the principle that a good gas seal can be achieved only if the pressure of the contained gas tends to enhance the seal. It is worth mentioning that sealing against gas leaks is very difficult compared to sealing against leakage of a contained liquid and that methods used for sealing liquids usually don't work for gases. For a gas, the escaping particle is an individual molecule rather than an aggregate of molecules as for a liquid.



RF COUPLING THROUGH ANTENNA POSITIONER
FIGURE D - 4

For this terminal with its predicted direct waveguide couplings it should be possible to provide suitable sealing and the gas bottle approach is considered satisfactory.

D-11 Alignment Procedures

The antenna alignment procedures and times for the two configurations are given in Tables D-5 and D-6. The procedures assume prior set-up of the trailer and removal of the antenna packing boxes. The times assume prior rehearsal.

D-12 Total Gain Loss due to Manufacturing Tolerances, Alignment and Pointing Errors

We have assumed that the mobile terminal should operate to expectation in winds up to 30 miles per hour. Above this, survival is the main criteria. In winds of 30 miles per hour, the antenna, mount and trailer* will suffer some distortions which contribute to an effective loss in antenna gain. This loss must be added to that already assumed for manufacturing tolerances.

Table D-7 combines all the contributions and indicates that effective loss of antenna gain of 0.95 dB may be expected in a 30 mile per hour wind. We have rounded this off to 1 dB for purposes of calculation.

In preparing Table D-7 we have made these assumptions:

1. The subreflector lateral displacement, rotation and periphery distortion pointing errors are constant for any set-up and can therefore be biased out during set-up procedures.

2. Residual trailer and mount levelling errors are constant for any set-up (at least for a reasonable period of time) and can therefore be biased out during set-up or re-levelling procedures.

3. Maximum peak tracking errors are assumed to be $\pm 0.050^{\circ}$. This assumption will be checked out in a currently active but separate contract.

4. All tracking errors are added on a peak basis, since there are not enough of them to consider rms addition.

5. Gain loss is determined after all tracking errors are added.

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* See Table D-3, Section E-3 and Section F-8.

TABLE D-5

CASSEGRAIN ANTENNA ASSEMBLY AND ALIGNMENT TIMES

		TIME
1.	Assemble and check the reflector	30 min.
2.	Assemble (on the ground) the subreflector and support assembly. (Adjust the axial position of the subreflector using the spacing rod).	10 min.
3.	Install the alignment mirror on the subreflector	2 min.
4.	Install the feed horn with the orthocoupler removed.	3 min.
5.	Mount the reflector to the support pedestal.	5 min.
6.	Connect the linear actuators.	5 min.
7.	Connect the telescope to the input of the feed horn	3 min.
8.	By means of the subreflector adjusting screws and the telescope, adjust the centering and perpendicularity of the subreflector. (The centering is accomplished by lining up the cross-hairs with the cross on the mirror and the perpendicularity is observed by collimation).	15 min.
9.	Install orthocoupler and waveguide connections	12 min.
		85 min.

TABLE D-6

FOCAL POINT FEED ANTENNA ASSEMBLY AND ALIGNMENT TIMES

		TIME
1.	Assemble and check the reflector	30 min.
2.	Connect (on the ground) the RF feed assembly to the vertex of the reflector	10 min.
3.	Install the feed support members	5 min.
4.	Adjust the centering of the horn by means of adjusting the 3 support members until the distances from the horn and the three targets on the reflector are identical. (The alignment rod is used to check the 3 equal distances).	5 min.
5.	Mount the antenna onto the pedestal	10 min.
6.	Connect the linear actuators	5 min.
7.	Connect the orthocoupler and the waveguides	10 min.
		75 min.

EFFECTIVE ANTENNA GAIN LOSS BUDGET

CAUSE	ACCURACY (in. or degrees)	POINTING ERROR (Degrees)		GAIN LOSS (dB)	NOTES
ANTENNA MISALIGNMENT					
Subreflector Axial Displacement	± 0.41"			0.09	1
Feed Horn Axial Displacement	± 0.58"			0.01	1
Surface Tolerance	± 0.015" (RMS)			0.20	1, 2
				0.30	
Subreflector Lateral Displacement	± 0.030"	± 0.015°			1, 3
Subreflector Rotation about Vertex	± 0.014°	± 0.010°			1, 3
Subreflector Periphery Distortion	± 0.020"	± 0.010°			1, 3
		± 0.050°			
TRAILER AND MOUNT					
Trailer Levelling	± 0.100"	± 0.065°			1, 5
Wind Distortion	± 0.050"		± 0.033 PEAK		4, 5
Mount Levelling	± 0.050"	± 0.033°			1, 5
Wind Distortion	± 0.020"		± 0.013° PEAK		4, 5
		± 0.098	± .046° PEAK		
TRACKING ERRORS (ASSUMED)			± .050° PEAK		
LOSS OF GAIN DUE TO WIND EFFECT ON SURFACE TOLERANCE				0.20 (RMS)	4
TOTAL POINTING ERRORS (UNCORRECTABLE)			± .096° PEAK	0.45	6
TOTAL GAIN LOSS				0.95 dB	7

TABLE D-7

TABLE D-7 (cont'd)

NOTES:

1. Field Alignment Accuracy Allowance.
2. No wind effects included.
3. Effects may be eliminated by bias adjustment.
4. Wind velocity assumed to be 30 m.p.h.
5. Accuracy defined as "off vertical" error along edge of trailer structure.
6. Added on a peak basis.
7. Maximum gain loss under 30 m.p.h. winds.

SECTION E

ANTENNA POSITIONER

E-1 General

There are several important criteria for the antenna positioner for the mobile terminal. The positioner must be compact, lightweight and capable of rapid assembly and dis-assembly from the trailer and from the antenna. The length of the feed from the transmitter to the antenna must be kept short because of the high losses at 14 GHz. The positioner should also be compatible with different possible tracking methods such as step track, programmed track and auto-track.

Only limited tracking movement is required at any one site but because the terminal is to be used over a very wide range of latitudes and longitudes the tracking angle relative to local vertical may vary appreciably.*

E-2 Tracking Needs

Tracking requirements are the subject of a separate active study for the CTS Ground terminals.** We are aware of the general requirements and problem areas and some comments can usefully be made at this time.

The CTS satellite will be in geo-stationary orbit with its antenna illuminating parts of the U.S.A. and/or Canada. The tracking needs will depend on how precisely the spacecraft can be positioned in orbit, and how much fuel is available for station keeping.

When there is no orbit eccentricity, other east-west motion, or inclination, there is no apparent satellite motion to a ground station and no tracking is required once the satellite has been acquired.

With orbit inclination only the apparent satellite motion is that of a very narrow figure 8 (its width is a fraction of a degree). The ground station antenna motion, unless it is on the zero degree longitude relative to the satellite's celestial position will be at some angle to the local vertical. This tracking angle and the required elevation and azimuth angles can readily be calculated; a study was carried out, using a computer to calculate values and patterns for various earth station locations, related to the CTS satellite station (Ref. E-1).

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* We define tracking angle as the angle made between the local vertical and the centre-line of the earth station's antenna tracking pattern, which follows the apparent satellite motion.

** Study Contract authorized for RCA Limited by CRC.

This study shows that for the anticipated worst orbit inclination the tracking angle would vary approximately $\pm 45^{\circ}$ from the local vertical, for possible sites in Canada, and the elevation angle tracked is approximately 2 degrees up and 2 degrees down from the mid position.

When there is also orbit ellipticity the apparent satellite motion is more complex, but there are also computer programs to show this (at CRC). With small ellipticity the pattern is pear shaped changing to an unbalanced elliptical shape as the ellipticity increases.

It is significant that the tracking pattern excursion is small about its centre-line (except for large ellipticities which are not predicted), thus if the positioner can be oriented to suit this angle, tracking about the elevation axis should be sufficient. This would tremendously simplify the means required to track within specification. Even with an excursion which is wider than an antenna beamwidth a simple correction, in azimuth, several times a day should suffice.

The above is so significant in its effect on tracking methods, with a potential for large cost reduction, that it becomes a design target for the antenna positioner.

E-3 Wind Loading

Wind forces vary approximately as the square of the wind velocity. For this application we suggest that 30 m.p.h. be selected as an operational (within specification) limit, with survival in winds up to 90 m.p.h.

The shape of the dish results in lift and drag forces. The worst are not head on, but at approximately 120° to the antenna boresight, i.e. at 30° behind the frontal edge.* Their data shows that the approximate torque on a typical positioner where the distance from the frontal edge to the positioner axis is approximately 35% of the diameter, is approximately 2800 lbs. feet at 90 m.p.h. and 225 lbs. feet at 30 m.p.h. The force varies with temperature increasing by approximately 20 percent at $-45^{\circ}F$ because of the higher air density.

In high winds the forces on the positioner can be reduced by stowing the antenna so that it points straight up. Adequate warning time is usually given for high winds but unpredicable local wind gusts do occur so that an adequate margin of safety must be provided.

Fortunately high winds are not normally associated with icing conditions but 1/2 inch of ice deposited on the front and back of a 10 foot reflector would add a significant torque (it would weigh approximately 400 lbs). We do not envisage that operation would continue during an ice storm so that survival is the sole criterion.

* According to information from Scientific Atlanta.

E-4 Design Concept

In this study the practical aspects of the antenna positioner have been considered in some detail. The specialized criteria for it practically rule out use of off-the-shelf antenna positioners.

The proposed concept is shown in Figure E-1. This sketch shows a simple, compact mechanism with three axes of rotation. It is unconventional in that the third axis permits adjustment so that motion about the elevation axis can be at any angle up to approximately 45° relative to the local vertical. Thus the tracking angle can be followed with adjustment of the elevation axis alone.

If desired the third axis can be adjusted and locked, so that elevation and azimuth axes are orthogonal and the positioner becomes a conventional elevation over azimuth unit.

The third axis shaft would be a large diameter tube with bearings at each end, upon which the trunnion which forms the elevation axis rotates. This is a convenient channel to route the waveguide feed (as shown in Figure D-3) in the most direct manner between the reflector and transmitter.

The elevation angles required at any of the various sites in Canada, will vary over a range from approximately 0° to 45° and to halve the angle through which flexible waveguide will have to twist the third axis should be pointed up approximately 23°.

A further advantage of the adjustable third axis is that it performs the function of polarizing the antenna, at no extra cost (ref. D-7).

Use of linear actuators, which is possible because of the small angles traversed, permits a very compact mechanism because linkages can be made through long lever arms without the heavy weight associated with large gears. The structural ring which is part of the reflector, becomes a gimbal when coupled to the positioner. Its motion is controlled with a good mechanical advantage through suitable location of pick-up points for the linear actuators. Positioner geometry can be selected so that overhang moments, and hence wind torques, can be minimized.

For this application, it is important to have simple, low cost, but reliable actuators. Aircraft actuators are practically ruled out because their sophisticated design, manufacturing and test requirements and low production quantities made, result in high cost units. A more suitable actuator is the Power Pak, manufactured by the Saginaw Steering Gear division of General Motors. This unit can easily be modified (by kit) to change the extension range up to 36 inches – and longer by special order – because it is merely a matter of changing the length of the ball screw and protective sleeve.

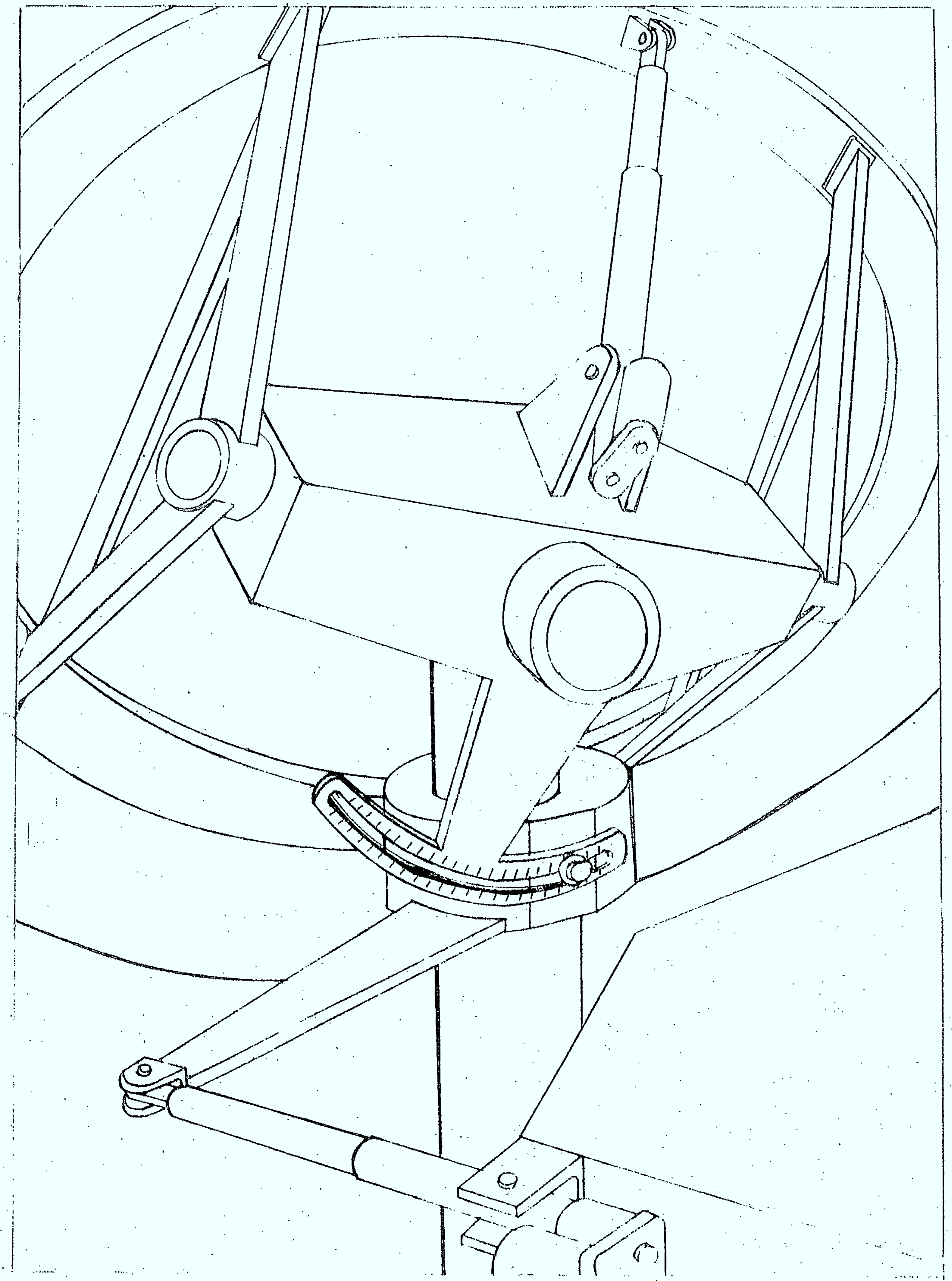


FIGURE E-1 - ANTENNA POSITIONER

The unit is commercial grade, so that certain changes may be necessary to meet the extremes of environment envisaged. These might involve provision of special lubricants, changes to seals, and changes to electrical connectors or terminations.

The actuators are driven by 12 volt d.c. motors. Their load capacity of 1500 lbs. (with a 55:1 gear ratio) is considered suitable to meet possible wind loads and they have a static rating of 3000 lbs.

Antenna play must be minimal to remain inside the pointing error budget, particularly when winds are gusting. The large moment arms possible with the linear actuators and limited play of the recirculating ball nuts – typically less than 0.005 inches – help in this regard. Care must be taken to select close tolerance trunion supports and self aligning end fittings for the actuators and of course, good design practices must be followed for the bearings for the various positioner axes, and in selection of sizes and section moduli of the structure of the positioner.

The positioner head is attached by a flange near the azimuth axis to the pedestal, which is simply a large diameter aluminum tube. This tube is hinged at the base and erected, (ref. Fig. B-5) by means of a similar actuator to that we have just discussed. The pedestal is clamped to the trailer or could be bolted to a strut, and for the modular trailer it will be required to remove the positioner for shipping, thus the weight and method of attachment are significant factors.

It is proposed that an accurate level be fitted to the positioner in addition to that on the trailer. Accuracy in levelling will determine how accurately programmed tracking can be carried out.

E-5 Programmer

Drive control of the positioner is the function of the tracking programmer. Where the control is active, i.e. servo control is used, sensing a satellite signal and driving the antenna to maintain it at peak value as in the "auto-track" method – or in the less sophisticated version known as the "step-track" method – there is no requirement to coordinate the programmer with the site coordinates and with sidereal time, or to accomodate changes in the satellite orbital characteristics. These advantages are not without cost however, as can be inferred from reading Appendix Section D-3.

Single axis programmed track methods should be inexpensive and can be used with the proposed positioner. The operation of such a programmer would require certain of the coordination activities noted above, but in practice this should not be difficult.

Tracking programmers will be dealt with in more detail in the tracking study already mentioned in E-1 but several concepts can be mentioned.

One concept is to use an accurate sidereal clock such as Bulova Accutron to drive a centre-tapped sinusoidally wound potentiometer. The potentiometer is connected to a precise voltage source and its output is an analogue equivalent of the satellite's apparent motion. This voltage is compared to that from a linear potentiometer which is coupled to the elevation axis. When the voltage comparator error reaches the turn on threshold a relay closes to drive the elevation linear actuator until the turn-off threshold is reached. By adjusting the voltage at the source adjustment of tracking amplitude can be made.

The battery operated clock has good accuracy to stay in phase with satellite motion, once the potentiometer has been coordinated and maintains synchronism when the station is not operating, driving the actuator to the correct position when operations are resumed.

Another concept is to program a small computer with a punch tape or cassette, to control tracking. This could also provide azimuth steps, as required, and could be useful for obtaining data for satellite acquisition. This method is in fairly common useage, as for example at the 30 foot antenna of C. R. C.'s. Such a method becomes attractive where the computer can be used for several purposes.

For this experimental terminal it would seem useful to test and evaluate more than one tracking method, so that a method suitable for other small low cost terminals can be determined.

SECTION F

TRAILER

F-1 General

A wide range of possible shelters has been investigated and rapidly discarded for the mobile terminal, including prefabricated panel shelters, construction site trailers, helicopter deliverable huts and conventional semi-trailers.

The basic trailer concepts termed the domestic trailer concept and the modular trailer concept have been quite extensively investigated. Each has certain advantages and limitations but both are generally suitable. A comparison is made in Table A-1 of the general factors and considerations for each concept. The other approaches, having been found unsatisfactory in one or more areas, are not included.

The required operational aspects have been carefully studied. A high degree of mobility is required, with many of the potential operating sites located at great distances from Ottawa. Shipping costs are very significant factors and the equipment must be protected from damage in transit to the maximum extent possible.

F-2 Domestic Trailer Concept

The feasibility of employing a domestic trailer modified to house the electronic equipment and to provide rigidity for the antenna pedestal has been investigated carefully and a visit was made to Travelux Coach Company in Newmarket, Ontario to discuss the requirements. The trip report, (Reference F-3), gives a description of some of the modifications which might be necessary and considerations for its application to the terminal.

The choice is not restricted to Travelux. The best trailers are probably made by Airstream who pioneered the all metal streamlined trailer, and similar trailers are made by Avion and Streamline. These trailers have elastomeric springs, walking beam axles, etc. which are considered superior, for this application, to the semi-elliptic springs of Travelux Trailers. Modifications to the chassis of any of the above trailers would be required to attach the outrigger and body jacks and it should be relatively inexpensive to attach a different running gear at this time.

Suitable trailers are available in a large number of sizes and with a wide variation in accessories. A large trailer would have sufficient space to permit retention of toilet, shower, and even limited sleeping accommodation, in addition to the gas operated heating system.

For comparison purposes a medium sized trailer of 25 feet nominal length (21' inside dimensions) has been selected and a possible floor plan is shown in Figure F-1. The cost differential for larger sizes is small.

Deletion of standard equipment could be traded off against the cost of structural modifications and the trailer could revert back to its original configuration, when its role as a TV mobile terminal has been completed.

A domestic trailer cannot be shipped via aircraft of the Boeing 737 class. Thus, should trips to remote areas by air be a significant portion of the operational phase of the TV mobile terminal, the costs of shipping via large aircraft such as Lockheed Hercules might become unreasonable. (See Table B-2) This is the greatest disadvantage of the domestic trailer concept.

F-3 Modular Trailer Concept

This concept was developed to overcome the one serious disadvantage of the modified domestic trailer: limitation in air transportability. It would consist of modular sections sized to suit the permissible pallet dimensions of a Boeing 737 aircraft, assembled onto a chassis to provide the required mobility.

The modules would serve as shipping containers for the equipment they house and should also provide controlled humidity storage capabilities. At the site, the end panels from the modular sections would be installed at the back of the trailer to provide additional shelter for storage purposes and to shelter and provide sound deadening for the engine generator set. They might also be used as wind deflectors about the antenna.

The ends of the chassis frame would fold or be removable so that the complete chassis could be loaded onto one pallet.

The modular trailer would require special care in its development and certain risks would be involved. Some of the design factors for trailers, and considerations for the modular trailer design, are included in Appendix F.

The feasibility or practicability of the modular approach is dependent on the development of hardware which can be assembled and disassembled quickly. Our study indicates that specialized handling equipment would have to be developed and the module structures would require extra strength to permit its use.

The module trailer concept has been discussed with Air Vision Industries in Pointe Claire, Quebec and with ATCO Research and Development in Calgary, Alberta. Both of these companies have had success in developing highly specialized mobile shelters. They have not conducted detailed proposal studies but having reviewed the requirements have no serious reservations about being able to develop such a trailer.

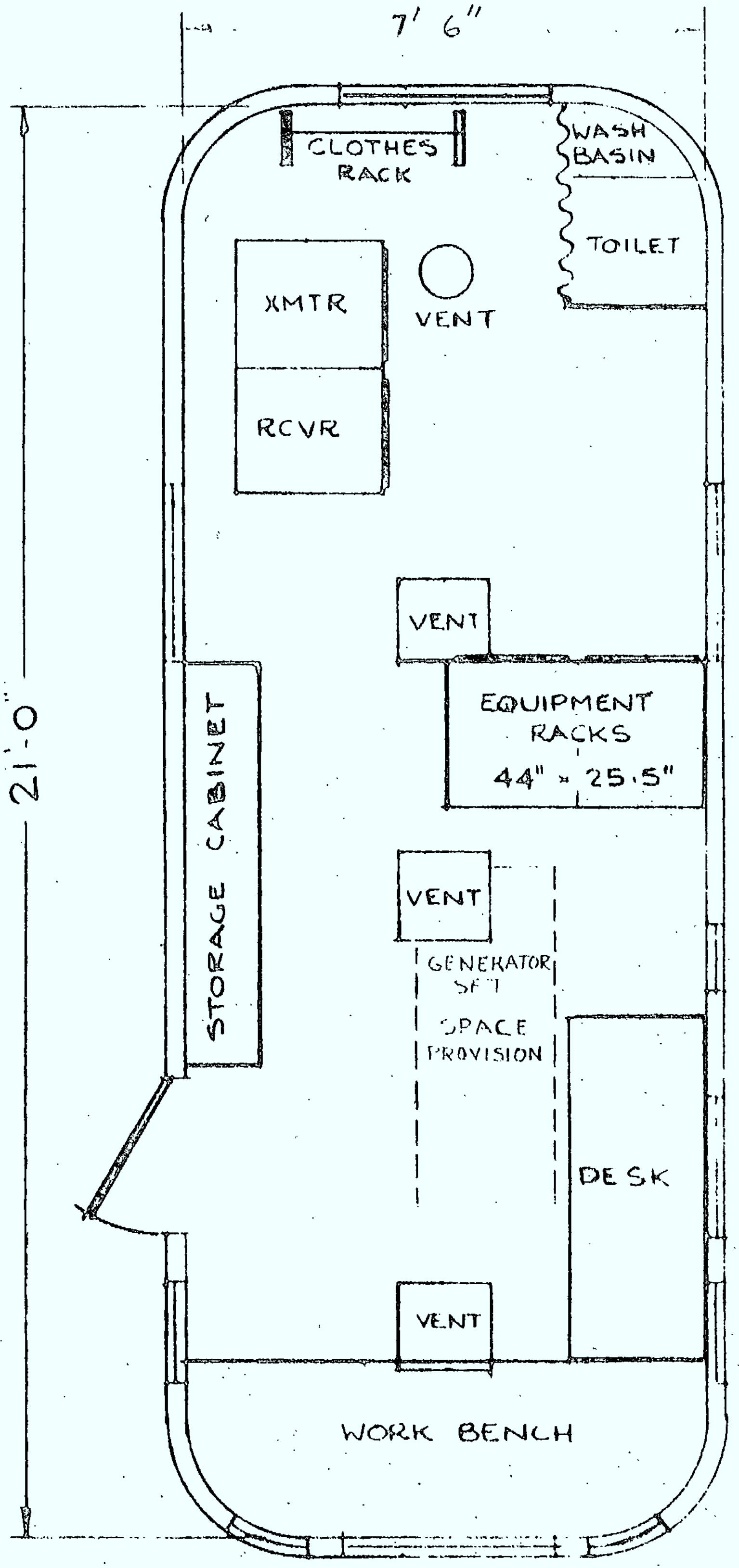


FIGURE F-1

MODIFIED DOMESTIC TRAILER LAYOUT

F-4 Modules

The modules would be sized to suit the maximum permissible pallet envelope for the Boeing 737 aircraft. They would each be approximately 5' x 7' x 8'6", with the end modules provided with mitred corners to provide clearance for running lights and to permit a shorter distance between the antenna pedestal and the transmitter rack.

Each module would require integral structural rigidity both as a module and when assembled with the other modules to form the trailer. A trailer frame inevitably has some flexibility therefore the fasteners or clamps between the modules would have to allow for initial misalignment and when fastened, the body should act as a "unibody" structure, i.e. it should not depend on the trailer frame for rigidity. Body mounted jacks would assist in limiting deflection during assembly and disassembly of the modules, in addition to their primary function of levelling and stabilizing the antenna pedestal.

The dimensions of a module provide constraints in the location of equipment racks, etc. Possible equipment layouts are shown in Figure F-2 and Figure F-3 for 3 and 4 module configurations.

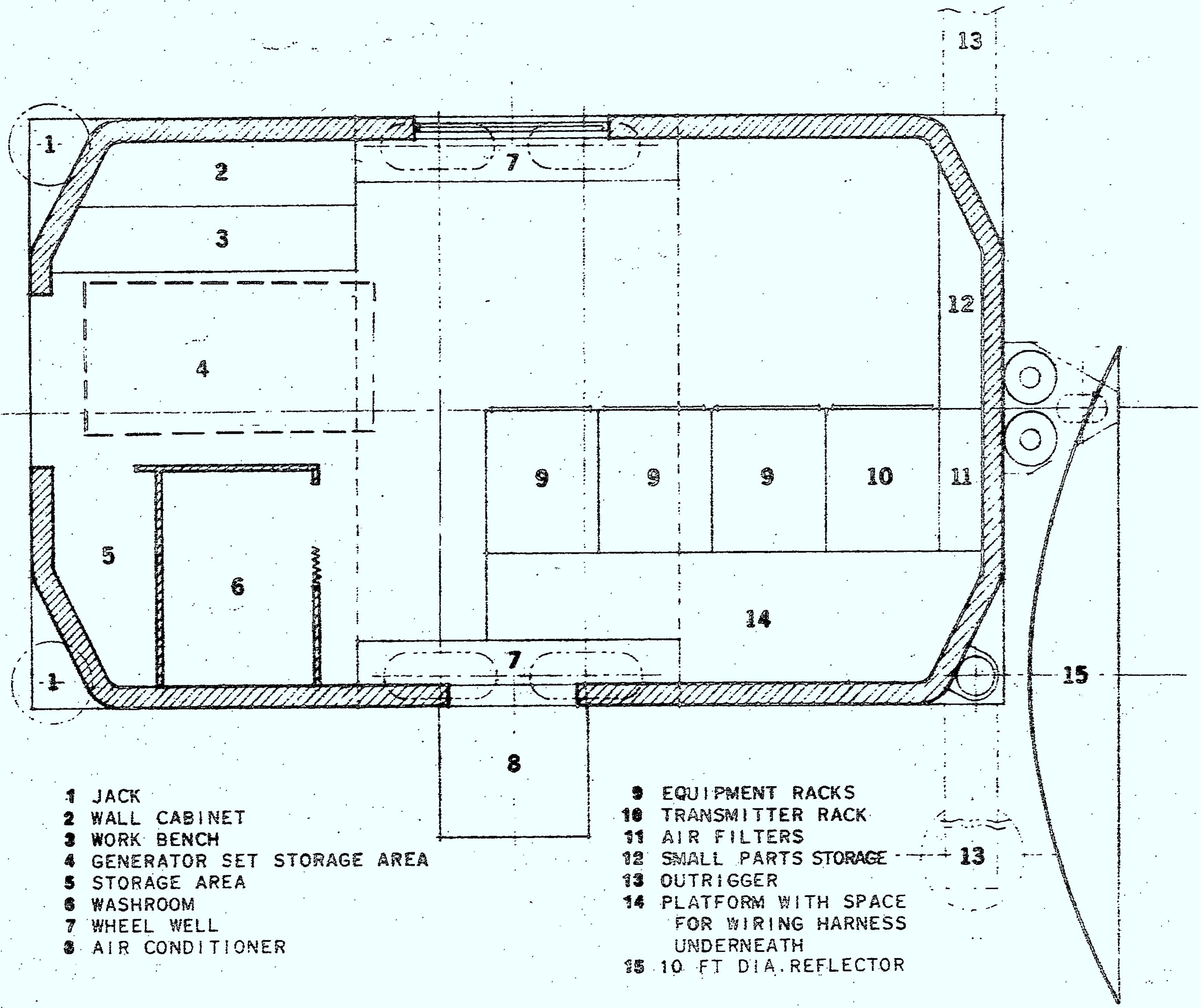
F-5 Chassis and Suspensions

The trailer chassis is a key factor in the modular trailer concept. A conventional chassis would be too large and too heavy to load safely on its side in a 737 aircraft, and if loaded on its wheels it would take up about 3 pallet lengths and might not get around the loading door at all.

To overcome the above difficulties a chassis with a folding frame has been considered and is shown in Figure F-4. In this concept the end sections fold up to permit loading onto a single pallet. The sections would require either a geared lifting mechanism or better yet, torsion spring assists which would permit lifting by one man. Design of the hinges, while not a major problem, would be made more difficult by the very large moment arms acting there. The folding arm concept trailer could probably not be made any longer than 3 modules long, with one module overhung at the front and one at the back, and it might be difficult to get the right weight distribution.

The folding frame concept shown assumes that a tandem axle domestic type trailer suspension with a domestic type hitch and front dolly jack would be used. This is in accordance with the recommendation of Appendix F-1-3 where military, domestic and commercial chassis configurations are compared.

The axles should normally be at the 55% - 60% station along the frame so that 10 to 15% of the trailer weight is on the hitch. A concept which would permit



1 JACK
2 WALL CABINET
3 WORK BENCH
4 GENERATOR SET STORAGE AREA
5 STORAGE AREA
6 WASHROOM
7 WHEEL WELL
8 AIR CONDITIONER
9 EQUIPMENT RACKS
10 TRANSMITTER RACK
11 AIR FILTERS
12 SMALL PARTS STORAGE
13 OUTRIGGER
14 PLATFORM WITH SPACE FOR WIRING HARNESS UNDERNEATH
15 10 FT DIA. REFLECTOR

FIGURE F-2
THREE MODULE TRAILER LAYOUT

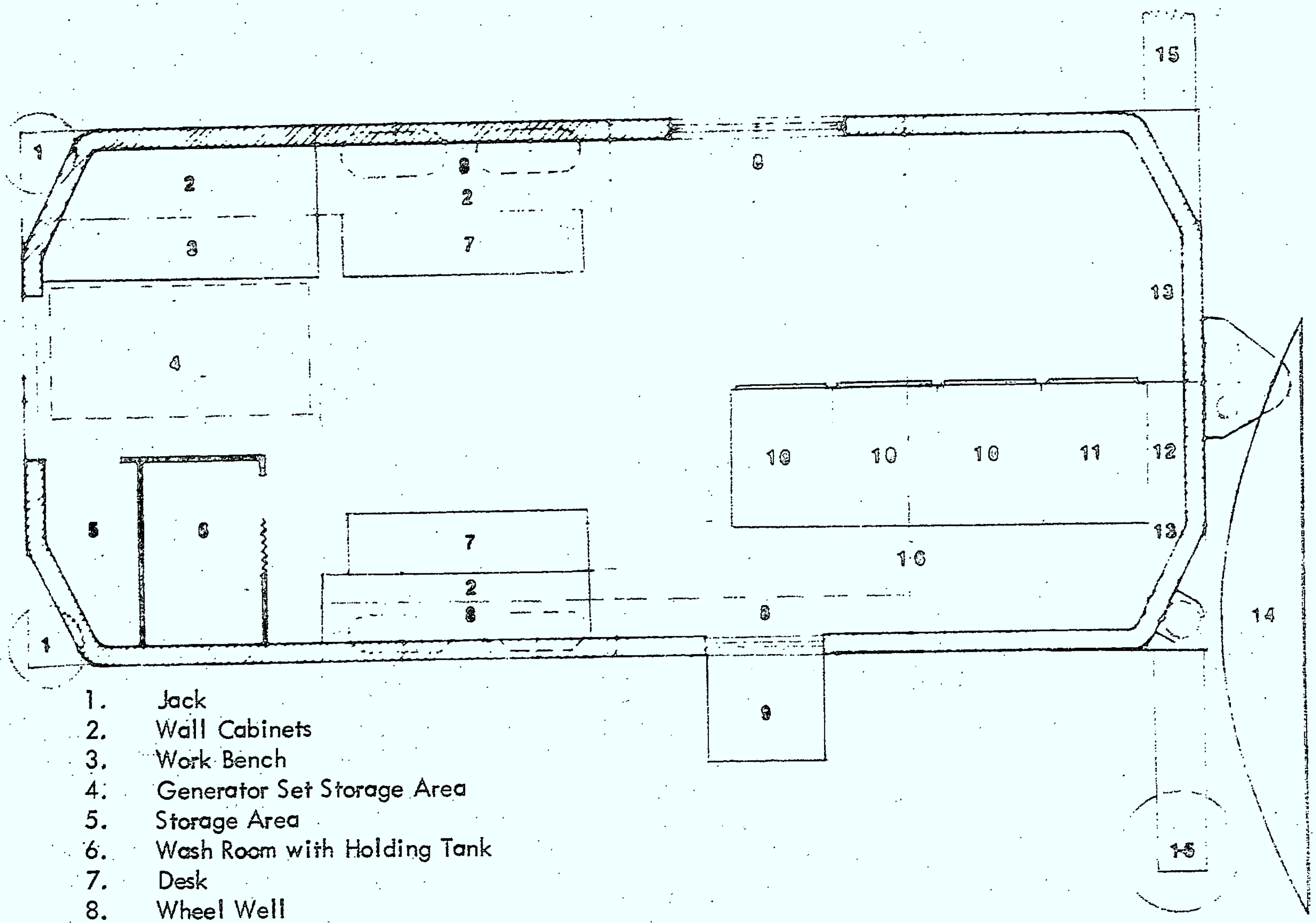


FIGURE F-3

FOUR MODULE TRAILER LAYOUT

1. Jack
2. Wall Cabinets
3. Work Bench
4. Generator Set Storage Area
5. Storage Area
6. Wash Room with Holding Tank
7. Desk
8. Wheel Well
9. Air Conditioner Unit
10. Equipment Racks
11. Transmitter Rack
12. Air Filter
13. Small Parts Storage
14. 10 Ft. Dia. Reflector
15. Outrigger
16. Platform with Space for Wiring Harness Underneath

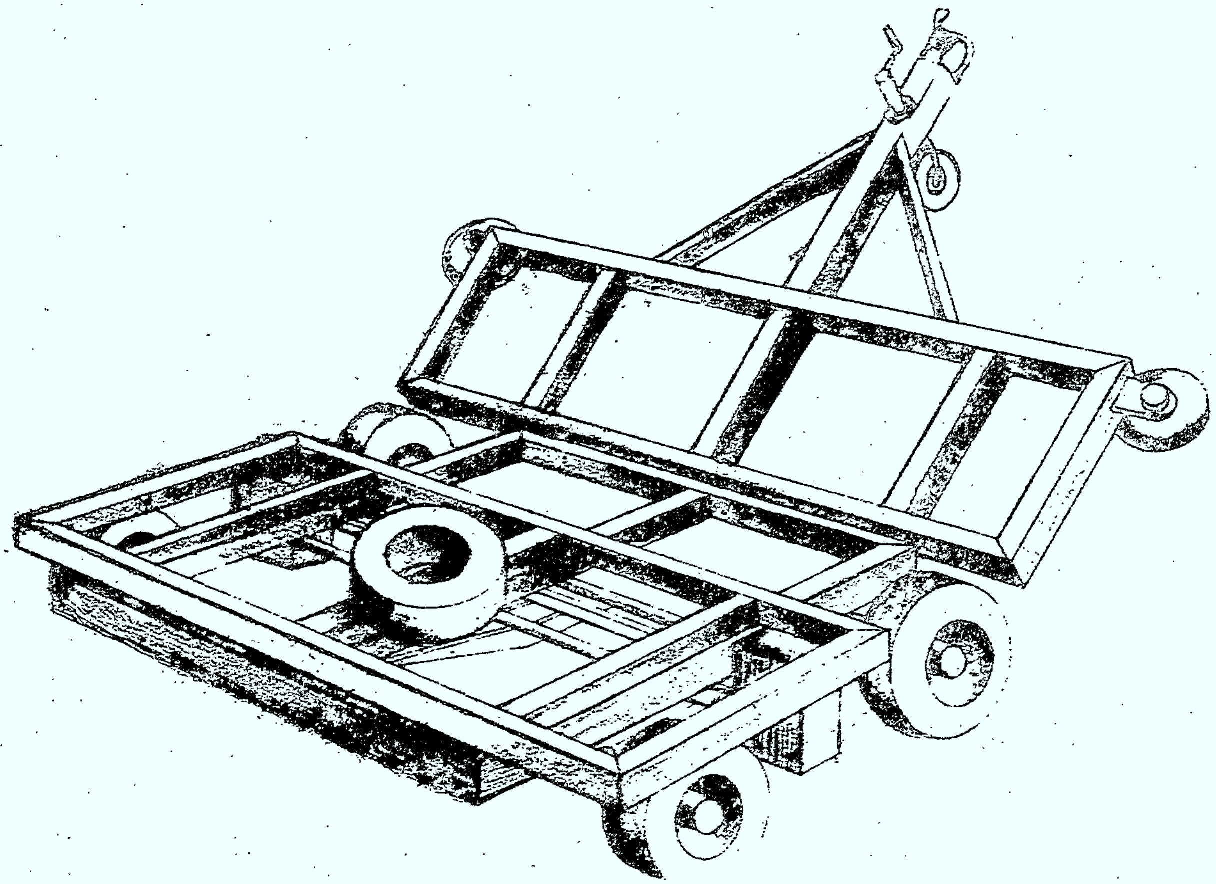


FIGURE F-4

FOLDING CHASSIS FRAME

this for either 3 or 4 modules is shown in Figure F-1-1 in the Appendix. This concept has the disadvantage that assembly and disassembly are more difficult, however the module special handling equipment could be used for positioning and withdrawing the end sections which telescope into the centre section.

Running gear with elastomeric suspension and walking beam axles is discussed in section F-1-4 and F-1-5 of the appendix. Information on this type of suspension has been obtained from Moryde. It appears to be highly suitable for a domestic trailer or for a folding or telescoping frame modular trailer. Running gear of this type is comparable in performance to that of an air suspension, is available at low cost and should be more reliable because it is inherently simpler and cannot develop air leaks.

F-6 Suspension and Rack Mounting Coordination

The suspension used for either trailer concept could be the same but the effect on electronic equipment rack installation must be considered because modules could be shipped separately from the chassis. A study has been made of various types of suspensions, reference Appendix F and this shows that air springs or elastomeric springs would probably be the best choice for road use of the trailer. They both have the advantage of providing a very low natural frequency, which provides a very low transmissibility of road disturbances to the trailer frame since transmissibility

$$T = \frac{1}{1 - (f/f_n)^2}$$

where f = disturbing frequency and

f_n = natural frequency of assembly.

With a low natural frequency suspension it would not be necessary to shock mount electronic equipment racks for road use and in fact it would not be recommended unless a large degree of damping is provided. This is because the natural frequency of the mounted rack could not easily be made lower than that of the trailer's suspension and transmissibility (ignoring damping) would be greater than 1.0 and much greater than 1.0 if f and f_n are very close to each other.

The racks when installed in modules would require shock mounting to protect them during shipping. A short duration high shock input is produced by free-fall drop of a shipping container. This calls for a soft suspension with low natural frequency and proper damping.*

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* For the domestic trailer - where the electronic racks will always have the benefit of the trailer's suspension - simple damping pads should be sufficient for the rack installation.

The natural frequencies of vehicles which might transport the modules vary considerably and typically may be as high as 7 Hz. This becomes the overriding consideration for shock mount selection for the equipment racks, which should be selected to provide a natural frequency in the range of 8 to 10 Hz.

With a high ratio between the rack suspension and trailer suspension frequencies, theoretical shock transmissibility would be approximately one, so that with inherent damping provided in the shock mounts, highway operation should be satisfactory.

F-7 Jacks and Outriggers

To provide the necessary stability and levelling capability either type of trailer would require body mounted jacks and outrigger jacks. The latter would be extendible to provide a more stable base to resist wind loading forces on the trailer and antenna and to help maintain the permissible pointing error.

For the short 15 foot modular trailer it is expected that 2 body mounted jacks, 2 outrigger jacks and the dolly jack would be fitted. For 20 foot or larger trailers 2 additional body mounted jacks could be advantageous.

The dolly jack would be used more often than the others and would accomplish the rough levelling and be used in coupling and uncoupling the trailer. A 12 volt DC powered jack is recommended or alternatively an hydraulic hand pump operated jack, to reduce operating time and effort.

The body mounted jacks, would not normally be required to lift through the same range or be subjected to as high loading as the dolly jack. We suggest hydraulic jacks for this application. Ideally, the jacks should attach to the trailer and be retractable out of the way but one could consider loose jacks that jack from the ground to pick-up points on the trailer, provided that jacks have sufficient side loading capability for any probable geometry with the bearing surfaces and for wind loading forces.

Hand crank operated jacks are suggested for the outriggers, which are only set after the trailer has been rough levelled. They should be firmly secured to the outrigger arms and have suitable side loading capability such that forces due to wind effects on the trailer - which conceivably could slightly raise an outrigger arm - could not cause displacement of the jacks. The outrigger must be designed to provide high rigidity when set, but must be easily moved into position or retracted.

The suggested levelling sequence would be to first use the trailer dolly jack, with a trailer mounted level, to obtain rough levelling in the fore and aft directions; then to jack up the trailer using body mounted jacks, located at the rear, and level in the crosswise direction. The dolly jack would again be readjusted, followed by the body jacks, to provide closer levelling and then the outriggers would be extended and their jacks set, approximately.

The close tolerance levelling would be carried out by two men, one who would observe a precision level* mounted on the antenna positioner head and who would direct the second man in his adjustment of the jacks. One man could do both functions but the task might take some time.

A recommended option is the use of electrically operated jacks, which would be controlled from the positioner location, to significantly shorten the operation.

As noted in section F-8, even load distribution is important to reduce distortion; means to achieve this are suggested there. Setting of the outrigger jacks to equalize their loading with the dolly jack is important and if more than 2 body jacks are fitted their adjustment also becomes more important and of course, more difficult.

For soft terrain, foot pads would be used to reduce the loading to permissible weight per unit area. (Even with foot pads at least one re-levelling action will probably be required as the pads settle in.) Where there is perma frost, a thermal insulation would also have to be provided, not only at the jack points but also under the entire trailer. The thermal insulation might be thick foam plastic board, or an insulating blanket.

F-8 Trailer Distortion

In transit the trailer suspension action, together with cross winds and head winds, would act to distort the trailer structure. The attachment of the body to the frame, and equipment racks to the body, should provide suitable flexibility and damping to keep stresses at low enough levels to prevent damage.

At the site, jacks and outriggers combined with the mass of the trailer would be required to maintain the pointing accuracy specified, resisting the action of wind, both steady and gusting, against the trailer and against the antenna dish. The wind forces vary as the square of the velocity and would also depend on the aerodynamic shapes of the trailer and antenna dish.

The domestic trailer is shaped to reduce wind forces to a minimum. The modular trailer could probably not be made with a good aerodynamic shape because of the constraints of the module sections and of the folding chassis, which would not permit a streamlined underbelly.

As noted in Section F-1-5 of the Appendix a single tandem axle located amidships would produce less torsional distortion to the trailer than two fore and aft mounted axles would. To reduce distortions due to unequal levelling of the jacks

* An accuracy better than $\pm 0.05^{\circ}$ is required.

the sequence described under "Jacks and Outriggers" should be followed whereby levelling is carried out with 3 jacks, followed by setting up of outriggers and the other jacks which could be finely adjusted with a torque wrench or with pressure sensors to obtain even load distribution.

The modular trailer should have good structural rigidity as a result of the structural requirements for the modules. This would permit attachment of the antenna pedestal directly to the corner of the trailer.

The domestic trailer body would also have rigidity due to its shape but it would not be feasible to attach the positioner to the lightweight stringers and frames used. Its chassis would require modification to allow for attachment of the outriggers and body mounted jacks so that the antenna pedestal could be attached using tubular framed struts attaching directly to the frame. The same method could also be used for the modular trailer. ATCO have indicated that this would simplify the design problems.

A value of 0.1" total permissible distortion has been assumed as a realistic value. Distortion is assumed to occur whenever the top of the antenna mount moves relative to the bottom by wind forces, settling, etc.

F-9 Set-up Procedures

The sequence of operation for setting up a trailer following air shipment would be dependent to some extent on the detailed design of the trailer but can be described in a general sense.

It is assumed that the pallets would be unloaded from the aircraft into a hanger or warehouse where fork-lift trucks are available. A fork-lifter could be used to remove the trailer chassis from its pallet and it could then be rolled to a clear area and set-up. Alternately, special module handling equipment could be used to lift the chassis and move it into position.

The set-up of the chassis would be dependent on whether the frame is hinged or telescoped, and if hinged, whether the end sections are rotated using torsion spring assists or by means of geared cranks. It would also be possible to attach a module positioner on each side of the end sections and raise and then lower them into position with it. The module positioner would also be suitable for raising telescoping sections into position and inserting them into the centre section should this type of frame be selected.

Body mounted jacks would be set to stabilize the chassis during assembly and then to level it prior to installation of modules.

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* Reference catalogue data for Prodelin radomes at 12 GHz.

The modules would either be removed from the pallets by fork-lift truck using slings or the module positioner would be attached directly, the modules raised and then driven into position near the chassis where they would be raised higher, rotated through 90° and driven into position with the module positioner straddling the frame.

Lowering of the modules would deflect the frame to some extent although this would be limited by the jacks. Therefore, when the mating module is brought up, the inter module fasteners would be required to pull the mating surfaces into alignment. Fasteners which operate using an Allen wrench, with fully concealed latches are available and have the advantage that only one turn is required. A large number of fasteners would be required to distribute the load, or several large bolts, provided that the module structure is designed for the purpose. As an example, flat plates could be attached between the top corners of mating modules, using capscrews into the tapped lifting ring holes.

Module attachment to the frame could simply be with bolts, could be through dowel pins and latches, or several other means. It is recommended that elastomeric pads be used between the modules and frame to provide self lubricated bearing plates which would also provide some damping.

With the modules assembled onto the chassis some final sealing might be necessary at the joints and it might be required to apply metallic tapes for EMC purposes.

The engine generator set, antenna positioner reflector and other components would then be loaded and secured, the trailer hitched to the tow vehicle and jacks retracted or removed and the mobile terminal would be ready to set out to its operation site.

There are no special set-up procedures required for the domestic trailer with the exception of setting of jacks and outriggers at the operational site, and setting up of the antenna, etc., which would be essentially similar for either trailer concept.

SECTION G

MODULE HANDLING, SPECIAL EQUIPMENT

G-1 General

This section is applicable to the modular concept. It deals with the special handling device--the module handler--that is required for assembly and disassembly of modules, whenever the terminal is to be transported by Boeing 737 Aircraft or others in this class.

The use of fork lift trucks, jib cranes, and winches has been studied but with each of these methods there is measurable risk of damage to expensive equipment and/or a too complicated and lengthy time required to accomplish the operations.

It is essential that setting up time and to a lesser extent disassembly time at the site be made as short as possible because of the high cost of field operations and also because weather conditions may make working outside very difficult and even dangerous.

G-2 Concept

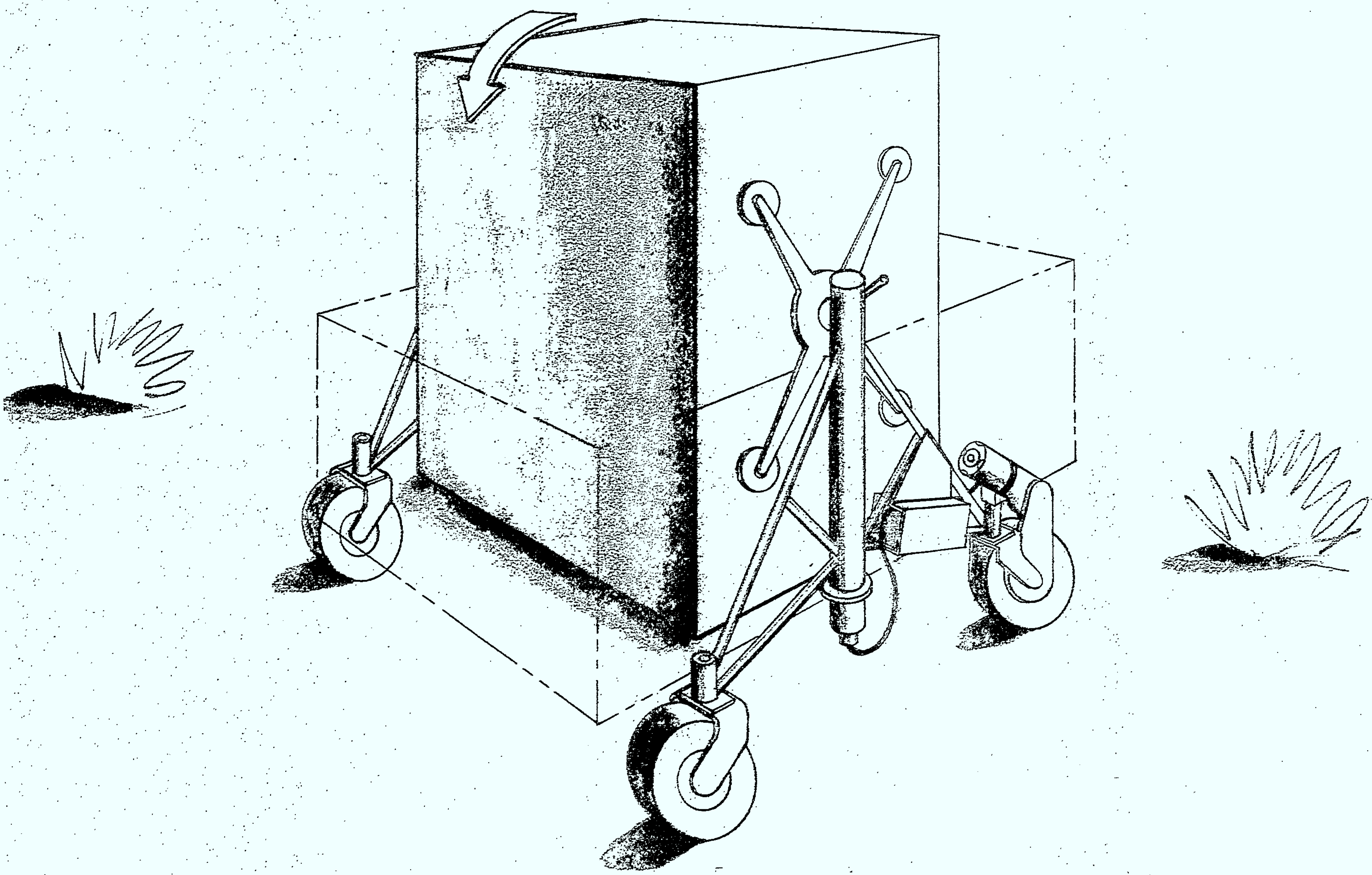
An investigation of possible methods for complying with the specialized requirements for module handling has been made. From this, a concept has evolved for a powered module handler which would consist of two 2-wheeled carrying units that attach to opposite sides of a module. Figures G-1 and G-2 show how such equipment would be used for raising and lowering modules, rotating them and carrying them into position on the chassis. The equipment could be used for other lifting and transporting tasks provided that suitable attachment accessories are provided.

It is envisaged that batteries would provide the motive power, with provision for rapid charging. A lightweight, high power to weight battery such as the Globe Gel Cel would be suitable and has the great advantage that it uses an electrolyte in a gel form, making it virtually spill-proof.

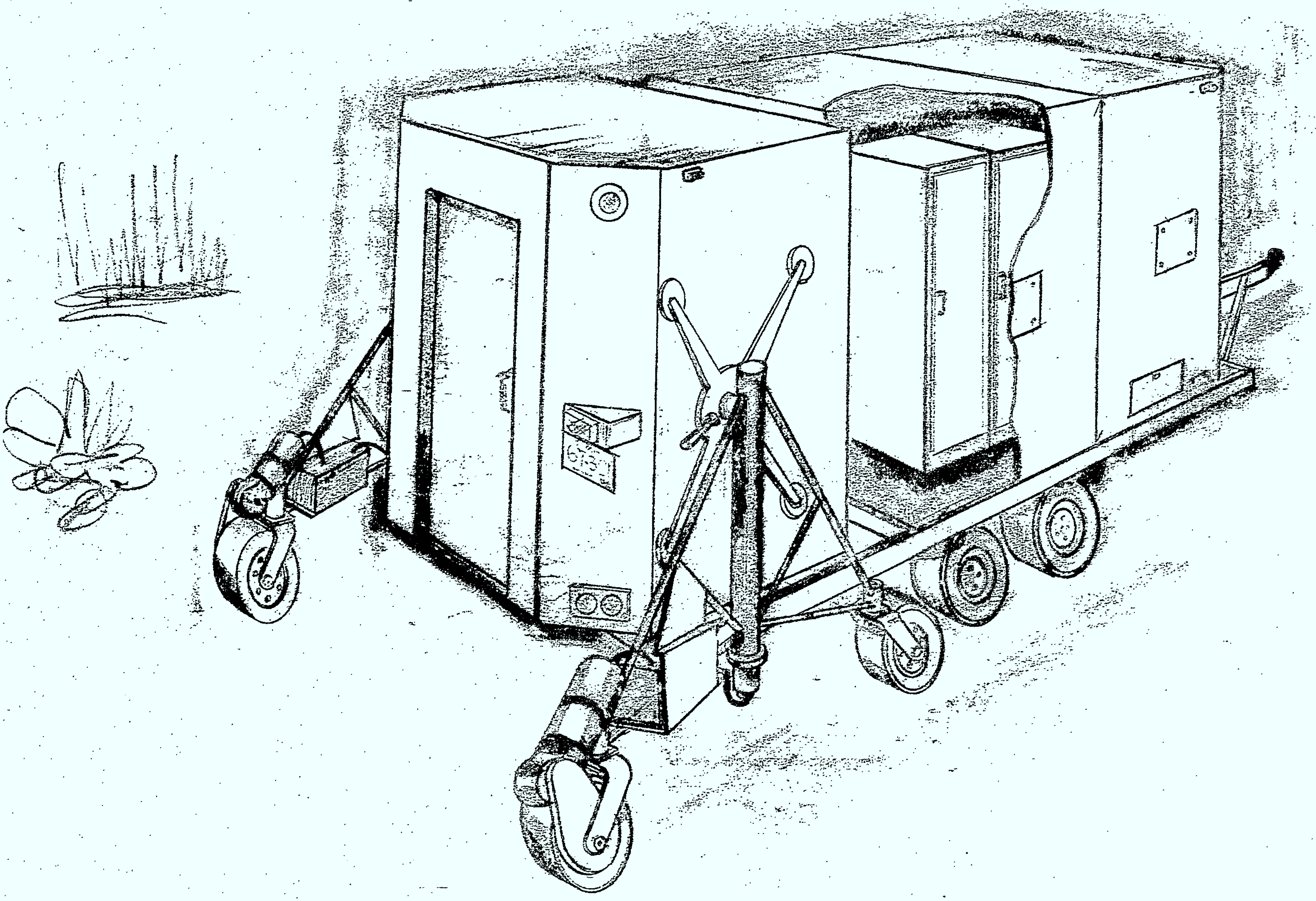
The lifting mechanism would use a conventional jack screw, motor driven, with a manual cranking over-ride. The mechanism must be protected from sand and dust, rain and humidity, and the pivot point must not cantilever directly off the jack screw. This suggests that the jack screw should be on the inside of the centre vertical tube with the pivot point sliding on the outside of the tube.

The method of attachment to the modules is very important. Lifting forces applied to the modules would tend to cause "oil canning"* of the sides unless sufficient bracing is provided.

* That is, the sides of the modules would bulge-out then sag inwards, often with an audible "pop", hence the term "oil canning".



LIFTING AND ROTATION OF MODULE
FIGURE G - 1



POSITIONING OF MODULE ONTO CHASSIS
FIGURE G - 2

Each side would be independently coupled to a module, thus for going over uneven terrain there must be freedom for the two carrying units to rotate with respect to each other, while still providing a constraint to hold the module in position; by locking the pivot point of one module and leaving the other free to rotate, independent action can take place. Disc or band brakes should be used, although slip clutches could be provided at the pivot points to provide the necessary constraints.

To better distribute loading, arms with rubber pressure pads attached to the pick-up pivot points should be used to press against structural members of the modules. One alternative to this method, which inevitably would simplify the module structural design, is to use larger arms that attach directly to the module corners at the lifting ring pick-up points. However, these arms would be quite cumbersome because of the large size of the modules.

Each side should be independently controlled and this means that side loading would occur at the pivot points and at the wheels. With castors on all four wheels this would be alleviated. A castor locking device would be provided at each powered wheel for the transporting mode.

It would be more difficult to couple power to castored wheels than to fixed wheels, however very compact high speed gear motors are available which can be mounted on the castors and linked by a chain drive to the wheels. As as alternative, high torque hydraulic motors which drive the wheel hub directly could be used.

G-3 Capabilities

The module handling equipment is required to lift and lower at a controlled rate, modules weighing approximately 2,000 lbs. each, to incorporate a means for rotation of the modules and to carry the modules, self powered, on to and away from the trailer chassis.

Detailed design of the modules is dependent on the parameters specified. The selection of safety factors, operating speeds, grades over which the handlers must be capable of traversing, steering requirements etc. would directly affect cost, weight, and power supply requirements. The cost of developing special components could be prohibitive.

The specifications enumerated in Table G-1 for the module handling equipment are considered achievable at this time but some changes would probably be necessary following preliminary design activities by specialist subcontractors.

TABLE G-1

SUGGESTED MODULE HANDLER TECHNICAL SPECIFICATIONS

PARAMETER	LIMITS	SPECIFICATION
a) Lifting Capacity		3,000 lbs. minimum
b) Pick-up Height Range		24 inches to 72 inches
c) Lifting Speed	Max. Load 2000 lbs. Load No Load	0.25 inches/sec 0.75 inches/sec 2.5 inches/sec
d) Lowering Speed	Max. Load 2000 lbs. Load No Load	10 inches/sec 5 inches/sec 2.5 Inches/sec
e) Max. Acceleration Rate (lowering)		5 feet/sec/sec
f) Min. Deceleration Rate of Braking (pick-up or lowering)		32 feet/sec/sec
g) Driving Speed Capability up 10% grade	Max. Load 2000 lbs. Load No Load	1 ft/sec. minimum 2 ft/sec. minimum 5 ft/sec. minimum
h) Driving Speed down 15% grade (without brakes)	Max. Load 2000 lbs. Load No Load	Controllable to 5 ft/sec. Controllable to 2 ft/sec. Controllable to 0.5 ft/sec.
i) Braking Capability down 15% grade (no skidding)	Max. Load	32 feet/sec/sec
j) Towing Speed Type III Mobility per MIL-M-8090E	Max. Load 2000 lbs. Load	5 ft/sec. 7½ ft/sec.
k) Worst Duty Cycle for Traction Motors		50 ft. up 10% grade at max. load, 2 minutes off, 50 ft. return at no load, 2 minutes off with cycle repeated 4 times.
l) Tires *MIL-W-8005B.		Arctic type *4.80/400-8 6 ply outside diam. 16.8", rolling radius 7.4".
m) Steering		2 Wheels castored, using separately controlled powered wheels (not castored)

TABLE G-1 con't

PARAMETER	LIMITS	SPECIFICATION
n) Power Supply		Integral Electric Power Pack 12 VDC, preferred or separate power cord connecting to 12 VDC or 115 VAC 60 Hz supply. Note: 24 VDC battery supply could be considered.
o) Control		Separate controls for each side using pendents.

G-4 Operation

In Section B, the operational sequences in which the module handling equipment would be employed is touched on. In this section, we deal somewhat more closely with the steps surrounding the handler itself. The actual procedures to be used would depend on the detail design of the module handling equipment.

While it may be possible for one man to control the lifting, driving, and steering of the handling equipment with a module attached, we recommend the use of two men, particularly during rotation of a module. Table G-2 lists a typical operating sequence for assembly of a trailer from pallets in a warehouse. Some of the tasks could be done in parallel, depending on the man power available. Figures G-1 and G-2 illustrate the module handler in action.

With few exceptions, the same sequence could be used for assembly of the trailer at the site, should this be required, and the sequence would be essentially reversed for trailer disassembly and pallet loading.

TABLE G-2

OPERATING SEQUENCE FOR LOADING MODULES ONTO CHASSIS

STEP		ACTIVITY	COMMENT	ESTIMATED TIME DURATION IN MINUTES
1		Unload module handling carrying units from pallet.	Probably loaded on same pallet as chassis.	2
2		Connect batteries and power control pendents to both units.	Batteries and pendents may be already installed.	3 (if applicable)
3	△1	Push left carrying unit up to left side of module No. 1.	Pushing may be difficult if high gear ratio electric motor used (then use battery power)	0.5
4		Raise or lower pick-up head and rotate to line up with module attachment fitting.	Assume that head is partially self-aligning, otherwise longer task.	1
5		Attach left carrying unit to module No. 1, lock brakes on pivot point, lock powered caster.	Assume bolts or capscrews not required.	1
6	△1	Push right lifting unit up to right side of module No. 1.		0.5
7		Raise or lower pick-up head and line up with module attachment fitting.		1
8		Attach right carrying unit to Module No. 1, leave brake unlocked, but lock caster.		1
9	△2	Clamp the two pendents together and raise each side approx. 6" off floor or clear of pallet.	Clamping makes electrical connection so that drive control can be through single lever.	1.5

....con't

TABLE G-2 con't

STEP	ACTIVITY	COMMENT	ESTIMATED TIME DURATION IN MINUTES
10	Drive with module to end of chassis and apply brakes to carrying units.	Steer by varying motor speeds of each side.	2
11	Raising each side equally, lift module to required height for module rotation.	Each side is independently controlled.	1
12 △3	Rotate module through 90° and lock brake at pivot point.	Assume that pick-up point of module related to C.G. is within ± 0.5 inch for fore and aft and within ± 1 inch for vertical.	3
13	Raise module sufficiently to clear chassis by approx. 6 inches.		0.5
14	Drive module into position and lower slowly to barely clear chassis.		1
15	Unlock back casters and lever module sideways into position.	This is not necessary if module has been accurately steered into position.	4
16	Attach module loosely to frame.		2
17	Lower module so that weight is taken by frame.	Module No. 1 will be fastened tightly after module No. 2 has been installed.	0.5
18	Detach carrying units and push back into positions on each side of module No. 2	See step #3 comment	4
19	Repeat operations for 2nd and 3rd modules to lift, carry and attach them to chassis.		

....con't

TABLE G-2 con't

STEP	ACTIVITY	COMMENT	ESTIMATED TIME DURATION IN MINUTES
20	Load handling equipment on board trailer and drive to site.		
21	Recharge batteries from 115 V.A.C. supply.		

NOTE: △1 Position of driving wheels at the rear is probably better for steering purposes, otherwise either carrying unit can be used on either side of a module.

NOTE: △2 For hand control, a pistol grip joy stick type lever is assumed. Pushing forward controls speed, to the left causes left turn, to the right causes right turn, centre is off and backwards reverses carrying unit. Push button switch on stick controls inching.

NOTE: △3 CAUTION: Extreme care is essential; stay clear of module as much as possible. C.G. of module may not be exactly coincident with pivot point; rotation torque required will either be positive or restraining. Brake at pivot point may be used for restraining purposes; restraining chain may also be advisable.

SECTION H

HEATING AND VENTILATION

H-1 General

Maintenance of a closely controlled temperature and humidity environment inside the terminal would require a reasonable amount of care in selection of equipment and in the design of heating and ventilation ducting. The large amounts of heat which would be dissipated by electronic equipment complicate cooling but could be used to advantage in cold weather.

It should be relatively simple to provide the installation in a domestic trailer. Domestic trailers are equipped with screened windows and overhead ventilators, some of which have fans. They are easily fitted with one or two overhead air conditioning units and as standard equipment have propane furnace installations with hot air circulation through ducts.

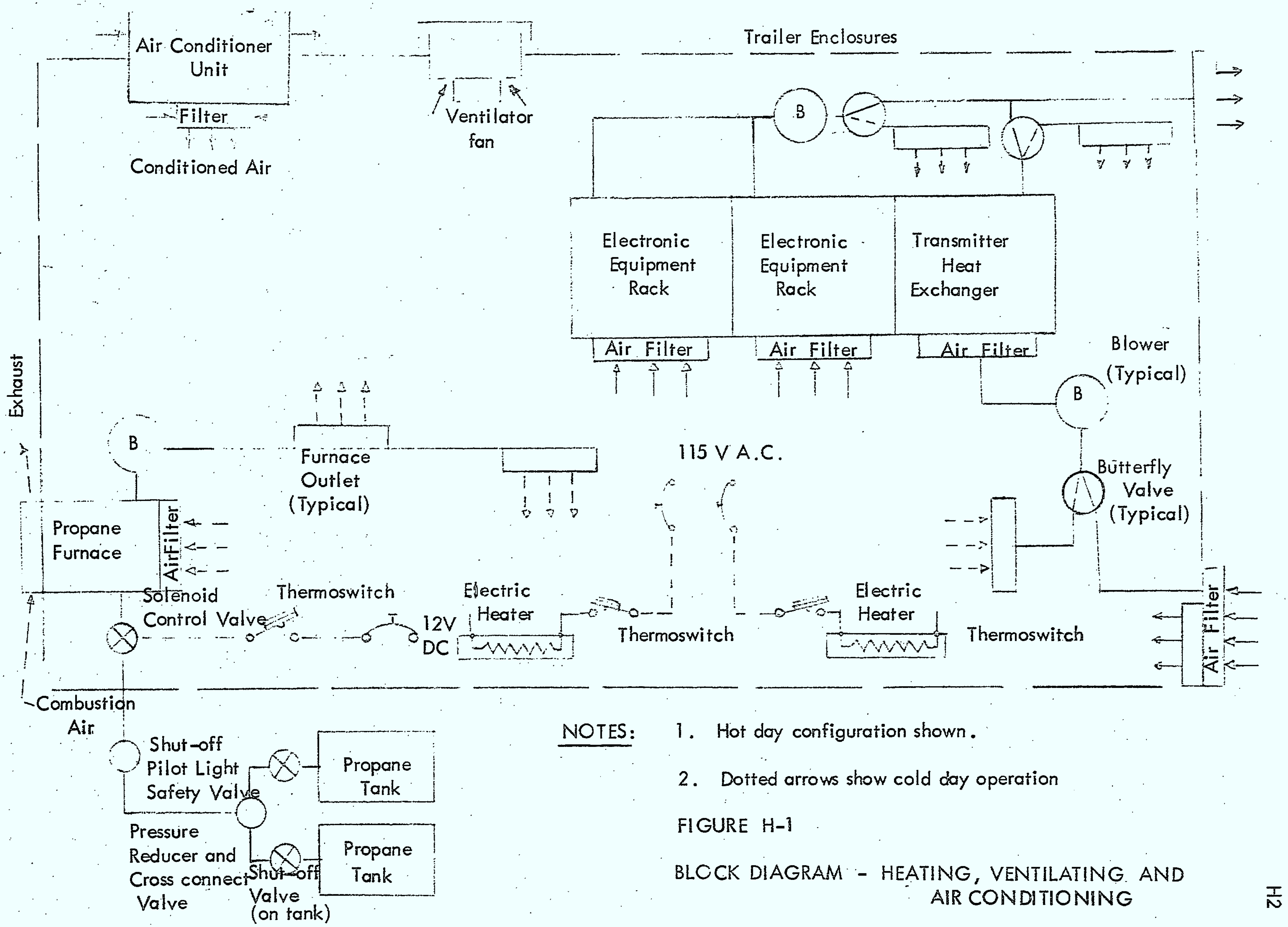
The heating and ventilation system of the modular trailer would be constrained by the separate modules. Ventilators and air intake should not protrude and must have positive seals because the modules are to be used as shipping containers. Windows would be limited in size because of the effects on the structure. They can not be permitted to interfere with the module handling pick-up points and they also would require positive gasket sealing to provide a controlled humidity shipping container.

Requirements for possible heating and winterization kits for the engine generator set and consideration for fuel are discussed briefly in this section along with the discussion of heating and ventilating of the terminal itself.

H-2 System Concepts

Figure H-1 is a typical block diagram of the heating and ventilating system for the trailer. Provision of fresh air would be through an air inlet provided with a control valve and fitted with a large air filter element. Outside air would normally mix directly with inside air; thus the inlet should be located where it will not be too close to personnel.

To maintain circulation of fresh air, several ventilators should be provided. On warm days roof ventilators with fans may be used. On hot days air would be cooled and circulated and a percentage exhausted by means of roof or wall mounted air conditioners, and in cold weather a small amount would still be exhausted to provide adequate ventilation. Circulation fans would provide ventilation and assist in temperature equalization. The air circulation requirement, according to MIL-STD-1472A, is for a minimum of 30 c.f.m. per man with approximately 2/3 of this fresh air.



NOTES:

1. Hot day configuration shown.
2. Dotted arrows show cold day operation

FIGURE H-1

BLOCK DIAGRAM - HEATING, VENTILATING AND AIR CONDITIONING

The electronic racks would be fitted with separate air filters and cooling fans to circulate air from inside the trailer. Heated air from the racks would be exhausted directly outside through ducts and roof vents, in warm weather. In cool weather some would be ducted outside and some inside with the ratio adjusted by means of a butterfly valve. In cold weather, all of the heat could be exhausted inside the trailer.

The cooling of the transmitter rack should be handled differently from the others because there is more heat involved. In hot weather the intake and exhaust air at this rack should be directly ducted to outside the terminal. This has the penalty that the cooling air is already at high temperature but air cooled power tubes are generally designed with a capability to operate at these temperatures.* A booster fan may be used if necessary to increase the circulation rate. The permissible heat sink temperature of the Sperry TWT considered, is 90°C with a required airflow of 100 c.f.m. (presumably at room temperature). While a small percentage of the transmitter heat will still be rejected inside the trailer, the net effect is that the air conditioner can be much smaller than it would be if required to also condition the cooling air for the transmitter.

For heating purposes, a propane furnace is recommended, primarily because of its simplicity, because it would not have to be drained or primed and because small compact furnaces of this type are very common. Oil fired furnaces would also be suitable and would have the advantage of using common fuel with a diesel engine powered generator set. Cost of fuel for heating would not be a big factor but diesel fuel would be less expensive.

The furnace and blower should operate from 12 volts d.c. with the thermostatic control. This would permit operation from batteries to keep the trailer warm in non-operating hours. When the generator is running or when connected to the hydro, electric heaters can provide supplemental heating.

H-3 Capacities

During operating periods, heat dissipated from electronic equipment supplemented where needed by electric heating would be used. The required BTU's for heating are dependent on so many factors that a detailed study would be required for the particular trailer selected.

The heat required to warm up ventilation air would be comparable to that required to make up the heat loss through the trailer.

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* Varian specifies that for their proposed klystron, only the body temperature need be temperature stabilized by liquid cooling. The major portion of the heat is still removed by a forced air flow past the collector cooling fins.

It is expected that approximately 20,000 BTU's capacity per hour would be required for heating, when the electronic equipment is off, provided that the overall U factor* can be kept low. This is the typical heater size for a winterized domestic trailer, and it normally operates for only a small percentage of the time. Should operation at very low temperatures be contemplated, the heating system of the trailer would require additional capacity and propane tanks would require heaters and insulation because propane freezes at -51°F.

Very low temperature operation would impose other problems such as in starting the engine generator set. It would be advisable to provide special low temperature kits which could include combustion heaters, or some other method, such as ducting of heated air from the trailer, to bring up to an easy starting temperature.

The air conditioning requirement is very dependent on power dissipation of the equipment, the number of personnel in the trailer, and the ventilation provided. The heat input through the trailer windows, the reflectance of the skin and the specified outside maximum temperature are also important factors. To reduce voltage and frequency start-up transients it would be better to have two medium sized units instead of one large unit. The units could be interlocked to prevent them from starting simultaneously.

H-4 Set-Up

Set-up operations at the site would include making the heating or air conditioning units operational. For the modular trailer there would be certain tasks involved such as sliding the air conditioning unit into place on rails and locking it into position, installation of propane tanks at the front of the trailer and connection of fuel lines to them and to the furnace, removal of furnace vent covers, and ventilator seals, and connection of airducts between modules, etc.

Particular care would be essential in connecting up the fuel system. The fuel lines should be provided with self sealing quick disconnects, where this would prevent fuel spills or gas leaks, and the furnace, if oil fired, should have a drain valve, so that it can be drained prior to removal of the module from the trailer chassis.

H-5 Operating Procedures

The operating procedures required are relatively simple.

Operation of manual control valves provides gross type control. Where the change in a valve position must be frequent, it should be controlled by thermostatically controlled or logic controlled solenoids, so that once started up little attention is needed to maintain a controlled environment.

* "U factor" is a figure of merit for the rate of average heat loss from an enclosure, defined in BTU's per square foot per degree Fahrenheit difference per hour. We have assumed a "U factor" of 0.2 for the modular trailer.

Start-up of a propane furnace is not difficult but usually involves several steps and there is a safety implication. Gusts of wind are not normally a problem to pilot lights but it is good practice to provi de a small wind breaker or deflector outside the furnace. The furnace thermostat should be set slightly higher than the electric heater thermostat, which in turn should be set slightly higher than the ventilation control thermostat. Thus the electric heater and the furnace would only switch on when insufficient heat would be available from other sources.

If an oil fired furnace is used there are possible problems with fuel flow and ignition but its reliability should be comparable to the propane furnace. For Northern use, Arctic type low viscosity fuel is advisable and care must be taken to prevent build-up of condensation in the fuel tank. Gas line anti-freeze (alcohol) would probably solve this problem.

For very cold temperature, one might consider providing ducting of heated air from the furnace to the engine generator set to alleviate problems. If this is done, special care to ensure that engine fumes cannot be sucked into the trailer is required. It would probably be better to have a separate combustion heater for the engine for this purpose.

SECTION I

POWER SOURCES

I-1 General

The selection of power supplies for the terminal is dependent on the power requirements of the equipment, anticipated duty cycle, desired operating life between minor and major overhauls, specific fuel consumption, fuel availability and weight and cost.

It is necessary to make the terminal self sufficient in terms of its normal and emergency power supplies and also to take into account availability of local public utilities.

I-2 Power Requirements

Table I-1 and Table I-2 have been prepared to show electrical loading operating modes, for typical d.c., and a.c. equipment, which would comprise the terminal. On this basis, a 10 kw generator set would be suitable but if we consider the possible selection of a more powerful transmitter, and possible increased in air conditioning requirements, a 12 to 15 Kw set might be required.

I-3 Motor Generator Set

Rating

Small generator sets are rated on the basis of kilowatts instead of k.v.a. because the prime mover is usually the limiting factor. Up to 15 Kw most sets are air cooled and there is a wide range of commerical and military sets available in both gasoline and diesel engine versions. Above 15 Kw most sets have water cooled engines.

Gas turbine powered sets are also available in the 15 Kw range. These have been developed primarily for Aircraft ground power or Auxiliary Power Unit (A.P.U.) applications where lightweight is a primary requirement, and where 400 Hz is the power frequency.

Prime Mover

Of the several choices for prime mover, an air cooled diesel is considered the most suitable.

Fuel consumption is typically 60% that of an equivalent gasoline engine. The engine is simpler, more rugged and is de-rated, thus its typical operating life of 1,000 hours between overhauls is at least twice that of an equivalent gasoline engine and it has an operating life between major overhauls of 5,000 hours.

MOBILE TERMINAL D.C. LOAD ANALYSIS

TABLE I-1

1. LOAD EQUIPMENT	Rated Load	Hot Day oper.	Hot Day Standby	Warm Day Oper.	Warm Day Standby	Cool Day Oper.	Cool Day Standby	Cold Day Oper.	Cold Day Standby
Housekeeping Equipment									
Interior Lighting	10	10	5	10	5	10	5	10	5
Exterior Lighting	2	2	-	2	-	2	-	2	-
Propane Furnace	4.5	-	-	-	-	-	0.9	1.5	2.5
Water Tank Pump	3	-	0.5	-	0.5	-	0.5	-	0.5
Ventilation Fan	3	-	3.	-	3	-	-	-	-
Battery Charging	10	-	-	-	-	-	-	-	-
Operational Equipment									
2 Antenna Pedestal Actuator	21	-	-	-	-	-	-	-	-
3 Antenna Positioner	21	-	-	-	-	-	-	-	-
3 HF XMTR/RCVR Inverter	15			Emergency Use Only					
Total Average Load (amperes)		12.0	8.5	12.0	8.5	12.0	6.4	13.5	8.0

Notes: Operating periods very short; average load not significant.

1. 12 V d.c. supply; loads are in amperes.
2. Operating periods short; average load insignificant
3. Emergency use only

MOBILE TERMINAL A. C. LOAD ANALYSIS (SHEET 1) TABLE I-2

1 LOAD EQUIPMENT	Rated Load	Hot Day Oper.	Hot Day Standby	Warm Day Oper.	Warm Day Standby	Cool Day Oper.	Cool Day Standby	Cold Day Oper.	Cold Day Standby
Housekeeping Equipment									
Lighting	300	300	100	300	100	300	100	300	100
Ventilation Fans	150	150	-	150	-	150	-	150	-
Air Conditioning	1750	1750	1750	-	-	-	-	-	-
Electric Heating	3000	-	-	-	-	-	3000	3000	-
A. C. - D. C. Converter	400	190	140	190	140	190	100	220	130
Coffee Maker	1500	-	750	-	750	-	750	-	750
Operational Equipment									
Antenna Anti-ice	3000	-	-	-	-	3000	3000	-	-
Receiver	300	300	-	300	-	300	-	300	-
Transmitter	3500	3500	-	3500	-	3500	-	3500	-
Driver TWT Chain	500	500	-	500	-	500	-	500	-
H. F. XMTR/RCVR	100	25	25	100	25	25	25	25	25
Sub-Total (Watts)		6765	2765	5040	1015	7965	6975	7995	1005

MOBILE TERMINAL A. C. LOAD ANALYSIS (SHEET 2) TABLE I-2

TEST EQUIPMENT	Rated Load	Hot Day Oper.	Hot Day Standby	Warm Day Oper.	Warm Day Standby	Cool Day Oper.	Cool Day Standby	Cold Day Oper.	Cold Day Standby
T.V. Oscilloscope	92	92	-	92	-	93	-	92	-
NTSC Vectorscope	95	95	-	95	-	95	-	95	-
Waveform Monitor	48	48	-	48	-	48	-	48	-
Signal Generator	55	55	-	55	-	55	-	55	-
Colour TV Picture Monitor	160	160	-	160	-	160	-	160	-

Notes: △1 115 V, 60 Hz a.c. supply; loads are in watts.
△2 Power factors have not been listed but overall factor should exceed 0.8 (typical rated power factor for generator sets)

Sub-Total (watts)	450	-	450	-	450	-	450	-
Sheet 1 Sub-Total (watts)	6765	2765	5040	1015	7965	6975	7995	1005
△2 Total (watts)	7215	2765	5470	1015	8514	6975	8445	1005

For the C.T.S. application, where 60 hours per week operation or more would be expected, the greater reliability and fuel economy would be a significant factor in reducing direct operating costs and in simplifying spares requirements.

Spark ignition engines are less costly and generally easier to start than diesels. Propane or natural gas powered engines have better life and are easier to start than gasoline fueled engines and would use the same fuel as that we are recommending for the furnace, however their fuel economy and life would still be poorer than an equivalent diesel's and provisioning of large supplies of fuel may be a problem. In the small air cooled size range there is not a significant weight difference between engines of the different types.

Gas turbine engines operate at high speeds, require a high quality gear box to get the right pad speed for the generator, are noisy and have a very high fuel consumption.

The heat rejection from gas turbines has been used with a suitable heat exchanger to heat living quarters and melt snow. This was an experimental installation, designed to be transported by helicopter, for military housing in the Arctic. Cost of such an installation would be high and together with the other drawbacks noted makes a gas turbine prime mover unattractive for this application.

Fuel cells and other energy conversion means power supplies are available but it is not considered that they would be competative (at this time) with the commonly available diesel or gasoline powered sets, either because of weight, cost, inadequate power capability, excessive fuel consumption or a combination of these factors.*

Generator and Voltage Regulator

A direct connected slow speed generator is recommended for low operating frequencies such as 60 Hz. The a.c. generator should be brushless and should be provided with a separate exciter and permanent magnet generator. The voltage regulator preferably should be transistorized but in any event, must be a static type.

The regulator and exciter should provide sufficient gain that transient dips and overshoots are minimized. The starting inrush requirements of the air conditioning units and other large loads must be carefully considered.

Speed response of a governor cannot be instantaneous therefore it is important to have a large flywheel effect and a wide diameter generator rotor helps here. The torsional coupling with the engine is a very important factor. There must be assurance from the generator set supplier that this has been tested, and if not, that there are large numbers of hours of operating experience to prove that torsional vibrations are within safe limits.

* Just at the time of final editing, we became aware that the Canadian Western Gas Co. in Calgary are participating in an evaluation program of 12.5 Kw natural gas powered fuel cells for domestic homes (project TARGET). These prototype cells were designed by United Aircraft and weigh approximately 1800 lbs. Further development may reduce this weight by up to 4 times. We recommend that a detailed evaluation of these cells be carried out.

Small electric generator plants are available with several optional electrical outputs such as 120/240 volts 1 phase; 120/208 volts 3 phase Y connected; 240 volts 3 phase delta connected, with 1 phase centre tapped; 220/380 volts 3 phase Y connected; 277/480 volts 3 phase Y connected; and 600 volts 3 phase delta connected, etc. These voltages refer to the generator capability with the regulated voltage typically 4% less, i.e. 115/200 volts system voltage for 120/208 generator rating.

For this application, the voltage option selected must be compatible with the electronic equipment. Most electronic equipment and trailer equipment use 115 volt single phase. Some equipment such as air conditioners may be more easily procured for 230 volts single phase. This indicates that a single phase 115/230 volt regulated input to the trailer would probably be best, but final selection will depend on whether or not any equipment requires a 3 phase input.

1-4 Battery and Charging

The trailer would be used in remote areas where very much depends on having an ultra reliable electrical power supply. Where practical, separate batteries should be provided for the basic trailer, for the engine generator set and for the module handling equipment, if required. At least one spare battery of each type should be provided.

The capacity required for the trailer is that to permit emergency communication, emergency lighting and to operate the propane furnace. Taking 3 amperes as the average load it would require 72 ampere hours for one day's operation. Two 80 ampere hour batteries would permit approximately 2 days operation, with the spare permitting a third day's operation. Battery charging would be through an a.c. to d.c. converter.

A single battery should suffice for the engine generator set. The set should have a manual cranking provision so that if it fails to start from its own battery manual starting procedures can be initiated to reduce the possibility that a second and even a third battery would be connected and run down in further starting attempts.

The third battery application is hardest to analyze. The module handling equipment would take high peak load currents from the battery, over a short time period. For example, to move a module 50 feet up a 10 percent slope in 25 seconds with a 50% efficiency would discharge the battery at a rate of approximately 90 amperes, if 12 volts is assumed.*

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* The Globe Gel-Cel lead acid battery is unspillable, has a high power to weight ratio and is very compact. It does require some care in charging, because during overcharge gases are vented and the electrotype cannot be restored. With suitable precautions taken, this type of battery would seem to be highly suitable for the module handling equipment.

A 24 volt supply would reduce line losses and improve efficiency. Aircraft 24 volt batteries are designed with thin plates for high discharge rates. They also are fitted with unspillable vent caps which would probably be required for this application. As an alternative two twelve volt batteries could be connected in series for operation and in parallel for charging and would be interchangeable with the batteries for the other two applications.

Lead acid batteries are considered adequate for all applications. They have the advantage of low cost; they are almost universally available, and charging and servicing techniques are fairly well known which are important factors when the equipment is operated in remote areas.

Silver zinc batteries have a very good power to weight ratio but are very expensive because of their silver content, even though they have some salvage value. These batteries should not be subjected to deep discharge. Special care is required in charging.

Nickel calcium batteries are used in many applications where reliability and long life are desired. Their performance at high discharge rates and at cold temperatures is better than lead acid equivalents. They require appropriate charge control and periodic re-condition discharge and charge cycles to maintain their rated capacity.

As a further factor an engine generator set comes equipped with a conventional alternator and transistor voltage regulator to supply 12 volt battery charging. A different charge regulator would be required to charge a nickel cadmium or silver zinc battery in place of the conventional lead acid type.

The increased costs to fit other than lead acid batteries and chargers may run into thousands of dollars. This cannot be justified for the mobile terminal where weight, while important, is not a critical factor. Final selection of required battery capacity ratings should be made when d.c. load requirements are better known, i.e. in the preliminary design phase.

1-5 Hydro Power

115/230 volts single phase power at 60 Hz is the normal domestic supply from the local electrical utility in most areas. A temporary service should be available on short notice and at nominal cost.

The conventional low voltage receptacles available at most sites are 115 volt single phase only and other receptacles such as for industrial equipment are usually at 575 volts 3 phase. Therefore special arrangements, preferably in advance, should be made to obtain anything special.

Where a temporary service is connected by the utility it is usually the responsibility of the user to provide the service panel. At the service panel the neutral is required to be grounded to earth and a disconnect switch is required with each pole of the switch, fuse or circuit breaker protected.

The service would be expected to be connected to a pole from which a suitable rubber covered cab-tire cable would connect to the input electrical panel of the trailer, in the same manner as from the engine generator set.

There should also be provision for connection of 115 volts single phase power using a conventional trailer input power plug, should the 115/230 volt supply not be readily available. This would permit operation of the trailer services without having to operate the engine generator set.

Supplies from different sources must not be connected in parallel because there would be no provision for synchronizing, or real and reactive power load sharing.

Double throw, centre-off a.c. contactors would prevent this possibility, while permitting either manual or automatic power supply changeover.

It should also be noted that the power available in some communities may have excessive conducted EMI, a poor form factor, excessive harmonics or voltage modulation, poor voltage regulation or other undesirable characteristics which would make it unsuitable for the terminal. When in doubt, the engine generator set should be used.

SECTION J

AVAILABILITY

J-1 General

The confidence that a given system can perform its function can be expressed in many ways. However, for the mobile terminal, we have chosen to use the concept of "availability" as the most practical parameter. Availability is defined as the percentage of the time that the terminal (or system) can be used in useful communications. It is affected by the following:

a) the number of predicted failures occurring over a given time period obtained from reliability data.

b) the most probable type of failure.

c) the most probable repair time for each failure.

d) judicious applications of sparing philosophy.

e) location of spares.

Availability may or may not be the most useful parameter. In certain cases, for example, outage time for any given failure may be most important. For example, in Broadcasting service, outage time is an extremely important parameter. Therefore, if the terminal is used in broadcast service, additional attention to outage time as well as availability should be made.

J-2 Communications Reliability

A reliability prediction for the mobile terminal, using complexity analysis, has been performed and is given in the Appendix J. The analysis indicates that

a) the receiving system MTBF is 1,508 hours.

b) the MTBF for the transmitter is 501 hours.

From this we see that the total system MTBF is 376 hours. On the basis of an 8 hour working day, and assuming that the MTBF applies only during operational hours, this amounts to an average of one failure every 47 days.

We note that since the reliability prediction is based on random failure, this failure rate is independent upon the past history. Therefore, probability that the terminal will operate without failure in the field for a period up to 3 weeks (15 to 21 working days) will reach at least .9.

An examination of the model used for the prediction indicates several things. First, a single failure anywhere has been assumed to be a system failure. Thus the failure in any one of the four audio channels of a composite TV transmission, or the sound channel or the TV audio single carrier, etc., is treated as a failure. For a given experiment, which only makes use of one of the possible signals, the reliability will be higher. Second, the analysis considers a failure when either of the parallel operating travelling wave tubes in the power system fails. This should not necessarily constitute a failure as in some experiments, operation could be completely satisfactorily using only one TWT. Even in the case of video signals, a higher signal power is required, loss of 1 tube could impair signal to noise ratio of the system but would not necessarily result in a system failure. Third, a driver TWT has the same failure rate as one of the power TWT's. Since it is not redundant, loss of the driver TWT is serious. Thus, this is one area where parallel redundancy could be used to improve performance. Fourth, returning to the output TWT's, a single power TWT package to replace either of the power TWT's should one fail, would also introduce a considerable measure of improvement in reliability. Fifth, the upconverter and down converter failure rates are relatively high. Thus some sparing of these units is indicated.

If the correct actions suggested by the reliability analysis are taken, the MTBF of the terminal could be extended by 2 or 3 times. This is a rather significant improvement.

J-3 Maintenance

Maintenance is defined for the purpose of the mobile terminal as largely consisting of mechanical maintenance and/or replacement of parts subject to wear. We assume that for mechanical equipment, the operational life of the equipment is defined by the conventional history consisting of a period of infant mortality, a relatively long, fairly flat portion where operation is very reliable, and a final degradation due to old-age, or wear-out. We assume that the infant mortality problems will be uncovered and remedied during the additional tests and checkouts. We further assume that parts will be replaced or serviced sometime prior to the normal wear-out points.

The remaining portion which is generally considered for the operational life, consists of quite reliable operational conditions. Adequate reliability data does not appear to be too available for this portion, so that we will attempt here to make estimates where possible, or to indicate what must be done to ensure reasonable reliable performance.

In most cases the mechanical equipment will be received in relatively good operating condition or, if not, the problems will be readily discernible and appropriate corrective actions can be taken. For example, if a mobile unit is sent via common carrier to a point and some of the attached fittings are damaged during transit, this damage will be readily apparent before the unit is placed into operation. Corrective action can then be taken during the initial set-up period following which there should be no problem at least during that term on duty in the same area. This suggests that for a given tour of duty, a reasonable allowance may be included for correction of problems such as the one noted above.

Equipment maintenance will be concerned largely with the following units:-

a) motor generator set

b) chassis and suspension

c) the module and attachments

d) module handling apparatus

e) antenna assembly

f) jacks and outriggers

We shall discuss these in turn.

The motor generator set consists of an internal combustion engine connected to an alternator and operated from a control panel. The maintenance will be applied against the alternator and against the engine generator set. The most likely problems, of course, will be associated with the internal combustion engine. If it is a gasoline engine then the spark plugs and fuel systems will be the most likely areas in which problems will be encountered. The correct maintenance will simply consist of the normal procedures applied to internal combustion engines in the area of ignition and fuel systems in order that the operation be as close to the design characteristics as possible. A regular schedule of maintenance, oil replacement, grease, etc., must be set up and applied in accordance with the manufacturers' recommendations. With respect to the alternator, normally very little maintenance other than keeping the machinery clean is required. With respect to the electrical distributions system, a regular schedule of maintenance and inspection of contactors, wire connections, and so forth, must be established.

A spare parts kit should be part of the motor generator set compliment. This kit should include such things as spare spark plug wires, spark plugs, rotor*, fuel pump, and so forth, which can be relatively easily installed in the field should the necessity arise.

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* As required. If a diesel engine is used, then spark plugs and wires, are of course, not needed. A fuel injector, however, would be.

For the chassis, a regular chassis lubrication in accordance with manufacturers recommendations should be provided. The chassis must be periodically inspected to determine whether any parts have been bent, loosened, or have become corroded due to operation in winter time over salted roads. The tires must be checked with respect to air pressure, cuts, abrasions, and so forth. Of course, a spare tire is also suggested.

The mobile attachments should be regularly inspected to see whether or not any of the fittings have been bent, corroded, or otherwise damaged. Further, the seals between the modules should be inspected after each tour of duty to check the integrity of the weather stripping, RFI shields, or electrical connections between them.

The module handling apparatus must be kept in a clean condition, and all the working parts kept in good operating order. Since it consists of a battery operated motor drive system, the state of the battery charge should be monitored. The motors should be checked for brushwear, dirt and lubrication. Tires must be inspected and checked in a manner similar to that done for the mobile unit itself.

The antenna assembly in particular must be kept clean so that reassembly of the antenna is possible and confidence is obtained thereby that the antenna reflector curvature is maintained. The axis bearings must be periodically inspected, and bearing replaced if any evidence of sticking or seizing is encountered. This is necessary to maintain good and smooth tracking performance. The spirit level indicator should be checked so that its indication of a level surface is compatible with the azimuth plane which is used as a overall reference for tracking.

Jacks and outriggers normally should give very little difficulty. The only maintenance probably necessary is periodic inspection to ensure that any castings used have not cracked due to the repeated application of loads, and that the moving parts be lubricated or greased as appropriate.

The above comments for the mechanical portions of the mobile terminal are no more or no less than would be recommended for any mechanical equipment. The concept of the mobile terminal is such that conventional and standard techniques have been used so that the maintenance procedures which have developed over the years is also applicable here. Thus in general, no new techniques need be learned. Further, the maintenance history is reasonably well established for many of the items specified.

J-4 Down Time and Corrective Actions

For the communications equipment, the most likely sources for failure are

a) the power TWT's

b) the driver TWT's

c) upconverter

d) downconverter

e) the tunnel diode amplifier.

The latter three items are supplied or rather recommended to be supplied as modular units therefore down time to replace these would consist of first, identifying that it has failed and b) second, module replacement. Thus we see that the identification of the failure is a normal procedure which would be taken for any failure and replacement will depend upon the proximity of the spare module. If the spares are located within the mobile terminals spare compliment, then replacement can be obtained or can be affected in a matter of minutes. However, if the module spares are located some distance away then we would have to add transportation time.

Thus for example, if the mobile unit is located in the north, and the spares are located at Ottawa, then the obtaining of the spares would depend upon first contacting Ottawa that the spares are required and the time taken for Ottawa to send up the spares. If the mobile terminal's communication system has failed, then communications with Ottawa could be rather difficult. An alternate means for communications would be required and in this case it would mean that the field crew would have to go to the nearest commercial or RCMP station and advise Ottawa. Communications with northland areas is rather difficult and days can in fact be lost just on communications. With regard to the delivery of the equipment, Nordair operates regular service throughout most of the eastern portions of the country in the north. Pacific Western operates in the western parts of the country. However, daily service is not necessarily available and further, weather conditions can affect even scheduled services. Typical 2 or 3 days would therefore be required as a maximum to send replacement modules after they are requested. At the very least, 5 or 6 flying hours would be used even if a module were placed immediately after requested on an aircraft and dispatched. Thus it becomes rather important that the spare modules should become part of the spares compliment for the terminal and that recourse to flying in or bringing in spare equipments should be made only on those rare type of failures occurring in otherwise very reliable hardware.

The same comments can be made for the driver TWT's. Standard packaged units are available complete with power supplies. If a standby unit is available then replacement of the failed unit with a standby unit regardless of whether the tube or the power supply had failed, is a simple procedure. This course is to be recommended.

The considerations with respect to the power TWT's is more complex. Since parallel operation will usually be required as a matter of operational procedures, a failure of one tube causes a loss of 6 dB rather than 3 dB, since the method of combining is via hybrid. The loss can be reduced to 3 dB by manually disconnecting the outputs of the TWT's, then directly reconnecting the operational TWT into the transmitter waveguide line. This takes time. However, the time can be reduced by inserting waveguide switches so that the reconnection can be made automatic. The penalty here is that additional line losses would result (perhaps half dB per switch) so that this course is not recommended if sufficient reserved power is not available, or if the time taken for waveguide re-arrangement is acceptable.

Some typical down times are given in Table J-1.

TABLE J-1

TYPICAL DOWN TIMES FOR SOME FAILURES IN COMMUNICATION EQUIPMENT

ACTIVITY	FAILURE			NOTES
Fault	Loss of 1 Power TWT	Loss of Driver TWT	Loss of Upconverter, Down Converter, TDA, etc.	
Corrective Action	Reconnect Output Waveguide	Replace Driver TWT Package	Replace Defective Module	
Time Intervals for				1
(a) Fault Diagnosis	5 minutes	5 minutes	5 minutes	
(b) Corrective Action	30 minutes	5 minutes	5 minutes	
(c) Turn-On	3 minutes	3 minutes	-	2
(d) Re-alignment	10 minutes	10 minutes	10 minutes	3
Total Down Time	48 minutes	23 minutes	20 minutes	4

Notes:
1. Spare Modules assumed available on-site.
2. TWT Warm-up cycle.
3. Assumes suitable test equipment available.
4. Some additional time for stabilization of oscillators, etc. may be required.

SECTION K

PROCUREMENT PLAN FOR THE MOBILE TV TERMINAL

K-1 General

A plan is presented which might be employed for procurement of the mobile TV terminal. The plan is divided into several phases; the first is the contract negotiation phase, followed by subcontractor selection phase and by design, manufacturing and testing phases.

Figure K-1 is a simplified CPM network illustrating the procurement plan. It is very general and describes the modular trailer concept procurement. The plan for the domestic trailer concept would be very similar and would be made by deletion of certain obvious activities.

K-2 Procurement Approach

We recommend that the mobile terminal be procured to a performance specifications through a single contractor who would have full responsibility for detailed designs, component procurement, fabrication, installation, and testing. The only exceptions to this would be in the area of Government Furnished equipment (such as two-way voice equipments, or transmitter tubes) where economic considerations or compatability requirements makes this course desireable.

The specification should be written as a document which lists only the most significant operational parameters, overall dimensions, weights, environmental requirements and general requirements for qualification and acceptance testing.

The terms of the contract can only be speculated on. The plan assumes that a fixed price contract would be invoked, therefore a period would be required for competing contractors to write preliminary requirement specifications and conduct a survey of suppliers to obtain realistic cost information.

Selection of a suitable contractor can be done following normal business practises involving the analysis of competative bids. However, we caution that selection on the basis of lowest cost alone does not necessarily indicate the best choice, particularly for the modular concept. There are many details that must be considered and, if through ignorance or carelessness, a potential contractor gives them, then he could be forced into financial embarrassment or even bankrupcy with disastrous consequences to all concerned.

The selected contractor should preferably have a basic skill centre in communications equipment, antennas, etc. but that system design, integration and testing can be carried out at his facilities.

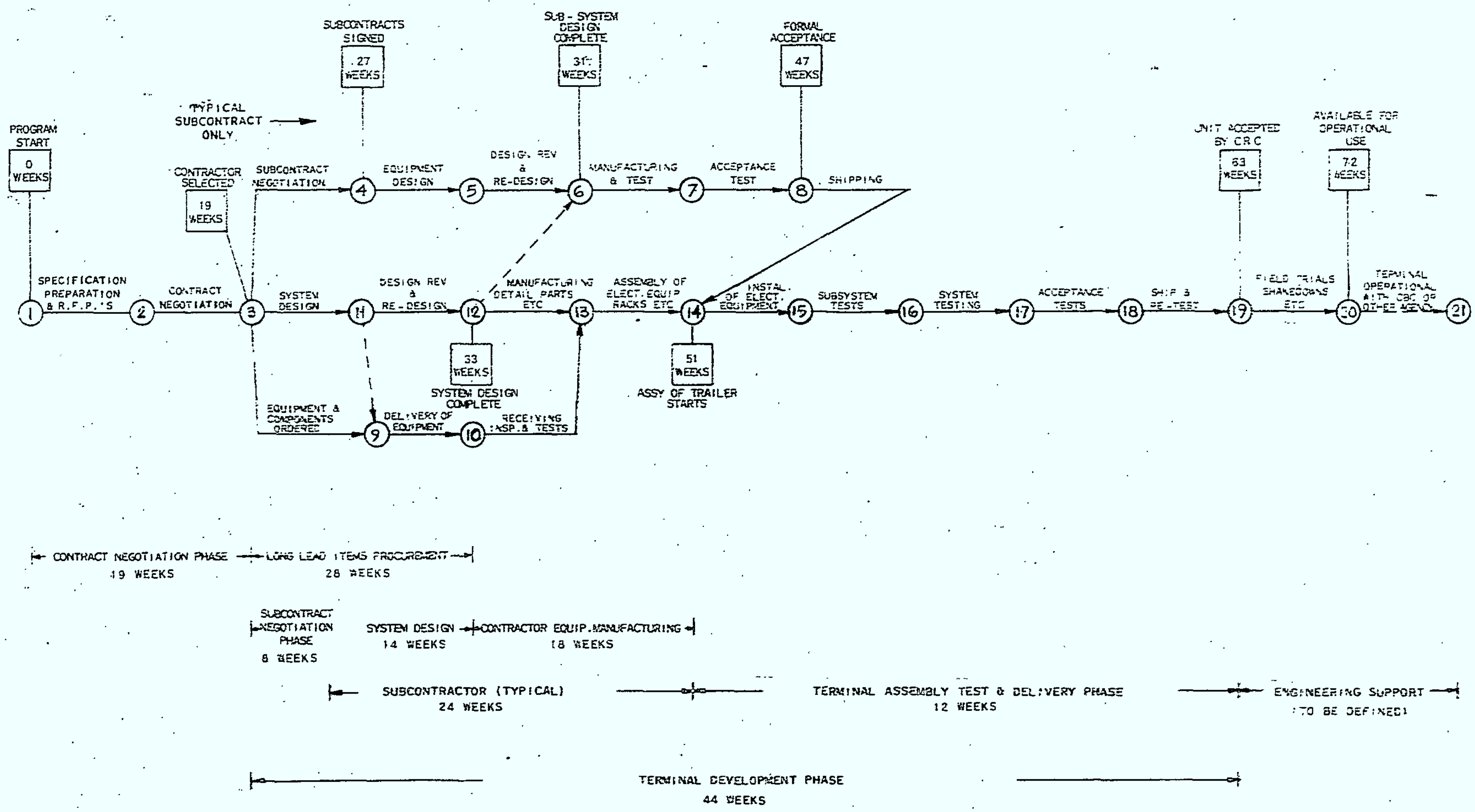

FIGURE K-1

C P M NETWORK

C T S MOBILE TERMINAL PROCUREMENT PLAN

Subcontracts will most likely be necessary. These would vary in complexity and delivery time. Rather than attempt to show each possible subcontract, a typical fragnet is shown in Figure K-1 for a relatively complex item such as the trailer or the module handling equipment.

K-3 Subcontracting

The contractor must prepare detailed specifications and control drawings and (probably) procure the trailer, trailer related equipment and operational electronic equipment from subcontractors through competitive bidding.

Some of the equipment would be off-the-shelf; other equipment would be slightly modified and some would require extensive development. The degree of specification detail and contract supervision required would be dependent on the risks involved.

The Contractor selected for supplying the Mobile Terminal should be permitted to select subcontractors of his choice with the possible exception of mutually accepted directed subcontracts, or government furnished equipment. Where these exceptions exist, the limits of liability must be clearly spelled out during the negotiation phase.

The Appendix and numerous trip reports from this study will give some insight into possible suppliers of equipment. A survey of power tubes is included in Appendix C-6 and a similar survey made for trailer suppliers in Appendix F-6 where there is included a rationale for procurement of trailer related equipment.

K-4 Other Considerations

Several other points of note regarding the procurement of the trailer may be made and are listed below. These points have been taken into consideration in developing the CPM network.

a) The trailer would be purchased complete with appointments such as heating and ventilating systems, air conditioning (area only), toilet, running water, cupboards, etc.

b) The trailer would include mounting provisions for electronic equipment and directly related equipment but these would be installed and tested by the contractor.

c) The contractor would make a full size mock-up of the terminal. This would be used for human factors engineering studies, for accurate dimensioning of waveguide and cooling ducts, etc.

d) Installation and testing of equipment are done in parallel where this is considered possible. If this is not possible due to long lead items or physical constraints, the program duration would have to be longer.

SECTION L

TESTING

L-1 General

A reasonably comprehensive testing program is suggested. Since testing can be expensive, some compromise between the depth of testing and the risks associated by dispensing of certain tests is desirable. We can, with reasonable confidence, use the results of tests on other similar systems in determining a realistic test program and in estimating the behaviour of the terminal.

A further cost effective measure would be to delay some of the tests until the final series are performed prior to acceptance tests. In this way the operation of several subsystems can be checked together and any corrective actions, if necessary, can be taken on all subsystems within a reasonably short time interval.

We discuss testing in this order:

a) Factory testing

b) Acceptance testing

c) Point of acceptance

d) Follow-up activities

e) Routine testing

Figure L-1 is a block diagram of the sequence of test groups.

L-2 Factory Testing

In general, for "off-the-shelf" items, the manufacturer's production testing program will usually be sufficient to determine correct operation of the units.* It may be desirable in certain cases to witness these tests. If additional testing is required, however, there would be additional costs specified by the manufacturer.

Examples of "off-the-shelf" hardware would be:

a) the motor generator set

b) the domestic trailer

c) the TWT power amplifier package.

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* Usually test specifications or limits for production testing can be obtained from the manufacturer.

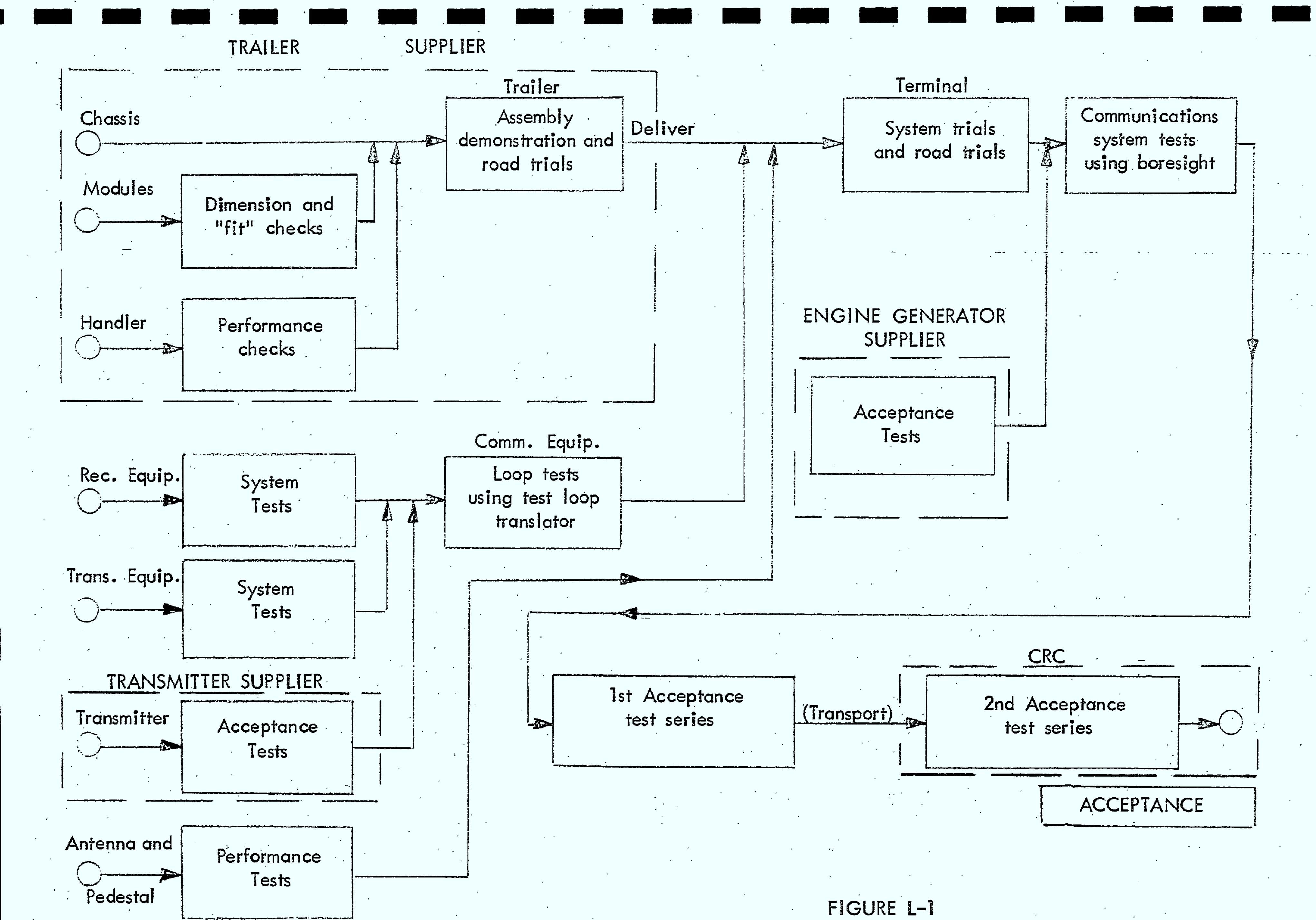

FIGURE L-1

BLOCK DIAGRAM OF TEST GROUP SEQUENCE

Factory Testing (Continued)

For specially designed equipment, or standard equipment which would undergo significant modifications, the situation is quite different. In these cases, the supplier should be asked to provide a test plan intended to demonstrate the correct operation of the equipment he is proposing to supply. This list would be examined prior to the award of contract and agreement would have to be reached between the supplier and the purchaser that the list of tests is both complete and necessary. Costs of such tests should be included in the overall cost of the equipment package.

Examples of special equipment would be:

a) the modular trailer

b) the module handling apparatus

c) the antenna mount

d) a specially designed transmitter (if specified)

These tests would ordinarily be witnessed by the purchaser at the supplier's plant at a mutually satisfactory date.

It should not be necessary to test equipment under environmental conditions. Thus, for example, the suspension for the trailer need not be tested at 40° below zero. However, the basic design and the selection of lubricants, etc. should be such that operation under these environmental conditions is possible. Similarity to equipments already in use in such environments should be sufficient to demonstrate capability.

The above comments apply to testing of units purchased under subcontract. With respect to the subsystems provided by the main contractor, the situation is not significantly different than the above except, obviously, that contractor witnessing of tests is not required. Subsystems included in this category would be:

a) receiving system

b) transmitting system

c) antenna system.

Here the main contractor would be responsible for designing, installing and wiring the units that make up these subsystems. He would have to prepare a procedure and test list for such tests as he feels are necessary to prove these subsystems. This list of tests would be part of the overall basic submission by the contractor to CRC during the proposal request phase. In principle however, the procedures are relatively standard.

L-3 Acceptance Testing

Acceptance testing is defined as that testing which would be applied to a completed terminal after

1. installation has been completed
2. all subsystems tests carried out, and
3. any corrective actions indicated as being necessary by these tests have been effected.

A tentative list of tests recommended for acceptance is:

a) demonstration of assembly and disassembly of the trailer modules (applicable only to the modular type)

b) Closed loop demonstration of the communications system including:

   1. noise figure measurements
   2. transmitter power
   3. Other RF characteristics such as gain, LO stability, etc.
   4. Baseband performance for video , audio and sound signal.
   5. Audio broadcast capability
   6. interface procedures

c) Boresight operation of the communication system via the antenna system using a field set-up transponder.

d) demonstration of the capability of moving the trailer and setting up in accordance with one of the following procedures:

   1. For the domestic concept, the terminal would be operated at the main contractor's plant. Measurements would be performed to establish a base line set of conditions. The trailer would then be towed to Ottawa where it would again be set up and some (or all) of the baseline measurements would be performed. Agreement between the two sets of measurements should be within mutually acceptable measurement accuracies* or other limiting conditions.

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* A detailed examination of what constitutes "acceptable measurement accuracies" is beyond the scope of this report. The terminal Contractor should be requested to suggest this during the bid phase.

2. For the modular concept, the traiter would be set up at the main controctor's plant where a baseline set of measurements would be taken. The system would then be towed to the nearest airport where cargo service with Boeing 737 aircarft is available, disassembled, and turned over to the airline for shipment. The terminal modules and components would then be flown from that airport to the Ottawa airport, or the closest commercial airport where service by that airline is available, and reassembled. The trailer would next be towed from the airport to CRC where it would be set up and some or all of the baseline measurements would be repeated. The two sets of measurements should agree within mutally acceptable measurement accuracies* or other limiting conditions.

L-4 Point of Acceptance

The contractor's responsibility with respect to the mobile terminal should be considered complete after the two sets of baseline measurements indicated in the previous section have been carried out and successfully completed. If the baseline sets do not agree within the "acceptable measurement accuracies* then analysis must be taken to determine why. Depending upon the results of the analysis, either the tests should be repeated, or some of the out of specificotion measurements could be waived.** For the modular trailer, it should not be necessary to subject the terminal again to an air flight unless the problems arose because of that air flight.

The mobile terminal should be officiolly accepted by CRC at Ottowa following the test outlined or the successful completion of the remedial steps if such are required.

L-5 Follow-up Activities

The acceptance of the terminal by CRC does not mean that the main contractor's interest is ended. Some degree of assistance or advise would be most helpful for the period immediately following acceptonce to:

1. Assist in fomiliarization of the crew with the terminal and its equipment.

2. Assist in advising the crew on some of the "finer details" regarding maintenance or other aspects.

3. Provide stand by service in the event of a failure or malfunction.

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* A detailed examinotion of what constitutes "acceptoble measurement accuracies is beyond the scope of this report. The terminal contractor should be requested to suggest this during the bid phase.

** Test equipment calibration errors, for example.

4. Assist in performing at least the first series of actual measurements.

5. Assist in the preparation of an operations manual (if it is not specified in the terminal procurement contract).

We would also recommend that for the first official tour of duty, a representative of the main contractor should be on hand for standby and/or assistance.

L-6 Routine Testing

As with any piece of equipment, the mobile terminal will require a regular series of routine maintenance and testing procedures in order to be sure its operation is to design standards. For the communications equipment, the routine testing need not, in principle, deviate from routine testing for any typical communications system and will include:

a) receiver noise figure measurements

b) transmitter power measurements

c) group delay measurements

d) "proof of the pudding" measurements of baseband signals

e) antenna gain measurements.

Because of the rather stringent requirements of the antenna surface tolerance and antenna curvature and because of the mobile use of this terminal, the antenna reflector should be subjected to a more than normal maintenance regimen. This should include:

a) keeping the antenna scrupulously clean, particularly those portions of the reflector which must mate during assembly.

b) boresight measurements to verify both gain and pointing for the antenna before and after trial disassembly.

c) checks of the surface tolerance and curvature accuracy using the supplied set of templates recommended for the antenna.

The motor generator set should be checked out using procedures appropriate to internal combustion engines. Such ordinary maintenance should reveal the onset of potential failures or marginal operation and corrective actions would be taken then. Additional measurements should be:

a) measurement of fuel consumption

b) dynamometer measurement

c) RPM measurements to ensure governor stability

d) general operational checks.

Batteries should be examined periodically with respect to charge status and electrolyte levels, etc. Discharge tests of the batteries should be performed at intervals recommended by battery suppliers.

When not in operational service the terminal should be moved at periodic intervals to exercise and to check the mating hardware and condition of the seals between the modules. At these times, checks should also be made of the condition of the suspension, tires, etc.

SECTION M

COST ESTIMATES

M-1 General

Determining cost estimates for the mobile terminal were complicated by one factor commonly encountered: potential suppliers did not wish to, or could not, provide accurate estimates for development activities. If they did not see a possibility to quote on a specific requirement, they naturally would not spend the time or effort on other than that necessary to obtain "ball par k prices". Indeed, in the absence of a detailed specification they often could do little more.

We have therefore accepted these estimates and, on the basis of what we could assess on the basis of face-to-face discussions, we have adjusted them up or down. We have used our best judgment in doing so, considering the type of equipment, special features, nature of the company, and so forth.

Since the modular concept requires more development activity than does the domestic concept, its estimates are subject to more manipulation. This factor must be kept in mind.

M-2 Estimate

Table M-1 summarizes the overall estimates for development of both concepts, including installation and test. These estimates are subject to the following conditions:

1. No taxes are included.
2. No duty has been included on imported parts.
3. Labour rates are based only on 1972 figures.
4. The transmitter is the basic parallel TWT version and is procured by the terminal contractor.
5. No documentation is included.
6. Formal drawings are not used.
7. The procurement plan shown in figure K-1 is assumed.

Table M-2 to M-5 are further breakdowns of the trailer, antenna, positioner and communications system areas. Sources of estimates are included.

Table M-6 is an estimate for test equipment, but is not included in the total costs since it may be available in normal central test equipment centres, or could be procured by CRC.

TABLE M-1

SUMMARY OF ESTIMATES FOR MOBILE TERMINAL

CATEGORY	TERMINAL CONCEPT DOMESTIC TRAILER	TERMINAL CONCEPT MODULAR TRAILER	NOTES
Trailer	$13,600	$88,800	See Table M-2
Antenna	32,500	32,500	See Table M-3
Positioner	13,600	13,600	See Table M-4
Communications	95,000	95,000	See Table M-5
M/G Set	4,000	4,000	Diesel Engine
Packaging	5,000	5,000	
Miscellaneous	4,000	5,000	Note 1
Engineering	46,700	58,350	
Misc. Manufacturing	10,000	10,000	Note 2
Installation	20,000	20,000	Note 3
SUB TOTAL	$244,400	$332,250	
Acceptance Tests	6,200	7,500	Note 4
Basic Cost	250,600	339,750	Note 5
Burden, profit	75,180	101,925	Note 6
BASIC PRICE	$325,780	$441,675	

TABLE M-1 (Continued)

NOTES

1. Includes tools, fuel containers, fire extinguishers, batteries (if not otherwise supplied), battery charger, utility cables, etc.

2. Including Materials, cable harness, fabrication of "on-the-job" fixtures, heating and ventilating ducts, rf lines, power distribution, etc.

3. Labour cost for technicians, wiremen, installers, etc.

4. Testing crews accompany unit during transportation to Ottawa. For the modular concept, a Nordair 737 aircraft is assumed to be chartered.

5. Basic cost is that for main contractor and does not include burden or profit, etc.

6. Assumed 30% combined.

7. No Duty and Sales Tax has been included.

8. No Contingency applied.

TABLE M-2

ESTIMATES FOR TRAILER PROCUREMENT

CATEGORY	DOMESTIC TRAILER ESTIMATE	DOMESTIC TRAILER ESTIMATE TYPE	DOMESTIC TRAILER SOURCE	DOMESTIC TRAILER NOTES	MODULAR TRAILER ESTIMATE	MODULAR TRAILER ESTIMATE TYPE	MODULAR TRAILER SOURCE	MODULAR TRAILER NOTES
Basic Unit	$7,250	Approx. Cost	Travelux	1	$55,000	Preliminary	Note 5	5
Modifications	3,450	Engineering	RCA	2	5,000	Estimate	RCA	6
Air Conditioners (2)	1,000	Quotation	Travelux		1,000	Quotation	Travelux	7
Heating System	--	--	--		500	Estimate	RCA	
Hitch	200	Engineering	RCA		200	Engineering	RCA	
Jacks	300	Engineering	RCA	3	300	Engineering	RCA	3
Module Handler	--	--	--		25,000	Engineering	RCA	8
Engineering Follow-up	1,400	Engineering	RCA	4	2,800	Engineering	RCA	4
TOTALS	$13,600				$88,800			

NOTES:

1. Basic unit includes trailer shell, heating system, toilet, water system, basic lighting
2. Modifications include chassis frame reinforcement, outriggers, antenna column, external stand, interface panel, EMI screening

...con't

TABLE M-2 CON'T

3. Hydraulic removeable type
4. Engineering follow-up includes visits to vendor's plant, witnessing of operations and demonstration of features if applicable
5. Basic unit is 3 module type, however, responses from ATCO and Air Vision are still quite unsatisfactory. We have adjusted preliminary cost information to improve concept.
6. Modifications include provision of water system, toilet, lighting, interface panels, outriggers, and antenna column
7. Air conditioners for other sources may be considered
8. Based on trailer supplier having responsibility for module handler

TABLE M-3

ESTIMATE FOR ANTENNA PROCUREMENT

CATEGORY	DOMESTIC TRAILER	MODULAR TRAILER	ESTIMATE TYPE	SOURCE	NOTES
Engineering	$13,700	$13,700	Engineering	RCA	1
Materials (Except Reflector)	1,300	1,300	Engineering	RCA	2
Manufacturing	3,500	3,500	Engineering	RCA	3
Reflector	14,000	14,000	Budgetary	Plastal	4
TOTALS	$32,500	$32,500			

NOTES:

1. Includes sub-contract follow-up
2. Includes tooling
3. Model Shop Labour
4. Total for materials and labour for quantity 2
5. Estimates at cost level only

TABLE M-4

ESTIMATE FOR ANTENNA MOUNT PROCUREMENT

CATEGORY	DOMESTIC TRAILER	MODULAR TRAILER	ESTIMATED TYPE	SOURCES	NOTES
Engineering	$6,600	$6,600	Engineering	RCA	1
Materials	1,500	1,500	Engineering	RCA	2
Manufacturing	3,500	3,500	Engineering	RCA	3
Remote Indicators	2,000	2,000	Engineering	RCA	4
TOTALS	$13,600	$13,600			

NOTES:

1. Includes manufacturing follow-up
2. Includes tooling
3. Model Shop (or equivalent labour)
4. Manual operation with remote indication of antenna elevation and azimuth
5. Estimate at cost level only

TABLE M-5

COST ESTIMATE FOR COMMUNICATIONS EQUIPMENT

ITEM	QUANTITY	COSTS
Bandpass filter	1	500
Isolator	4	1,300
W/G Switch	2	300
Coupler	4	1,200
TDA	1	1,500
Bends	7	250
Straight W/G WR75	7 ft.	100
Flex W/G WR75	10 ft.	120
Transitions type 'N'	2	120
Attenuator Coax	1	100
P.A.	1	35,000
Line Amp. ADA	1	1,360
Up-Converter	1	6,000
Down-Converter	1	5,500
50 ohm feed	20 ft.	100
Coax. Switch	2	400
Power Load	1	250
Detection	1	150
L.P.F.	1	800
Test Loop Translator	1	4,950
	Sub-Total	$60,000

TABLE M-5 (cont'd)

ITEM	QUANTITY	COSTS
Rack	2	800
P.S.	1	800
Hybrids	2	400
IF Patch Panel in "U" Links	1	100
B.B. Patch Panel in "U" Links	1	100
IF B.P. Filter	5	1,500
Video Mod.	1	3,500
Video Demod.	1	2,500
Video Processing Transmit	1	2,000
Video Processing Receive	1	
T.V. Sound Mod 4.5 MHz	1	2,900
T.V. Sound Demod. 4.5 MHz	1	300
4 Ch. T.V. Sound Mod.	1	10,000
4 Ch. T.V. Sound Demod.	1	1,200
F.M. B'cast Mod.	1	4,000
F.M. B'cast Demod.	1	400
IF Back up facility	1	2,000
Racks	4	800
Power Supply	1	800
Miscellaneous	1	1,000
	Sub-Total	$35,000
	Sub-Total Forward	60,000
	TOTAL:	$95,000

NOTES:

1. Catalogue Prices Assumed
2. Estimate valid for either terminal concept

TABLE M-6

ESTIMATES FOR TEST FACILITY

ITEM	UNIT COST
RF Metering Facilities	540
VTVM HP412A	520
Multimeter AVO8	180
Precision Power Meter HP 432A + Mount 009	810
Pads and Detectors Weinschel	540
Frequency Counter	2,700
Link Analyzer Tx and Rx	900
Oscilloscope and Cart Tektronix 585A and 202-2	3,600
RF Sweep Generator 12 - 14 GHz HP 8690B	8,100
BB Detection for 6 O/PS	720
6 CH. Per Recorder	6,300
Video W/F Gen.	2,250
Video W/F Monitor	1,800
Audio Signal Generator HP3550B) Audio Power Meter HP 3550B)	1,800
Monoscope (Telemet Mod. 1511A)	4,000
Psophometer HP 3555B	900
Video Weighting Network (MI5822102)	720
Misc. Cables, Connectors, Attenuators, IF Cable	1,080
VU Meter (MI581974-B)	1,080
Camera HP197A	810
TOTAL:-	$36,150

Notes: 1. Catalogue Prices Assumed
2. Estimate valid for either terminal concept

M-3 Further Procurement

If an additional terminal of either concept were required, certain non-repetitive engineering costs would not be repeated, therefore, the basic prices would be reduced. The amount of reduction would be greater for the modular concept than for the domestic concept in recognition of the higher initial development costs. If a second terminal is ordered at the same time, then the estimated basic price for the second unit would be:

Cost for 2nd Domestic terminal - $252,100

Cost for 2nd Modular terminal - $277,500

If the terminal is ordered at a later date, the costs would be higher since a second start-up would be required, sketches would not be available, special tooling may have to be remade, etc.

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F-7 Canadian Code for Building in the North 1970
NRC Associate Committee on the National Building Code

F-8 ATCO Publications

1. Advanced Concepts in Shelters and Containers
2. A Summary of the Airmobile Maintenance Shelter (AMS) System
3. A Summary of the Type E277 Multi-Purpose Expandable Shelter System
4. A Summary of the Lightweight Multi-Purpose Container/Packaging System.
5. A Summary of the Electronic Equipment Shelter (EL-816) System

I-1 Canadian Western Natural Gas Company Limited Brochure on Fuel Cells.

I-2 Data Sheets for Powertronics Battery Chargers

I-3 Data Sheets for VARTA Nickel-Cadmium Batteries (represented by Globelite Batteries)

I-4 Data Sheets for Globe GEL/CELL Batteries

APPENDIX A-1

EQUIPMENT COMPLEMENT

Lists of the equipment which comprise the Mobile T.V. terminal are provided here for reference purposes. These lists are tentative but do indicate some of the optional equipment and serve to indicate the quantity of items of each type. This will assist in determining shipping container requirements, pallet loads for aircraft shipping, storage requirements to be provided in the basic trailer--in addition to their primary function of identifying procurable items.

LIST A

TRAILER	QUANTITY	NOTES
Chassis,	1	1
Spare tire	Optional	
Modules		2
Front	1	
Center	1	
Rear	1	
Other	Optional	
End Covers	4 - 3 Module 6 - 4 Module	
Air Conditioner	1 or 2	
Toilet	1	
Holding Tank	1	
Water Tank	30 galls. (or as req'd)	
Sink	1	
Furnace	Approx. 30,000 BTU/Hr.	
Propane Tank	2 installed	
Propane Change Over Valve		
Propane Tanks (spare)	as req'd.	
Electric Heater	3 - 1500 Watt each	
Hot Plate	1 - 1500 Watt	
Batteries	2 - 80 Amp. Hr, 12 Volt	
Charger	1	
Distilled Water	1	
Carrying Strap	1	
Hydrometer	1	
Jacks (body)	2 or 4	
Hydraulic Fluid	1 pint	
Jack Pads	5 to 7	
Foam Plastic Board	as req'd.	
Tool Kit (wrenches etc.)	1	
Tire pump and repair kit		
Tubin, wire, tape, fittings		
Terminals, soldering iron		
Electric Drill, etc.		
Hitch	1	
Hose (with thermostatic controlled heater tape)	1	
Septic Tank Hose	1	
Septic tank elbows, fittings, etc.	Assorted	
Electric Power Cable	1	
Straps, Chains, pads, etc. (for shipping)	Assorted	
Desk	1	
Filing Cabinet	1	
Work Bench	1	

LIST B

COMMUNICATIONS EQUIPMENT	QUANTITY
Bandpass filter	1
Isolator	4
W/G Switch	2
Coupler	4
TDA	1
Bends	7
Straight W/G WR75	7 ft.
Flex W/G WR75	10 ft.
Transitions type 'N'	2
Attenuator Coax.	1
Transmitter	1
Line Amp. ADA	1
Up-converter	1
Down-converter	1
50 ohm feed	20 ft.
Coax. Switch	2
Power Load	1
Detection	1
Low Pass Filter	1
Test Loop Translator	1
Rack	2
Power Supply	1
Hybrids	2
IF Patch Panel in "U" Links	1
B.B. Patch Panel in "U" Links	1
IF B.P. Filter	5
Video Mod.	1
Video Demod.	1
Video Processing Transmit	1
Video Processing Receive	1
T.V. Sound Mod. 4.5 MHz	1
T.V. Sound Demod. 4.5 MHz	1
4 Ch. T.V. Sound Mod.	1
4 Ch. T.V. Sound Demod.	1
F.M. B'cast Mod.	1
F.M. B'cast Demod.	1
IF Back up facility	1
Racks	4
Power Supply	1

LIST C

ANTENNA	QUANTITY
Antenna Reflector	4 sections
Antenna Positioner	1
Antenna Pedestal	1
Sub-reflector and Tripod	1
Antenna Feed – Cassegrain Feed	1
– Ortho Coupler	1
– Twists	Assortment
– Waveguide and Bends	Assortment
– Pressurization Bottle and Plumbing	1
Alignment Kit (complete with case)	1
Shipping Container	2

LIST D

ENGINE GENERATOR	QUANTITY
Engine Generator Set (Diesel)	1
Fuel Tank Drum	as req'd.
Fuel Tank Jerry Can	as req'd.
Fuel Tank Support	1
Fuel Pump Electric	1
Fuel Pump (for manual prime)	1
Fuel Funnels (with screens)	as req'd.
Fuel Lines (flexible)	Assortment
Fuel Filter	as req'd.
Air Filters	1
Lubricating Oil & Grease	as req'd.
Tool Box	1
Oil Can	1
Grease Gun	1
△1 Fire Extinguisher	1
△2 Battery	2
Crank (or starting rope)	1
Power Cable	1
Remote Control Cable	1
△3 Cold Weather Kit	1
Chassis with Retractable Casters	1
Shipping Container	1

△1 Should include sensor, extinguisher bottle and discharge nozzles
△2 Includes spare
△3 May be included with basic set, or procured separately

APPENDIX A-2

INTERFACE TRANSMISSION MEDIA AND INTERFACE IMPEDANCES

TABLE A-2-1 RF INTERFACES

INTERFACE	MEDIA	TYPE
Transmit Direction		
Up-Converter Output to Power Amplifier Input	Waveguide	WR75
Output	Waveguide	WR75
Up-Converter Internal Ccts. (RF)	Coaxial Cable	50 ohms
Test Loop Translator Output to Antenna Feed	Waveguide	WR75
Power Amplifier Output to Antenna Feed	Waveguide	WR75
Receive Direction		
Antenna to TDA Input	Waveguide	WR75 or WR90
TDA Output to Down-Converter Input	Waveguide	WR75 or WR90
S/C Input	Waveguide	WR75 or WR90
Antenna Test Loop Translator Input	Waveguide	WR75 or WR90
FM Broadcast Receive (undemodulated)	Coaxial Cable	50 ohms

TABLE A-2-2 IF INTERFACES

INTERFACE	MEDIA	TYPE
Up-converter and Down-converter Internal Ccts. (IF)	Coaxial Cable	50 ohms
Modulator Output to Up-Converter Input to Up-Converter Input	Coaxial Cable	50 ohms
Down-Converter Input to Demodulator Output	Coaxial Cable	50 ohms
Video Processing Chain (transmit and receive)	Coaxial Cable	50 ohms
IF Back-up Chain (transmit and receive)	Coaxial Cable	50 ohms
FM Broadcast Receive (undemodulated)	Coaxial Cable	50 ohms

TABLE A-2-3 BASEBAND INTERFACES

INTERFACE	MEDIA	TYPE
Video Output	Coaxial Cable	75 ohms unbalanced
Video Input	Coaxial Cable	75 ohms unbalanced
Audio Output	Shielded Twisted Pair	600 ohms balanced
Audio Input	Shielded Twisted Pair	600 ohms balanced
Sound Output	Shielded Twisted Pair	600 ohms balanced
Sound Input	Shielded Twisted Pair	600 ohms balanced
Two-way Voice	Shielded Twisted Pair	600 ohms balanced

Note: These impedances also apply at the terminal interface panel.

APPENDIX A-3

EXTRACTS FROM MIL-STD-1472A

A3-1 Dimensional Limits - Standing Operations

Kick space - 4 inches deep and high

Work space - 48 inches in front of each console, whenever feasible. Lateral work space 18 inches on one side and 4 inches on the other. For racks having drawers weighing more than 45 lbs., 18 inches required on each side.

Work Bench height - 36 inches

Visual displays - 41 inches to 74 inches

Special visual displays - 50 inches to 69 inches

Control placement - 34 inches to 74 inches

Special control placement - 34 inches to 57 inches

A3-2 Dimensional Limits - Sitting Operations

Desk height - 30 inches

Work Surface - 30" wide by 16" deep

Writing Surface - 23" wide by 16" deep

Seat adjustments - 16" to 21" in height, back rest to be provided which reclines between 103° and 115°

Knee Room - 25" high, 20" wide, 18" deep

Visual displays - 6" to 48" above sitting surface

Special visual displays - 14" to 37" above sitting surface

Warning displays - at least 22.5" above sitting surface

Control placement - 8" to 35" above sitting surface

Special Control placement - 8" to 30" above sitting surface

A3-3 Dimensions for Unusual Working Positions

Dimension	Minimum	Preferred* in.	Arctic in.
Squatting workspace:			
Height:	48	--	51
Depth:	27	36	40
Display area:	--	27-43	--
Control area:	--	19-34	--
Stooping workspace:			
Depth:	36	40	44
Display area:	--	32-48	--
Control area:	--	24-39	--
Kneeling workspace:			
Depth:	42	48	50
Height:	56	--	59
Optimum work point:		27	
Display area:	--	28-44	--
Control area:	--	20-35	
Kneeling crawlspace:			
Height:	31	36	38
Length:	59	--	62

* The values for display and control areas represent vertical measurements from the floor.

	Minimum	Preferred* in.	Arctic in.
Prone Work or crawlspace:			
Height:	17	20	24
Length:	96	--	--
Supine workspace:			
Height:	20	24	26
Length:	74	76	78

A3-4 Doors

Vertical or sliding doors shall never be installed as the only personnel exit from a compartment. When a sliding door is used, a hinged door shall be provided in it for personnel use. Fixed equipment shall be at least three inches from the swept area of hinged doors.

A3-5 Heating

Interior dry bulb temperature must be above 50°F within mobile personnel enclosures and a minimum of 68°F within permanent and semi-permanent facilities. Heating facilities shall be designed such that hot air discharge is not directed on personnel.

A3-6 Ventilation

A minimum of 30 cubic feet per minute per man, of which approximately 2/3 shall be outside air shall be provided. Air should move past personnel at less than 100 ft. per minute--65 feet per minute, if possible. Intakes shall be located as to minimize the introduction of contaminated air from exhaust pipes, etc. For vehicles, outside fresh air of 15 c.f.m. per man shall be maintained, with ventilation increasing to 150 to 200 feet per minute for temperatures above 90°F.

A3-7 Air Conditioning should be provided if temperature exceeds 85°F during extended operating periods. Cold air discharge should not be directed on personnel.

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* The values for display and control areas represent vertical measurements from the floor.

A3-8 Humidity

Relative humidity should be 45% at 70°F, decreasing with higher temperature but not becoming less than 15%.

A3-9 Temperature Uniformity

The temperature of the air at floor level and at head level should not differ significantly (maximum of 10%).

A3-10 Specific Task Illumination Requirements

Illumination Levels

Work Area or Type of Task	Foot Candles* Recommended	Minimum
Assembly, general		
coarse	50	30
medium	75	50
fine	100	75
precise	300	200
Bench work		
rough	50	30
medium	75	50
fine	150	100
extra fine	300	200
Console surface	50	30
Dials	50	30

* As measured at the task object or 30 inches above the floor.

Illumination Levels con't

Work Area or Type of Task	Foot Candles* Recommended	Foot Candles* Minimum
Electrical equipment testing	50	30
Emergency lighting	--	3
Office work, general	70	50
Panels:		
front	50	30
rear	30	10
Passageways	20	10
Repair work:		
general	50	30
instrument	200	100

A3-11 Noise

Requirements for maximum noise are specified by noise criteria (NC) curves. NC 60 curves are specified as maximum allowable for work areas, and NC 40 where telephone conversation is required.

	Octave band Centre Freq.	63	125	250	1000	2000	8000
Sound Pressure Levels in dB rel 0.0002 microbar	NC 45	66	61	55	46	45	42
	NC 60	77	72	67	62	60	57

* As measured at the task object or 30 inches above the floor.

A3-12 Hazards and Safety Markings

Warning placards shall be provided for high voltage, hot surfaces, explosive vapours, etc. C.G. and weight locations shall be distinctly marked where there is a safety implication for handling.

APPENDIX A-4

MOBILE UNIT ROADABILITY REQUIREMENTS (EXTRACTED FROM MIL-M-008090 (USAF) 18 APRIL, 1966)

Classification:		Type 111 for Highway and Improved Cross-Country Terrain	
Group:		C- Four Wheel running gear	
Roadability:			
a)	Towing Power	Truck-tractor	
b)	Height of Towing Pintle Hook or Manual Force. (Inches above ground to center of opening.)	30-48	
c)	Towing Speed (MPH)	Paved Highway	50 to 60
		Graded Gravel	20 to 25
		Belgian Block	15 to 20
		Cross-Country Terrain	15 to 20
d)	Turning Speed, Right or Left at Maximum Cramping Angle (MPH)	8	
e)	Withstand Sudden Stops Without Damage From (MPH)	20	
f)	Slope Operation:		
	Sides	20% Up and Down	
	Longitudinal	60% Up and Down	

APPENDIX A-5

DESIGN ASPECTS TO BE EVALUATED FOR MODULAR CONCEPT

A5-1 Seals between modules:

It will be difficult to get an air tight seal and to prevent water and ice build-up at interfaces between modules. If there is not a good seal and if there is a good conductive path beteen inside and outside, there will be a problem with frost build-up and possible problems in disassembly.

A5-2 Fasteners between modules:

Captive fasteners should be used and these should not protrude significantly from panel faces. Fasteners should be located, and be a type to minimize effects of low temperature, ice build-up, etc. They should not provide a significant thermal path between outside and inside. Mating halves should exert a pull to ensure positive compression on seals and metal to metal contact between modules.

A5-3 Module cover panels:

Cover panels will be required for shipping purposes, 4 for a 3-module trailer and 6 for a 4-module trailer. It is assumed that skids will not be required on the panels, because lifting rings will be provided on the modules but the panels must be able to withstand abuse in shipping and should also add rigidity to the modules. They will be comparatively large to handle so that a light weight rigid sandwich panel construction is probably required.

It is essential that panels provide a water-tight and air-tight seal with the modules so that dessicant can be used to maintain a low humidity storage. Some modules will be vented and these vents should be closed for shipping, perhaps with pressure-sensitive tape. The number of fasteners used should be kept to a minimum. They should be compatible with the inter-module fasteners and should be captive, yet not interfere with other panels when stacked.

The modules when used as shipping containers will have certain loose equipment stored inside them and the equipment racks will require special shipping protection. This could be provided by incorporating rubberized horsehair or other types of cushions, bungee cords, clamps, etc. on the panels.

Consideration should be given to addition of smaller hinged or removeable panels to provide limited access without having to fully remove a panel and for provision of indicator type dessicant cartridge.

When removed, it is intended that the panels can be assembled together to form a shelter which attaches to the trailer, and that they can be stacked at the back or front of the trailer for road transit.

A5-4 Module attachment to chassis:

This should be a simpler problem than that of attaching modules together, however, there may be special problems such as accessibility to fastening points, provision of sufficient strength at attachment points, limiting of vibrational effects, play between chassis and modules, and differences in thermal expansion between aluminium and steel.

A5-5 Chassis and running gear:

The interface between the modules and chassis is important as is the location of the running gear axles to provide the correct weight at the hitch. The selection of rigidity for the bare chassis should consider the rigidity of the modules and their method of attachment to the chassis. There may be a requirement for a chassis which can be easily altered to suit either a three-module or a four-module configuration, and which can also be disassembled to simplify loading into an aircraft.

A5-6 Pick-up and handling provisions:

The modules will be moved about frequently and each one should be provided with lifting rings or threaded inserts for eye bolts at each corner. The corners must be specially strengthened. To permit lifting and rotation, two of the sides will require special strengthening and provision of pick up points near the centre of gravity. Alternatively, lifting fixtures which attach to four corners could be used. It cannot be assumed that the end panels are in place whenever a module is being lifted or transported, however, internal shipping struts might be considered.

A5-7 EMI seals:

For shielding and bonding pruposes it may be necessary to have low resistance metal mesh gaskets between interlocking modules. This will further increase the design problem at the module faces, as these gaskets must also not get frozen up with frost and provide a further tolerance problem.

A5-8 Propane installation:

Propane tanks will be required with a certified gas line installation. Propane is normally carried at the front of the chassis in 20 or 30 lb tanks. For Northern use larger tanks, obtained locally might be more suitable with provision for quick changeover from one tank to another with extra spares. The installation will be complicated by the need to have a reliable disconnect between the module and the gas line at the chassis. The installation of the furnace must also be considered in the design of one of the modules because the former will have to be vented and exhausted to the outside and the amount of protrusion and location must be carefully controlled.

A5-9 Water and toilet installation:

The trailer will include conveniences such as running water and a toilet. These probably should be located in the same module, in an easily removable subassembly with small door providing access to the water and sewer connections. A marine type toilet can be turned on its side, but there may be some problem in fully draining the holding tanks. Provision for positive drainage of all water lines should be provided.

The design of the module will be complicated by the requirements for the water and sewer connections points which should not be subject to freezing and ventilation of the holding tank will also be required.

A5-10 Electrical and electronic harnesses:

The modular approach will result in many additional electrical connectors being required.

An interconnection harness between modules for distribution could be run alongside the chassis rails. It could use Rayclad tubing or equivalent to provide a fully environmentally protected harness breaking out to recessed bulkhead connectors provided with chained caps. Inter-rack wiring and experimental wiring could be run inside the modules underneath a low platform or in cable trays at the back or top of the racks. To meet the E.M.C. requirements considerable shielding will be necessary and as much physical separation as possible should be provided between sensitive and non sensitive bundles.

Power input at 60 Hz and interface connectors to connect tv signals etc. should enter through separate panels. These should be located as close as possible to the electronic racks and preferably should have sealed bulkhead connectors. Ground studs should be provided and bonding between modules should be accomplished in accordance with MIL-B-5087 requirements.

APPENDIX B-1

EXTRACTS FROM PROVINCE OF QUEBEC ORDER-IN-COUNCIL # 3142

B1-1 **Trailer**

"Section 2 - Maximum Dimensions of Vehicles"

c) Combination of vehicles - 65 feet.

d) A trailer except a mobile home - 45 feet.

e) A semi-trailer - 42 feet.

B) Height - $13\frac{1}{2}$ feet.

C) Width - $8\frac{1}{2}$ feet, however exterior rear view mirrors may protrude beyond this limit.

"Section 3 - Load and Gross Vehicle Weight"

I. Max. single axle load - 22,000 lbs.

II. Max. tandem axle load - 38,000 lbs.

III. Max. front axle load of towing vehicle - 12,000 lbs.

A Tandem axle by definition means two or more axles in an assembly where the distance between the centres of the leading and rear axles is greater than 40 inches but less than 96 inches and which are so designed and assembled such that the axle loads are equally distributed.

Permissible weights for every permissible vehicle combination are specified. The permissible weight for the simplest combination, a tractor unit coupled to a semi-trailer forming a three axle combination, is 56,000 lbs. All other combinations have greater permissible weights.

B1-2 **Tires**

The maximum load per inch of tire width of a pneumatic tire shall not exceed 500 lbs. for tires of less than 6 inches, and shall not exceed 600 lbs for tires of 6 inches or more.

B1-3 **Interdiction During Periods of Thaw of Rain**

This Order in Council specifies that the Minister of Roads may impose reductions in permissible axle and gross vehicle weight. In accordance with the superceded Order in Council #1371, this was typically a 50% reduction.

Long wide loads, such as mobile homes, mobile cranes, farm machinery and construction equipment, etc. which exceeds the total length, width and weight restrictions may be covered by special or general permits issued by the Ministry of Transportation.

Such permits may indicate the dates of transportation, the route to be followed and any special conditions such as police surveillance and control of movement.

B1-4 **Rear Lights**

Clause 1 - Two red lights are required, one on each side of the vehicle. (These lights must be visible at a distance of 500 feet). It is not specified, but these are assumed to also include stop, and turn signals, since this is the normal vehicle configuration.

Clause 4 - Illumination is required for the plate bearing the registration number so that such number is identifiable at a distance of at least 100 feet. Colour is not specified, so assume this to be a white light.

Clause 5 - If back-up lights are fitted, no more than two lights shall be provided and such lights must remain extinguished when the vehicle is moving forward.

Clause 9b)- Two additional red lights and two red reflectors, located within 6 inches of extreme right and extreme left side of the vehicle are required. Such lights and reflectors must be visible at a distance of 500 feet.

Clause 10b)- Three red lights placed horizontally, at the centre and as near to the top of the vehicle as possible are required. These shall be spaced not less than 6 nor more than 12 inches apart.

B1-5 **Front Lights**

Clause 9a)- Two amber lights, one located within 6 inches from the extreme left, the other within 6 inches from the extreme right side of the vehicle are required. These lights must be visible at a distance of 500 feet from the front.

Clause 10a)- Three amber lights, placed horizontally, at the centre and as near to the top as possible are required. They shall be spaced not less than 6 inches nor more than 12 inches apart. It is specified that in the case of the combination of vehicles the three front lights may be located as near the top of the traction vehicle as its permanent structure will permit.

B1-6 Side Lights

Clause 11a)- Vehicles shall carry one amber light, located sidways near the front part on each side of the vehicle and one red light located sideways near the rear part. Such lights must be visible at a distance of 500 feet from the side of the vehicle or combination of vehicles.

B1-7 Flashing Red Lights

Clause 7 - Only police or fire department vehicles or ambulances may be provided with a fixed, intermittent or revolving red light.

B1-8 Safety Device for Trailers

Order in Council #1993, concerns safety devices for trailers as specifically related to the fastening device between the trailer and the towing vehicle.

It specifies that trailers which are not equipped with automatic brake systems which could immobilize the vehicle in case of separation of the trailer and the towing vehicle will be equipped with chains, for the purpose of maintaining a mechanical connection between the trailer and the towing vehicle should the regular towing connections or any one of the component parts become broken.

B1-9 Regulation Concerning Combinations of Motor Vehicles

Permissible weights and dimensions of highway vehicles is governed by Order in Council No. 3142, as has been noted. This Order in Council also specifies that no combination of vehicles exceeding in number one tractor unit coupled to two trailers or semi-trailers shall operate on the public highway. The coupling device of each vehicle forming such combinations must be of sufficient strength to withstand all the stresses occasioned by the tow, and must be so fitted that when the combination is travelling in a straight line neither of the towed vehicles shall swing or deviate from the course of the tractor unit by more than three inches on either side.

APPENDIX B-2

FIRE PROTECTION

The three classes of fires normally encountered are A, B and C. A covers fires in paper, cloth and wood, B covers gasoline, oil and paint fires and C covers live electrical equipment fires.

The primary hazards are the engine generator set which is class B and C and the propane gas system including furnace, which is also class B and C. The electrical and electronic equipment and wiring harnesses are class C and are considered a secondary hazard although theoretically capable of initiating a fire through short circuiting or arcing.

Coordinated circuit protection must be provided for all electrical wiring and the installation should be suitably protected against lightning strikes. Wire insulation should be carefully selected, in particular in high temperature zones and where subject to mechanical abrasion.

Small portable extinguishers should provide adequate protection when the terminal is manned. These should have an ABC rating, but a BC rating would probably be acceptable because most of such extinguishers are also suitable for small surface class A fires. Carbon dioxide which is rated BC is probably the best extinguisher for the CTS terminal because it leaves no residue, will not damage equipment and is non toxic.

During periods when the trailer is not manned and when the heating system is left on, consideration must be given to installation of a limited form of automatic protection. Even when the trailer is manned, the engine generator set is essentially unattended and a small fire could quickly get out of control.

A common system for automatic fire protection employs detectors at strategic locations which control discharge of CO_2. There are several detector types to consider, thermostatic-electrical, fire detector cable which is most effective with direct flame impingement, thermistors, and pneumatic or electric rate of rise, among others. The rate of rise of temperature detector normally will provide the fastest and surest response.

Rate may be sensed with electrical circuits, by compensating arm thermostats, etc. Probably the best method is to connect a small air chamber by a tube to a control head, which includes a diaphragm with a metred bleed valve through which slow rates of pressure build-up are relieved. A fire will cause a rate of rise sufficient to trigger a discharge valve using CO_2 pressurant for power and can be used to switch off electrical power, close the propane tank valve, close ventilators, shut down the engine, etc., independently of electrical power.

For maximum effectiveness a sufficient number of CO_2 cylinders and nozzles could be provided to totally flood the trailer or the engine enclosure. This would not be practical for the trailer because the weight of CO_2 to fill approximately 1,000 cubic feet of trailer volume would be approximately 125 lbs. (normal portable extinguishers contain 5 to 15 lbs. of CO_2).

As a more practical alternative, nozzles and sensors could be provided for the engine generator set, for the propane furnace and possibly for the electronic equipment racks.

It is considered unlikely that fires will originate in the electronics racks because combustion due to localized overheating or due to short circuits can be made self extinguishing through proper design techniques. There would also be the practical aspect of where to locate sensors so that they could detect a small fire quickly. In contrast, the operators should be able to detect a fire by the smell or the smoke very quickly. Normally, the racks will not be left energized when unattended and provision of separate automatic protection is probably not justified.

Of course, there is the remote possibility of a fire outside the racks getting out of control and destroying them but even with their own extinguishers, they would only be protected for a limited period of time. Fire protection can only be considered as a means of reducing risks, not as a means of eliminating them.

APPENDIX C1

SOME IF CONSIDERATIONS

C1-1 General

The appropriate IF Frequency depends upon many factors such as the bandwidth of the signals being received, the noise figure of the transistors at the frequencies, the availability of appropriate test equipment, and so forth. Consider first the relationship between center frequency and bandwidth.

Generally speaking the useable bandwidth of an IF amplifier covers the frequency range wherein the second or higher harmonics of any signal frequency does not fall inside the band. Consider a band centered on the local oscillator frequency F_{LO}. The minimum frequency f_{MIN} is given by

$$f_{MIN} = F_{LO} - BW/2 \qquad (1)$$

and the maximum frequency f_{MAX} is given by

$$f_{MAX} = F_{LO} + BW/2 \qquad (2)$$

The frequency limits occur where

$$f_{MAX} = 2\, f_{MIN} \qquad (3)$$

so that

$$F_{LO} + BW/2 = 2\,(F_{LO} - BW/2) \qquad (4)$$

therefore

$$BW = 2/3\, F_{LO} \qquad (5)$$

With this as a starting point, Table C1-1 has been prepared listing some of the more commonly used local oscillator frequencies. Columns have been added to the table to list

a) the maximum bandwidth from equation (5)

b) a more practical limit considering practical circumstances

c) nominal noise figure of amplifiers operating at these frequencies, and

d) comments on the frequencies.

TABLE C1-1

LIST OF POTENTIAL IF FREQUENCIES

IF FREQ. (MHz)	BANDWIDTH LIMIT FROM EQ.5 (MHz)	PRACTICAL (MHz)	TYPICAL NOISE FIGURE (dB)	TYPICAL USAGE
10	6.7	6.0	1.5	
30	20.0	18	2.0	Radar, TV Relay
45	30.0	27	2.0	TV IF
60	40.0	36	2.5	Radar, TV Relay
70	43.3	40	2.5	CCIR
90	60.0	54	3.0	
100	66.7	60	3.0	
120	80	72	3.0	
140	86.7	80	3.5	CCIR
210	140	120	3.5	CCIR

C1-2 Discussions

The Mobile terminal will be called upon to operate experiments covering a wide range of frequency and bandwidth requirements. Table C2-2 lists some of these requirements that are known at this point. Considering maximum bandwidth, we note especially that where the Mobile Unit is used for television transmission from the North to Ottawa, the video bandwidth requirements are of the order of 32 MHz. The bandwidth considerations therefore rule out frequencies below about 60 MHz for video, (TDMA signals of 85 MHz IF bandwidth may require higher IF frequencies*)

As the IF frequency increases, the noise figure of the amplifiers also increase so that in a given system somewhat more transmitter powers are required. Considering this fact then we should limit the top IF frequency to something not exceeding about 140 MHz.

Considering the standardization, IF frequencies of 60, 70, 100, or 140 MHz are candidate choices. Of these four frequencies, the 70 and 100 MHz values seen most appropriate. For the 70 MHz frequency, the bandwidth extends from 47 to 93 MHz while for the 100 MHz center frequency, the bandwidth extends from about 67 MHz to 133 MHz.

The bandwidths either of the two primary choices is quite adequate for any of the signals that are currently contemplated. In view of the fact that the total possible spectrum occupancy can be as high as 85 MHz (which is the transponder bandwidth) it would be convenient to provide the mobile terminal with a capability of 85 MHz as well. This can be done by combining the bandwidth requirements at 70 MHz with that at 100 MHz thus indicating a bandwidth capability from about 45 MHz to 135 MHz, a total of 90 MHz. The avoidance of the second harmonic consideration noted at the start of this section is accomplished through the use of IF filtering for any single signal. The basic IF amplifier capability can now handle signals at 70 or 100 MHz center frequency as desired for particular experiment thereby providing considerable flexibility. Figure C1-1 shows the frequency and bandwidth relationships. Amplifiers having the characteristics of Figure C1-1 are currently available on the market. Optimized amplifiers could be developed following standard design procedures. Two additional benefits arise from the IF bandwidth capability. These are:

a) an IF of 60 MHz may also be accommodated and the bandwidth of the signals at 60 MHz can be about 25 MHz.

b) the entire VHF FM band extending from 88 to 108 MHz can be accommodated. This simplifies compatibility for FM reception.

Typical noise figures for IF preamplifiers at 70 MHz center frequency are about 2.5 dB and maximum values are about the 3 dB. Special low noise units may be obtained with maximum noise figures of 2.5 dB.

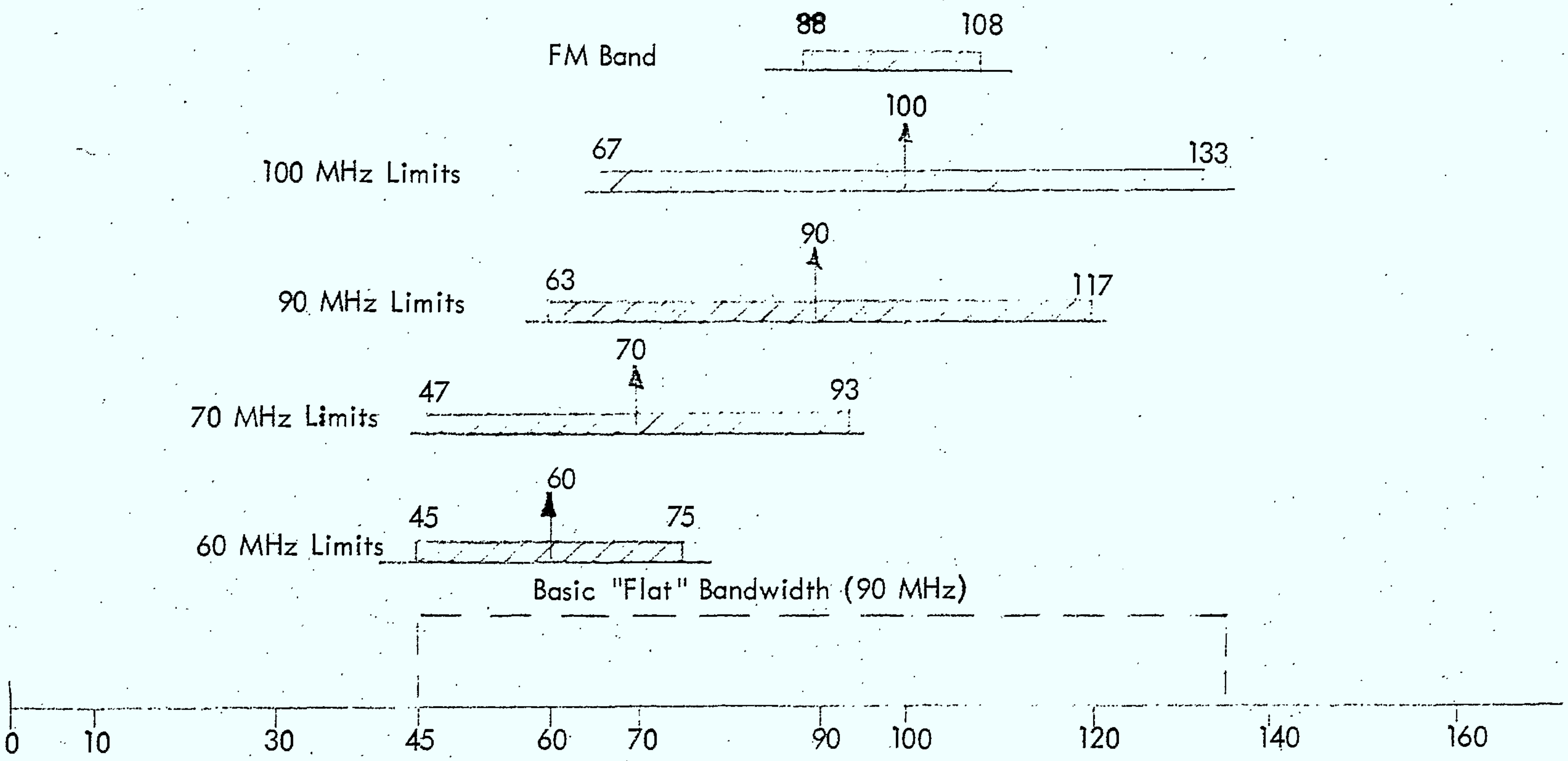
* TDMA requirements are not yet defined. 85 Megabits is used to demonstrate the maximum capability considering the spacecraft RF bandwidth only.

TABLE C1-2

SUMMARY OF SIGNAL BANDWIDTHS

SERVICE	DIRECTION	BASEBAND	IF BANDWIDTH (nominal)
Sound	Transmit	15 kHz	220 kHz
	Receive	15 kHz	220 kHz
2 Way Voice	Transmit	3.1 kHz	14 kHz
	Receive	3.1 kHz	14 kHz
TDMA	Transmit	42.5 MHz	85 MHz
	Receive	47.5 MHz	85 MHz
Television			
- Video Only	Transmit	4.2 MHz	32 MHz
	Receive	4.2 MHz	19.2 MHz
- Audio Only	Transmit	15 kHz	150 kHz
	Receive	15 kHz	150 kHz
- Video + 4 Subcarriers	Transmit	8.35 MHz	38.6 MHz
	Receive	6.1 MHz	16.5 MHz
Beacon	Receive	Carrier	2 kHz

NOTE: Baseband and IF Bandwidths were computed July/72 using program COMM1A. Values are subject to change pending further clarification of experimental program definition.



IF FREQUENCY

FIGURE C1-1

BASIC IF AMPLIFIER BANDWIDTH REQUIREMENTS

APPENDIX C-2

REQUIRED RECEIVER TRANSMIT REJECTION FILTER LOSS

1.	Typical total input power to TDA for 1 dB compression	=	- 80 dBW
	Additional back-off allowance	=	10 dB
	Permissible level of transmit signal leakage	=	- 90 dBW
2.	Nominal Transmitter Power Level	=	25 dBW
	Permissible Transmitter Leakage		- 90 dBW
	Required Isolation		115 dB
3.	Total Required Isolation	=	115 dB
	Isolation Obtained from Orthocoupler		35 dB
	Required Transmitter Rejection Filter		80 dB

Notes:

(1) Reject band of transmit rejection filter - 14.0 to 14.5 GHz

(2) Pass band of transmit rejection filter - 11.7 to 12.2 GHz

(3) Low Pass filter may be used. Typical insertion loss in the passband can be held to 0.3 dB or less.

APPENDIX C3

RF LINE LOSSES

Tables C3-1 and C3-2 list the losses estimated for the item comprising the RF transmit and receive lines respectively. The values shown are representative only as the actual values will depend on the specific manufacture of the items, and on the final line configurations.

For purpose of calculation, we have "rounded off" the losses to 1.0 dB in the transmit direction and 0.7 dB in the receive direction.

TABLE C3-1

ESTIMATED WAVEGUIDE LOSSES IN THE TRANSMIT DIRECTION

ITEM		LOSS
2 Pieces Flex 6" each		0.100
2 Twists		0.100
2 x 1 1/2 Waveguide Straight		.092
2 x 150° Bend 6"		0.016
Coupler		0.100
Filter		0.200
Waveguide Switch		0.100
4 Right Angles		0.064
2 ft. Straight Waveguide		0.066
	TOTAL	.838 dB

TABLE C3-2

ESTIMATED WAVEGUIDE LOSSES IN THE RECEIVE DIRECTION

ITEM	LOSS
3 Right Angle Bend	.050
2 x 6" flux (60°)	0.016
2 x 1 ft. flex	0.100
1 Twist	0.050
1 1.2 ft. Straight Waveguide	0.049
150° Bend 6"	0.005
3 ft. Straight W/G	0.033
150° Bend 6"	0.049
6" Straight W/G	0.005
Coupler	0.100
Filter	0.200
TOTAL LOSSES	.657 dB

APPENDIX C-4

COMMENTS ON THE TRANSMISSION OF TWO OR MORE SOUND CHANNELS USING ONE SOUND SUB-CARRIER

1. Transmission of audio frequencies much below 300 Hz requires the use of expensive filtering which becomes very difficult to make at very low frequencies (about 50 Hz).

2. The alternative is to use double sideband techniques, but this is very wasteful of bandwidth.

3. Much more complex circuitry and greater circuit tolerance are required for a given performance. The result is a poor cost comparison.

4. There is a saving on bandwidth since 3 or more sound channels would require that the sound sub-carrier be placed above the region of the colour sub-carrier second harmonic.

5. The only situation in which this type of arrangment might be seriously considered is the employment of only two sound channels (or three of low quality) with no thought of future expansions. This could be situated in the spectrum below the colour sub-carrier . Since this arrangement is not likely, it has not been studied.

APPENDIX C-5

ELECTROMAGNETIC COMPATIBILITY

C5-1 General

The mobile terminal is designed to operate in a wide variety of conditions. Because of this and because the terminal contains sensitive receiving equipment, this section on electromagnetic compatibility (EMC) has been included to point out practices which should be followed to minimize interference problems. Greater detail on the practices covered and EMC theory are to be found in the references listed at the end of this section. We are essentially considering incidental radiating and conducting interference sources in what follows. The transmitter, however, produces radiation as a desired end-product; the CTS EMC specification will be used as a reference to ensure compatibility of the transmitter and communication system with the CTS objectives.

C5-2 Earth Grounding

Operation in regions of poor earth conductivity is guaranteed particularly in perma-frost and rocky regions. The question arises whether the unsatisfactory grounds in those locations are more hazardous (with respect to electrical storms) than no ground at all. Where only solid rock foundations exist, no ground at all is possible. Department of Transport* experience with northern telecommunications and radar equipment suggest that operations with no ground are routine simply because it is necessary. Their experience is such that no ground is preferable to a poor ground. In suitable circumstances, a good ground can be implemented by submerging a copper plate 4' by 4' in a nearby body of water and running a long copper wire to its center. DOT has used lengths of 1/4 mile or so effectively.

In circumstances where a ground is feasible, it should be located as close to the terminal as practical and consist of one copper rod 6 feet in length and 1 inch in diameter. If a ground of these dimensions is found to be inadequate, no ground at all should be used.

C5-3 Structure

The domestic trailer and the modular trailer will each require different EMI reduction techniques. A typical domestic trailer is constructed using aluminum paneling and hence will not be the best with respect to EMC unless steps are takan to ensure proper bonding between the panels. A number of bonding alternatives are available:

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* Telephone conversation with Gerry Pankshurst of DOT, Dorval Reference File.

- Conductivity tape (or gasket)

- Bonding straps

- Conducting epoxy

- Conductive "weather stripping" around door edges.

Screening is suggested between the outer and inner walls; doors, windows and vents should be screened. The screening, panels and all structural members should be bonded together using direct bonding where possible. The structure will be connected to the earth ground if one is used. It is recommended that bonding be supervised by the contractor, when the trailer is under construction.

The modular trailer can use easily replaceable conductive gaskets between the modules to ensure RF conductivity. Ground strap bonding between modules and between chassis and modules will provide a safe path for lightning once the chassis itself has been connected to the earth ground.

Standard commercial grade, non-anodized aluminum if used to construct the modules should be adequate with respect to EMC.

A single point ground should be established; the bus bar used should be bonded directly to the trailer chassis and should be the only point common to the grounds of the various systems requiring grounds. Separate studs on the bar are recommended for each ground connection.

C5-4 Microwave and VHF EMC

Attention has been given to protecting the TDA against unintentional shifting of its bias level. This can come about in the presence of RF power exceeding -40 dBm in magnitude as a result of rectification by the diode. A minimum of 120 dB of attenuation has been designed into the path between the transmitter output and the receiver input. The +60 dBm transmit signal will consequently not exceed -60 dBm in the region of the TDA. The receiver filter will also inhibit external interference as well as any which might come via the test loop translator.

Additional measures to be taken:

- Good RF practice to be followed.
- Type N connectors (or equivalent).
- Double shielded cables.
- Tight waveguide connectors. In particular, good bonding is required between the antenna and its feed.

C5-5 Video

Matched cables of 75 ohms impedance are recommended. The BNC or UHF cables commonly used in this application provide no options with respect to grounding procedures. Video levels are normally high and hence provide a degree of interference protection.

C5-6 Audio

Audio cables should be twisted, balanced and shielded; the shields should be grounded at only one point. Three-pin connectors should be used with the third pin used to carry the ground through the connector.

C5-7 Power Distribution and Lighting

Power will be supplied either from local power utilities or from the engine-generator set. In the latter case the generator, which may be installed several hundred feet from the terminal, should not be grounded; the neutral wire should not be connected to the single-point terminal ground. Within the vehicle and within equipment, the AC neutral should be left floating. The neutral should have no fuses or circuit breakers. Where power is delivered from local utilities, grounding arrangements will conform to those specified by the utility. Minimization of inductive fields about the power leads can be achieved by balancing the 3-phase loads. All power should be introduced to the terminal via line filters chosen to reduce broadband (VHF) noise. These filters are an important precaution, since the power lines can conduct interference from the power utility or from the engine-generator set.

Lighting is operated from 12V batteries eliminating flourescent light noise sources, the battery chargers however, can be noisy and will require line filters on the input and output. The charger and the batteries must be operated with little physical separation for most efficient filtering.

C5-8 Transient Suppression

Good engineering use as appropriate of combinations of diodes, capacitors and resistors to suppress EMI arising from relay electromagnets and from operation of switch and relay contacts will be employed as shown in Fig. C5-1. Protection of the contacts may also be considered especially since the lighting system is operated

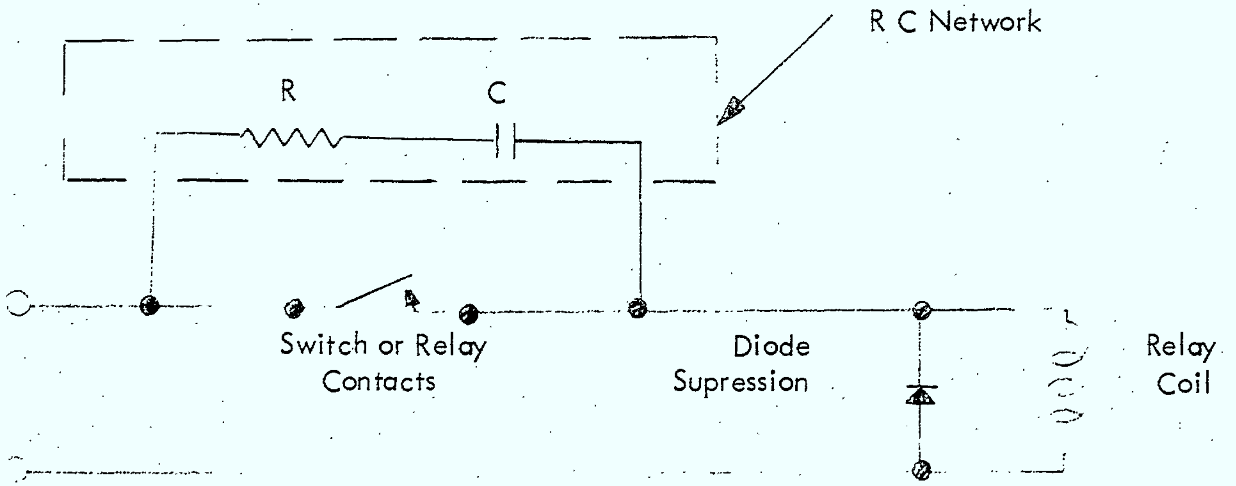

FIGURE C5-1

RELAY TRANSIENT SUPRESSION

from DC. Consideration must be given to the characteristics of the load fed through the contacts when selecting the switch or relay. It must be determined whether any contacts will operate dry and if so the device is to be chosen accordingly. Design of the RC network is an analytical problem (Ref. C-3).

C5-9 Additional Considerations

This section discusses further EMC procedures of importance.

- The effects of EMI from the engine-generator set will be attenuated by operating the unit as far as practicable from the mobile terminal. EMC will be an important factor in selection of the actual unit. Suppressors will be required on the ignition system.

- Every effort should be made to operate the terminal in an EMC clean environment. Airports and superhighways are not clean. Possibly a survey of the EMI environment should be undertaken before committing the terminal to a particular site. It is a good idea to locate south of small northern communities so that the antenna will not see RFI generated by the community.

- All equipment units should have EMI suppression designed into them.

- All units must be adequately grounded to restrict intermittent noise.

- Cable routing once found to be satisfactory should be similar on subsequent assemblies of the module trailer. Cable segregation should be planned by grouping wires and cables according to categories:

  1. Power and control
  2. Sensitive wiring
  3. Other wiring

  These three wire categories might have an identifying colour for ease of identification. They should be run separately via different routing and should cross at right angles (Ref. C-4).

APPENDIX C-6

SURVEY OF POWER TUBES AND/OR TRANSMITTERS

C-6-1 General

A survey of the availability or the near availability of microwave power sources, TWT's, klystrons, or transmitters, capable of operating in the 14.0 to 14.5 GHz bands and having a capability in power from about 300 watts to about 1 kilowatt was made. Table C-6-1 is a summary of the sources contacted and the results obtained. Most are telephone conversations and are recorded in the author's files.

C-6-2 Current Transmitter Availability

At the moment there are these main options for suitable microwave power sources for the CTS mobile terminal.

1. A 350 watt-TWT tube amplifier package, and output combiner, to provide a parallel TWT transmitter.

2. A 500 watt klystron transmitter using a VA930 klystron, tuned to cover 14 to 14.5 GHz range.

3. A 500 watt modified TWT tube amplifier package to increase the power of their 2-tube amplifier package from 350 watts to 500 watts.

4. A 500 watt klystron transmitter using an optimized VA 930 klystron tube to provide a wider bandwidth.

5. A 2000 watt klystron transmitter using a proposed tube from Varian Associates of Canada.

These 5 options are listed in Table C-6-2. Also included are known technical data for each based upon a specific and investigated source. Note that these are not the only sources and that others may be found with somewhat different capabilities. *

C-6-3 Power Tube Options

We have primarily considered the use of TWT's and klystrons. Other devices, such as Carpinotrons, BWO's, etc., are not considered suitable for communications purposes.

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* For example, Energy Sources in Los Angeles also provide klystron amplifiers. Varian Associates of Canada are also keeping in mind the possibility of developing a transmitter using their proposed VKM-2451A1 tube.

TABLE C-6-1

POWER TUBE SURVEY CONTACTS

REFERENCE	DATE	CALL TO	REPLY	COMMENTS
1.	Dec. 6/71	Sperry		Requested information on 14 GHz TWT amplifier.
2.	Dec. 29/71	Varian		Requested information on 14 GHz TWT's.
3.	Jan. 4/72	Varian		Requested data on 14 GHz High power klystrons.
4.	Jan. 4/72	Hughes A/C		Requested availability of 14 GHz TWT power tubes.
5.	Jan. 5/72	Phillips		Requested information on availability of power tubes from either Phillips or Mullard.
6.	Jan. 5/72	Siemens		Requested information on availability of power tubes.
7.	Jan. 5/72	Hughes A/C	Earlier call	Data on modification of existing TWT tubes given.
8.	Jan. 6/72	Sperry	From earlier call	Information on possible TWT amplifier package under evaluation at Sperry's main plant. Information will be available shortly.
9.	Jan. 6/72	Technical Associates		Requested information on possible power TWT's from MEC.
10.	Jan. 6/72	Thompson-CSF		Requested information on possible power tubes for CRS program.
11.	Jan. 6/72	Crawford Associates		Requested information on possible high powered TWT's availability from Watkins-Johnson.
12.	Jan. 6/72	Ferranti Packard		Requested information on high powered microwave tubes.
13.	Jan. 7/72	Malectro Reps		Requested information on possible Nippon Electric high power microwave tubes.

TABLE C-6-1 (Cont'd)

REFERENCE	DATE	CALL TO	REPLY	COMMENTS
14.	Jan. 7/72	English Electric		Requested information on possible availability of microwave power tubes.
15.	Jan. 7/72	Sperry	From earlier call	Data on lab measurements of a TWT package consisting of two tubes was made and information given.
16.	Jan. 10/72	Phillips	From earlier call	No tubes in frequency band from either Phillips or Mullard.
17.	Jan. 10/72	Hughes A/C	To earlier call	Information on possible modifications given, price estimate also made.
18.	Jan. 11/72	Microwave Cavity Laboratories		Requested information on whether MCL has a klystron microwave amplifier.
19.	Jan. 13/72	Phillips	To earlier request	No tubes available in our power or frequency band from Phillips or Mullard.
20.	Jan. 13/72	Malectro Reps	Replied	Nippon tubes are made under licence in Canada by Varian. Varian should therefore be contacted.
21.	Jan. 17/72	General Electric		Requested information on possible high powered tubes in CTS microwave band. GE say they do not make tubes in this frequency band.
22.	Jan. 18/72	Varian		Requested information on possible Nippon Electric tubes in the CTS frequency band.
23.	Jan. 20/72	MCL	To earlier call	MCL provided price for a klystron amplifier package using a modified VKU 7791 klystron and operating over the 14 to 14.5 GHz band.

TABLE C-6-1 (Cont'd)

REFERENCE	DATE	CALL TO	REPLY	COMMENTS
24.	Jan. 25/72	Siemens	Follow-up	Siemens has nothing. In about June they will begin development of a 2 KW liquid cooled TWT.
25.	Jan. 25/72	Thompson-CSF	Follow-up	No suitable tubes. Other devices, such as Carpinotrons available 15 to 18 GHz. Several can be locked in parallel. 1 KW TWT exists at X Band. Scaling possible.
26.	Feb. 10/72	Sperry		Discussed our requirements. Witnessed tests (see Trip Report dated Feb. 14, 1972. S/O DTC110).
27.	Feb. 10/72	Varian		Discussed possible adjustments to Varian tube for CTS purposes.
28.	Mar. 1/72	MCL		Discussed our requirements. Required budgetary quote of MCL Transmitter using Varian's scaled-up 2 KW tube. (See Trip Report dated March 6/72 - S/O DTC 110).
29.	Mar. 7/72	MCL		Sent MCL preliminary information on Varian 2 KW tube.
30.	Mar. 20/72	Varian Canada		Discussed details of Varian's proposed 2 KW tube. (See Trip Report dated March 24/72 - S/O DTC 110).
31.	Apr. 10/72	MCL		Received budgetary quote on Transmitter using Varian 2 KW tube.

TABLE C-6-2

POSSIBLE TRANSMITTER CONFIGURATIONS IN THE 14 - 14.5 GHz FREQUENCY BAND FOR THE MOBILE TERMINAL

	PARAMETER	TRANSMITTERS				
1.	Option	1	2	3	4	5
2.	Configuration	Parallel TWT	Basic Klysyron	Optimized Parallel TWT	Optimized Basic Klystron	2KW Klystron
3.	Model	Not assigned	10287	Not assigned	-	Not assigned
4.	Supplier	Sperry	MCL	Sperry	Possibly MCL	MCL
5.	Power Tube	STU 54304	VA930	Modified STU54304	Optimized VA930	VKM-2451A1
6.	Tube Supplier	Sperry	Varian	Sperry	Varian	Varian Canada
7.	Min. Output RF Power	350 watts	500 watts	500 watts	500 watts	2000 watts
8.	Instantaneous Bandwidth	500 MHz	40 MHz(1 dB)	500 MHz	60 MHz (1 dB)	85 MHz (1 dB)
9.	Tuning	Fixed	14-14.5 GHz	Fixed	14-14.5 GHz	2 bands
10.	Cooling	Air	Air	Air	Air	Air - collector water - body
11.	Weight	575 lbs.	700 lbs.	575 lbs.	700 lbs.	Not Given
12.	Line Voltage (60Hz)	115V, single phase	220V, three phase	115V, single phase	220V, three phase	220V, three phase
13.	Line Service	2 x 25 amperes	15 amperes	2 x 25 amperes	15 amperes	Not Given
14.	Power Supply	Regulated	Unregulated	Regulated	-	Regulated
15.	Cost (US)	$30,000	$27,105	$80,000	-	$32,967
16.	Power Tube Costs	Included	Included	Included	-	Not Included
17.	Delivery (ARD)	120 days	120 days	240 days	-	180 days

Notes: <u>Parameters 4 & 6</u>

Sperry	-	Sperry Electron Tube Division, Gainsville, Florida.
MCL	-	Microwave Cavity Laboratories - La Grange, Illinois.
Varian	-	Varian, Palo Alto, California.
Varian Canada	-	Varian Associates of Canada Ltd., Georgetown, Ontario.

<u>Parameter 9</u>

The Varian Canada 2 KW Klystron is pretuned to 2 fixed 85 MHz bands by adjusting stops on the cavity plungers.

<u>Parameter 10</u>

Body cooling requirements are about 250 watts.

<u>Parameter 15</u>

Costs are budgetary estimates only. Duties and taxes are not included. Costs shown are basic selling costs by the supplier.

The best choice for power tubes at the time of writing are listed in Table C-6-3. The range varies from existing devices to new developments to meet the most flexible experimental need.

C-6-4 Discussion

One can summarize the situation as follows:

At the moment only klystrons provide the required power level of 500 watts, but do not provide the bandwidths to match the RF bandwidth of the spacecraft. Thus, if simultaneous transmissions of carriers occupying essentially the full transponder bandwidths are required, several klystrons or klystron amplifiers would be required. TWT's on the other hand have the bandwidth, but not the power. At the moment an amplifier package consisting of two power TWT's can only provide a minimum output of 350 watts RF power.

As far as existing tubes or amplifier packages are concerned, Sperry's budgetary price for their 350 watt 2-tube TWT package is about $27,000 whilst MCL's cost for their klystron package is somewhat over $26,000. With respect to current weight estimates, the klystron amplifier package weight is about 700 lbs. while the Sperry 2-tube TWT amplifier package is about 575 lbs., including rack.

To increase this power level for TWT's would require additional funds. Thus Hughes would scale an existing TWT in another frequency range at a cost of $90,000 for a 500 watt tube or $150,000 for a 1 kilowatt tube. Sperry would optimize the current tubes to provide 500 watts in a two amplifier package at an additional cost of $50,000.

With respect to life times, in general klystron amplifiers tend to be more long lived than TWT power amplifiers. Thus, Varian claims that the expected life for the VA930 klystron is an excess of 10,000 hours. Typically, the expected life for a TWT is in excess of 2,000 hours. An aspect still to be explored is whether specific tubes, either TWT or klystron, can be built after the life is over.*

One drawback of the klystron is that it is a multi-cavity device which requires a rather extensive and particular retuning procedure whenever the frequency is changed. Operating personnel must therefore have considerable experience in this type of operation. The VA930 uses 4 cavities which must be adjustable so that the frequency response, group delay characteristics, phase characteristics are within acceptable limits. Because the television signals to be handled by the CTS experimental program use rather broad deviation characteristics, these limits are small indeed.

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* In most cases, rebuilding of TWT's after cathode failure is not economically practical. It is preferable to procure a new tube. Klystrons can usually be rebuilt at nominal cost.

TABLE C-6-3

POSSIBLE TRANSMITTER TUBES

PARAMETER	TUBE				NOTES
Option	1	2 (Note 1)	3 (Note 2)	4 (Note 2)	
Type	TWT	TWT	TWT	TWT	
Model	STU54302	STU54302	--	--	
Supplier	Sperry	Sperry	Hughes	Hughes	8
Status	Existing	Optimized	Scaled	Scaled	
Transmitter Option	1	3	--	--	6
Information	Data Sheet	Letter	Telephone	Telephone	
Expected Life	--	2000 hrs.	--	--	7
Construction	Helix	Helix	Depressed Coll.	Depressed Coll.	
Focussing	PPM	PPM	PPM	PPM	
Cooling	100 cfm	--	200 cfm	200 cfm	11
Frequency Coverage	9-17 GHz	14-14.5 GHz	14-14.5 GHz	14-14.5 GHz	
Instantaneous Bandwidth	8 GHz	0.5 GHz	0.5 GHZ	0.5 GHz	
Tuning	Fixed	Fixed	Fixed	Fixed	9
Minimum Power Out	100W	250W	500W	1000W	
Gain	40 dB min.	40 dB	--	--	
Efficiency-Basic	11%	--	14%	16%	
-Depressed Col.	--	--	24%	26%	
Collector Voltage	--	--	-7.7 KV	-9.5 KV	
Cathode or Beam Voltage	-9.0 to -9.6 KV	--	19.2 KV	24 KV	
Cathode or Beam Current	0.2 amps.	--	.186 amps.	.260 amps.	
Heater Voltage	6.3 volts	--	--	--	
Heater Current	2.3 amps.	--	--	--	
Input Power	900 watts	--	--	--	
Length	19 3/4"	--	21"	21"	10
Width	2 1/8"	--	5 1/4"	5 1/4"	10
Height	2 13/32"	--	5 1/4"	5 1/4"	10
Weight	7 lbs.	--	19 lbs.	21 lbs.	10
Costs - Develop	--	$40,000 (Qty. 2)	$95,000	$150,000	
- Unit	--	--	$25,000	$ 25,000	

TABLE C-6-3 (cont'd)
POSSIBLE TRANSMITTER TUBES

PARAMETER					NOTES
Option	5 (Note 3)	6	7 (Note 4)	8 (Note 5)	
Type	TWT	Klystron	Klystron	Klystron	
Model	--	VA930	VA930	VK-2451A1	
Supplier	Thompson/CSF	Varian	Varian	Varian Canada	8
Status	Scaled	Existing	Optimized	Proposed	
Transmitter Option	--	2	4	5	6
Information	Telephone	Description	Telephone	Data Sheet	
Expected Life	--	10,000 hrs.	--	--	7
Construction	--	4-cavity	4 cavity	--	
Focussing	PPM	External magnet	External Magnet	External Magnet	
Cooling	--	400 lbs/hr.	400 lbs/hr.	1000 lbs/hr	11
Frequency Coverage	14-14.5 GHz	14-14.5 GHz	14-14.5 GHz	14-14.3 GHz	
Instantaneous Bandwidth	0.5 GHZ	50 MHz	60-05 MHz	85 MHz	
Tuning	Fixed	5 Position	5 Position	2 Position	9
Minimum Power Out	1000W	500W	500W	2000W	
Gain	--	37 dB	37 dB	--	
Efficiency-Basic	--2	25-35%	--	30%	
-Depressed Col.	--	--	--	--	
Collector Voltage	--	--	--	--	
Cathode or Beam Voltage	--	5 KV	--	7.3 KV	
Cathode or Beam Current	--	0.5 amps.	--	.96 amps.	
Heater Voltage	--	6.0 volts	--	6.3V dc	
Heater Current	--	6.0 amps.	--	20A dc	
Input Power	--	--	--	--	
Length	--	8"	--	12 1/4"	10
Width	--	12"	--	12 1/4"	10
Height	--	11"	--	12 1/4	10
Weight	--	--	--	90 lbs.	10
Costs - Develop	$100,000	--	--	$100,000	
- Unit	--	$11,100	--	Included	

NOTES:

1. This Tube would be a modified and optimized STU54302 Tube over the desired band of 14 to 14.5 GHz. Costs quoted are increased costs for two tubes.

2. Hughes stated that estimated costs may be reduced if a proposed X-band scaling program is awarded to them.

3. Thompson/CSF (New York) suggests that detailed requirements specifications be submitted to their engineers in France for more specific details.

4. Bandwidth broadening is achieved at the expense of ripple and gain. 60 to 65 MHz may be achievable within 1 dB ripple specification.

5. A quantity of 3 tubes is included in the development costs.

6. See Table C-6-2 for Options. The estimated cost for power supplies or packaging is not included in the tube costs.

7. Detailed life data or TWT's is not available. Sperry says 10,000 hrs. can be expected for some TWT's but we have chosen to use a more conservative value.

8. Sperry - Sperry Electron Tube Division, Gainsville, Florida.
   Hughes - Electron Dynamics Division, Hughes Aircraft Company, Torrance, California.
   Thompson/CSF - Thompson/CSF Electron Tubes Inc., New York, New York.
   Varian - Varian, Palo Alto, California.
   Varian Canada - Varian Associates of Canada Ltd., Georgetown, Ontario.

9. The Klystron in Option 8 has two pre-settable channels. Those in Options 6 and 7 has 5 presettable channels. Tuning between channels can usually be done in several seconds.

10. The weight and dimensions of the Klystrons including the magnet.

11. Liquid cooling must also be provided for the body of klystron Option 8. Body power dissipation is about 210 watts maximum.

APPENDIX C-7

PERFORMANCE CALCULATIONS

Performance calculations of some video, audio, sound, TDMA and beacon links between the Ottawa Communications Control station and the mobile terminal at a remote location on the 5° coverage circle are listed in this section.

The calculations were made using program COMM1A currently being finalized under a separate contract. The link calculation include:

Case 6	:	TDMA signals from Ottawa to Remote
Case 7	:	Beacon signals from CTS to Remote
Case 8	:	Video signals from Remote to Ottawa
Case 9	:	Composite TV Signals (with 4 audio subcarriers) from Remote to Ottawa
Case 10	:	Audio signals from Remote to Ottawa
Case 11	:	Sound signals from Remote to Ottawa
Case 13	:	TDMA signals from Remote to Ottawa

The current parameters for the mobile terminal were used.

CTS COMMUNICATIONS CALCULATIONS
PROGRAM COMM1A - VERSION 1

CASE 6 : COMPLETE SYSTEM CALCULATIONS

BASIC SYSTEM CONFIGURATION

A TDMA SIGNAL IS BEING TRANSMITTED.
TRANSMISSION IS FROM A 30.0 FT DIAMETER ANTENNA AT OTTAWA
TO A 10.0 FT DIAMETER ANTENNA IN THE NORTH.
THE RECEIVER HAS A TDA FRONT END.
UP-PATH POWER CONTROL IS USED.

RANGE AND FREQUENCY

RANGE (UP-PATH)	39.1910	KM/1000	PATHUP
RANGE (DOWN-PATH)	41.1280	KM/1000	PATHDN
UP-PATH FREQUENCY	14.2480	GHZ	QRUPGH
DOWN-PATH FREQUENCY	12.0810	GHZ	QDWNGH

SPACE TEMPERATURE AT ANTENNA TERMINAL

TRANSPONDER TEMPERATURE	2000.0000	KELVINS	TRDK
OTHER TEMPERATURE CONTRIBUTIONS	25.0000	KELVINS	TSDK
EARTH TEMPERATURE	290.0000	KELVINS	TEDK
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

GROUND RECEIVING SYSTEM (TDA)

SKY TEMPERATURE	40.0000	KELVINS	TSK
SIDE LOBE TEMPERATURE	36.0000	KELVINS	TSIDE
FRONT END NOISE FIGURE	6.5000	DB	FAMP
FRONT END GAIN	20.0000	DB	GAMP
SECOND STAGE NOISE FIGURE	12.0000	DB	FA2
INPUT FILTER LOSS	.3000	DB	FIN
INPUT FEED LOSS	.5000	DB	FEED
DOWN-PATH SYSTEM TEMPERATURE	1[illegible]5[illegible].0[illegible]38	KELVINS	TGSDK

SIGNAL-TO-NOISE RATIOS FOR STANDARD ATMOSPHERE

UNWEIGHTED SNR	8.4000	DB	SNRDB
IMPLEMENTATION FACTOR	3.0000	DB	FIM

GENERAL

MAXIMUM BIT RATE	85.0000	MHZ	BITW
DOWNPATH-TO-TOTAL NOISE RATIO	.8675		X
RF NOISE BANDWIDTH	85.0000	MHZ	RFBW

UPPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	2.8000	DB	RAINUP
SCATTER MARGIN	1.0000	DB	SCATUP

DOWNPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	1.2000	DB	RAINUP
SCATTER MARGIN	3.0000	DB	SCATUP

UP-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA DIAMETER	30.0000	FEET	DG(TR)
TRANSMIT GAIN	60.1020	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	207.3806	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.2020	DB	ATML(UP,DN)
ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
RECEIVE GAIN	36.2000	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	112.2806	DB	CPL(UD)

DOWN-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
TRANSMIT GAIN	36.3000	DB	G(GS)T
BEAM EDGE ALLOWANCE	2.6000	DB	A(GS,TR)
PATH LOSS	206.3666	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.6620	DB	ATML(UP,DN)
ANTENNA DIAMETER	10.0000	FEET	DG(TR)
RECEIVE GAIN	49.1265	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	125.2020	DB	CPL(UD)

LINK PARAMETERS

UP-PATH

GROUND TRANSMITTER POWER (NOM.)	17.7975	DBW	PGTNDB
GROUND TRANSMITTER POWER (NOM.)	60.2219	WATTS	PGTNWT
TRANSMITTER LINE LOSSES	1.0000	DB	ATOFDB
GROUND TRANSMITTER POWER (MAX.)	20.8125	DBW	PGTRDB
GROUND TRANSMITTER POWER (MAX.)	120.5732	WATTS	PGTRWT
POWER CONTROL RANGE (MIN)	3.0150	DB	XMARGX
EIRP	79.9145	DBW	EIRP(GS)
TRANSMIT SPECTRAL DENSITY (LIN)	-22.4611	DBW/4KHZ	SPEC(GS)T
COUPLING LOSS (STD. ATM.)	112.2806	DB	CPL(UD)
POWER RECEIVED AT SPACECRAFT	-95.4830	DBW	CSRDB
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK
UP-PATH NOISE POWER	-115.6614	DBW	XNSR
CARRIER-TO-TEMPERATURE RATIO	-129.1285	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	2.5545	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-138.7566	DBW/4KHZ	SPEC(GS)R

UP-PATH CNR	20.1784	DB	CNRU

DOWN-PATH

TRANSPONDER GAIN	114.0061	DB	GSTRDB
TRANSPONDER TUBE CARRIER POWER	19.0231	DBW	PSTRDB
TRANSPONDER TUBE CARRIER POWER	79.8566	WATTS	PSTRWT
CARRIER-TO-TEMPERATURE RATIO	37.5389	DBW/K	CT(RS)DB
TRANSMIT SPECTRAL DENSITY (LIN)	-24.2505	DBW/4KHZ	SPEC(GS)T
TRANSPONDER OUTPUT FEED LOSS	.5000	DB	ASO
COUPLING LOSS (STD. ATM.)	125.2020	DB	CPL(UD)
TOTAL MARGIN, UP-PATH POWER CTL	3.0363	DB	XMARG
POWER RECEIVED AT GROUND	-106.6789	DBW	CGRDB
DOWN-PATH SYSTEM TEMPERATURE	1151.0038	KELVINS	TGSDK
NOISE POWER IN DOWN-PATH	-118.6961	DBW	XNGR
CARRIER-TO-TEMPERATURE RATIO	-137.9069	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	18.5158	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-138.7566	DBW/4KHZ	SPEC(GS)R
DOWN-PATH CNR	12.0172	DB	CNRD

SYSTEM

EFFECTIVE SYSTEM TEMPERATURE	1326.7808	KELVINS	TSE
EFFECTIVE NOISE POWER IN SYSTEM	-118.0789	DBW	XNSEQ
TOTAL LINK CNR	11.4000	DB	CNRDB

CTS COMMUNICATIONS CALCULATIONS
PROGRAM COMM1A - VERSION 1

CASE 7 : COMPLETE SYSTEM CALCULATIONS

BASIC SYSTEM CONFIGURATION

THIS IS A BEACON SIGNAL.
TRANSMISSION IS TO A 10.0 FT DIAMETER ANTENNA IN THE NORTH.
THE RECEIVER HAS A TDA FRONT END.

RANGE AND FREQUENCY

RANGE (DOWN-PATH)	41.1280	KM/1000	PATHDN
DOWN-PATH FREQUENCY	11.7000	GHZ	QDWNGH

GROUND RECEIVING SYSTEM (TDA)

SKY TEMPERATURE	40.0000	KELVINS	TSK
SIDE LOBE TEMPERATURE	36.0000	KELVINS	TSIDE
FRONT END NOISE FIGURE	6.5000	DB	FAMP
FRONT END GAIN	20.0000	DB	GAMP
SECOND STAGE NOISE FIGURE	12.0000	DB	FA2
INPUT FILTER LOSS	.3000	DB	FIN
INPUT FEED LOSS	.5000	DB	FEED
DOWN-PATH SYSTEM TEMPERATURE	1151.0038	KELVINS	TGSDK

GENERAL

RF NOISE BANDWIDTH	.0020	MHZ	RFBW

DOWNPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	1.2000	DB	RAINUP
SCATTER MARGIN	3.0000	DB	SCATUP

DOWN-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA BEAMWIDTH	17.0000	DEGREES	WS(TR)
TRANSMIT GAIN	15.0000	DB	G(GS)T
BEAM EDGE ALLOWANCE	3.0030	DB	A(GS,TR)
PATH LOSS	206.0882	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.6620	DB	ATML(UP,DN)
ANTENNA DIAMETER	10.0000	FEET	DG(TR)
RECEIVE GAIN	48.8482	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	146.9020	DB	CPL(UD)

LINK PARAMETERS

TRANSPONDER TUBE CARRIER POWER	-6.9897	DBW	PSTRDB
TRANSPONDER TUBE CARRIER POWER	.2000	WATTS	PSTRWT
CARRIER-TO-TEMPERATURE RATIO	11.2477	DBW/K	CT(RS)DB
TRANSPONDER OUTPUT FEED LOSS	.5000	DB	ASO
COUPLING LOSS (STD. ATM.)	146.9020	DB	CPL(UD)
TOTAL MARGIN, NO POWER CTL	3.2311	DB	XMARGW
POWER RECEIVED AT GROUND	-157.1228	DBW	CGRDB
DOWN-PATH SYSTEM TEMPERATURE	1151.0038	KELVINS	TGSDK
NOISE POWER IN DOWN-PATH	-164.9800	DBW	XNGR
CARRIER-TO-TEMPERATURE RATIO	-188.3508	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	18.2374	DB/K	GNTEM(RS)
DOWN-PATH CNR	7.8572	DB	CNRD

CTS COMMUNICATIONS CALCULATIONS
PROGRAM COMM1A - VERSION 1

CASE 8 : COMPLETE SYSTEM CALCULATIONS

BASIC SYSTEM CONFIGURATION

AN NTSC COLOUR SIGNAL IS BEING TRANSMITTED.
TRANSMISSION IS FROM A 10.0 FT DIAMETER ANTENNA IN THE NORTH
TO A 30.0 FT DIAMETER ANTENNA AT OTTAWA.
SIGNAL PARAMETERS ARE OPTIMIZED.
THE RECEIVER HAS A PARAMP FRONT END.
NO UP-PATH POWER CONTROL IS USED.

RANGE AND FREQUENCY

RANGE (UP-PATH)	41.1280	KM/1000	PATHUP
RANGE (DOWN-PATH)	39.1910	KM/1000	PATHDN
UP-PATH FREQUENCY	14.0530	GHZ	QRUPGH
DOWN-PATH FREQUENCY	11.8860	GHZ	QDWNGH

SPACE TEMPERATURE AT ANTENNA TERMINAL

TRANSPONDER TEMPERATURE	2000.0000	KELVINS	TRDK
OTHER TEMPERATURE CONTRIBUTIONS	25.0000	KELVINS	TSDK
EARTH TEMPERATURE	290.0000	KELVINS	TEDK
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

GROUND RECEIVING SYSTEM (PARAMP)

SKY TEMPERATURE	9.0000	KELVINS	TSK
SIDE LOBE TEMPERATURE	9.0000	KELVINS	TSIDE
FRONT END NOISE FIGURE	3.5000	DB	FAMP
FRONT END GAIN	24.0000	DB	GAMP
SECOND STAGE NOISE FIGURE	12.0000	DB	FA2
INPUT FILTER LOSS	.3000	DB	FIN
INPUT FEED LOSS	.5000	DB	FEED
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK

SIGNAL-TO-NOISE RATIOS FOR STANDARD ATMOSPHERE

WEIGHTED SNR	54.0000	DB	SNWDB
WEIGHTING FACTOR	13.0000	DB	FNW
PEAK-RMS FACTOR	6.0000	DB	F2
UNWEIGHTED SNR	35.0000	DB	SNRDB

GENERAL

BASEBAND NOISE BANDWIDTH	4.2000	MHZ	BBBW
MODULATION INDEX	2.8143		XMOD
DOWNPATH-TO-TOTAL NOISE RATIO	.3222		X

THRESHOLD BACKOFF	2.0000	DB	ATHDB
CALCULATED THRESHOLD	9.1991	DB	THRESB
MINIMUM CNR	9.3000	DB	THRES
RF NOISE BANDWIDTH	32.0403	MHZ	RFBW

UPPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	2.0000	DB	RAINUP
SCATTER MARGIN	3.5000	DB	SCATUP

DOWNPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	1.4000	DB	RAINUP
SCATTER MARGIN	1.0000	DB	SCATUP

UP-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA DIAMETER	10.0000	FEET	DG(TR)
TRANSMIT GAIN	50.4399	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	207.6799	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.9050	DB	ATML(UP,DN)
ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
RECEIVE GAIN	36.2000	DB	G(GS)R
BEAM EDGE ALLOWANCE	3.0000	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)

DOWN-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
TRANSMIT GAIN	36.3000	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	205.8062	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.1480	DB	ATML(UP,DN)
ANTENNA DIAMETER	30.0000	FEET	DG(TR)
RECEIVE GAIN	58.5276	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)

LINK PARAMETERS

UP-PATH

GROUND TRANSMITTER POWER (NOM.)	24.1624	DBW	PGTNDB
GROUND TRANSMITTER POWER (NOM.)	260.7609	WATTS	PGTNWT
TRANSMITTER LINE LOSSES	1.0000	DB	ATOFDB
EIRP	77.6643	DBW	EIRP(GS)
TRANSMIT SPECTRAL DENSITY (LIN)	-14.8739	DBW/4KHZ	SPEC(GS)T
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)
POWER RECEIVED AT SPACECRAFT	-102.7826	DBW	CSRDB
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

UP-PATH NOISE POWER	-119.8986	DBW	XNSR
CARRIER-TO-TEMPERATURE RATIO	-136.4281	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	2.5545	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-141.8190	DBW/4KHZ	SPEC(GS)R
UP-PATH CNR	17.1160	DB	CNRU

DOWN-PATH

TRANSPONDER GAIN	107.9978	DB	GSTRDB
TRANSPONDER TUBE CARRIER POWER	6.2152	DBW	PSTRDB
TRANSPONDER TUBE CARRIER POWER	4.1833	WATTS	PSTRWT
CARRIER-TO-TEMPERATURE RATIO	38.4563	DBW/K	CT(RS)DB
TRANSMIT SPECTRAL DENSITY (LIN)	-32.8212	DBW/4KHZ	SPEC(GS)T
TRANSPONDER OUTPUT FEED LOSS	1.0000	DB	ASO
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)
TOTAL MARGIN. NO POWER CTL	4.1272	DB	XMARGW
POWER RECEIVED AT GROUND	-106.9114	DBW	CGRDB
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK
NOISE POWER IN DOWN-PATH	-127.2576	DBW	XNGR
CARRIER-TO-TEMPERATURE RATIO	-138.1170	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	32.2411	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-141.8190	DBW/4KHZ	SPEC(GS)R
DOWN-PATH CNR	20.3462	DB	CNRD

SYSTEM

EFFECTIVE SYSTEM TEMPERATURE	1319.9485	KELVINS	TSE
EFFECTIVE NOISE POWER IN SYSTEM	-122.3386	DBW	XNSEQ
TOTAL LINK CNR	15.4272	DB	CNRDB

CTS COMMUNICATIONS CALCULATIONS
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CASE 9 : COMPLETE SYSTEM CALCULATIONS

BASIC SYSTEM CONFIGURATION

AN NTSC COLOUR SIGNAL IS BEING TRANSMITTED.
4 AUDIO SUBCARRIER(S) ARE INCLUDED.
TRANSMISSION IS FROM A 10.0 FT DIAMETER ANTENNA IN THE NORTH
TO A 30.0 FT DIAMETER ANTENNA AT OTTAWA.
SIGNAL PARAMETERS ARE OPTIMIZED.
THE RECEIVER HAS A PARAMP FRONT END.
NO UP-PATH POWER CONTROL IS USED.

RANGE AND FREQUENCY

RANGE (UP-PATH)	41.1280	KM/1000	PATHUP
RANGE (DOWN-PATH)	39.1910	KM/1000	PATHDN
UP-PATH FREQUENCY	14.0530	GHZ	QRUPGH
DOWN-PATH FREQUENCY	11.8860	GHZ	QDWNGH

SPACE TEMPERATURE AT ANTENNA TERMINAL

TRANSPONDER TEMPERATURE	2000.0000	KELVINS	TRDK
OTHER TEMPERATURE CONTRIBUTIONS	25.0000	KELVINS	TSDK
EARTH TEMPERATURE	290.0000	KELVINS	TEDK
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

GROUND RECEIVING SYSTEM (PARAMP)

SKY TEMPERATURE	9.0000	KELVINS	TSK
SIDE LOBE TEMPERATURE	9.0000	KELVINS	TSIDE
FRONT END NOISE FIGURE	3.5000	DB	FAMP
FRONT END GAIN	24.0000	DB	GAMP
SECOND STAGE NOISE FIGURE	12.0000	DB	FA2
INPUT FILTER LOSS	.3000	DB	FIN
INPUT FEED LOSS	.5000	DB	FEED
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK

SIGNAL-TO-NOISE RATIOS FOR STANDARD ATMOSPHERE

WEIGHTED SNR	54.0000	DB	SNWDB
WEIGHTING FACTOR	13.0000	DB	FNW
PEAK-RMS FACTOR	6.0000	DB	F2
UNWEIGHTED SNR	35.0000	DB	SNRDB

AUDIO SUBCARRIERS

SIGNAL-TO-NOISE	57.000	57.000	57.000	57.000	DB	SNDB
BASEBAND BANDWIDTH	.010	.010	.010	.010	MHZ	ABMH

SUBCARRIER BANDWIDTH	.220	.220	.220	.220	MHZ	BWMH
MODULATION INDICES	10.000	10.000	10.000	10.000		XXMI
SUBCARRIER FREQUENCIES	6.850	7.610	7.970	8.350	MHZ	FRMH

NUMBER OF SUBCARRIERS	4		ISUB
BANDWIDTH AND POWER INCREASE	1.2043		DELPLN
FACTOR "D"	.1315		D

GENERAL

BASEBAND NOISE BANDWIDTH	8.3500	MHZ	BBBW
MODULATION INDEX	1.3106		XMOD
DOWNPATH-TO-TOTAL NOISE RATIO	.3222		X
THRESHOLD BACKOFF	2.0000	DB	ATHDB
CALCULATED THRESHOLD	9.1991	DB	THRESB
MINIMUM CNR	9.3008	DB	THRES
RF NOISE BANDWIDTH	38.5868	MHZ	RFBW

UPPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	2.0000	DB	RAINUP
SCATTER MARGIN	3.5000	DB	SCATUP

DOWNPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	1.4000	DB	RAINUP
SCATTER MARGIN	1.0000	DB	SCATUP

UP-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA DIAMETER	10.0000	FEELT	DG(TR)
TRANSMIT GAIN	50.4399	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	207.6799	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.9050	DB	ATML(UP,DN)
ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
RECEIVE GAIN	36.2000	DB	G(GS)R
BEAM EDGE ALLOWANCE	3.0000	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)

DOWN-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
TRANSMIT GAIN	36.3000	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	205.8062	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.1480	DB	ATML(UP,DN)
ANTENNA DIAMETER	30.0000	FEELT	DG(TR)
RECEIVE GAIN	58.5276	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)

LINK PARAMETERS

UP-PATH

GROUND TRANSMITTER POWER (NOM.)	24.9699	DBW	PGTNDB
GROUND TRANSMITTER POWER (NOM.)	314.0401	WATTS	PGTNWT
TRANSMITTER LINE LOSSES	1.0000	DB	ATOFDB
EIRP	77.6643	DBW	EIRP(GS)
TRANSMIT SPECTRAL DENSITY (LIN)	-14.8739	DBW/4KHZ	SPEC(GS)T
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)
POWER RECEIVED AT SPACECRAFT	-101.9752	DBW	CSRDB
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK
UP-PATH NOISE POWER	-119.8986	DBW	XNSR
CARRIER-TO-TEMPERATURE RATIO	-136.4281	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	2.5545	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-141.8190	DBW/4KHZ	SPEC(GS)R
UP-PATH CNR	17.1160	DB	CNRU

DOWN-PATH

TRANSPONDER GAIN	107.9978	DB	GSTRDB
TRANSPONDER TUBE CARRIER POWER	7.0226	DBW	PSTRDB
TRANSPONDER TUBE CARRIER POWER	5.0380	WATTS	PSTRWT
CARRIER-TO-TEMPERATURE RATIO	38.4563	DBW/K	CT(RS)DB
TRANSMIT SPECTRAL DENSITY (LIN)	-32.8212	DBW/4KHZ	SPEC(GS)T
TRANSPONDER OUTPUT FEED LOSS	1.0000	DB	ASO
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)
TOTAL MARGIN, NO POWER CTL	4.1272	DB	XMARGW
POWER RECEIVED AT GROUND	-106.1040	DBW	CGRDB
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK
NOISE POWER IN DOWN-PATH	-127.2576	DBW	XNGR
CARRIER-TO-TEMPERATURE RATIO	-137.3095	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	32.2411	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-141.8190	DBW/4KHZ	SPEC(GS)R
DOWN-PATH CNR	20.3462	DB	CNRD

SYSTEM

EFFECTIVE SYSTEM TEMPERATURE	1319.9485	KELVINS	TSE
EFFECTIVE NOISE POWER IN SYSTEM	-122.3386	DBW	XNSEQ
TOTAL LINK CNR	15.4272	DB	CNRDB

CTS COMMUNICATIONS CALCULATIONS
PROGRAM COMM1A - VERSION 1

CASE 10 : COMPLETE SYSTEM CALCULATIONS

BASIC SYSTEM CONFIGURATION

A SEPARATE TV AUDIO CARRIER IS BEING TRANSMITTED.
TRANSMISSION IS FROM A 10.0 FT DIAMETER ANTENNA IN THE NORTH TO A 30.0 FT DIAMETER ANTENNA AT OTTAWA.
SIGNAL PARAMETERS ARE COMPATIBLE, WHERE POSSIBLE, WITH BROADCAST STANDARDS.
THE RECEIVER HAS A PARAMP FRONT END.
NO UP-PATH POWER CONTROL IS USED.

RANGE AND FREQUENCY

RANGE (UP-PATH)	41.1280	KM/1000	PATHUP
RANGE (DOWN-PATH)	39.1910	KM/1000	PATHDN
UP-PATH FREQUENCY	14.0770	GHZ	QRUPGH
DOWN-PATH FREQUENCY	11.9100	GHZ	QDWNGH

SPACE TEMPERATURE AT ANTENNA TERMINAL

TRANSPONDER TEMPERATURE	2000.0000	KELVINS	TRDK
OTHER TEMPERATURE CONTRIBUTIONS	25.0000	KELVINS	TSDK
EARTH TEMPERATURE	290.0000	KELVINS	TEDK
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

GROUND RECEIVING SYSTEM (PARAMP)

SKY TEMPERATURE	9.0000	KELVINS	TSK
SIDE LOBE TEMPERATURE	9.0000	KELVINS	TSIDE
FRONT END NOISE FIGURE	3.5000	DB	FAMP
FRONT END GAIN	24.0000	DB	GAMP
SECOND STAGE NOISE FIGURE	12.0000	DB	FA2
INPUT FILTER LOSS	.3000	DB	FIN
INPUT FEED LOSS	.5000	DB	FEED
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK

SIGNAL-TO-NOISE RATIOS FOR STANDARD ATMOSPHERE

WEIGHTED SNR	57.0000	DB	SNWDB
WEIGHTING FACTOR	9.6000	DB	FNW
UNWEIGHTED SNR	47.4000	DB	SNRDB

GENERAL

BASEBAND NOISE BANDWIDTH	.0150	MHZ	BBBW
MODULATION INDEX	1.6667		XMOD
DOWNPATH-TO-TOTAL NOISE RATIO	.3222		X

CALCULATED THRESHOLD	9.9023	DB	THRESB
MINIMUM CNR	25.8905	DB	THRES
EXCESS MARGIN ABOVE THRESHOLD	15.9882	DB	EXCESS
RF NOISE BANDWIDTH	.2000	MHZ	RFBW

UPPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	2.0000	DB	RAINUP
SCATTER MARGIN	3.5000	DB	SCATUP

DOWNPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	1.4000	DB	RAINUP
SCATTER MARGIN	1.0000	DB	SCATUP

UP-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA DIAMETER	10.0000	FEET	DG(TR)
TRANSMIT GAIN	50.4547	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	207.6947	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.9050	DB	ATML(UP,DN)
ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
RECEIVE GAIN	36.2000	DB	G(GS)R
BEAM EDGE ALLOWANCE	3.0000	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)

DOWN-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
TRANSMIT GAIN	36.3000	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	205.8237	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.1480	DB	ATML(UP,DN)
ANTENNA DIAMETER	30.0000	FEET	DG(TR)
RECEIVE GAIN	58.5452	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)

LINK PARAMETERS

UP-PATH

GROUND TRANSMITTER POWER (NOM.)	16.6411	DBW	PGTNDB
GROUND TRANSMITTER POWER (NOM.)	46.1439	WATTS	PGTNWT
TRANSMITTER LINE LOSSES	1.0000	DB	ATOFDB
EIRP	70.1579	DBW	EIRP(GS)
TRANSMIT SPECTRAL DENSITY (LIN)	-22.3952	DBW/4KHZ	SPEC(GS)T
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)
POWER RECEIVED AT SPACECRAFT	-110.3039	DBW	CSRDB
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

UP-PATH NOISE POWER	-141.9453	DBW	XNSR
CARRIER-TO-TEMPERATURE RATIO	-143.9494	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	2.5545	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-149.3402	DBW/4KHZ	SPEC(GS)R
UP-PATH CNR	31.6414	DB	CNRU

DOWN-PATH

TRANSPONDER GAIN	107.9978	DB	GSTRDB
TRANSPONDER TUBE CARRIER POWER	-1.3061	DBW	PSTRDB
TRANSPONDER TUBE CARRIER POWER	.7403	WATTS	PSTRWT
CARRIER-TO-TEMPERATURE RATIO	30.9525	DBW/K	CT(RS)DB
TRANSMIT SPECTRAL DENSITY (LIN)	-40.3425	DBW/4KHZ	SPEC(GS)T
TRANSPONDER OUTPUT FEED LOSS	1.0000	DB	ASO
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)
TOTAL MARGIN, NO POWER CTL	4.1272	DB	XMARGW
POWER RECEIVED AT GROUND	-114.4327	DBW	CGRDB
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK
NOISE POWER IN DOWN-PATH	-149.3042	DBW	XNGR
CARRIER-TO-TEMPERATURE RATIO	-145.6382	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	32.2586	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-149.3402	DBW/4KHZ	SPEC(GS)R
DOWN-PATH CNR	34.8716	DB	CNRD

SYSTEM

EFFECTIVE SYSTEM TEMPERATURE	1319.9485	KELVINS	TSE
EFFECTIVE NOISE POWER IN SYSTEM	-144.3852	DBW	XNSEQ
TOTAL LINK CNR	29.9526	DB	CNRDB

CTS COMMUNICATIONS CALCULATIONS
PROGRAM COMM1A - VERSION 1

CASE 11 : COMPLETE SYSTEM CALCULATIONS

BASIC SYSTEM CONFIGURATION

A BROADCAST STANDARD FM SOUND SIGNAL IS BEING TRANSMITTED.
TRANSMISSION IS FROM A 10.0 FT DIAMETER ANTENNA IN THE NORTH TO A 30.0 FT DIAMETER ANTENNA AT OTTAWA.
SIGNAL PARAMETERS ARE COMPATIBLE, WHERE POSSIBLE, WITH BROADCAST STANDARDS.
THE RECEIVER HAS A PARAMP FRONT END.
NO UP-PATH POWER CONTROL IS USED.

RANGE AND FREQUENCY

RANGE (UP-PATH)	41.1280	KM/1000	PATHUP
RANGE (DOWN-PATH)	39.1910	KM/1000	PATHDN
UP-PATH FREQUENCY	14.0820	GHZ	QRUPGH
DOWN-PATH FREQUENCY	11.9150	GHZ	QDWNGH

SPACE TEMPERATURE AT ANTENNA TERMINAL

TRANSPONDER TEMPERATURE	2000.0000	KELVINS	TRDK
OTHER TEMPERATURE CONTRIBUTIONS	25.0000	KELVINS	TSDK
EARTH TEMPERATURE	290.0000	KELVINS	TEDK
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

GROUND RECEIVING SYSTEM (PARAMP)

SKY TEMPERATURE	9.0000	KELVINS	TSK
SIDE LOBE TEMPERATURE	9.0000	KELVINS	TSIDE
FRONT END NOISE FIGURE	3.5000	DB	FAMP
FRONT END GAIN	24.0000	DB	GAMP
SECOND STAGE NOISE FIGURE	12.0000	DB	FA2
INPUT FILTER LOSS	.3000	DB	FIN
INPUT FEED LOSS	.5000	DB	FEED
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK

SIGNAL-TO-NOISE RATIOS FOR STANDARD ATMOSPHERE

WEIGHTED SNR	57.0000	DB	SNWDB
WEIGHTING FACTOR	9.6000	DB	FNW
UNWEIGHTED SNR	47.4000	DB	SNRDB

GENERAL

BASEBAND NOISE BANDWIDTH	.0150	MHZ	BBBW
MODULATION INDEX	5.0000		XMOD
DOWNPATH-TO-TOTAL NOISE RATIO	.3222		X

CALCULATED THRESHOLD	10.0224	DB	THRESB
MINIMUM CNR	15.9344	DB	THRES
EXCESS MARGIN ABOVE THRESHOLD	5.9120	DB	EXCESS
RF NOISE BANDWIDTH	.2200	MHZ	RFBW

UPPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	2.0000	DB	RAINUP
SCATTER MARGIN	3.5000	DB	SCATUP

DOWNPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	1.4000	DB	RAINUP
SCATTER MARGIN	1.0000	DB	SCATUP

UP-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA DIAMETER	10.0000	FEET	DG(TR)
TRANSMIT GAIN	50.4578	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	207.6978	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.9050	DB	ATML(UP,DN)
ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
RECEIVE GAIN	36.2000	DB	G(GS)R
BEAM EDGE ALLOWANCE	3.0000	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)

DOWN-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
TRANSMIT GAIN	36.3000	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	205.8274	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.1480	DB	ATML(UP,DN)
ANTENNA DIAMETER	30.0000	FEET	DG(TR)
RECEIVE GAIN	58.5488	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)

LINK PARAMETERS

UP-PATH

GROUND TRANSMITTER POWER (NOM.)	7.0989	DBW	PGTNDB
GROUND TRANSMITTER POWER (NOM.)	5.1273	WATTS	PGTNWT
TRANSMITTER LINE LOSSES	1.0000	DB	ATOFDB
EIRP	60.6187	DBW	EIRP(GS)
TRANSMIT SPECTRAL DENSITY (LIN)	-31.9375	DBW/4KHZ	SPEC(GS)T
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)
POWER RECEIVED AT SPACECRAFT	-119.8461	DBW	CSRDB
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

UP-PATH NOISE POWER	-141.5314	DBW	XNSR
CARRIER-TO-TEMPERATURE RATIO	-153.4916	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	2.5545	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-158.8825	DBW/4KHZ	SPEC(GS)R
UP-PATH CNR	21.6852	DB	CNRU

DOWN-PATH

TRANSPONDER GAIN	107.9978	DB	GSTRDB
TRANSPONDER TUBE CARRIER POWER	-10.8484	DBW	PSTRDB
TRANSPONDER TUBE CARRIER POWER	.0823	WATTS	PSTRWT
CARRIER-TO-TEMPERATURE RATIO	21.4139	DBW/K	CT(RS)DB
TRANSMIT SPECTRAL DENSITY (LIN)	-49.8847	DBW/4KHZ	SPEC(GS)T
TRANSPONDER OUTPUT FEED LOSS	1.00[illegible]	DB	ASO
COUPLING LOSS (STD. ATM.)	112.1266	DB	CPL(UD)
TOTAL MARGIN, NO POWER CTL	4.1272	DB	XMARGW
POWER RECEIVED AT GROUND	-123.9749	DBW	CGRDB
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK
NOISE POWER IN DOWN-PATH	-148.8903	DBW	XNGR
CARRIER-TO-TEMPERATURE RATIO	-155.1805	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	32.2622	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-158.8825	DBW/4KHZ	SPEC(GS)R
DOWN-PATH CNR	24.9154	DB	CNRD

SYSTEM

EFFECTIVE SYSTEM TEMPERATURE	1319.9485	KELVINS	TSE
EFFECTIVE NOISE POWER IN SYSTEM	-143.9713	DBW	XNSEQ
TOTAL LINK CNR	19.9964	DB	CNRDB

CTS COMMUNICATIONS CALCULATIONS
PROGRAM COMM1A - VERSION 1

CASE 13 : COMPLETE SYSTEM CALCULATIONS

BASIC SYSTEM CONFIGURATION

A TDMA SIGNAL IS BEING TRANSMITTED.
TRANSMISSION IS FROM A 10.0 FT DIAMETER ANTENNA IN THE NORTH TO A 30.0 FT DIAMETER ANTENNA AT OTTAWA.
THE RECEIVER HAS A PARAMP FRONT END.
NO UP-PATH POWER CONTROL IS USED.

RANGE AND FREQUENCY

RANGE (UP-PATH)	41.1280	KM/1000	PATHUP
RANGE (DOWN-PATH)	39.1910	KM/1000	PATHDN
UP-PATH FREQUENCY	14.0530	GHZ	QRUPGH
DOWN-PATH FREQUENCY	11.8860	GHZ	QDWNGH

SPACE TEMPERATURE AT ANTENNA TERMINAL

TRANSPONDER TEMPERATURE	2000.0000	KELVINS	TRDK
OTHER TEMPERATURE CONTRIBUTIONS	25.0000	KELVINS	TSDK
EARTH TEMPERATURE	290.0000	KELVINS	TEDK
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK

GROUND RECEIVING SYSTEM (PARAMP)

SKY TEMPERATURE	9.0000	KELVINS	TSK
SIDE LOBE TEMPERATURE	9.0000	KELVINS	TSIDE
FRONT END NOISE FIGURE	3.5000	DB	FAMP
FRONT END GAIN	24.0000	DB	GAMP
SECOND STAGE NOISE FIGURE	12.0000	DB	FA2
INPUT FILTER LOSS	.3000	DB	FIN
INPUT FEED LOSS	.5000	DB	FEED
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK

SIGNAL-TO-NOISE RATIOS FOR STANDARD ATMOSPHERE

UNWEIGHTED SNR	8.4000	DB	SNRDB
IMPLEMENTATION FACTOR	3.0000	DB	FIM

GENERAL

MAXIMUM BIT RATE	85.0000	MHZ	BBBW
DOWNPATH-TO-TOTAL NOISE RATIO	.3222		X
RF NOISE BANDWIDTH	85.0000	MHZ	RFBW

UPPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	2.0000	DB	RAINUP
SCATTER MARGIN	3.5000	DB	SCATUP

DOWNPATH MARGINS FOR 99.9 PERC. OF THE TIME

RAIN MARGIN	1.4000	DB	RAINUP
SCATTER MARGIN	1.0000	DB	SCATUP

UP-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA DIAMETER	10.0000	FEET	DG(TR)
TRANSMIT GAIN	50.4399	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	207.6799	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.9050	DB	ATML(UP,DN)
ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
RECEIVE GAIN	36.2000	DB	G(GS)R
BEAM EDGE ALLOWANCE	3.0000	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)

DOWN-PATH CHARACTERISTICS THROUGH STANDARD ATMOSPHERE

ANTENNA BEAMWIDTH	2.5000	DEGREES	WS(TR)
TRANSMIT GAIN	36.3000	DB	G(GS)T
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
PATH LOSS	205.8062	DB	XLPL(UD)
STD. ATMOSPHERE ATTENUATION	.1480	DB	ATML(UP,DN)
ANTENNA DIAMETER	30.0000	FEET	DG(TR)
RECEIVE GAIN	58.5276	DB	G(GS)R
BEAM EDGE ALLOWANCE	0.	DB	A(GS,TR)
POINTING ERROR LOSS	1.0000	DB	AGTEDB
ORBIT INCLINATION LOSS	0.	DB	ANRBDB
COUPLING LOSS (STD. ATM.)	142.1266	DB	CPL(UD)

LINK PARAMETERS

UP-PATH

GROUND TRANSMITTER POWER (NOM.)	24.3725	DBW	PGTNDB
GROUND TRANSMITTER POWER (NOM.)	273.6831	WATTS	PGTNWT
TRANSMITTER LINE LOSSES	1.0000	DB	ATOFDB
EIRP	77.8744	DBW	EIRP(GS)
TRANSMIT SPECTRAL DENSITY (LIN)	-18.9011	DBW/4KHZ	SPEC(GS)T
COUPLING LOSS (STD. ATM.)	125.9450	DB	CPL(UD)
POWER RECEIVED AT SPACECRAFT	-102.5725	DBW	CSRDB
UP-PATH SYSTEM TEMPERATURE	2315.0000	KELVINS	TSSYDK
UP-PATH NOISE POWER	-115.6614	DBW	XNSR
CARRIER-TO-TEMPERATURE RATIO	-136.2181	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	2.5545	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-145.8461	DBW/4KHZ	SPEC(GS)R
UP-PATH CNR	13.0889	DB	CNRU

DOWN-PATH

TRANSPONDER GAIN	107.9978	DB	GSTRDB
TRANSPONDER TUBE CARRIER POWER	6.4252	DBW	PSTRDB
TRANSPONDER TUBE CARRIER POWER	4.3906	WATTS	PSTRWT
CARRIER-TO-TEMPERATURE RATIO	38.6663	DBW/K	CT(RS)DB
TRANSMIT SPECTRAL DENSITY (LIN)	-36.8484	DBW/4KHZ	SPEC(GS)T
TRANSPONDER OUTPUT FEED LOSS	1.0000	DB	ASO
COUPLING LOSS (STD. ATM.)	112.1265	DB	CPL(UD)
TOTAL MARGIN, NO POWER CTL	4.1272	DB	XMARGW
POWER RECEIVED AT GROUND	-106.7013	DBW	CGRDB
DOWN-PATH SYSTEM TEMPERATURE	425.2608	KELVINS	TGSDK
NOISE POWER IN DOWN-PATH	-123.0204	DBW	XNGR
CARRIER-TO-TEMPERATURE RATIO	-137.9069	DBW/K	CT(RS)DB
GAIN-TO-TEMPERATURE RATIO	32.2411	DB/K	GNTEM(RS)
RECEIVE SPECTRAL DENSITY (LIN)	-145.8461	DBW/4KHZ	SPEC(GS)R
DOWN-PATH CNR	16.3190	DB	CNRD

SYSTEM

EFFECTIVE SYSTEM TEMPERATURE	1319.9485	KELVINS	TSE
EFFECTIVE NOISE POWER IN SYSTEM	-118.1013	DBW	XNSEQ
TOTAL LINK CNR	11.400[illegible]	DB	CNRDB

APPENDIX D-1

GAIN LOSS AND BORESIGHT CHANGES DUE TO REFLECTOR DEFLECTIONS AND OPTICAL MISALIGNMENT

D-1-1 General

Antenna reflector distortions and general antenna misalignment can result in a loss of gain and a shift in the electrical boresight relative to the mechanical axis of the reflector. Gain loss can be a result of defocussing due to misalignment or optical system random errors, i.e. reflector distortions due to general manufacturing tolerances and gravity or wind deflections. A change of electrical boresight is the result of a non-random phase error caused either by a non-random reflector distortion or by a lateral displacement of the feed components relative to the reflector's mechanical axis.

Tables D-1-1 and D-1-2 summarize the gain loss and beam deflection characteristics of the proposed focal point feed and Cassegrain antennas respectively. An estimate of the required set-up accuracy is included.

D-1-2 Gain Loss

Surface Errors

The loss of gain due to optical errors can be calculated from an estimate of the RMS value of the main reflector's surface errors (and the subreflector's surface errors for a Cassegrain antenna) using the following simple relation:

$$\eta_p \text{ (dB)} = 10 \log (1 - 16 \pi^2 \Delta\lambda^2)$$

where $\Delta\lambda$ = the RMS surface error of the reflector in wavelengths.

Defocussing

A loss of gain will be experienced if the phase center of the feed is not coincident with the focus of the reflector. For the focal point feed antenna this defocussing simply refers to an axial displacement of the feed horn. For the Cassegrain antenna, defocussing can occur due to axial misalignments of the horn and/or the subreflector.

The following formulae and the graph in Figure D-1-1 can be used to determine the loss of gain due to feed defocussing:

TABLE D-1-1

FOCAL POINT FEED

EFFECTS OF MISALIGNMENT AND REFLECTOR DISTORTIONS

PARAMETER	CAUSE	NUMERICAL RELATIONSHIP	REQUIRED SETUP ACCURACY
Loss of gain 0.1 dB budget	Axial displacement of the feed horn	$\Delta f = \frac{37}{360} \frac{\lambda}{(1 - \cos \ m)}$	$\Delta f = \pm 0.160''$
$h_s = 0.2$ dB (budget)	Reflector surface errors	$h_s = 10 \log (1-16\pi^2\Delta^2/\lambda^2)$ where Δ is the rms surface error of the reflector	$\Delta = \pm 0.015''$ rms
Beam deflection BD_h (budget) $= \pm 0.025°$	Lateral displacement of the feed horn	BD_h (degrees) = Kd where d is the lateral displacement of the feed horn in inches, K = 1.01	$d = \pm 0.025''$
BD_r (budget) $= \pm 0.025°$	Reflector, deflection (maximum distortion at the periphery)	BD_r (degrees) = 1.2Rd where Rd is the maximum deflection of the edge of the reflector in inches.	$Rd = \pm 0.020''$

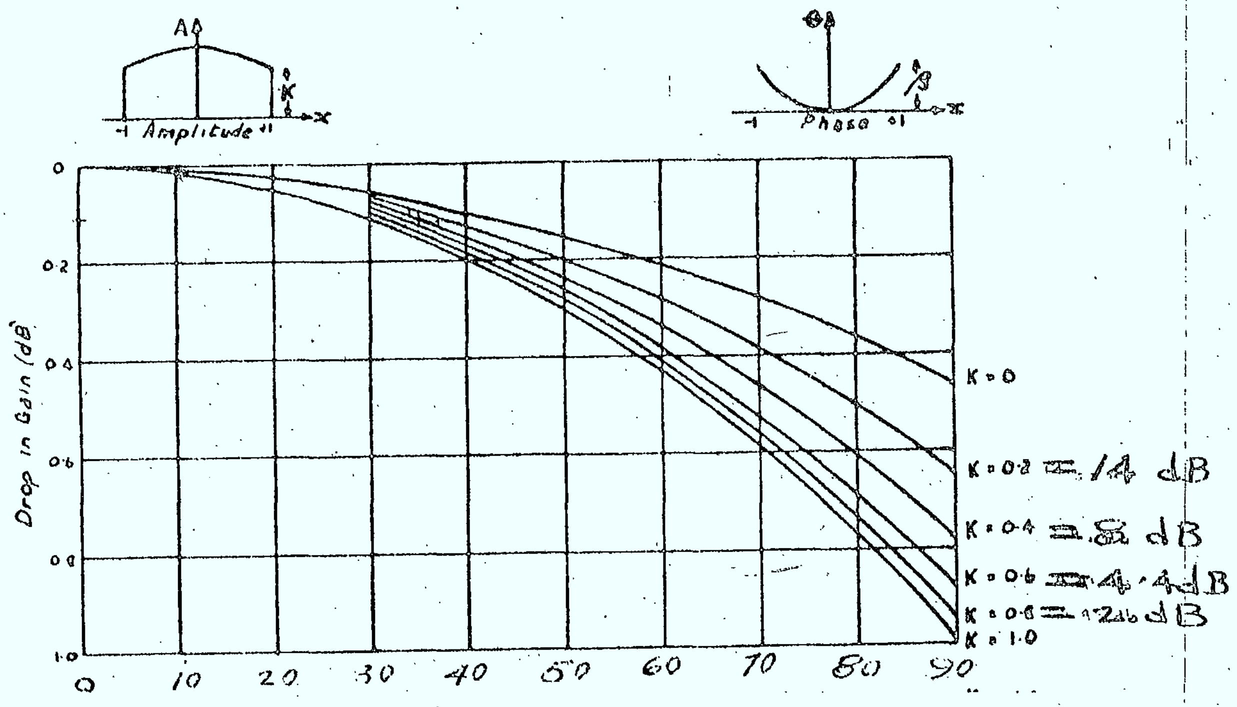
TABLE D-1-2

CASSEGRAIN ANTENNA

EFFECTS OF MISALIGNMENT AND REFLECTOR DISTORTIONS

PARAMETER	CAUSE	NUMERICAL RELATIONSHIP	REQUIRED SETUP ACCURACY
Loss of gain 0.09 dB (budget) which is equiv. to 28° max. quadratic phase error at the edge of the dish	Axial displacement of the subreflector	$\Delta_s = \frac{35}{360} \cdot \frac{1}{(2 - \cos\psi m - \cos\Theta m)}$ (See figures 1 and 2 (14.5 GHz) = 0.815")	$\Delta_s = \pm 0.141"$
0.01 dB (budget) which is equiv. to 10° max. quadratic phase error at the edge of the dish	Axial displacement of the feed horn	$\Delta h = \frac{10}{360} \lambda \cdot \frac{1}{(1 - \cos\Theta m)}$ (See figures 1 and 2)	$\Delta_h = \pm 0.58"$ *
$\eta_s = 0.2$ dB (budget)	Reflector surface errors	$\eta_s = 10 \log (1 - 1677^2 \Delta_\lambda^{\ 2})$	$\eta_s = \pm 0.015"$RMS
Beam deflection BD_{ST} (budget) = $\pm 0.015°$	Lateral displacement of the subreflector	BD_{ST} (degrees) = $\Delta_{sl} \cdot (K - \frac{K}{M})$ where M = 2.02, Δ_{sl} is the displ. of the subreflector in inches, K = 1.01	$\Delta_{sl} = \pm 0.030"$
BD_{SR} (budget) = $\pm 0.01°$	Rotation of the subreflector about its vertex	BD_{SR} (degrees) = NKTanα where N = 4.0 and α = rotation of the subreflector axis relative to the focal axis	$\alpha = \pm 0.14°$
BD_r (budget) = $\pm 0.025°$	Reflector, deflection (max. distortion at the periphery)	BD_r (degrees) = 1.2 Dr where Rd is the max. deflection of the edge of the reflector in inches.	Dr = $\pm 0.020"$

* Assumes that the effect on the input VSWR due to reflections from the subreflector back into the horn are negligible. Otherwise, $\pm$ 0.1" might be a more practical figure.



β = phase error at the aperture edge (degrees)

FIGURE D1-1

DROP IN GAIN DUE TO QUADRATIC PHASE ERROR

Focal Point Feed Antenna - Feed Axial Displacement

$$\Delta f = \frac{\beta}{360} \lambda (1 - \cos \psi_m)$$

where: Δf is the axial displacement of the feed

β is the maximum quadratic phase error (see Figure D-1-1)

λ is the wavelength.

(ψ_m is defined in Figure D-1-2)

Cassegrain Antenna

Horn displacement (Δh)

$$\Delta h = \frac{\beta}{360} \lambda \frac{1}{(1 - \cos \theta m)}$$

(θm is defined in Figure D-1-2)

Subreflector Axial Displacement (Δs)

$$\Delta s = \frac{\beta}{360} \lambda \frac{1}{(2 - \cos \psi m - \cos \theta m)}$$

(ψm and θm are defined in Figure D-1-2)

D-1-3 Boresight Deflection

Focal Point Feed Antenna

A change in the direction of the electrical boresight relative to the reflector's mechanical axis for a 10 foot diameter reflector having a focal distance of 50.4" is given by the relation:

$$\theta_d = 0.89 \frac{d}{50.4} \times \frac{180.0}{\pi} = 1.01 \text{ d (degrees)}$$

or $\theta_d = K_d$ ($K = 1.01$)

where d is the lateral displacement of the feed and the factor 0.890 is taken from Figure D-1-3.

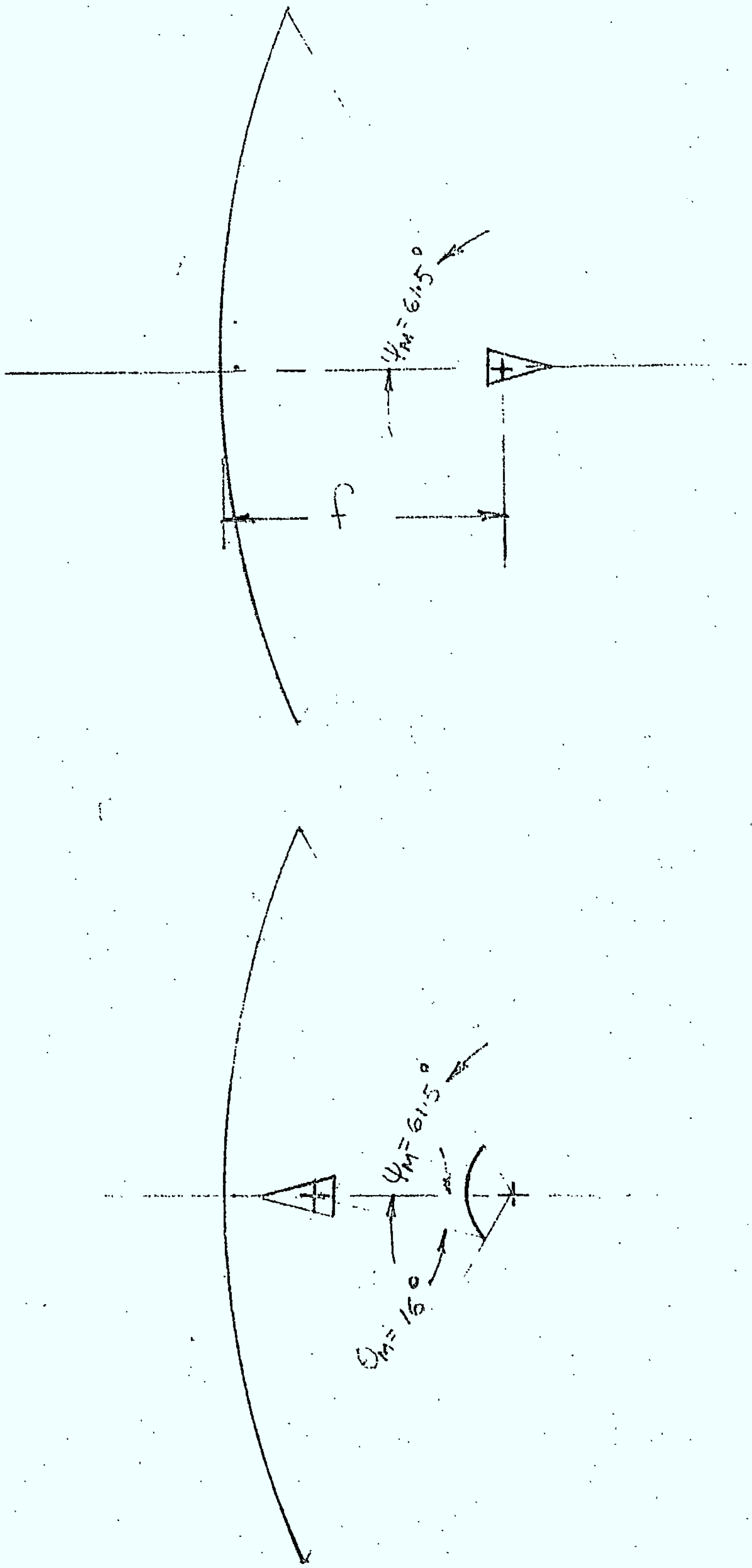


FIGURE D-1-2

FOCAL POINT FEED AND CASSEGRAIN ANTENNA GEOMETRIES

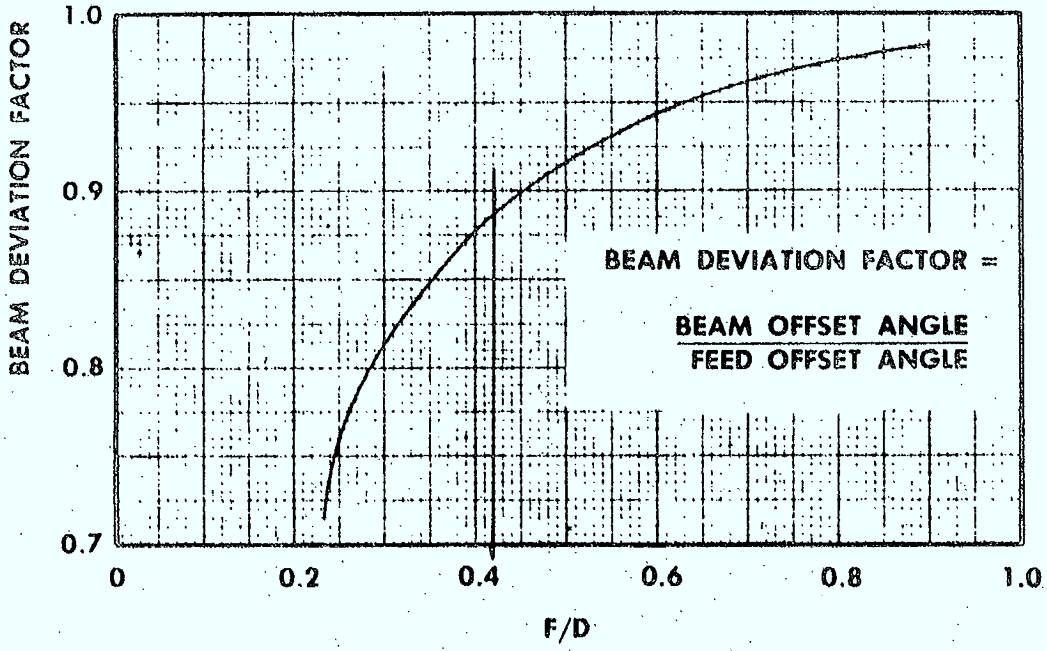


FIGURE D-1-3

BEAM DEVIATION FACTOR

This displacement can be the result of a direct feed movement relative to the reflector or due to a deflection (due to gravity or windload) of the reflector. In the case of reflector deflections, the new best bit focal axis must be found graphically or numerically for the reflector. The displacement of the new focal point relative to the old focal point then gives the beam deviation angle.

For reflector deflections, the angular shift of the new focal axis relative to the old focal axis must be added to the beam deviation due to the effective feed displacement or:

$$\theta_{dr} \text{ ref.} = \theta_f + 0.890 \; \theta_f = 1.890 \; \theta_f$$

where θ_f = the angle between the new and old focal axes.

θ_f can be estimated with sufficient accuracy by utilizing the figure representing the maximum distortion at the edge of the reflector.

$$\theta_f = (1.890 \times \frac{Dr}{60} \times \frac{180}{\pi} \times \frac{1}{1.5} = \frac{1.8 \, Dr}{1.5} = 1.2 \, D_r$$

where D_r is the deflection of the edge of the reflector.

1.5 is an estimated weighting factor for non-uniform illumination.

Cassegrain Antenna

A deflection of the boresight can result from distortion of the reflector for which the same formulas as presented above still apply. Sub-reflector lateral translation and rotation, and feed horn lateral displacement are also factors which contribute to boresight deflections. These are dealt with in the following subsections.

Sub-reflector and Feed Horn Translation

The beam deviation due to subreflector translation is found conveniently mathematically by first assuming that the feed horn moves with the sub-reflector. The beam deviation due to the displaced focal point is then calculated in the same manner as is done with the simple focal point feed antenna. (Translating the feed horn and sub-reflector together is electrically equivalent to translating the feed horn of a focal point feed antenna system). From this value is subtracted the effect of translating the feed horn back to the focal axis. The formula then is:

Total beam deviation = focal point displacement - feed horn displacement back to focal axis

$$\text{or} \quad \theta_T = \Delta_{s_K} - \frac{\Delta_c}{M} K$$

where θ_T is the total beam deviation due to translation of the sub-reflector (degrees)

Δ_s is the displacement of the sub-reflector (inches)

$\Delta_c = \Delta_s$ = the displacement of feed horn back to the focal axis.

M magnification factor of the sub-reflector $= \dfrac{e+1}{e-1}$

where e is the eccentricity of the sub-reflector

K is the beam deviation factor (same as for the focal point feed arrangement)

$$(K = 0.890 \times 50.4 \times \frac{18.0}{\pi} = 1.01)$$

It should be noted that translation of the feed horn results in a new virtual focal point whose position is dependent on M. Similarly, the effect of translating the sub-reflector is to create a displaced virtual focal point which deviates the beam in proportion of the antenna's beam deviation factor. Figure D-1-4 geometrically illustrates the computational approach.

The expected beam deviation due to subreflector translation can be calculated as follows:

$$BD_{ST} = \Delta_S \left(K - \frac{K}{M}\right)$$

$M = 2.02$

$K = 1.01$

Let $\Delta_s = 1$ inch

$BD_{ST} = 0.51$ degrees/inch.

It is noted that the effect of the second factor in the equation is approximately one-half the first factor indicating that the effect of translating the feed horn in

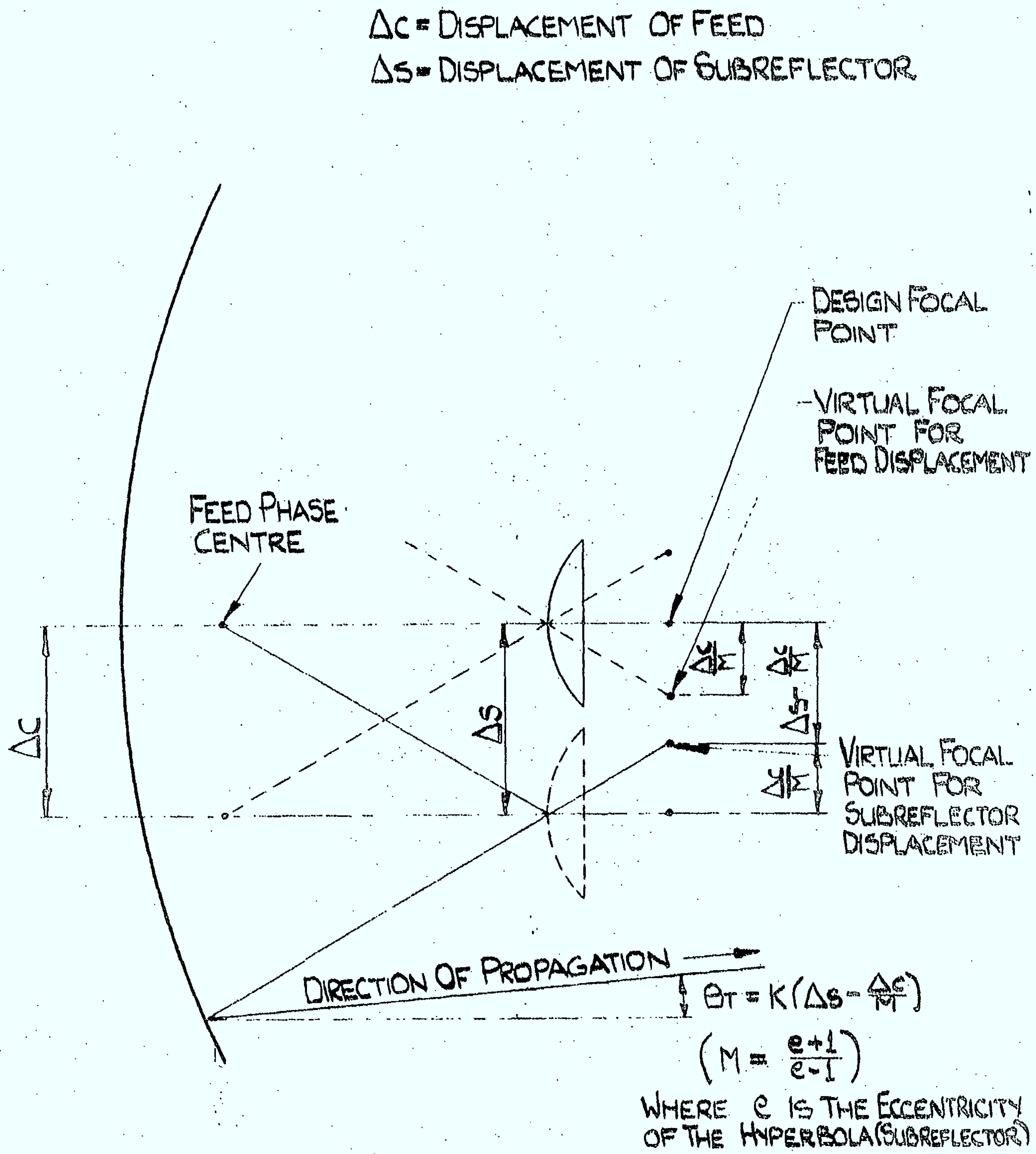


FIGURE D-1-4

GEOMETRICAL ILLUSTRATION OF THE EFFECT OF SUBREFLECTOR TRANSLATION a Cassegrain antenna system is only approximately one-half as significant as translating the sub-reflector.

The second term in this equation represents an improvement in sub-reflector translation sensititivity offered by the Cassegrain antenna over feed translation sensitivity in the focal point feed antenna.

Subreflector Rotation (about its vertex)

The subreflector rotation about its vertex is illustrated geometrically in Figure D-1-5. (Rotation about any other point can be resolved into a translation normal to the focal axis and a rotation about the vertex and, therefore, the two modes of motion discussed here are sufficient to analyze subreflector motions.) The beam deviation formula is as follows:

$$R = N \; K \; \mathrm{TAN} \, \alpha$$

where: N = is the distance between the focal point and the vertex of the subreflector (4.0 inches)

α = is the subreflector's angle of rotation about the vertex of the subreflector

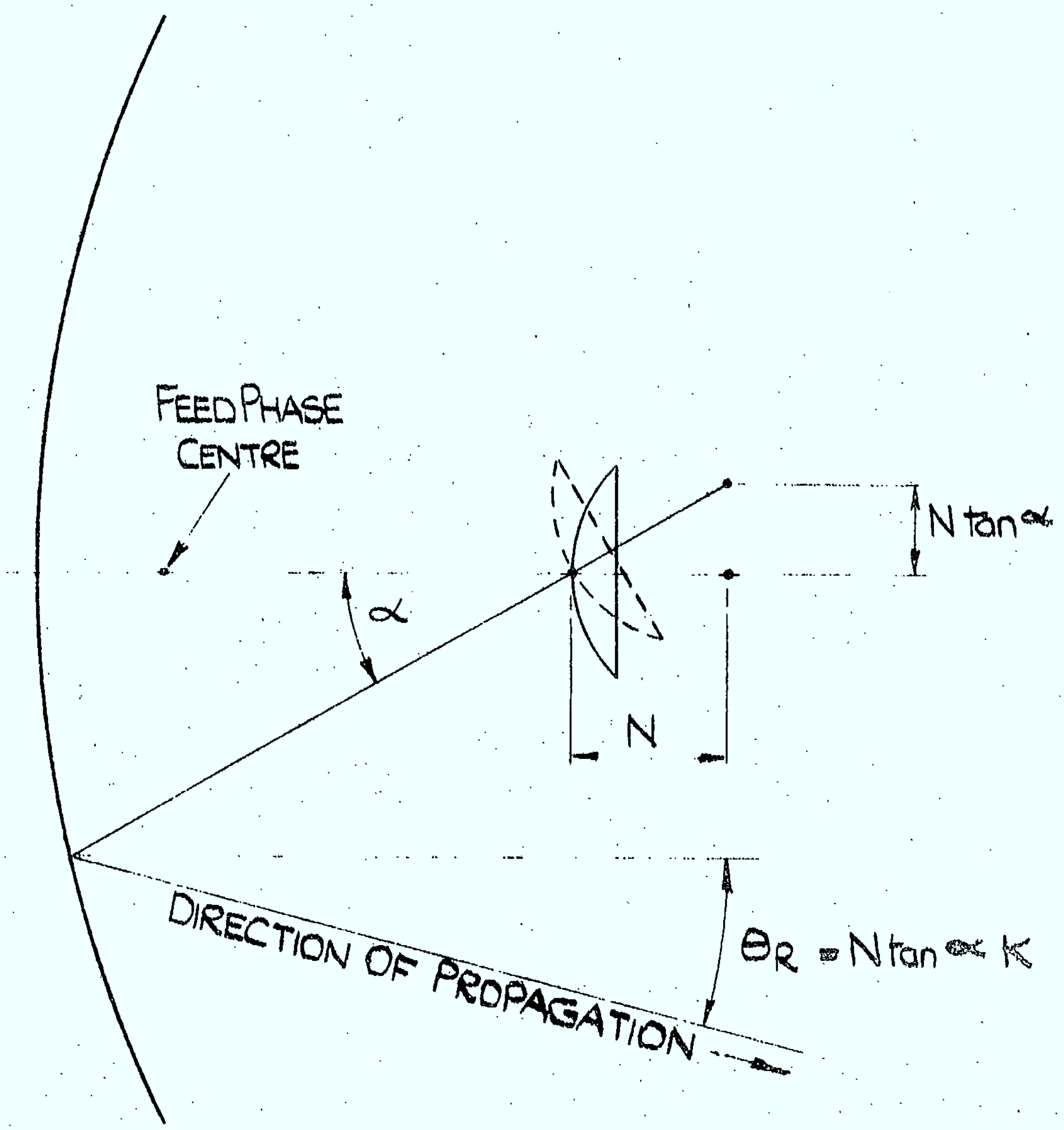


FIGURE D-1-5

GEOMETRICAL ILLUSTRATION OF THE EFFECT OF SUBREFLECTOR ROTATION

APPENDIX D-2

ANTENNA OPTICAL ALIGNMENT

D-2-1 General

The optical alignment of either the focal point feed or the Cassegrain optical system refers to first, the correctness of the geometry of the reflector(s) and second, to the axial and lateral alignment of the feed components (including the horn for both antenna types and the subreflector) relative to the focal axis of the main reflector.

Adjustment of the components for correct optical alignment is usually accomplished by means of adjustment screws which are designed into the antenna system. This is usually a straight forward design problem and will not, therefore, be discussed any further.

The following subsections deal with the various means for checking the optical alignment of the antenna.

D-2-2 Main Reflector Geometry Check

The geometry of the main reflector can be checked either by trigonometry, with the aid of a theodolite (see Figure D-2-1) or by means of a metal template possessing the contour of the reflector. Experience has shown that the template provides the most accurate and reliable check - especially for relatively small reflectors. For instance, the template would provide an ideal means of checking a 10 foot reflector.

D-2-3 Focal Point Feed Antenna Check

Axial alignment would best be checked by means of a calibrated rod representing the exact distance between the feed horn and the vertex of the reflector. (See Figure D-2-1.)

Lateral alignment could be checked by means of a rigid locating tool such as a rod mounted rigidly to the vertex of the main reflector and extending to the aperture of the horn. This tool would also be used to check the axial alignment. Another means would involve the use of a calibrated rod representing the exact distance from the horn to the periphery of the reflector. (See Figure D-2-2.)

A telescope viewing the horn from the vertex of the reflector would present still another lateral alignment method provided the feed tube does not enter the center of the reflector but pierces the reflector at some other point.

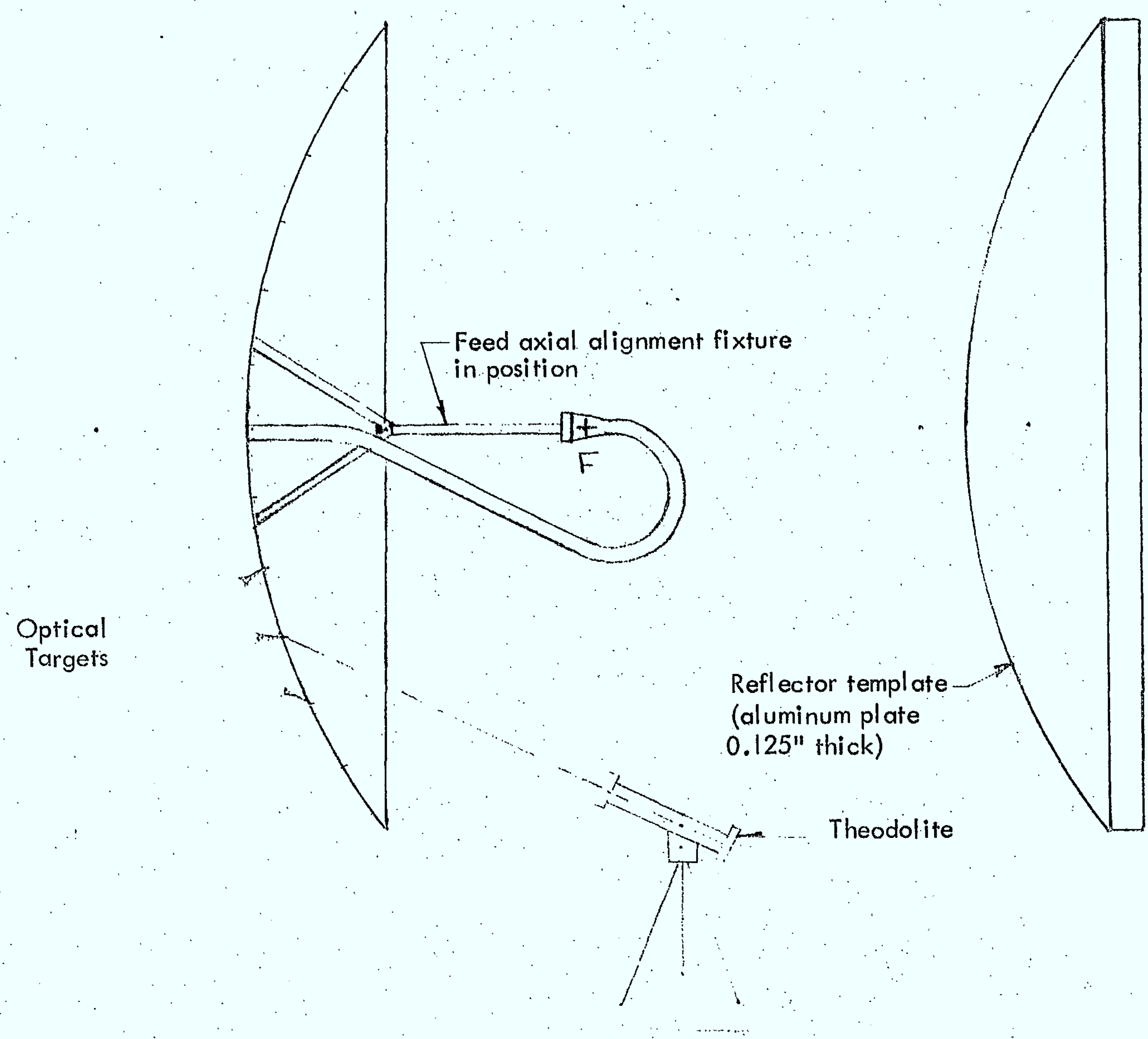


FIGURE D-2-1 - FOCAL POINT FEED ANTENNA

REFLECTOR GEOMETRY CHECK AND AXIAL ALIGNMENT OF THE FEED

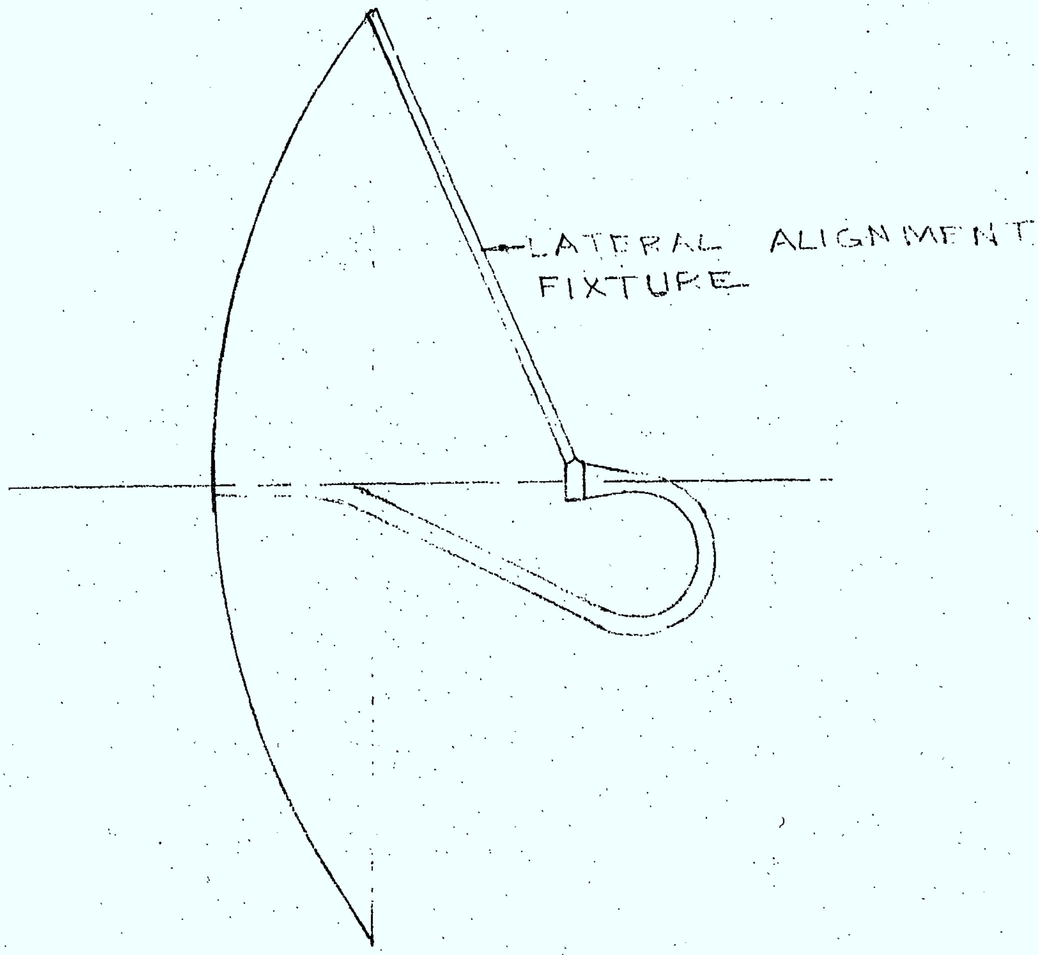


Figure D-2-2 - FOCAL POINT FEED ANTENNA

LATERAL ALIGNMENT OF THE FEED

D-2-4 Cassegrain Antenna Feed Horn Alignment Check

It is expected that the exact axial position of the feed horn would be determined during the development of the antenna and that on the final design the horn would be rigidly mounted and located with dowel pins to eliminate the need for the further alignment.

It is worth mentioning that the exact axial position of the feed horn must be determined experimentally since the exact location of the horn's phase center can be calculated only approximately.

Lateral alignment of the feed horn is unnecessary since the feed horn can be located by means of dowel pins, exactly onto the focal axis of the main reflector. A minor electrical misalignment of the beam in the horn would cause a negli ible shift of the electrical boresight since the Cassegrain antenna is relatively immune to small feed horn translations.

D-2-5 Subreflector - Alignment

Axial Alignment

The subreflector can be best aligned axially by means of a calibrated rod representing the distance between the feed horn and the subreflector. (See Figure D-2-3.) No further consideration should be necessary here.

Lateral and Rotational Alignment

The lateral and rotational alignment of the subreflector can be checked by any of the following three fixtures listed in their order of preference:

i) Laser source at the vertex of the main reflector and a mirror on the vertex of the subreflector. (See Figure D-2-4.)

ii) Autocollimating theodolite mounted through the vertex of the reflector and a mirror mounted on the vertex of the subreflector. (See Figure D-2-5.)

iii) Calibrated rod representing the distance between the edge of the reflector and a marked ring locus at an arbitrary radius on the main reflector. (See Figure D-2-4.)

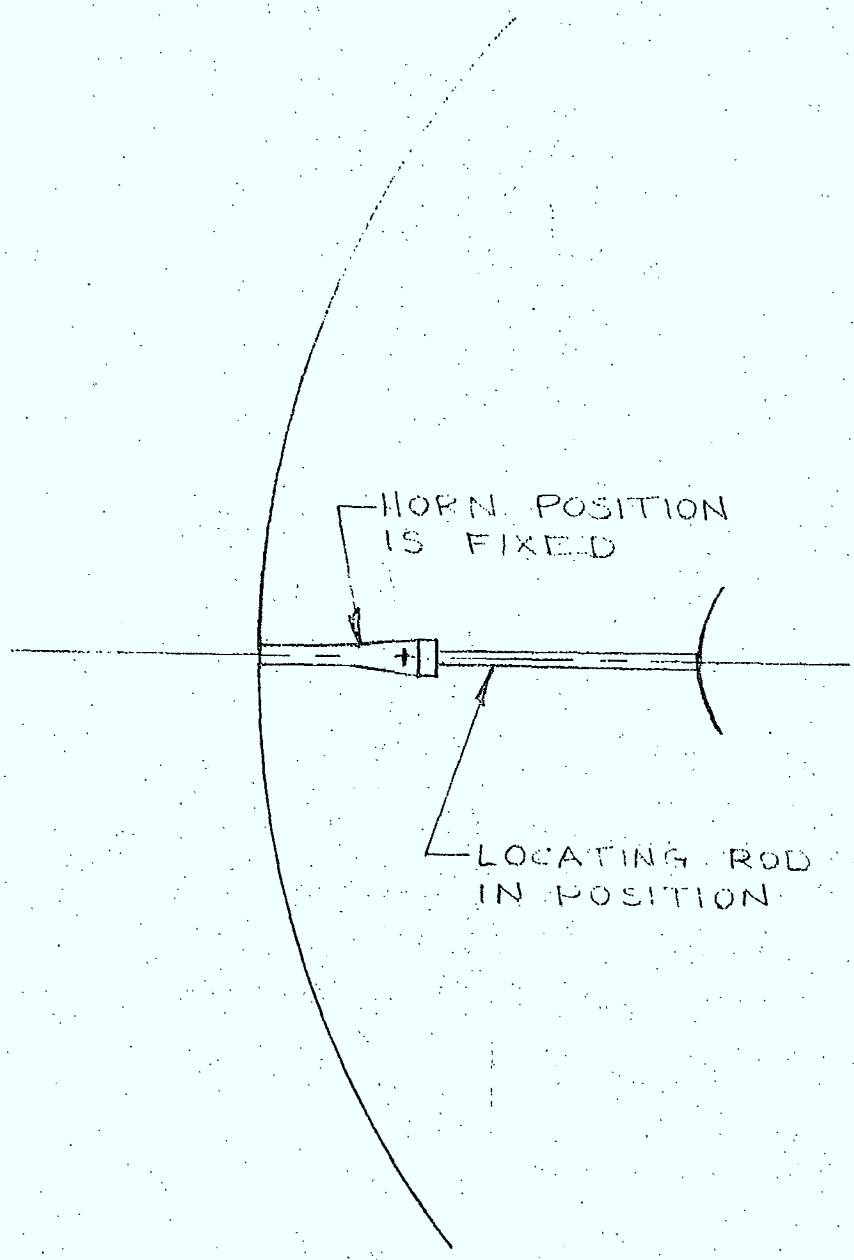


FIGURE D-2-3 - SUBREFLECTOR AXIAL ALIGNMENT BY MEANS OF A CALIBRATED LOCATING ROD

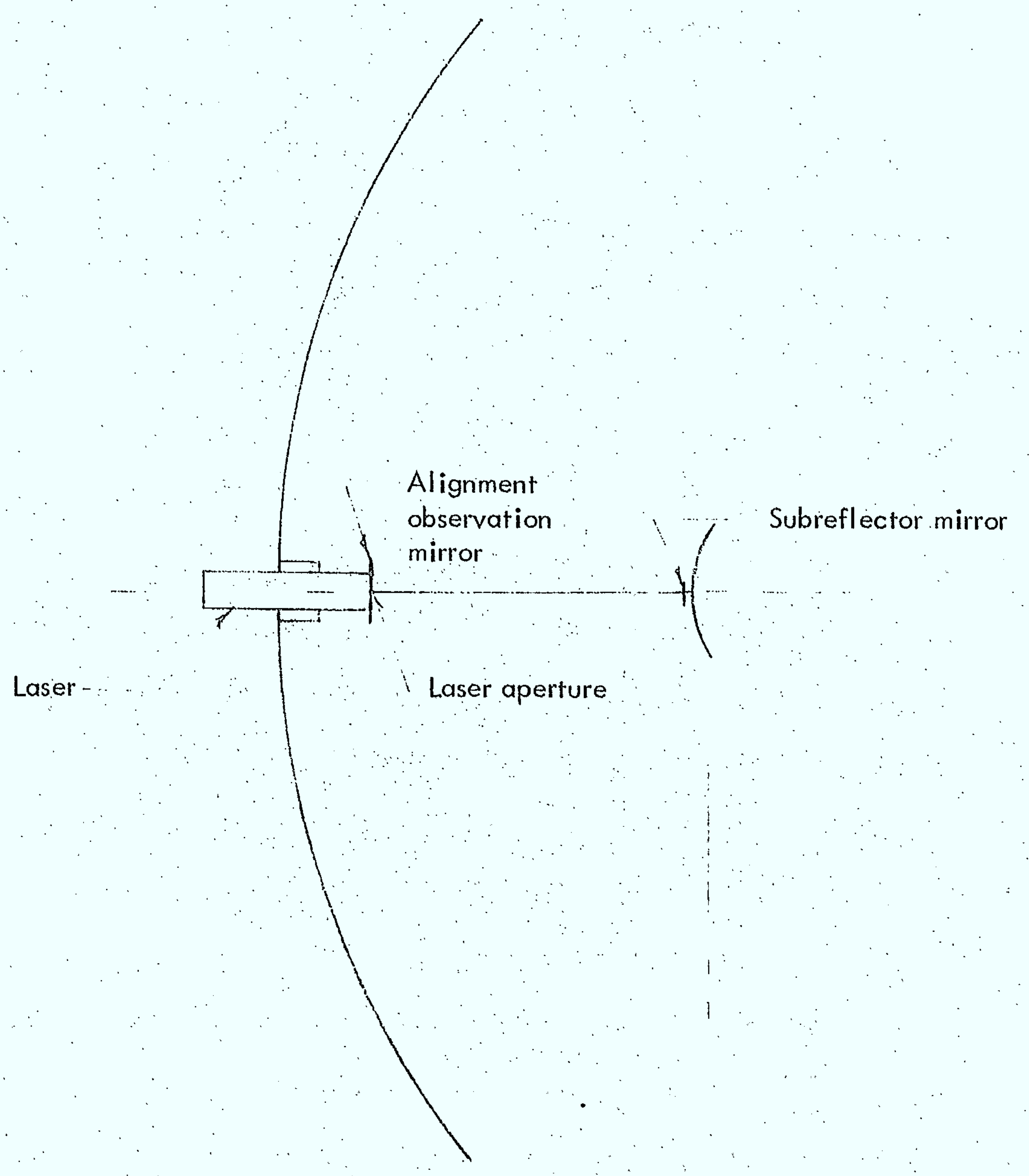


FIGURE D-2-4 SUBREFLECTOR ALIGNMENT BY MEANS OF A LASER SOURCE

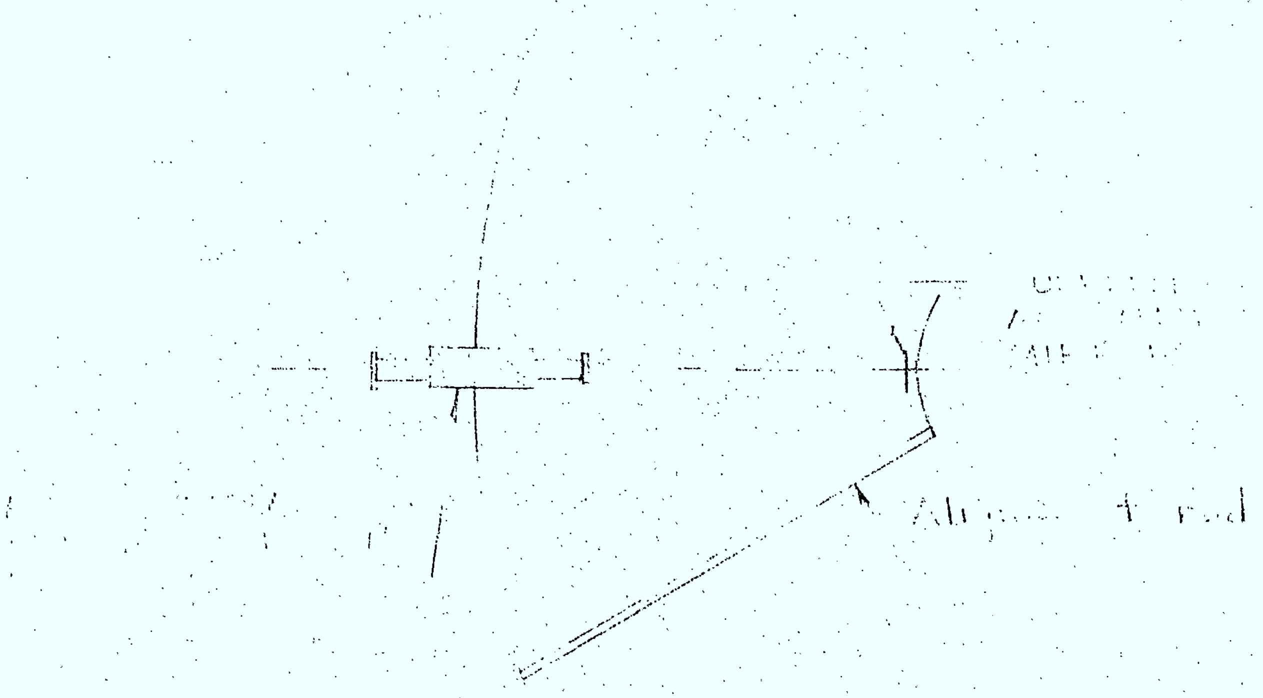


FIGURE D-2-5 - SUBREFLECTOR ALIGNMENT BY MEANS OF AN AUTOCOLLIMATING THEODOLITE OR AN ALIGNMENT ROD

APPENDIX D-3

MONOPULSE TRACKING FEED SYSTEM FOR THE CASSEGRAIN ANTENNA

D-3-1 General

This section provides data and illustrations of an existing RCA 4 - 6 GHz tracking feed system design which could be scaled to operate in the 11 - 15 GHz band. The given data applies to a feed compatible with a 36 diameter reflector in the 4 GHz band. Since the scaling factor would be approximately 3:1, the existing design, scaled, would be compatible with a 10 - 12' diameter antenna operating in the 11 - 15 GHz frequency band.

The feed to be described comprises an integral communications and tracking feed assembly which operates through the same feed horn of the Cassegrain antenna. The overall feed cylinder is shown in Figures D-3-1 and D-3-2.

D-3-2 Description

A simplified schematic diagram of the tracking feed is shown in Figure D-3-3. It can be seen that the feed consists essentially of the following items:

1. Transmit - receive orthogonal coupler
2. Mode coupler
3. Mode filter
4. Monopulse combiner
5. Multimode horn.

Orthogonal Coupler

The orthogonal coupler couples the mutually orthogonal communications transmit and receive signals into the circular line which connects to the mode coupler at the aperture of the horn.

Mode Coupler

The mode coupler contains one large central aperture symmetrically surrounded by eight small apertures. The central aperture carries the communications and tracking sum mode signals. The eight smaller apertures, by correct phasing, serve to synthesize the difference mode tracking patterns. The mode coupler thus serves to launch the composite communication and tracking waveform into the throat of the horn. The mode coupler is shown in Figure D-3-4.

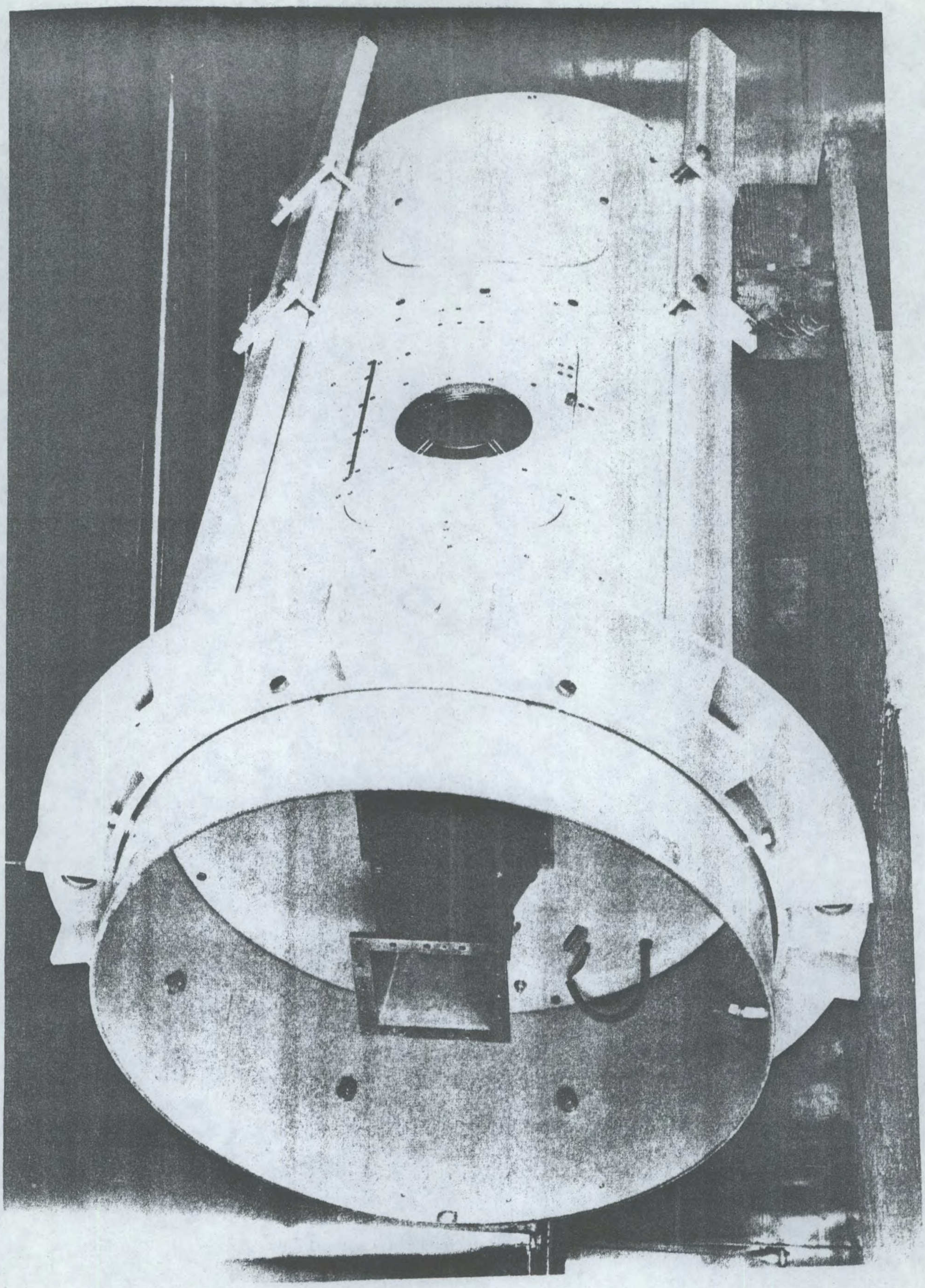


FIGURE D-3-1 - OUTPUT OF THE FEED CYLINDER

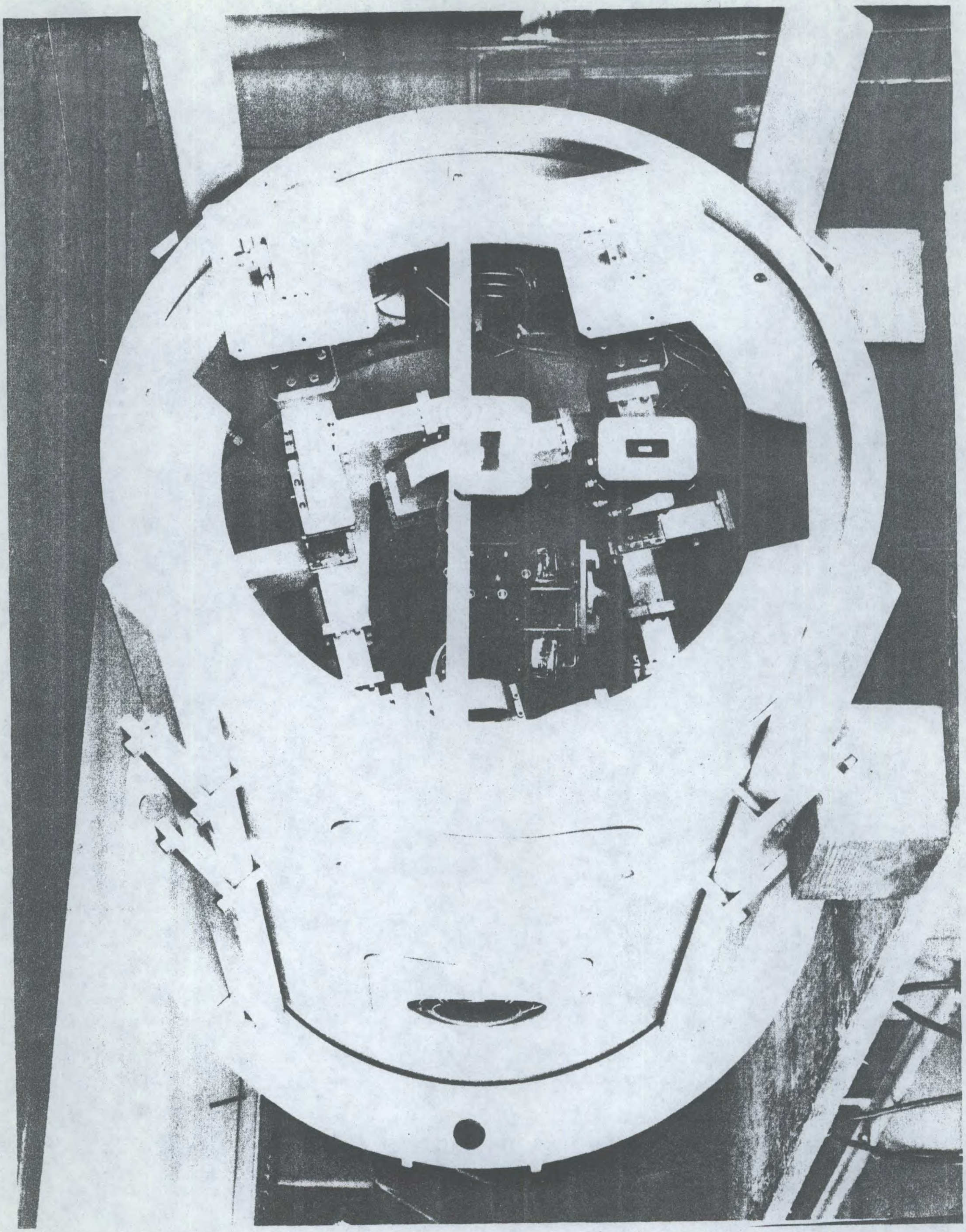


FIGURE D-3-2 - INPUT OF THE FEED CYLINDER

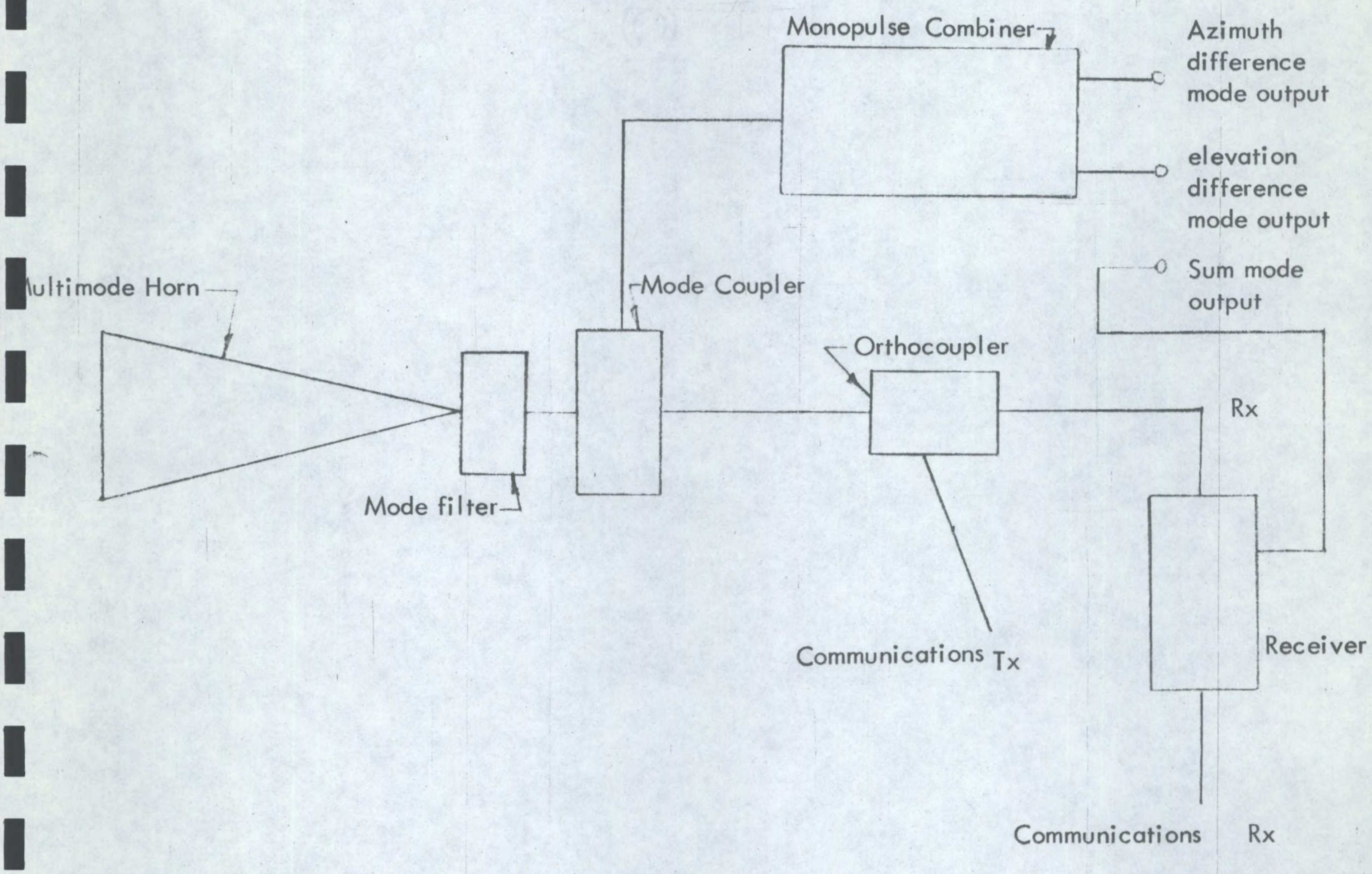


FIGURE D-3-3 - TRACKING FEED SYSTEM SCHEMATIC DIAGRAM

Mode Filter

The mode filter, located between the throat of the horn and the mode coupler serves to filter out any incidental unwanted higher order modes. (See Figure D-3-5.)

Monopulse Combiner

The monopulse combiner provides the interface between the difference mode tracking signal outputs (2 outputs for azimuth and elevation tracking) and the eight ports of the mode coupler. It phases the eight ports of the mode coupler to provide right hand circularly polarized difference mode patterns in the two orthogonal azimuth and elevation planes. The monopulse combiner can be seen in Figure D-3-6.

Multimode Horn

The multimode horn carries and phases the sum and difference waveguide modes, generated by the mode coupler, to its aperture where the phasing is such that it provides the optimum radiation patterns for both communications and tracking. The multimode horn can be seen in Figure D-3-7.

It is worth mentioning that the communications portion of the feed can be modified to include circular or orientatable linear polarization by including an additional assembly between the orthocoupler and the mode coupler.

D-3-3 Monopulse Combiner (Difference Mode Circuit)

The difference mode circuit (Figure D-3-5) connects the 8 element array described previously to the D1 and D2 difference mode output terminals. The 8 element array is coupled to the throat of the multimode horn (through the mode filter) by means of the mode coupler in such a way that it produces two orthogonal difference modes with right circular polarization in the aperture of the horn. The block diagram exhibiting the layout of the circuit is shown in Figure D-3-8. The same figure indicates the polarization and phase relationships between the D1 and D2 terminals and the array apertures of the difference mode circuit.

The receiving end section of the difference mode circuit consists of two Magic-Tee hybrids, two short slot hybrids, plus various bends and waveguide sections. The isolation of the Magic-Tee hybrids between E and H plane arms is better than 50 dB and their reflection coefficients are better than 30 dB when the other terminals are perfectly matched. The reflection coefficient of the short slot hybrids is better than 30 dB, and the power unbalance is better than +0.1 dB between output ports, when these ports are terminated perfectly. The

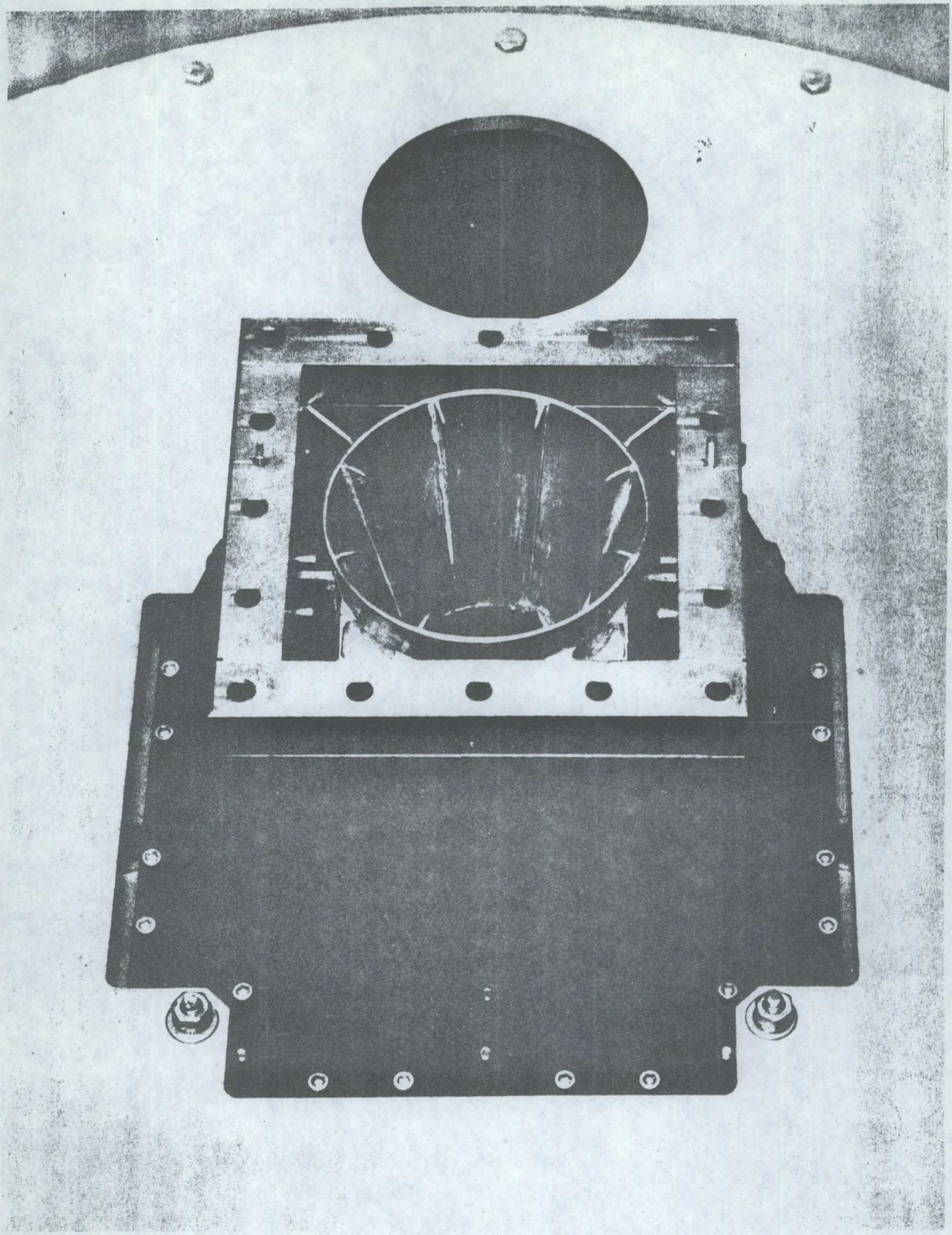


FIGURE D-3-4 - MODE COUPLER ASSEMBLY

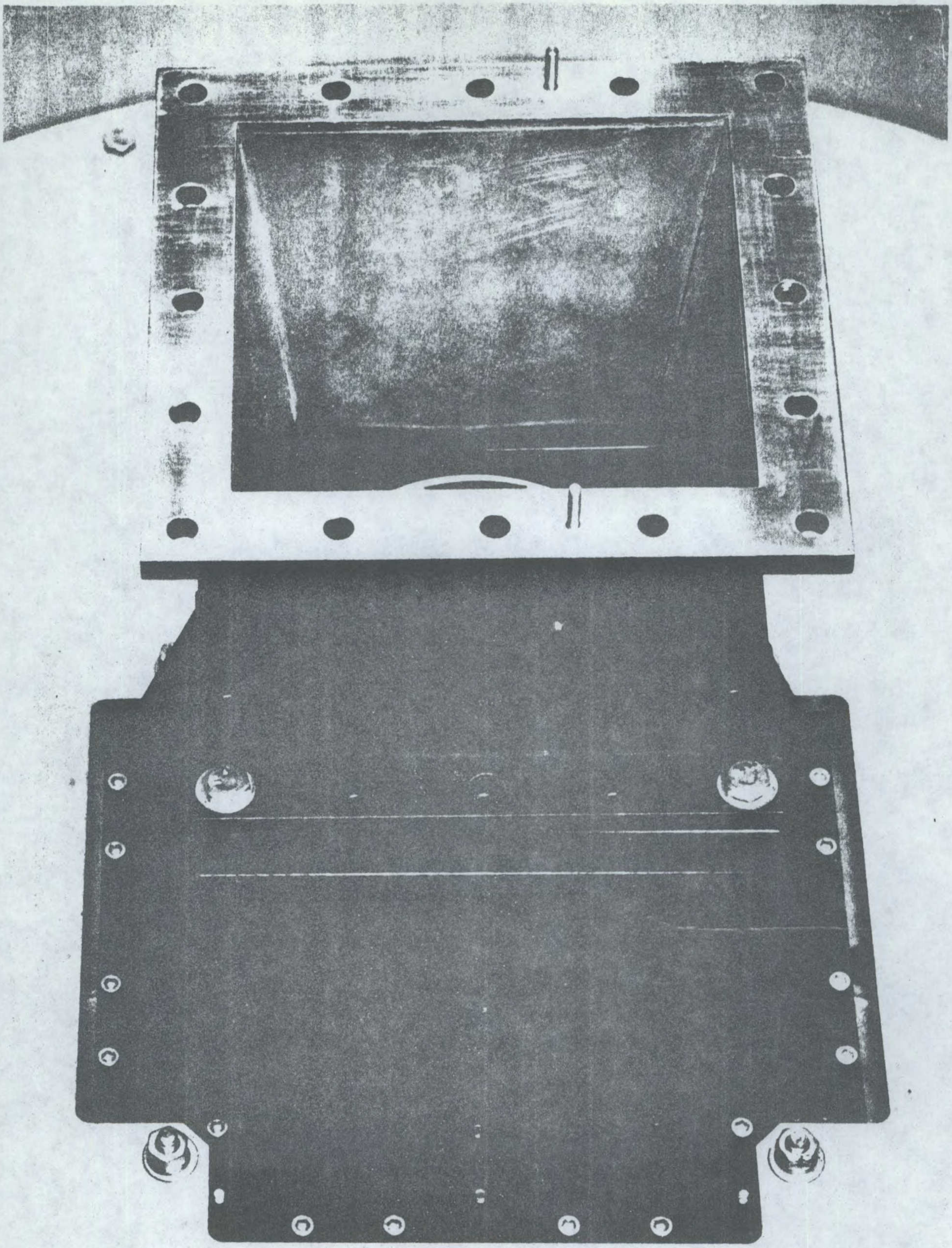


FIGURE D-3-5 - MODE FILTER CONNECTED TO THE MODE COUPLER

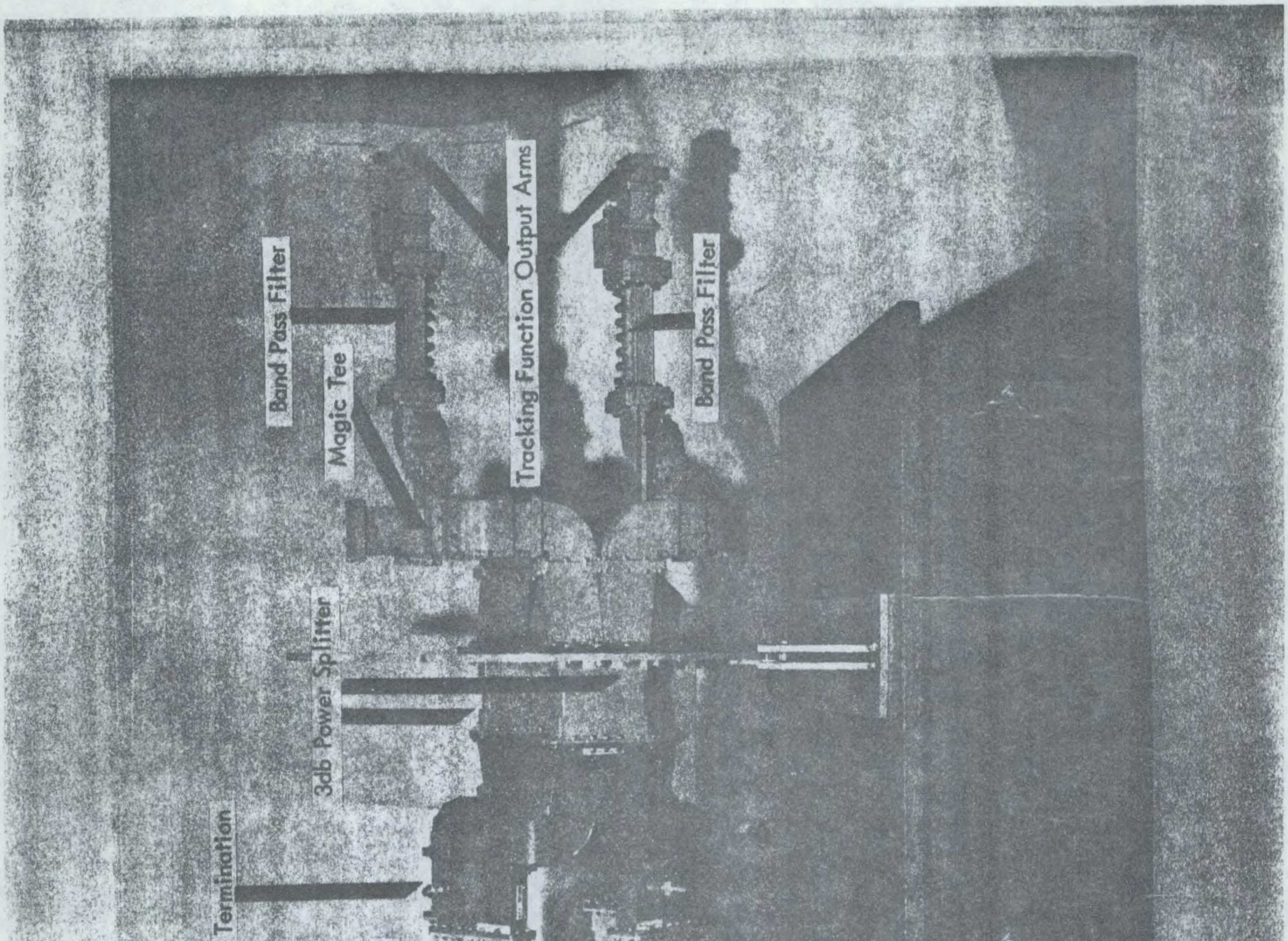


FIGURE D-3-6 - MONOPULSE COMBINER
(DIFFERENCE MODE CIRCUIT)

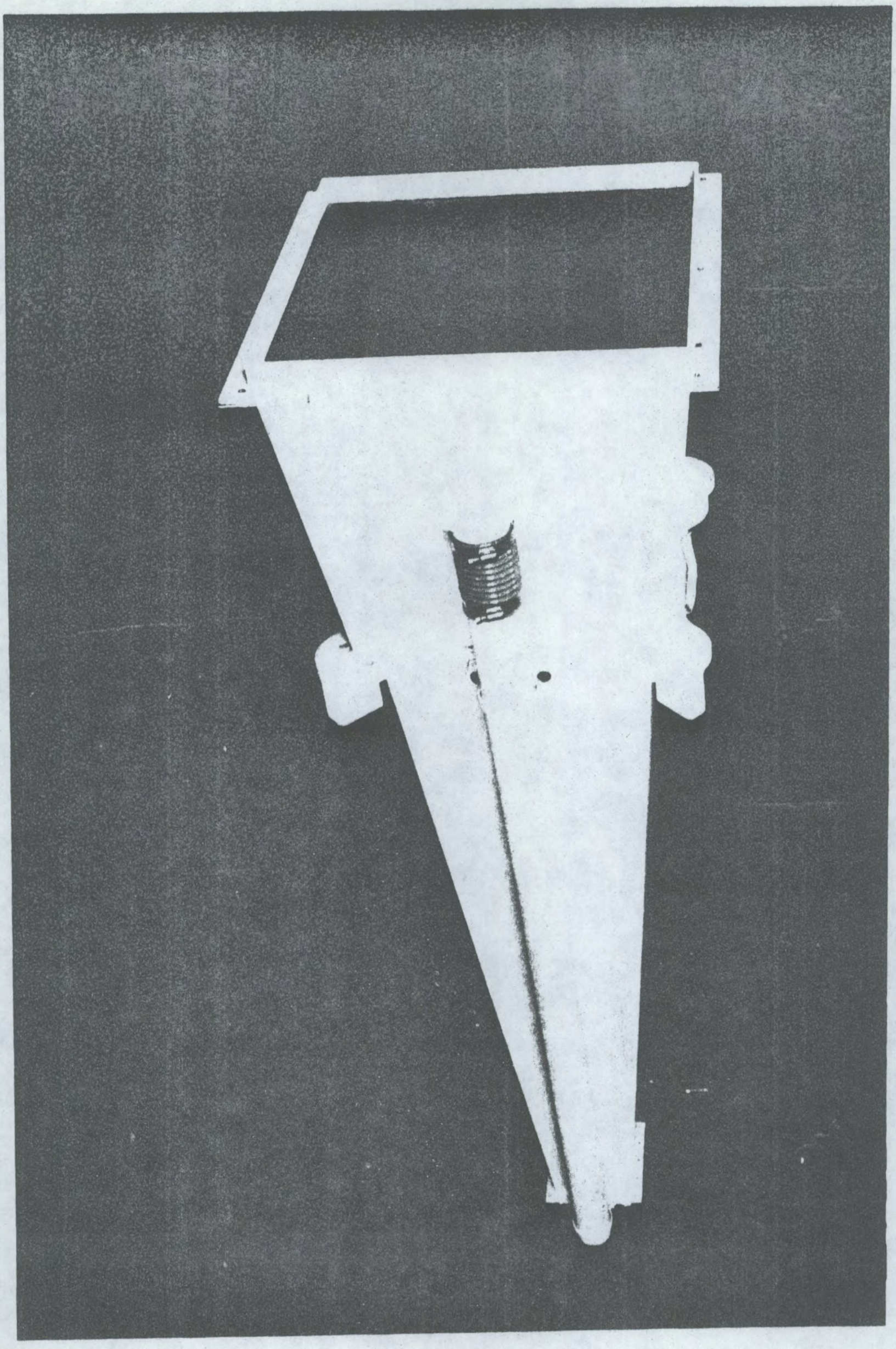
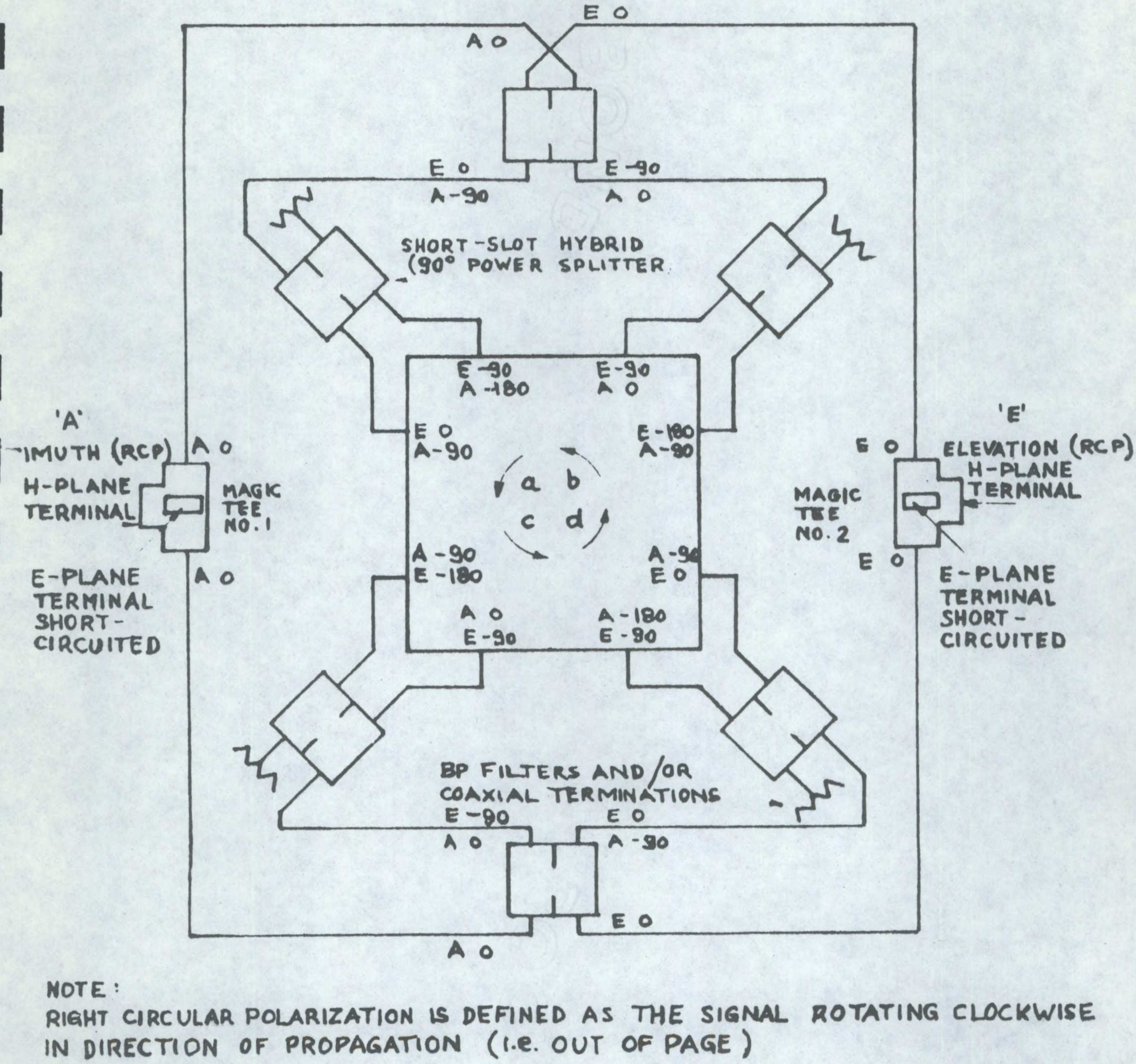


FIGURE D-3-7 - MULTIMODE HORN



NOTE:
RIGHT CIRCULAR POLARIZATION IS DEFINED AS THE SIGNAL ROTATING CLOCKWISE IN DIRECTION OF PROPAGATION (i.e. OUT OF PAGE)

FIGURE D-3-8
BLOCK DIAGRAM AND PHASE RELATIONSHIP IN THE DIFFERENCE MODE CIRCUIT

reflection coefficient of waveguide bends and offset waveguide sections is better than 40 dB. The output signal at the unused (E-plane) ports of the Magic-Tees is more than 37 dB down when the four output terminals of this assembly are simultaneously short circuited. The D_1 and D_2 ports of this assembly are connected to a circulator and a bandpass filter. The circulator provides more than 26 dB isolation between the difference channel downconverters and the Magic-Tee terminals at the expense of approximately 0.15 dB loss. The bandpass filters provide 60 dB minimum rejection against transmit band signals at the expense of approximately 0.06 dB passband loss.

The antenna end of the difference mode circuit consists of four short-slot hybrids, electroformed waveguide bends, and a waveguide assembly with eight arms, referred to as the "octupus". The fourth (unused) port of the short-slot hybrid are connect ed to waveguide-to-coax transitions. These transitions are terminated by coaxial loads.

The assembly shown in Figure D-3-6 may be called the difference mode array, capable of producing linearly polarized difference mode signals, into an eight-waveguide aperture difference mode array capable of producing circular polarization. The "octupus" is inserted for the purpose of bringing the eight-element array into a square shaped ring configuration.

Mode Coupler, Mode Filter and Horn

The mode coupler (see Figure D-3-9) is a 10 port device. It has a circular waveguide port for connecting the three-port polarizer end of the communication channel and eight waveguide ports connecting the difference mode circuit assembly. Finally, it has a single square waveguide terminal toward the mode filter where the communication (sum) and tracking (difference) mode signals are all combined into a single aperture. The mode coupler has various transitions and matching elements between the ports, and is built with a high degree of symmetry in order to assure impedance match and low level of cross coupling for the individual terminals. The reflection coefficient into the conical transition of the communication port is 21 dB and 20 dB in the receive and transmit bands respectively. The eight difference channel terminals support four separate 0.905 inch thick pressurizing windows.

A mechanically simple, but important element is placed between the square horn and the mode coupler. This element is called the mode filter and it serves as a filtering and phasing element between various waveguide modes at the throat of the horn. The unit has an oversized square waveguide cross-section and its width varies along the direction of propogation. The dimensions dimensions of this unit are selected in such a manner that only the desired higher order sum and difference modes can propogate through this section and the amplitude and phase relationship between these wanted modes assures low side lobes in the primary pattern, and leaves the axial ratio of the circularly polarized difference modes unchanged. The output cross-section of the mode filter is large enough that onl y a small amount of additional differential phase shift takes place between the sum modes in the multi-

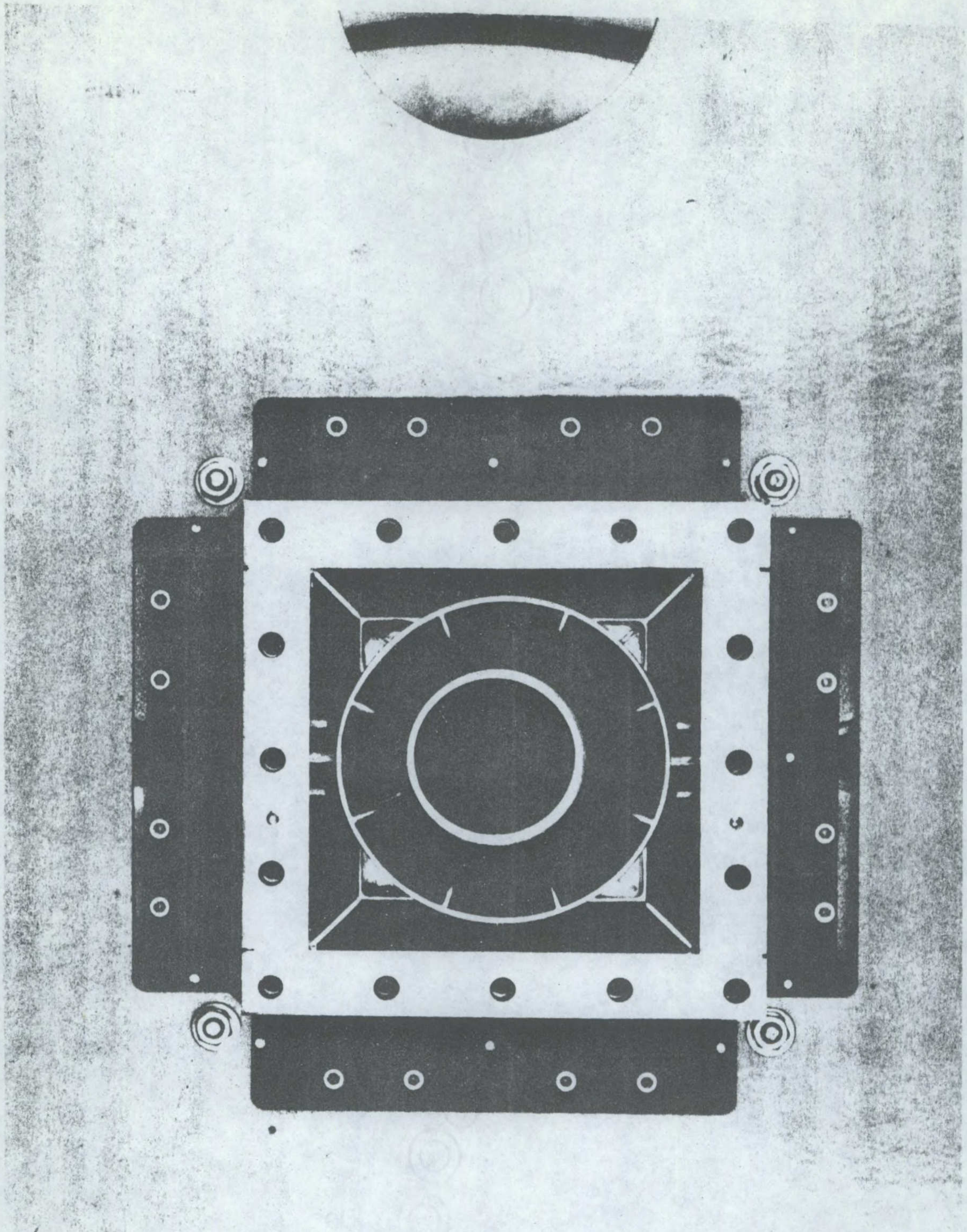


FIGURE D-3-9

DIFFERENCE MODE POLARIZER AND MODE COUPLER ASSEMBLY

APPENDIX D-4

ANTENNA PATTERN BETWEEN HALF-POWER POINTS

The gain pattern between the 3 dB down points diameter cassegrainian type antenna at 14 GHz has been plotted in Figure D-4-1. A nominal antenna efficiency of 55% has been assumed.

The effective antenna loss due to pointing errors may be obtained directly off this figure. Thus, in order to maintain the loss gain to 0.5 dB or less, the pointing errors must be held within $\pm$ 0.1°. This is the peak value for pointing error assumed for the mobile terminal.

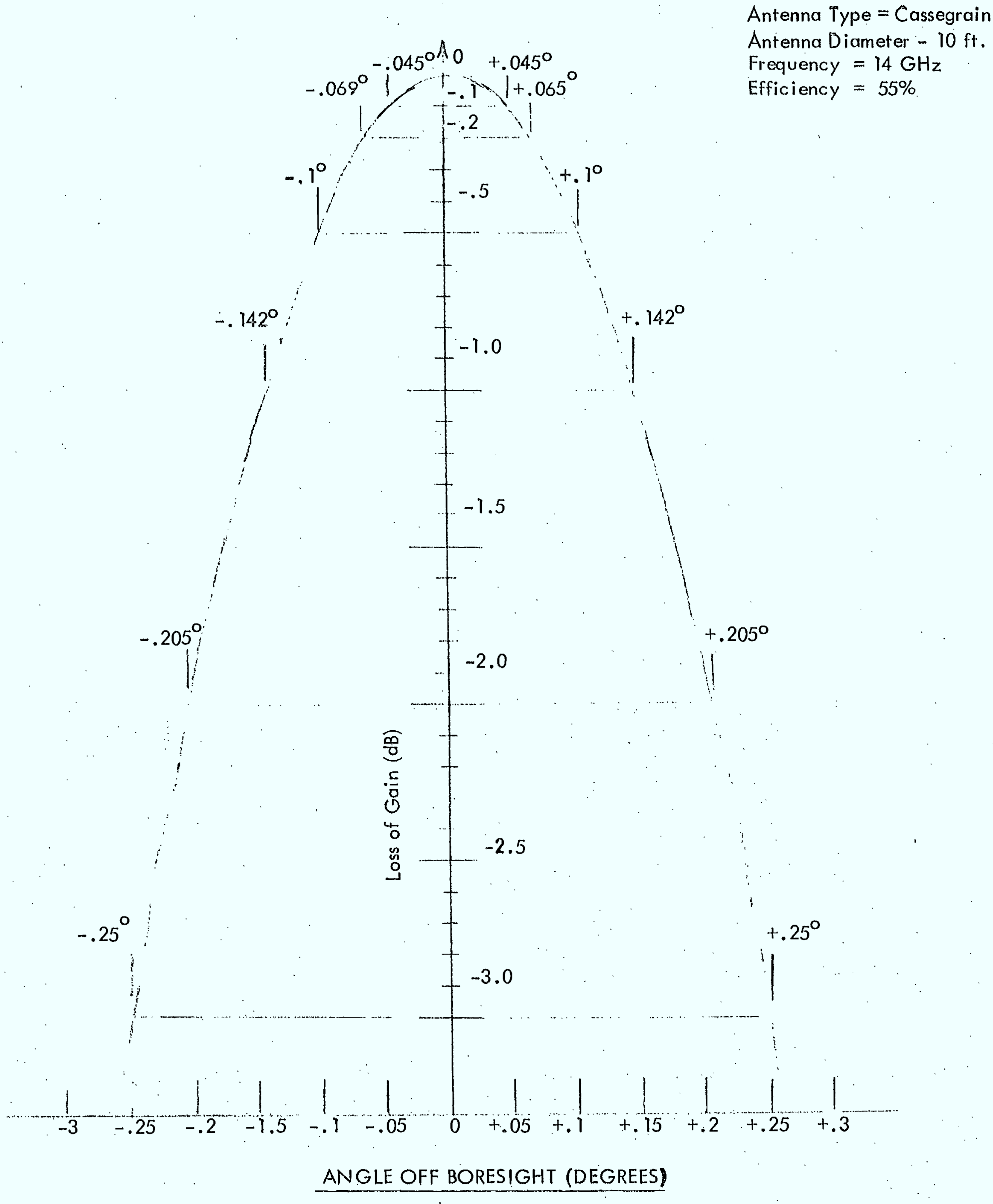


FIGURE D4-1

LOSS OF ANTENNA GAIN WHEN POINTING OFF BORESIGHT

APPENDIX E - 1

COMMENTS ON SIMPLIFIED GROUND STATION ANTENNA ACQUISITION OF COMMUNICATIONS TECHNOLOGICAL SATELLITE

E-1-1 General

In order to acquire the satellite with a ground station antenna, it is required to determine the required pointing angles in elevation and azimuth and to sweep the frequency band until the present carrier-to-noise ratio threshold is received at which point the receiver should lock on.

Coordinates of the station are used with a table to determine the required pointing angles. The major problem is to obtain a true north reference for azimuth. The north magnetic pole is located approximately in the center of the Canadian North at about latitude 75°N longitude 90°W, so that a magnetic compass reading may be subject to considerable error. Celestial navigation using the sun or the stars is possible but there will be periods when this is not possible. For the mobile terminal this means the magnetic compass may have to be used; this can be coupled with use of known land marks to obtain a better orientation.

It is assumed that a motor driven antenna positioner is provided for the antenna. The permissible drive rate is governed by the search bandwidth and the frequency scanning rate. A search bandwidth of 3 MHz is assumed. This should be greater than any shift in tuning frequency. In general, the signal should be acquired when the carrier-to-noise figure exceeds an adjustable threshold for larger than the reciprocal of the signal bandwidth, which we will assume to be 15 KHz. To provide a safety factor this period will be made 10 times larger so that scanning timer per sweep should be at least 10/75 seconds. For scanning purposes, the drive actuators will be controlled to provide 1°. This speed is sweeping through one antenna beamwidth, with provision made for incremental steps of fractions of a beamwidth.

E-1-2 Probable Errors in Pointing

Ground station coordinates must be known accurately to determine the pointing angles. At northern latitudes the longitudinal meridans are close together so that a probable maximum error of ±5 degrees is assumed. Latitude is easier to determine and an error of ±2 degrees is assumed. Table E-1-1 shows typical azimuth and elevation angles for latitude and longitude coordinates.

The maximum effect of an error of ±5° in longitude in determining elevation angle is about ±1° at northern latitudes if we assume maximum relative longitude = 40°.

TABLE E-1-1

POINTING ANGLES FOR GROUND STATION ANTENNA

	LATITUDE									
	40°		50°		60°		70°		80°	
LONGITUDE	Elev.	Azim.	Elev.	Azim.	Elev.	Azim.	Elev.	Azim.	Elev.	Azim.
0°	44	0	32.6	0	22	6	11.5	0	1.2	0
10°	41	15.5	31.8	13	21	11.5	10.5	10.5	.5	10
20°	39.2	29.5	29.5	25.5	20	22.9	10	21	-	-
30°	34.5	42	26	32	17.5	33.5	8.5	31.5	-	-
40°	28	52.5	21.3	47.5	14	44	6.5	42	-	-
50°	21.3	61.5	16	57.5	10	54	4	51.5	-	-
60°	14	69.5	10	66	5.7	63.5	1	61.5	-	-
70°	6.5	78	4	74.5	1	72.5	-	-	-	-
80°	-	-	-	-	-	-	-	-	-	-

VALUES ARE IN DEGREE
LONGITUDES ARE RELATIVE TO SATELLITE TO EARTH LINE

E-1-2 Probable Errors in Pointing (Continued....

(The longitude spread across northern Canada is approximately 80°).

The effect of an error of $\pm 2^\circ$ in latitude in determining elevation angle is a maximum at zero relative longitude and is approximately $\pm 2^\circ$ maximum.

The effect of an error of $\pm 5^\circ$ in longitude in determining azimuth angle is about $\pm 7.5^\circ$ maximum and a $\pm 2^\circ$ error in latitude is about $\pm .4^\circ$ maximum.

It should be possible to set the elevation angle with a measuring accuracy of better than 1 degree using the level and elevation scale. The maximum combined elevation error should be $\pm 4^\circ$ and the maximum combined error in azimuth should be 38°, if we assume a maximum probable error of 30° in determining the reference angle for true north.

There is a possible change in antenna angle on a daily basis if the satellite orbit is not coincident with the earth's equatorial plane. This variation can be corrected for, based on the time of day and a chart for different coordination.

E-1-3 Probable Acquisition Time for Portable Station

As has been noted, there are several variables which must be correctly set in order to acquire the satellite. In this analysis only the probability of correctly pointing at the satellite is considered.

For simplicity, it is assumed that the antenna axis about which azimuth is swept, the third axis, has been set with sufficient accuracy that it does not affect probable azimuth or elevation errors. It is also assumed that possible variations in satellite position due to misalignment of the satellite's orbit are correctly accounted for.

In attempting to predict acquisition times two different antenna search patterns are compared. The patterns are rectangular rather than elliptical, to simplify the search procedure.

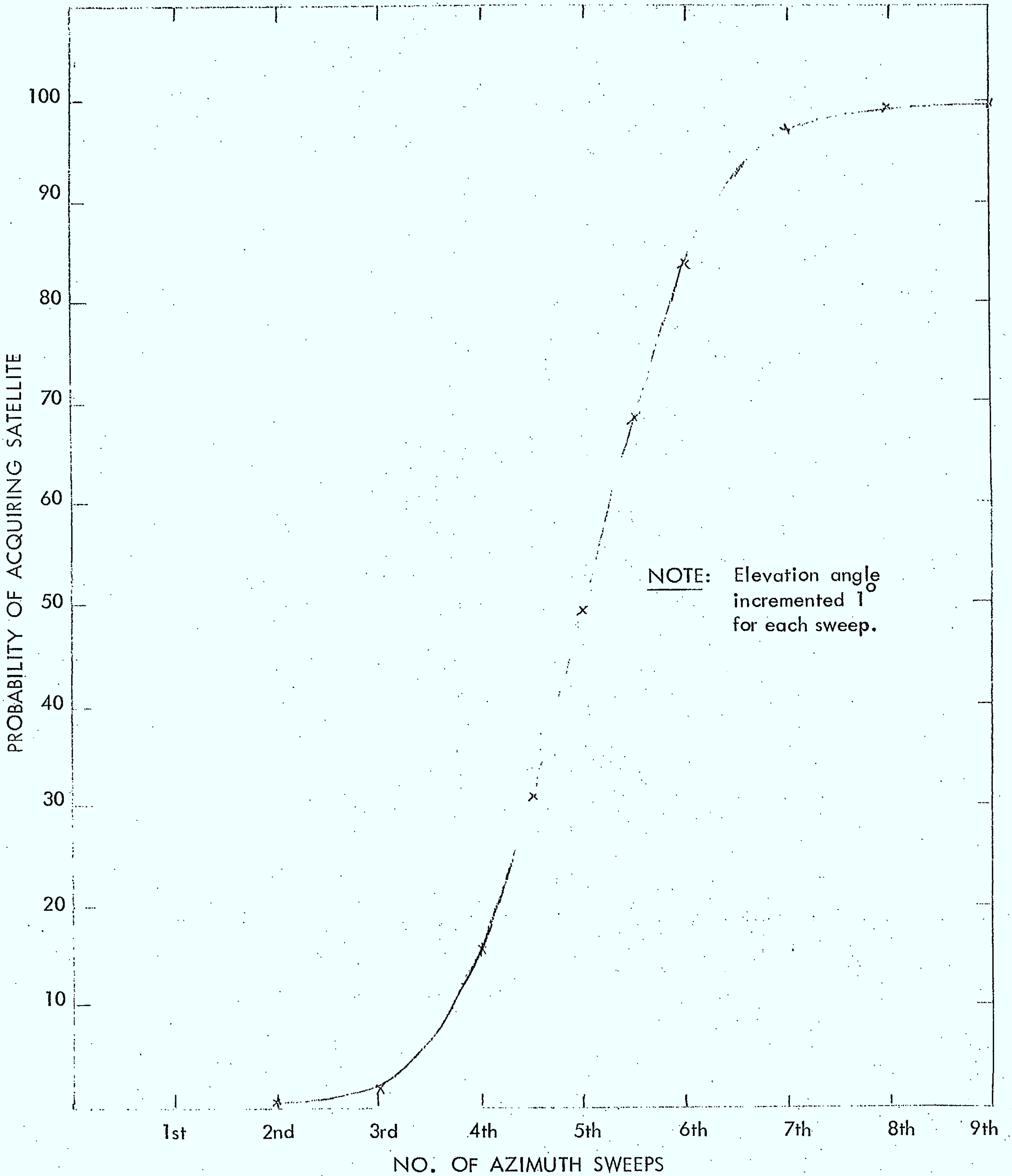
For this analysis the search rectangle* determined of $\pm 38^\circ$ in azimuth and $\pm 4\ 1/2^\circ$ in elevation about the predicted pointing is assumed. It is assumed that the antenna coverages is a 1 degree square for simplicity and the necessary corrections can be made for different antenna diameters.**

Figure E-1-1 shows the probability of acquisition based on a normal probability distribution and a search pattern which starts at the predicted elevation angle plus or minus 4 degrees and scans between predicted azimuth angle limits of ± 38 degrees, in elevation steps of 1 degree.

---

*In practice a parallelogram search pattern results due to the tracking axis angle (see Fig. B-7).

**For a 10 foot dish the typical beamwidth is 0.6°, 3dB down. To extrapolate for this size, the scanning times should be approximately twice as long per sweep or approximately 4 times as long overall.



ACQUISITION PROBABILITY - SEARCH START 4° OFF PREDICTED ELEVATION

FIGURE E1-1

E-1-3 Probable Acquisition Time for Portable Station (Continued....

Each 1 degree step is considered equal to the standard deviation for elevation errors and each 76 degree azimuth sweep is considered equal to the 3 sigma error.

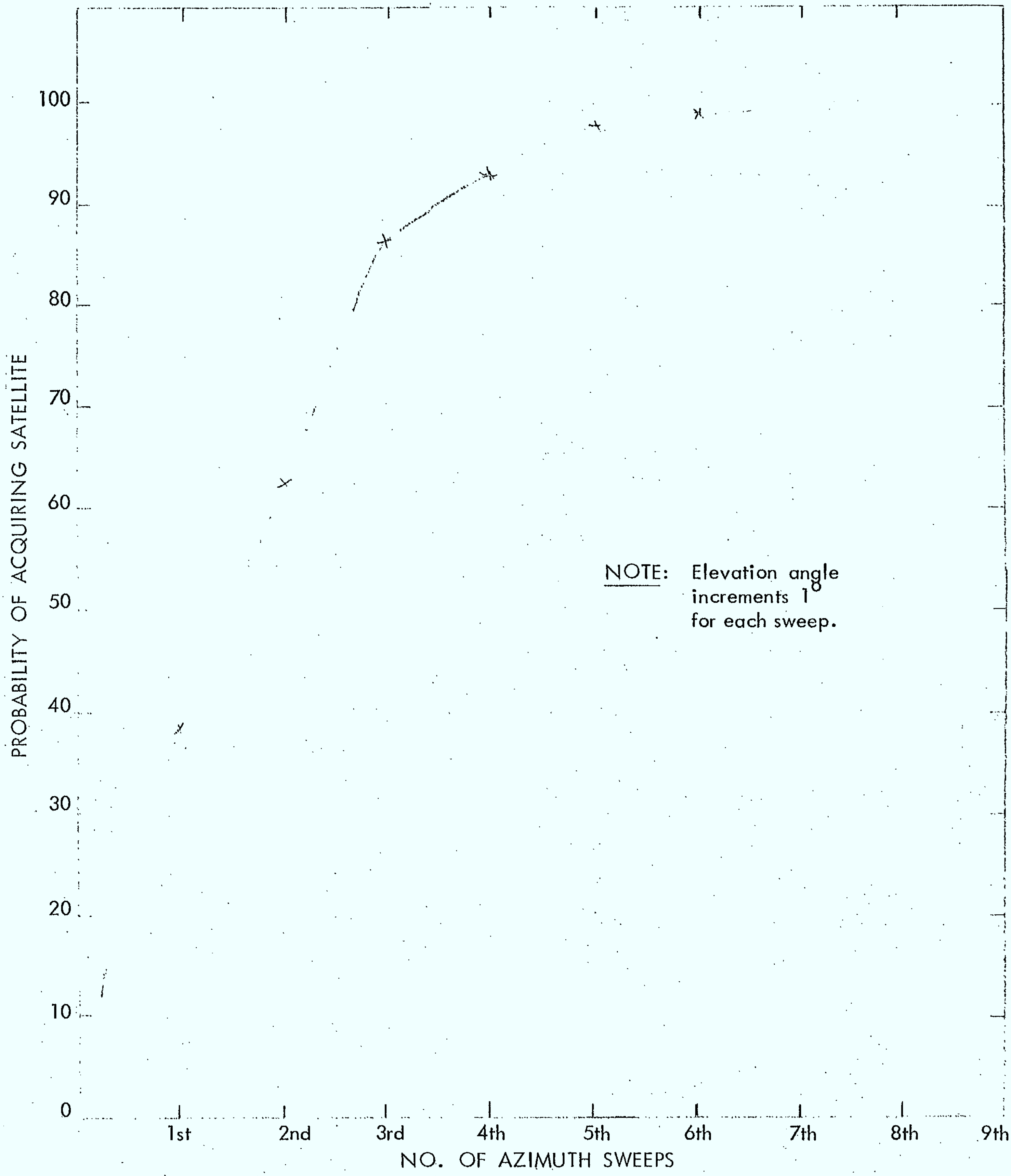
The probability of acquisition on any successive sweep is cumulative and is determined by summing the integrated areas under the normal distribution curves, with 50% probability of acquisition on the 5th of the 9 sweeps.

Figure E-1-2 is based on the same assumption but the scanning sequence starts at the predicted elevation followed by sweeps at 1 degree, 2 degrees, 3 degrees and 4 degrees on either side of this angle. This method has a much higher degree of probability of early acquisition, but is slightly more difficult to perform.

The maximum times for acquisitions would be approximately the same and equal to (9x38) + (8x5) = 382 seconds where 5 seconds has been allowed for each elevation step. The first method has an 84% probability of acquisition within 6 sweeps, or 253 seconds. The second method has an 86% probability within 3 sweeps, or 124 seconds.*

These times are relative and order of magnitude only. They are representative of acquisition time for the smaller stations. Errors due to frequency drift or signal fade could result in a significantly larger acquisition period if these factors are not considered in the receiver design.

*For a 10' dish, the typical beamwidth is 0.6°, 3dB down. To extrapolate for this size, the scanning times should be approximately twice as long per sweep or approximately 4 times as long overall.



ACQUISITION PROBABILITY - SEARCH START AT PREDICTED ELEVATION ANGLE

FIGURE E1-1

APPENDIX E - 2

ANTENNA TRACKING CONSIDERATIONS FOR CTS GROUND TERMINALS

E-2-1 General

After the satellite has been acquired by the ground station antenna there is still a probable daily change in relative angle should the satellite orbit not be coplanar with the earth's equatorial plane. The apparent axis of this movement will vary and for most stations corrections to azimuth and elevation angle are necessary of up to 2 degrees. There is also a tolerance on station keeping of the satellite of ±0.2 degrees.

It is possible to adjust the third axis (the axis about which antenna is rotated in azimuth) to make it parallel to the earth's spin axis such that it is possible to follow satellite daily movement by changes in elevation only.

The small audio broadcast receive stations with 2-foot dishes should not require tracking. Their beamwidth is approximately 3 degrees at 12 GHz, 3 dB down.

The portable two-way voice stations may not require tracking, depending on their duty cycles. Their beamwidth is sufficiently wide that they should not require re-adjustment during a normal transmission period.

Programmed tracking could be considered for the television receive stations and for the Instrument Station. To simplify the hardware it would be advantageous to adjust the third axis so that changes in elevation only are required and variations in amplitude for different station locations could be easily made. It would be required to synchronize the tracking with a clock and probably to resynchronize it occasionally.

Automatic tracking provides the ability to search for a signal in azimuth and elevation and to follow the movement of the satellite actively with motor drives.

The mobile station will be moved regularly and with its narrow beam of .6 degrees for a 10 foot antenna, acquisition using manual search could be a problem. This station should have manual tracking capability as a back-up.

Automatic tracking is clearly required for the 30 foot antenna of the Ottawa Control Station which is too big to consider manual control. Its beamwidth of approximately $.15^{o}$ at 14 GHz would make programmed tracking difficult because it is narrower than the tolerance on the satellite station keeping of $\pm 0.2^{o}$ in the east-west direction.

E-2-2 Summary of Acquisition and Tracking Requirements

Station	Antenna Diameter	Acquisition Method	Tracking Method
Audio Receive	2'	Manual	Not required
Portable two-way voice	4'	Manual	Manual
Television Receive	8'	Manual	Programmed
Instrument Station	8'	Manual	Programmed
Mobile Unit	10'	Automatic & Manual	Automatic & Manual
Control Station	30'	Automatic	Automatic

APPENDIX F-1

COMPARISON OF CHASSIS TYPES

F-1-1 General

The chassis for the trailer to house the mobile terminal can be selected from a wide selection of configurations. A comparison is made of the more common ones used by Military, Commercial and Domestic type trailers.

F-1-2 Military

Military trailers are designed to meet various classes of mobility, such as are defined in MIL-M-8090. Generally a high degree of mobility for off the road use is required so that trailers are rugged but no necessarily very suitable for highway use.*

To permit easy manoeuvering of the trailer, by a variety of vehicles or by soldiers, the trailers usually have front and rear axles, either or both of which are steerable through the steering tongue and towbar which is fitted with a lunette eye (large ring). The lunette eye is easily coupled and uncoupled to the two vehicle and can be used with a variety of hooks or chains, if required, and none of the trailer weight is carried by the towing vehicle.

Tracking correctly behind the tow vehicle may be poor because the pivot points for the vehicles turn radii may not be coincident. For high speed towing, wheel shimmying, tire scrub and fish tailing may be a problem.

Ackerman type steering, similar to that used on an automobile is normally employed, so that in going around a curve the front wheels turn through the correct angles, so that the pivot point for a turn radius locates on a line through the rear axle. For improved tracking some trailers have both front and back steering axles. This shifts the pivot point for a turn radius to be on the line which right bisects the centre line of the trailer, between the two axles, but this point may still not be coincided with the pivot point of the tow vehicles.

A military type chassis might be suitable for the CTS trailer provided that the correct mobility class is selected, however the cost of running gear which has been qualified is relatively high and not considered justified for this application.

---

* For highway use, commercial type semi-trailers are sometimes used.

F-1-3 Commercial

Semi-trailers with single or tandem axles at the rear are the most common trailers used commercially. There are many specialized variants including tandem trailer combinations. The trailers couple to a specialized truck (tractor) through a massive coupling plate.

The combination of vehicles is highly manoeuverable; ease in backing up is particularly important, and because a high percentage of the trailer weight is carried by the back axle of the tractor, its traction is good.

It would be possible to adapt a commercial trailer for this application, which would be air transportable in a Hercules but it would not be feasible to adapt the chassis and running gear to the modular trailer concept because of the limited permissible weight.

F-1-4 Domestic

These also are usually semi-trailers, but the single or tandem axle is located so that only 10 to 15 percent of the trailer weight is carried by the towing vehicle, which may be an automobile or light truck.

The chassis configuration is very suitable for highway operation and with the correct hitch provides a good road handling vehicle. A semi-trailer is not subjected to the same torsional loading when going over uneven terrain as is a front and rear axled trailer. The towbar and hitch method are considered to be better than that of the typical military trailer for highway use and the tandem axle running gear could easily be adapted to modular trailer concept, where it is important to be able to load the running gear and frame on one pallet.

APPENDIX F-2

SUSPENSIONS

F-2-1 General

Only the more common suspension methods are analyzed. These can be divided into independent, non-independent, and walking-beam which is a form of independent suspension. Each of the above is generally available with different methods of springing and shock-absorbing, or damping.

F-2-2 Independent Suspensions

The chief advantage is the good ride provided over uneven roads because each wheel can travel up and down without affect on its opposite wheel. The unsprung weight, which is an important factor in its effect on bottoming forces, is considerably less because of the absence of the beam axle. It is possible to adjust the centre of roll to an optimum position to improve roadability on curves.

For a steerable axle it is important to maintain the correct camber and caster. These factors affect shimmy, scrub and steering effort. With an independent suspension they can be better controlled, because of a parallelogram type of linkage can be used so that their up and down motion (of the wheels) is essentially in the same plane.

"A arms" are the commonest suspension method, using two hinged unequal arms with ball joint coupling to the axle spindle. The actual linkages vary considerably depending on requirements for roll centre, spring rate and bounce and rebound capability.

Trailing arm suspensions are another common type for rear axles. Their primary advantage is their direct in-line linkage to the frame rather than the cantilevered arm linkages of the A arm suspensions. This is particularly advantageous for powered axles and for braking but is also a factor in reducing damage from striking pot holes, etc. Lateral loading is better handled by the "A arm" suspension, but is not normally a problem.

F-2-3 Non-independent

This is the simplest type of suspension. It consists of a beam axle, which may be straight or offset. As one wheel rises its camber decreases and the opposite wheel's camber increases. Going over bumps can result in loss of steering control. For a rear axle the effect is much less significant and the ride is generally satisfactory provided the axle is suitably sprung.

There is a type of non-independent axle which has certain advantages. It consists of an offset beam axle with torsion springs fitted around the beam. The axle rotates in bearings against the spring action and a variable spring rate results, to cover a full range of loads. At light loads the axle lever arms are approximately parallel to the frame and produce a high leverage, while at heavy loads the axle lever arms are in a more vertical position and the leverage is reduced. This axle has another advantage in that both springs take the load evenly, regardless of how unevenly the load is distributed, and the frame rides level.

Tandem axles which are individually non-independent generally have independent axles so that an effect similar to independent suspension can be achieved using load equalization techniques.

F-2-4 Walking Beam Axle

In this tandem axle suspension the two axle beams are connected on each side to spring mounted pivotted beams. Each side is essentially independent of the other and the pivotted beams allow the wheels to walk over obstacles like a caterpillar, without the resultant jounce and bounce of other types of suspensions. The load is evenly distributed on the four wheels, except during braking when there is a slight variation.

During braking the front wheels of the bogees will exert an upward torque on the rear wheels. The trailer weight will prevent the rear wheels from rising but the braking force exerted by the rear wheels will be slightly less than that of the front wheels.

A typical walking beam suspension uses elastomer and metal sandwiches to provide omnidirectional springing and reduce road shock transmissal to the frame. Roll resistance is good because the spring centers are in line with the tires instead of being inboard of the wheels as they are for conventional suspensions.

APPENDIX F-3

SPRING TYPE COMPARISON

F-3-1 Leaf and Coil Springs

The leaf spring has the important advantage of accurately positioning the wheel with respect to the frame, both laterally and fore and aft, without the aid of radius rods, control arms or other linkages.

Coil springs meet the requirements for independent suspensions well because of their compactness.

Coil or leaf springs have a substantially constant spring rate. This is a disadvantage which can be overcome to some extent by use of helper springs and variable pitch coils.

A soft spring suspension will provide a comfortable ride on a relatively smooth road, but will provide too much up and down motion on a rough road. It is difficult to provide enough clearance between the frame and the unsprung portion and to prevent bottoming out. Road handling also suffers due to effects of centrifugal force and uneven loading that cause sideways tilting. Brake hopping is also likely to be a problem with leaf springs.

Long soft springs tend to wind up due to brake torque and the wheels hop as the torque changes and the spring snaps back. This can result in excessive tire wear and skidding.

F-3-2 Air Springs

Three parameters control the rate characteristics of air springs. They are the changes in internal volume, operating pressure and effective area.

Internal volume changes with deflection. The rate of change can be reduced by adding a reservoir to the system. The rate change is in the correct direction because it increases with load.

Operating pressure is determined by the load and the effective area. This can be altered for different load or road situations through addition or bleeding of air.

The effective area is determined by the effective diameter and this may change as the spring moves, depending on the spring design.

The rate will increase as the static load increases, as a result, the equivalent static deflection and natural frequency remain essentially unchanged.

With a steel spring, static deflection is the actual amount the spring is deflected from its free height when a load is applied to it. Because of this, it is required to have a very long spring and a large static deflection to achieve a low natural frequency.

With air suspensions the equivalent static deflection has no physical dimension and an equivalent static deflection of 40 inches or more is attainable in a physical height of less than 12 inches.* The static deflection is a functional figure equivalent to an actual length change in a steel spring. As a result lower natural frequencies can be obtained than with other springing methods and even lower frequencies are possible with an external reservoir.

Because of the very low damping effect of air springs due to their high efficiency it is essential to provide shock absorbers. The air springs also require support linkages for fore and aft and lateral stability. This is usually provided for by utilizing a trailing axle. The shock absorbers dampen out recurring oscillations and limit downward axle travel to prevent over extension of the air springs. The solid arm eliminates brake hopping.

One feature worth noting is that air springs may be manifolded together to provide load equalization between wheels in a tandem axle.

F-3-3 Elastomeric Springs

Elastomers of many types are used for control of vibration and shock and also as elastomeric springs. The spring rate is set by the dimensions and by the type of elastomer used.

Many special formulations have been made. Some will operate over very wide temperature ranges and are resistant to ozone, oils, brake fluids, etc. The environment should be carefully analyzed when a spring is specified.

The elastomer is bonded to metal plates and is loaded in shear, in a typical application. The deflection should not generally be greater than the distance between plates. Mountings with permissible deflections of several feet can be made, but would not be suitable for trailer suspensions because of their size.

Elastomeric springs have been developed for railroad cars and automotive applications. These give the same ride characteristics under all load conditions and can be designed to give a low natural frequency similar to air springs.

An elastomeric walking beam type suspension is used on the domestic trailers of Avion and other manufacturers and has been proven on thousands of trailers.

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* According to data from Firestone for Airide springs.

F-3-4 Torsion Bars and Torsion Springs

Torsion bars are commonly used in automative suspensions. They are available in several configurations with either side or cross mounting. The side mount design gives a lower unsprung weight because axle beams are eliminated. The cross mount design typically has individual torsion bars for each wheel mounted inside the cross axle with the torsion applied through an offset arm.

As described in the discussion of non-independent suspensions, coil springs can be used to act as torsion springs. These can also be used for independent suspensions by making the cross axle in two pieces with each side connected through a bearing sleeve.

Torsion bars have lower mass, faster response and longer life than conventional leaf springs. It is considered that they are intermediate in performance between leaf springs and air springs (or elastomeric springs).

F-3-5 Hydropneumatic Springs

A very sophisticated suspension system was developed for the Citroen DS-19 automobile. Spring units utilizing sealed air chambers, diaphragms and hydraulic cylinders are provided with control and levelling valves to maintain constant road clearance for different loads and to permit manual controlled road clearance.

It is considered that there would be many problems in adapting such a system to a trailer. Development of cylinders and other components of the correct dimensions would be very expensive and a substitute for the engine driven pump of the Citroen would be required.

APPENDIX F-4

FRAME DESIGN

Trailer frames are usually much simpler structures than those for automobiles or trucks. There is no requirement to torsionally couple an engine to an axle and generally there is no attempt to provide a very low centre of gravity for the trailer so that straight constant section, light guage, longitudinal beams are used. The alignment accuracy for single or tandem axles is not so critical as for steerable axles; the structures are not complicated by the requirements for support points for "A frames" and power train components.

Frames usually are slightly flexible because the weight of a fully rigid frame would be prohibitive and by permitting a certain amount of play in the frame and between the frame and the body, some additional isolation of road shock results.

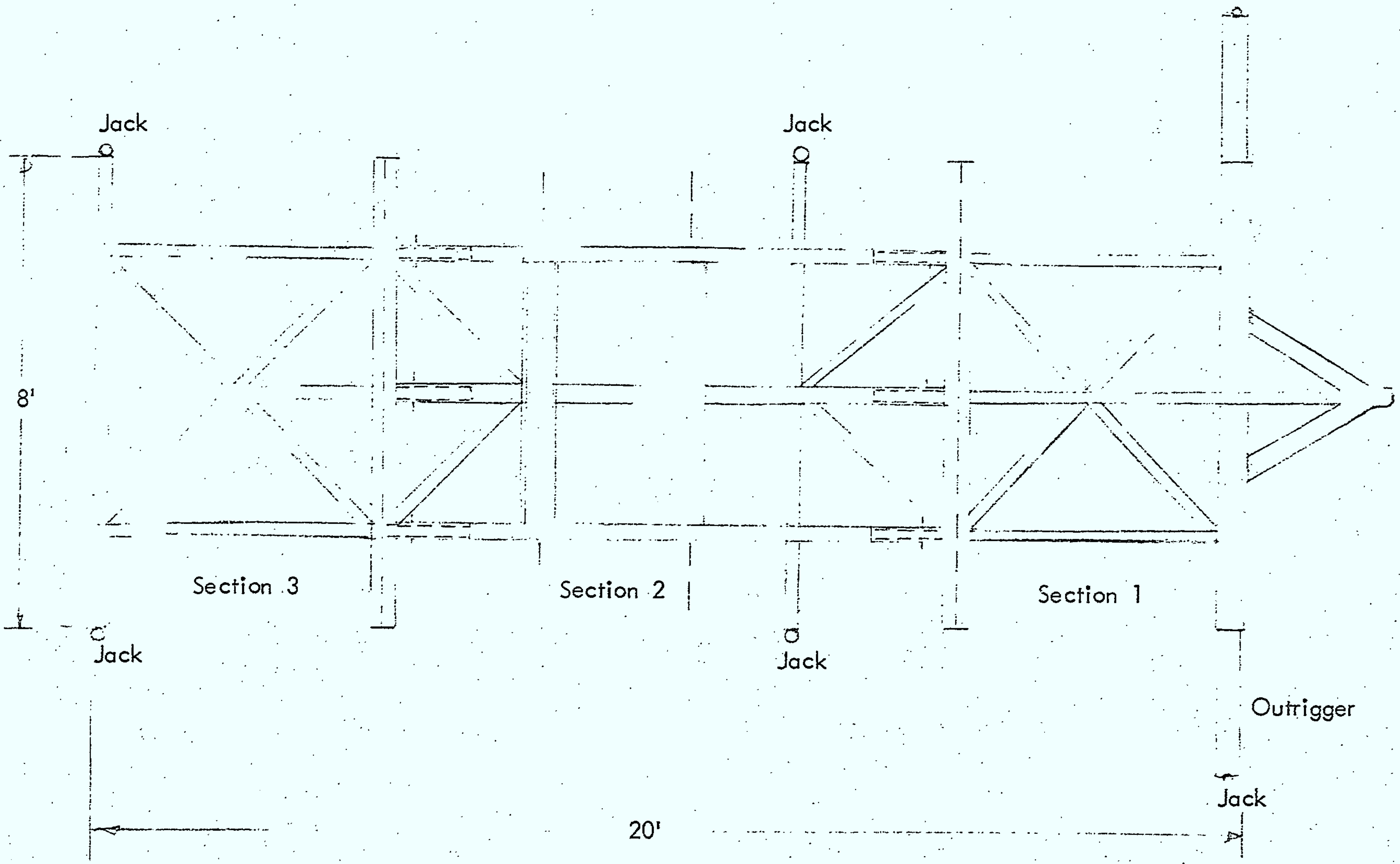
The torsional rigidity required for a semi-trailer is usually less than for a trailer with front and rear axles which can work against each other through the frame, however, if the load is seriously unbalanced about the centre line a semi-trailer will be subjected to similar loading due to road shocks.

The C.T.S. trailer has special requirements for high rigidity when installed at the site, so that the antenna pedestal will not deflect significantly due to wind. This does not necessarily mean that the frame has to be any more rigid than normal because outrigger jacks can be used to provide stability and the body of the trailer should provide additional rigidity.

For the modular trailer concept the frame design is more critical than for other trailers. Frame pick-up points for the modules require a positive, simple attachment method, and it may be advisable to attach the modules through rubber pads. The frame width, cross member locations, etc. are dependent on the type of structure used in the modules, but must also be compatible with the dimensional restrictions of the Boeing 737.

For ease in aircraft loading there are several possible alternatives. The running gear could be made easily removeable so that it could be separately loaded. The frame would be too large to preload on pallets and would have to be manually loaded into the aircraft. The frame dimensions would be too large to permit flat loading. The door is only 86" high so that to permit loading it on its side the frame width would either have to be less than 86" or it would have to be tilted. This would be difficult and dangerous, because of the weight of the frame which might be approximately 1,500 lbs.

Alternatively, the frame could be made in several easily assembled or disassembled sections. For example of this concept see Figure F-1-1. This has the advantage that the running gear does not have to be removed and that the frame could likely



4 module configuration shown.
For 3 module configuration reverse Section 2, do not use Section 3, but bolt bumper from Section 3 at rear of Section 2.

TELESCOPING FRAME CONFIGURATION
FOR
MODULAR TRAILER

FIGURE F1-1

be loaded on the pallets, outside the aircraft. The disadvantage is that to obtain the necessary rigidity the frame would probably have to be made heavier and special care would have to be taken with fit tolerances, and to obtain simple but positive attachment means. It does lend itself to the option of providing for a modular trailer of 3 units for air travel, and of 4 units, where air travel is not required.

As another alternative a folding frame could be made with the two ends folding onto the centre section which would be attached to the running gear.* This would provide the ultimate in ease of assembly and disassembly at the expense of not being suitable for 4 units for road travel. One could consider a second non-folding chassis for this purpose, however.

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* This frame is shown in Figure F-1-1.

APPENDIX F-5

COMPARISON OF SHELTER CONCEPTS

F5-1 General:

There are several possible concepts to choose from for housing the electronic equipment and providing space and operating conveniences for a mobile TV terminal. Shelters which are transported and assembled at the site, and those that can be towed, as a trailer, to the site are the primary candidates. A brief comparison is made of several of these types to show the main advantages and disadvantages to their use.

Conclusion:

The domestic trailer and the modular trailer concepts, which are discussed in greater detail in the body of this report generally meet this rather specialized requirement, and are considered the primary candidates.

The other trailers each have certain advantages but the disadvantages noted, in our opinion make them unsuitable for this application. Unfortunately, the scope of this study does not permit their more detailed evaluation.

F5-2 Prefabricated Building Panel Shelter

Advantages:

Permits any reasonable size. Panels can be stocked and transported by almost any size of aircraft, helicopter, truck, etc.

Disadvantages:

Assembly time of shelter may be high. Multiple seals would be required; these would require frequent replacement and could pose problem with frost build-up which would make dismantling difficult. Shielding for EMC could be a similar problem. It would be required to ship all the terminal equipment separately and to install it at the site. To some extent equipment could be in pre-assembled modules but the time and effort for assembly and disassembly would be excessive.

Prefabricated shelter construction does not lend itself to close coupled installation of a 10' antenna dish.

F5-3 Commercial Trailer

Advantages:

A relatively large size shelter could be procured at reasonable cost, provided no special development is required. Trailers are rugged and highly manoeuverable with their tractor.

Disadvantages:

These are large and heavy for air transport. In general they are not adequately insulated for northern use. They can only be towed by a tractor truck. Trailers are normally high off the ground so that wind forces on the terminal would be high. The large volume increases air conditioning load and heating load.

To obtain suitable characteristics it is considered that many special modifications would be required, primarily to meet EMC requirements but also to improve the U factor.

F5-4 Helicopter Huts

Advantages:

These huts are relatively light in weight and designed for use in the Arctic. They can be transported by helicopter.

Disadvantages:

The typical size is too large for air transportation - with equipment installed it would be too heavy for a conventional helicopter. Huts employ a wooden frame with aluminium skin. The strength of this structure is considered inadequate to support an antenna and extensive modification would be required to provide outrigger jacks and support structure.

In addition, helicopter transportation is very expensive.

F5-5 Military Shelter

Advantages:

A variety of air transportable shelters is available. Some have been developed for use as field hospital or workshop complexes so that a large shelter can be assembled, which requires only a very short assembly time. Expendable types are available which have the advantage that they expand outward or upward from a core section where equipment can be permanently installed. They have removable running gear so that they can be towed to or from an aircraft and the wheels can be removed to permit loading in a relatively small aircraft.

Disadvantages:

Most of the shelters which provide an adequate expanded size are too large to load in commercial aircraft such as the 737. One possible exception is a vertically expanding type but this would pose problems in the installation of electronic equipment racks. Cost of military shelters is very high because of the specialized nature of their construction - honeycomb sandwich panels with many hinged panels and special seals.

The trailer with its normal running gear would not be suitable for highway speeds. * The axles are located front and back and a steerable axle poses problems as discussed in Appendix section F-Z.

The limited core section volume of a typical trailer would be very restrictive on possible equipment locations and might not readily permit changes for experiments.

F5-6 Domestic Trailer

Advantages:

There is a wide selection of low cost trailers which would be suitable for the equipment and crew presently envisaged or for a larger terminal requirement. The streamline rivetted aircraft type construction models are light in weight, strong, and highly suitable for towing.

Conveniences such as air conditioning, heating and ventilation, running water and toilet facilities and even sleeping and eating facilities, if desired, are standard equipment.

Disadvantages:

The primary disadvantage is that they are too large to load in a normal commercial aircraft such as the Boeing 737.

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* Running gear is available for high speed operation but cost is approximately $8,000. and this may not be readily adaptable to every shelter type.

F5-7 Modular Trailer

Advantages:

Would permit air transportability in commercial aircraft of the Boeing 737 class. This is a significantly lower cost method than chartering of an aircraft of the Hercules class. The modules also would provide ready made containers for storage of equipment.

Disadvantages:

Development cost would be relatively high because they would include development of a specialized module handler required to raise, lower rotate and carry modules each of which might weigh 2000 lbs. The maximum practical length envisaged for air shipment is approximately 15 feet. This is restrictive on the amount of equipment which could be installed. The module dimensions would also limit equipment layout possibilities.

APPENDIX F-6

FEATURES REQUIRED FOR CTS MOBILE TERMINAL TRAILER

Apart from the basic requirements of the trailer for installation of electronic equipment racks and other equipment related directly to the experimental function of the terminal, there are features which must be incorporated to meet requirements of Highway Codes, human factors, engineering and housekeeping type functions. The following list should be considered as a guide with some of the items optional and a high probability that other features are required.

a) Running gear suitable for 50 m.p.h. speeds, with suitable vibration and shock dampers to ease requirements for electronic equipment mounting.

b) Electric or hydraulic brakes with suitable controls to tow vehicle, or with surge brake control which operates automatically through thrust on the tow bar.

c) Hitch provision, with safety chains and break-away switch to apply brakes, with jack and dolly wheel.

d) Cold water storage tanks, with external water hose connection and drain fittings, suitably insulated and located to prevent freezing. For this purpose, electrical wrap-around heater tapes may be used.

e) Toilet and wash-basin with holding tank and external sewer connection fittings properly vented to outside.

f) A hot water heater is an optional extra. If a propane heater is used, it will require ventilation.

g) Two 30-pound propane tanks, gas regulator and change over valve and gas lines.

h) Propane furnace, blower, ducting and vent to outside.

i) External lights and reflectors in accordance with Highway Code and safety flares and portable reflectors.

j) Internal area lighting and equipment rack lighting, preferably 12 volts operated through a convertor or from a storage battery.

k) Suitable battery box for 2 automotive type batteries with acid resisting coating, ventilation and provision for heating, mounted outside the trailer. A battery charger and converter for 12 volt operated equipment, with suitable instruments and controls for regulating charging rate and converter voltage.

l) Power distribution centre for battery operated and a.c. power operated equipment with circuit breaker protection and switch control of batteries and input a.c. power.

m) Weatherproof external receptacle for input a.c. power which will be 3-phase 115/200 volt 60Hz, 50 ampere rating with grounded neutral.

n) Grounding rod and 3/8 inch ground stud with braided strap with .001 ohm max resistance between stud and metal structure of trailer, installed at convenient location. Consideration should be given to installing a fail safe protection system to prevent operating unless there is an adequate ground.

o) Weatherproof external receptacles for a.c. and d.c. power to supply external floodlights, tools and actuators (standard 3 pin C.S.A. approved receptacles.)

p) Weatherproof external receptacles for connection to cabtire cord and trailer plug to towing vehicle to control external lights, brakes, battery charging etc.

q) Connection panel for order wires and r.f. links to associated t.v. production trailer. This panel to be approximately 15" square.

r) A 12 to 15,000 BTU capacity air conditioning unit, together with screened ventilators and screened windows. Windows should not transmit a significant portion of the ultra violet spectrum and screens should shield against transmission of r.f. energy.

s) Hold down provisions for equipment such as the engine generator set, antenna reflector container and other miscellaneous equipment which will be transported inside the trailer.

t) Body mounted and outrigger mounted jacks, lifting rings and attachment plates and fittings for antenna positioner installation.

APPENDIX J-1

COMMUNICATION SYSTEM RELIABILITY ANALYSIS

A reliability prediction, using complexity analysis, has been performed on the communications system for the mobile terminal. The basic analysis is given in the first attached memorandum dated 25 May 1972, titled "CTS Communications System Earth Mobile Station" and was performed for a single conversion IF system.

Following this, the analysis was adjusted for a double conversion IF system and the resulting value changes were stated in the second attached memorandum of 11 July 1972, titled "CTS - Earth Mobile Terminal".

Included in the second memorandum is a note on the assumptions used in developing the failure rate for TWT units.

Internal Correspondence RCA

To	J. Stovman	Location	Aerospace Engineering	Date	25 May 1972
From	P.G. Bass	Location	Product Assurance	Telephone	573

Subject: CTS COMMUNICATIONS SYSTEM - EARTH MOBILE STATION

A Reliability Prediction, using complexity analysis, has been performed on the subject system, with the following results:

The Receiving part of the system has been estimated to have a failure rate of 567 Failures/10^6 hours. (Receiver MTBF = 1765 hours.)

The Transmitting part of the system has been estimated to have a failure rate of 1898 Failures/10^6 hours. (Transmitter MTBF = 527 hours.)

Therefore, the System Failure Rate would be approximately 2464 Failures/10^6 hours. (System MTBF = 406 hours.)

Attached are:

1) A list of the Conditions assumed in making the analysis.

2) Table 1, which lists the units, with RCA drawing numbers, that were indicated by Mr. G. Kadar to be similar in complexity to the units that will constitute the projected system.

3) Figure 1, the Reliability Block Diagram of the specified Receiving System.

4) Figure 2, the Reliability Block Diagram of the specified Transmitting System.

Note that the analysis was based entirely on the indicated similarity to units of a comparable system. For reference, all details of the analysis are held on file by Product Assurance.

P.G. Bass

P.G. Bass, Manager,
Product Assurance.

PGB/sep

Att. 4

ATTACHMENT 1

CONDITIONS

1) Wherever feasible, RADC Notebook II was used as the source of the failure rate figures, using:

   a) Ambient Temperature of 35°C,

   b) Average application factors and stress ratios, based on statistical data available in Product Assurance files,

   c) Ground Mobile environmental factors.

2) CRC failure rates supplied on the CTS project, and suitably modified for the new environment, were used as a substitute wherever necessary.

3) Similarities to other equipment are indicated by numbers on the block diagrams. These numbers are identified as Reference Numbers in Table 1.

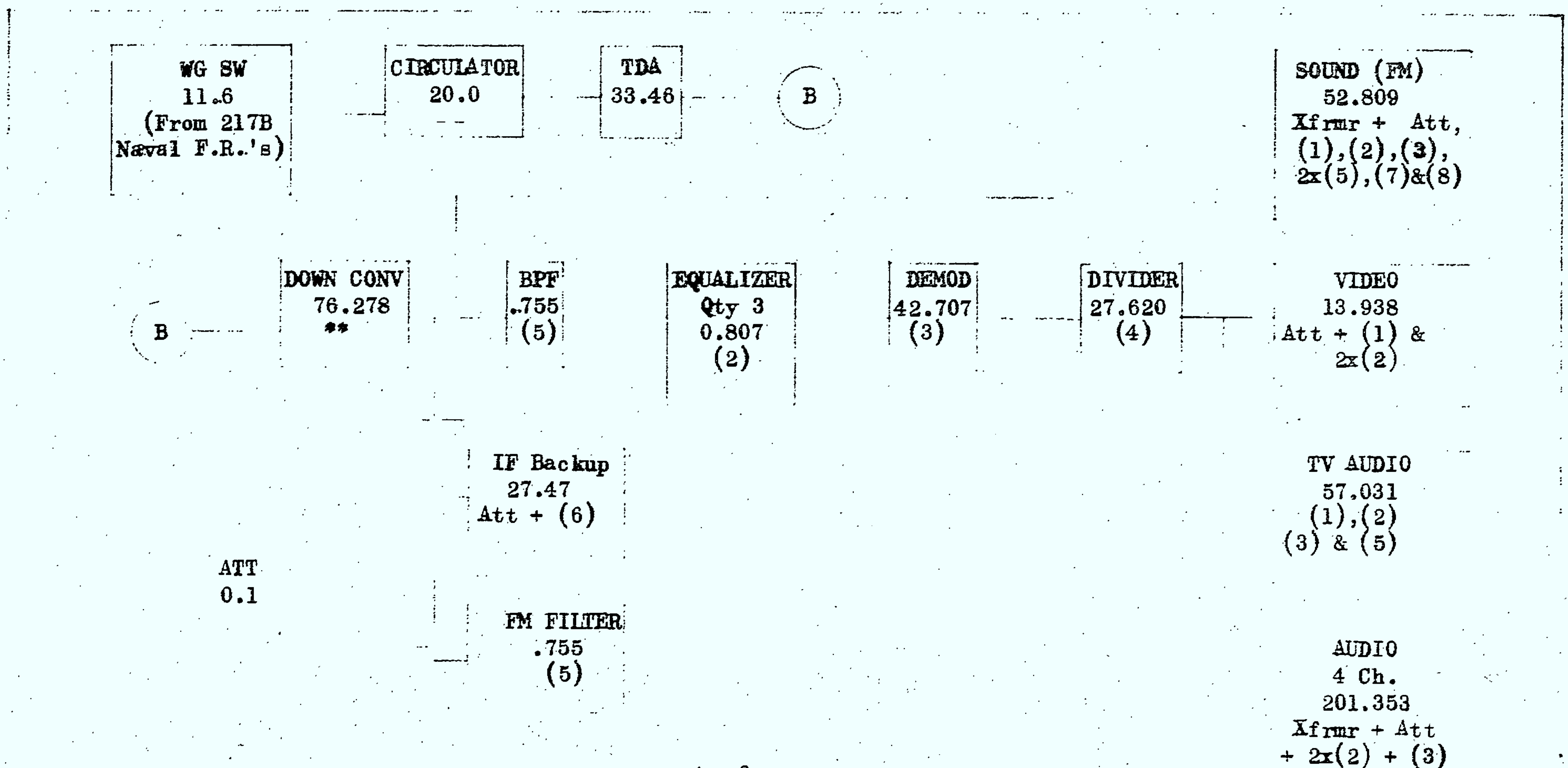
4) Series Configuration was used in the analysis.

ATTACHMENT 2

Table 1

UNITS USED FOR SIMILARITY ANALYSIS

Ref. No.	RCA Drawing Number	Title
1	1085970 - 501	Baseband Amplifier
2	2517119 - (SK 1156)	Low Pass Filter
3	2518232 - 501	Audio Subcarrier Modulator
4	1586807 - 502	IF Driver, Up Converter Assembly
5	2517121 - (SK)	Band Pass Filter
6	1586806 - 502	IF Amplifier Module (50% Complexity)
7	1810825 - 501	Mixer
8	1810118 - 502	Oscillator



Receiver Failure Rate: 566.683 Failures / 10^6 hours.

** Includes 2 Circulators, 1 diode, and Units 5 to 8.

Figure 1. Receiver Reliability Block Diagram

Attachment 3

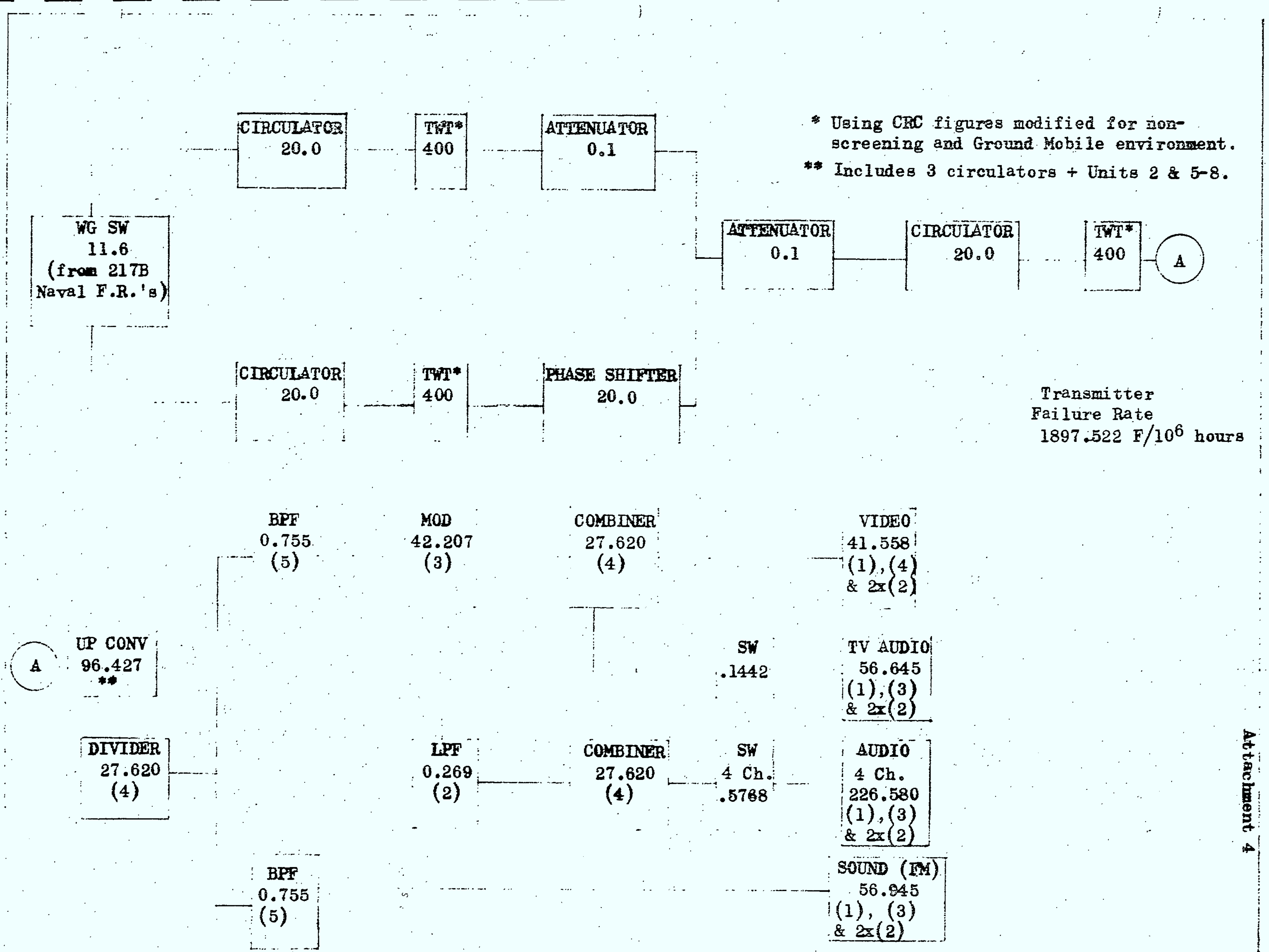


Figure 2. Transmitter Reliability Block Diagram

Attachment 4

Internal Correspondence RCA

To	J. Stovman	Location	Aerospace Engineering	Date	11 July 1972
From	C. Durand	Location	Product Assurance	Telephone	576
cc:	P.G. Bass				
Subject	CTS - Earth Mobile Station				

Ref: Memo from P.G. Bass, dated 25 May 1972.

The addition of another conversion stage to the Receiving and Transmitting part of the system results in doubling the Down and Up Converters failure rates indicated in figure 1 and 2 of the reference.

The TWT failure rate was based on the CRC figure of 2.5 Failures/10^6 hours for the 20 Watts unit used in the CTS project and includes a built-in power supply. Finally, a factor of 20 was used for conversion to a ground mobile environment and another factor of 8 for the conversion to a non-screened condition. The resultant TWT failure rate figure of 400 Failures/10^6 hours should be compared to the ones supplied in the RADC Notebook II from which the other failure rate data were derived. An extract of this volume is attached.

The TDA failure rates given in figure 1 of the reference was derived from the list of parts of the 3 stages unit used in the SHF transponder of the CTS project. Adding a circulator to the TDA will increase the unit failure rate by 20 Failures/10^6 hours.

Correcting the previously supplied failure rates for the second stage of conversion and the addition of a circulator in the TDA gives the following:

Receiving Part	-	663 Failures/10^6 hours (MTBF = 1508 hours)
Transmitting Part	-	1994 Failures/10^6 hours (MTBF = 501 hours)
Overall system	-	2657 Failures/10^6 hours (MTBF = 376 hours)

C. Durand
Product Assurance

dm

Failure Rate Information for
Travelling Wave Tubes
(Based on Data Listed in RADC Notebook II)

Type	Failures per 10^6 hours	Average Power (watts)	Operating Frequency	Extent of Data (Part-hr)
-	380*	300	L-Band	8.9×10^5
394H	120	5 - 20	1.8 - 30 GH_z	4×10^4
349H	42	10	1.8 - 3.2 GH_z	1.7×10^5
314H	28	2 - 5	1.5 - 2.5 GH_z	3.2×10^5

*Assumption: $\frac{MTBF}{MTBR} = 1.7$, where R means Removals.

APPENDIX J-2

SUGGESTED MINIMUM SPARES COMPLEMENT

A. COMMUNICATIONS SYSTEM	QUANTITY
Baseband and Amplifier Equipment	1
I.F. Amplifier module	1
Modulator (BB - IF)	1
Demodulator (IF - BB)	1
L.O. (should be good for upconverter and downconverter)	1
W/G Switch (if remotely operated type)	1
Power supply of each type	1
Consumeable spares for TDA (or TDA complete if high availability required)	1
Transmitter Consumeable Spares List	1
Transmitter spare power supply	1
Transmitter spare tube (if field installable)	2
Coax cable lengths	as required
Flexible W/G	Duplicate set
Crystals	1 ea. freq.
Consumeable Spares for Sound Demod	1 set
T.W.T. for driver	1

B. CASSEGRAIN ANTENNA

Item	QUANTITY
Horn cover	1
Subreflector	1
Subreflector support member	1
Subreflector heater	1
Orthocoupler	1
Flexible waveguide	Assortment
Waveguide twists and bends	Assortment
Silicone sealant and grease	
"0" Rings	Assortment
Assembly - disassembly tools	Assortment

C. TRAILER - SPARES

	QUANTITY	
	Modular Concept	Domestic Concept
Wheel and Tire	1	1
Propane Tank	2-30 lb. Tanks	2-30 lb. Tanks
Fasteners	Selection	Not applicable
Environmental Seals	1 set	" "
Gasket Seals	2 sets	" "
Propane Furnace	1	1
Water Pump	1	1
Air Filter Elements	2 sets	2 sets
Electrical Wire	Selection	Selection
Electrical Connectors	Selection	Selection
Pins, Terminal Lugs, Tie wraps, machine screws, Terminal blocks, etc.	Selection	Selection
Batteries	1	1
Gas Line Fittings	Selection	Selection
Changeover and pressure reducing valve	1	1
Butterfly Valve	1	1
Sewer Connection Pipe	1	1
Module Shipping Panel	1	Not applicable
Module fasteners	Selection	" "
Module environmental seals	2 set	" "
Module EMI gasket seals	3 sets	

D. MODULE HANDLER (Modular Concept Only)

	QUANTITY
Spare Tire	2
Wheel and Caster sub-assembly	1
Drive motor, gear box and chain sub-assembly	2
Jack and motor sub-assembly	1
Pick-up Head and Arms	1
Carrying Unit assembly	1
Battery	2
Electrical Harness	1
Pendent and Control Cable	1

E. SPARES - ENGINE GENERATOR SET

SPARES - ENGINE GENERATOR SET	QUANTITY
Air Filter	2
Oil Filter	2 sets
Fuel Pump	1
Wheel and Tire	1
Shock Mounts	1 set
Starter Motor	1
Starter Solenoid	1
Battery	1
Funnel with Sieve	1
Jerry Can	1
Fuel Line and Sieve, Hand Pump	1
Muffler	1
Flexible Exhaust Pipe	1
Injector Pump	1
Pintle Nozzles	1 Set
Flyball Governor	1
V-Belt	1 (if required)
Brushes	1 Set (if required)
Glow Plugs	1 Set
Voltage Regulator (A.C. Generator	1
Voltage Regulator (Battery Charger)	1
Battery Cables	1 Set

APPENDIX K-1

RATIONALE FOR PROCUREMENT OF TRAILER RELATED EQUIPMENT

To assist in determining a procurement policy, an analysis is made of the factors involved in procurement of equipment, directly related to the trailer, excluding electronic operational equipment and racks, furniture such as desks, filing cabinets, etc., and furnishing which would be expected to come with the trailer.

The directly related equipment is shown in Table K-1-1, which also shows the recommended suppliers, based on present information, together with some comments on the recommendations made.

Further comments can be made on procurement factors. As noted in the procurement section of this report, we have assumed that the trailer would be subcontracted. The trailer manufacturer would not be expected to have expertise in all of the directly related equipment, but would in turn subcontract these items to specialist suppliers. The trailer subcontractor thus would benefit from direct control of mechanical interfaces and the main contractor would be relieved of some of the problems of writing detailed specifications. Interface coordination would be simpler.

The disadvantages are that the trailer manufacturer might not have experience with subcontracting of development items; detailed proposals might have to be written by the subcontractor; these would require coordination and approval by the contractor, particularly in the case of the modular concept. Costs would be expected to be higher because of the subcontractor's mark-up and probably there would be a greater risk of schedule slippage. Thus, the contractor would assume responsibility for subcontracting of these items.

The prospective contractor's policy on procurement of trailer related items should be clearly stated in his bid. To ensure that this is complied with, the RFQ's should specify the requirement.

EQUIPMENT	SUGGESTED SUPPLIER	COMMENTS
Outrigger complete with jacks	Subcontractor for trailer	Suggested because of direct relationship to chassis design and no significant development problems anticipated.
Body Mounted Jacks	Subcontractor for trailer	Direct relationship to chassis design. Should be available"off-the-shelf".
Antenna Pedestal & Positioner	Specialist Subcontractor	Relatively complex mechanical assy. Control is best exercised by Contrator who will assemble and test with reflector and feed.
Antenna Reflector and Feed	Contractor	Requires antenna specialists to develop satisfactory antenna. There are many sources for parabolic dishes.
Special Handling Equipment for trailer modules (not reqd. for Domestic Trailer)	Specialist Subcontractor	Development is closely related to modular trailer design. Trailer subcontractor should be supplier, should he have capability in special handling eqpt.
Cooling Air System for Electronic Equipment	Contractor	Contractor should best know heat sources, cooling air requirements and rack layouts. He can use mock-up to fabricate accurate ducts. Filters and fans are readily available.
Heating Equipment and Ducting	Trailer subcontract for furnace installation. Contractor to install electric heaters and ducting	Propane furnace is normal option for trailers. Special ducting and control valves to tie in with heat from electronic equipment relates directly to cooling duct installation.
Air Conditioning and Ventilation	Subcontractor for trailer	Should larger than normal air conditioning (15,000 BTU) be required, procurement should be by contractor.
Trailer Hitch & Optional Dolly	C.R.C.	Choice is dependent on towing vehicle(s) used. Hitches are normally purchased and installed (welded to frame) at same dealer.
Engine Generator Set	Contractor	Little impact on trailer design, apart from space provision for transit purposes.

TABLE K-1-1

SOURCING OF TRAILER RELATED EQUIPMENT

RCA