M-SAT PHASE A EXTENSION

CANADIAN DEMONSTRATION SPACECRAFT

REPORT AND BASELINE PERFORMANCE DOCUMENT ADDENDUM

TASK 1 M-SAT

L-SAT - NO DND PAYLOAD

REPORT REF. NO. DOC-CR-SP-82-004-A

PREPARED FOR THE DEPARTMENT OF COMMUNICATIONS

Contract No. OST81-00181

Contract File No. 15ST36001-1-3040

Prepared By: The staff of Spar Satellite and Aerospace Systems Division with assistance from British Aerospace Dynamics Group.

Approved By:

S. F. Archer
Director, Engineering

C. F. Morgan
M-SAT Program Manager

Spar Aerospace Limited
21025 Trans-Canada Highway
Ste-Anne-de-Bellevue, Quebec
Canada H9X 3R2

SPAR

Checked 10/83

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this document is to define the performance of a Canadian demonstration M-SAT spacecraft carrying only a commercial mobile transponder in the high UHF band and to report on the trade-offs leading up to the selection of the satellite configuration.

This volume is an addendum to the main Phase A report. Some sections of the spacecraft are unchanged in which case reference is made to the Phase A report.

This report contains one parametric variation described in section 8.0 which includes the L-band capability and a low UHF receive capability from 401 to 406.1 MHz for data relay and search and rescue operations.

2.0 APPLICABLE DOCUMENTS

The following document is applicable to and forms part of this report. In general, only those sections are applicable which are specifically referenced herein, however, the document provides considerable background material which is essential for understanding the satellite system.

(1) M-SAT Canadian Demonstration Spacecraft Report and Baseline Performance Document, Volumes I and II.

Report Ref. # : DOC-CR-SP-81-047-A
Contract # : OST-00133
Contract File #: 15ST.36100-0-0768

3.0 SYSTEM DESCRIPTION

This Canadian Demonstration M-SAT spacecraft is intended to demonstrate the feasibility of providing reliable high quality communications by means of a geostationary satellite to commercial mobile users in the high UHF band.

In addition, it is intended that, during the life of the satellite, a significant user population would be built up. Experience with this user population would develop the market for, and verify the feasibility of implementing a self supporting operational system in time to be launched before the end of life of the demonstration model.

The coverage pattern for the high UHF band is shown in Figure 3-1. Six beams are provided to cover Canada rather than the previous four. This is accomplished by using two antennas rather than one with odd numbered beams in one antenna and even numbered beams in the other. This provided a higher antenna gain (by 0.5 dB) due to the higher cross-over level.

The communication system is unchanged from the baseline and is described by Figure 3.4-1(a) of the Phase A report except that the backhaul frequency band is changed to 14/12 GHz.

Frequency reuse is planned but would not be required if the available bandwidth is greater than 2.5 MHz. The available band is divided into three subbands and each subband is used twice for the six beams.

The frequency and polarization plan for the high UHF band is unchanged from the baseline described in the Phase A report. Voice activation is assumed to reduce the power drain on the highly critical high UHF downlink and increase the number of channels that the spacecraft can support.

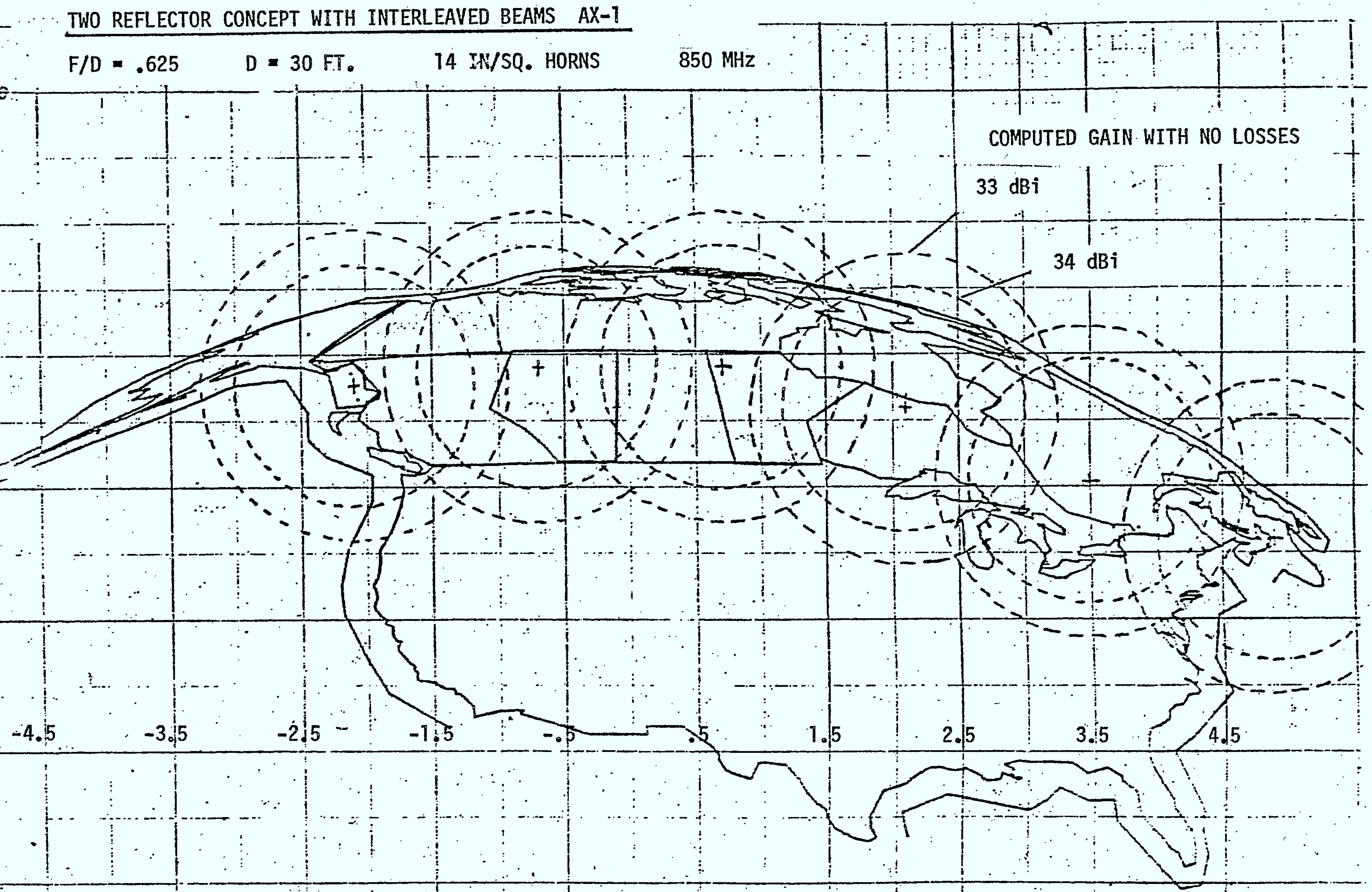


FIGURE 3-1 COVERAGE PATTERN FOR OPTION AX-1

4.0 TRADE-OFF STUDY

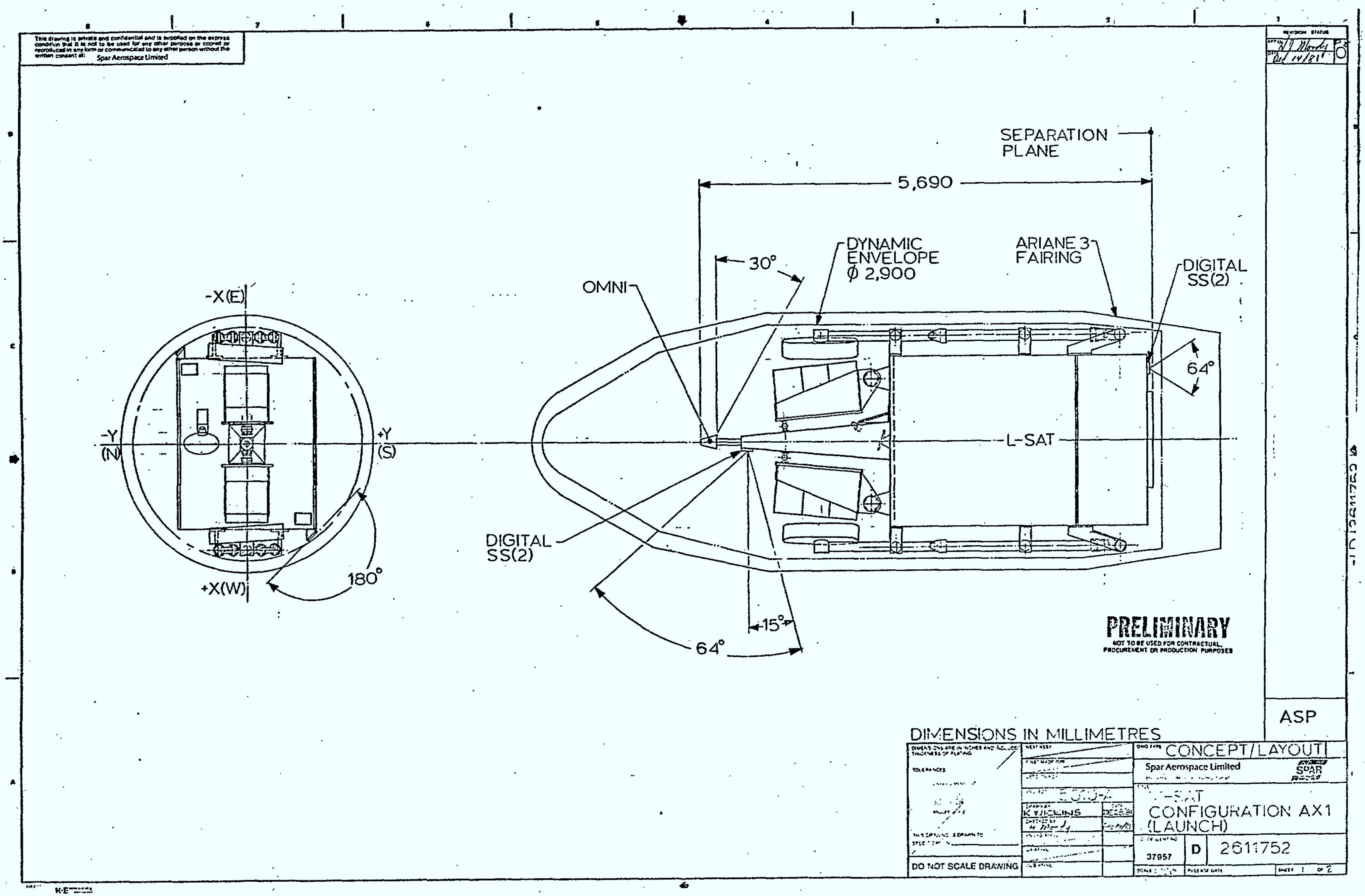
4.1 Configurations Summary

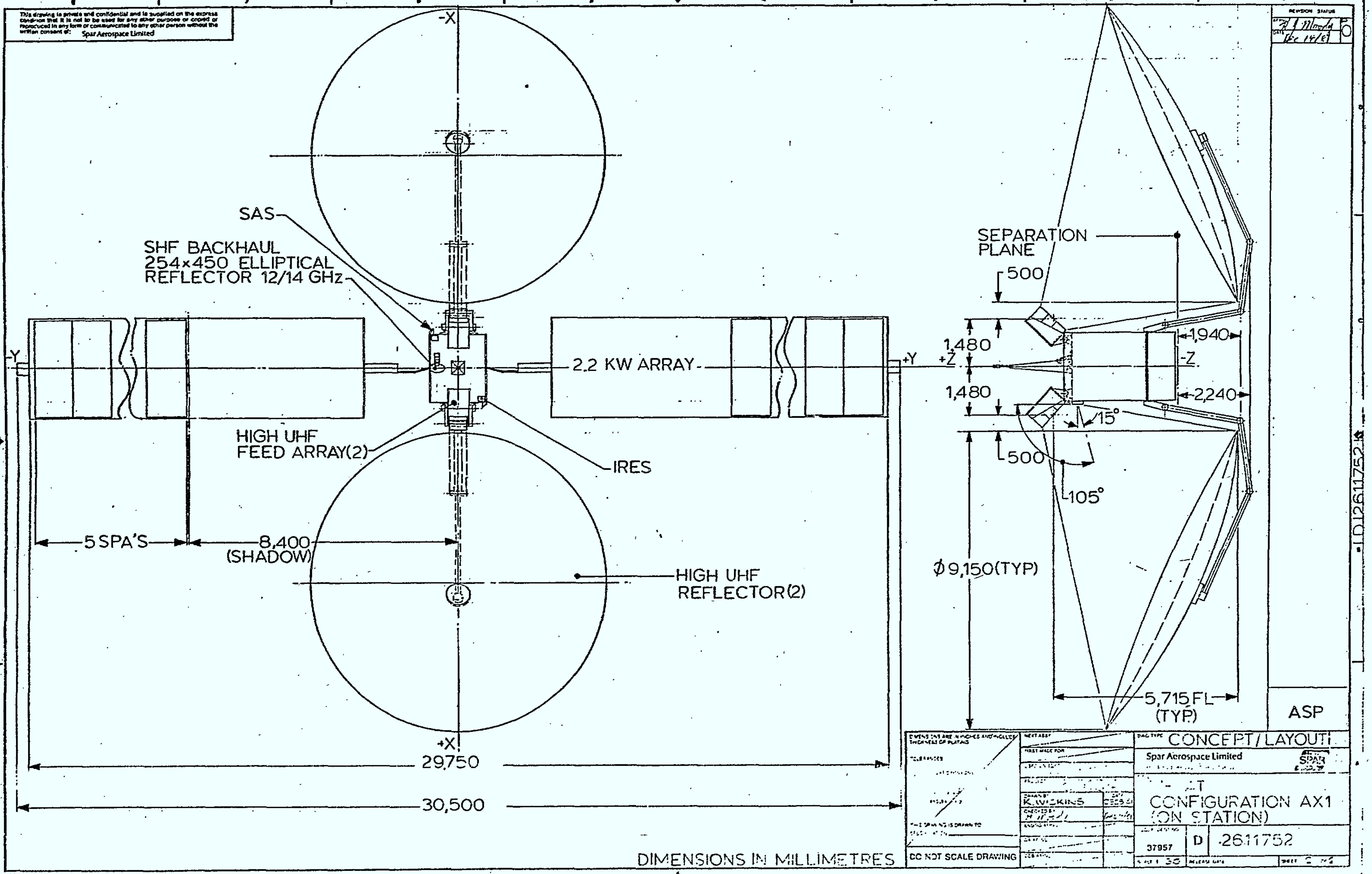
Two basic configurations were considered for the spacecraft carrying only high UHF payload.

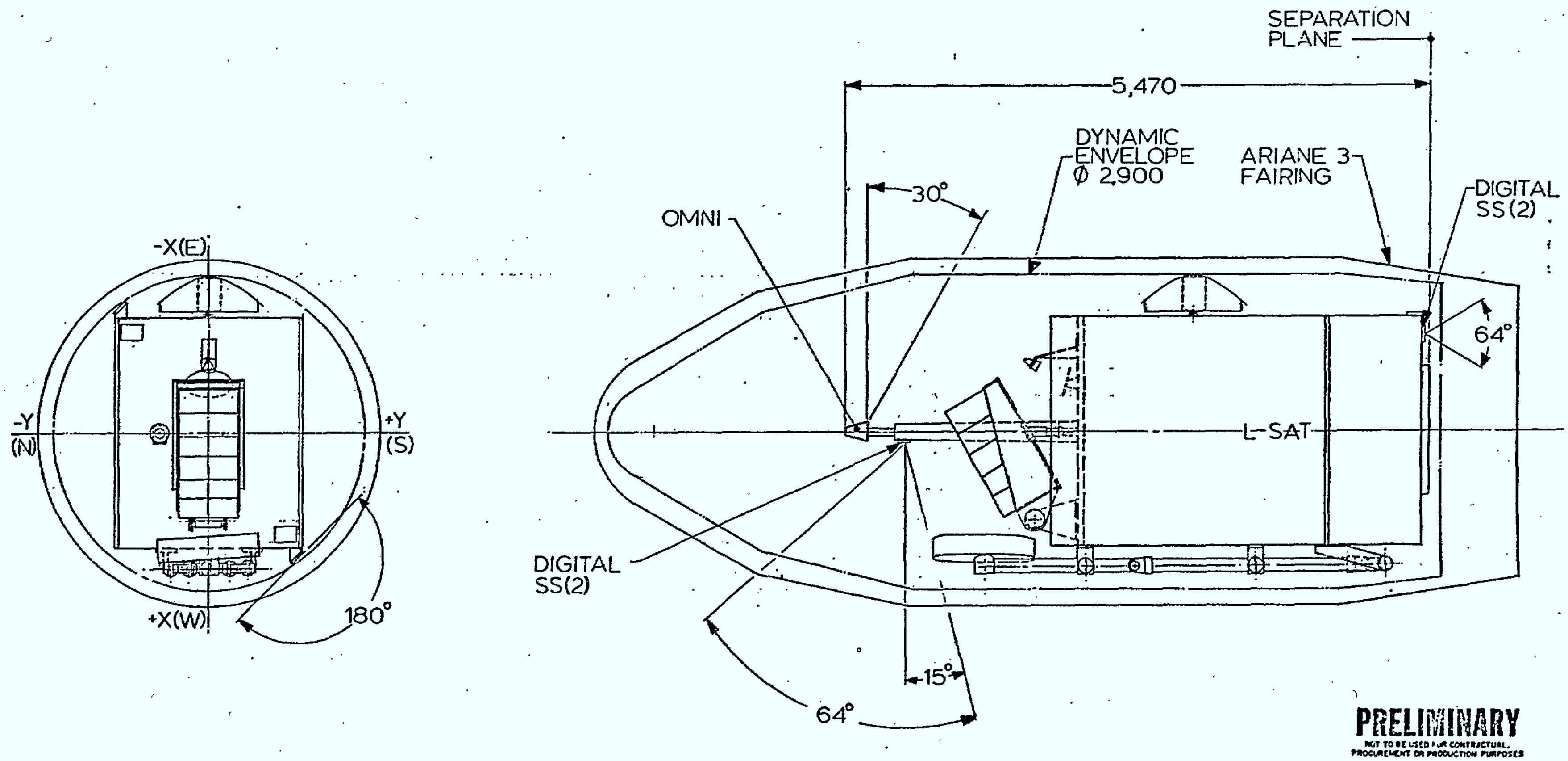
The first configuration (AX-1) was a symmetrical spacecraft with two identical 9.1 meter aperture reflectors mounted off the east and west deck respectively and two solar arrays with a total of 10 S.P.A.'s (5 on each side). This allowed a single horn to be used for each beam with alternate beams in each antenna for a total of six beams in the two antennas. The use of a single horn per beam eliminated the beam forming network and saved the 0.75 dB allowance for phase and amplitude imbalance effects. In addition, with six beams instead of four, a higher cross-over level was obtained giving 0.5 dB higher antenna edge gain. This gives a total of 1.25 dB higher antenna gain than the single antenna configuration.

The second configuration (AX-2) uses a single reflector and feed assembly identical to the baseline design and adds a solar sail to balance the solar torque. The net antenna gain was identical to that in the baseline design and includes the allowance for phase and amplitude imbalance. In addition, 0.5 dB has been subtracted for cable losses. This configuration was short on power with excess weight margin so four S.P.A.'s were added to the baseline to bring the total to 14. This resulted in very high power amplifiers and a low eclipse capability.

The stowed and on station drawings of the two versions are shown in the drawings number 2611752 and 2611753 for the AX-1 and AX-2 configurations respectively. It is seen that there is plenty of space to stow both configurations within the Ariane III shroud restrictions. Table 4.1-1 summarizes the characteristics of the two configurations.


This drawing is private and confidential and is supplied on the express condition that it is not to be used for any other purpose or copied or reproduced in any form or communicated to any other person without the written consent of: Spar Aerospace Limited
SEPARATION PLANE
5,690
30°
DYNAMIC ENVELOPE
ϕ 2,900
ARIANE 3 FAIRING
DIGITAL SS(2)
OMNI
-X(E)
-Y (N)
+Y (S)
+X(W)
180°
64°
L-SAT
DIGITAL SS(2)
15°
64°
PRELIMINARY
NOT TO BE USED FOR CONTRACTUAL, PROCUREMENT OR PRODUCTION PURPOSES
ASP
DIMENSIONS IN MILLIMETRES
DO NOT SCALE DRAWING
K WICKINS
CONCEPT/LAYOUT
Spar Aerospace Limited
SPAR
CONFIGURATION AX1
(LAUNCH)
37957
D
2611752


This drawing is private and confidential and is supplied on the express condition that it is not to be used for any other purpose or copied or reproduced in any form or communicated to any other person without the written consent of: Spar Aerospace Limited
-X
SAS
SHF BACKHAUL
254×450 ELLIPTICAL
REFLECTOR 12/14 GHz
-Y
+Y
2.2 KW ARRAY
HIGH UHF
FEED ARRAY(2)
IRES
5 SPA'S
8,400
(SHADOW)
HIGH UHF
REFLECTOR(2)
+X
29,750
30,500
DIMENSIONS IN MILLIMETRES
SEPARATION
PLANE
500
1,480
+Z
1,480
500
-Z
1,940
2,240
15°
105°
ϕ9,150(TYP)
5,715 FL
(TYP)
ASP
DO NOT SCALE DRAWING
CONCEPT/LAYOUT
Spar Aerospace Limited
SPAR
K.WICKINS
CONFIGURATION AX1
(ON STATION)
37957
D
2611752
D2611752



PRELIMINARY
NOT TO BE USED FOR CONTRACTUAL, PROCUREMENT OR PRODUCTION PURPOSES

ASP

DIMENSIONS IN MILLIMETRES.

DRAWN BY: K. WICKINS

Spar Aerospace Limited

L-SAT
CONFIGURATION AX2
(LAUNCH)

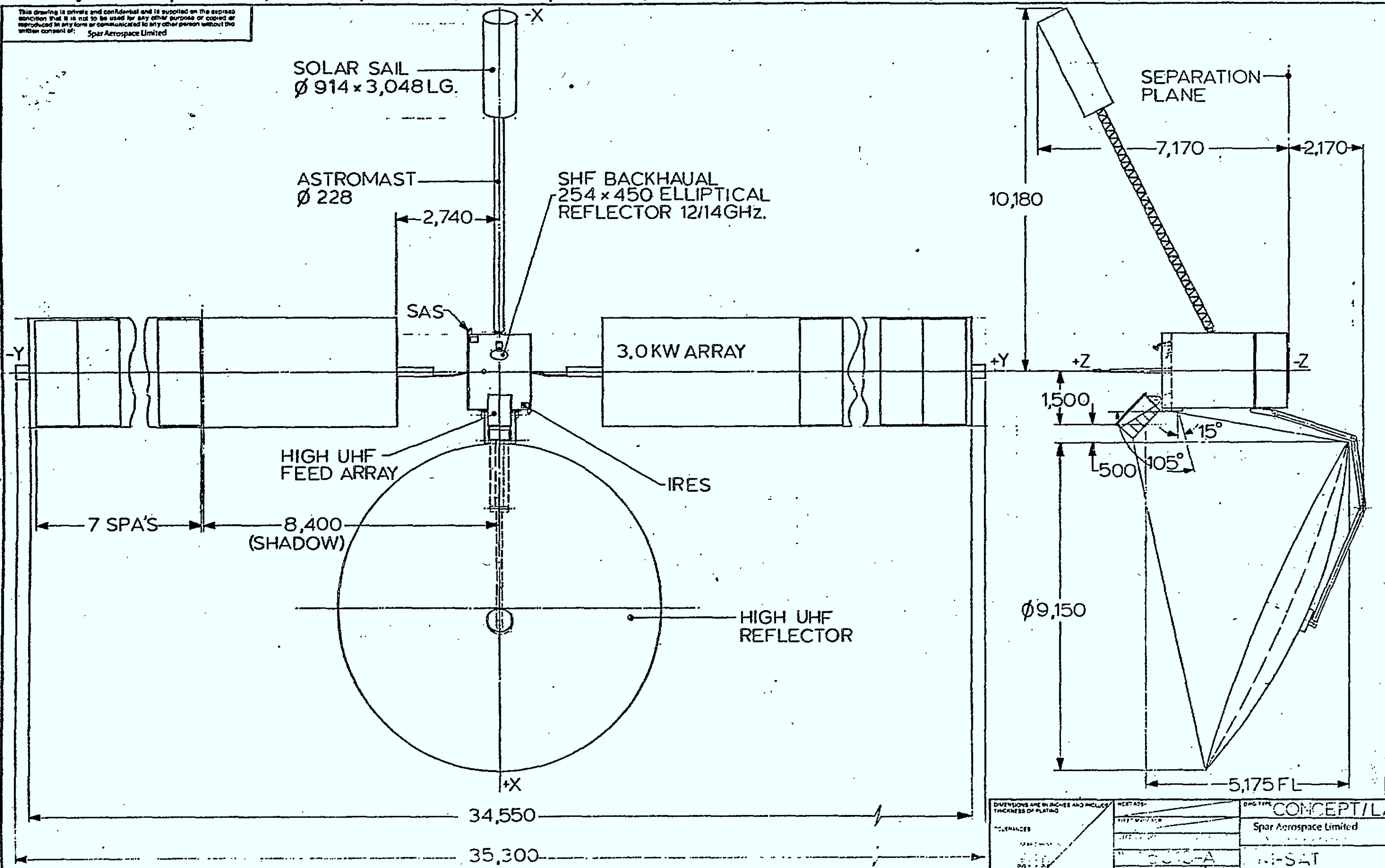
37957 | D | 2611753

SCALE 1/20 | SHEET 1 of 2

DO NOT SCALE DRAWING

D 2611753

K·E



DIMENSIONS IN MILLIMETRES

DRG TYPE	CONCEPT/LAYOUT
	Spar Aerospace Limited
	M-SAT CONFIGURATION AX2 (ON STATION)
DRAWN	K. NICKINS
	37857
	D 2611753
SHEET	2 of 2

DO NOT SCALE DRAWING

ASP

	CONFIGURATION AX-1	CONFIGURATION AX-2
Payload	High UHF Only	High UHF Only
Bus	L-SAT	L-SAT
Number of Reflectors	2	1
Number of Beams	6	4
Beam Forming Network	No	Yes
Net Antenna Gain	31.5	30.25
Horn Configuration	Single Horn Per Beam	Overlapping 4-Horn Cluster
Voice Activation	Yes	Yes
Solar Array	10 S.P.A.'s	14 S.P.A.'s
Battery	Two NiH_2	Two NiH_2
Solar Sail	No	Yes

TABLE 4.1-1 SUMMARY OF CHARACTERISTICS OF THE TWO CONFIGURATIONS

4.2 Traffic Capability Comparison

Table 4.2-1 for the two reflector configuration (AX-1) gives the system parameters and the calculation resulting in the number of channels that the spacecraft can support. Table 4.2-2 is the same for the single reflector configuration (AX-2). Voice activation is assumed in both cases. It is used in calculating the size of the power amplifiers required and the number of channels that can be assigned per beam in relation ship to the number that must be simultaneously powered, as well as the number assignable for the whole spacecraft. The numbers given are only representative of what can be done. For instance, each amplifier can be increased in size so that more channels can be carried in a single beam. However, this increases the minimum power drain and reduces the total number of channels for the whole spacecraft.

The single reflector configuration (AX-2) is shown with more channels in sunlight but fewer in eclipse. This is because both configurations carry the same battery capability. If the battery size could be adjusted so that each configuration provided exactly 25% eclipse capability, then the number of channels in sunlight would be very similar.

The number of channels have been determined for both narrow band FM assuming an EIRP of 39.7 dBw and pitch excited LPC assuming an EIRP of 33.7 dBw. The number of channels in both sunlight and eclipse for the whole spacecraft is given in Table 4.2-3 along with the estimated number of users that can be supported assuming a 10% blockage rate and 0.0125 Erlong per user.

TABLE 4.2-1 HIGH UHF ONLY DEMONSTRATION MODEL - TWO REFLECTOR AX-1
(CALCULATION OF CHANNEL CAPACITY)

Coding Type		NBFM	PELPC
Antenna Diameter	(m)	9.1	9.1
	(ft)	30	30
Number of Beams	(N_b)	6	6
Edge EIRP Channel	(dBw)	39.7	33.7
Antenna Gain	(dB)	32.5	32.5
Pointing Error Loss	(dB)	1.0	1.0
Transponder RF Power/Channel	(dBw)	8.2	2.2
Output Circuit Loss	(kB)	1.3	1.3
HPA RF Power/Channel	(dBw)	9.5	3.5
	watts	8.91	2.24
Max. Conversion Efficiency (0.3 X .9)	(ratio)	.27	.27
Voice Activation		yes	yes
Max. No. of Active Channels per Beam	N_{BA}	10	40
Max. No. of Assignable Channels per Beam	N_{APD}	10	83
Total Number of Active Channels	N_{TA}	30	120
Total No. of Assignable Channels	N_{ass}	60	280
Max RF Power/Beam	(dBw)	89.1	89.6
Max. DC Power per Amp.	(watts)	330.1	331.9
Max. DC Power for 6 Amps.	(watts)	1199.2	1204.9
Remainder of Transponder	(watts)	73	73
Total DC Power of Transponder	(watts)	1272.2	1277.8
No. of Active Channels in Eclipse		22	87
No. of Assignable Channels in Eclipse		40	200
Total DC Power in Eclipse	(watts)	1063.9	1062.0
Unit Weight of HPA & EPC	(kg)	6.0	6.0
Total Weight of 10 HPA's and FPC's	(Kg)	60.0	60.0
Channel Spacing	(kHz)	30	5.0
Frequency Reuse		yes	yes
Bandwidth per Beam	MHz	1.333	1.333
Required Bandwidth/Beam	MHz	.33	.415

TABLE 4.2-2 HIGH UHF ONLY DEMONSTRATION MODEL - ONE REFLECTOR AX-2

(CALCULATION OF CHANNEL CAPACITY)

		NBFM	PELPC
Coding Type		NBFM	PELPC
Antenna Diameter	(m)	9.1	9.1
	(ft)	30	30
Number of Beams	(N_b)	4	4
Edge EIRP	(dBw)	39.7	33.7
*Antenna Gain	(dB)	32	32
Pointing and Imbalance Allowance	(dB)	1.75	1.75
Transponder RF Power/Channel	(dBw)	9.45	3.45
Output Circuit Loss	(dB)	1.3	1.3
HPA RF Power/Channel	(dBw)	10.75	4.75
	(watts)	11.9	3.0
Maximum Conversion Loss	ratio	.27	.27
Voice Activation		yes	yes
Max. No. of Active Channels per Beam	N_{ba}	15	59
Max. No. of Assignable Channels per Beam	N_{APD}	22	130
Total Number of Active Channels	N_{TA}	37	147
Total Number of Assignable Channels	N_{ass}	76	347
Max. RF Power per Channel	(watts)	178.3	176.1
Max. DC Power per AMP.	(watts)	660.3	652.4
Max. DC Power for 5 Amps.	(watts)	1987	1979
Remainder of Transponder		74.4	74.4
Total DC Power for Transponder		2062	2053.4
No. of Active Channels in Eclipse		8	31
No. of Assignable Channels in Eclipse		8	61
Total DC Power in Eclipse		1048.4	1041.7
Unit Weight of HPA and EPC		11.38	11.38
Total Weight of 9 PHA and EPC		102.4	102.4

	Total Channels	Total Erlongs 10% Blockage	Total Users .0125 Erl/User
Sunlight			
NBFM	60	60	4800
PELPC	280	312	24982
Eclipse			
NBFM	40	38	3040
PELPC	200	220	17635

TABLE 4.2-3(a) TOTAL NUMBER OF USERS SERVICED FOR THE TWO REFLECTOR CONFIGURATION AX-1

	Total Channels	Total Erlongs 10% Blockage	Total Users .0125 Erl/User
Sunlight			
NBFM	76	78	6240
PELPC	347	389	31120
Eclipse			
NBFM	8	5.5	440
PELPC	61	60	4800

TABLE 4.2-3(b) TOTAL NUMBER OF USERS SERVICED FOR THE SINGLE REFLECTOR CONFIGURATION AX-2

4.3 BUS CHANGES

4.3.1 Configuration AX-1

This configuration results in bus requirements within all the limitations of the Baseline M-SAT requirements and therefore no bus changes are necessary. This configuration however, results in a reduced battery capacity requirement which could be traded for additional payload weight. A possible change could be to replace one of the Nickel Hydrogen batteries with a Nickel Cadnium - as to the original L-SAT concept. As shown in Table 4.3-1, however, this does not result in a weight saving. Rather than change to a different battery system, it is recommended at this stage to maintain the same battery configuration as the Baseline M-SAT and utilize the available additional eclipse capability.

4.3.2 Configuration AX-2

This configuration requires additional solar array power and additional heat dissipation capability. The changes to the solar array and power subsystem include the addition of 4 S.P.A.'s increasing the solar panel output to that of the L-SAT 1 solar array (while still maintaining the blank panels for shadowing). One additional shunt dump module is added to the power subsystem, returning to the original L-SAT configuration. As shown in Table 4.3.2, this results in a weight increase of 19.3 Kg. In order to maintain unit temperatures below 60 degrees, it is necessary to substantially increase the heat pipe and doubler complement resulting in a heat pipe/doubler weight of 36 Kg for the 5 HPA panel and 20 Kg for the 4 HPA panel. As shown in Table 4.3.2, this results in a net weight increase of 44 Kg, leading to a 63.3 Kg total increase for the bus. The bending frequency of the solar sail can be accommodated by the attitude control subsystem without any changes.

TABLE 4.3.1 CONFIGURATION AX-1

Power Subsystem Changes

	M-SAT	AX-1	MASS CHANGE (Kg) Down	Up
Shunt Dump Modules	2	2	0	
35 AH_r Batteries NiH_2	2	1	35	
24 AH_p Batteries NiCd	-	1		36.5
Battery Discharge Regulations	5	4	2.3	
NiCd Mounting	-	1		2.8
NiH_2 Radiator	2	1	1.3	
Subtotal			38.6	39.3
Total				0.7

Conclusion: The two NiH_2 Batteries should be retained.

TABLE 4.3.2 CONFIGURATION AX-2

Power Subsystem Changes

	M-SAT	AX-2	MASS CHANGE (Kg) Down	MASS CHANGE (Kg) Up
Shunt Dump Module	2	3		4.4
Array Both Wings Active Sections	10	14		14.9
Subtotal				19.3

Thermal Subsystem Changes

	M-SAT	AX-2	MASS CHANGE (Kg) Down	MASS CHANGE (Kg) Up
Heat Pipes (Kg)	7	56 Kg (Heat Pipes and Doublers combined)		44 (Heat Pipes and Doublers combined)
Doublers (Kg)	5			
Total Mass Increase				63.3

Shunt			POWER CHANGE (Watts) Down	POWER CHANGE (Watts) Up
Shunt Dump Module	85.7	128.5		42.8

4.4 WEIGHT AND POWER COMPARISON

The weight summary for the dual reflector configuration AX-1 is given in Table 4.4-1 and for the single reflector version AX-2 in Table 4.4-2. The power summaries for the two configurations are given in Tables 4.4-3 and 4.4-4 respectively.

The tables show that the two reflector configuration ends up with a higher weight margin and a higher power margin than the one reflector version. This gives a slightly higher confidence that implementation uncertainties can be handled within the allowed margins.

TABLE 4.4-1

HIGH UHF DEMONSTRATION MODEL - TWO REFLECTOR (AX-1)
(L-SAT BUS WITH ARIANE III LAUNCH)

WEIGHT SUMMARY (KG)

SUBSYSTEM			
REPEATERS		101.1	
High UHF Repeater	101.1		
L-Band Repeater	-		
DRP and EPIRB Repeater	-		
ANTENNAS		106.7	
High UHF Antennas	94.9		(Two at 30 Ft. Diameter)
Backhaul Antenna	2.7		
L-Band Antenna	-		
DRP and EPIRB Antenna	-		
Central Support Tower	9.1		
PLATFORM		858	
Structure	219.5		
Thermal	49.4		
Attitude Control	87.8		
Power	334.3		
TT&C	21.6		
Propulsion	125.4		
Balance	20.0		
SPACECRAFT DRY MASS		1065.8	

	ARIANE III		ARIANE III GROWTH	
FUEL & RESIDUALS (7 YEARS LIFE)	1211.7		1266.0	
ADAPTOR	48.3		48.3	
MARGIN*	144.2	(13.5%)	199.9	(18.7%)
LAUNCH CAPABILITY	2470.0		2580.0	

*20% MARGIN ON PAYLOAD + 10% MARGIN ON BUS = 127 Kg.

TABLE 4.4-2

HIGH UHF DEMONSTRATION MODEL - ONE REFLECTOR (AX-2)
(L-SAT BUS ON ARIANE III LAUNCH)

WEIGHT SUMMARY (KG)

SUBSYSTEM		
REPEATERS		143.4
High UHF	143.4	
ANTENNAS		69.4
High UHF	56.7	
Backhaul Antenna	2.7	
Central Control Tower	1.8	
Solar Sail	8.2	
PLATFORM		921.3
Structure	219.5	
Thermal	93.4	
Attitude Control	87.8	
Power (14 Panels)	353.6	
TT&C	21.6	
Propulsion	125.4	
Balance	20.0	
SPACECRAFT DRY WEIGHT		1134.1

	ARIANE III		ARIANE III GROWTH	
FUEL & RESIDUALS	1152.6	(4.5 Years NSSK)	1266.0	(7 years NSSK)
ADAPTOR	48.3		48.3	
MARGIN*	135.0		131.6	
LAUNCH CAPABILITY	2470.0		2580.0	

*20% MARGIN ON PAYLOAD + 10% ON BUS = 135 Kg.

4.5 SELECTED OPTION

Table 4.5-1 summarizes the differences between the two configurations, AX-1 with two reflectors and AX-2 with one reflector. By removing one reflector and replacing it with a solar sail, a net weight savings of 37.3 Kg is realized. This weight is used to provide more solar array which increases the number of channels. However, with a single reflector a transponder beam forming network is required with the attendance 0.75 dB allowance for phase and amplitude imbalance. In addition, with only four beams, the cross over level is 0.5 dB lower for the single reflector: a net difference of 1.25 dB. Table 4.5-1 shows that the one reflector configuration can support 16 more NBFM channels in sunlight but since the battery size is the same, there are considerably fewer channels in eclipse with the one reflector configuration. The L-SAT batteries are assembled into fully qualified battery packs and there would be a considerable expense involved in changing the battery size. Table 4.5-2 shows the net result if solar array and HPA weight was transferred to batteries to make the capacity for the two reflector versions. A decrease of 16 sunlight channels to equalize the sunlight capacity at 60 would add 22 channels to the eclipse capability. This raises the eclipse capability to 30 which is still less than the 40 eclipse channels supported by the two reflector configuration.

In addition, the single reflector configuration requires power amplifiers with twice the maximum dissipation. This necessitates the addition of 44 Kg of heat pipes and doublers to the thermal subsystem. This weight penalty has been accommodated by reducing the north south station keeping fuel.

In conclusion, the single reflector configuration entails additional risk and expense without any apparent advantage. These risks center around the requirement for a transponder beam forming network (a requirement that the two reflector configuration does not have). The risk areas can be detailed as follows:

a) Phase and gain stability of the power amplifiers independent of drive level, temperature and life.

b) Phase and gain stability of the low noise amplifiers independent of temperature and life.

TABLE 4.4-3

HIGH UHF ONLY DEMONSTRATION MODEL - TWO REFLECTOR (AX-1)
POWER SUMMARY (WATTS)

	ON STATION POWER REQUIREMENTS	
	SUNLIGHT	ECLIPSE
Payload (High UHF)	1277.8	1063.9
Platform		
Structure	-	-
Thermal	232.0	41.0
AOCS (Incl. SADAPTA)	116.6	116.6
Power (Incl. Harness)	30.5	30.5
TT&C	29.1	29.1
Propulsion	-	-
Subtotal	408.2	217.2
Misc. Losses		
ELI Loss	22.8	22.8
Battery Charging	175.0	-
Shunt Dump Loss	85.7	-
BDR Loss	-	57.5
Subtotal	283.5	80.3
Required	1969.5	1361.4
Available	2195.0	1515.0
Margin	224.5	153.6
	(11.4%)	(11.3%)

TABLE 4.4-4

HIGH UHF DEMONSTRATION MODEL - ONE REFLECTOR (AX-2)

POWER SUMMARY (WATTS)

	ON STATION POWER REQUIREMENTS	
	SUNLIGHT	ECLIPSE
Payload High UHF	2062.0	1048.4
Platform		
Structure	-	-
Thermal	232.0	41.0
AOCS (Incl. SADAPTA)	116.6	116.6
Power (Incl. Harness)	30.5	30.5
TT&C	29.1	29.1
Propulsion	-	-
Subtotal	408.2	217.2
Misc. Losses		
ELI Loss	22.8	22.8
Battery Charging	175.0	-
Shunt Dump Loss	128.5	-
BDR Loss	-	57.5
Subtotal	326.3	80.3
Required	2796.5	1345.9
Available	3073.0	1515.0
Margin	276.5	169.1
	(9.9%)	(12.6%)

c) Careful tailoring of cable lengths so that phase coherence is maintained from the beam forming network to the horn aperture.

d) Compensation of line length changes which occur due to the introduction of redundant units, both HPA's and LNA's.

e) A requirement to minimize temperature difference between power amplifiers so as to minimize the phase change due to temperature.

f) Design of power amplifiers with twice the power dissipation. This is partly a result of the allowance for phase and amplitude imbalance and partly that the available channels are distributed among four beams rather than six.

g) The higher total power dissipation of the spacecraft raises the maximum temperature of the power amplifiers as well as other units and has a deleterious effect on the overall reliability.

For these reasons, the two reflector version has been adopted as the optimum.

TABLE 4.5-1 COMPARISON OF TWO REFLECTOR AND ONE REFLECTOR CONFIGURATION

Parameter	AX-1	AX-2
Number of Reflectors	2	1
Maximum RF Power Per Amplifier (Watts)	90	180
Maximum Amplifier Dissipation (Watts)	241	482
Total Spacecraft Power (Watts)	2195	3073
Calculated Antenna Gain (dB)	33.5	33.0
Beam Forming Network	No	Yes
Phase and Amplitude Imbalance	No	Yes
Total Number of NBFM Channels		
Sunlight	60	76
Eclipse	40	8
Margin		
Weight	13.5%	10.0%
Power	11.4%	9.9%
NSSK Capability	7 years	4.5 years

TABLE 4.5-2 EFFECT OF CONTINUOUS CHANGE IN BATTERY SIZE ON THE SINGLE REFLECTOR CONFIGURATION

UNIT	WEIGHT (KG)	POWER (WATTS)	KG/WATT	NET KG/WATT	RATIO	CHANGE IN CHANNEL CAPACITY SUNLIGHT	CHANGE IN CHANNEL CAPACITY ECLIPSE
ONE BATTERY	40	758	.0528	.0528			+22
4 SPA'S	20	878	.0228		1.41		
				.0743		-16	
10 HPA + EPC	102.4	1987	.0515				

5.0 SPACE SEGMENT DESCRIPTION

5.1 General

The description of the overall spacecraft design configuration is provided in Section 4.0 of this report.

5.2 Launch Vehicle Interface

The launch vehicle interface is identical with that of the baseline M-SAT design as described in Section 5.2 of the main M-SAT Baseline Performance Document.

5.3 Mission Scenario

The mission scenario is identical with that of the baseline M-SAT design as described in Section 5.3 of the main M-SAT Baseline Performance Document.

6.0 SUBSYSTEM DESCRIPTIONS

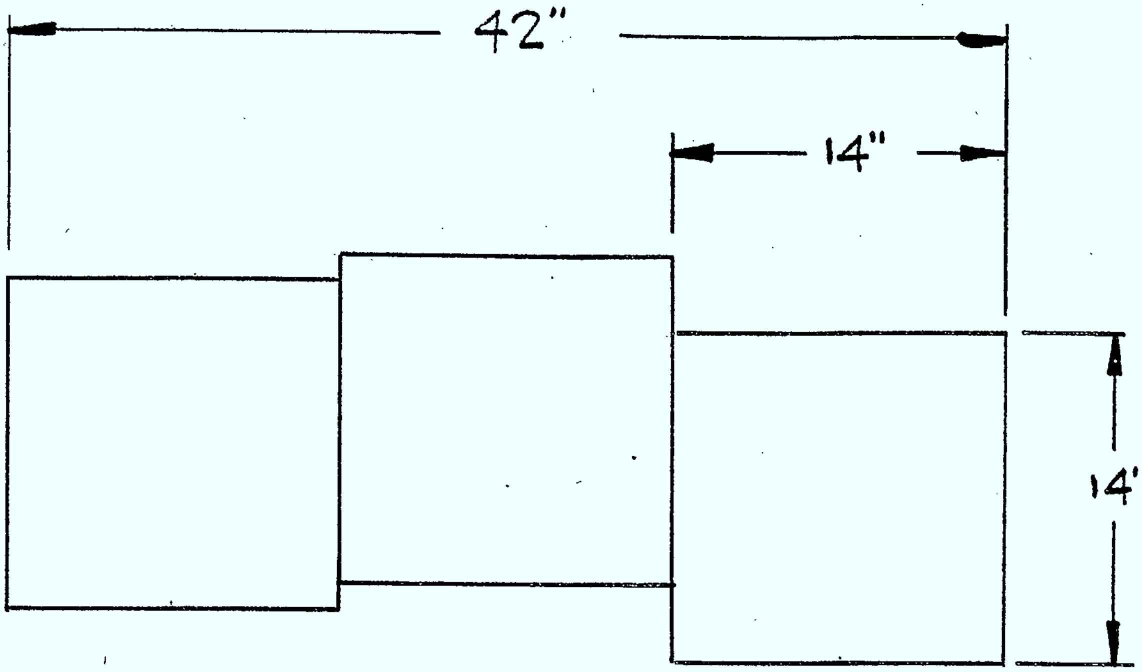
6.1 Antenna Subsystem

The antenna subsystem consists of two 9.1 meter aperture diameter antennas for the high UHF band and a elliptical aperature antenna for all Canada coverage at 14/12 GHz. The high UHF reflectors are identical to the 9.1 meter antenna used for the baseline, however, the feed assembly is different. The present antenna used a single feed horn per beam with three beams in each antenna. Odd numbered beams are radiated by one antenna and even numbered beams are in the other. The two feed assemblies are shown in Figure 6.1-1. The antenna pattern provided by the two antennas is given in Figure 3-1.

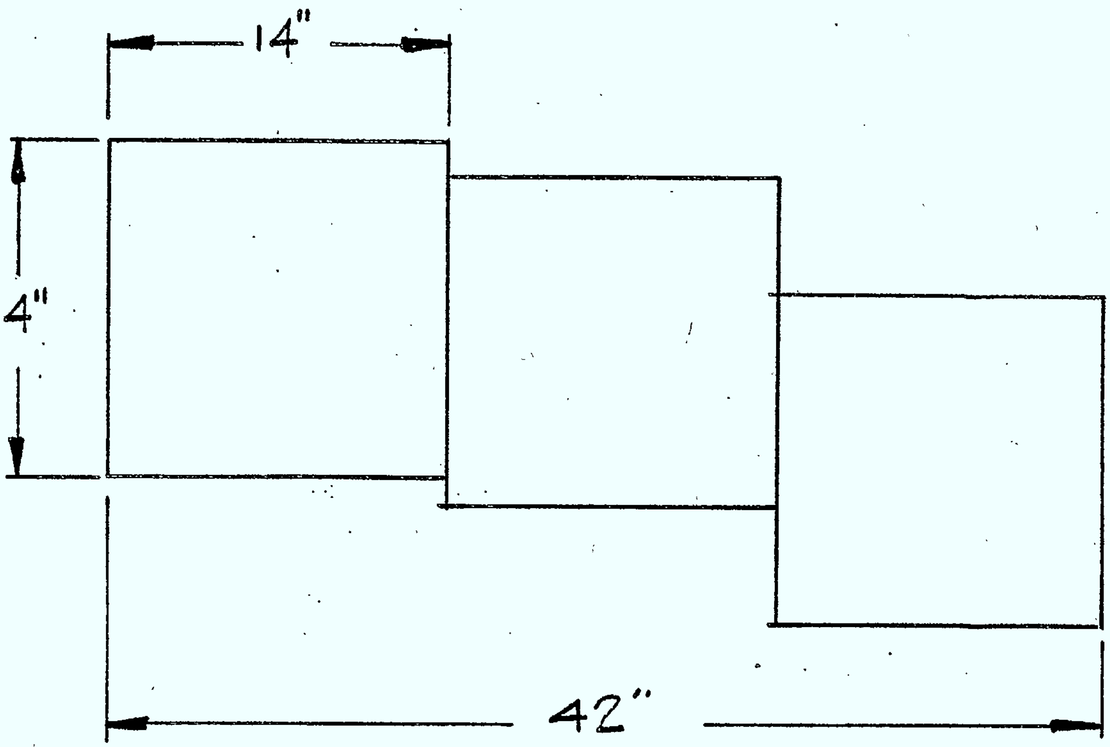
The backhaul antenna at 14/12 GHz is an elliptical aperature reflector. The 12 GHz beam is assumed to be horizontally polarized while the 14 GHz beam is vertically polarized. The antenna is a single horn off-set fed parabola with a focal length of 11.0 inches and an aperture of 21.0 inches by 9 inches.

The horn aperture size is 1.4 inches by 2.8 inches and is 5.0 inches long. The reflector inner surface is gridded in both directions while the outer portion is gridded horizontally only as shown in Figure 6.1-2. This is to reduce the reflector aperture size for the receive beam. Subtracting 0.15 dB for the horn and orthocoupler loss, the net gain at 14.25 GHz is 24.5 dBi while the gain at 11.95 GHz is 26.7 dBi at the extremities.

The contour map at 12 GHz is shown in Figure 6.1-3 and at 14 GHz in Figure 6.1-4.



(a) HORN ASSEMBLY FOR ANTENNA NO. 1



(b) HORN ASSEMBLY FOR ANTENNA NO. 2

FIGURE 6.1-1 HORN ASSEMBLY CONFIGURATION f/D = .625 D = 9.1 m

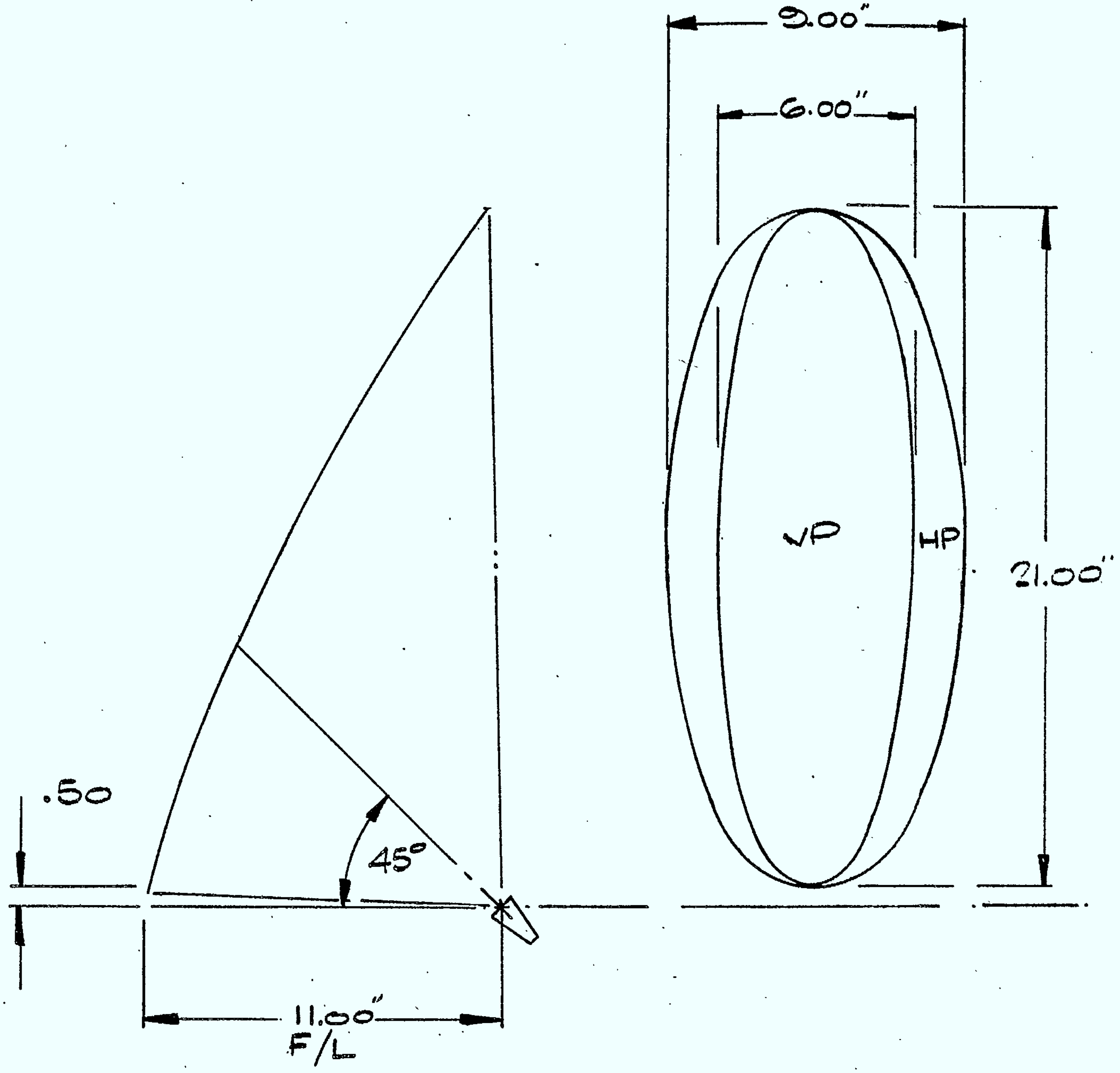


FIGURE 6.1-2 MSAT BACKHAUL 12/14 GHz ANTENNA

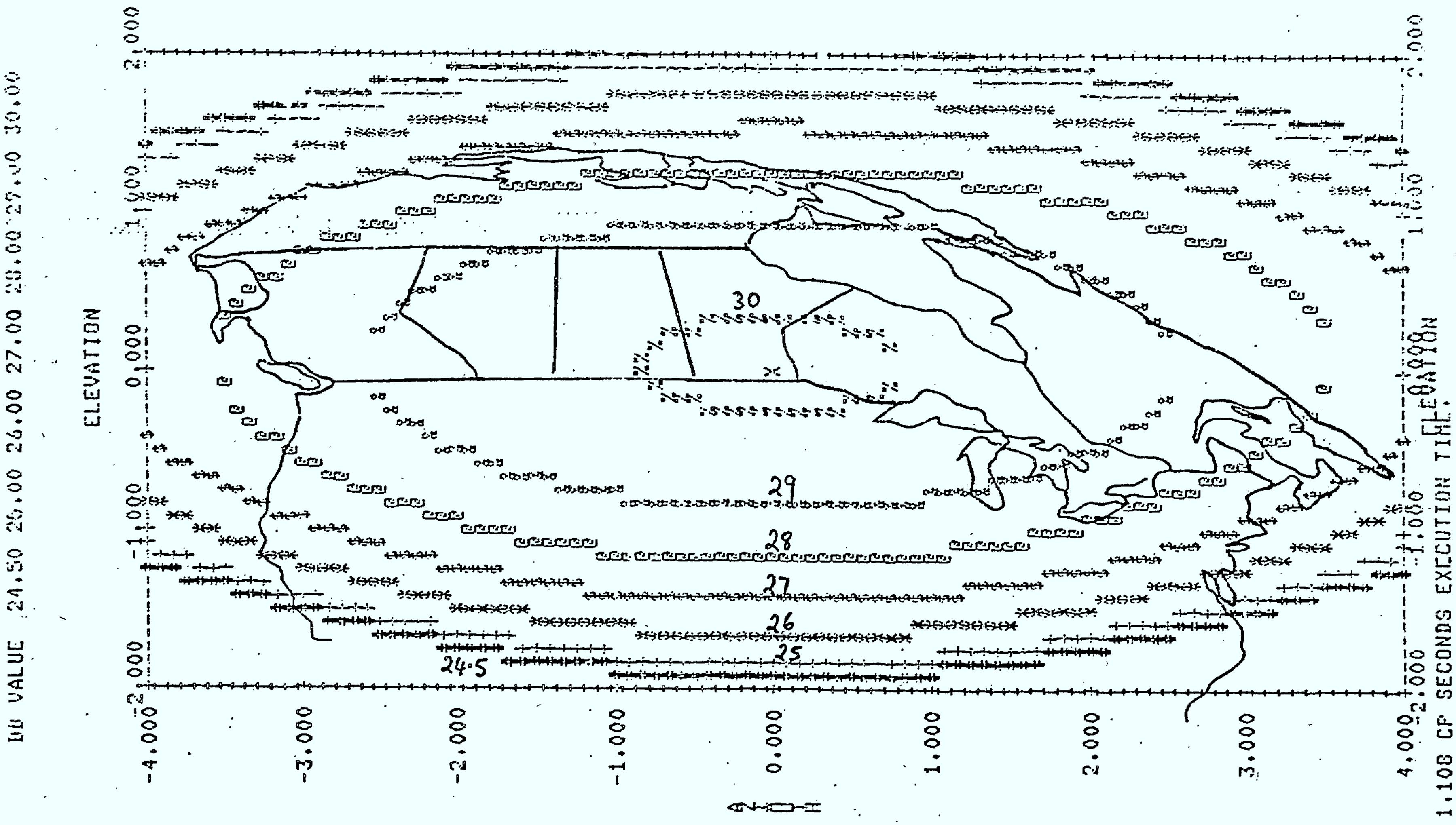


FIGURE 6.1-3 M-SAT, BACKHAUL BEAM, 11.95 GHz, HP

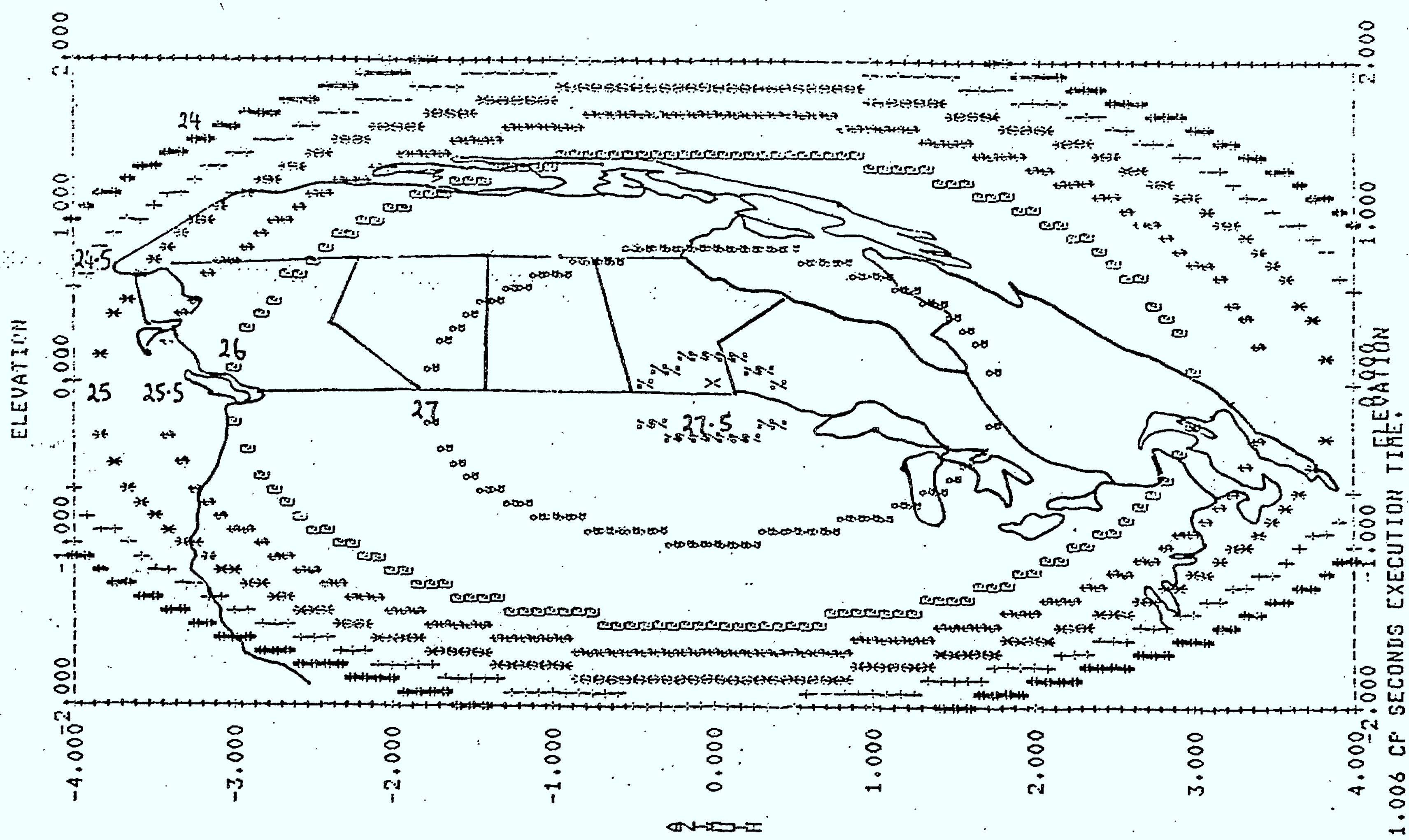


FIGURE 6.1-4 M-SAT, BACKHAUL BEAM, 14.25 GHz, VP

6.2 TRANSPONDER SUBSYSTEM

The transponder block diagram is shown in Figure 6.2-1. There are six beams with a single horn for each beam. Since no beam forming network is required each amplifier carries signals for only one beam and six active amplifiers are required for the six beams. The transponder is divided in two halves for mounting on the north and south panels. Two redundant power amplifiers and low noise amplifiers are provided on each panel for a total of 10 in all. These are connected in an open ring redundancy scheme on each panel. Except for the backhaul, there are no signal interconnections between panels.

Because there is no beam forming network, there is no requirements on phase and amplitude stability or control. This simplifies the transponder design, the design of many components as well as the complexity of integration and test.

The transponder is a double conversion type similar to that selected for the baseline demonstration model as well as for the operational design. This allows the use of all the UHF bandwidth without having to subtract bandwidth for filter guard bands. The conservative approach may not be necessary for the demonstration model if sufficient bandwidth is available. However, it seems fairly certain that bandwidth will be a restriction at least in an operational system if not in the demonstration model so the double conversion transponder is used.

The backhaul frequency has been changed from the military band at 7/8 GHz. 14/12 GHz has been selected for the purpose of providing weight and power estimates. This is the same band selected for the operational system but the trade-off performed then is only partially valid. A single all Canada backhaul beam is used required one redundant transmitter and one redundant receiver. All the frequency segments in the UHF bands are stacked in frequency and translated to the 14/12 GHz band for transmission to/from the gateway stations.

The detailed frequency plan is given in Table 6.2-1. In the forward path, the 14 GHz receive signal is translated to an IF frequency in the vicinity of 400 MHz where the band is separated into six segments for the six UHF beams. The six frequency segments are then translated by different local oscillator frequencies to the appropriate location in the 866-870 MHz band. In the return path, the uplink signals at 821-825 MHz are translated to an IF frequency in the region of 300 MHz where the frequency segments are multiplexed together and translated to 12 GHz for transmission to the gateway station. The local oscillator frequencies are all harmonically related with a separation of 8 MHz and controlled from a master oscillator.

This plan is somewhat different from the baseline. It has been designed to allow the easy addition of the L-band and the DRP's and EPIRB's described in Section 8.0. In addition, the IF bands have been selected so that they do not overlap thus eliminating one possible source of interference.

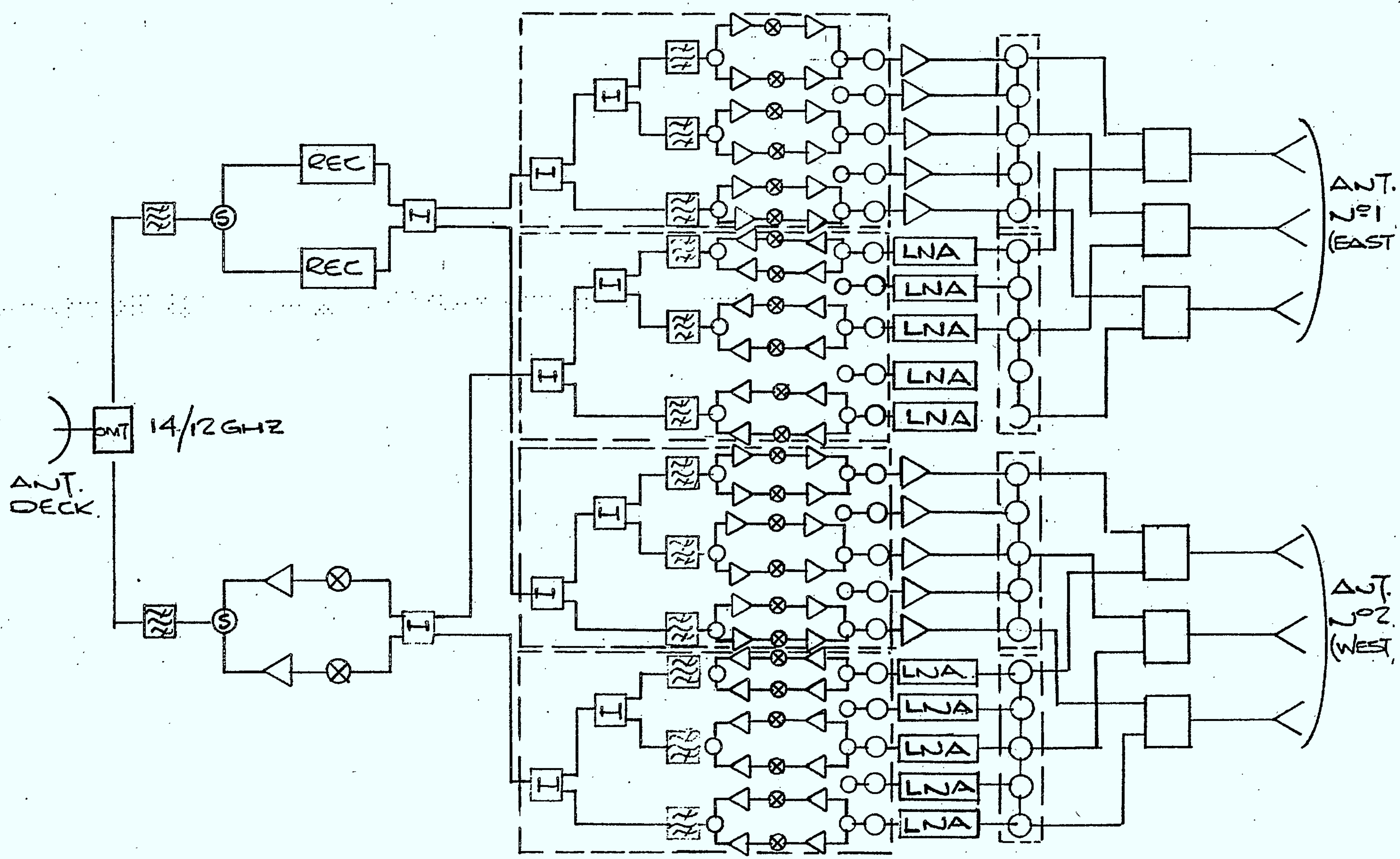


FIGURE 6.2-1 TRANSPONDER BLOCK DIAGRAM FOR SELECTED CONFIGURATION (AX-1)

TABLE 6.2-1 DETAILED FREQUENCY PLAN FOR THE HIGH UHF TRANSPONDER

Forward Link

14 GHz UPLINK	L.O.	IF FILTER BANDS	L.O.	HIGH UHF TRANSMIT
14018 - 14062	13720	298 - 299.33	568	866.0 - 867.33
		307.33 - 308.67	560	867.33 - 868.67
		316.67 - 318.0	552	868.67 - 870.0
		322.0 - 323.33	544	866.0 - 867.33
		331.33 - 332.67	536	867.33 - 868.67
		340.67 - 342.0	528	868.67 - 870.0

Return Link

HIGH UHF RECEIVE	L.O.	IF FILTER BANDS	L.O.	12 GHz DOWNLINK
821.0 - 822.33	472	349.0 - 350.33	11360	11709.0 - 11753.0
822.33 - 822.67	464	358.33 - 359.67		
823.67 - 825.0	456	367.67 - 369.0		
821.0 - 822.33	448	373.0 - 374.33		
822.33 - 823.67	440	382.33 - 383.67		
823.67 - 825.0	432	391.67 - 393.0		

6.3 BUS SUBSYSTEMS

As the bus is unchanged from that of the baseline M-SAT design, the descriptions provided in Sections 6-3 thru 6.8 of the main M-SAT Baseline Performance Document are unchanged for this configuration.

7.0 SPACECRAFT SYSTEM BUDGETS

7.1 Spacecraft and Power Budgets

The spacecraft level mass budget is given in Table 7.1-1 and the power budget in Table 7.1-2. Both the basic Ariane III launch capability of 2470 Kg and the projected capability of 2580 Kg are given. The objective is to obtain 20% margin on the payload weight and 10% on the bus weight for a total of 127 Kg. This has been comfortably exceeded with the basic Ariane III and greatly exceeded with the projected capability. The required power margin is 10% which is exceeded at 11.4%.

TABLE 7.1-1

HIGH UHF DEMONSTRATION MODEL - TWO REFLECTOR

(L-SAT BUS WITH ARIANE III LAUNCH)

WEIGHT SUMMARY

SUBSYSTEM					
REPEATERS		101.1			
High UHF Repeater	101.1				
L-Band Repeater	-				
DRP and EPIRB Repeater	-				
ANTENNAS		106.7			
High UHF Antennas	94.9		(Two at 30 Ft. Diameter)		
Backhaul Antenna	2.7				
Central Support Tower	9.1				
PLATFORM		858.0			
Structure	219.5				
Thermal	49.4				
Attitude Control	87.8				
Power	334.3				
TT&C	21.6				
Propulsion	125.4				
Balance	20.0				
SPACECRAFT DRY MASS		1065.8			

	ARIANE III		ARIANE III GROWTH	
FUEL AND RESIDUALS (7 YEARS LIFE)	1211.7		1266.0	
ADAPTOR	48.3	(13.5%)	48.3	(18.7%)
*MARGIN	144.2		199.9	
LAUNCH CAPABILITY	2470.0		2580.0	

*For 20% Margin on Payload - 10% Margin on Bus.
Total Margin Required = 127 Kg.

TABLE 7.1-2

HIGH UHF ONLY DEMONSTRATION MODEL - TWO REFLECTOR (AX-1)
POWER SUMMARY (WATTS)

	ON STATION POWER REQUIREMENTS	
	SUNLIGHT	ECLIPSE
Payload (High UHF)	1277.8	1063.9
Platform		
Structure	-	-
Thermal	232.0	41.0
AOCS (Incl. SADAPTA)	116.6	116.6
Power (Incl. Harness)	30.5	30.5
TT&C	29.1	29.1
Propulsion	-	-
Subtotal	408.2	217.2
Misc. Losses		
ELI Loss	22.8	22.8
Battery Charging	175.0	-
Shunt Dump Loss	85.7	-
BDR Loss	-	57.5
Subtotal	283.5	80.3
Required	1969.5	1361.4
Available	2195.0	1515.0
Margin	224.5	153.6
	(11.4%)	(11.3%)

7.2 PAYLOAD MASS AND POWER BREAKDOWN

The transponder weight and power breakdown is given in Table 7.2-1 for a total of 101.1 Kg and 73.0 watts. The items with item numbers are generally identical in weight and power to the items in the baseline. The main exceptions are the power amplifiers which have been resized and the frequency synthesizer which has been increased to six frequencies and separated into two units.

The antenna and tower elements including the associated tie-down and deployment mechanisms are listed in Table 7.2-2. The quantity of each item is listed along with the estimated unit and total mass. The total weight of these items is 106.7 Kg.

TABLE 7.2-1

High UHF Repeater (Mass and Power) 2 Reflectors

	Quantity per S/C	Unit Wt (kg)	Total Wt (kg)	Power (watts)
115 Receiver BSF	1	.23	.23	-
116 Receiver BPF	1	.23	.23	-
117 Receiver isolator	2	.07	.14	-
118 Rec. Few. Sw.	2	.07	.14	-
119 Preamp	2	0.9	1.8	1.0
401 SHF/UHF D/C Redund	1	.54	.54	1.8
404/412 Redund SW	2 sets	.25	.50	0.8
402 UHF U/C non red	10	0.2	2.0	14.4
406 UHF PA & EPC	10	6.0	60.0	as per table
407/408 Redund SW	4 sets of 5	0.14	2.8	
408 Duplexer	6	.68	4.1	
410 UHF Preamp	10	.18	1.8	2.2
415 UHF/SHF u/c Red	1	.47	.47	0.4
414 UHF D/C non Red	10	.15	1.5	2.3
416 SHF TWTA (10W)	2	3.0	6.0	35.0
417 W/G SW	1	.64	.64	
418 Freq. synth red	2	1.9	3.8	6.8
419 PWR, Tlm. & Cmd	1	1.5	1.5	
Brack/Hardware	1 set	0.9	0.9	
Cable & Wire Harness	1 set	9.0	9.0	
Master Oscillator	1	1.5		2.3
Backhaul L.O.	1	1.5		6.0
Total			101.1	73.0

PAYLOAD ANTENNA - HIGH UHF (LOCKHEED)

ITEM	UNIT NAME	QUANTITY PER S/C	UNIT MASS (KG)	TOTAL MASS (KG)	REMARKS
	Reflector	2	18.27	36.54	30 Ft. Diameter Aperture
	Deployment Boom:				
	GFEC Boom	2	9.77	19.54	230 Inch Long
	Hinge/Damper Assembly	6	2.12	12.72	Titanium
	Antenna Attach Fitting	2	1.36	2.72	
	Feed Array	2	11.70	23.40	
	SUBTOTAL			94.90	

TABLE 7.2-2 ANTENNA MASS BREAKDOWN

PAYLOAD 14/12 GHz BACKHAUL ANTENNA AND TOWER

ITEM	UNIT NAME	QUANTITY PER S/C	UNIT MASS (KG)	TOTAL MASS (KG)	REMARKS
	14/12 GHz Antenna	1	2.7	2.7	Elliptical Aperture
	Support Tower	1	9.1	9.1	
	SUBTOTAL			11.8	

TABLE 7.2-2 ANTENNA MASS BREAKDOWN (CONT'D)

7.3 BUS MASS AND POWER BREAKDOWN

The bus subsystems are identical to the baseline. The design, performance and mass properties of the bus are given in considerable detail in the final report on the M-SAT baseline spacecraft, listed as an applicable document to this report, and will not be repeated here.

8.0 PARAMETRIC VARIATION

8.1 Summary

The requirement is to add the L-band capability and a low UHF receive capability to the high UHF payload described in Section 6.0. This is accomplished using the L-band quad helix and a single low UHF helix which has only one deployment mechanism, the extension of the helix. The power required for these services is subtracted from the high UHF budget which reduces slightly the number of available channels. The size of the high UHF power amplifiers was not reduced, instead the weight additions were taken from the available margin which reduces the margin to the requirement of 20% on the payload and 10% on the bus.

8.2 PAYLOAD DESCRIPTION

The transponder block diagram is given in Figure 8.2-1. It includes the L-band transponder with an offset reflector antenna and a single helix receive antenna for signals from data relay packages and EPIRB's. The low UHF (DRP at 401 to 403 and EPIRB's at 406-406.1 MHz) are connected directly into the IF combiner without frequency translation. The L-band is translated down to the IF band and combined with the high UHF signal so as to make use of the same backhaul. The detailed frequency plan showing how this is accomplished is given in Table 8.2-1.

TABLE 8.2-1 FREQUENCY PLAN OF TRANSPONDER INCLUDING L-BAND DRP's AND EPIRB'S

Forward Link

UPLINK (MHz)	L.O. (MHz)	IF BAND (MHz)	L.O. (MHz)	DOWNLINK (MHz)
14007 - 14062	13720	287 - 294.5*	1248	1535 - 1542.5*
		298.0 - 299.33	568	866 - 867.33
		307.33 - 308.67	560	867.33 - 868.67
		316.67 - 318.0	552	868.67 - 870.0
		322.0 - 323.33	544	866.0 - 867.33
		331.33 - 332.67	536	867.33 -868.67
		340.67 - 342.0	528	868.67 - 870.0

Return Link

821.0 - 822.33	472	349.0 - 350.33	11360	11709 - 11780
822.33 - 823.67	464	350.33 - 351.67		
823.67 - 825.0	456	367.67 - 369.0		
821.0 - 822.33	448	373.0 - 374.33		
822.33 - 823.67	440	382.33 - 383.67		
823.67 - 825.0	432	391.67 - 393.0		
401.0 - 403.0	-	401.0 - 403.0	DRP's	
406.0 - 406.1	-	406.0 - 406.1	EPIRB's	
1636.5 - 1644.0*	1224	412.5 - 420.0	L-Band	

*Two MHz to be selected from this band

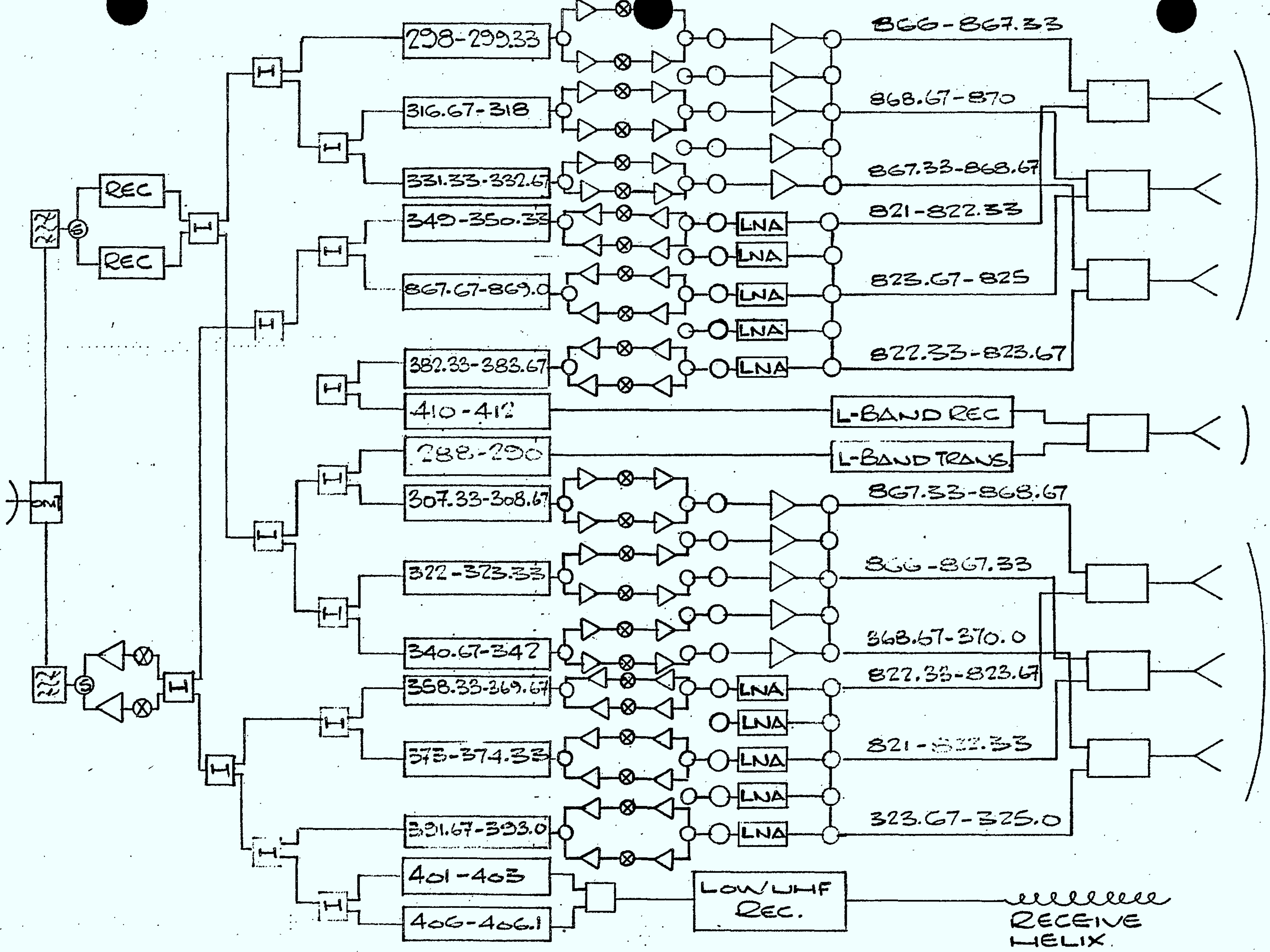


FIGURE 8.2-1 BLOCK DIAGRAM OF HIGH UHF WITH L-BAND LOW UHF RECEIVE ADDED

8.3 CALCULATION OF TRAFFIC CAPACITY

The calculation of the total number of channels is given in Table 8.3-1. The size and weight of the power amplifiers is unchanged from that given in Section 7.0, however, the total number of channels for the whole spacecraft, both during sunlight and eclipse, is reduced. In Table 8.3-2 the number of channels for both narrow band FM and pitch excited LPC are converted to the number of users that can be supported using the standard conditions of 10% blockage and .0125 erlong per user.

TABLE 8.3-1

High UHF only Demonstration model -2 reflector

(Calculation of Channel Capacity)

Coding Type		NBFM	PELPC
Antenna diam	(m)	9.1	9.1
	(ft)	30	30
Number of beams	(Nb)	6	6
Edge EIRP/channel	(dBW)	39.7	33.7
Antenna gain	(dB)	32.5	32.5
Pointing error loss	(dB)	1.0	1.0
Transponder RF power/ch	(dBW)	8.2	2.2
Output circuit loss	(dB)	1.3	1.3
HPA RF power/channel	(dBW)	9.5	3.5
	Watts	8.91	2.24
Max Conversion efficiency (0.3 x .9)	(ratio)	.27	.27
Voice activation		yes	yes
Max number of active ch per beam	NBA	10	40
Max number of assignable ch. per beam	NAPB	10	83
Total number of active channels	NTA	28	111
Total number of assignable channels	Nass	54	258
Max RF power/beam	(dBW)	89.1	89.6
Max DC power per AMP	(watts)	330.1	331.7
Max DC power for 6 AMPs	(watts)	1149.4	1146.4
Remainder of transponder	(watts)	73	73
Total DC power of transponder	(watts)	1222.4	1219.4
No. of active ch in eclipse		19	78
No. of assignable ch in eclipse		32	177
Total DC power in eclipse	(watts)	986.7	1002.2
Unit weight of VHPA & EPC	(kg.)	6.0	6.0
Total wt of 10 HPAs plus EPC	(kg.)	60.0	60.0
Channel spacing	(RH)	30	5.0
Freq. hose		yes	yes
Bandwidth per beam	(MH)	1.333	1.333
Required bandwidth/beam	(MH)	.33	.415

TABLE 8.3-2

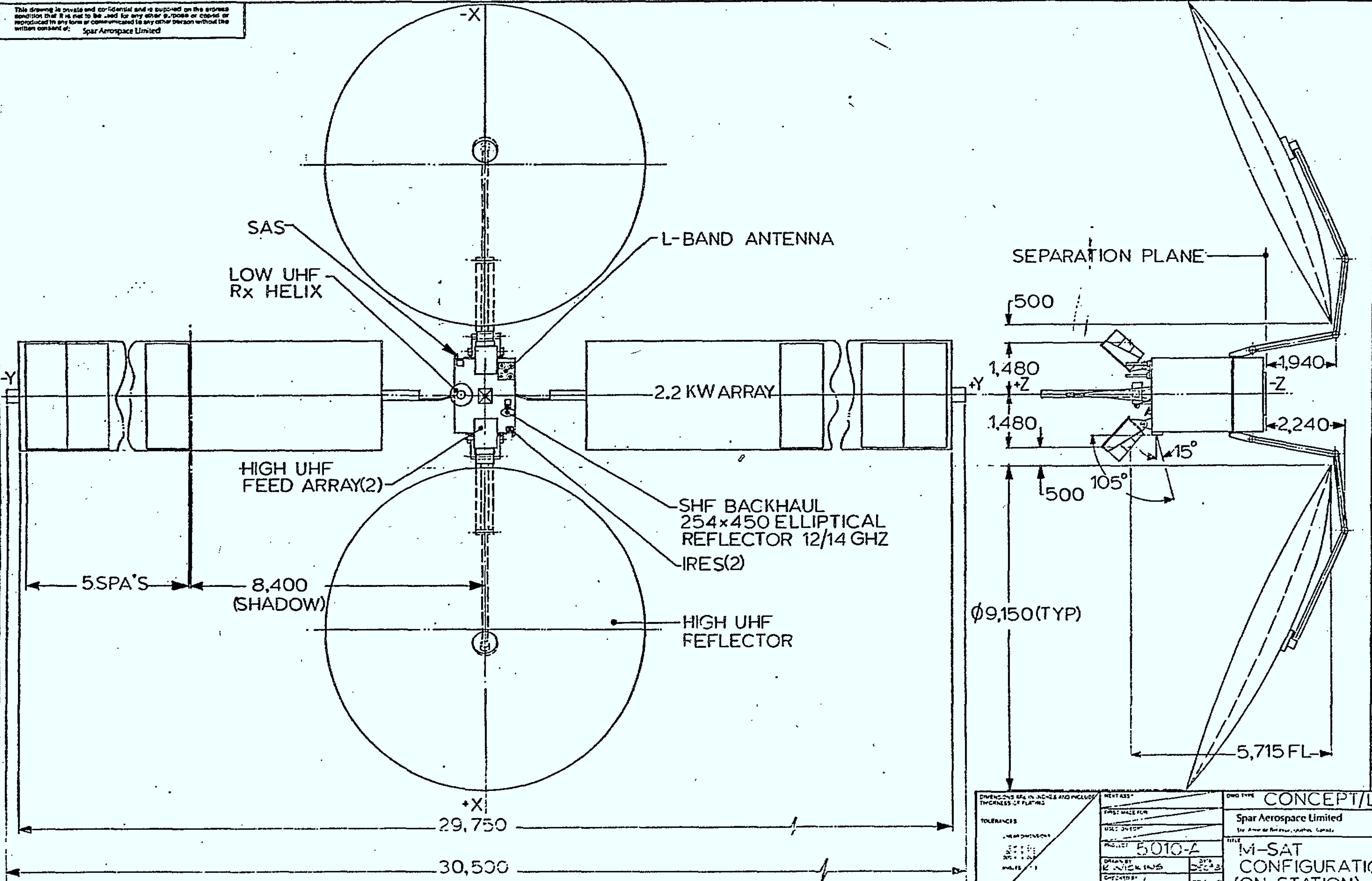
TOTAL NUMBER OF USERS THAT CAN BE SUPPORTED IN BOTH SUNLIGHT AND ECLIPSE FOR NBFM AND PELPC

	Total Channels	Total Erlongs 10% Blockage	Total Users .0125 Erl/User
Sunlight			
NBFM	54	52	4160
PELPC	258	287	22962
Eclipse			
NBFM	32	27	2160
PELPC	177	194	15520

8.4 SPACECRAFT CONFIGURATION

The spacecraft configuration both fully deployed on station and stowed for launch in the Ariane III shroud is shown in drawing number 2611755. The single low UHF helix is mounted on a pedestal on the antenna deck on the north side of the spacecraft. Only a single deployment is required, an extension of the helix to its full length. The L-band antenna and the 14/12 GHz backhaul antenna are mounted on the south side to improve balance. Both antennas are tipped north but it was found that it was possible to obtain adequate clearance for these two antennas with respect to the central tower and the high UHF feed assembly.

In the deployed state one problem appears, the low UHF helix extends beyond the TT&C bicone. This is no problem while on station but will interfere with the telemetry and command if attitude control is lost during the mission life.



DIMENSIONS IN MILLIMETRES

ASP

DO NOT SCALE DRAWING

PROJECT 5010-A

DRAWN BY K. WICKINS

DWG TYPE CONCEPT/LAYOUT

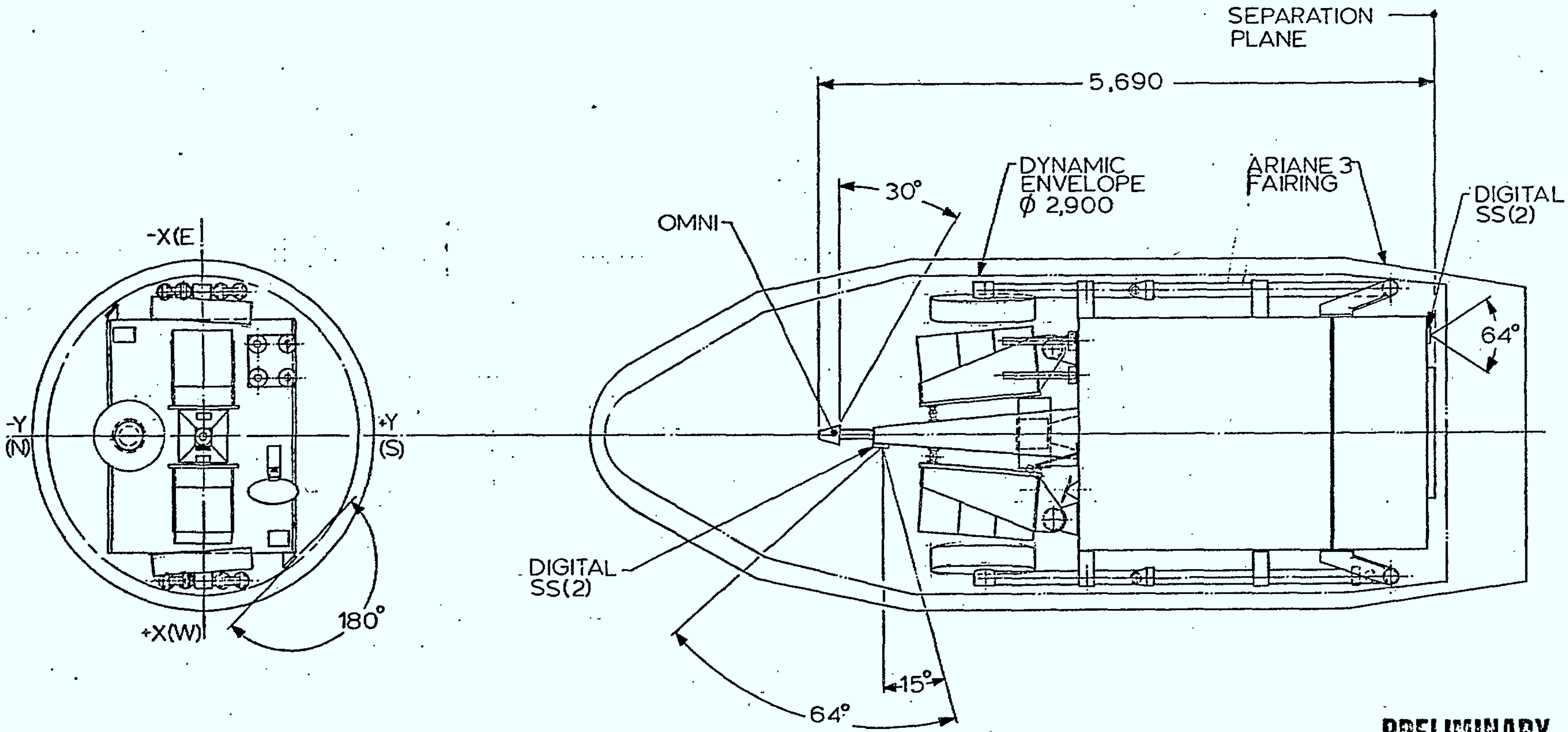
Spar Aerospace Limited

SPAR

TITLE M-SAT CONFIGURATION AX3 (ON STATION)

CODE IDENT NO 37957 | D | 2611755

SCALE 1/50 | SHEET 2 OF 2



PRELIMINARY
NOT TO BE USED FOR CONTRACTUAL, PROCUREMENT OR PRODUCTION PURPOSES

ASP

DIMENSIONS IN MILLIMETRES

DO NOT SCALE DRAWING

DWG TYPE: CONCEPT/ LAYOUT

Spar Aerospace Limited

PROJECT: 5010-A

DRAWN BY: K.WICKINS

TITLE: M-SAT CONFIGURATION AX 3 (LAUNCH)

CODE IDENT NO: 37957 | D | 2611755

SHEET 1 OF 2

8.5 MASS AND POWER BUDGETS

The spacecraft level mass and power budgets are given in Tables 8.5-1 and 8.5-2 respectively. Both the basic Ariane III launch capability of 2470 Kg and the projection to 2580 Kg are given. The margin exceeds the objective of 127 Kg for the basic Ariane III and greatly exceeds it for the projected capability.

The weight and power estimates for the L-band repeater and low UHF receiver are given in Table 8.5-3. These are in addition to the high UHF repeater which is unchanged in weight from that given in Section 7.0. The two additional antennas are listed in Table 8.5-4.

TABLE 8.5-1

HIGH UHF WITH DRP AND EPIRB DEMONSTRATION MODEL
(L-SAT BUS WITH ARIANE III LAUNCH)

WEIGHT SUMMARY (KG)

SUBSYSTEM		
REPEATERS		108.6
High UHF Repeater	101.1	
L-Band Repeater	6.67	
DRP and EPIRB Repeater	0.84	
ANTENNAS		115.0
High UHF Antennas	93.1	
Backhaul Antenna	2.7	
L-Band Antenna	3.2	
DRP and EPIRB Antenna	6.8	
Central Support Tower	9.1	
PLATFORM		858.0
Structure	219.5	
Thermal	49.4	
Attitude Control	87.8	
Power	334.3	
TT&C	21.6	
Propulsion	125.4	
Balance	20.0	
SPACECRAFT DRY MASS		1081.6

	ARIANE III		ARIANE III GROWTH	
FUEL & RESIDUALS (7 YEARS LIFE)	1211.7		1266.0	
ADAPTOR	48.3		48.3	
MARGIN*	128.4	(11.9%)	184.1	(17%)
LAUNCH CAPABILITY	2470.0		2580.0	

*[illegible]% MARGIN ON PAYLOAD + 10% MARGIN ON BUS = 127 Kg.

TABLE 8.5-2

HIGH UHF AND DRP AND EPIRB DEMONSTRATION MODEL (POWER SUMMARY)

	ON STATION POWER REQUIREMENTS	
	SUNLIGHT	ECLIPSE
PAYLOAD		
High UHF	1222.4	1002.2
L-Band	58.6	58.6
DRP and EPIRB	1.3	1.25
SUBTOTAL	1282.3	1062.1
PLATFORM		
Structure	-	-
Thermal	232.0	41.0
AOCS (Incl. SADAPTA)	116.6	116.6
Power (Incl. Harness)	30.5	30.5
TT&C	29.1	29.1
Propulsion	-	-
SUBTOTAL	408.2	217.2
MISC. LOSSES		
ELI Loss	22.8	22.8
Battery Charging	175.0	-
Shunt Dump Loss	85.7	-
BDR Loss	-	57.5
SUBTOTAL	283.5	80.3
REQUIRED	1974.0	1359.6
AVAILABLE	2195.0	1515.0
MARGIN (10%)	221.0	155.4

TABLE 8.5-3

PAYLOAD WEIGHT AND POWER SUMMARY

L-Band Repeater

	L-Band	Repeater	Unit Weight (Kg)	Weight (Kg)	Power (Watts)
306	Duplexer	1	.68	.68	
302	Driver Amp.	2	.28	.56	2.4
303	Power Amp.	2	1.82	3.64	55.0
304	Tx Red SW	1	.09	.09	
305	Tx BSF	1	.23	.23	
307	Rx BSF	1	.32	.32	
308	Rx Red SW	1	.09	.09	
309	Preamp-D/C	1	.28	.28	.75
301	U/C - Amp.	1	.28	.28	0.4
	L.O. source derived from high UHF				
	Brackets and Cabling set		.50	.50	
		Total		6.67 Kg	
				58.60 Kg	

DRP and EPIRB Receiver

102	Rx Red SW	1	.09	.09	
103	Preamp.	1	.27	.27	0.45
111	UHF Return	1	.28	.28	0.8
	Misc.	set	.20	.20	
		Total		.84	1.25

TABLE 8.5-4 ANTENNA MASS BREAKDOWN

PAYLOAD L-BAND AND LOW UHF ANTENNA

ITEM	UNIT NAME	QUANTITY PER S/C	UNIT MASS (KG)	TOTAL MASS (KG)	REMARKS
	L-Band Antenna				
	Helix Elements (4 off)	set	0.91	0.91	
	Ground Plane Cups (4 off)	set	0.68	0.68	
	Coax Feed	1	0.23	0.23	
	Support Base & Attachment Hardware	1	1.36	1.36	
	Subtotal			3.18	
	Low UHF Antenna	1	6.8	6.8	Single Helix
	Subtotal			10.0	

APPENDIX

Volume two of the Phase A final report given as an applicable document contains specifications for the various subsystems on the spacecraft. These will require updating for the configuration described herein as indicated in the list below:

1.	CMCSS Repeater	Delete
2.	Maritime Mobile Repeater	Modifications Required
3.	Commercial Mobile Repeater	Modifications Required
4.	CMCSS Antenna Subsystem	Delete
5.	Maritime Mobile Antenna	Minor Modifications Required
6.	Commercial Mobile Antenna	Minor Modifications Required
7.	L-SAT TT&C Subsystem	Unchanged
8.	L-SAT Power Subsystem	Unchanged
9.	L-SAT Attitude and Orbit Control Subsystem	Unchanged
10.	Structure Subsystem	Unchanged
11.	L-SAT Thermal Control Subsystem	Unchanged
12.	L-SAT Combined Propulsion Subsystem	Unchanged
13.	L-SAT Solar Array Subsystem	Unchanged
14.	L-SAT Electrical Distribution and Pyrotechnic Subsystem	Unchanged