

Book Case.

①
DATA COLLECTION
AND
FISHERIES SURVEILLANCE
SATELLITE PROJECT
PHASE 1
PRELIMINARY SYSTEM DESIGN REVIEW

29 JUNE, 1976

P
91
C655
D639
1976

ADIAN ASTRONAUTICS LIMITED

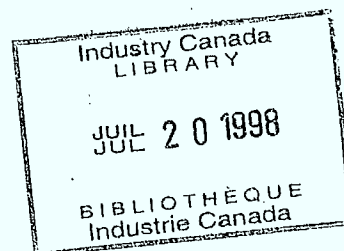
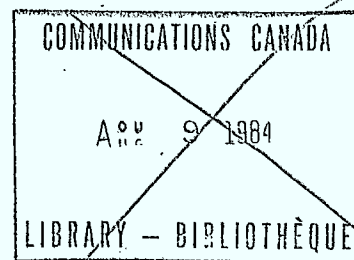
CANADIAN ASTRONAUTICS LIMITED

Suite 221, 39 Bell Mews Plaza, Highway 15, Bells Corners, Ontario K2H 8R2
(613) 829-2025

P
91
C655
D639
1976

①
DATA COLLECTION
AND
FISHERIES SURVEILLANCE
SATELLITE PROJECT
PHASE 1
PRELIMINARY SYSTEM DESIGN REVIEW

29 JUNE, 1976



P
91
C655
D639
1976

DD 466141Z
DL 4661424

10003720

TABLE OF CONTENTS

CHAPTER 1 SYSTEM CONCEPT AND REQUIREMENTS

- 1.1 SYSTEM CONCEPT
- 1.2 DATA COLLECTION SYSTEM
- 1.3 FISHERIES SURVEILLANCE SYSTEM

CHAPTER 2 DATA COLLECTION SYSTEM DESIGN

- 2.1 SYSTEM CAPACITY ANALYSIS
- 2.2 MESSAGE ENCODING AND MODULATION
- 2.3 DCP SIGNAL FREQUENCY
- 2.4 RF LINK
- 2.5 DATA DECODER
- 2.6 DATA PROCESSING AND STORAGE
- 2.7 DATA DISTRIBUTION

CHAPTER 3 FISHERIES SURVEILLANCE SYSTEM DESIGN

- 3.1 LOCATION ACCURACY/CAPACITY ANALYSIS
- 3.2 ID ENCODING AND MODULATION
- 3.3 LIP FREQUENCIES
- 3.4 RF LINK
- 3.5 LIP DECODER
- 3.6 DATA PROCESSING

CHAPTER 4 SYSTEM CONFIGURATION

- 4.1 DATA COLLECTION PLATFORMS
- 4.2 LOCATION INDICATION PLATFORMS
- 4.3 GROUND STATIONS
- 4.4 MISSION CONTROL
- 4.5 SATELLITE ORBITS

TABLE OF CONTENTS (CONT'D)

CHAPTER 5 SPACECRAFT CONFIGURATION

- 5.1 SPACECRAFT DESIGN CONSTRAINTS
- 5.2 SUBSYSTEM ALTERNATIVES
- 5.3 CONFIGURATION TRADEOFFS
- 5.4 CONFIGURATION ALTERNATIVES
- 5.5 BASELINE SPACECRAFT CONFIGURATION

CHAPTER 6 PRELIMINARY COST ESTIMATES

CHAPTER 1

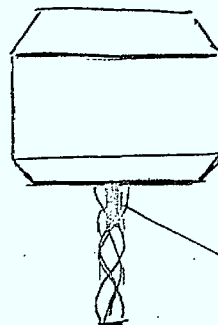
SYSTEM CONCEPT

AND REQUIREMENTS

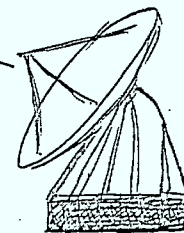
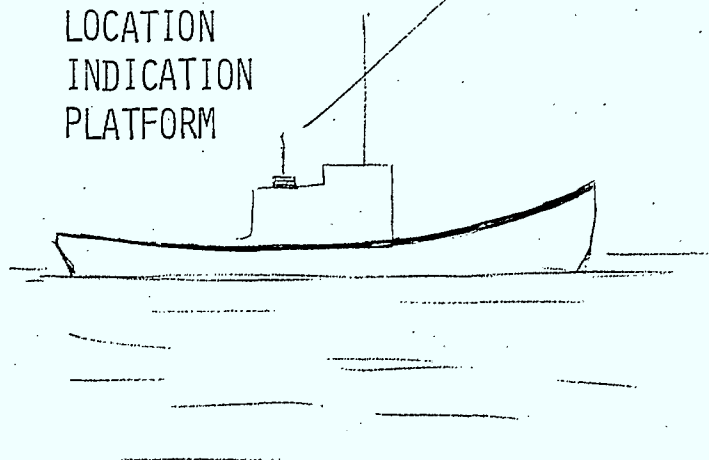
1-1 SYSTEM CONCEPT

- o POLAR ORBIT
- o LOW ALTITUDE, 1000-1500 KM
- o SCOUT LAUNCHED
- o OPERATIONAL
- o 2000 DATA COLLECTION PLATFORMS - DCP'S
- o 1000 LOCATION INDICATING PLATFORMS - LIP'S
- o CENTRAL GROUND STATIONS
- o CANADIAN COVERAGE
 - 40 W LONG BY 42 N LAT BY 142 W LONG
- o SYSTEM LIFETIME - 10 YEARS
- o LOW COST

SATELLITE



LOCATION
INDICATION
PLATFORM



TELEMETRY
DCP DATA
LIP DATA

DATA
COLLECTION
PLATFORM



SYSTEM CONFIGURATION

1-2

DATA COLLECTION SYSTEM

REQUIREMENTS:

DCP'S	2000
LOCATABLE	100
ID CODE CAPACITY	2048 (HIGHER NO. PREFERABLE)
BIT ERROR RATE	10^{-4}
RECEPTION FREQUENCY	95% PROBABILITY OF RECEIVING EACH DCP EVERY 2 HOURS
CAPACITY	24 SETS OF DATA PER DAY
LOCATION ACCURACY	5 KM - 3 SIGMA (ASSUME 5 KM/HR RANDOM DCP VELCITY)
DCP VERIFICATION	ON SITE
COVERAGE	40 W LONG BY 42 N LAT BY 145 W LONG BY 55 N LAT BY 142 W LONG

1-3

FISHERIES SURVEILLANCE SYSTEM

REQUIREMENTS:

LIP's	700 EAST COAST 300 WEST COAST
ID CODE CAPACITY	2048
LOCATION ACCURACY	5 KM 3 SIGMA (ASSUME 10 KM/HR RANDOM LIP VELOCITY)
ID CODE BIT ERROR RATE	10^{-4}
LOCATION FREQUENCY	48 HR
COVERAGE	EAST AND WEST COASTS ATLANTIC: 40 N LAT TO 55 N LAT PACIFIC: 42 N LAT TO 55 N LAT

CHAPTER 2

DATA COLLECTION

SYSTEM DESIGN

DATA COLLECTION SYSTEM

2-1 SYSTEM CAPACITY ANALYSIS

A. SYSTEM MODEL

- o RANDOM ACCESS
 - DUTY CYCLE
 - BIT RATE
 - MESSAGE LENGTH
- o FREQUENCY DIVERSITY
 - NUMBER OF CHANNELS
- o TYPES OF DCP'S
 - VARIABLE MESSAGE LENGTHS
 - LATITUDE VARIATION
- o ORBIT GEOMETRY
 - AVERAGE VISIBILITY TIME

B. PROBABILITY OF SUCCESSFUL MESSAGE TRANSMISSION

DEFINE:

N_I = NUMBER OF INFORMATION BITS FROM D.C.P. STATION TYPE "I"
(INCLUDING IDENTIFIER AND PARITY BITS)

M_I = NUMBER OF D.C.P. STATIONS TYPE "I".

P_I = PROBABILITY OF SUCCESSFUL TRANSMISSION OF N_I INFORMATION BITS

P_{IJ} = P_I IN PRESENCE OF N_J BIT MESSAGE INTERRUPTS

R = BIT RATE (BITS/SECOND)

τ = DUTY CYCLE PERIOD (SECONDS)

Q = NUMBER OF CHANNELS

X = $QR \propto$ TOTAL BANDWIDTH (Hz)

T = AVERAGE COVERAGE TIME FOR A TWO HOUR PERIOD

THEN:

$$\begin{aligned} P_{IJ} &= \left\{ 1 - \left(\frac{N_I + N_J}{\tau R} \right) \left(\frac{1}{Q} \right) \right\}^{M_J} \\ &= \left\{ 1 - \frac{N_I + N_J}{\tau X} \right\}^{M_J} \end{aligned}$$

$$P_I = \prod_J P_{IJ}$$

C. MINIMUM BANDWIDTH SOLUTION

PROBABILITY OF ONE OR MORE SUCCESSFUL TRANSMISSIONS TO BE GREATER THAN .95 IMPLIES

$$(1 - \min_I P_I)^{T/\tau} < 0.05$$

FOR T = 15 MINUTES, MINIMUM X OCCURS AT $\tau = 3$ MINUTES

THE FOLLOWING TWO D.C.P. DISTRIBUTION MODELS WERE CONSIDERED.

STATION MODEL	I	NO. OF DATA BITS N _I -Z	NO. OF DCP'S M _I
SM1	1	50	1250
	2	100	400
	3	150	75
	4	200	185
	5	250	75
	6	600	45
	7	1250	10
SM2	1	50	1250
	2	100	350
	3	150	60
	4	200	175
	5	250	75
	6	600	55

NOTE: THE NUMBER OF SYNCHRONIZATION (~15) AND IDENTIFICATION (~10) BITS IS REPRESENTED BY Z. THE SM2 MODEL PROVIDES FOR DUTY CYCLE DEPENDENCE ON LATITUDE: ALL STATIONS NORTH OF 60° LATITUDE WERE GIVEN HALF THE STANDARD DUTY CYCLE. ALSO THE FROZEN SEA MESSAGES WERE SPLIT INTO TWO SMALLER MESSAGE LENGTHS.

D. RESULTS

CASE	MODEL	DESCRIPTION	MINIMUM X
1	SM1	MESSAGE LENGTHS BROKEN INTO STANDARD 50 BIT MESSAGES - 95% CRITERIA APPLIED TO EACH STD. MESSAGE	3,500
2	SM1	VARIABLE MESSAGES BETWEEN 50 & 1250 BITS	20,000
3	SM1	CHANNELIZATION (1) 50-100 BIT MESSAGES X=...2500 (2) 150-250 BIT MESSAGES X=...1200 (3) 700-1250 BIT MESSAGES X=...1000	5,000*
4	SM2	VARIABLE MESSAGES BETWEEN 50 & 600 BITS	10,000
5	SM2	CHANNELIZATION (1) 50-100 BIT MESSAGE X=...2500 (2) 150-600 BIT MESSAGE X=...2500	5,000

* IN ORDER TO INSURE FREQUENCY SEPARATION BETWEEN MESSAGE CHANNELS, DOPPLER SHIFT GUARD BANDS (APPROX. 16KHZ) MUST BE APPLIED TO EACH CHANNEL.

DATA COLLECTION SYSTEM

2-2

MESSAGE ENCODING AND MODULATION

ALTERNATIVES

(A) ERTS FORMAT

- o 2.5 KBPS RATE 1/2 MANCHESTER ENCODED (5 KBPS CHIPRATE)
- o CHIPS FSK'ED ± 3.5 KHz DEVIATION
- o FIXED MESSAGE LENGTH 64 BITS - 95 BITS TOTAL

(B) MODIFIED ERTS FORMAT

- o AS (A) BUT WITH VARIABLE MESSAGE LENGTH. SMALL NUMBER OF BITS IN DATA SEQUENCE INDICATE MESSAGE LENGTH.

(C) DPSK

- o 2.5 KBPS $\pm 90^\circ$ PHASE SHIFT KEYING.
- o NO ENCODING.
- o VARIABLE MESSAGE LENGTH.

(D) ENCODED DPSK

- o 2.5 KBPS DATA RATE, RATE 1/2 OR RATE 3/4 CONVOLUTIONAL CODED (5 KBPS OR 3.33 KBPS CHIPRATE). $\pm 90^\circ$ PHASE SHIFT.
- o VARIABLE MESSAGE LENGTH.

(E) ENCODED MSK (MINIMUM SHIFT KEYING)

- o AS (D) BUT PHASE SHIFT $< 90^\circ$ ($\sim \pm 1$ RADIAN)

DATA COLLECTION SYSTEM

2-2

MESSAGE ENCODING AND MODULATION

TRADEOFFS

ALTERNATIVE	ADVANTAGES	DISADVANTAGES
ERTS FORMAT	<ul style="list-style-type: none">o ESTABLISHED, RELIABLEo EXISTING DCP'S	<ul style="list-style-type: none">o INEFFICIENT BANDWIDTH USAGEo FIXED MESSAGE LENGTH
MODIFIED ERTS FORMAT	<ul style="list-style-type: none">o ESTABLISHED, RELIABLEo EXISTING DCP'S MAY BE MODIFIED	<ul style="list-style-type: none">o INEFFICIENT BANDWIDTH USAGE
DPSK	<ul style="list-style-type: none">o MORE EFFICIENT BANDWIDTH (1.2XBIT RATE) THAN ERTSo ESTABLISHED, RELIABLE	<ul style="list-style-type: none">o NEW DCP'S OR MODIFIED DCP'So SUSCEPTABLE TO MULTI-PATH
ENCODED DPSK	<ul style="list-style-type: none">o BETTER BIT ERROR RATE THAN DPSK (1.2XCHIP RATE)o ESTABLISHED, RELIABLE	<ul style="list-style-type: none">o REQUIRES MORE BANDWIDTH THAN DPSK (1.2X CHIP RATE)
ENCODED MSK	<ul style="list-style-type: none">o MORE EFFICIENT BANDWIDTH THAN EQUIVALENT CHIP RATE PSK	<ul style="list-style-type: none">o SLIGHTLY WORSE BIT ERROR RATE THAN ENCODED DPSKo RELATIVELY UNPROVEN FOR OPERATIONAL USE

SELECTION: ENCODED DPSK
DATA RATE 2.5 Kbps
RATE 3/4 CONVOLUTIONAL ENCODER
CHIP RATE 3.33 Kbps
CHIP ERROR RATE $<10^{-4}$ FOR 6 DB MARGIN OVER WORST
CASE DESIGN CONDITION (52 DBHZ)
DATA ERROR RATE $<<10^{-4}$

2-3

DATA COLLECTION SYSTEM

DCP SIGNAL FREQUENCY

BANDWIDTH REQUIREMENT 100 KHz

ALTERNATIVES

- (A) UHF BAND 401-403 MHz
- (B) VHF BAND 100-200 MHz
- (C) L OR S BAND 1500-2500 MHz

TRADE-OFFS

BAND	ADVANTAGES	DISADVANTAGES
UHF	<ul style="list-style-type: none">o ESTABLISHED SPECTRUM ALLOCATIONo AVAILABLE DCP HARDWAREo LOW GALACTIC NOISEo ACCEPTABLE PATH LOSS FOR LOW POWER (5W) TRANSMITTERS	
VHF	<ul style="list-style-type: none">o LOWER PATH LOSS	<ul style="list-style-type: none">o HEAVY USE OF SPECTRUMo NO SPECTRUM ALLOCATIONo GALACTIC NOISE PROBLEM
L,S	<ul style="list-style-type: none">o MORE SPECTRUM AVAILABLE	<ul style="list-style-type: none">o MUCH HIGHER PATH LOSS (>10DB)

SELECTION UHF 401-403 MHz

RF LINKA. DCP UPLINK BUDGET

TRANSMITTER POWER (5 WATT)

37 DBM

CIRCUIT, FEED LOSSES

- 1 DB

0° ELEVATION90° ELEVATION

TRANSMITTING ANTENNA GAIN

+ 11.5 DB

- 2 DB

PATH LOSS (400 MHz)

-156.9 DB

-146.4 DB

TRANSMITTING ANTENNA POINTING

INACCURACY $\pm 5^\circ$

- 0.5 DB

- 0.5 DB

POLARIZATION LOSS

- 2 DB

- 2 DB

SATELLITE RECEIVE ANTENNA GAIN

7 DB

- 2 DB

RECEIVE ANTENNA POINTING INACCURACY $\pm 5^\circ$

- 1 DB

0 DB

TOTAL RECEIVED POWER

-115.9 DBM

-116.9 DBM

TRANSMITTER MODULATION LOSS

- 0.45 DB

- 0.45 DB

RECEIVED SIGNAL POWER

-116.3 DBM

-117.3 DBM

RECEIVER NOISE SPECTRAL DENSITY

-170.8 DBM/Hz

 $T_{\text{SYSTEM}} = 600^\circ\text{K}$ S/N_0

54.5 DBHz

53.5 DBHz

2-4

RF LINKB. DATA DOWNLINK BUDGET

SPACECRAFT TRANSMITTER POWER (5 WATT)

37DBM

CIRCUIT LOSSES

- 1DB

0° ELEVATION90° ELEVATION

TRANSMITTING ANTENNA GAIN

PATH LOSS

470 MHz

-158.3DB

-147.8DB

1.6 GHz

-168.9DB

-158.4DB

TRANSMITTING ANTENNA POINTING

INACCURACY LOSS

- 1 DB

0 DB

POLARIZATION LOSS

- 2 DB

- 2 DB

RECEIVE ANTENNA GAIN

20 DB

20 DB

470 MHz ~ 2.5 M DIA. 20° BEAMWIDTH

1.6 GHz ~ .75 M DIA. 20° BEAMWIDTH

RECEIVE ANTENNA POINTING

0 DB

0 DB

INACCURACY LOSS

TOTAL RECEIVED POWER

470 MHz

- 98.3 DBM

- 95.8 DBM

1.6 GHz

-108.9 DBM

-106.4 DBM

TRANSMITTER MODULATION LOSS

DCP 45%

- 3.5 DB

LIP 45%

- 3.5 DB

TLM 10%

- 10 DB

RECEIVER NOISE SPECTRAL DENSITY

470 MHz T_{SYSTEM} 300°

-173.8 DB/HZ

1.6 GHz T_{SYSTEM} 150°

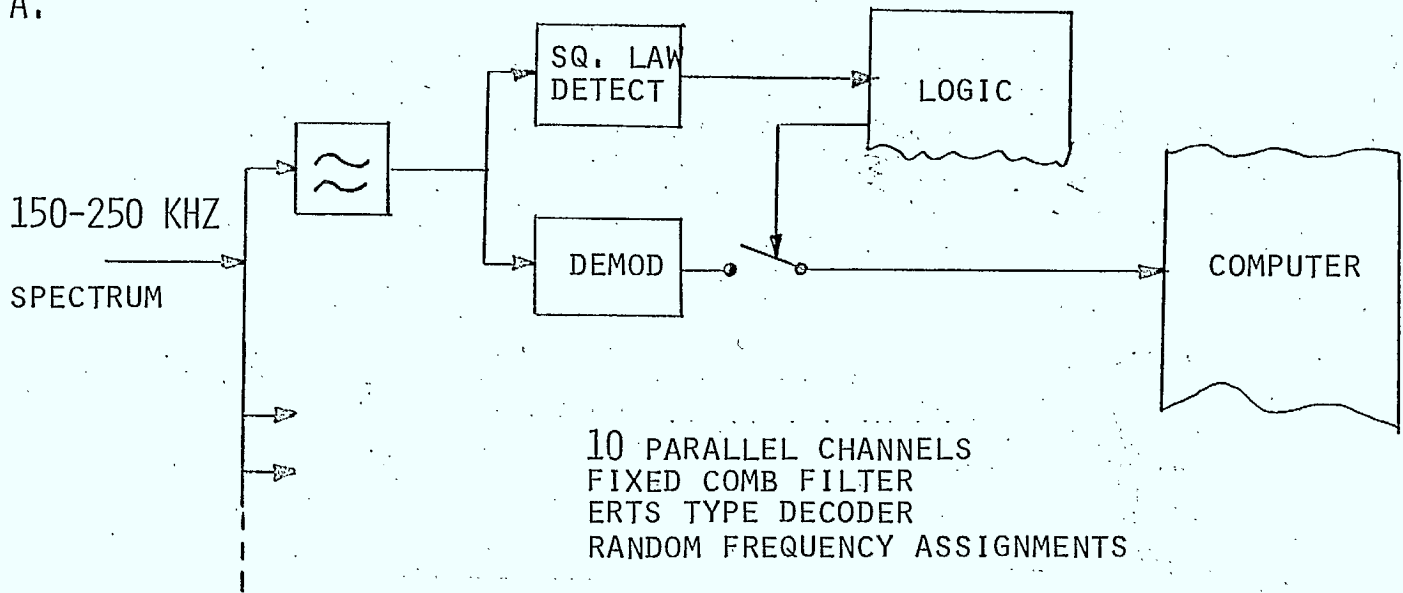
-176.8 DB/HZ

B. DATA DOWNLINK BUDGET (CON'T)

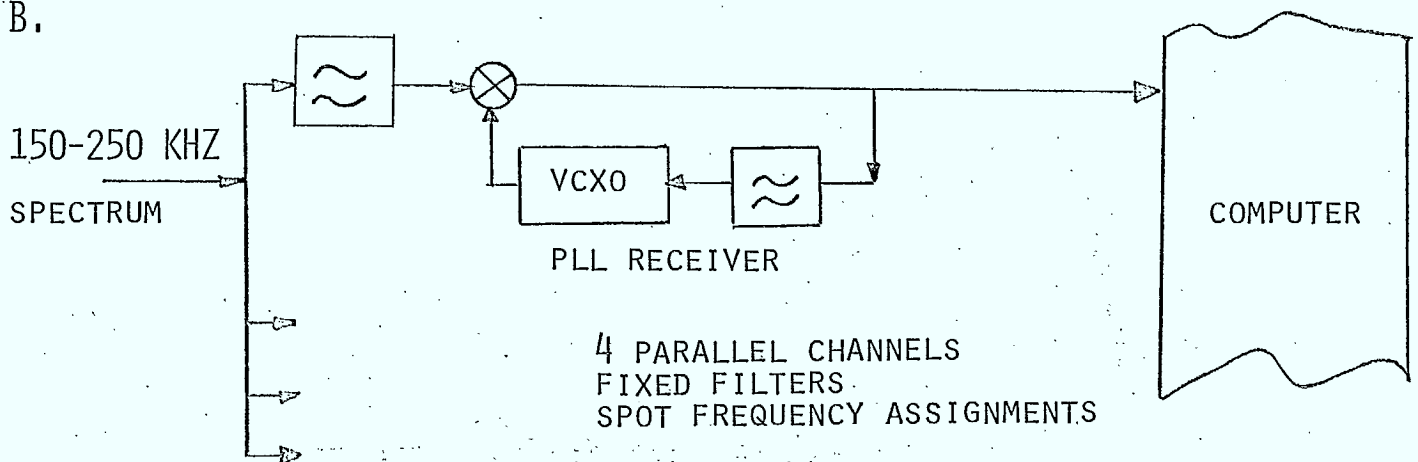
	<u>0° ELEVATION</u>	<u>90° ELEVATION</u>
DCP RECEIVED POWER (DBM)		
470 MHz	-101.8	- 99.3
1.6 GHz	-112.4	-109.9
LIP RECEIVED POWER (DBM)		
470 MHz	-101.8	- 99.3
1.6 GHz	-112.4	-109.9
TLM RECEIVED POWER (DBM)		
470 MHz	-108.3	-105.8
1.6 GHz	-118.9	-116.4
S/N ₀ DCP (DBHz)		
470 MHz	72.0	74.5
1.6 GHz	64.4	66.9
S/N ₀ LIP (DBHz)		
470 MHz	72.0	74.5
1.6 GHz	64.4	66.9
S/N ₀ TLM (DBHz)		
470 MHz	65.5	68.0
1.6 GHz	57.9	60.4

2-5 DATA DECODER

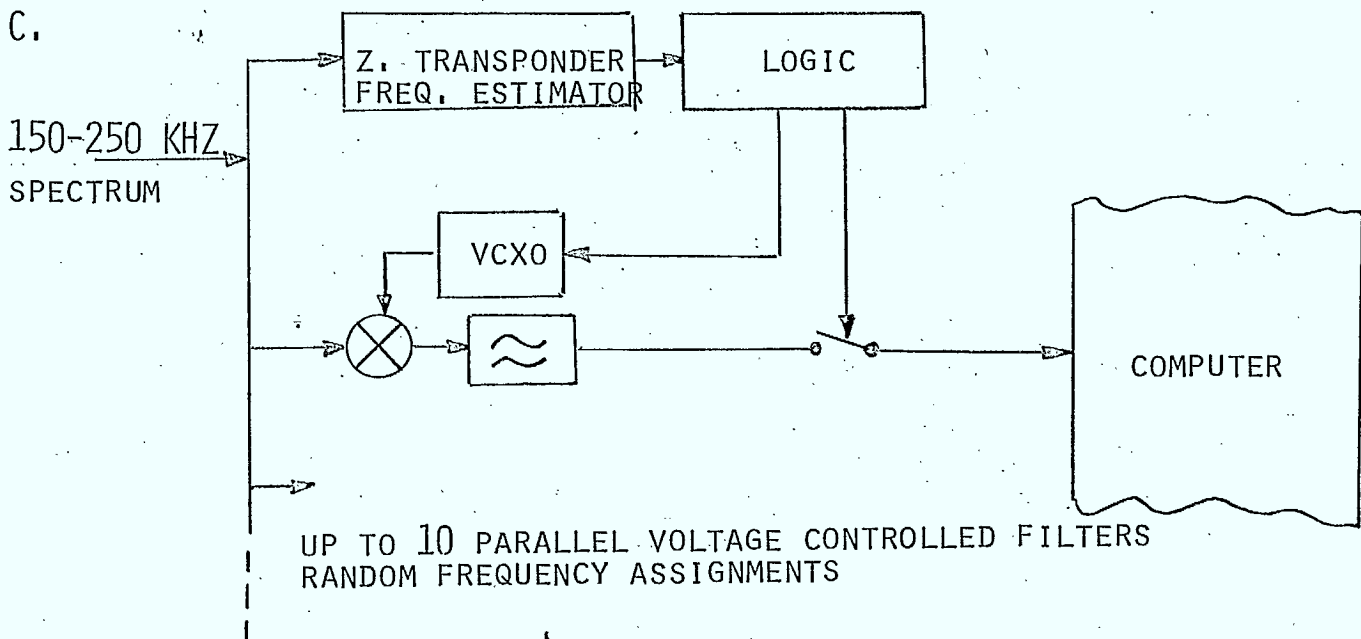
A.

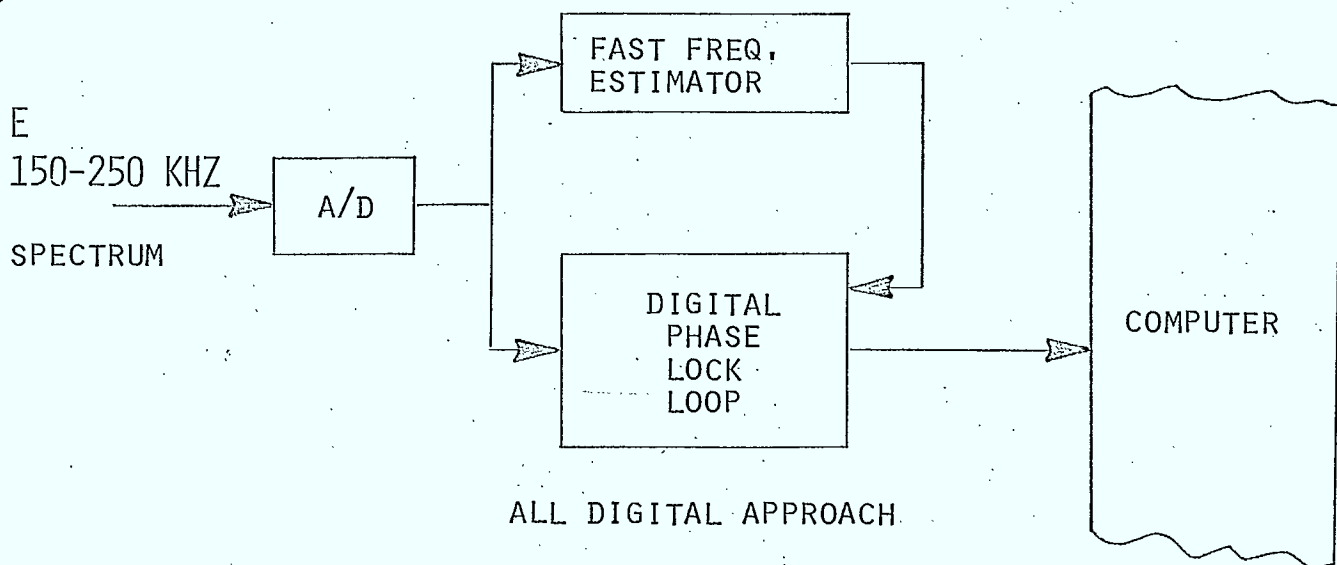
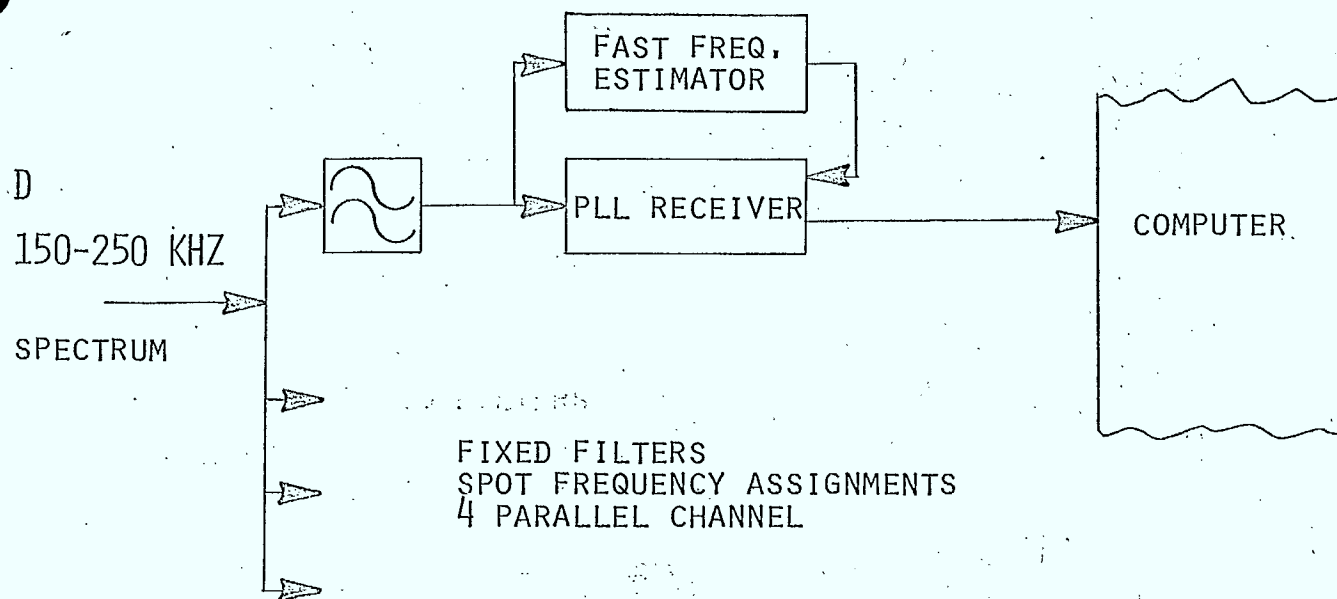


B.



C.



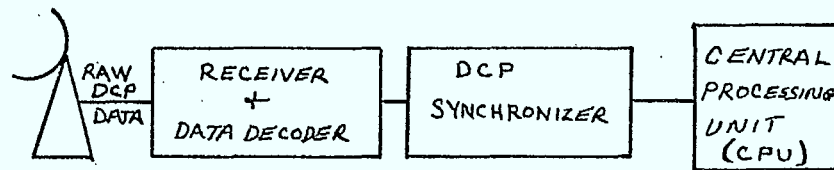


SELECTION: TO BE DETERMINED

2.6 DATA PROCESSING AND STORAGE

A. GENERAL

o DATA FLOW

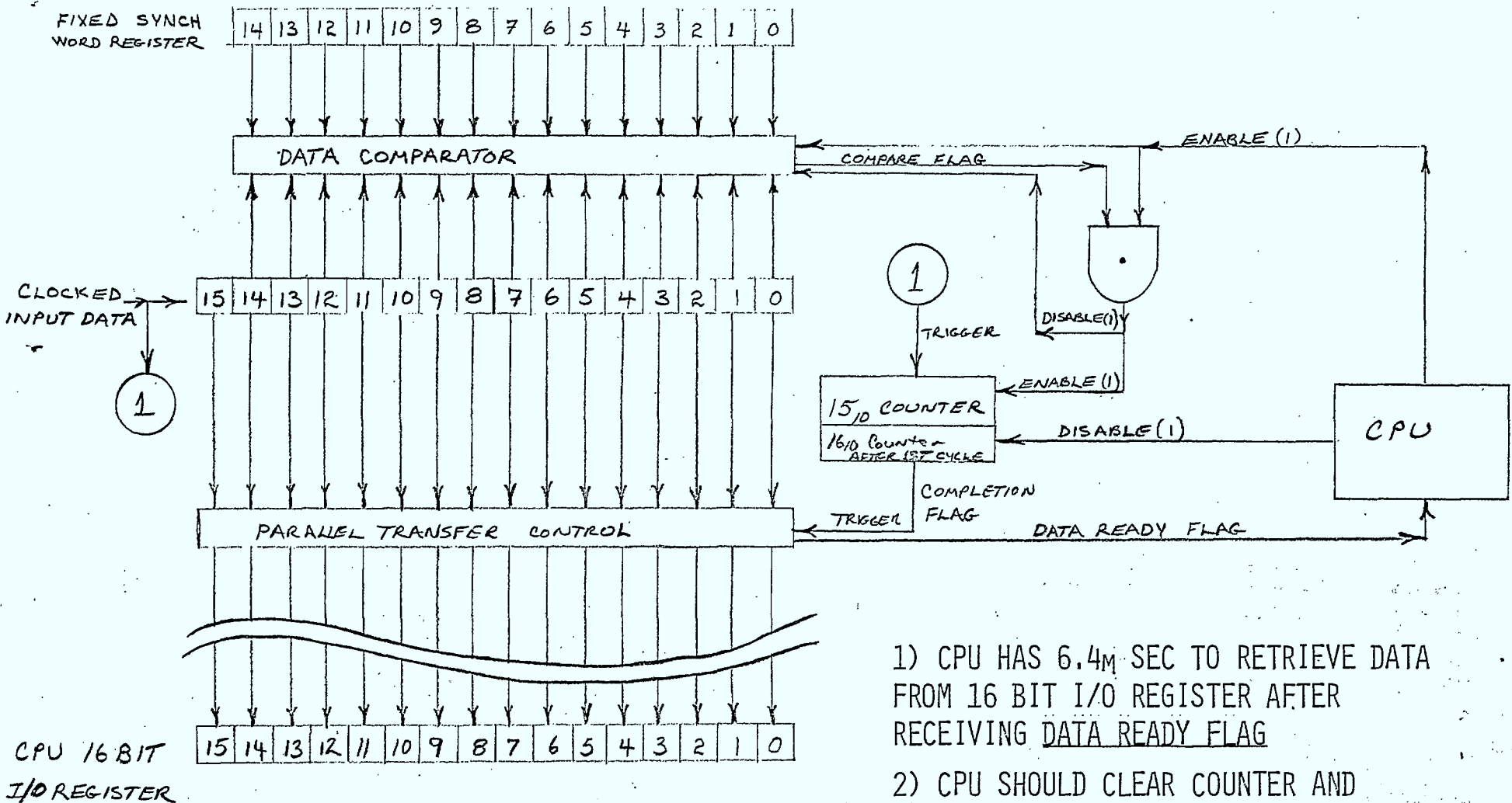


- o FUNCTIONS OF DCP SYNCHRONIZER
 - SYNCHRONIZE DATA BITS
 - SYNCHRONIZE DATA FRAME
 - PROVIDE BUFFER OF BINARY DATA FOR CPU STORAGE
- o FUNCTIONS OF CPU
 - ACKNOWLEDGE PRESENCE OF NEW DCP DATA
 - CONTROL FRAME SYNCHRONIZER
 - RETRIEVE BUFFERS OF DCP DATA AND STORE IN REAL TIME
 - SORT DATA AND CONVERT TO SCIENTIFIC UNITS
 - CONTROL TRANSMISSION OF DATA TO USERS

B. DATA SORTING

- o INPUT DATA IS ASSUMED TO CONSIST OF A 15 BIT FRAME SYNCH WORD, A 10 BIT CODE AND SOME NUMBER OF 8 BIT DATA WORDS
- o UPON RECEIVING DATA READY INTERRUPT FROM FRAME SYNCHRONIZER
 - CPU READS 16 BIT WORD FROM I/O CHANNEL AND PICKS OUT DCP ID
 - FROM ID CPU DETERMINES # WORDS TO BE INPUT AND SETS UP COUNTER SEQUENCE TO INPUT THE RIGHT AMOUNT OF DATA
 - DATA IS THEN SORTED AND STORED ONTO DISC ACCORDING TO DCP ID CODES

DCP FRAME SYNCH CONTROL



1) CPU HAS 6.4_m SEC TO RETRIEVE DATA FROM 16 BIT I/O REGISTER AFTER RECEIVING DATA READY FLAG

2) CPU SHOULD CLEAR COUNTER AND ENABLE DATA COMPARATOR FOR NEXT FRAME WITHIN 6_m SEC

3) NEXT FRAME HAS TO BE AT LEAST 6.4_m SEC. FROM PREVIOUS

4) CPU DETERMINES NO. OF DATA POINTS TO BE INPUT AFTER DECODING ID

C. CONVERSION TO SCIENTIFIC UNITS

o DCP DATA IS CONVERTED TO SCIENTIFIC UNITS (IF REQUIRED) UPON REQUEST FOR TRANSMISSION OF DATA

o TECHNIQUES USED

- POLYNOMIAL APPROXIMATION TECHNIQUE

$$Y = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4X^4 + A_5X^5$$

WHERE Y IS OUTPUT IN SCIENTIFIC UNITS

X IS INPUT DATA IN DECIMAL COUNTS

A₀-A₅ USER SUPPLIED COEFFICIENTS FOR FIFTH DEGREE POLYNOMIAL

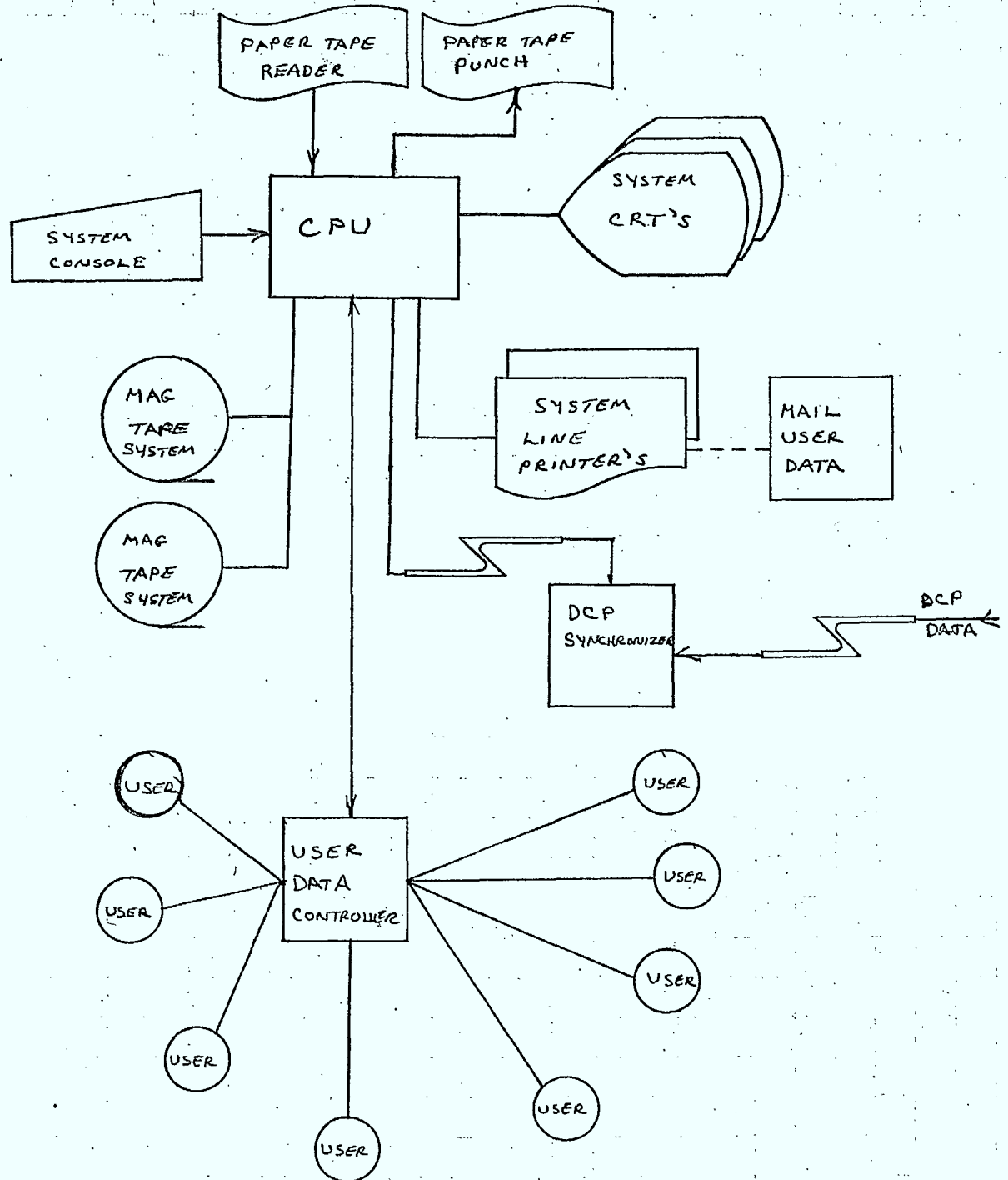
- LINE SEGMENT TECHNIQUE

USER SUPPLIES ONE OR MORE COMPOSITE LINE SEGMENTS TO RECREATE DATA IN THE FORM OF SCIENTIFIC UNITS

D. STORAGE

- o DATA IS STORED IN DESIGNATED DISC AREAS DETERMINED BY ID CODE AND TIME TAG
- o DATA IS STORED IN RAW COMPRESSED FORM (IE. 2-8 BIT WORDS PACKED INTO 1-16 BIT COMPUTER WORD)
- o DATA IS STORED TEMPORARILY ON A DISC FOR QUICK ACCESS DATA AND ON MAGNETIC TAPE FOR DATA TRANSMITTED VIA MAIL
- o MAGNETIC TAPE BACKUPS OF THE DISC ARE MADE AS SOON AS DISC SYSTEM IS FULL

COMPUTER SYSTEM



DATA COLLECTION SYSTEM DESIGN

2-7 DATA DISTRIBUTION

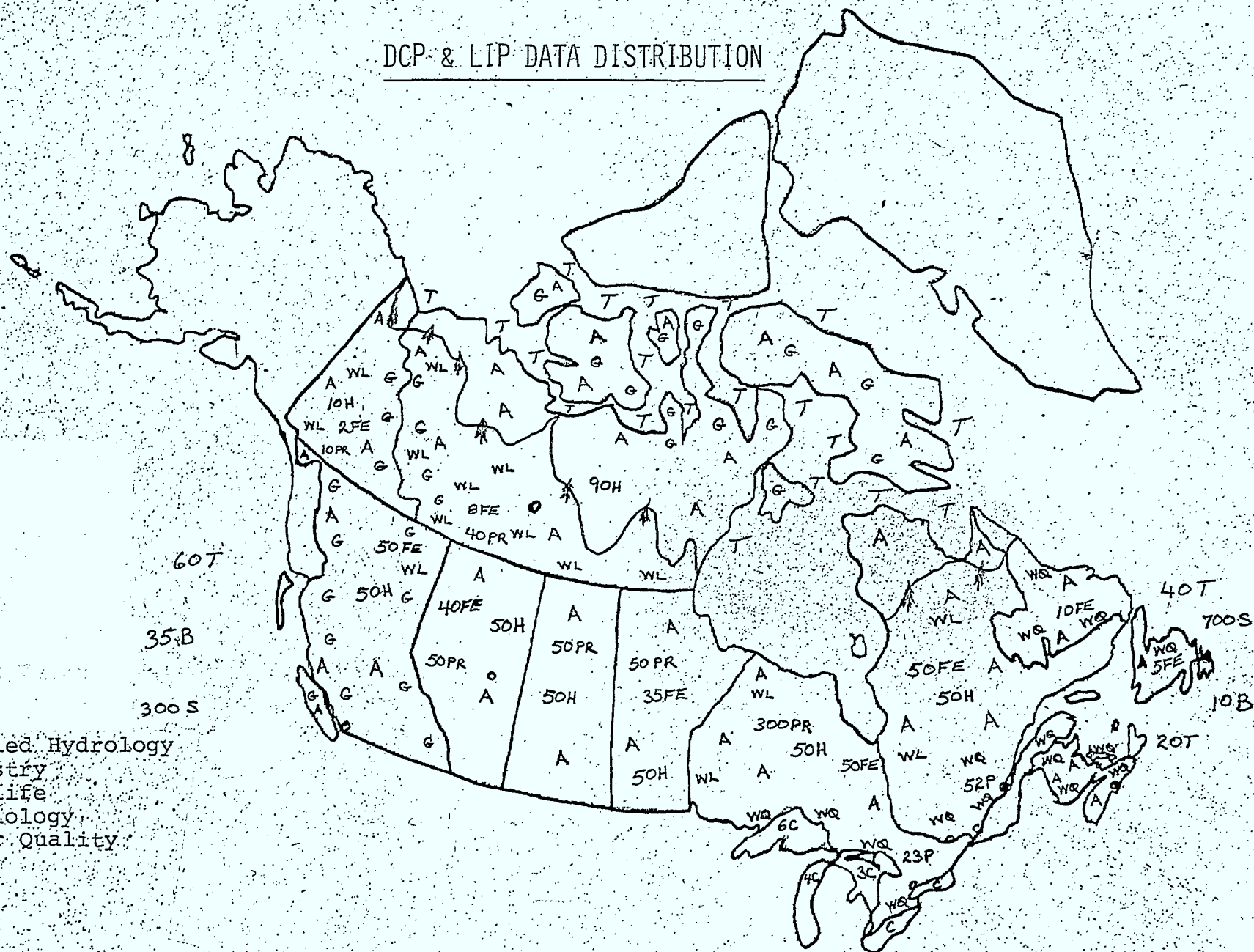
A. GENERAL





- o HIGH PRIORITY DATA VIA HIGH SPEED DATA LINKS
- o LOW PRIORITY DATA VIA MAIL

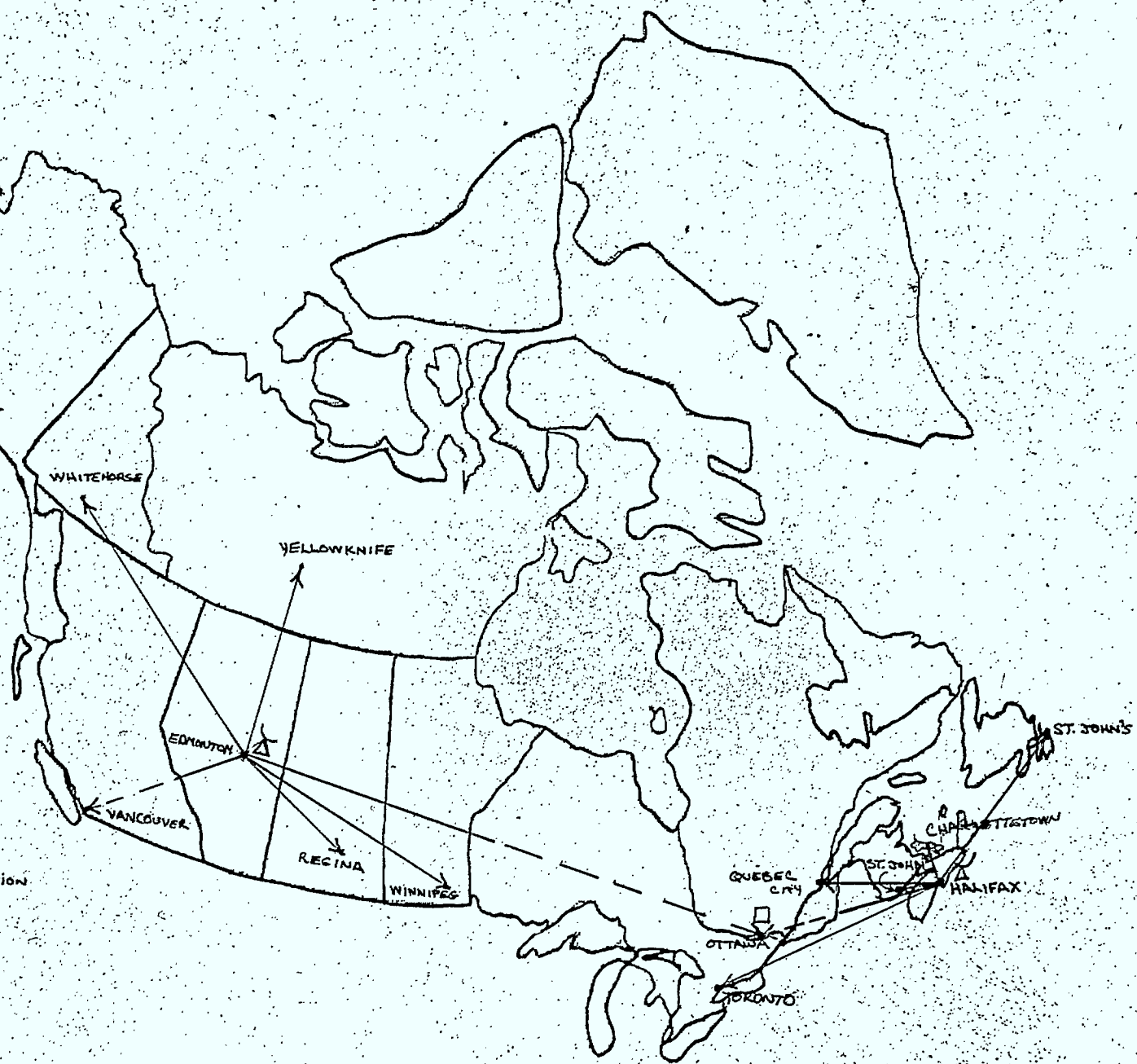
B. DATA LINK ANALYSIS

- o DCP GEOGRAPHIC DISTRIBUTION MODEL
- o TRANSMISSION NETWORK MODEL
- o DCP USER MODEL
- o STANDARD MESSAGE FORMAT (SCIENTIFIC UNITS)
- o TRANSMISSION NETWORK LOADING CHART
- o DATA LINK ALTERNATIVES
- o LINE COST DATA

H - Applied Hydrology
FE - Forestry
WL - Wildlife
G - Glaciology
WQ - Water Quality
P - EPS
A - AES
C - CCIW
B - OAS
T - Tides & Water Level
F - Frozen Sea
PR - Provincial Forestry
S - Fishery Surveillance Beacons



-  DCP+LIP Ground Station
-  CONTROL CENTER
-  DCP Data
-  DCP+LIP Data



DCP DATA DISTRIBUTION NETWORK

DCP USER MODEL

DATA TRANSMISSION		TYPE OF DATA REQUIRED												
FROM	TO	H	FE	WL	G	WQ	P	A	C	B	T	F	PR	S
EDMONTON	WHITEHORSE	10	2	2	0	0	0	0	0	0	0	0	10	0
	YELLOWKNIFE	90	8	8	0	0	0	0	0	0	0	0	40	0
	VANCOUVER	50	50	1	0	0	0	5	0	35	0	0	200	300
	REGINA	50	0	0	0	0	0	2	0	0	0	0	50	0
	WINNIPEG	50	35	0	0	0	0	2	0	0	0	0	50	0
	OTTAWA	0	0	0	30	0	0	0	0	0	80	10	0	0
	EDMONTON	50	40	0	0	0	0	20	0	0	0	0	50	0
HALIFAX	ST. JOHN'S	0	15	0	0	3	0	3	0	0	0	0	0	0
	CHARLOTTETOWN	0	0	0	0	1	0	0	0	0	0	0	0	0
	ST. JOHN	0	0	0	0	2	0	2	0	0	0	0	0	0
	QUEBEC CITY	50	50	2	0	4	52	6	0	0	0	0	300	0
	OTTAWA	0	0	0	0	0	0	0	0	0	60	0	0	0
	TORONTO	50	50	2	0	4	23	4	15	0	0	0	300	0
	HALIFAX	0	0	0	0	1	0	1	0	10	0	0	0	700
TOTAL		400	250	15	30	15	75	45	15	45	140	10	1000	1000



TRANSMITTED IN REAL TIME



TRANSMITTED BY MAIL SERVICE

DCP STANDARD MESSAGE (CONVERTED)

LINE	MESSAGE				CHARACTERS/LINE*	# CHAR./RAW MESSAGE
1	ID	XXXX	FLAG	X	32	
2	DATE	YY MO DY	TIME	HR MN SC.TTT	44	
3					2	
4	WORD#	DATA	WORD#	DATA	36	
5	01	±X.XXXXXE±XX	21	±X.XXXXXE±XX	40	
6	02	±X.XXXXXE±XX	22	±X.XXXXXE±XX	40	
7	03	±X.XXXXXE±XX	23	±X.XXXXXE±XX	40	274/50-60 BITS
8	04	±X.XXXXXE±XX	24	±X.XXXXXE±XX	40	
9	05	±X.XXXXXE±XX	25	±X.XXXXXE±XX	40	
10	06	±X.XXXXXE±XX	26	±X.XXXXXE±XX	40	314/72 BITS
11	07	±X.XXXXXE±XX	27	±X.XXXXXE±XX	40	
12	08	±X.XXXXXE±XX	28	±X.XXXXXE±XX	40	
13	09	±X.XXXXXE±XX	29	±X.XXXXXE±XX	40	394/100 BITS
14	10	±X.XXXXXE±XX	30	±X.XXXXXE±XX	40	
15	11	±X.XXXXXE±XX	31	±X.XXXXXE±XX	40	
16	12	±X.XXXXXE±XX	32	±X.XXXXXE±XX	40	514/150 BITS
17	13	±X.XXXXXE±XX	33	±X.XXXXXE±XX	40	
18	14	±X.XXXXXE±XX	34	±X.XXXXXE±XX	40	
19	15	±X.XXXXXE±XX	35	±X.XXXXXE±XX	40	714/240 BITS
20	16	±X.XXXXXE±XX	36	±X.XXXXXE±XX	40	
21	17	±X.XXXXXE±XX	37	±X.XXXXXE±XX	40	
22	18	±X.XXXXXE±XX	38	±X.XXXXXE±XX	40	834/288 BITS
23	19	±X.XXXXXE±XX	39	±X.XXXXXE±XX	40	
24	20	±X.XXXXXE±XX	40	±X.XXXXXE±XX	40	

* INCLUDES 2 CHARACTERS FOR CR & LF

NETWORK LOADING

X-MISSION MODE:		# CHARACTERS/# DCP'S/MESSAGE												TOTAL # CHAR/DAY *
FROM	TO	H	FE	WL	G	WQ	P	A	C	B	T	F	PR	
EDMONTON	WHITEHORSE	2740	548	548	0	0	0	0	0	0	0	0	2740	78912
	YELLOWKNIFE	24660	2192	2192	0	0	0	0	0	0	0	0	10960	644448
	VANCOUVER	13700	13700	274	0	0	0	4170	0	13790	0	0	54800	1033840
	REGINA	13700	0	0	0	0	0	1668	0	0	0	0	13700	423632
	WINNIPEG	13700	9590	0	0	0	0	1668	0	0	0	0	13700	461992
	OTTAWA	0	0	0	15420	0	0	0	0	0	31520	9140	0	756480
	EDMONTON	13700	10960	0	0	0	0	16680	0	0	0	0	13700	827760
HALIFAX	ST. JOHN'S	0	4110	0	0	942	0	2502	0	0	0	0	0	76488
	CHARLOTTETOWN	0	0	0	0	314	0	0	0	0	0	0	0	0
	ST. JOHN	0	0	0	0	628	0	1668	0	0	0	0	0	40032
	QUEBEC CITY	13700	13700	548	0	1256	37128	5004	0	0	0	0	82200	832496
	OTTAWA	0	0	0	0	0	0	0	0	0	23640	0	0	567360
	TORONTO	13700	13700	548	0	1256	16422	3336	7710	0	0	0	82200	815594
	HALIFAX	0	0	0	0	314	0	834	0	3940	0	0	0	114576
# MESSAGES/ DAY		24	4	24	4	24	3	24	3	24	24	50	4	

* DOES NOT INCLUDE DATA TRANSMITTED BY MAIL



TRANSMITTED BY MAIL

DATA LINK ALTERNATIVES

- o DEDICATED TELEPHONE LINE (DATA LINKS)
- o DIAL-UP TELEPHONE
- o COMPUTER UTILITY DISTRIBUTION
- o TELEX
 - VARIOUS LINE SPEEDS

COST FOR TELEX SYSTEM

LINE SPEED: 396 CHAR/MIN.

FROM	TO	X-MIT. TIME (MIN.)	COST/MIN.	COST/DAY
EDMONTON	WHITEHORSE	199.27	55.2¢	\$ 110.00
	YELLOWKNIFE	1627.39	55.2¢	\$ 898.32
	VANCOUVER	2610.71	41.4¢	\$ 1080.83
	REGINA	1069.78	41.4¢	\$ 442.89
	WINNIPEG	1166.65	48.3¢	\$ 563.49
	OTTAWA	1910.30	82.8¢	\$ 1581.73
	EDMONTON	2090.30	13.8¢	\$ 288.46
HALIFAX	ST. JOHN'S	193.15	41.4¢	\$ 79.96
	CHARLOTTETOWN	0	13.8¢	\$ 0.00
	ST. JOHN	101.09	13.8¢	\$ 13.95
	QUEBEC CITY	2102.26	34.5¢	\$ 725.28
	OTTAWA	1432.73	41.4¢	\$ 593.15
	TORONTO	2059.58	48.3¢	\$ 994.78
	HALIFAX	289.33	13.8¢	\$ 39.93

COST FOR DATA TELEX SYSTEM (8 LEVEL CODE)

LINE SPEED: 1050 CHAR/MIN.

FROM	TO	X-MIT. TIME (MIN.)	COST/MIN.	COST/DAY
EDMONTON	WHITEHORSE	75.15	55.2 ¢	\$ 41.49
	YELLOWKNIFE	613.76	55.2 ¢	\$ 338.80
	VANCOUVER	984.61	41.4 ¢	\$ 407.63
	REGINA	403.46	41.4 ¢	\$ 167.03
	WINNIPEG	439.99	48.3 ¢	\$ 212.52
	OTTAWA	720.46	82.8 ¢	\$ 596.54
	EDMONTON	788.34	13.8 ¢	\$ 108.79
HALIFAX	ST. JOHN'S	72.85	41.4 ¢	\$ 30.16
	CHARLOTTETOWN	0	13.8 ¢	\$ 0.00
	ST. JOHN	38.13	13.8 ¢	\$ 5.26
	QUEBEC CITY	792.85	34.5 ¢	\$ 273.53
	OTTAWA	540.34	41.4 ¢	\$ 223.70
	TORONTO	776.76	48.3 ¢	\$ 375.17
	HALIFAX	109.12	13.8 ¢	\$ 15.06

COST FOR DATA TELEX SYSTEM (5 LEVEL CODE)

LINE SPEED: 1500 CHAR/MIN.				
FROM	TO	X-MIT. TIME (MIN.)	COST/MIN.	COST/DAY
EDMONTON	WHITEHORSE	52.61	55.2 ¢	\$ 29.04
	YELLOWKNIFE	429.63	55.2 ¢	\$ 237.16
	VANCOUVER	689.23	41.4 ¢	\$ 285.34
	REGINA	282.42	41.4 ¢	\$ 116.92
	WINNIPEG	307.99	48.3 ¢	\$ 148.76
	OTTAWA	504.32	82.8 ¢	\$ 417.58
	EDMONTON	551.84	13.8 ¢	\$ 76.15
HALIFAX	ST. JOHN'S	50.99	41.4 ¢	\$ 21.11
	CHARLOTTETOWN	0	13.8 ¢	\$ 0.00
	ST. JOHN	26.69	13.8 ¢	\$ 3.68
	QUEBEC CITY	555.00	34.5 ¢	\$ 191.47
	OTTAWA	378.24	41.4 ¢	\$ 156.59
	TORONTO	543.73	48.3 ¢	\$ 262.62
	HALIFAX	76.38	13.8 ¢	\$ 10.54

COST FOR BROADBAND SYSTEM (4 KC)

TELEX

LINE SPEED: 12 KCHAR/MIN.				
FROM	TO	X-MIT. TIME (MIN.)	COST/MIN.	COST/DAY
EDMONTON	WHITEHORSE	6.58	↑ NOT AVAILABLE ↓	\$ (-3.63)*
	YELLOWKNIFE	53.70		\$ (29.64)
	VANCOUVER	86.15		\$ (35.67)
	REGINA	35.30		\$ (14.62)
	WINNIPEG	38.50		\$ (18.60)
	OTTAWA	63.04		\$ (52.20)
	EDMONTON	68.98		\$ (9.52)
HALIFAX	ST. JOHN'S	6.37	NOT AVAILABLE	\$ (2.64)
	CHARLOTTETOWN	0		\$ (0.00)
	ST. JOHN	3.34		\$ (.46)
	QUEBEC CITY	69.37		\$ (23.93)
	OTTAWA	47.28		\$ (19.57)
	TORONTO	67.97		\$ (32.83)
	HALIFAX	9.55		\$ (1.32)

* Based on Regular Telex Charges

COST FOR BROADBAND SYSTEM (48 KC)

TELEX

LINE SPEED: 306 K CHAR/MIN.				
FROM	TO	X-MIT. TIME (MIN.)	COST/MIN.	COST/DAY
EDMONTON	WHITEHORSE	.26	↑ AVAILABLE ↓	\$ (.14) *
	YELLOWKNIFE	.21		\$ (.12)
	VANCOUVER	3.38		\$ (1.40)
	REGINA	1.38		\$ (.57)
	WINNIPEG	1.51		\$ (.73)
	OTTAWA	2.47		\$ (2.05)
	EDMONTON	2.71		\$ (.37)
HALIFAX	ST. JOHN'S	.25	Not AVAILABLE	\$ (.10)
	CHARLOTTETOWN	0		\$ (0.00)
	ST. JOHN	.13		\$ (.02)
	QUEBEC CITY	2.72		\$ (.94)
	OTTAWA	1.85		\$ (.77)
	TORONTO	2.67		\$ (1.29)
	HALIFAX	.37		\$ (.05)

* Based on Regular Telex Charges

CHAPTER 3

FISHERIES SURVEILLANCE

SYSTEM DESIGN

FISHERIES SURVEILLANCE SYSTEM

3-1 LOCATION ACCURACY/CAPACITY ANALYSIS

A. DOPPLER DATA

- o FUNCTION OF IN-TRACK AND CROSS-TRACK ANGLES
- o ERROR SOURCES INCLUDE
 - CENTRE FREQUENCY UNCERTAINTY
 - TROPOSPHERIC AND IONOSPHERIC EFFECTS
 - DATA MEASUREMENT ERROR DUE TO MEASUREMENT TIME AND S/N RATIO

B. ACCURACY REQUIREMENTS

- o DATA SPAN (SYMMETRIC AND LONGER THAN 8 MINUTES)
- o ORBIT HEIGHT, MINIMUM ELEVATION ANGLE (AFFECT DATA SPAN)
- o NUMBER OF MEASUREMENTS (GREATER THAN 30)
- o DATA MEASUREMENT ERROR (1σ NOISE LESS THAN 5Hz)
- o AMBIGUITIES CAUSED BY L.I.P. VELOCITY PATTERNS
(NOT APPRECIABLE FOR LESS THAN 30 KM/HR.)
- o CROSS-TRACK ANGLE (BETWEEN 5 AND 20 DEGREES)

C. TRANSMISSION REQUIREMENTS

DEFINE: P = PROBABILITY OF A SUCCESSFUL TRANSMISSION

τ = DUTY CYCLE (SECONDS)

$\Delta\tau$ = SIGNAL BURST TIME

Q = NUMBER OF CHANNELS

M = NUMBER OF POSSIBLE INTERFERING L.I.P.'S

THEN:

$$P = \left[1 - \left(\frac{2\Delta\tau}{\tau} \right) \left(\frac{1}{Q} \right) \right]^M$$

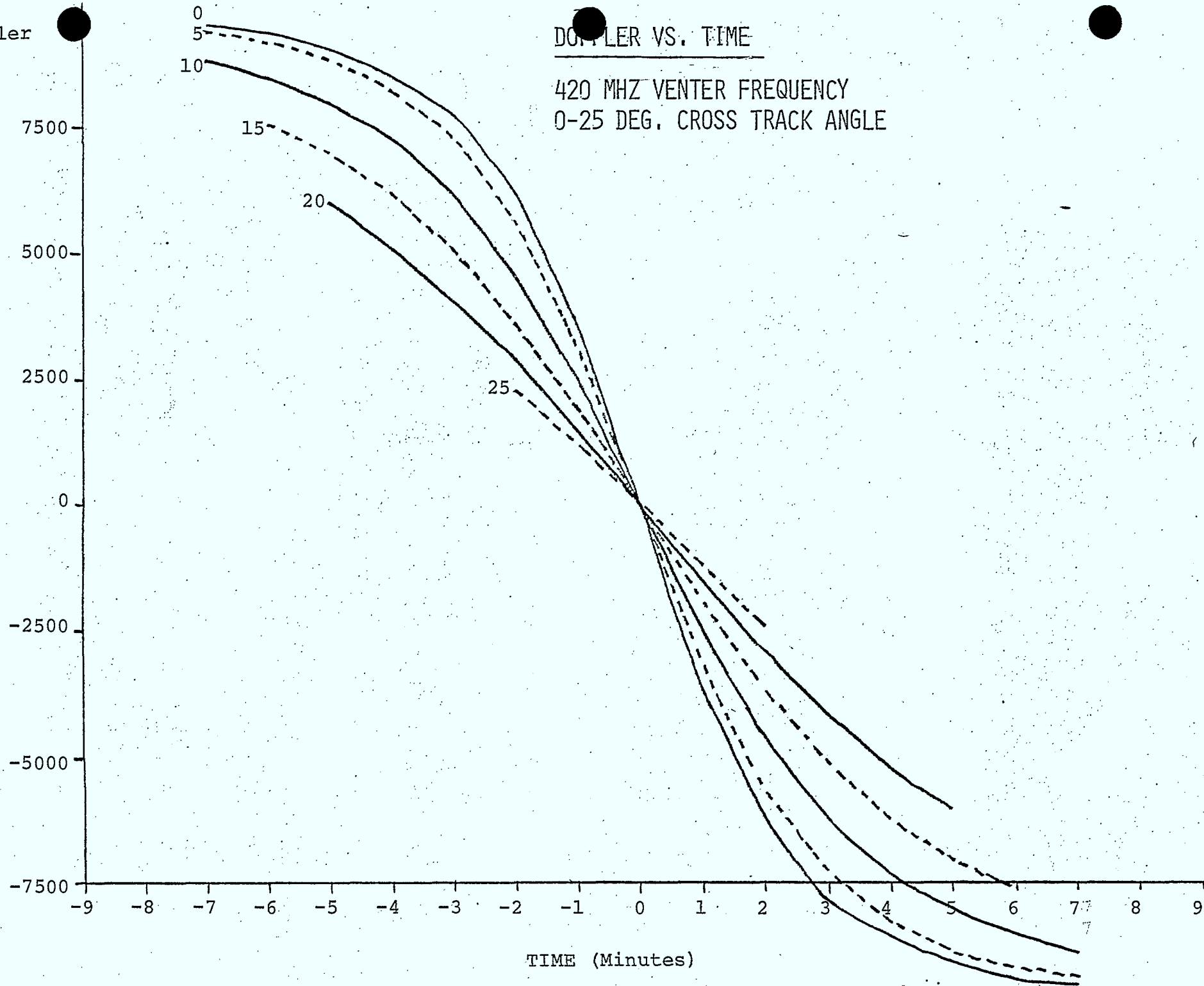
ONE SOLUTION:

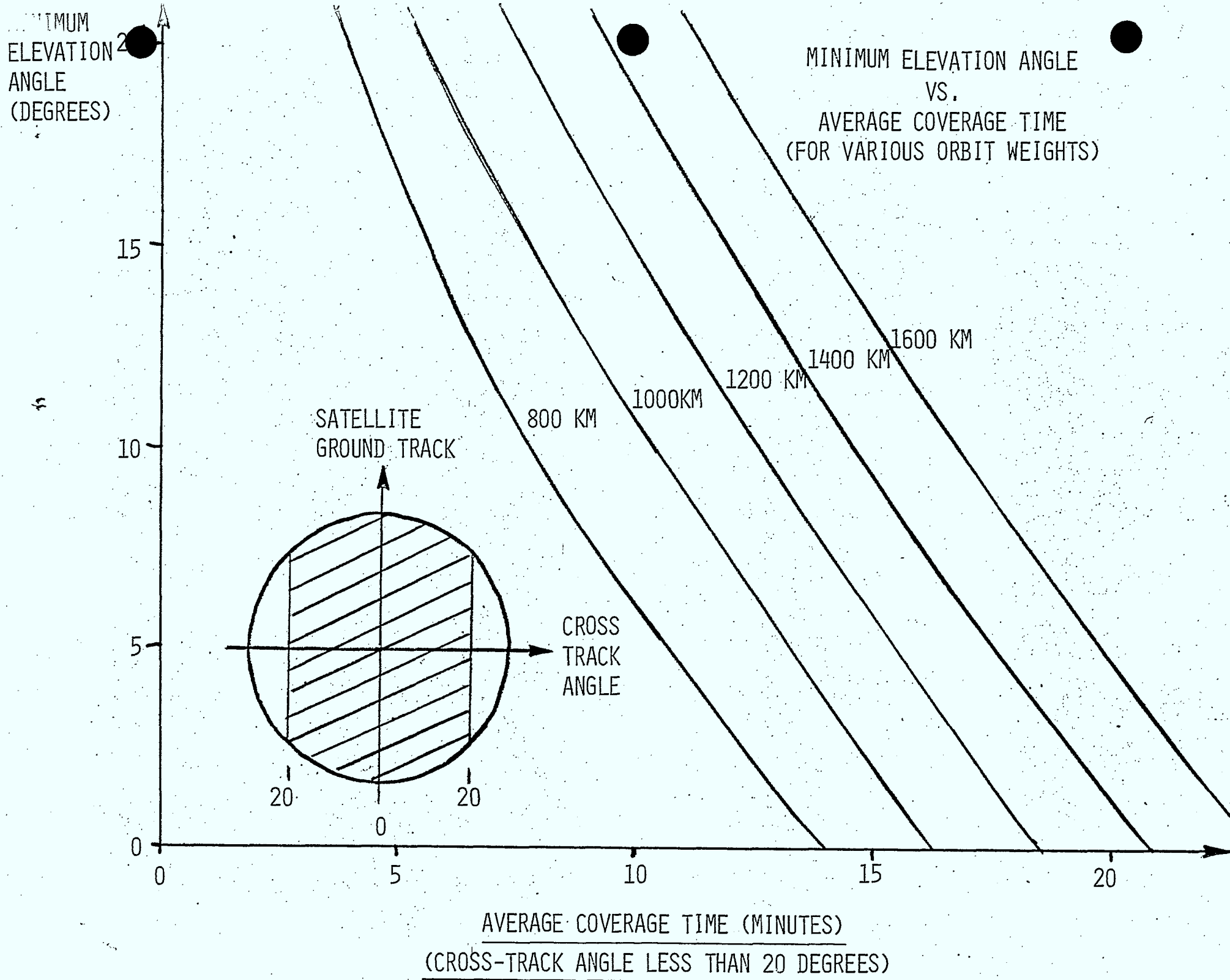
FOR M = 700, τ = 15 SECONDS, $\frac{\Delta\tau}{Q} = 0.005$, THE PROBABILITY OF 30 OR MORE DATA POINTS (IN A 5 MINUTE PASS) IS 0.99. FOR A SIGNAL MEASUREMENT TIME LESS THAN 0.005 SECONDS THE MINIMUM RMS DATA NOISE SIGNIFICANTLY INCREASES L.I.P. POSITION ERRORS (ASSUMING A S/N OF 50 DBHZ). FOR PRACTICAL SYSTEMS, SIGNAL ACQUISITION TIME REQUIRES $\Delta\tau$ TO BE SUBSTANTIALLY LARGER THAN MEASUREMENT TIME.

Doppler
(Hz)

DOPPLER VS. TIME

420 MHZ VENTER FREQUENCY
0-25 DEG. CROSS TRACK ANGLE





EXPECTED
ERROR (KM)

EXPECTED ERROR (1σ) VS. CROSS-TRACK ANGLE

DATA RATE = 4 PTS./MINUTE

DATA NOISE = 10 HZ (1σ)

DATA SPAN = 5 MINUTES

TIME FROM INITIALIZATION TO
BROADSIDE

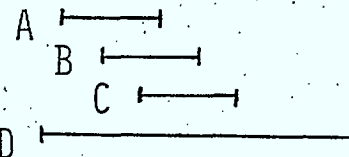
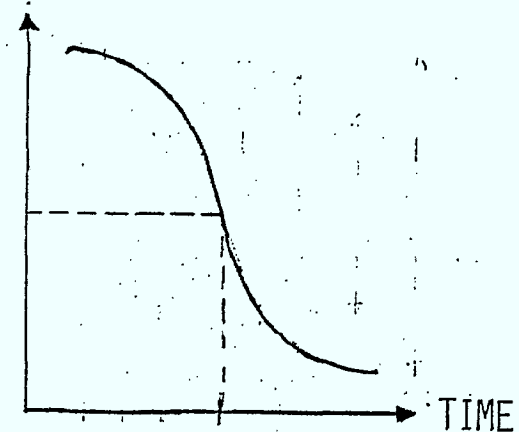
A. 7 MINUTES

B. 5 MINUTES

C. 3 MINUTES

D. COMPLETE DATA SPAN

FREQUENCY



6.0

4.0

2.0

3

6

9

12

15

18

21

24

CROSS-TRACK ANGLE (DEGREES)

Normalized
Expected
Error
(km)

NORMALIZED EXPECTED ERROR (N.E.E.)

VS.

CROSS TRACK ANGLE

$$1\sigma \text{ Error} \approx \frac{\bar{n}}{\sqrt{N}} \times \text{N.E.E.}$$

$\bar{n} \approx 1\sigma$ -Measurement Error (Hz)

$N \approx$ Number of frequency measurements

3.0

2.0

1.0

0

3

6

9

12

15

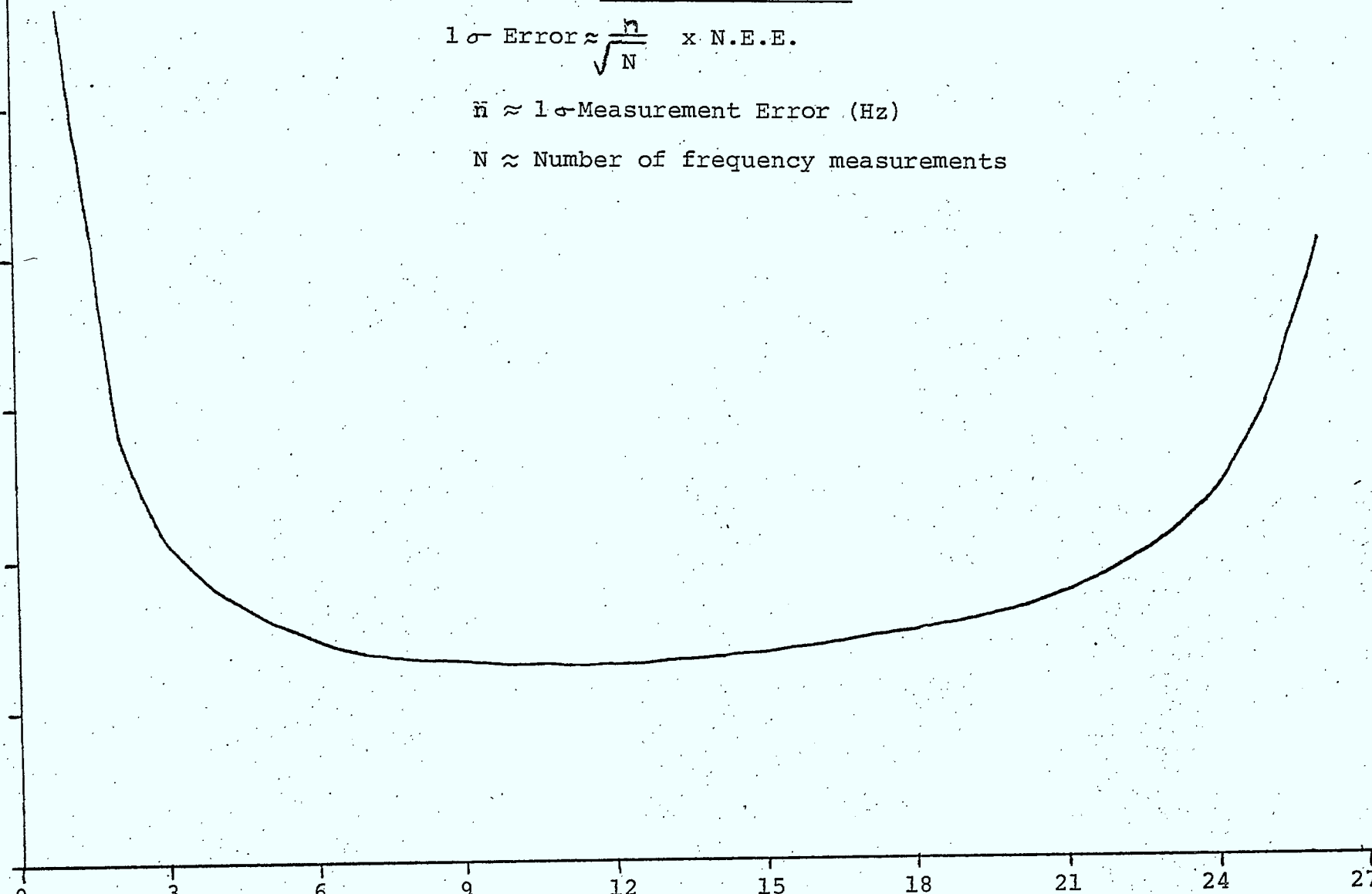
18

21

24

27

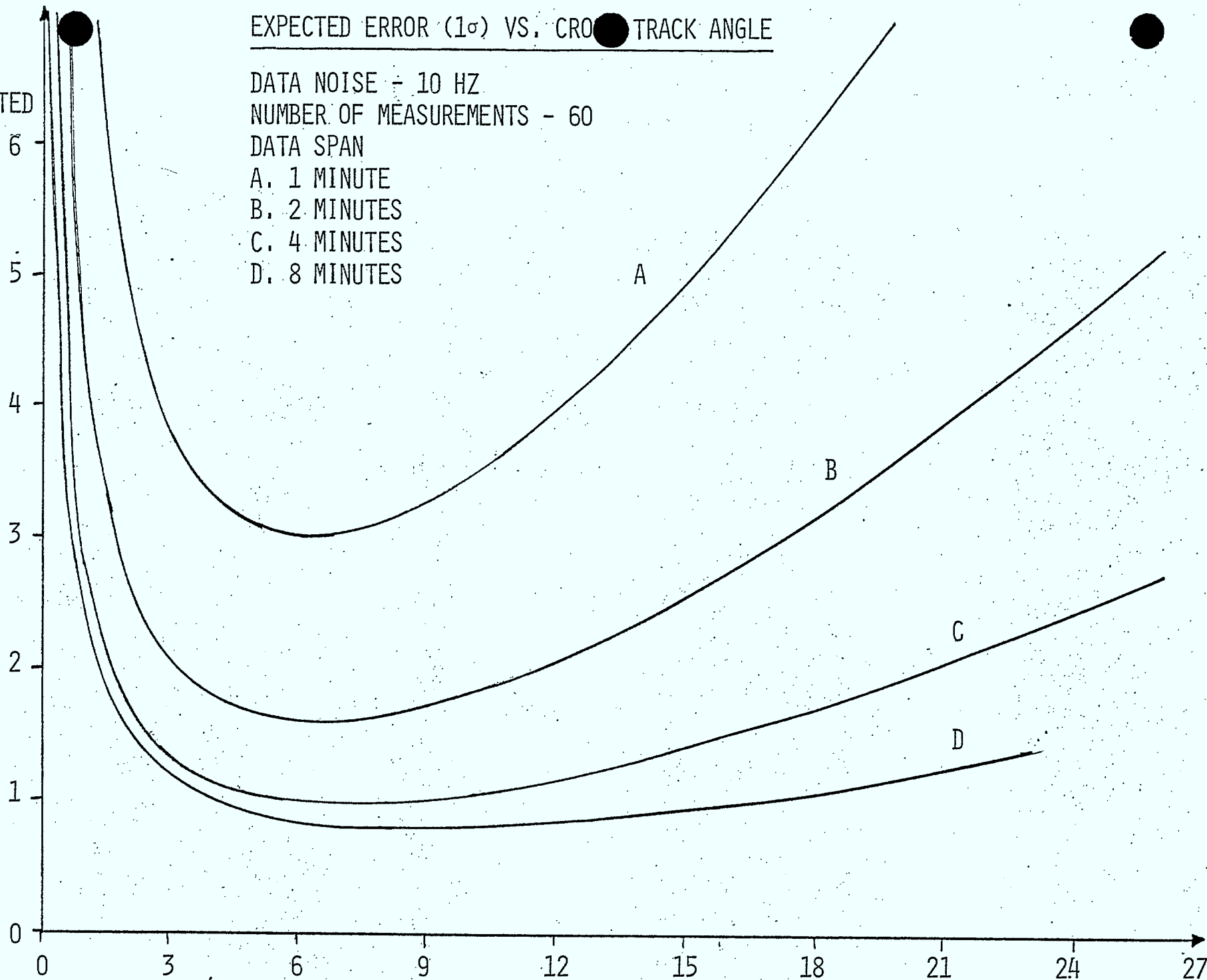
Cross-Track Angle (Degrees)



EXPECTED ERROR (1σ) VS. CROSS-TRACK ANGLE

DATA NOISE - 10 HZ
NUMBER OF MEASUREMENTS - 60
DATA SPAN
A. 1 MINUTE
B. 2 MINUTES
C. 4 MINUTES
D. 8 MINUTES

EXPECTED
ERROR
(KM)



CROSS-TRACK ANGLE (DEGREES)

FISHERIES SURVEILLANCE SYSTEM

3-2

ID ENCODING AND MODULATION

ALTERNATIVES

- (A) 50 MS CARRIER BURST FOLLOWED BY 10 BIT ID CODE PSK'D AT 2.5 Kbps, RATE 3/4 ENCODED.
- (B) PREAMBLE FOLLOWED BY PSK ID @ 2.5 Kbps FOLLOWED BY CW CARRIER FOR ABOUT 30 MS.
- (C) 50 MS BURSTS OF CW CARRIER. LIP ID DETERMINED ON BASIS OF FREQUENCY ASSIGNMENT AND INDIVIDUAL PRF. EACH LIP ON ONE OF 10 FREQUENCY ASSIGNMENTS HAS ONE OF 100 PRF'S LOCKED TO THE STABLE CRYSTAL OSCILLATOR.

TRADEOFFS

ALTERNATIVES	ADVANTAGES	DISADVANTAGES
50 MS CW FOLLOWED BY ID	<ul style="list-style-type: none"> o CLEAN CW TIME FOR RAPID ACQUISITION o NO NEED TO REPEAT ID 	<ul style="list-style-type: none"> o ID CORRUPTS END OF SIGNAL FOR FREQUENCY MEASUREMENT
ID FOLLOWED BY CW	<ul style="list-style-type: none"> o CLEAN CW SIGNAL AT END OF BURST FOR ACCURATE FREQUENCY MEASUREMENTS 	<ul style="list-style-type: none"> o PREAMBLE REQUIRED BEFORE ID AND MUST BE REPEATED TO ENSURE RECEPTION o ID DELAYS ACQUISITION OF FREQUENCY MEASUREMENT LOOP
CODED CENTER FREQUENCIES & PRF'S	<ul style="list-style-type: none"> o LIP SIGNAL IS PURE CW o RAPID ACQUISITION o BEST FOR FREQ. MEAS. o EASILY ADAPTED FOR DIGITAL PROCESSING o SIMPLIFIES LIP DESIGN o NO DEMODULATION IN GROUND STATIONS 	<ul style="list-style-type: none"> o PROCESSOR MUST ACCURATELY MEASURE TIME OF SIGNAL (10MS) AS WELL AS FREQ. o ADDITIONAL PROCESSING TO IDENTIFY LIP'S

SELECTION: CODED FREQUENCIES AND PRF'S

FISHERIES SURVEILLANCE SYSTEM

3-3

LIP FREQUENCIES

BANDWIDTH REQUIREMENT 200 KHz

ALTERNATIVES

- (A) UHF BAND 420-450 MHz
- (B) VHF BAND 100-200 MHz
- (C) L OR S BAND 1500-2500 MHz

TRADE-OFFS

BAND	ADVANTAGES	DISADVANTAGES
UHF	<ul style="list-style-type: none">o CLOSE TO DCP BAND 401-403o PERMITS COMMON USE OF ANT. AND RECEIVERo ACCEPTABLE IONOSPHERIC REFRACTIONo LOW GALACTIC NOISEo ACCEPTABLE PATH LOSS FOR LOW POWER (5W) TRANSMITTERSo REGULATORY DEFINITION IS CLOSE TO INTENDED USE	<ul style="list-style-type: none">o NO SPECIFIC ALLOCATION TO RADIO LOCATION-SATELLITEo POSSIBLE INTERFERENCE FROM US RADARS AND AMATEUR SERVICE
VHF	<ul style="list-style-type: none">o LOWEST PATH LOSS	<ul style="list-style-type: none">o NO SPECIFIC ALLOCATION TO RADIO LOCATION-SATELLITEo POSSIBLE GALACTIC NOISE PROBLEMo GREATEST IONOSPHERIC REFRACTIONo POTENTIAL INTERFERENCE FROM HEAVY USE OF THIS BAND
L,S	<ul style="list-style-type: none">o MORE SPECTRUM AVAILABLEo NO SIGNIFICANT IONOSPHERIC EFFECTSo NO SIGNIFICANT GALACTIC NOISE	<ul style="list-style-type: none">o MUCH HIGHER PATH LOSS (>10DB)o MORE EXPENSIVE LIP'So NO SPECIFIC ALLOCATION TO SERVICE

SELECTION: UHF 420-450 MHz

FISHERIES SURVEILLANCE SYSTEM

3-4

RF LINK

A. LIP UPLINK BUDGET

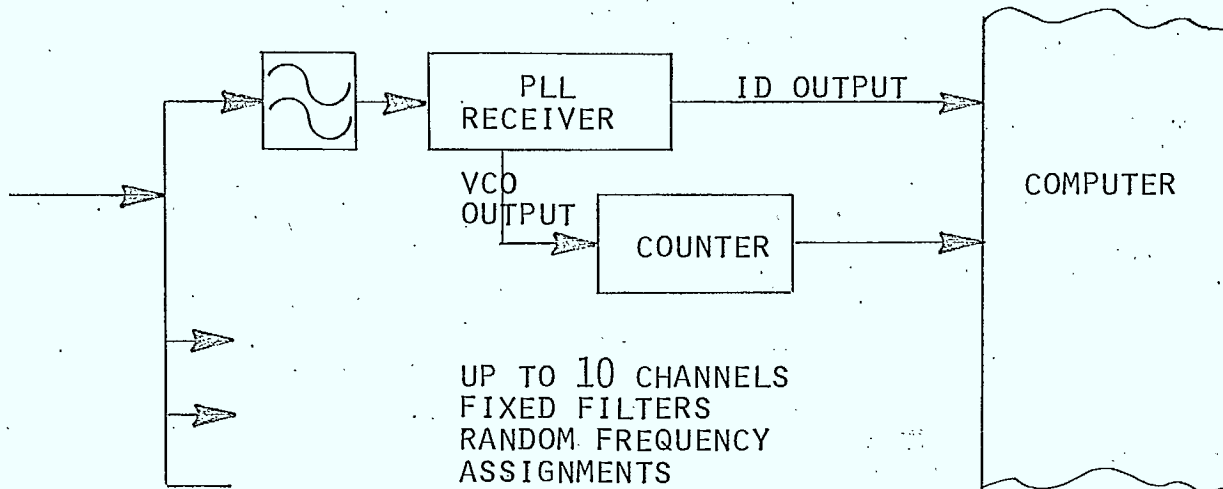
TRANSMITTER POWER (5 WATT)		37 DBM
CIRCUIT FEED LOSSES		- 1 DB
TRANSMITTING ANTENNA GAIN (HEMISPHERICAL COVERAGE WORST CASE)		0 DB
	<u>0° ELEVATION</u>	<u>90° ELEVATION</u>
PATH LOSS (420 MHz)	-157.3 DB	-146.8 DB
TRANSMITTING ANTENNA POINTING INACCURACY LOSS	0 DB	0 DB
POLARIZATION LOSS	- 2 DB	- 2 DB
RECEIVER ANTENNA GAIN	7 DB	- 2 DB
RECEIVE ANTENNA POINTING INACCURACY LOSS	- 1 DB	0 DB
TRANSMITTER MODULATION LOSS	0 DB	0 DB
RECEIVED POWER	-117.3 DBM	-114.8 DBM
RECEIVER NOISE SPECTRAL DENSITY $T_{\text{SYSTEM}} = 600^{\circ}\text{K}$		-170.8 DBM/Hz
UPLINK C/N_0	53.5 DBHz	56 DBHz

B. DATA DOWNLINK BUDGET

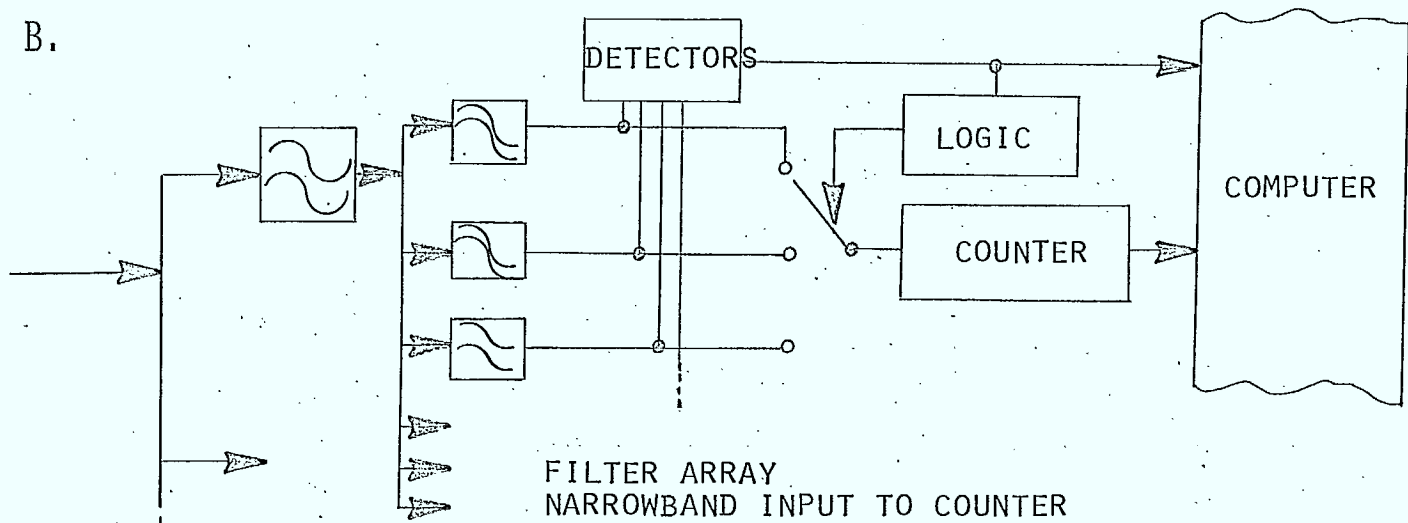
(SEE SECTION 2-4 B.)

3-5 LIP DECODER

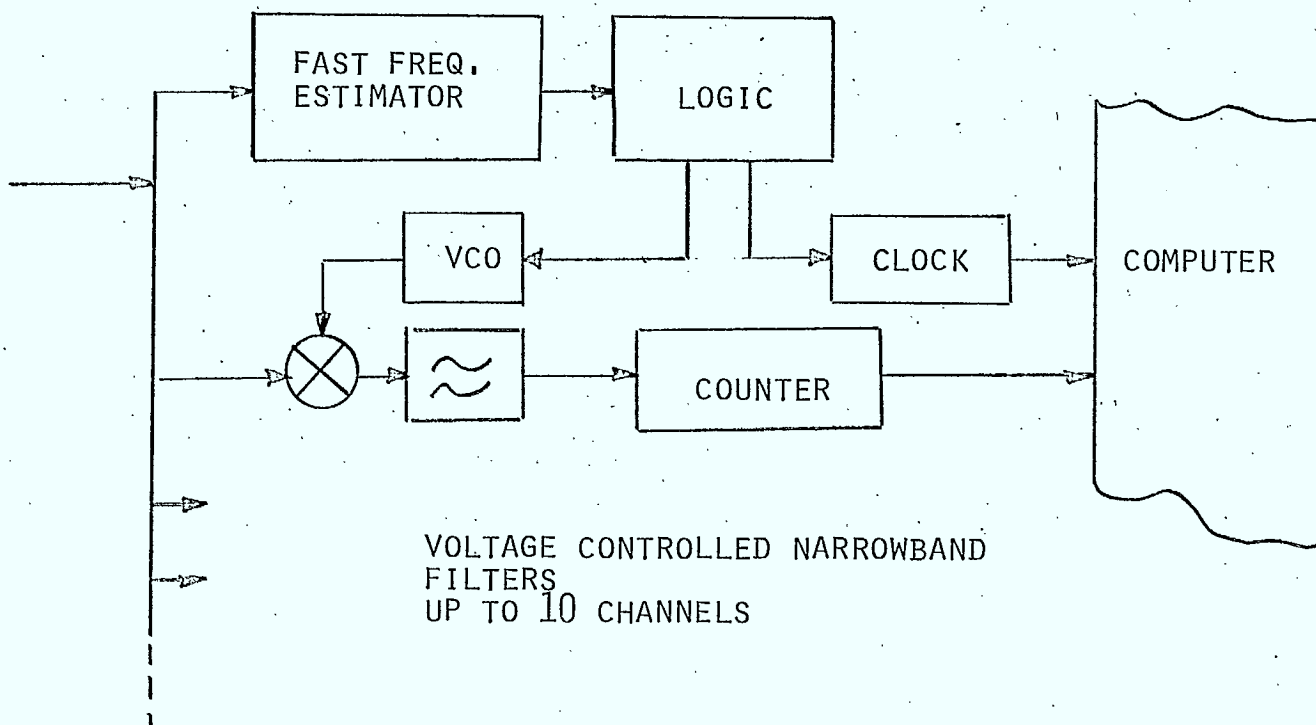
A.



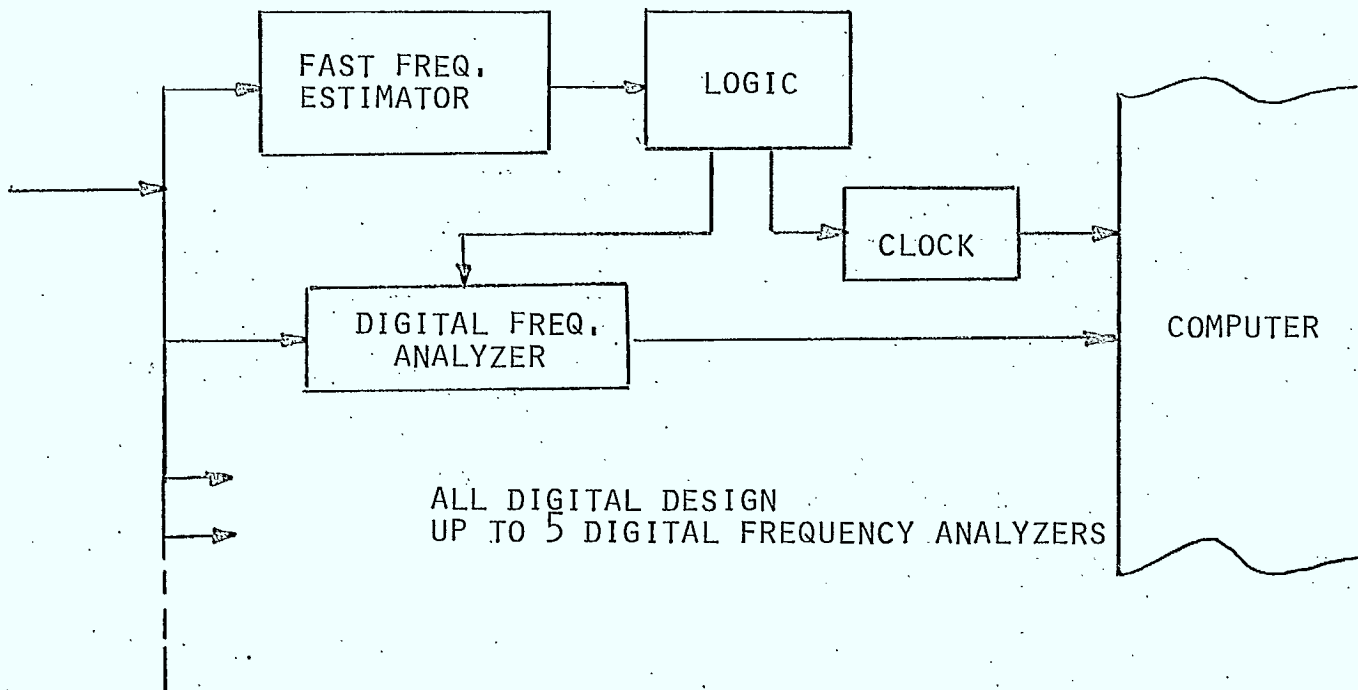
B.



C.



D.



FISHERIES SURVEILLANCE SYSTEM

3-6 DATA PROCESSING

A. FUNCTIONAL TASKS

- o DATA SORTING, LIP IDENTIFICATION
- o ORBIT DETERMINATION AND PREDICTION
- o LIP LOCATION DETERMINATION

B. DATA SORTING, LIP IDENTIFICATION

- o DUTY CYCLE, FREQUENCY CORRELATION
- o ORBIT DATA - FIXED LIP'S
- o SHIP DATA - OTHER LIP'S

C. ORBIT DETERMINATION AND PREDICTION

- o TECHNIQUES
 - WEIGHTED LEAST SQUARES
 - KALMAN FILTER
 - ANALYTIC INTEGRATION
- o ESTIMATED PARAMETERS
 - 6 KEPLERIAN ELEMENTS
 - 1 DRAG TERM
 - 1 SYSTEMATIC DATA BIAS (FREQUENCY)
- o OUTPUT
 - POSITION AND VELOCITY VECTORS
 - AZ-EL PREDICTIONS

D. LIP LOCATION DETERMINATION

- o TECHNIQUES
 - KALMAN FILTER
 - WEIGHTED LEAST SQUARES - SPECIAL
 - 3 PASSES THROUGH DATA

FISHERIES SURVEILLANCE SYSTEM

(CON'T)

3-6 DATA PROCESSING

D. LIP LOCATION DETERMINATION (CON'T)

o ESTIMATED PARAMETERS

- LATITUDE
- LONGITUDE
- CENTER FREQUENCY (OPTIONAL)
- FREQUENCY DRIFT (OPTIONAL)

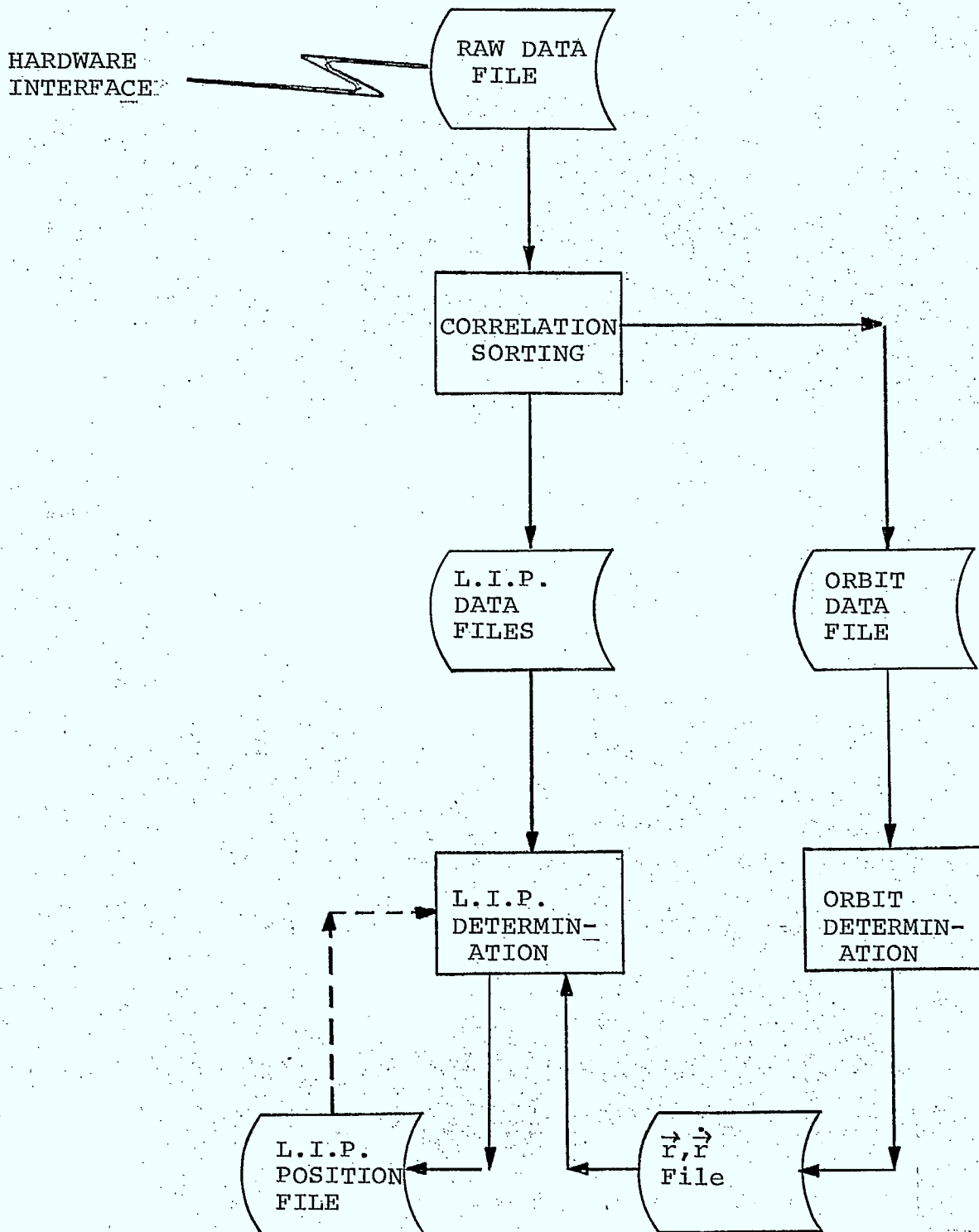
o OUTPUT FILE

- LIP IDENTIFICATION
- LATITUDE
- LONGITUDE
- STANDARD DEVIATIONS
- NO. OF DATA PROCESSED
- CENTER FREQUENCIES & DRIFT (OPTIONAL)

FISHERIES SURVEILLANCE SYSTEM

DATA PROCESSING

BLOCK DIAGRAM



CHAPTER 4

SYSTEM CONFIGURATION

4-1 DATA COLLECTION PLATFORM (DCP)

STATE-OF-THE-ART DESIGNS EXIST FOR DCP'S FOR THE EXISTING LANDSAT AND GOES SYSTEMS.

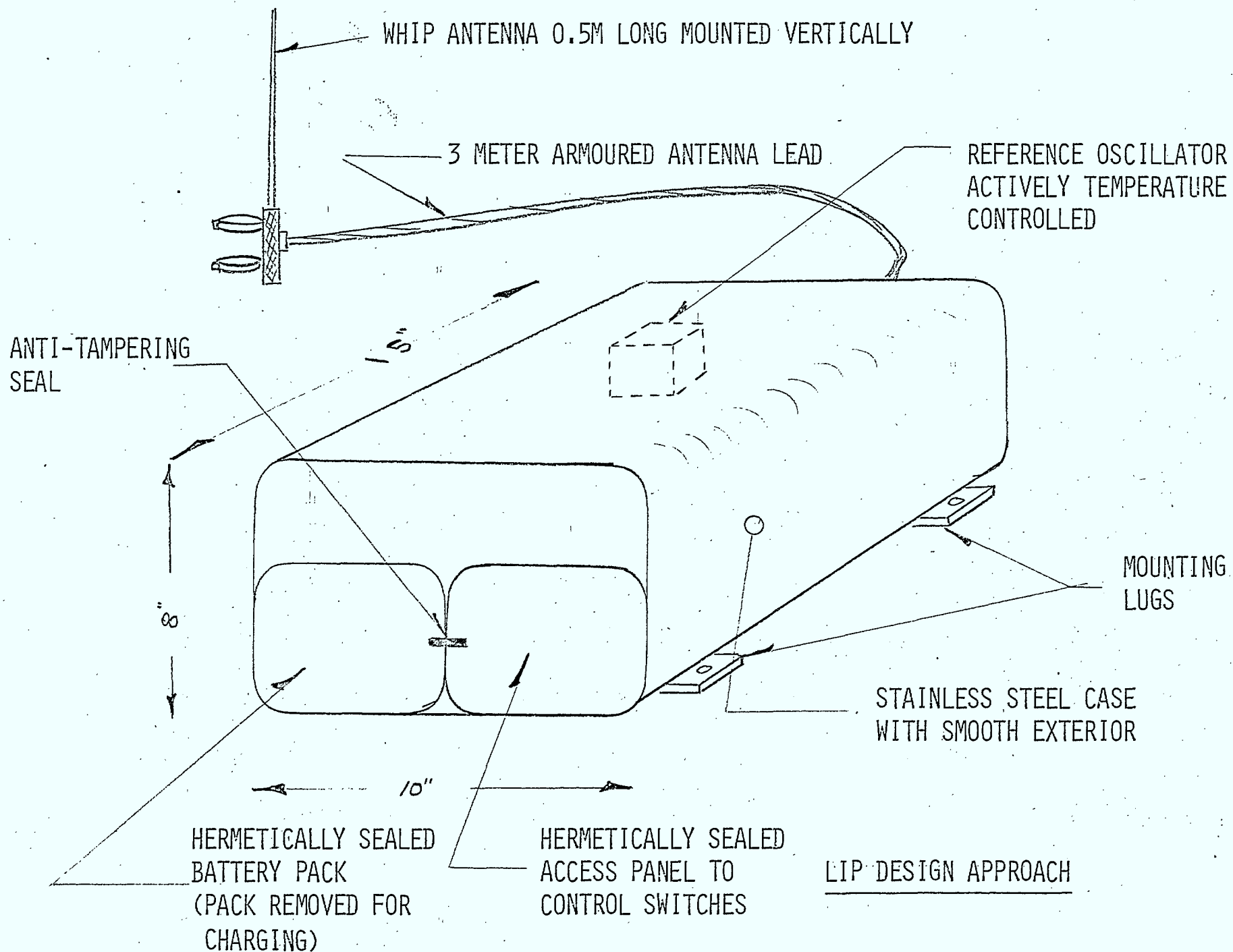
o THE PROPOSED SYSTEM WILL USE SIMILAR PLATFORMS TO THOSE MANUFACTURED BY THE FOLLOWING COMPANIES:

- BALL BROTHERS RESEARCH
- BRISTOL AEROSPACE
- GENERAL ELECTRIC
- MAGNAVOX
- LABARGE INC. ELECTRONICS DIVISION

4-2 LOCATION INDICATION PLATFORM (LIP)

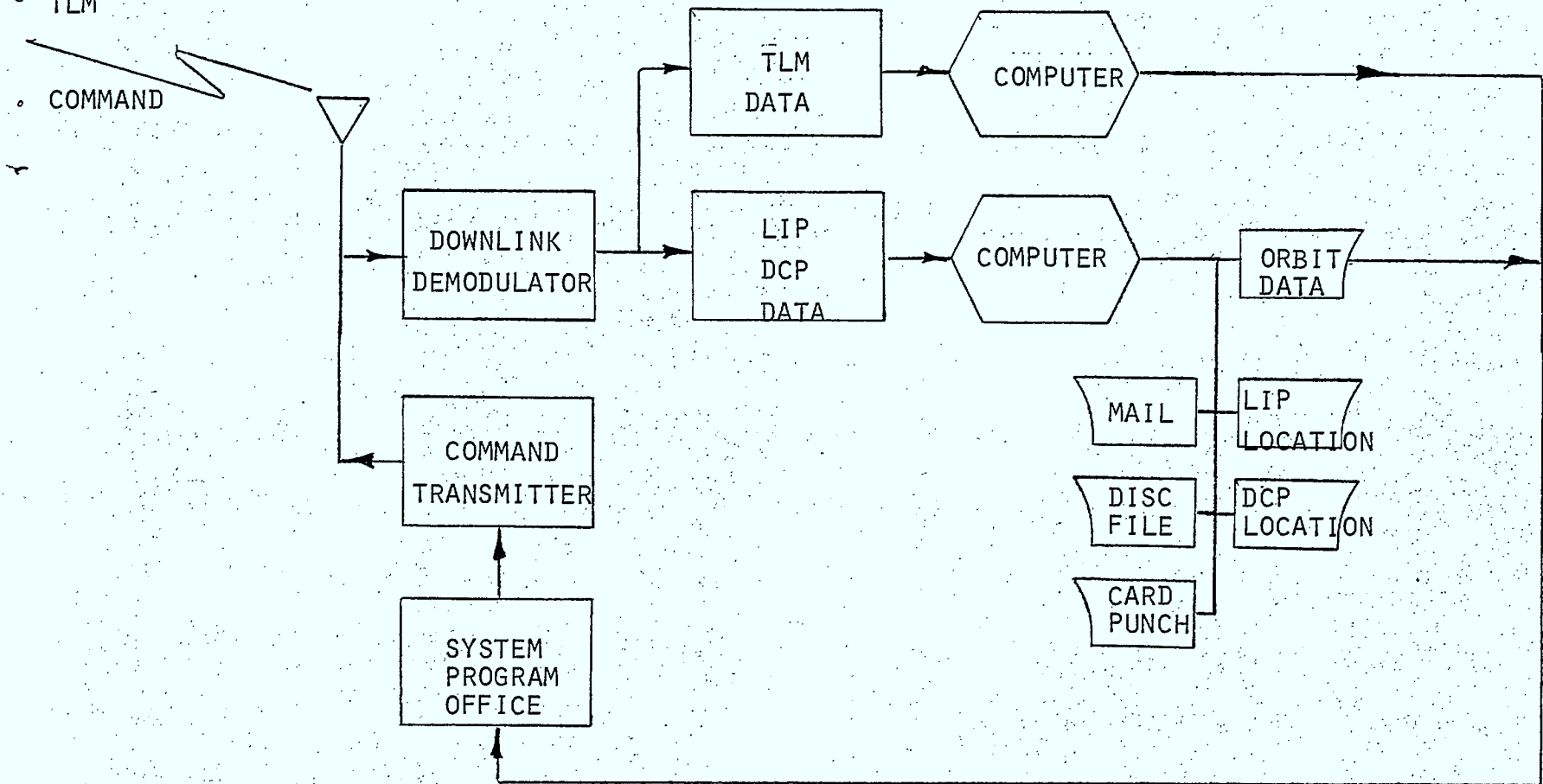
DESIGN REQUIREMENTS:

- o UNATTENDED OPERATION OVER TEMPERATURE EXTREMES
- o COMPACT DESIGN
- o WEATHER PROOF
- o UNIVERSAL CLAMPS TO FACILITATE MONITORING ON VESSELS
- o CAPABILITY FOR OPERATIONAL TEST AFTER INSTALLATION
- o MUST MEET THE SYSTEM REQUIREMENTS FOR EIRP OVER EXPECTED VIEW ANGLES, OSCILLATOR STABILITY, AND DUTY CYCLE.



A. GENERAL CONFIGURATION

- DCR
- LIP
- TLM

GROUND SEGMENT: DATA FLOW

4-3 GROUND STATIONS

B. GROUND SEGMENT CONFIGURATION TRADEOFFS

- CRITERIA

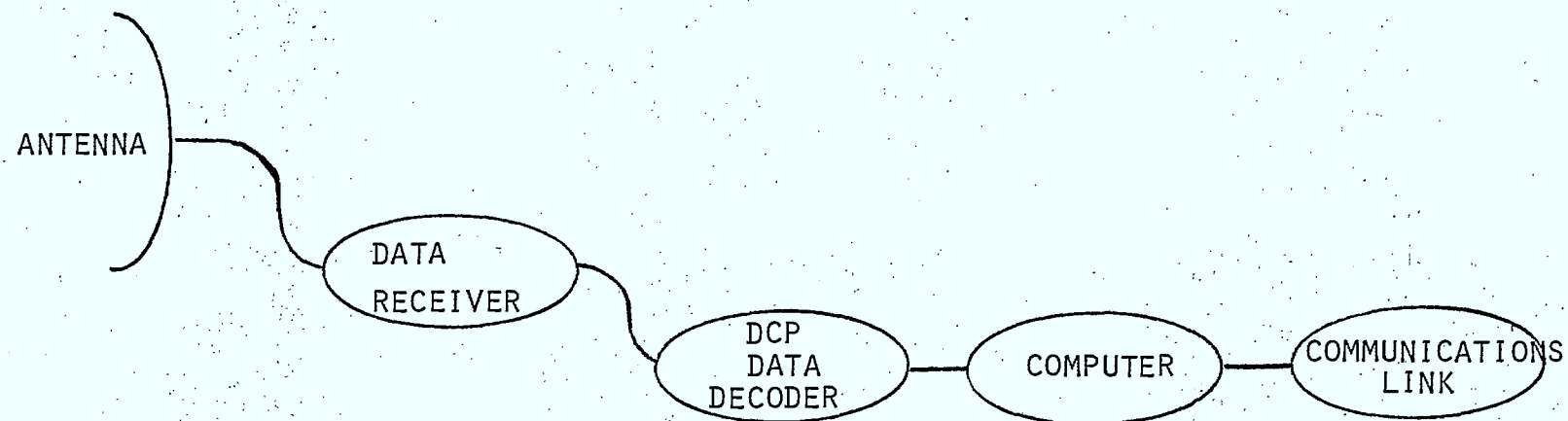
- o MINIMIZE NUMBER OF LOCATIONS CONSISTENT WITH PROVIDING REQUIRED COVERAGE
- o MINIMIZE SYSTEM IMPLEMENTATION COST CONSIDERING BOTH GROUND STATION HARDWARE AND DATA TRANSMISSION COSTS.

- APPROACH

- o GROUND SEGMENT HARDWARE DIVIDED INTO THE FOLLOWING FUNCTIONAL UNITS:
 - DATA COLLECTION TERMINAL (DCT)
 - LOCATION INDICATION TERMINAL (LIT)
 - COMBINED DCT AND LIT
 - COMMAND AND TELEMETRY TERMINAL (T&C)
 - ORBIT DETERMINATION CAPABILITY (ODC)
- o THE FUNCTIONAL UNITS WERE ALLOCATED TO LOCATIONS CHOSEN TO PROVIDE THE REQUIRED COVERAGE
- o SYSTEM CONFIGURATION WAS EVALUATED FOR MINIMUM IMPLEMENTATION COSTS

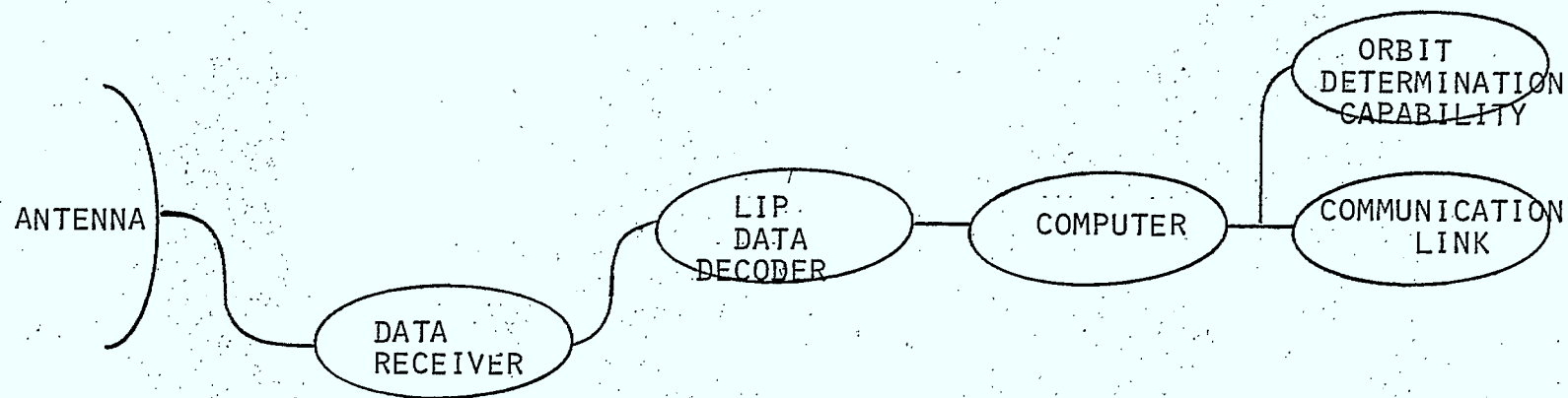
- ALTERNATIVES ASSESSED

1. MINIMUM HARDWARE CONFIGURATION
2. CENTRALIZED CONTROL CONFIGURATION
3. DECENTRALIZED FACILITIES
4. SEPARATE DCP, LIP SYSTEMS



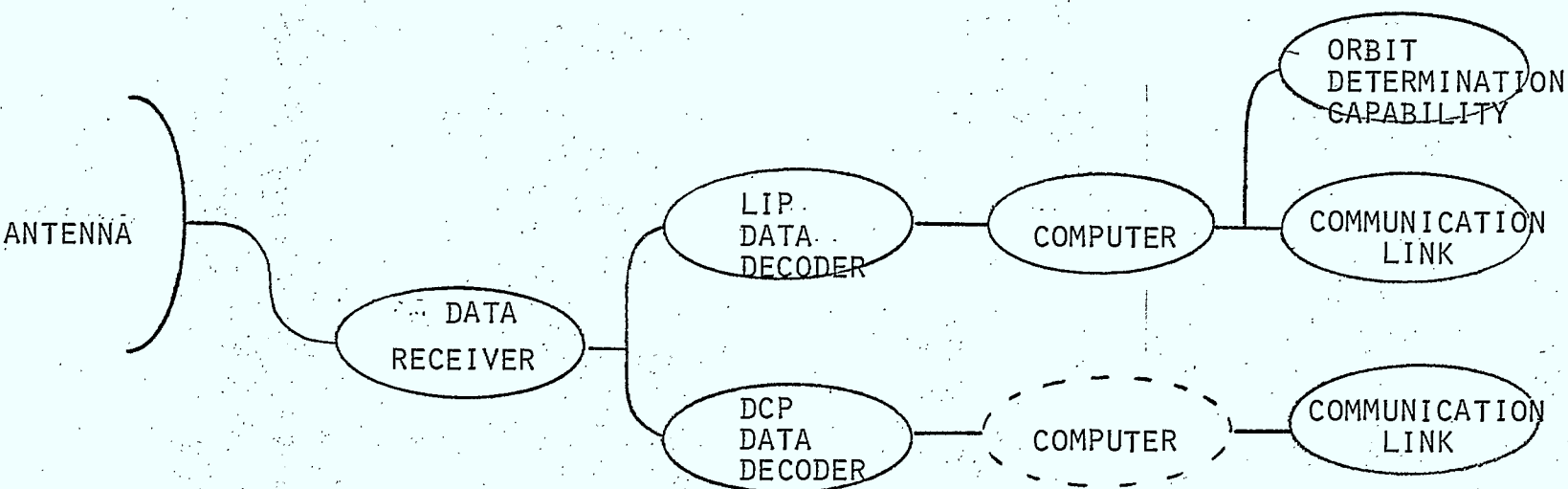
C. GROUND STATION TYPE

DATA COLLECTION TERMINAL (DCT)



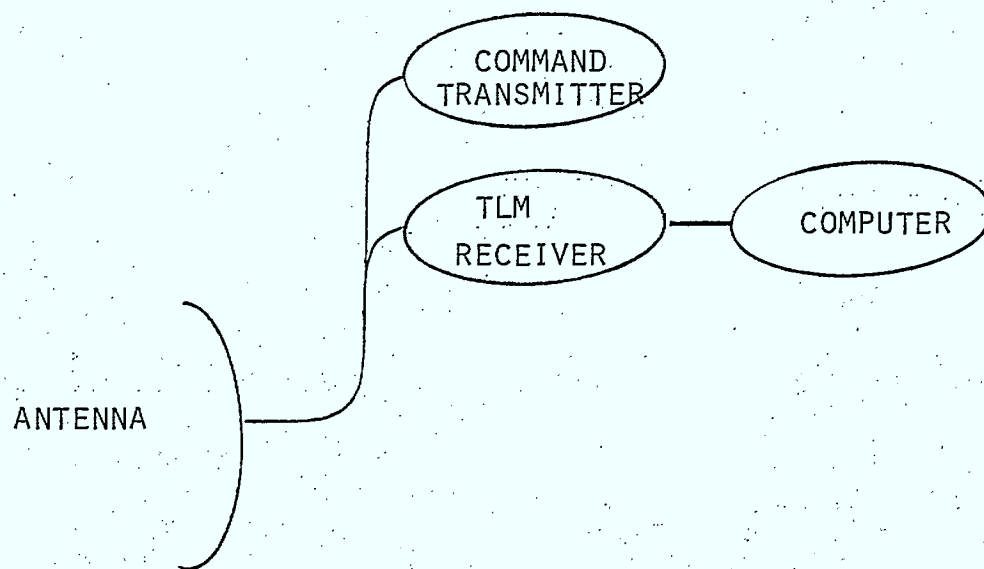
C. GROUND STATION TYPE

LOCATION INDICATION TERMINAL (LIT)



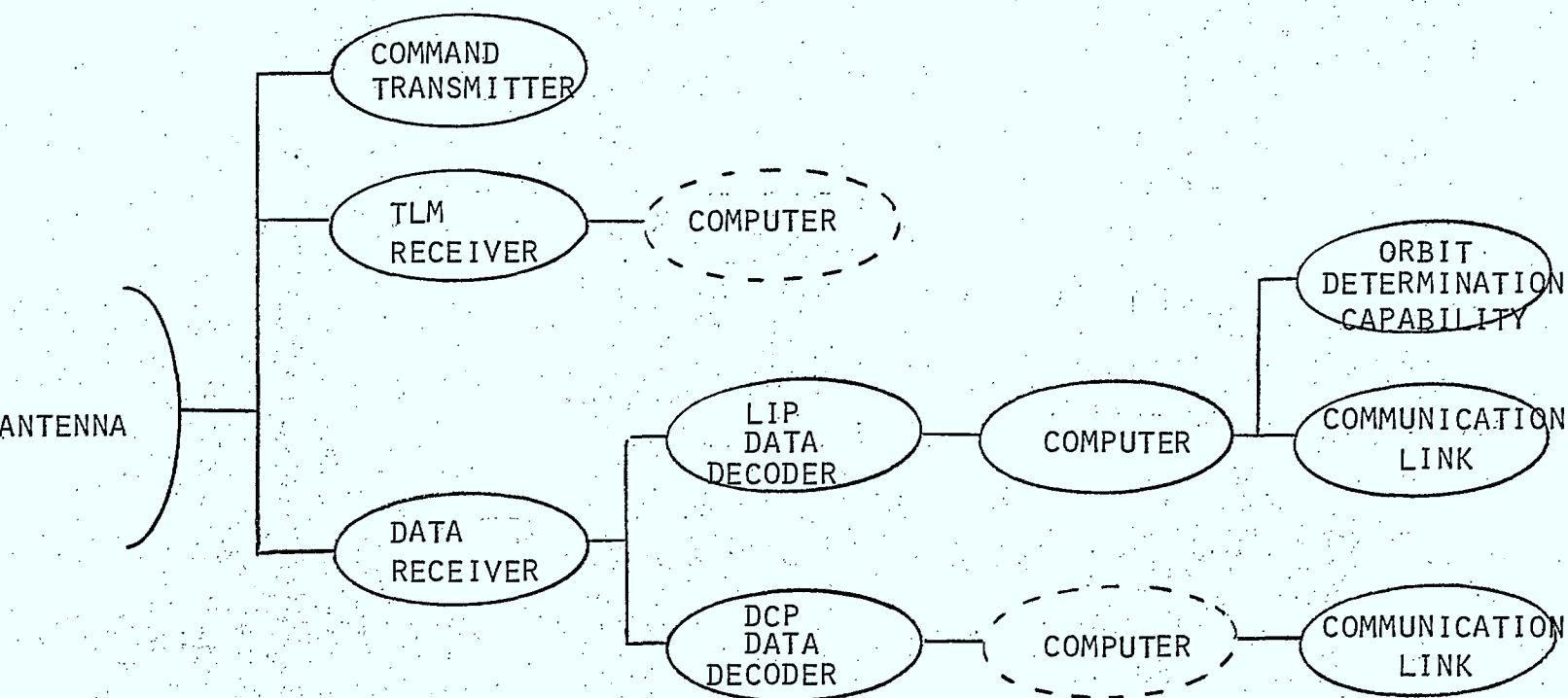
C. GROUND STATION TYPE

EO DATA COLLECTION & LOCATION INDICATION TERMINALS (DCT, LIT)



C. GROUND STATION TYPE

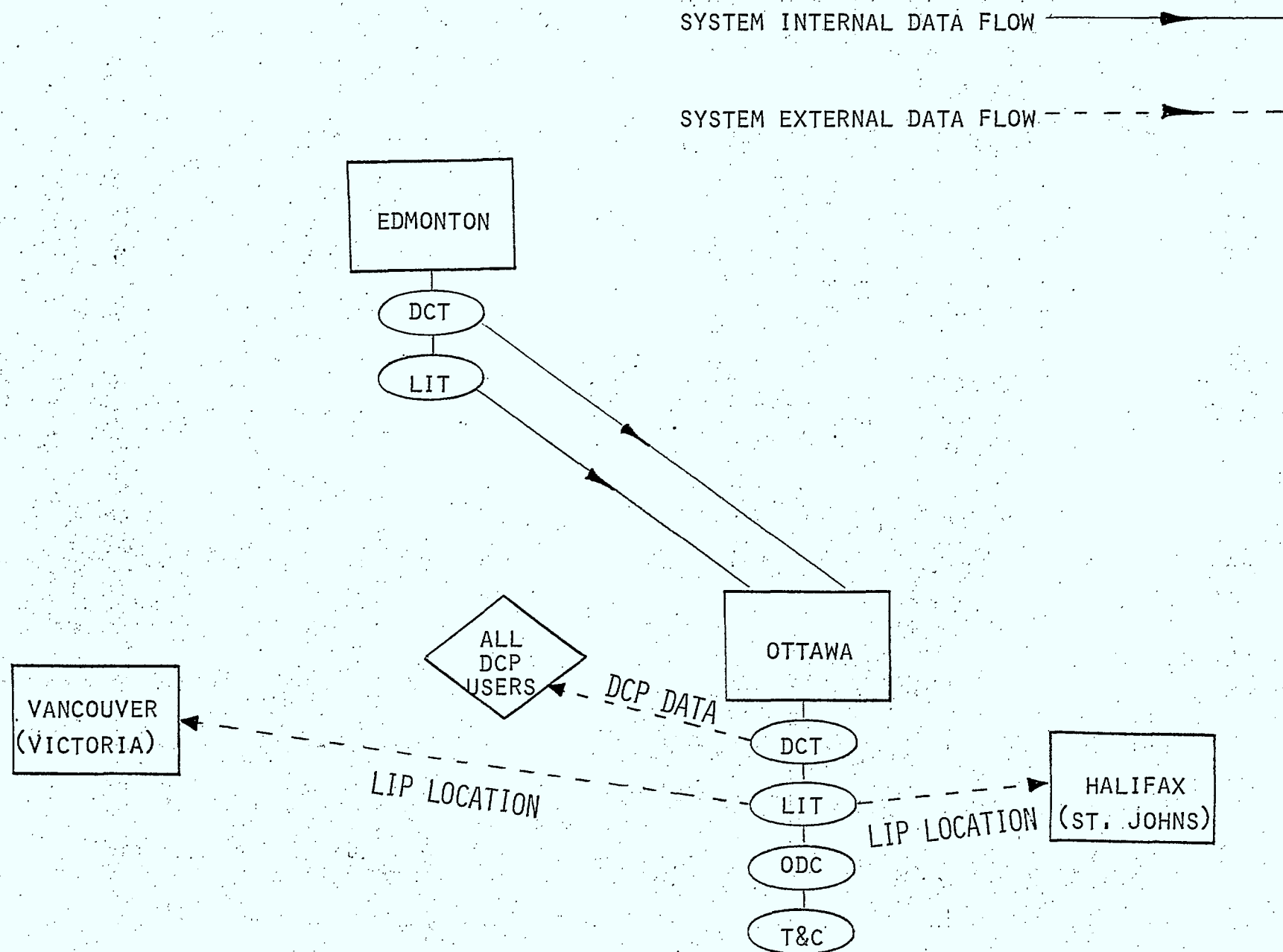
TELEMETRY & COMMAND TERMINAL (T&C)



C. GROUND STATION TYPE

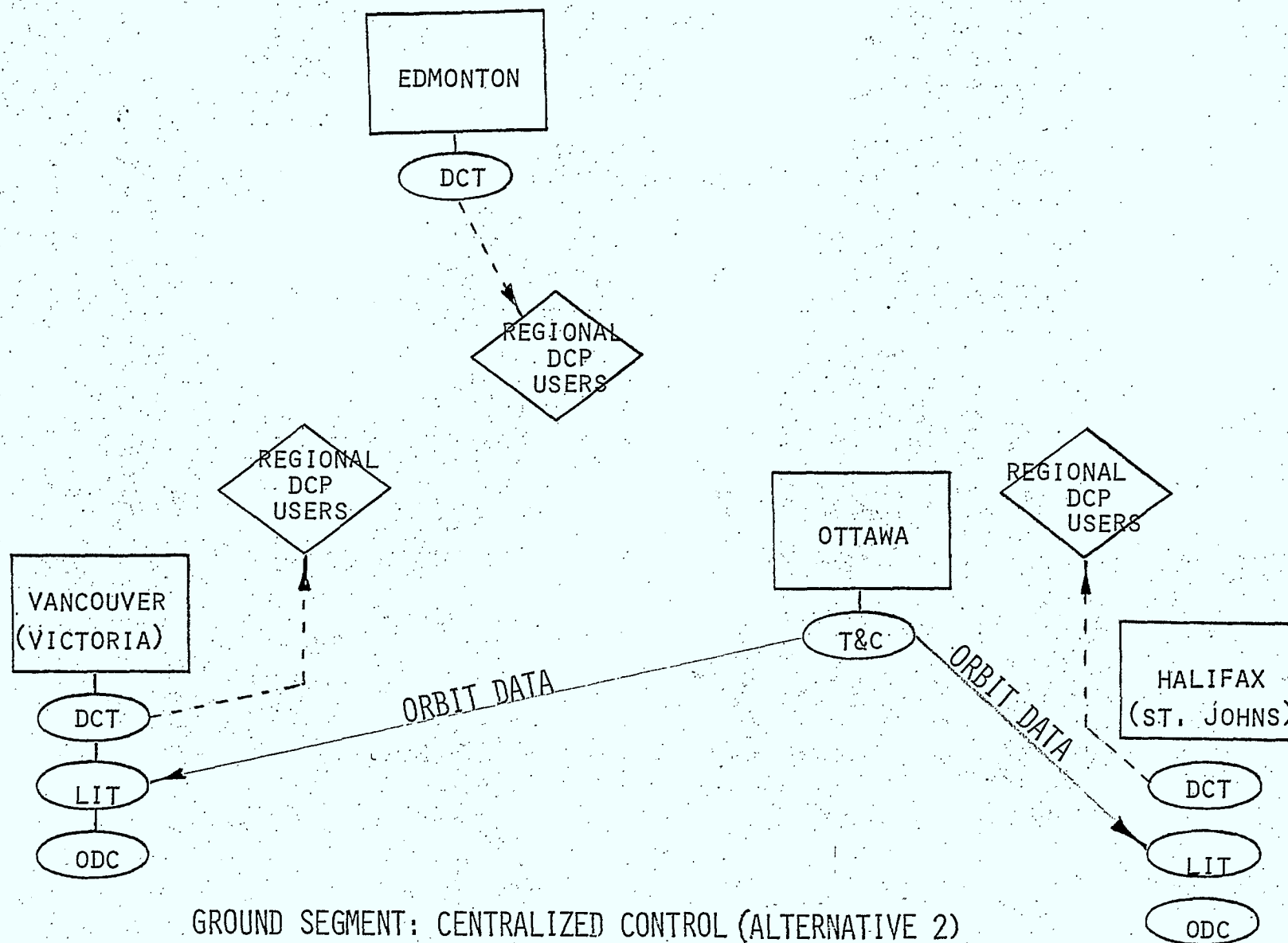
FULL CAPABILITY TERMINAL

D. GROUND STATION LOCATIONS



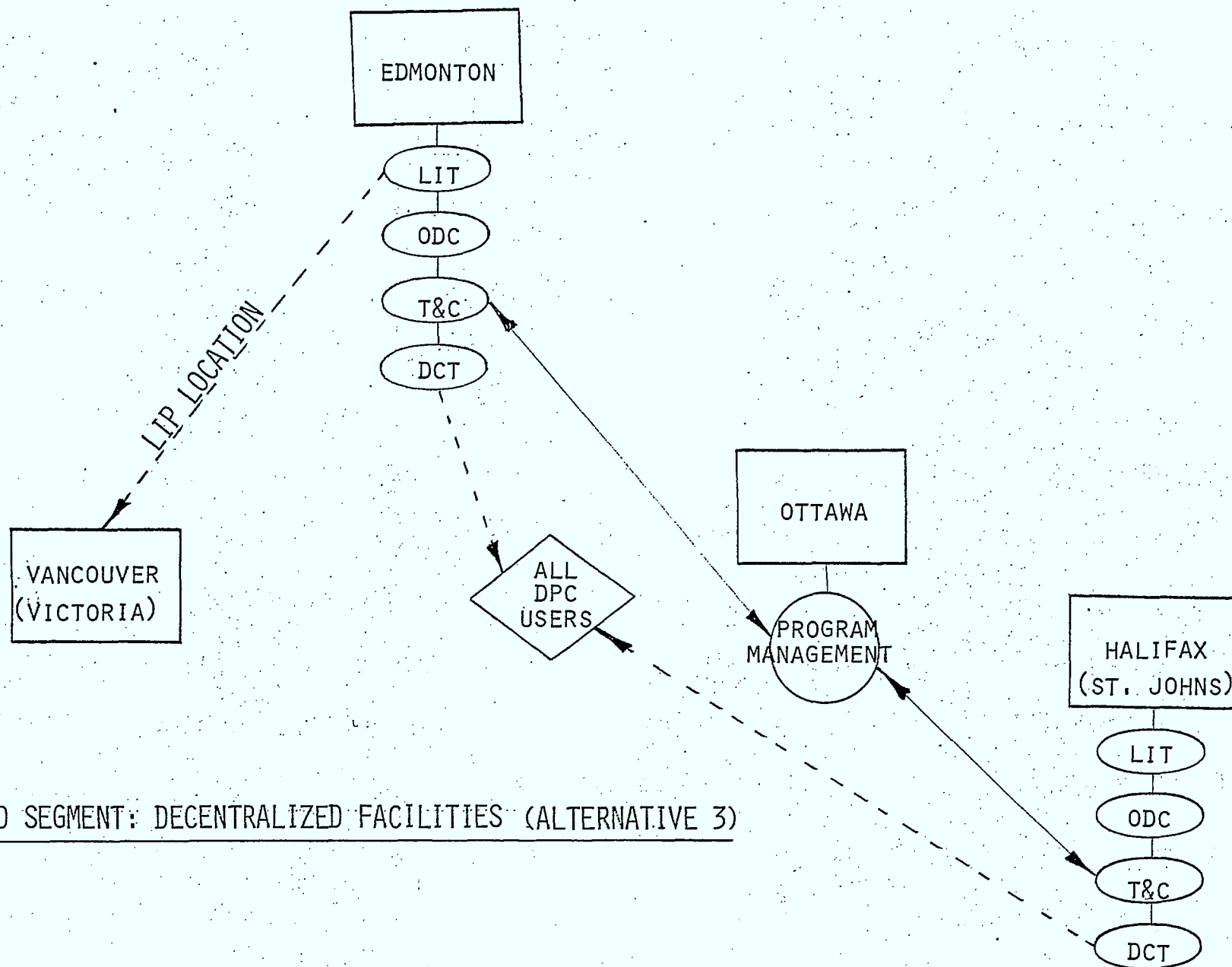
GROUND SEGMENT: MINIMUM GROUND STATION (ALTERNATIVE 1)

D. GROUND STATION LOCATIONS



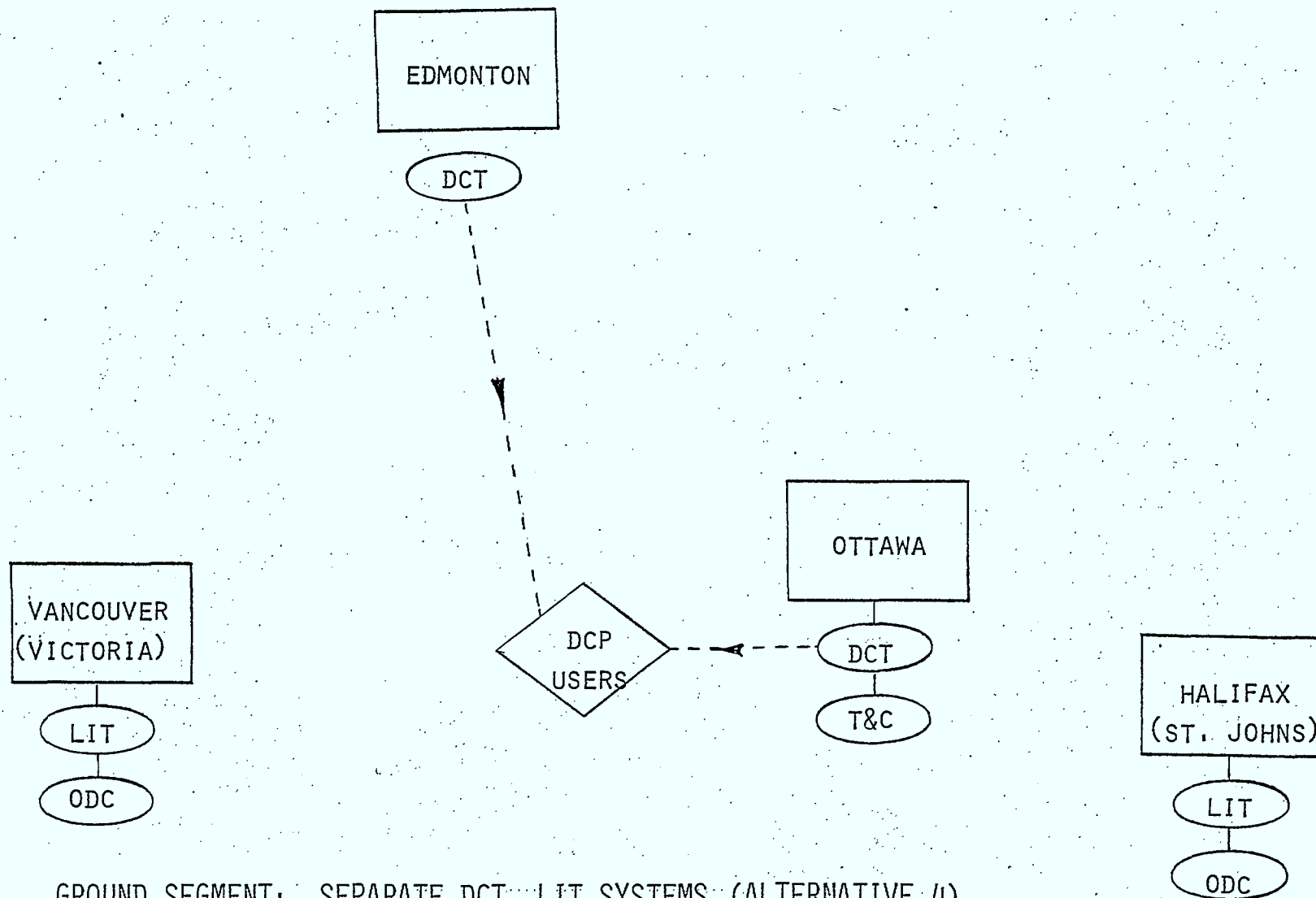
GROUND SEGMENT: CENTRALIZED CONTROL (ALTERNATIVE 2)

D. GROUND STATION LOCATIONS

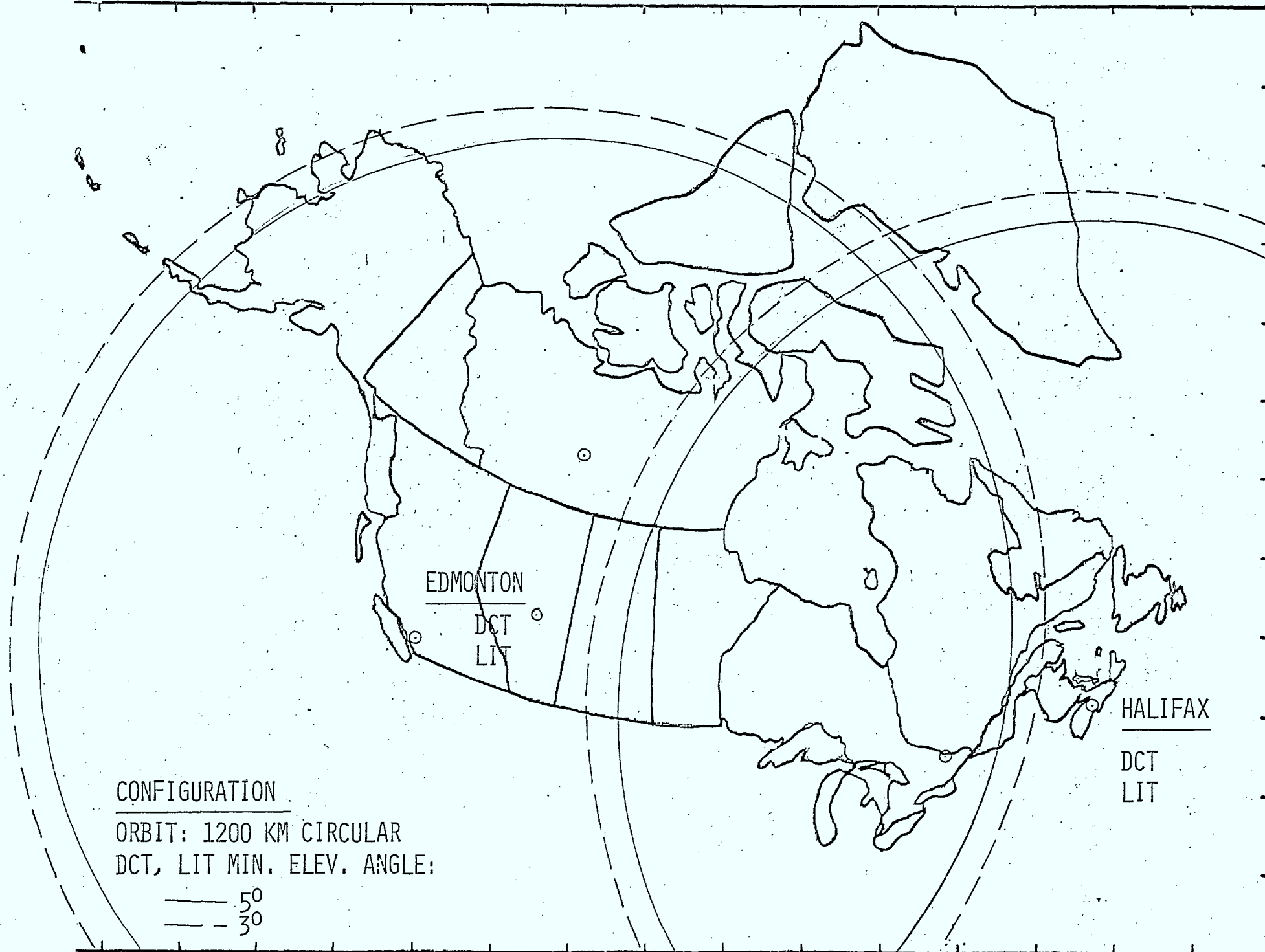


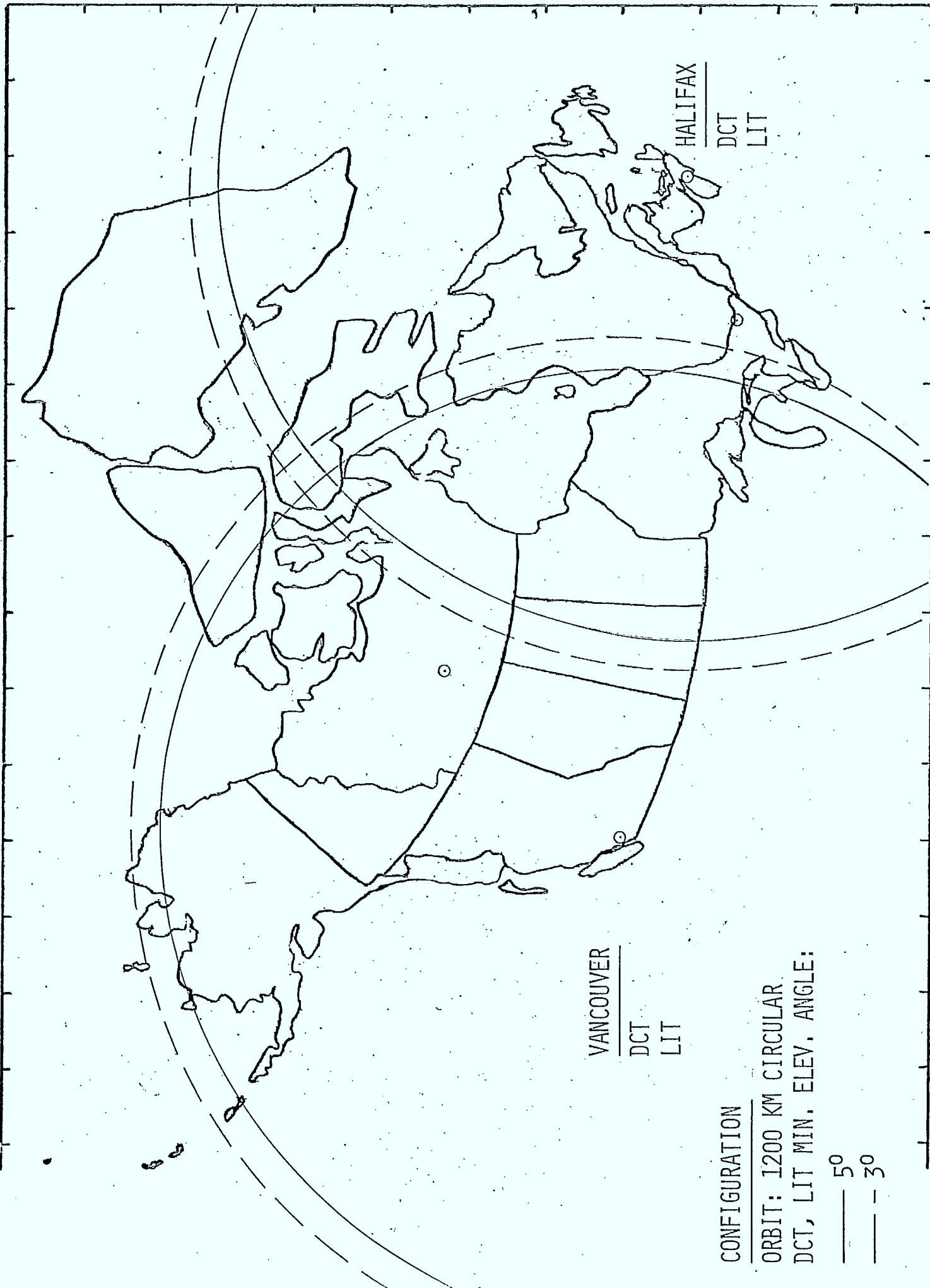
GROUND SEGMENT: DECENTRALIZED FACILITIES (ALTERNATIVE 3)

D. GROUND STATION LOCATIONS



GROUND SEGMENT: SEPARATE DCT, LIT SYSTEMS (ALTERNATIVE 4)





NORTH

10° ELEV.
1200 KM.

○ DCP
OR
LIP

4-4 MISSION CONTROL

A. FUNCTIONS

- o MONITORS S/C HEALTH AND STATUS
- o CONTROLS LAUNCH AND ATTITUDE ACQUISITION
- o STORES HISTORICAL DATA
- o PROVIDES DATA FOR MANAGEMENT CONTROL OF SYSTEM

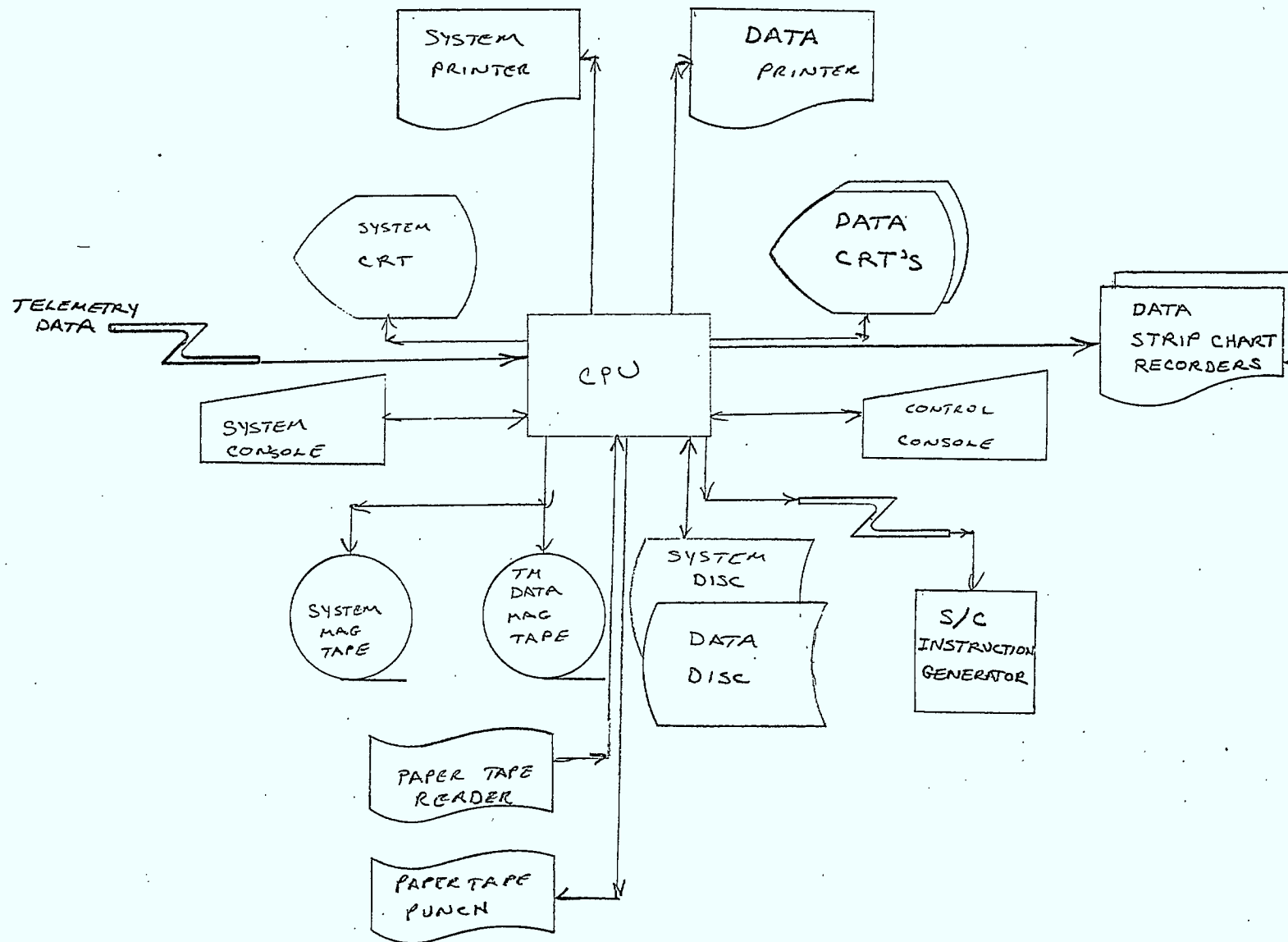
B. LOCATION

- o AT PROGRAM MANAGEMENT OFFICE

C. MISSION CONTROL COMPUTER CONFIGURATION

- o RECEIVES TELEMETRY DATA
- o CONVERTS TO SCIENTIFIC UNITS
- o DISPLAYS TELEMETRY DATA
- o STORES DATA
- o ANALYZES DATA
- o VERIFYS COMMANDS
- o TRANSMITS COMMANDS TO GROUND STATIONS

COMPUTER CONFIGURATION



4-4 MISSION CONTROL

D. TELEMETRY AND COMMAND

COMMAND UPLINK BUDGET

TRANSMITTER POWER (20 WATTS)	43 DBM
CIRCUIT LOSSES	- 1 DB
TRANSMITTING ANTENNA GAIN	20 DB
TRANSMITTING ANTENNA POINTING INACCURACY LOSS	0 DB

	<u>0° ELEVATION</u>	<u>90° ELEVATION</u>
PATH LOSS	-156.9 DB	-146.4 DB
POLARIZATION LOSS	- 2 DB	- 2 DB
RECEIVE ANTENNA GAIN OMNI-DIRECTIONAL WITH 10 DB NULLS	- 10 DB	- 10 DB
RECEIVE ANTENNA POINTING INACCURACY LOSS	0 DB	0 DB
TOTAL RECEIVED POWER	-106.9 DBM	-96.4 DBM
TRANSMITTER MODULATION LOSS	- 3 DB	- 3 DB
RECEIVER SIGNAL POWER	-109.9 DBM	- 99.4 DBM
RECEIVER NOISE SPECTRAL DENSITY	-170.8 DBM/Hz	

$$T_{\text{SYSTEM}} = 600^{\circ}\text{K}$$

S/N ₀	60.9 DBHz	71.4 DBHz
------------------	-----------	-----------

E. ORBIT DETERMINATION
TRACKING SYSTEM ALTERNATIVES

TECHNIQUE	A. DOPPLER DATA FROM FIXED LIP'S	B. RANGE WITH (A) RANGE RATE (B) AZ-EL (C) INTERFEROMETER "MINITRACK"
COST	MINIMUM	(A) MODERATE (B) EXPENSIVE (C) EXPENSIVE
ADDITIONAL SPACE- CRAFT REQUIREMENTS	NONE	TRANSPONDER RANGING
GROUND STATION HARDWARE	ACCURATELY LOCATED LIP'S	(A) SPECIALIZED LIP (B) FULL TRACKING ANTENNA (C) SEVERAL ANTENNAE
COMPUTER PROCESSING/ DATA HANDLING	NO ADDITIONAL DATA HANDLING ROUTINES	ADDITIONAL DATA FLOW AND STORAGE REQUIREMENTS
SYSTEM EXAMPLES	TRIAD I TIROS N, DCS	LANDSAT
ACCURACY	VERY HIGH WITH SUFFICIENT DATA SPAN	VERY GOOD
COMMENTS	1. ONLY ONE LIP AT GROUND STATION INITIALLY WITH OPTIONS TO INCREASE NUMBER OF DESIRED. 2. SINCE NO STATIONKEEPING IS ASSUMED ORBIT ACCURACY IMPROVES WITH TIME.	1. LANDSAT SATELLITES ARE STATIONKEPT AND HENCE REQUIRE ACCURATE ORBIT DETERMINATION AND PREDICTION. ALSO SHORTER DATA SPANS ARE ASSUMED.

4-5 SATELLITE ORBITS

A. ORBIT PARAMETERS

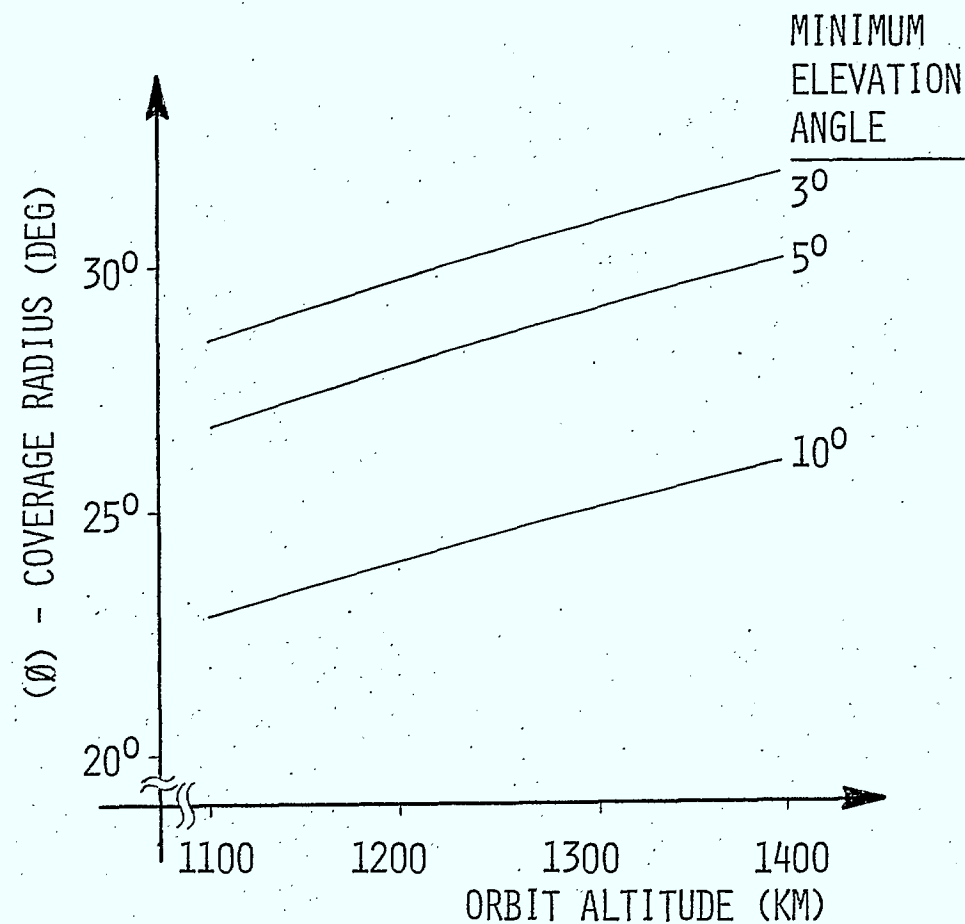
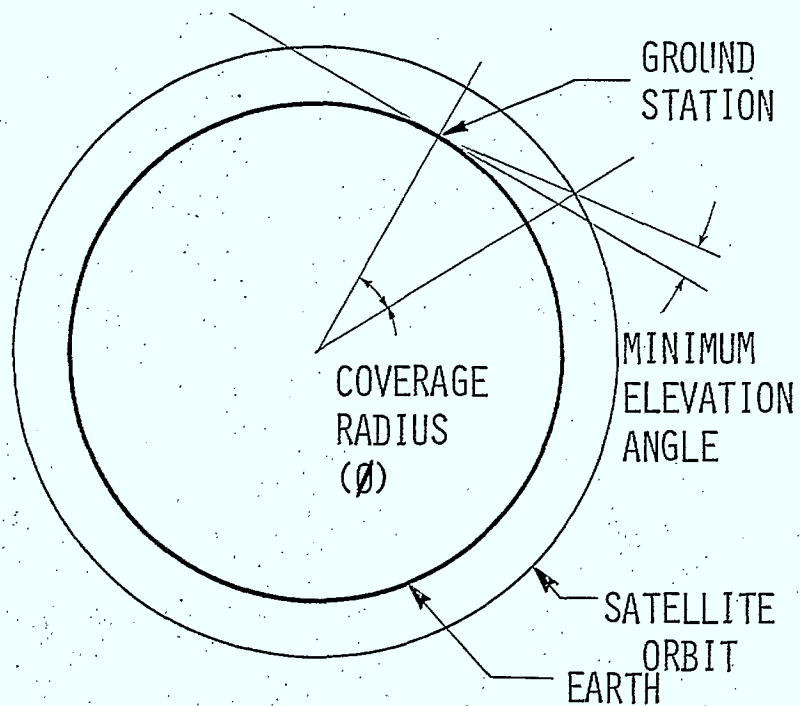
WHY NOT A SUN SYNCHRONOUS ORBIT?

1. DUE TO THE LARGE MAGNITUDE OF THE SCOUT INJECTION ERRORS, INITIALIZING THE ORBIT FOR SUN SYNCHRONISM WILL REQUIRE A REACTION CONTROL SUBSYSTEM WHICH DECREASES THE PAYLOAD WEIGHT AVAILABLE, GREATLY INCREASES THE COST OF THE SPACECRAFT, ETC.
2. A WEIGHT PENALTY IS PAID FOR LAUNCHING INTO A SUN SYNCHRONOUS ORBIT VS A POLAR ORBIT.
3. THE SENSITIVITY OF NODAL ROTATION RATE TO SCOUT INJECTION ERRORS IS ABOUT THREE TIMES LARGER FOR A SUN SYNCHRONOUS ORBIT VERSUS A POLAR ORBIT.
4. SINCE ORBIT PLANES ARE NOT ORIENTED IN THE SAME DIRECTION RELATIVE TO THE SUN EARTH LINE, THERE IS NO ADVANTAGE TO BE GAINED BY DESIGNING THE SPACECRAFT TO HAVE ITS SOLAR PANELS ORIENTED IN SOME OPTIMUM DIRECTION TO MAXIMIZE SOLAR RADIATION INPUT.

A. ORBIT PARAMETERS (CON'T)

WHY NOT AN ELLIPTICAL ORBIT?

1. IF AN ELLIPTICAL ORBIT IS DESIRED TO ACHIEVE A HIGH APOGEE OVER THE NORTH POLE FOR INCREASED VISIBILITY TIMES, A REACTION CONTROL SUBSYSTEM WILL BE REQUIRED FOR STATIONKEEPING DUE TO THE HIGH PERIGEE PRECESSION RATES.
2. RADIATION DAMAGE IS MORE SEVERE AT HIGHER (APOGEE) ALTITUDES.
3. A GRAVITY GRADIENT STABILIZED SATELLITE WILL EXPERIENCE PERTURBING TORQUES AT ORBITAL RATE DUE TO ORBIT ECCENTRICITY.
4. IF COVERAGE IS OPTIMISED FOR CANADIAN COVERAGE, COVERAGE IS POOR AT MORE SOUTHERLY LATITUDES.



RADIUS OF COVERAGE OF A GROUND STATION BY A SATELLITE

A. ORBIT PARAMETERS (CONT'D)

A. ORBIT PARAMETERS (CON'T)

PARAMETER SELECTION

ECCENTRICITY = 0 (CIRCULAR ORBIT)

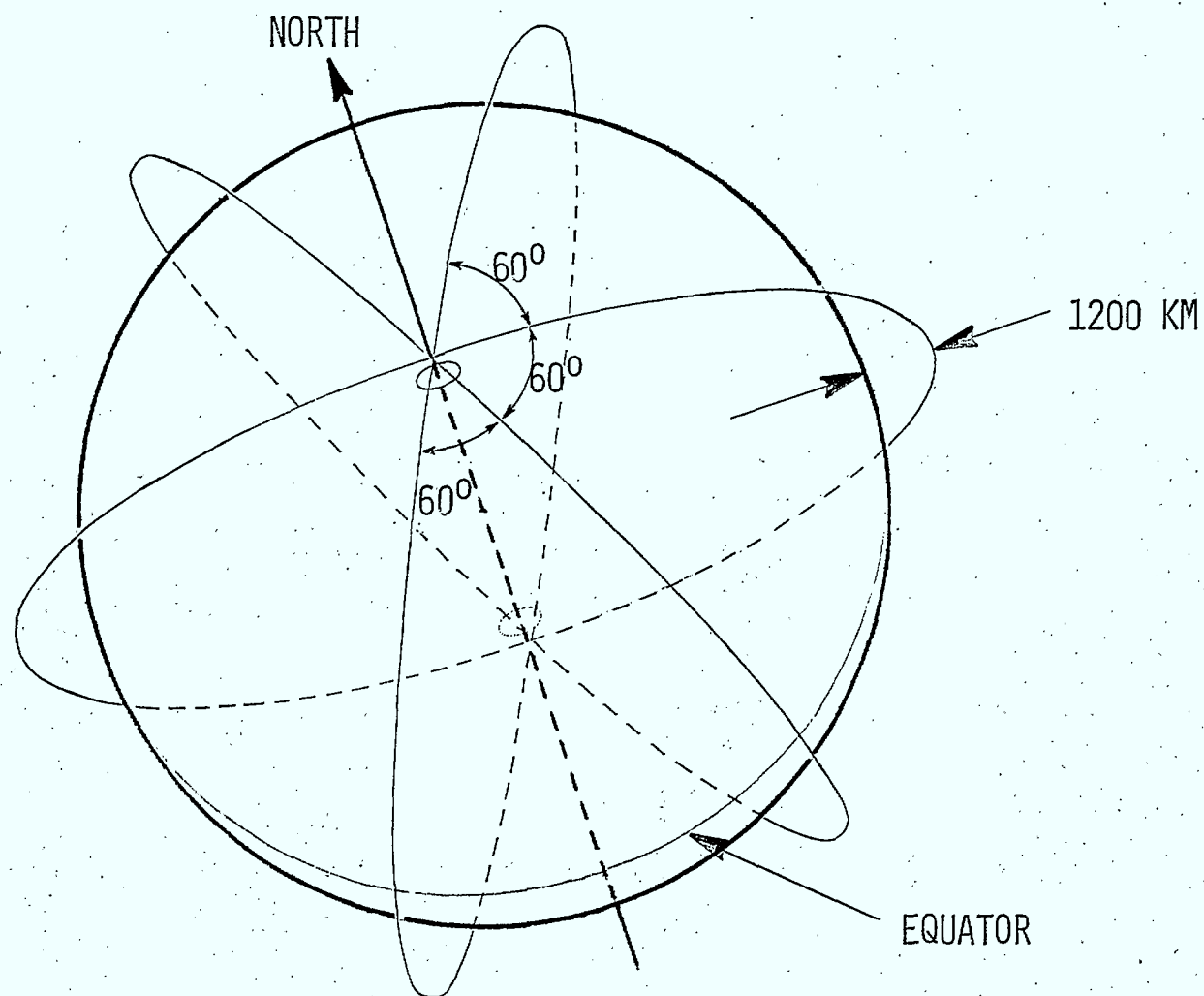
ALTITUDE = 1200 KM

INCLINATION = 90° (POLAR ORBIT)

RIGHT ASCENSION OF ASCENDING NODE:

1ST SATELLITE: ARBITRARY

FOR 2ND AND SUBSEQUENT SATELLITES, THE ORBITS ARE
ORIENTED NOMINALLY SO AS TO EQUALLY SPACE THE
ORBIT PLANES.

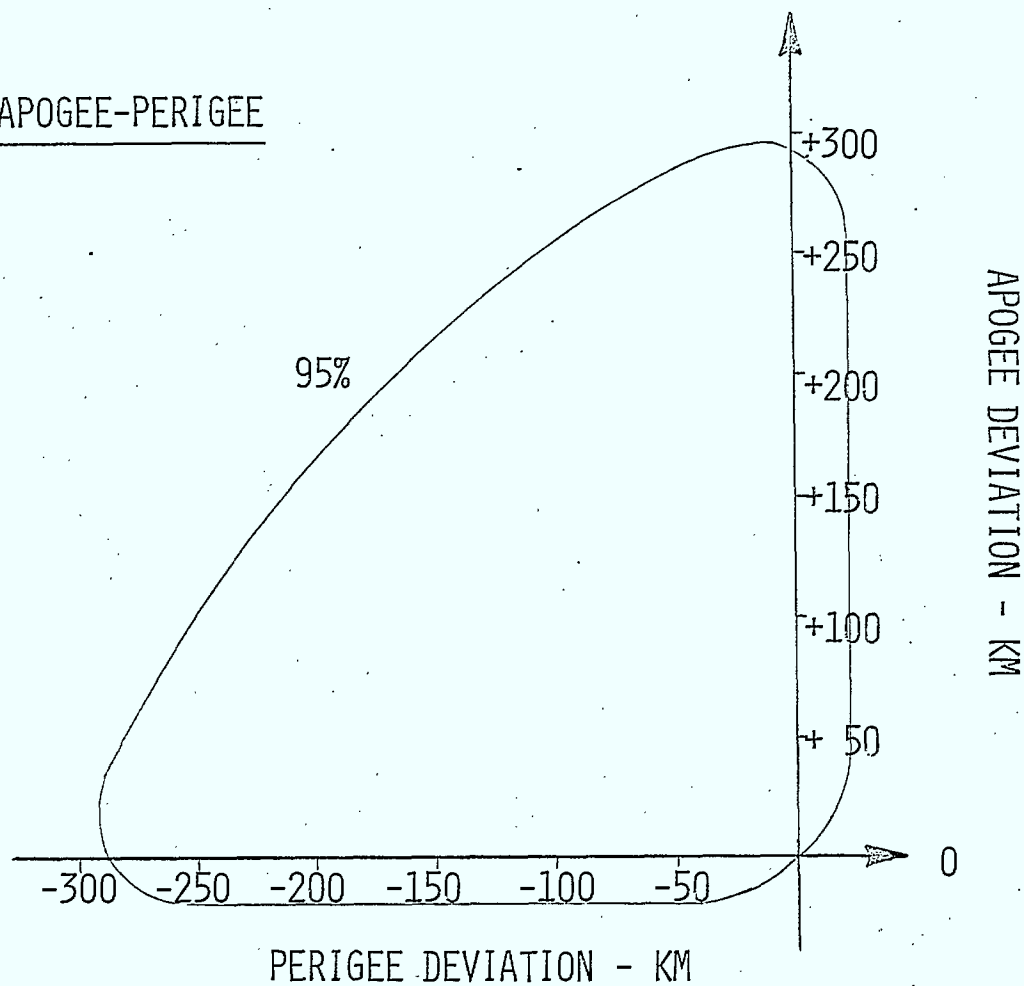


DATA COLLECTION AND FISHERIES SURVEILLANCE SATELLITE

ORBIT CONSTELLATION

A. ORBIT PARAMETERS (CONT'D)

APOGEE-PERIGEE



INCLINATION

WITH ROLL-YAW COMPENSATION:

$0.2^\circ \pm 6$
(CRUDE ESTIMATE)

WITHOUT ROLL-YAW COMPENSATION:

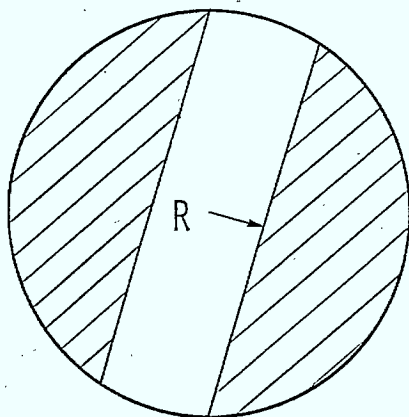
$0.55^\circ \pm 6$

ESTIMATED SCOUT INJECTION ERRORS - 1200 KM ORBIT

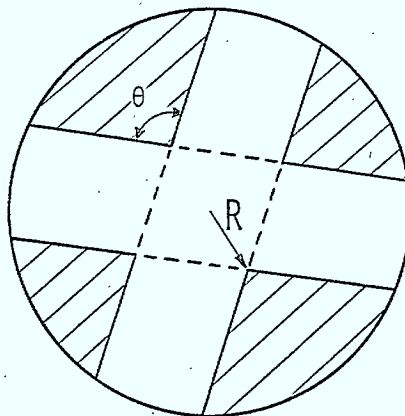
B. SCOUT INJECTION ERRORS

B. EFFECT OF LAUNCH VEHICLE INJECTION ERRORS

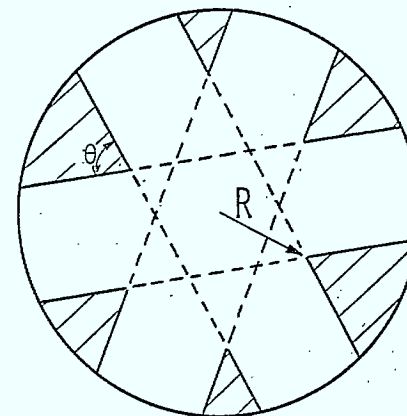
- o RADIUS OF COVERAGE OF A GROUND STATION VARIES FROM NOMINAL (14% PER 100 KM ALTITUDE DEVIATION FROM 1200 KM)
(N.B. - THE PERIGEE, OR MINIMUM ALTITUDE POINT IN THE ORBIT ROTATES APPROXIMATELY 1000 DEGREES PER YEAR)
- o RIGHT ASCENSION OF ASCENDING NODE (Ω) DOES NOT REMAIN FIXED IN INERTIAL SPACE - THAT IS, THE ORBIT PLANES WILL ROTATE RELATIVE TO EACH OTHER, CHANGING THE NOMINAL SPACING. (34.7 DEGREES ROTATION PER YEAR PER DEGREE OF INCLINATION ERROR). THEREFORE, TO MAINTAIN SOME MAXIMUM ALLOWABLE PLANE SEPARATION, EITHER AN ON BOARD PROPULSION SYSTEM IS REQUIRED, OR ONE OR MORE ADDITIONAL SATELLITE LAUNCHES ARE REQUIRED.
- o ACTUAL ORBIT IS LIKELY TO BE SLIGHTLY ELLIPTICAL, INCREASING THE GRAVITY GRADIENT TORQUE PERTURBATIONS
- o ORBIT PERIODS WILL NOT BE THE SAME (ERROR IN PERIOD IS ABOUT 1 MINUTE - 1σ)



ONE SATELLITE CONSTELLATION



TWO SATELLITE CONSTELLATION



THREE SATELLITE CONSTELLATION

- WHITE BANDS REPRESENT SWATHS OF SATELLITE COVERAGE (CENTERED ON SUBSATELLITE TRACK)
- HATCHED AREAS ARE NOT SEEN BY ANY SATELLITE DURING ONE ORBITAL CYCLE
- EARTH ROTATION EFFECTS IGNORED DURING COVERAGE PASS
- R IS THE RADIUS OF A CIRCULAR ZONE WHICH IS ALWAYS COVERED DURING ANY ORBIT CYCLE (THE COVERAGE PATTERNS SHOWN ROTATE APPROXIMATELY 28 DEGREES EACH ORBIT CYCLE (APPROX. 2 HRS.))
- θ IS THE MAXIMUM ANGLE BETWEEN ANY TWO SWATHS IN MULTISATELLITE CONSTELLATION
- S IS THE PROJECTED SWATH WIDTH ($=R$ FOR ONE SATELLITE CONSTELLATION)

POLAR PROJECTION OF SATELLITE SWATHS ON SURFACE OF EARTH

SHOWING AREA COVERED EVERY TWO HOURS

C. NO. OF SATELLITES

$$S = R_E \sin \phi$$

S IS THE PROJECTED SWATH WIDTH

R_E IS RADIUS OF EARTH

ϕ IS COVERAGE RADIUS

$$R = \frac{S}{\sin \frac{\theta}{2}}$$

R IS THE RADIUS OF THE CIRCULAR COVERAGE ZONE

θ IS THE ANGLE BETWEEN THE TWO MOST WIDELY SEPARATED SWATHS

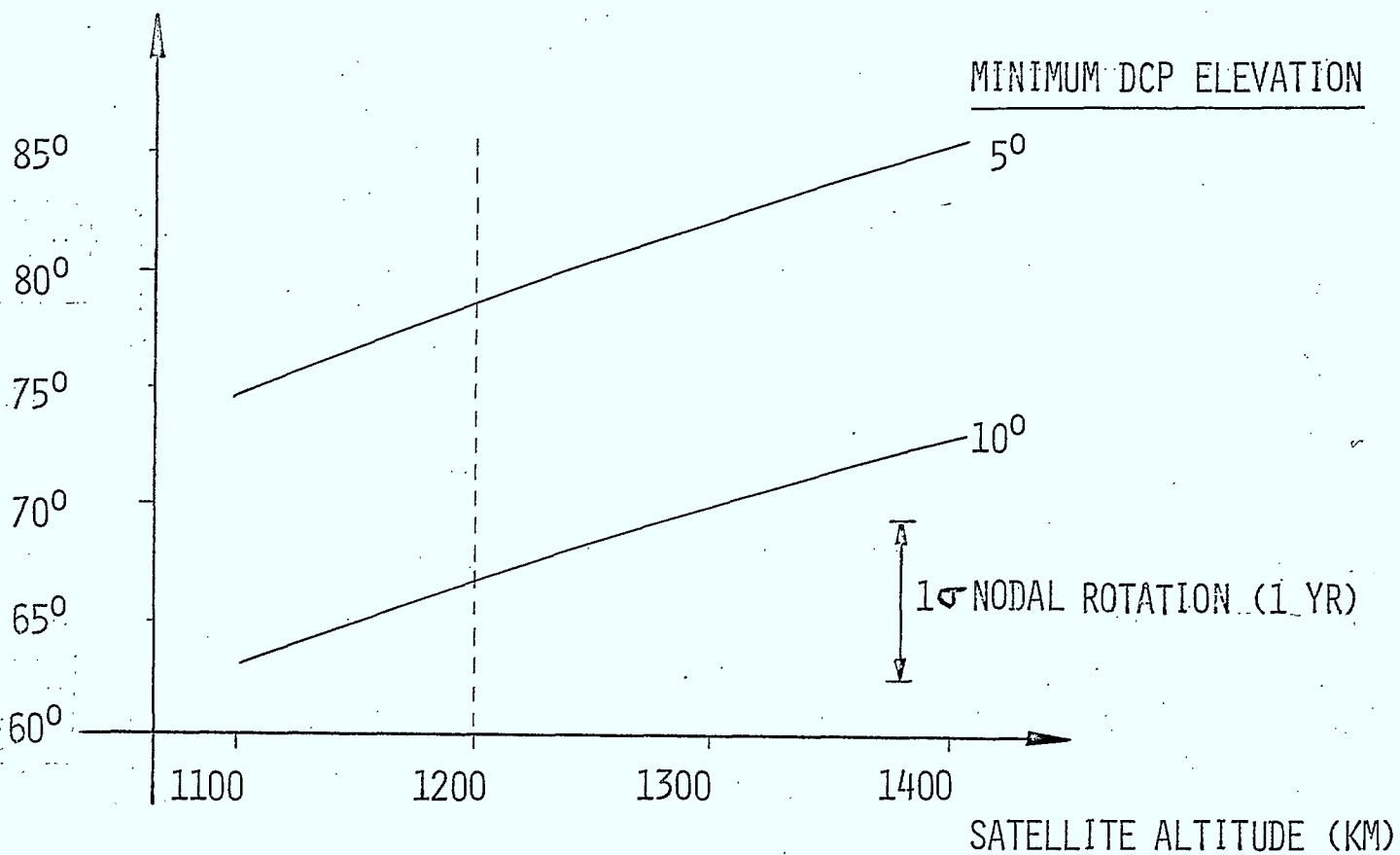
$$\lambda = \cos^{-1} \left(\frac{R}{R_E} \right) = \cos^{-1} \frac{\sin \phi}{\sin \frac{\theta}{2}}$$

λ IS THE MINIMUM LATITUDE OF THE COVERAGE ZONE

$\lambda = 41.98^\circ$ FOR MAX. SPACING OF 66.4° AND 10° MIN. ELEV. ANGLE

C. NO. OF SATELLITES

MAX. ALLOWABLE ORBIT PLANE SEPARATION



MAXIMUM SPACING BETWEEN ORBIT PLANES FOR TWO HOUR COVERAGE

C. NO. OF SATELLITES

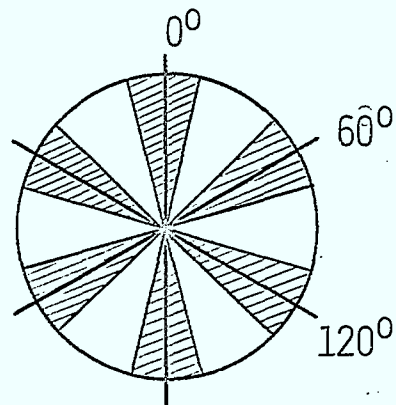
C. NUMBER OF SATELLITES

MEAN FREQUENCY OF COVERAGE

3 SATELLITE CONSTELLATION

- MEAN FREQUENCY OF COVERAGE IN THE NORTH (ABOVE 66°N) IS ONE PASS EVERY 37 MINUTES
- MEAN FREQUENCY OF COVERAGE AT THE SOUTHERN BOUNDARY IS ONE PASS EVERY 103 MINUTES

EFFECT OF ORBIT PERIOD & PHASING ON COVERAGE



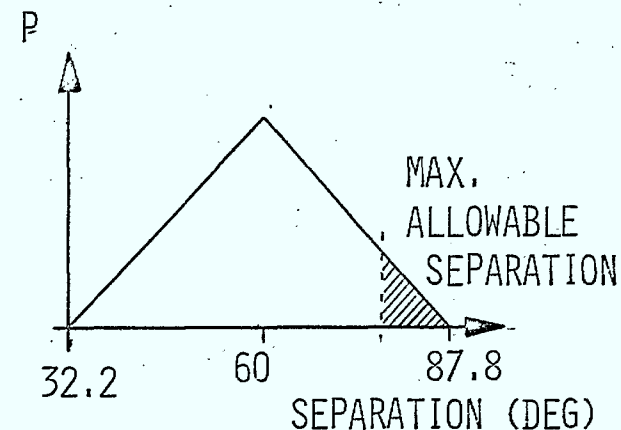
ORBIT PERIOD IS ABOUT 1.85 HOURS

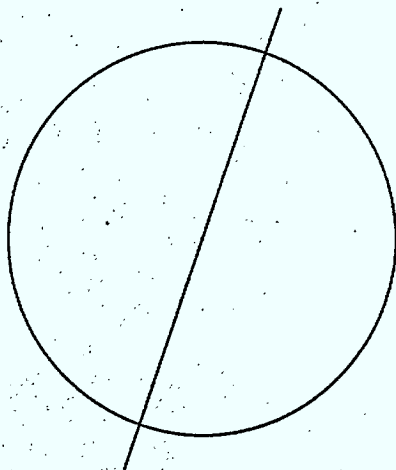
SATELLITE PASS CAN BE EARLIER OR LATER THAN REFERENCE TIME
BY $1.85/2$ HOURS OR 13.9 DEGREES OF EARTH ROTATION

IF ORBIT PLANES ARE SEPARATED BY 60° IN INERTIAL COORDINATES:
THEN SEPARATION OF GROUND TRACKS IS $60^\circ \pm 13.9^\circ$ (UNIFORM
DISTRIBUTION)

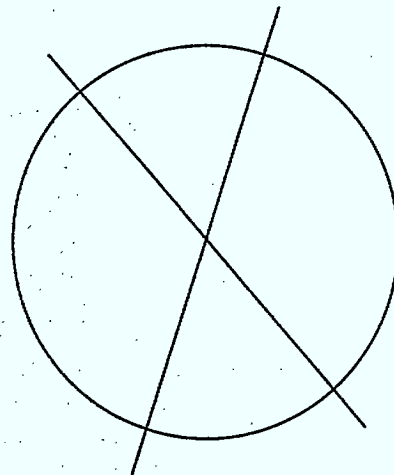
PROBABILITY OF SEPARATION BETWEEN ANY TWO
PLANES IS REPRESENTED BY A TRIANGULAR
DISTRIBUTION

PROBABILITY THAT SEPARATION IS GREATER THAN
SOME MAXIMUM ALLOWABLE ANGLE IS SHOWN SHADED
30% FOR 66.4°

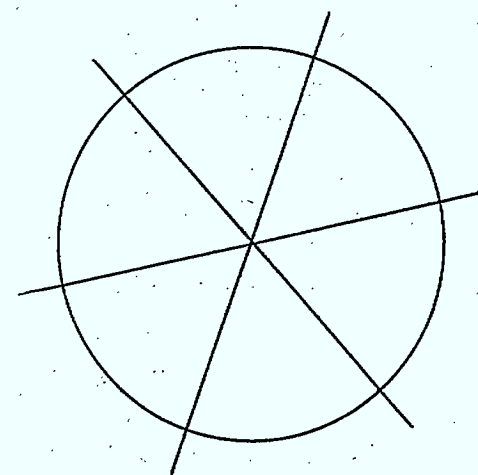




1ST LAUNCH



2ND LAUNCH



3RD LAUNCH

TARGET

$$\dot{\Omega}_1 = \text{ARBITRARY}$$

$$\dot{\Omega}_1 = 0$$

$$\Omega_2 = \Omega_2' + 60^\circ$$

$$\dot{\Omega}_2 = E_1$$

$$\dot{\Omega}_3 = \frac{\dot{\Omega}_1'' + \dot{\Omega}_2''}{2}$$

$$\dot{\Omega}_3 = \frac{E_1 + E_2}{2}$$

ACTUAL

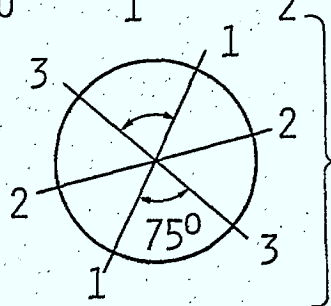
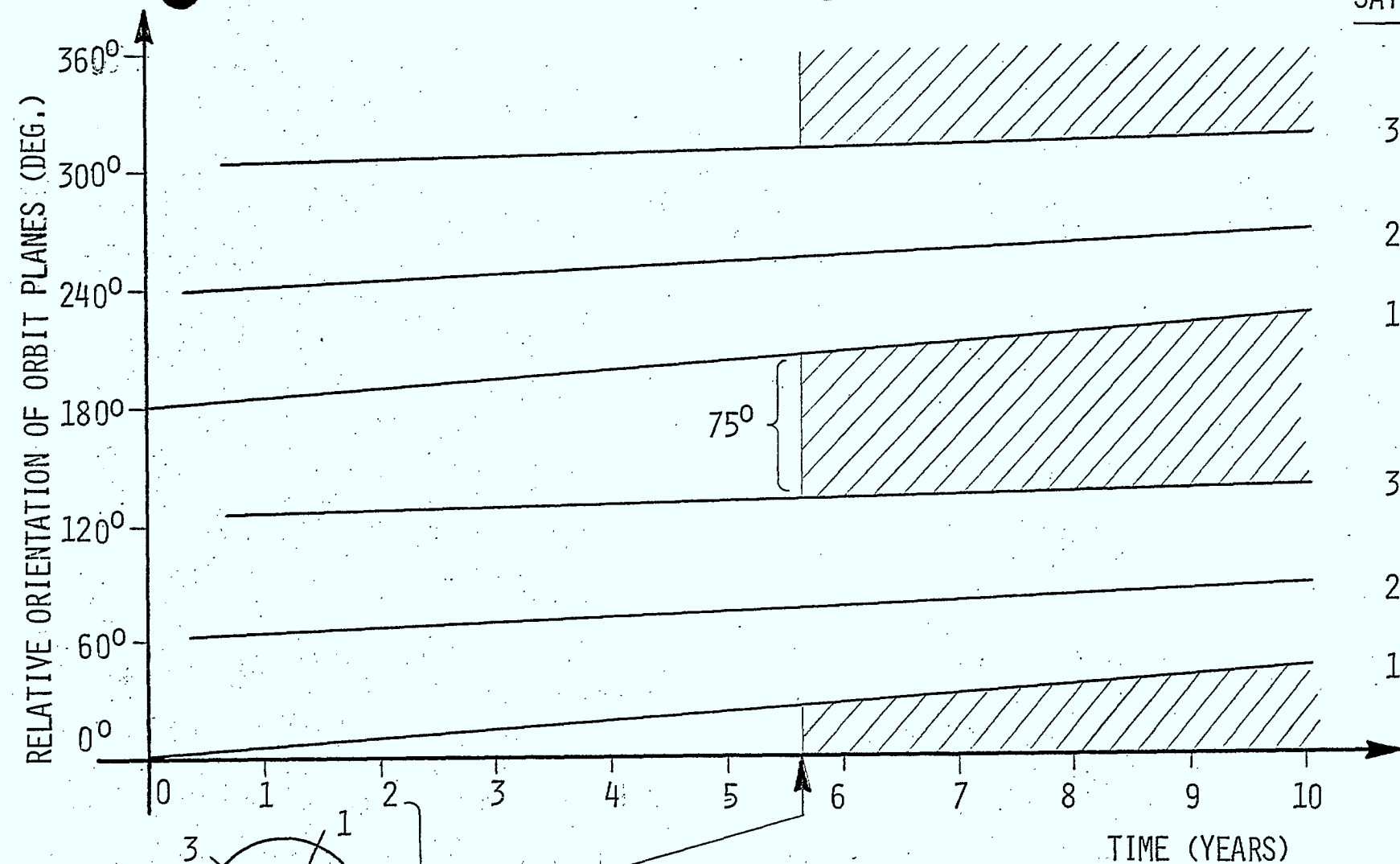
$$\dot{\Omega}_1 = E_1$$

$$\dot{\Omega}_2 = E_1 + E_2$$

$$\dot{\Omega}_3 = \frac{E_1 + E_2}{2} + E_3$$

(N.B. SINGLE PRIME IS VALUE AT TIME OF SECOND LAUNCH, DOUBLE PRIME - AT TIME OF THIRD LAUNCH)

D. LAUNCH STRATEGY - FIRST THREE LAUNCHES



TYPICAL LAUNCH SEQUENCE AND RESULTING
RELATIVE ORIENTATION OF ORBIT PLANES VS. TIME
(HATCHED AREA SHOWS TIME DURING WHICH MAXIMUM
ALLOWABLE SEPARATION ANGLE IS EXCEEDED - HERE 75°)

D. LAUNCH STRATEGY (CON'T)

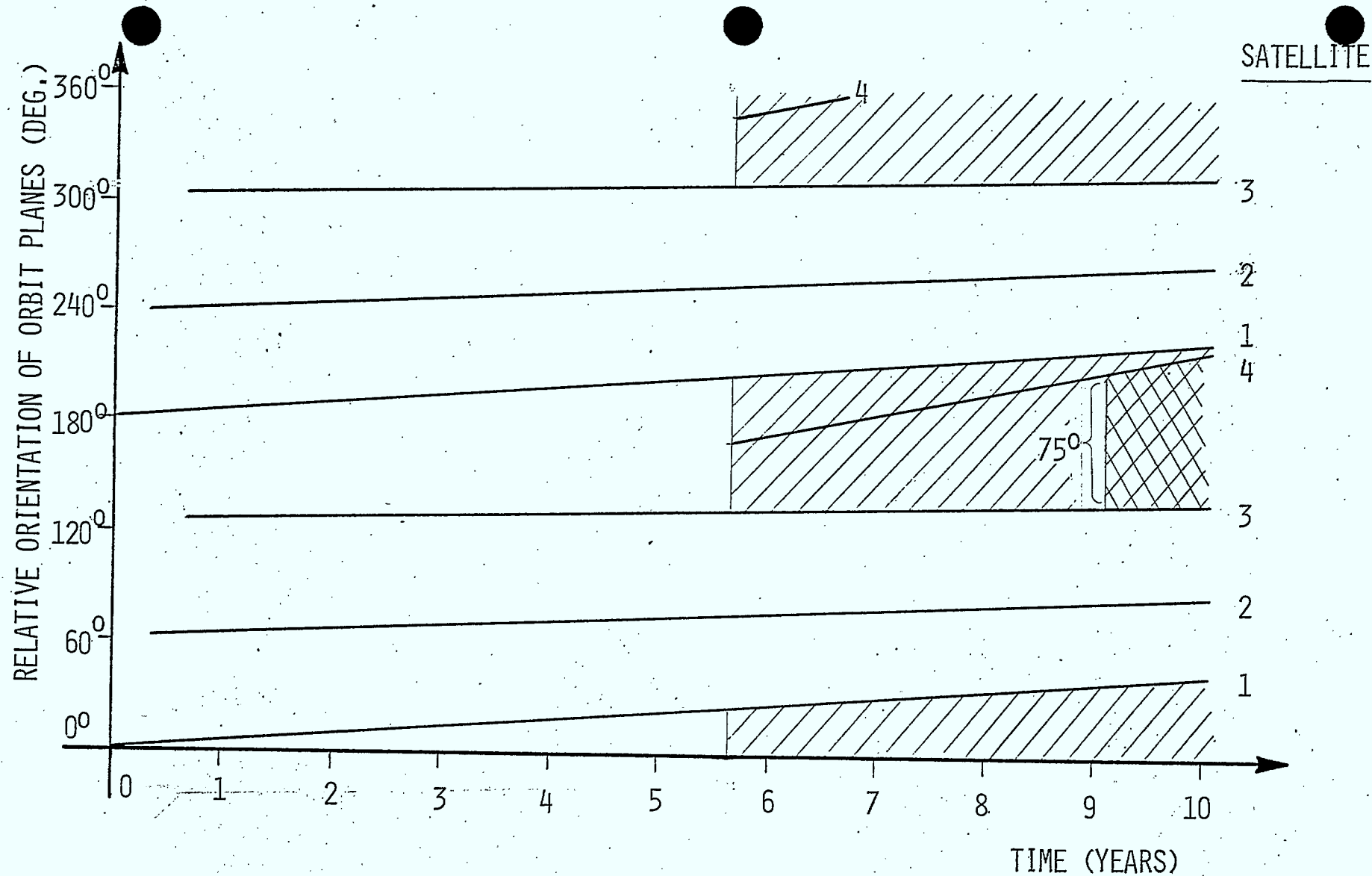
D. LAUNCH STRATEGY - FOURTH AND SUBSEQUENT LAUNCHES

WHEN MAXIMUM ALLOWABLE ORBIT PLANE SEPARATION ANGLE IS EXCEEDED,
ANOTHER SATELLITE MAY BE LAUNCHED TO FILL THE GAP USING THE
FOLLOWING TARGET:

$$\Omega = \frac{\Omega_N + \Omega_M}{2}$$

$$\dot{\Omega} = \frac{\dot{\Omega}_N + \dot{\Omega}_M}{2}$$

- WHERE N AND M ARE THE PLANES WITH THE WIDEST SEPARATION

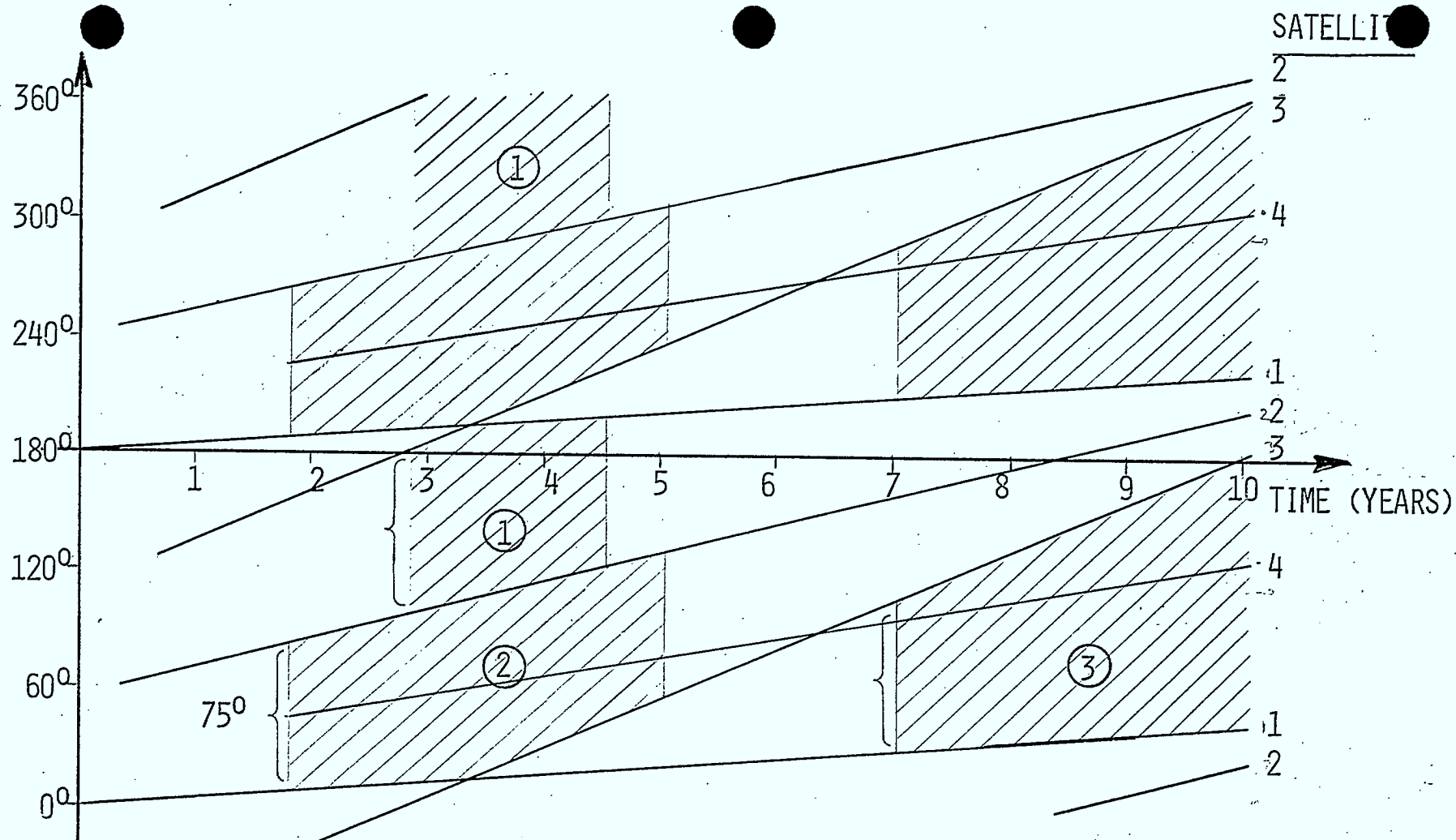


FOURTH SATELLITE LAUNCHED TO FILL 75 DEGREE GAP AND RESULTING
RELATIVE ORIENTATION OF ORBIT PLANES VS. TIME

D. LAUNCH STRATEGY (CONT'D)

D. LAUNCH STRATEGY (CONT'D)

ANY GAP WHICH APPEARS IN A THREE SATELLITE CONSTELLATION WILL EVENTUALLY BE FILLED BY ONE OF THE THREE SATELLITES. IF THIS TIME PERIOD IS SHORT (AND THE SEPARATION ANGLE DOES NOT INCREASE TO AN UNREASONABLE AMOUNT), THE FOURTH SATELLITE MAY BE RESERVED FOR A LATER LAUNCH, OR THE LAUNCH MAY BE TARGETED TO FILL A LATER GAP AS WELL AS THE PRESENT GAP.



ALTERNATE LAUNCH STRATEGY FOR RELATIVELY SHORT DURATION GAPS

- ① - SHORT GAP - ALLOW TO CLOSE BY ITSELF
- ② AND ③ - TARGET TO FILL BOTH GAPS

D. LAUNCH STRATEGY (CONT'D)

CHAPTER 5

SPACECRAFT CONFIGURATION

5. SPACECRAFT CONFIGURATION

5-1 SPACECRAFT DESIGN CONSTRAINTS

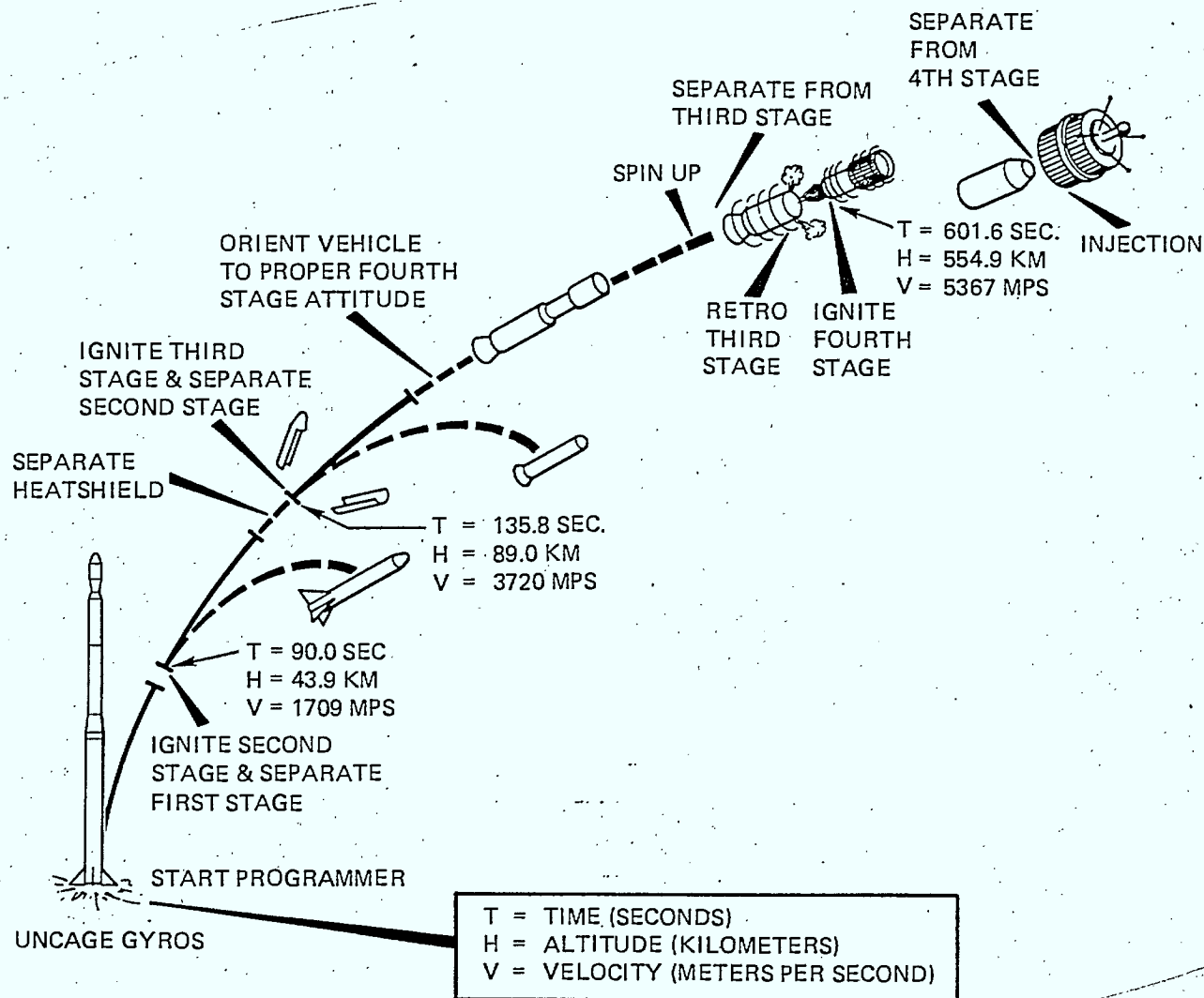
A. GENERAL

- o HIGH RELIABILITY
- o PERFORMANCE
- o LOW COST
- o HIGH CANADIAN CONTENT
- o UTILIZATION OF EXISTING TECHNOLOGY
- o GROWTH POTENTIAL FOR FUTURE MISSIONS
- o SUITABLE FOR GLOBAL USAGE
- o 10 YEAR SYSTEM LIFETIME

5-1 SPACECRAFT DESIGN CONSTRAINTS

B. TYPICAL SCOUT MISSION PROFILE

FOR POLAR ORBITTING S/C



5-1 SPACECRAFT DESIGN CONSTRAINTS

C. SCOUT LAUNCH VEHICLE CONSTRAINTS

PAYLOAD MASS

- o "PAYLOAD" DEFINED AS SUM OF:
 - SPACECRAFT
 - L/V ADAPTER
 - MARMON CLAMP & SEPARATION HARDWARE & CIRCUITRY
 - YO-YO DESPIN DEVICE (IF REQUIRED)
 - SNUBBERS, CABLES, ETC. (IF REQUIRED) FOR CONSTRAINING S/C APPENDAGES TO L/V SHROUD OR SCOUT FOURTH STAGE
- o SCOUT CAPABILITY DEPENDS ON WHICH L/V SHROUD IS USED:

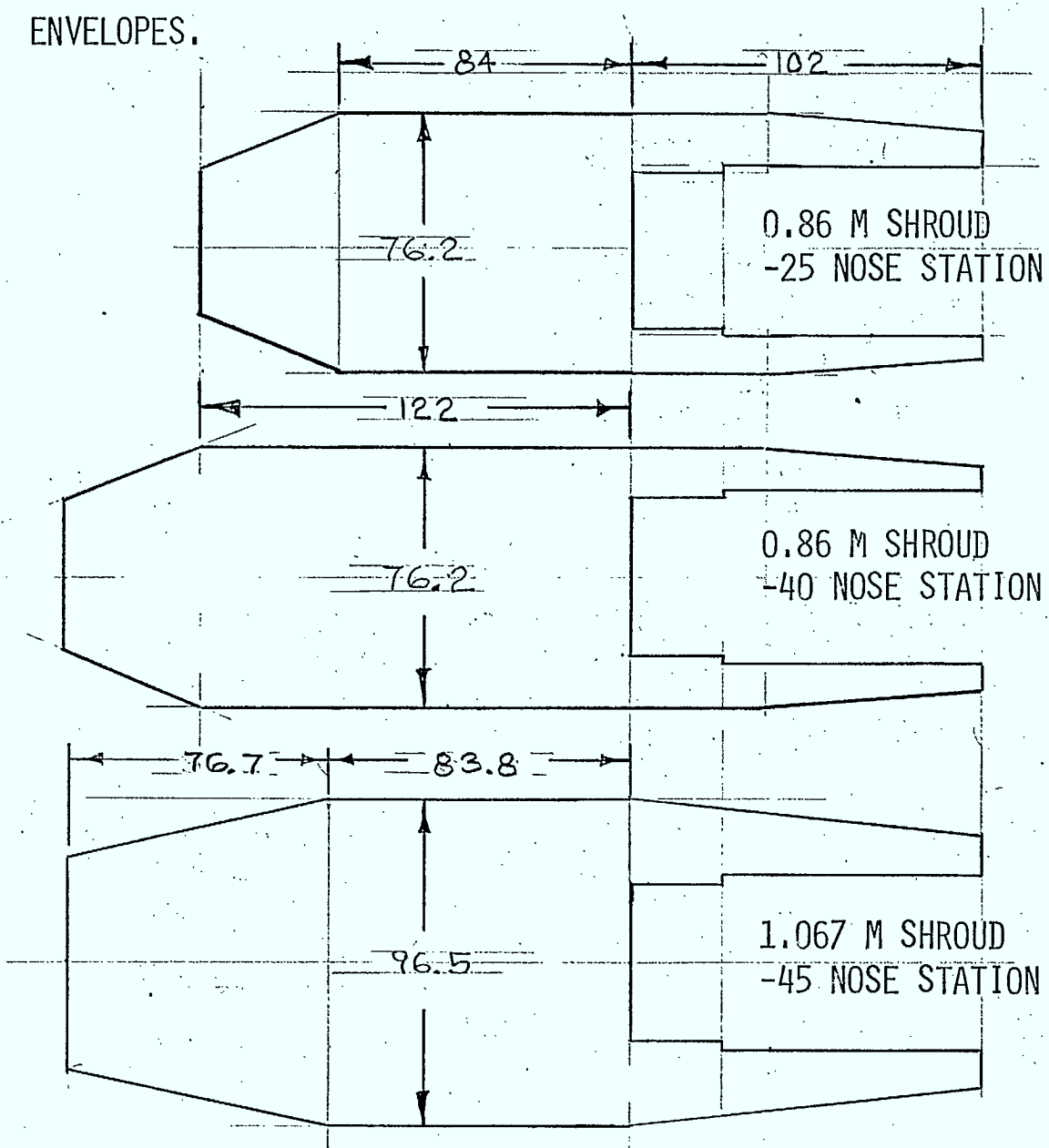
<div>L/V SHROUD</div> <div>ALTITUDE (KM)</div>	0.86 M	1.067 M
1200	96 KG	91 KG
1300	87 KG	83 KG
1400	82 KG	78 KG

5-1 SPACECRAFT DESIGN CONSTRAINTS

D. SCOUT LAUNCH VEHICLE CONSTRAINTS

PAYLOAD VOLUME

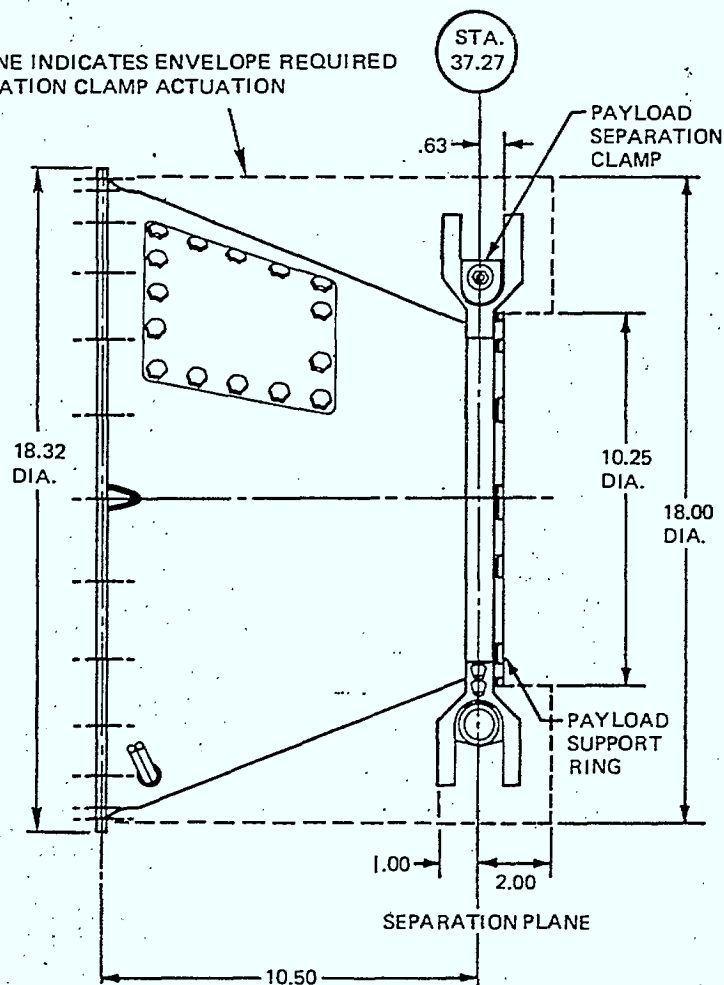
VOLUMES SHOWN ARE THE LIMITS FOR THE STATIC SPACECRAFT DIMENSIONS. DYNAMIC EXCURSIONS CAN EXCEED THESE ENVELOPES.



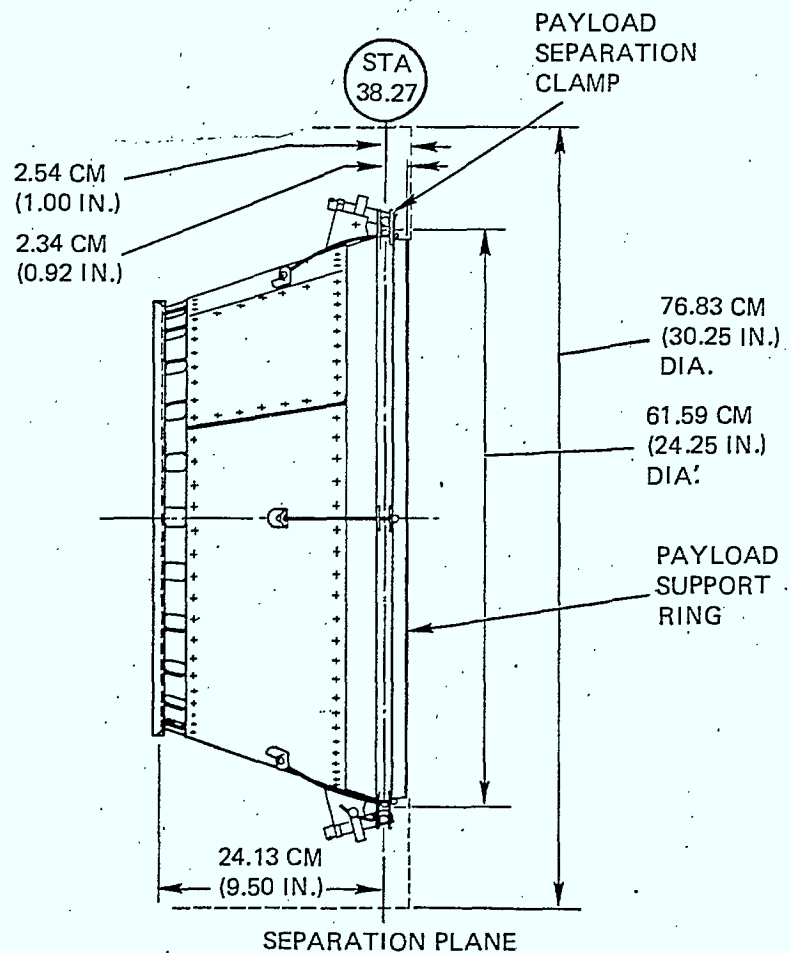
5-1 SPACECRAFT DESIGN CONSTRAINTS

E. LAUNCH VEHICLE TO SPACECRAFT ADAPTER SECTIONS

DASHED LINE INDICATES ENVELOPE REQUIRED FOR SEPARATION CLAMP ACTUATION



"E" SECTION ADAPTER



SERIES 25 "E" SECTION ADAPTER

5-1 SPACECRAFT DESIGN CONSTRAINTS

F. MECHANICAL ENVIRONMENTAL

	FLIGHT PREDICT LEVELS	QUALIFICATION ⁽³⁾ TEST LEVELS
o THRUST AXIS QUASI-STATIC ACCELERATION ⁽¹⁾	16 G'S	20 G'S
o LATERAL AXES QUASI-STATIC ACCELERATION		3 G'S @ S/C C. OF M.
o FOURTH STAGE SPIN ANGULAR VELOCITY	140-180 RPM	TBD
o TIME FOR SPINUP	1 SECOND	TBD
o THRUST AXIS SINUSOIDAL VIBRATION ⁽²⁾ INPUT	TBD	6 G'S @ 44-65 Hz 4.5 G'S @ 65-2000 Hz
o LATERAL AXES SINUSOIDAL INPUT VIBRATION	TBD	0.97 CM DA @ 10-28 Hz 1.5 G'S @ 28-2000 Hz
o RANDOM VIBRATION INPUT, ALL AXES	TBD	7.5 G RMS
o ACOUSTIC	TBD	N/A
o SHOCK, ALL AXES	N/A	30 G 1/2 SINE PULSE FOR 7-13 MS

(1) FOURTH STAGE ACCELERATION PEAK

(2) NOTCHING TO BE USED. MAX. RESPONSE LEVEL T.B.D.

(3) S/C TO BE "LIVE" DURING TESTS

5-1 SPACECRAFT DESIGN CONSTRAINTS

G. SPECIFIC DESIGN REQUIREMENTS

- o 7 YEAR S/C LIFETIME MTBF
- o REDUNDANCY TO MINIMIZE SINGLE POINT FAILURES
- o MECHANICAL SYSTEM RELIABILITY OF 0.95
- o MINIMUM WEIGHT (WITHIN LOW COST CONSTRAINT)
- o CIRCULAR POLAR ORBIT IN THE RANGE OF 1200-1400
KM ALTITUDE ORBIT PERIOD 1 3/4 - 2 HOURS
- o LAUNCH WITH FOUR STAGE SCOUT VEHICLE FROM WTR
- o 90° ORBIT INCLINATION
- o NO ORBIT PRECESSION CONTROL

5-1 SPACECRAFT DESIGN CONSTRAINTS

H. SPACECRAFT PAYLOAD WEIGHT (1)

<u>SUBSYSTEM</u>	<u>UNIT</u>	<u>NO. OF UNITS PER S/C</u>	<u>TOTAL WEIGHT (KG)</u>
POWER	BATTERY (2)	2	6.0
	BATTERY CHARGER, BATTERY CTL. MODULE, BATTERY SENSORS }	1	3.3
	POWER SWITCHING ASSY. (3)	1	1.5
	(4) { INVERTER	2	0.4
	28V REGULATOR	2	0.4
	15V REGULATOR	2	0.8
	5V REGULATOR	2	0.4
	FILTER	2	0.4
			13.2
TELEMETRY & COMMAND	COMMAND DEMODULATOR (3)	1	1.3
	COMMAND REGISTER	1	1.0
	CLOCK	1	1.3
	TLM ENCODER	1	2.0
			5.6

H. SPACECRAFT PAYLOAD WEIGHT (1) (CONT'D)

<u>SUBSYSTEM</u>	<u>UNIT</u>	<u>NO. OF UNITS PER S/C</u>	<u>TOTAL WEIGHT (KG)</u>
ATTITUDE CONTROL	MAGNETIC TORQUE COILS	2	1.0
	MAGNETIC TORQUE CONTROLLER	1	1.0
	SUN SENSORS & ELECTRONICS	4	1.0
	MAGNETOMETERS AND ELECTRONICS	4	1.0
	ACS INTEGRATION UNIT	1	2.0
	GRAVITY GRADIENT BOOM (5)	1	1.5
	DAMPER	1	1.0
			<u>8.5</u>
DCP/LIP TRANSPONDER (6)	INPUT FILTER	2	8.6
	LOW NOISE AMPLIFIER		
	SPLITTER		
	FILTER		
	MIXER		
	L.O.		
	IF AMP		
	COMBINER		
	VCO		
	LO		
	MIXER		
	HPA		
	CABLES, HARNESS		
	FILTER		
	CROSS STRAPPING		1.0
			<u>9.6</u>

H. SPACECRAFT PAYLOAD WEIGHT⁽¹⁾ (CONT'D)

<u>SUBSYSTEM</u>	<u>UNIT</u>	<u>NO. OF UNITS PER S/C</u>	<u>TOTAL WEIGHT (KG)</u>
INTERFACE	WIRING HARNESS	1	4.5
	UMBILICAL & BTY. FLT. PLUG	1	.4
	SEPARATION SWITCH	1	.2
	BALANCE WEIGHTS	TBD	1.0
	YO-YO DESPIN	1	1.4
			<u>7.5</u>
ANTENNAS	OMNI DIRECTIONAL	1	0.3
	UPLINK QUADRIFILAR	1	1.5
	DOWNLINK QUADRIFILAR	1	0.4
			<u>2.2</u>
TOTAL			46.6 KG

(1) STRUCTURE, THERMAL, SOLAR ARRAY SUBSYSTEM WEIGHTS ARE CALCULATED AS PART OF S/C CONFIGURATION GRAVITY GRADIENT CONFIGURATION ASSUMED FOR THIS TABLE.

(2) CELL REDUNDANCY ASSUMED

(3) REDUNDANCY INTERNAL TO UNIT

(4) REDUNDANT UNITS

(5) SPRING LOADED, NON-RETRACTABLE

(6) FULL REDUNDANT UNITS. ELEMENTS OF DCP AND LIP TRANSPONDERS ARE COMBINED

5-1 SPACECRAFT DESIGN CONSTRAINTS

1. EQUIPMENT LAYOUT

- o REQUIRED FLAT PANEL AREA FOR IMU'S IS $\sim 7000 \text{ CM}^2$
- o REQUIRED VOLUME FOR EQUIPMENT IS $\sim 10^5 \text{ CM}^3$
- o FOR SPINNING S/C, MINIMUM MOI RATIO OF 1.1 ABOUT SPIN AXIS IS REQUIRED
- o THERMAL BALANCE REQUIREMENTS
- o C.G. LOCATION ON THRUST AXIS AND AS FAR AFT AS POSSIBLE
- o PROVISION FOR ANTENNAS AND GRAVITY GRADIENT BOOM (IF GG STABILIZATION SYSTEM IS USED)

5-1 SPACECRAFT DESIGN CONSTRAINTS

J. POWER REQUIREMENTS

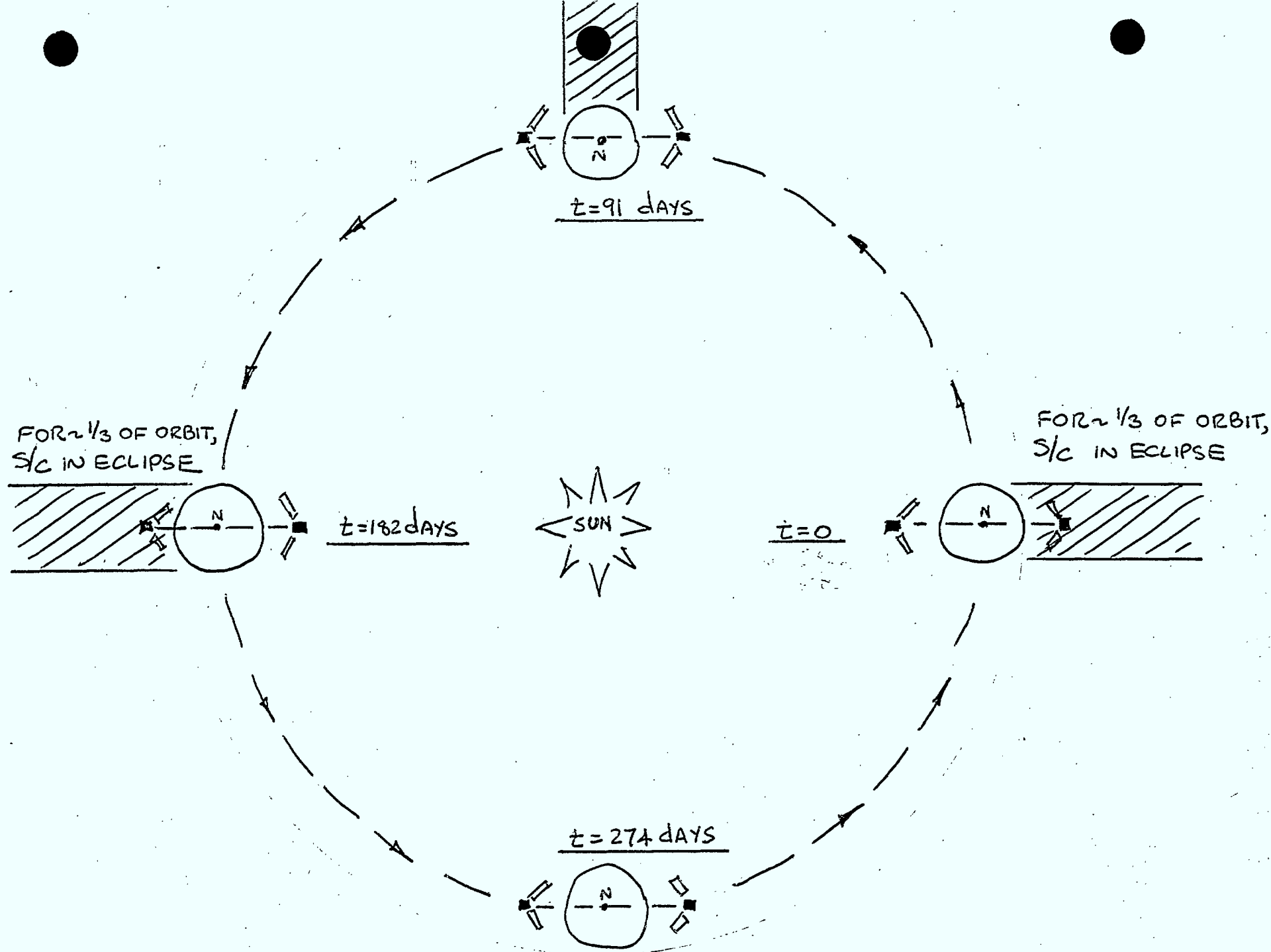
	<u>MISSION</u>	<u>ATT. ACQUISITION</u>
DCS TRANSPONDER		
FS TRANSPONDER	32W	10, TBD ⁽¹⁾
TELEMETRY TRANSMITTER		
TELEMETRY & COMMAND	2	2
POWER CONTROL	1	1
SUN SENSORS AND MAGNETOMETERS	5	5
MAGNETIC TORQUE COILS	-	8
THERMAL HEATERS (2)	-	
PRIMARY POWER	40W	26W
BATTERY CHARGE POWER (3)	30W	
PEAK SOLAR ARRAY POWER DEMAND	70W	

* INCLUDES SOME PARTS FOR T&C

(1) DURING ACQUISITION, "KEEPALIVE" TRANSPONDER POWER

(2) THERMAL HEATERS, IF REQUIRED, WOULD BE SUBSTITUTE HEATERS

(3) ASSUMES MAGNETOMETERS, SUN SENSORS, MAGNETIC TORQUE COILS NOT USED DURING ECLIPSE POWER DRAIN.



K. SEASONAL SOLAR IRRADIATION ~ POLAR ORBITTING SPACECRAFT

5-2 SUBSYSTEM ALTERNATIVES

A. ATTITUDE CONTROL

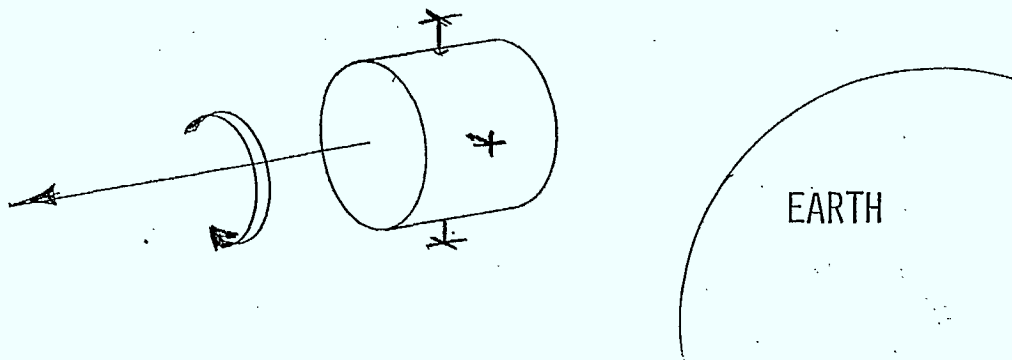
- o NON-ORIENTED (TUMBLING)
- o MAGNETIC TORQUE ATTITUDE CAPABILITY ONLY*
- o SPIN STABILIZED WITH SPIN AXIS NORMAL TO ORBIT PLANE
- o SPIN STABILIZED WITH SPIN AXIS ALIGNED WITH EARTH NORTH-SOUTH AXIS
- o GRAVITY GRADIENT STABILIZED, EARTH POINTING
- o REACTION AND MOMENTUM WHEEL STABILIZED, EARTH POINTING
- o 3 AXIS STABILIZATION INCORPORATION THRUSTER SYSTEMS

*ASSUME MAGNETIC TORQUE ATTITUDE CONTROL CAN BE USED
IN CONJUNCTION WITH ANY OF THE ACS SCHEMES

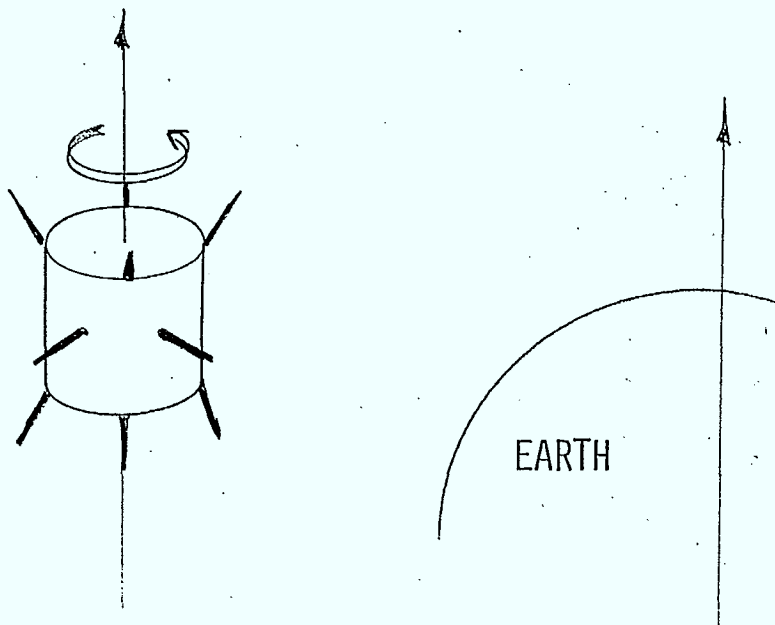
5-2 SUBSYSTEM ALTERNATIVES
B. SPACECRAFT ANTENNA ALTERNATIVES (CONT'D)

SPINNING CONFIGURATIONS

BARREL-ROLL (SPIN ABOUT SUN LINE)



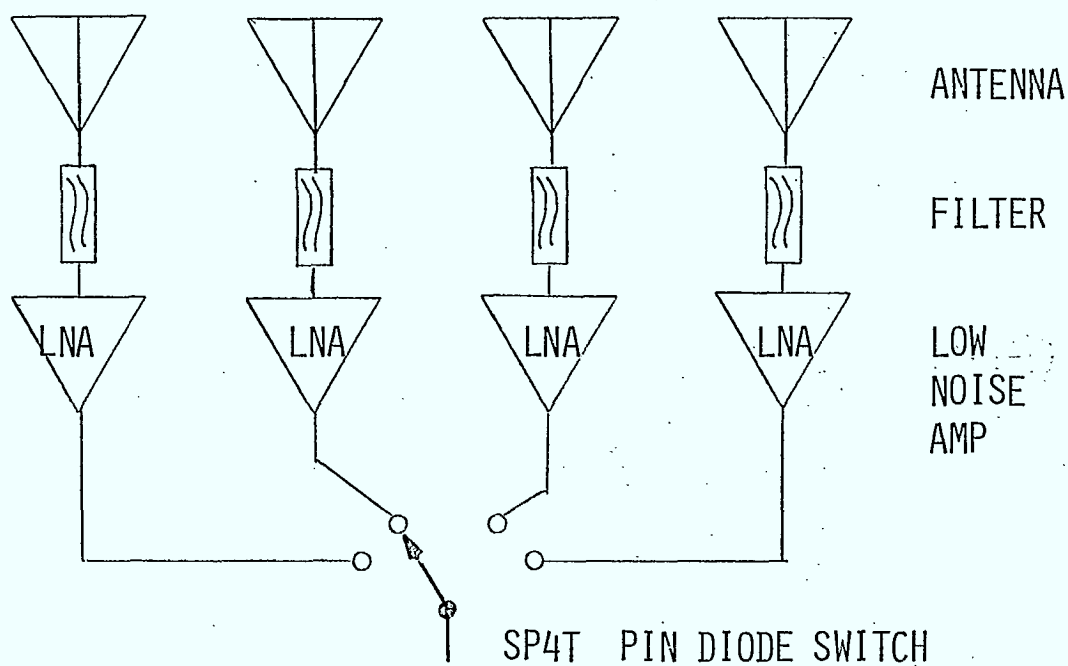
SPIN AXIS ALIGNED WITH EARTH AXIS



EITHER CONFIGURATION IS OPTIMIZED BY SWITCHING ACTIVE ANTENNA ELEMENTS IN SYNCHRONISM WITH THE SPIN RATE

B. SPACECRAFT ANTENNA ALTERNATIVES (CONT'D)

SWITCHED ANTENNA ELEMENT CONCEPT



TYPICAL SWITCH (GENERAL MICROWAVE DM 871) SPECIFICATION

MIN. ISOLATION	60 DB
MAX. INSERTION LOSS	1.5 DB
MAX. VSWR (ON POSITION)	1.5 DB
WEIGHT	127 GM
POWER REQUIREMENT	45 WATT

B. SPACECRAFT ANTENNA ALTERNATIVES (CONT'D)

BODY STABILIZED

QUADRIFILAR HELIX ANTENNA

PRODUCES SHADED - CONICAL RADIATION PATTERNS.

- THE RADIATED ENERGY CAN BE CONCENTRATED INTO A CONE WITH GAIN DECREASING FROM A MAXIMUM AT THE EDGE TO A LOCAL MINIMUM ON AXIS.
- PATTERN IS NEAR OPTIMUM FOR LOW-EARTH-ORBIT SPACECRAFT COMMUNICATIONS.
- PARTICULARLY SUITED FOR SPACECRAFT WITH AN EARTH POINTING FACE.

θ_{BW} beamwidth from the center of the cone to the 3 db point outside the pattern maximum. Note that this is the ordinary 3-dB beamwidth if the pattern maximum is along the cone axis.

θ_p angle between the cone axis and the peak of the radiation pattern.

α_{db} depth of the pattern minimum at $\theta = 0^\circ$ relative to the pattern maximum. Patterns with a secondary minimum significantly below the level at $\theta = 0^\circ$ are noted.

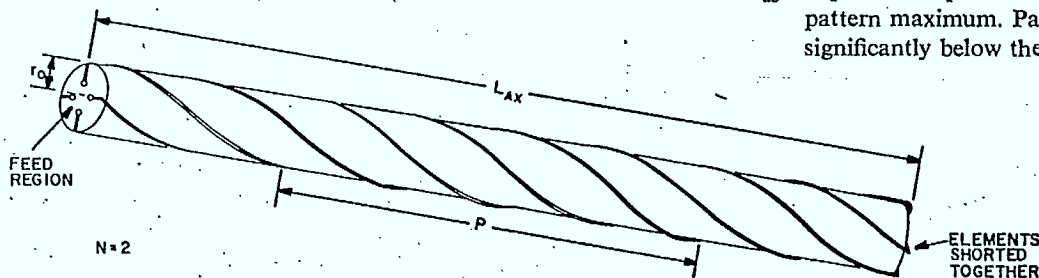
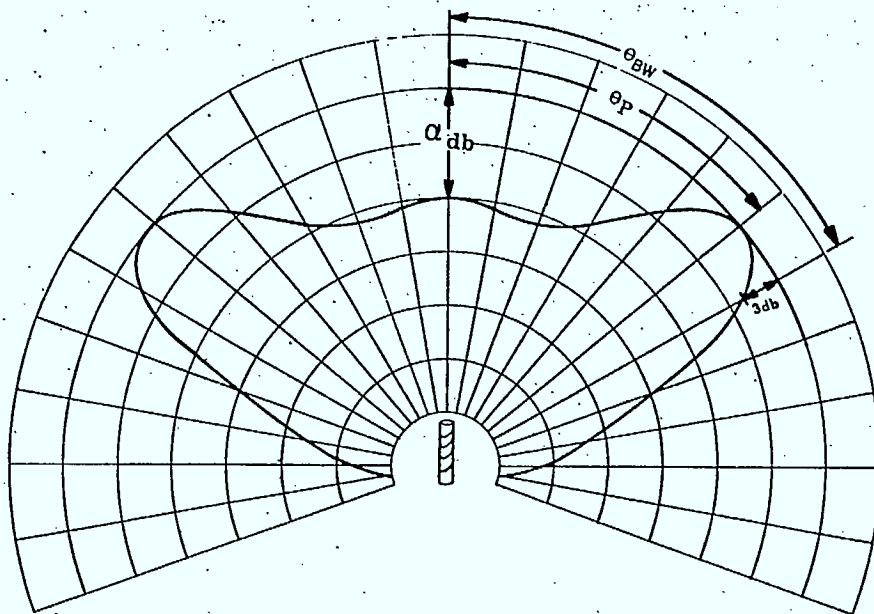


Fig. 1. Helical parameters.



Typical radiation pattern shaped-conical beam quadrifilar helix.

5-2 SUBSYSTEM ALTERNATIVES

C. SOLAR ARRAY

- o S/C BODY MOUNTED SOLAR PANELS
- o S/C BODY MOUNTED SOLAR PANELS AND SOLAR ARRAY PADDLES
- o SOLAR ARRAY PADDLES, NO CELLS ON S/C BODY,
 - CELLS ONE SIDE OF PADDLE
 - CELLS BOTH SIDES OF PADDLES
 - 2,3, OR 4 PADDLES
- o SOLAR ARRAY PADDLES, FIXED RELATIVE TO S/C
- o SOLAR ARRAY PADDLES, ABLE TO ARTICULATE RELATIVE TO S/C ACCORDING TO SEASON
- o SOLAR ARRAY PADDLES WITH ACTIVE SUN TRACKING SYSTEM
- o RIGID SOLAR ARRAY PADDLES
- o FLEXIBLE SOLAR ARRAY
- o CELL/COVERGLASS SELECTION

5-2 SUBSYSTEM ALTERNATIVES

D. STRUCTURE

- o CONFIGURATIONS BASED ON 1.067 M SHROUD OR 0.86 M SHROUD
- o CONFIGURATIONS BASED ON EG, E, 25E L/V ADAPTER SECTIONS
- o CONFIGURATIONS BASED ON CUSTOM DESIGNED L/V ADAPTER FOR PADDLE TYPE ARRAYS, CONFIGURATIONS FOR 2.3 OR 4 PADDLES
- o CONFIGURATIONS WHEREBY S/C PROVIDES BUMPER FOR L/V SHROUD AND ABSORBS SHROUD LOADS
- o DAMPED STRUCTURE VS NORMAL CONSTRUCTION

5-2 SUBSYSTEM ALTERNATIVES

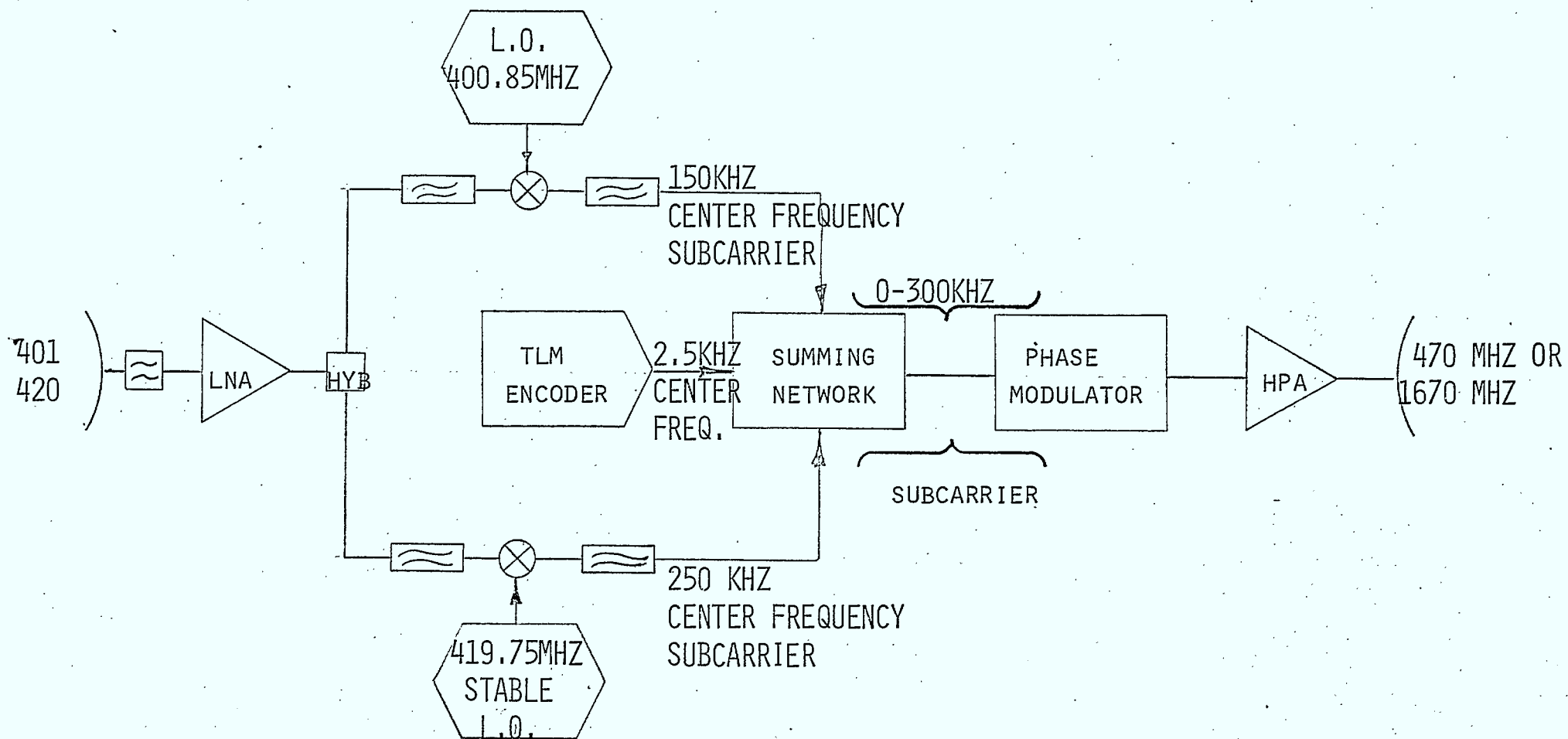
E. THERMAL

- o COMPLETELY PASSIVE CONFIGURATION
- o SEMI-PASSIVE CONFIGURATION USING SUBSTITUTE HEATERS WHEN TRANSPONDERS ARE NOT OPERATING
- o ACTIVE CONFIGURATION USING HEATERS, TEMPERATURE CONTROL AND SWITCHING WITH ON-BOARD LOGIC
- o SEMI-PASSIVE CONFIGURATION INCORPORATING TEMPERATURE ACTIVATED LOUVERS

5-2 SPACECRAFT PAYLOAD DESIGN

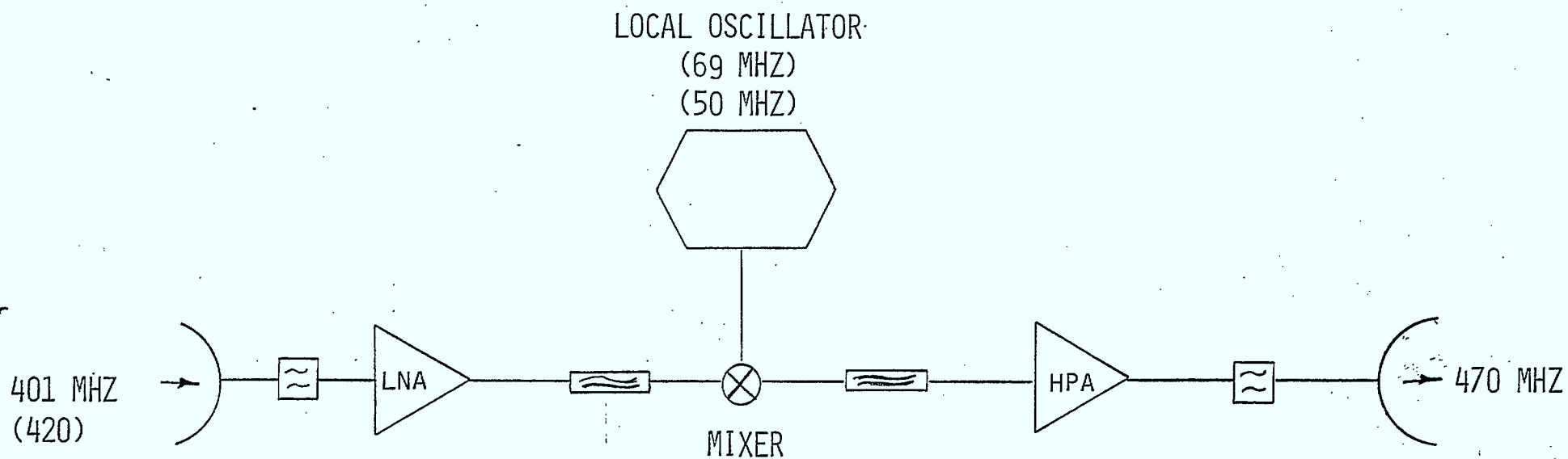
F. TRANSPONDER CONFIGURATION

- o REMODULATION TRANSPONDER
- o SINGLE CONVERSION TRANSFORMER
- o DOUBLE CONVERSION TRANSFORMER



REMODULATION TRANSPONDER

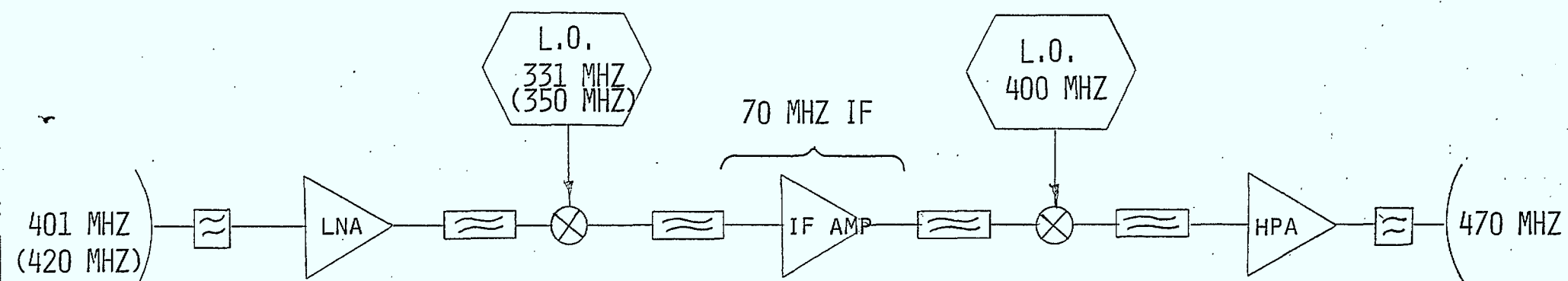
F. DCP OR CLIP CHANNEL (CONT'D)



LNA = LOW NOISE AMPLIFIER
HPA = HIGH POWER AMPLIFIER

SINGLE CONVERSION TRANSPONDER

F. DCP OR (LIP) CHANNEL (CONT'D)



LNA - LOW NOISE AMP

L.O. - LOCAL OSCILLATOR

IF - INTERMEDIATE FREQUENCY AMP

HPA - HIGH POWER AMPLIFIER

DOUBLE CONVERSION TRANSPONDER

F. DCP OR (LIP) CHANNEL (CONT'D)

F. TRANSPONDER TRADE-OFF (CONT'D)

OPTION	ADVANTAGES	DISADVANTAGES
1. Single Conversion	<ul style="list-style-type: none"> - simplest - good for wide band system 	<ul style="list-style-type: none"> - needs special input filter design - HPA must operate in linear region to reduce intermodulation - Power sharing is a problem; special provisions must be made for this - difficult if L-band downlink
2. Double Conversion	<ul style="list-style-type: none"> - filtering is accomplished at IF frequency - IF frequency can be chosen at a standard value 	<ul style="list-style-type: none"> - requires one more mixer and L.O. - HPA must operate in linear region to reduce intermod - Downlink power sharing must be accomplished
3. FM Remodulation	<ul style="list-style-type: none"> - downlink doppler effect not included for position determination - power sharing on downlink is more easily accomplished - carrier present for ground receiver lock-up - HPA can be operated at saturation - more efficient - HPA has constant drive - L-band downlink is easily implemented 	<ul style="list-style-type: none"> - needs greater band-width - more complex components on spacecraft

SELECTION: FM REMODULATION

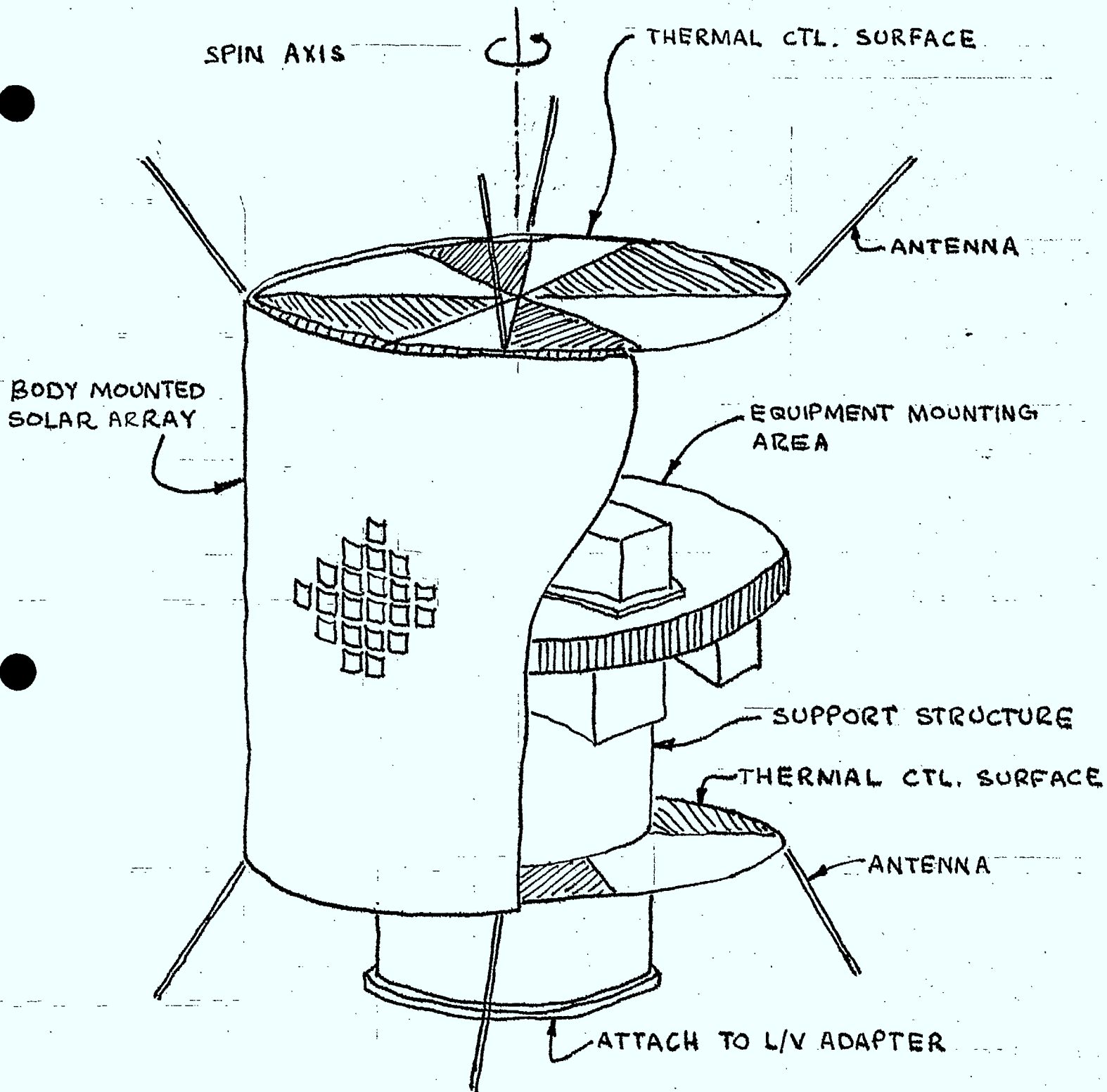
5-3 CONFIGURATION TRADEOFFS

A. SHOULD S/C BE SIZED FOR 0.86M OR 1.067 M DIA.
SCOUT SHROUD?

- o APPROX. 5% MORE CAPACITY IF WE USE 0.86M SHROUD.
- o FOR SPINNING S/C, LARGE SHROUD APPEARS GENERALLY BEST BECAUSE OF INCREASED CELL AREA FOR BODY ARRAY
- o FOR EARTH POINTING PADDLE-TYPE S/C - EITHER COULD BE USED. IT APPEARS BETTER TO DESIGN FOR SMALLER SHROUD - AS THIS GIVES P/L GROWTH MARGIN, LESS STRINGENT WEIGHT MONITORING AND CONSEQUENTLY LOWER DESIGN COST.
- o APL TRANSIT S/C USED SMALL SHROUD. GSFC AEM S/C USES LARGE SHROUD. BOTH ARE EARTH FACING.

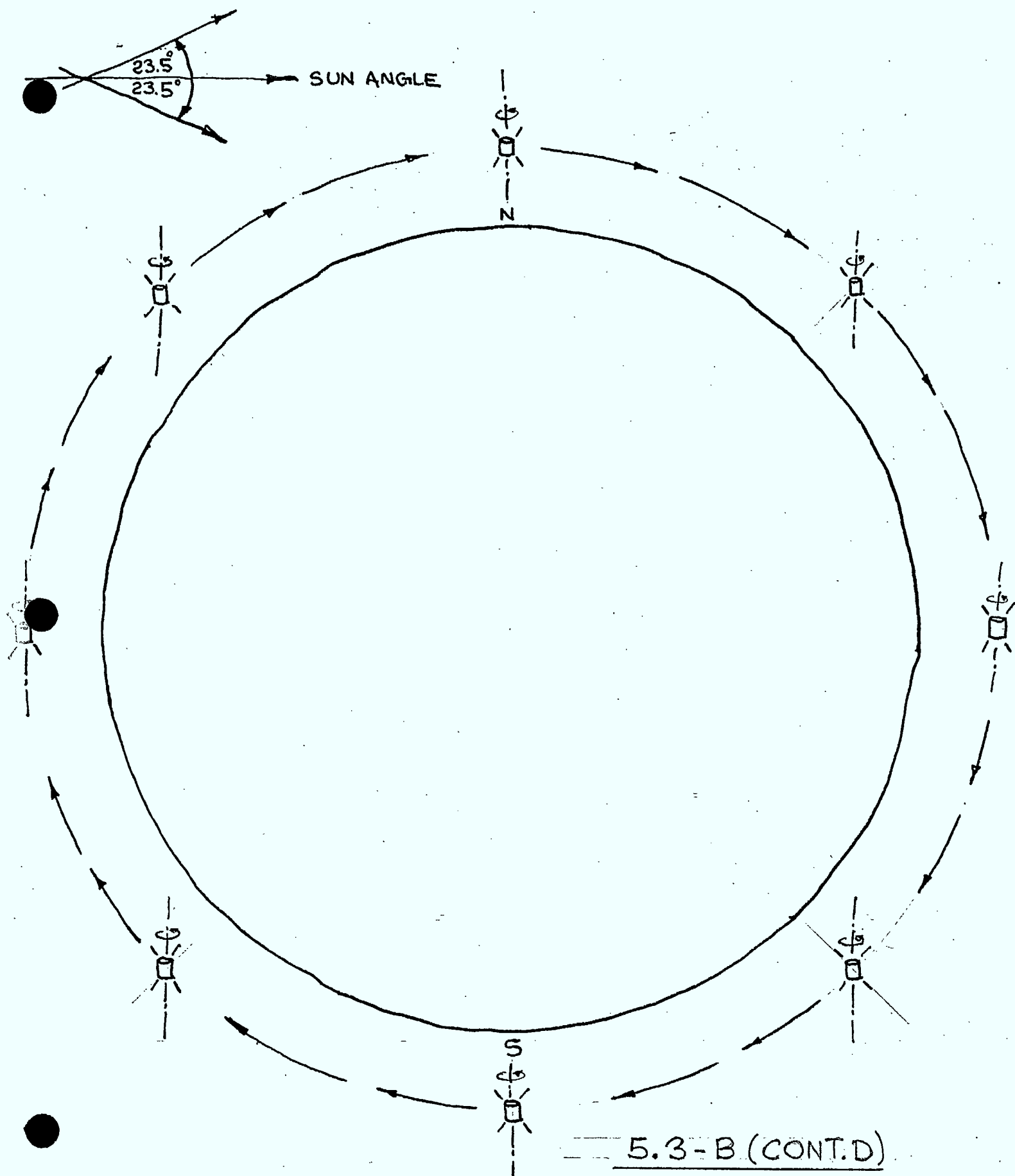
B. SHOULD S/C BE SPIN STABILIZED?

- o MAJOR SYSTEM CONSTRAINT ON ANTENNA DESIGN: MECHANICAL DESPIN INTRODUCES WEIGHT, POWER, RELIABILITY CONSIDERATIONS. ELECTRICAL DESPIN INTRODUCES RELIABILITY, SWITCHING LOGIC CONSIDERATIONS WITH A ~ 2 KG WEIGHT PENALTY; NO DESPIN-OMNI DIRECTIONAL ANTENNA HAS LESS GAIN. DOWN BY ~ 67 DB FROM EARTH FACING AT MAXIMUM RANGE LEADS TO MORE POWER IN DCP'S & LIP'S OR POORER S/N. LIMITED CAPABILITY FOR FOLLOW-ON MISSIONS.
- o IMPLIES 1.067M SHROUD FOR BODY ARRAYS.
- o SIMPLER STRUCTURAL/THERMAL DESIGN THAN EARTH POINTING SYSTEM.
- o NO PADDLES REQUIRED, CONSEQUENTLY LOWER COST FOR SOLAR ARRAY. POSSIBLE WEIGHT ADVANTAGE - EVEN THOUGH LARGER SHROUD IS USED, THE PENALTY MAY BE TOTALLY OFFSET BY LACK OF SOLAR ARRAY PADDLES.
- o LIMITED POWER GROWTH CAPABILITY.
- o POSITIVE MOI RATIO IS REQUIRED ABOUT SPIN AXIS.
- o NO YO-YO DEVICE REQUIRED. SAVE WEIGHT (1 KG) PLUS ONE OF THE 4 AVAILABLE S/C-L/V-I/F COMMANDS.
- o MORE OPERATIONAL 'BURDEN' THAN EARTH POINTING S/C TO UPDATE ATTITUDE PERIODICALLY, MORE EQUIPMENT IN GROUND STATIONS OR ON S/C.
- o GALACTIC NOISE DEGRADES SIGNAL IF ANTENNAS ARE ESSENTIALLY OMNI-DIRECTIONAL.
- o REQUIRES A SUN SENSOR.
- o COULD REQUIRE EARTH SENSORS FOR ANTENNA SWITCHING.
- o REQUIRES NUTATION DAMPER.



ELEMENTS OF SPIN STABILIZED S/C CONFIG.
 (SPIN AXIS PARALLEL TO EARTH N/S AXIS)

5.3-B (CONT'D)



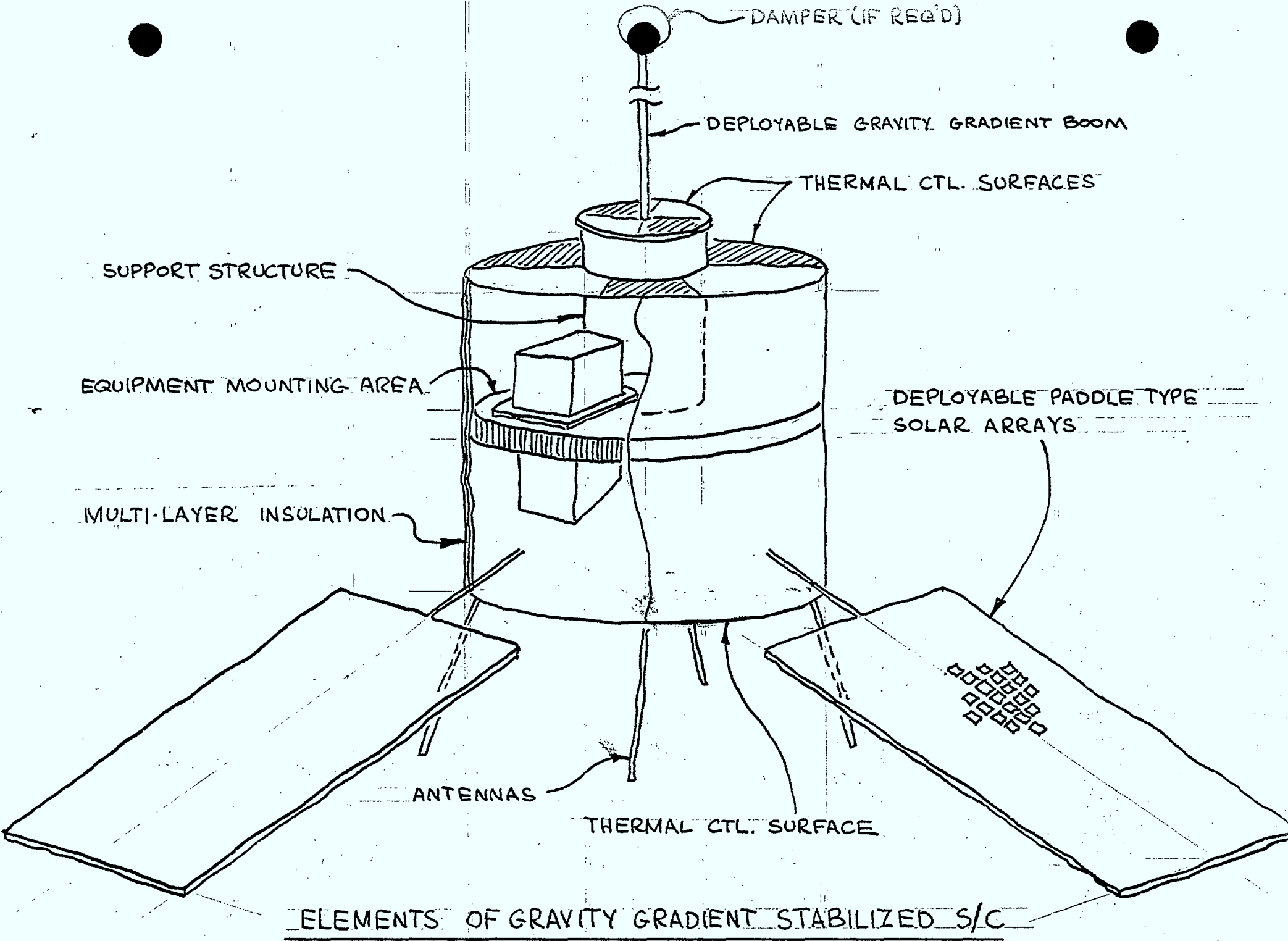
ONE ORBIT ~ SPIN STABILIZED S/C ~ SPIN
 AXIS PARALLEL TO EARTH N-S AXIS

C. SHOULD S/C BE EARTH POINTING?

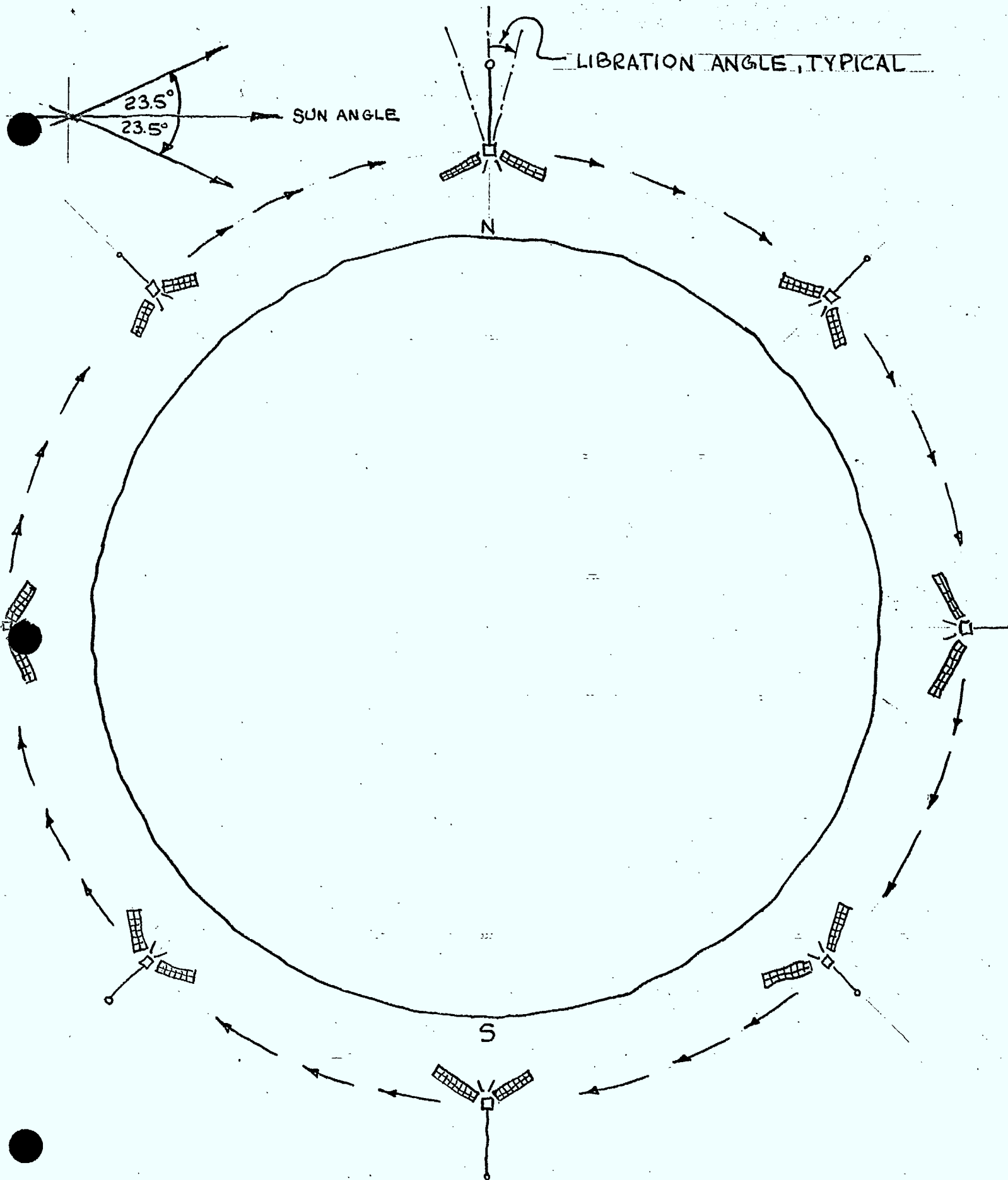
- o HIGHER GAIN, SIMPLER ANTENNA DESIGN IS THEN POSSIBLE.
- o SOLAR ARRAY PADDLES (2,3 OR 4) ARE REQUIRED.
- o ALLOWS GROWTH CAPABILITY FOR OTHER MISSIONS REQUIRING BETTER POINTING ACCURACY THAN DCFS.
- o STRUCTURAL AND THERMAL DESIGN BECOMES MORE COMPLEX.
- o EARTH POINTING ANTENNA IS ALMOST MANDATORY FOR MISSIONS USING LESS THAN 400MHz DUE TO GALACTIC NOISE.
- o ATTITUDE ACQUISITION IS MORE COMPLEX THAN SPIN STABILIZED S/C.
- o MOI RATIO ATTAINABLE WITH SOLAR ARRAY PADDLES FOR STABILITY DURING SPIN DOWN.
- o SUN & EARTH SENSORS NOT MANDATORY.
- o EQUIPMENT REQUIRED FOR ATT. STABILIZATION ADDS WEIGHT:
 - YO-YO DESPIN DEVICE
 - LIBRATION DAMPERS
 - ELECTRONICS
 - STABILIZATION DEVICE (WHEELS, GG BOOM, ETC.)
- o EXTRA EQUIPMENT IMPACTS RELIABILITY AND COULD REQUIRE MORE POWER.
- o SLIGHTLY MORE COST THAN SPIN STABILIZED

D. IF EARTH POINTING IS A GRAVITY GRADIENT SYSTEM TO BE USED?

- o POTENTIALLY NO POWER CONSUMPTION (SPRING LOADED SYSTEM).
- o ONLY 1 COMMAND (+ REDUNDANT = 2) REQUIRED TO INITIATE DEPLOYMENT.
- o GG BOOM WEIGHT IS ~ 2 KG. BOOM IS ~ 15 M TO 30 M DAMPER CAN WEIGH 1-4 KG.
- o S/C POINTING ACCURACY - IF ONLY GG SYSTEM ONBOARD, IS $\sim 10^0$ WORST CASE LIBRATION ANGLE. (TRANSIT S/C DATA).
- o POSSIBILITY OF INVERTING S/C DURING BOOM DEPLOYMENT AND SUBSEQUENT LOSS OF MISSION. (APL EXPERIENCE). RELIABILITY REQUIRES A RECOVERY MODE BY MAGNETIC TORQUING AND POSSIBLY A RETRACTABLE BOOM.
- o POSSIBILITY OF THERMAL FLUTTER (APL EXPERIENCE) OF THE BOOM. CAREFUL DESIGN AND TEST REQUIRED. THIS IMPACTS COST.
- o DAMPING SYSTEM IS REQUIRED FOR BOTH IN ORBIT PLANE AND NORMAL TO ORBIT PLANE LIBRATIONS. SEVERAL DESIGNS HAVE BEEN FLOWN.
- o ONCE ATTITUDE ACQUISITION IS MAINTAINED AND LIBRATIONS ARE DAMPED, THEN SYSTEM CAN BE PASSIVE. THIS LEADS TO A LONG S/C LIFETIME.
- o GRAVITY GRADIENT TECHNIQUES HAVE BEEN DEVELOPED BY APL, NRL, GSFC AND OTHERS. APL TRANSIT IS NOW HIGHLY RELIABLE. THERE WERE SOME MISSION FAILURES AS GRAVITY GRADIENT SYSTEMS WERE BEING DEVELOPED, BUT THE CAUSES ARE NOW KNOWN.
- o IF ORBIT HAS APPRECIABLE ELLIPTICITY GRAVITY TORQUE PERTURBATIONS MUST BE CONTROLLED.



5.3-D CONT'D



ONE ORBIT ~ GRAVITY GRADIENT STABILIZED S/C

5.3-D CONT'D

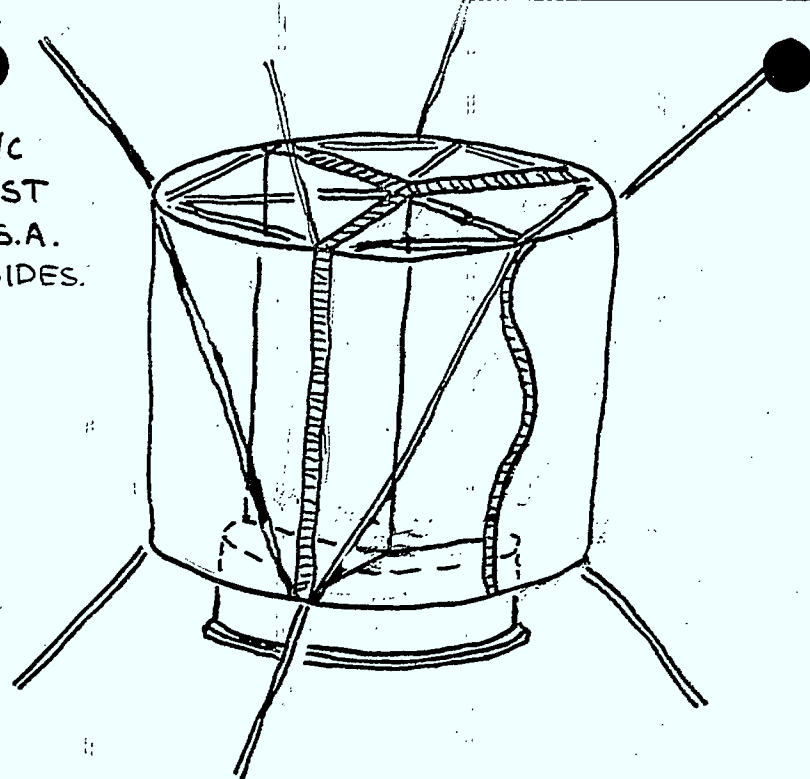
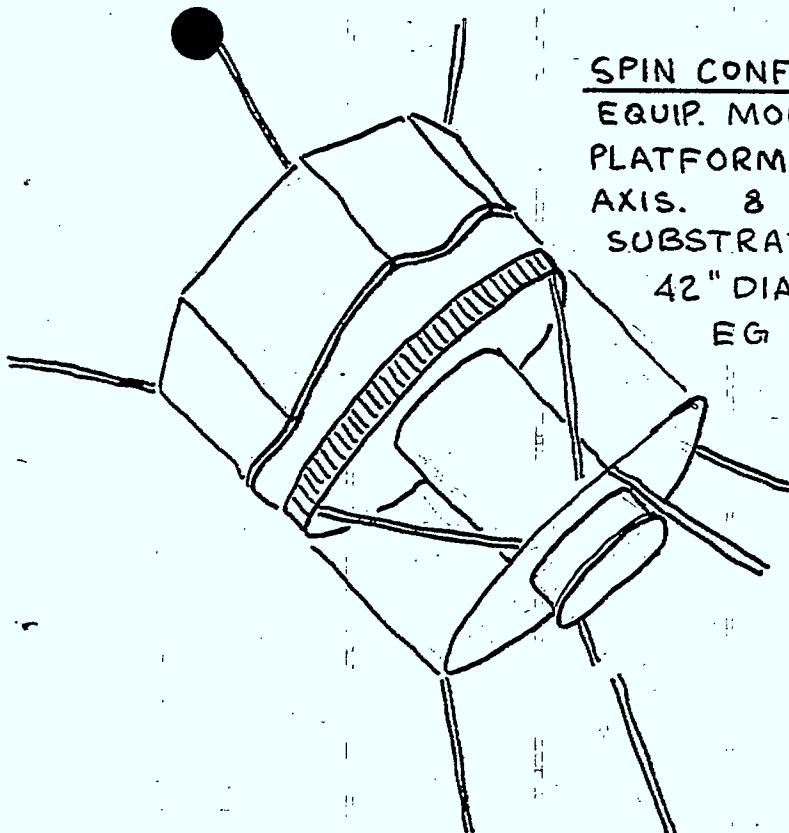
E. IF EARTH POINTING, ARE MOMENTUM/REACTION WHEELS TO BE USED?

- o POINTING ACCURACY IS POTENTIALLY $\pm 1^\circ$ OR BETTER. GIVES EXCELLENT GROWTH POTENTIAL FOR FUTURE MISSIONS.
- o BASED ON AEM S/C DATA (MAY 1974) EACH WHEEL WEIGHS 3.7 KG AND REQUIRES 3.3W. NOMINALLY 2 WHEELS ARE REQUIRED AND POSSIBLY THREE. ELECTRONICS WEIGHS 3.9 KG. THIS IS SEVERE WEIGHT PENALTY.
- o WHEELS HAVE RELIABILITY ASPECT AND MAY NOT RUN FOR LONG DURATION MISSION. REDUNDANCY IS REQUIRED.
- o MORE COMMAND + TM CHANNELS REQUIRED THAN GG SYSTEM.
- o POWER PENALTY.
- o MOMENTUM DUMPING OPERATION REQUIRED.
- o CAN HANDLE PERTURBATIONS DUE TO NON-CIRCULAR ORBIT.

F. SHOULD WHEEL AND GRAVITY GRADIENT SYSTEM BE USED?

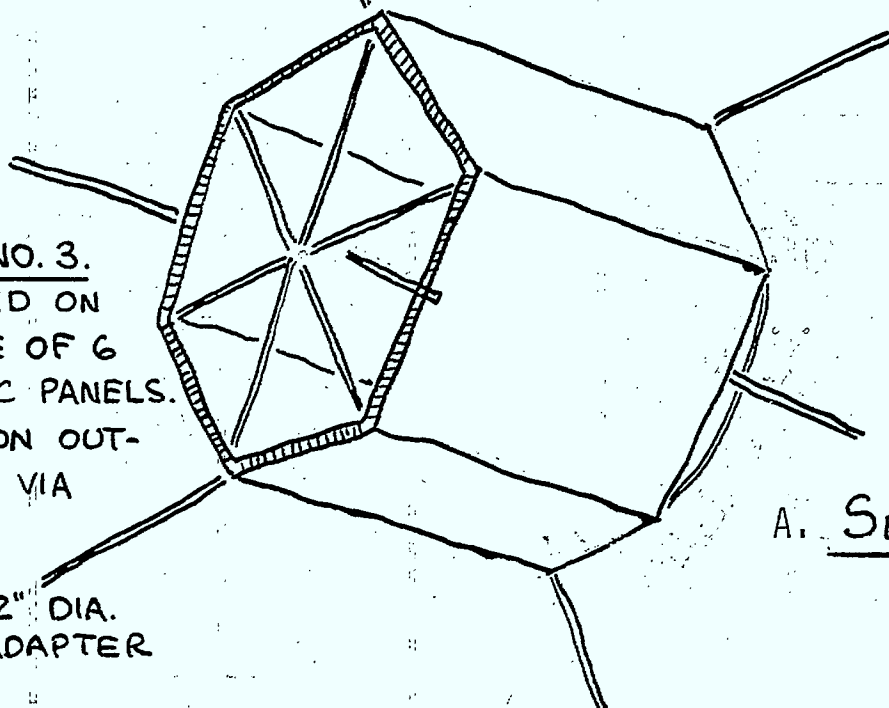
- o PROVIDES REDUNDANCY. COULD FLY THE BOOM AS A BACKUP AND DEPLOY IT IN THE EVENT THE WHEEL SYSTEM FAILED. WEIGHT PENALTY IS ~ 5 KG.
- o PYROTECHNICS DEVICE WOULD HAVE TO WORK RELIABLY AFTER ~ SEVERAL YEAR SPACE EXPOSURE - TO DEPLOY BOOM.

SPIN CONFIG NO. 1
 EQUIP. MOUNTED ON H/C
 PLATFORM \perp TO THRUST
 AXIS. 8 FLAT H/C S.A.
 SUBSTRATES @ S/C SIDES.
 42" DIA. SHROUD,
 EG ADAPTER



SPIN CONFIG NO. 2
 EQUIP. MOUNTED ON BOTH
 SIDES OF 3 RADIAL PANELS \parallel
 TO THRUST AXIS. 42" DIA.
 SHROUD, 25 E ADAPTER.
 3 CURVED S.A. SUBSTRATES
 @ S/C SIDES.

SPIN CONFIG NO. 3.
 EQUIP. MOUNTED ON
 INBOARD FACE OF 6
 PERIPHERAL H/C PANELS.
 SOLAR CELLS ON OUT-
 BOARD FACES VIA
 STRUCTURAL
 ISOLATION
 TECHNIQUE. 42" DIA.
 SHROUD, 25 E ADAPTER



5-4 CONFIGURATION ALTERNATIVES

A. SPINNING S/C CONFIGURATIONS

B. SPINNING S/C CONFIGURATION NO. 1 (S-1)

GOOD POINTS

- o SIMPLICITY OF DESIGN - LOW COST
 - o THERMAL DESIGN IS SIMPLE, USING FORWARD & AFT FACES AS CONTROL SURFACES
 - o APPROX. 90W BOL AVAILABLE FROM BODY ARRAY @ 23.5° SUN ANGLE
- MORE POWER AVAILABLE IF ARRAY SUBSTRATES ARE EXTENDED FORWARD

BAD POINTS

- o GENERAL LIMITATIONS OF NON-EARTH POINTING S/C

COMMENTS

- o POSITIVE MOI RATIO EASY TO ACHIEVE
- o IMU FOOTPRINT AREA = $\sim 8000 \text{ CM}^2$
- o VOLUME = $< 10^5 \text{ CM}^3$ (AS DRAWN)
- o WEIGHT:

STRUCTURE	12.3 KG
SOLAR ARRAY	5.6
THERMAL	1.4
L/V ADAPTER	<u>5.7</u>
	25.0 KG

THIS LEAVES 53. KG FOR REMAINDER OF PAYLOAD, 1400 KM ORBIT

B. SPINNING S/C CONFIGURATION NO. 2 (S-2) (CONT'D)

GOOD POINTS

- o MORE EQUIPMENT FOOTPRINT AREA THAN S-1. 17000 CM² AS DRAWN. COULD BE REDUCED TO 9000 CM². DESIGN CAN ACCOMMODATE MORE P/L THAN DCFS MISSION.
- o SOLAR ARRAY SAME AS S-1.

BAD POINTS

- o GENERAL LIMITATIONS OF NON-EARTH POINTING S/C
- o STRUCTURE/THERMAL MORE COMPLEX THAN S-1.
- o HEAVIER THAN S-1.

COMMENTS

- o POSITIVE MOI ACHIEVABLE, BUT NOT AS EASILY AS S-1 OR S-3.

o WEIGHT: STRUCTURE 18.8
 SOLAR CELLS 5.6 KG
 THERMAL 1.4
 L/V ADAPTER (25 E) 9.4

 35.2 KG

(FOR 9000 CM² AREA)

THIS LEAVES 43 KG FOR REMAINDER OF P/L, 1400 KM ORBIT

B. SPINNING S/C CONFIGURATION NO. 3 (S-3) (CONT'D)

GOOD POINTS

- o SIMPLICITY OF DESIGN
- o EQUIPMENT FOOTPRINT AREA = 20,000 cm^2 AS DRAWN. COULD BE REDUCED TO 8000 cm^2 .
- o SOLAR ARRAY POWER SAME AS S-1 AND S-2

BAD POINTS

- o GENERAL LIMITATIONS OF NON-EARTH POINTING S/C
- o USING PERIPHERAL PANELS FOR BOTH EQUIPMENT MOUNTING AND SOLAR ARRAY SUBSTRATES REQUIRES STRUCTURAL ISSOLATION TECHNIQUE TO PROTECT CELLS. THIS EXTRA ANALYSIS DESIGN, TEST COST.
- o HEAVIER THAN S-1.

COMMENTS

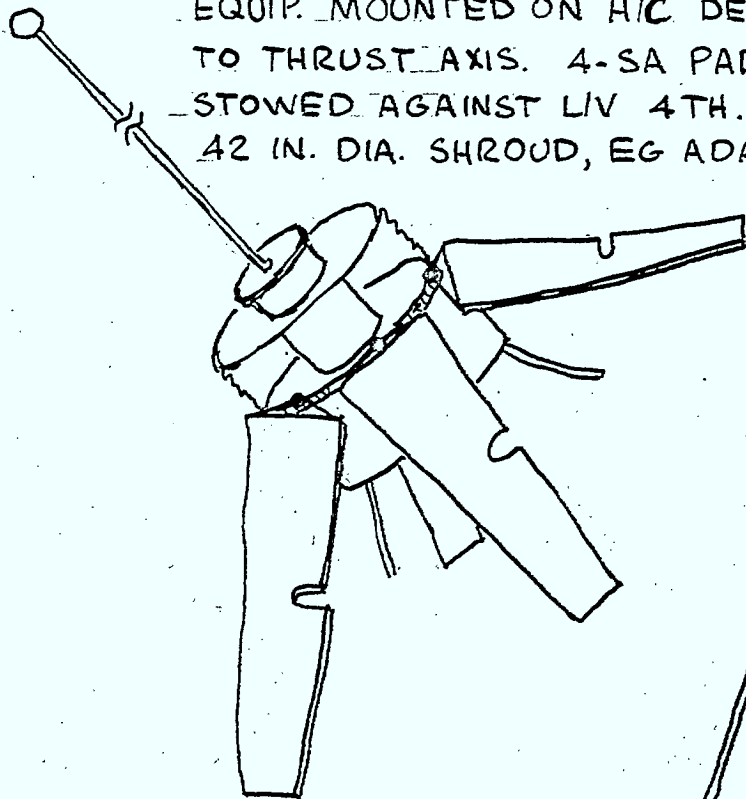
- o POSITIVE MOI RATIO IS EASIEST TO ACHIEVE

o WEIGHT:	STRUCTURE	19.0	(FOR 9000 cm^2 AREA)
	SOLAR CELLS	5.6	
	THERMAL	1.4	
	L/V ADAPTER (25 E)	9.4	
		<u>35.4</u> KG	

THIS LEAVES 42.6 KG FOR REMAINDER OF P/L, 1400 KM ORBIT.

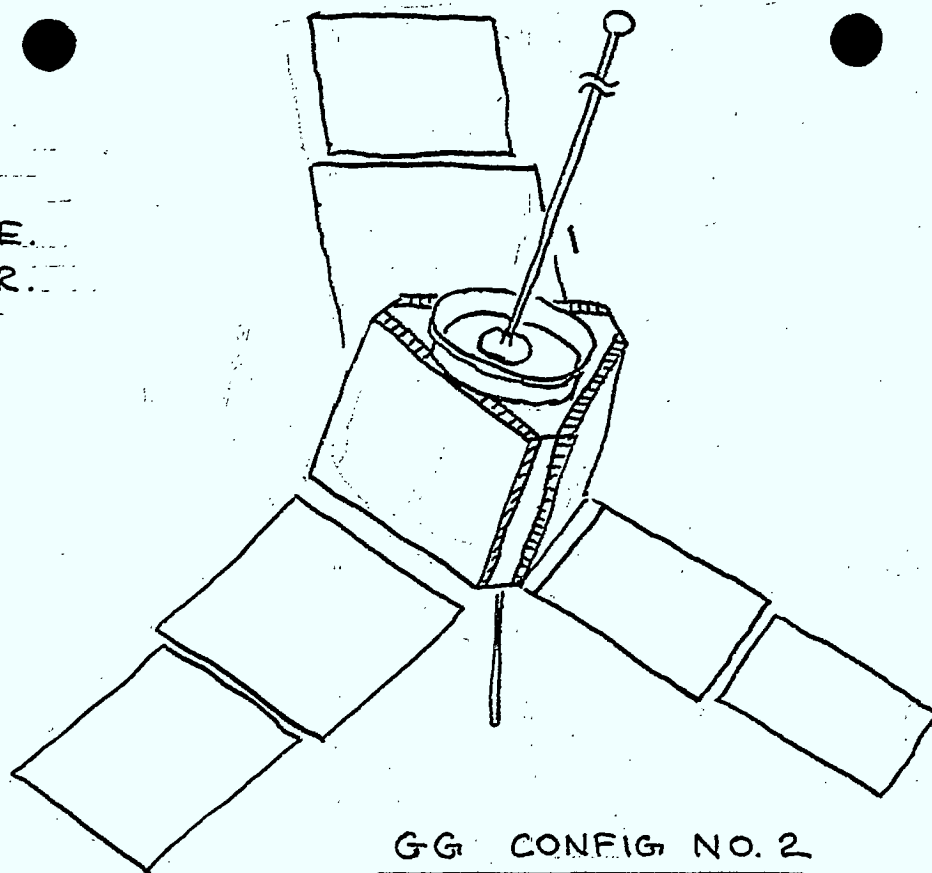
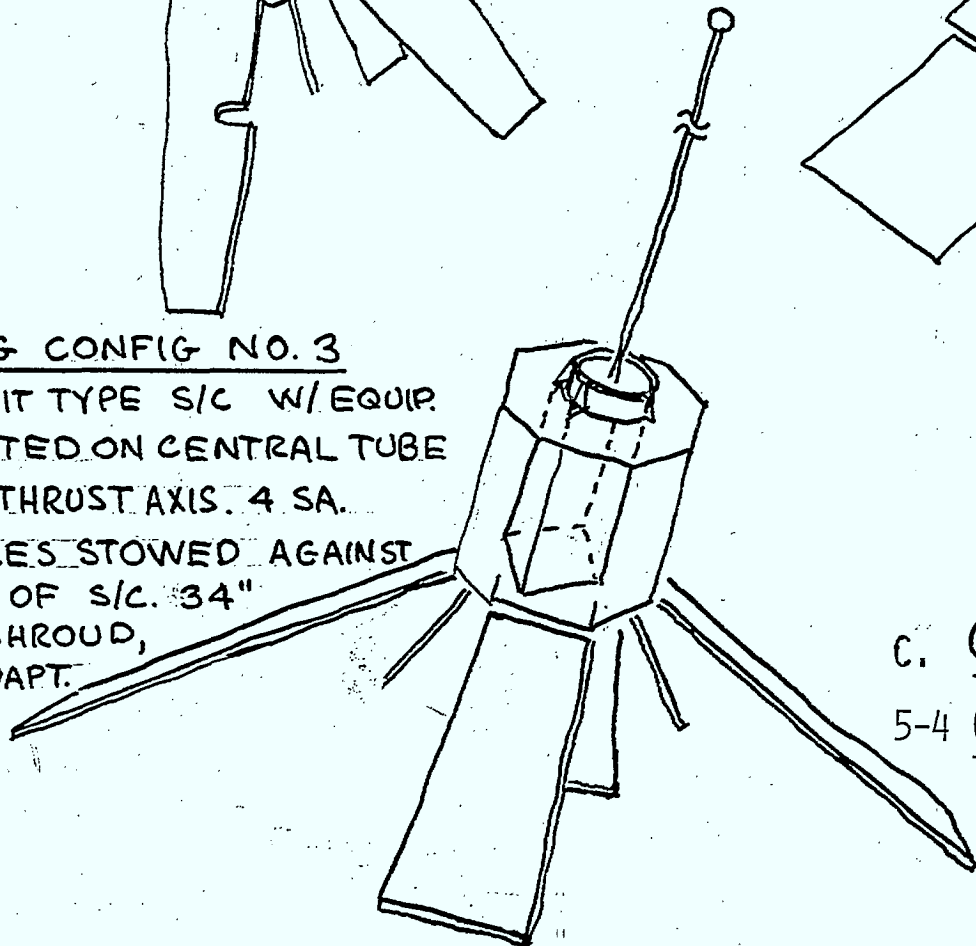
GG CONFIG NO. 1

EQUIP. MOUNTED ON H/C DECK 1
TO THRUST AXIS. 4-SA PADDLES
STOWED AGAINST LIV 4TH. STAGE.
42 IN. DIA. SHROUD, EG ADAPTER.



GG CONFIG NO. 3

TRANSIT TYPE S/C W/EQUIP.
MOUNTED ON CENTRAL TUBE
|| TO THRUST AXIS. 4 SA.
PADDLES STOWED AGAINST
SIDES OF S/C. 34"
DIA. SHROUD,
EG ADAPT.



GG CONFIG NO. 2

EQUIP. MOUNTED ON INBOARD FACE OF
3 H/C PANELS @ SC SIDES. PANELS ||
TO THRUST AXIS. 3 HINGED SA
SUBSTRATES STOWED AGAINST S/C BODY
34" DIA. SHROUD, 25E ADAPTER

C. GRAVITY GRADIENT S/C CONFIG'S
5-4 CONFIGURATION ALTERNATIVES

D. EARTH POINTING S/C NO. 1 (EP-1)

GOOD POINTS

- o GENERAL INCREASED PERFORMANCE DUE TO EARTH FACING
- o SIMPLE THERMAL/STRUCTURAL DESIGN
- o FOOTPRINT AREA = $\sim 8000 \text{ CM}^2$ AS DRAWN

BAD POINTS

- o GENERAL INCREASED MECHANICAL COMPLEXITY DUE TO PADDLES
- o PADDLES SNUBBED AGAINST L/V FOURTH STAGE IS AN ADDED I/F
- o F/P AREA REQUIRES 1.06M SHROUD

COMMENTS

- o POWER CHARACTERISTICS PER FIG.
- o WEIGHT:

STRUCTURE	13.4
SOLAR CELLS(1)	5.6
THERMAL	1.4
L/V ADAPTER (EG)	5.7
	<u>26.1</u>

THIS LEAVES 52 KG FOR REMAINDER OF P/L, 1400 KM ORBIT

- (1) CELLS CONSIDERED ON ONE SIDE ONLY OF EACH OF 4 PADDLES. PEAK POWER
DEPENDING ON ARRAY CONFIGURATION

D. EARTH POINTING S/C NO. 2 (EP-2) (CONT'D)

GOOD POINTS

- o GENERAL INCREASED PERFORMANCE DUE TO EARTH FACING
- o APPROXIMATELY 11,000 CM² OF FOOTPRINT AREA, AS DRAWN, BUT CAN EASILY BE VARIED
- o THREE SOLAR PANELS INSTEAD OF FOUR. POWER PROFILE PER FIG.
- o WIDE PANELS, SNUBBING AGAINST 4TH STAGE NOT REQUIRED

BAD POINTS

- o HINGED SOLAR PANEL IS ADDED COMPLEXITY - BUT SIMILAR DESIGNS HAVE FLOWN.

COMMENTS

o WEIGHT:	STRUCTURE	14.0
	SOLAR CELLS	6.0
	THERMAL	1.4
	L/V ADAPTER (25 E)	<u>9.4</u>
		30.8

THIS LEAVES 51 KG FOR REMAINDER OF P/L; 1400 KM ORBIT

(1) CELLS ON ONE SIDE ONLY OF EACH OF 3 PADDLES

D. EARTH POINTING S/C NO. 3 (EP-3) (CONT'D)

GOOD POINTS

- o GENERAL INCREASED PERFORMANCE DUE TO EARTH FACING
- o TRANSIT TYPE DESIGN, EXCEPT ARRAYS NOT STOWED AGAINST 4TH STAGE
- o USES BOTH SMALL SHROUD AND LIGHT WEIGHT ADAPTER
- o FOOTPRINT AREA = $10,000 \text{ CM}^2$ AS DRAWN, CAN EASILY BE INCREASED.

BAD POINTS

- o LATERAL STRUCTURAL LOADS CAN CAUSE PROBLEMS

COMMENTS

o WEIGHT:	STRUCTURE	12.2 KG
	SOLAR CELLS	6.0 KG ⁽¹⁾
	THERMAL	1.4 KG
	L/V ADAPTER (EG)	5.7 KG
		<u>25.3 KG</u>

THIS LEAVES 57 KG FOR REMAINDER OF P/L, 1400 KM ORBIT

(1) CELLS ONE SIDE OF EACH OF 4 PADDLES, AS DRAWN. CAN BE MODIFIED TO 3 PADDLE DESIGN.

5-4 CONFIGURATION ALTERNATIVES

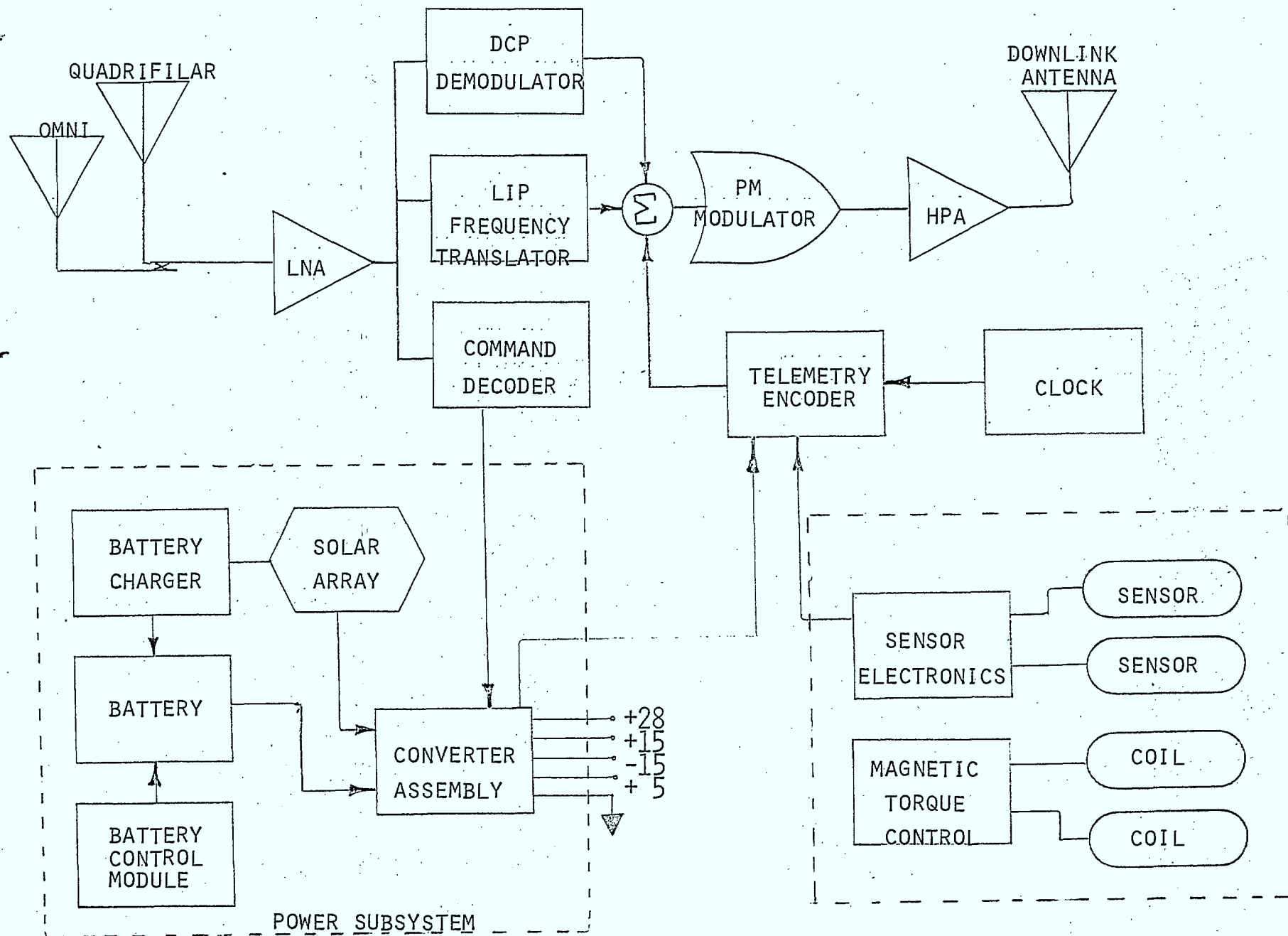
E. SPACECRAFT CONFIGURATION EVALUATION

- o EARTH POINTING CONFIGURATION GIVES SIGNIFICANT SYSTEM RF LINK IMPROVEMENT
- o EARTH POINTING GRAVITY GRADIENT SYSTEM IS WEIGHT COMPETITIVE WITH SPIN STABILIZED SPACECRAFT
- o BY USING 0.86 M SHROUD, THE EARTH POINTING SYSTEM CAN PRODUCE MORE P/L CAPACITY THAN A SPIN STABILIZED CONFIGURATION USING 1.067 M SHROUD
- o GRAVITY GRADIENT SYSTEM WITH WORST CASE 10^0 POINTING ACCURACY MEETS MISSION REQUIREMENTS
- o SPIN STABILIZED SYSTEM IS INHERENTLY SIMPLER, CONSIDERING ATTITUDE ACQUISITION AND SOLAR ARRAY DESIGN - BUT SWITCHED ANTENNA DESIGN IS COMPLEX
- o EARTH POINTING REACTION/MOMENTUM WHEEL STABILIZATION SYSTEM HAS WEIGHT, POWER, RELIABILITY PENALTIES. IT SUPPLIES POINTING ACCURACY ($\sim 1^0$) IN EXCESS OF MISSION REQUIREMENTS

5-5 BASELINE SPACECRAFT

- o GRAVITY GRADIENT STABILIZED ATTITUDE CONTROL
- o RIGID PADDLE TYPE DEPLOYABLE QUADRIFILAR ANTENNAS.
SOLAR ARRAYS
- o CONFIGURATION TO FIT 0.86 M L/V SHROUD
- o PASSIVE THERMAL CONTROL SYSTEM
- o MAGNETIC TORQUE CAPABILITY SUFFICIENT TO RE-ORIENT A
S/C IF GRAVITY GRADIENT BOOM IS INVERTED DURING
ATTITUDE ACQUISITION

5-5 SPACECRAFT LOAD DESIGN



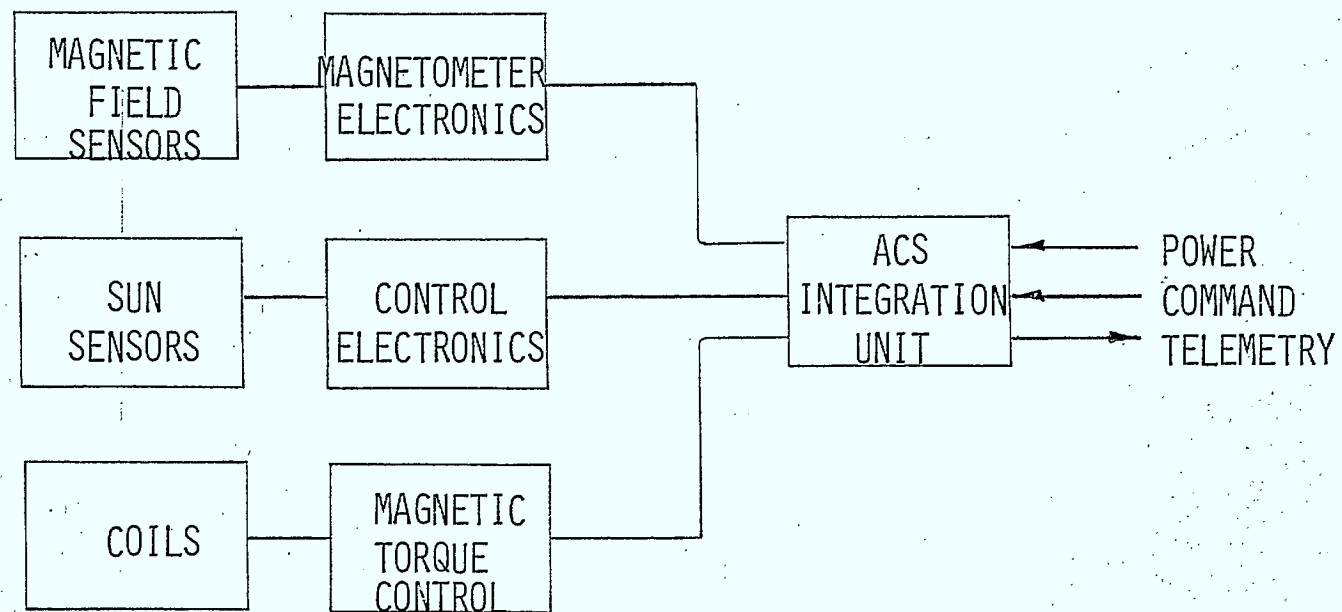
A. SPACECRAFT BLOCK DIAGRAM

5-5 BASELINE SPACECRAFT CONFIGURATION

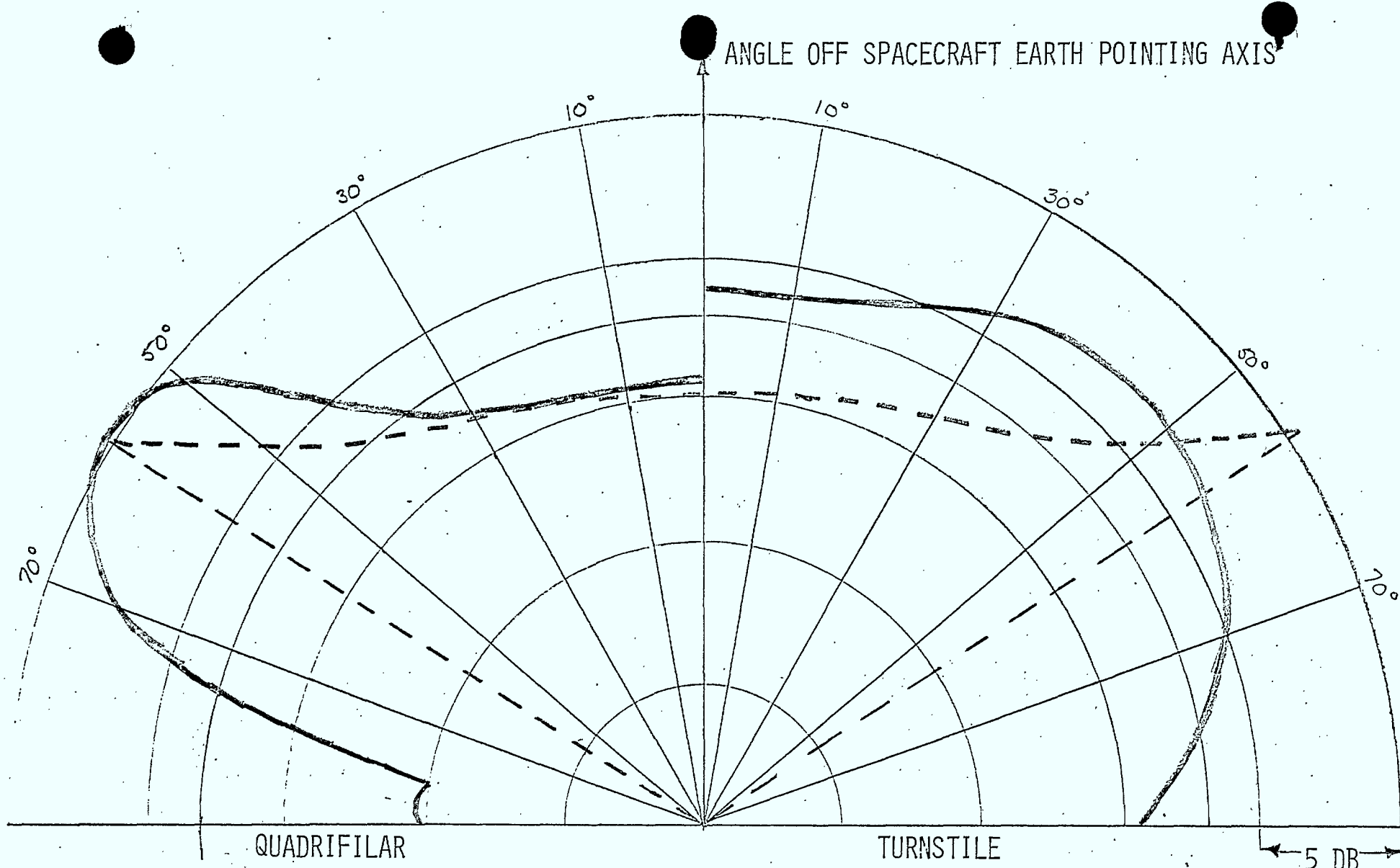
B. ATTITUDE CONTROL SUBSYSTEM

- o SINGLE BOOM 25-30 METERS LONG, DESIGNED TO MINIMIZE THERMAL DISTORTION
- o NO YAW CONTROL
- o PITCH & ROLL AXES LIBRATION ANGLES LIMITED TO $\pm 5^\circ$ BY DAMPING SYSTEM
- o MAGNETOMETERS FOR MAGNETIC TORQUING REFERENCE. SUN, EARTH SENSORS T.B.D.
- o DESIGN FOR S/C REORIENTATION IF ATTITUDE ACQUISITION FAILS.

5-5 SPACECRAFT PAYLOAD DESIGN



B. ATTITUDE CONTROL SUBSYSTEM (CONT'D)



0 DB RELATIVE TO ISOTROPIC RADIATOR

TURNSTILE

5 DB

- — — — — CALCULATED REQUIRED PATTERN FOR CONSTANT SIGNAL STRENGTH SATELLITE ATTITUDE 1250 KM
- MEASURED PATTERN FROM ANTENNA

C. SPACECRAFT ANTENNA PATTERNS

5-5 BASELINE SPACECRAFT CONFIGURATION

D. SOLAR ARRAY SUBSYSTEM

- o ETCHED SILICON 10 -CM HYBRID 2X2 CM CELLS. BOL
POWER OUTPUT = 65MW/CELL @ R.T.
- o SERIUM DOPED COVERGLASS, NOMINAL THICKNESS .030 CM
- o SOLAR ARRAY TO PROVIDE ADEQUATE POWER FOR BATTERY
CHARGING DURING ECLIPSE SEASON
- o ARRAY SIZED FOR EOL POWER, 7 YEAR MISSION
- o CELLS ON ONE SIDE OF PADDLES ONLY
- o DESIGN FOR KEEP-ALIVE POWER IF ATTITUDE ACQUISITION
FAILURE AND SUBSEQUENT S/C REORIENTATION REQUIRED

5-5 BASELINE SPACECRAFT CONFIGURATION

E. STRUCTURAL SUBSYSTEM

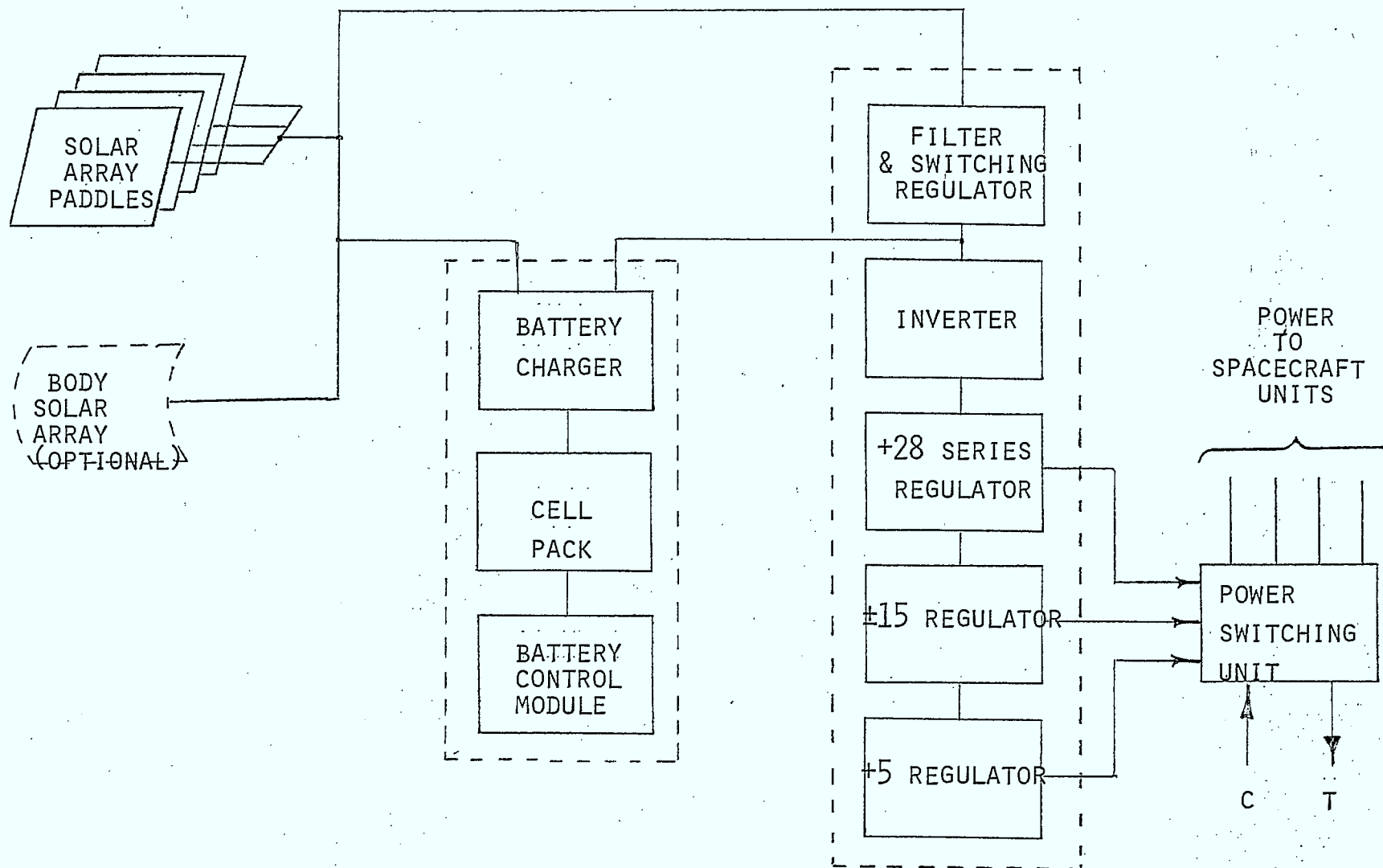
- o COMPATIBILITY WITH E SECTION L/V ADAPTER
- o MAGNESIUM USED FOR STRUCTURAL COMPONENTS WHERE WEIGHT EFFECTIVE
- o SOLAR ARRAY SUBSTRATE IS ALUMINUM HONEYCOMB CORE WITH FIBERGLASS, ALUMINUM OR KAPTON FACESHEET
- o HONEYCOMB PANELS TO HAVE EDGE PROTECTION FOR HANDLING

5-5 BASELINE SPACECRAFT CONFIGURATION

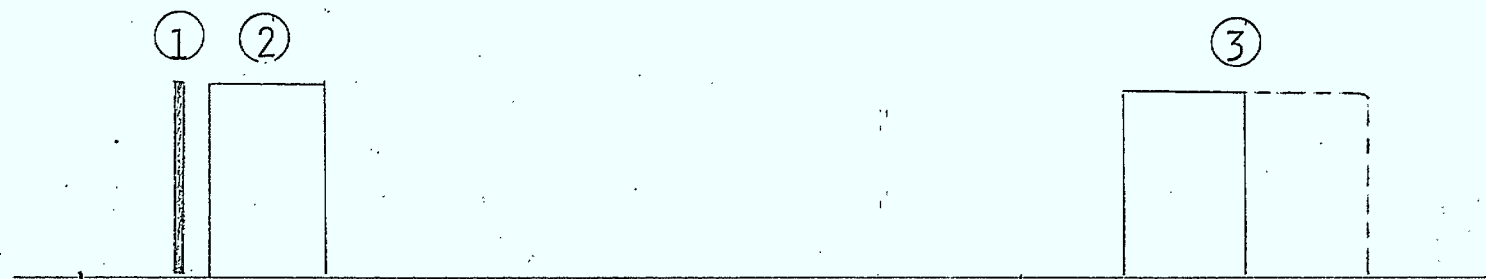
F. THERMAL SUBSYSTEM BASELINE

- o PASSIVE DESIGN IS BASELINE BUT LOUVERS AND HEATERS WILL BE USED IF NECESSARY
- o THERMAL CONTROL SURFACES: .005" SILVERED TEFLON SUNSHIELDS AND MULTILAYER INSULATION COMBINATION BLANKET.
- o INSULATED SURFACES: ALUMINIZED KAPTON MULTILAYER INSULATION
- o CONTROL EQUIPMENT LOCAL TEMPERATURES BETWEEN -10°C AND $+40^{\circ}\text{C}$ EXCEPT FOR HIGH INTERNAL DISSIPATING COMPONENTS
- o CONTROL BATTERY TEMPERATURES BETWEEN 5°C AND 30°C WITH MINIMUM GRADIENTS
- o DESIGN FOR SPIN, ATTITUDE ACQUISITION, ON ORBIT SEASONAL CASES
- o DESIGN FOR KEEP-ALIVE TEMPERATURES IF ATTITUDE ACQUISITION FAILURE AND SUBSEQUENT S/C REORIENTATION REQUIRED

5-5 SPACECRAFT PAYLOAD DESIGN

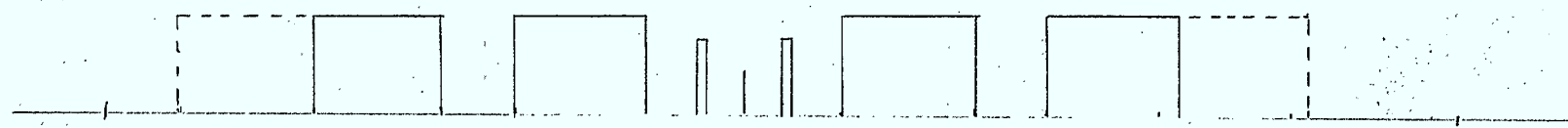
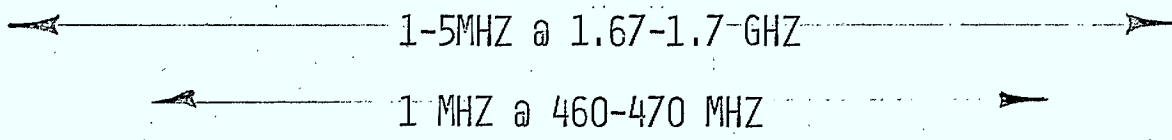


G. POWER SUBSYSTEM



- ① COMMAND 20 KHZ IN 400.15 - 404 MHZ BAND
- ② DCP 100 KHZ IN 401-403 MHZ BAND
- ③ LIP 100-200 KHZ IN 420-450 MHZ BAND

UPLINK



460 MHZ }
1670 MHZ } OPTION

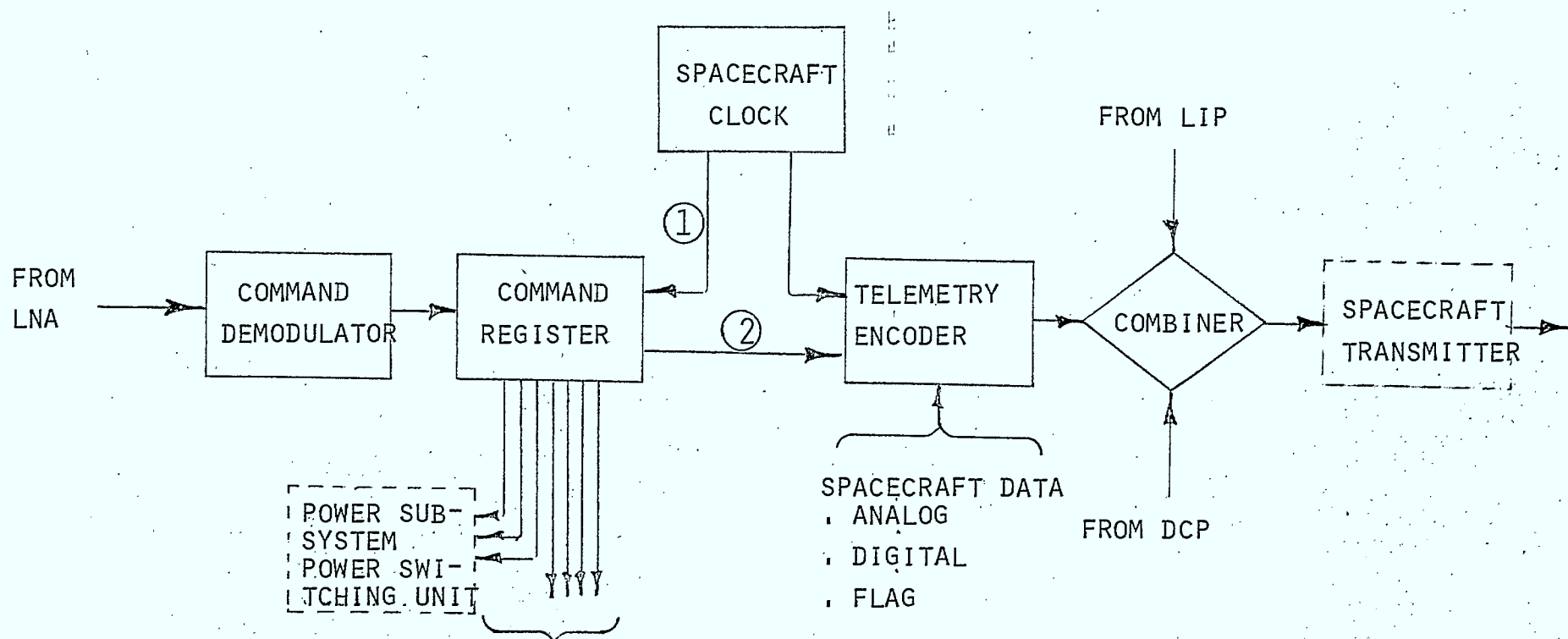
470 MHZ }
1700 MHZ } OPTION

DOWNLINK

H. TRANSPONDER CONFIGURATION
FREQUENCY PLAN

5-5 SPACECRAFT PAYLOAD DESIGN

- ① DELAYED COMMAND EXECUTE TIMING
- ② COMMAND REGISTER CONTENT



I. TELEMETRY & COMMAND SUBSYSTEM

I. TELEMETRY LISTING (CONT'D)

TYPICAL

FLAGS

- o SOLAR ARRAY PANEL LOCK
- o TRANSPONDER 1 ON, 2 OFF
- o TRANSPONDER 2 ON, 1 OFF
- o CONVERTER 1 ON, 2 OFF
- o CONVERTER 2 ON, 1 OFF
- o SEPARATION SWITCH

ANALOGUE

- o +28 CURRENT
- o ± 15 CURRENT
- o ± 5 CURRENT
- o BATTERY CELL TEMP. (SUBCOMMUTATED)
- o BATTERY CELL VOLTAGE (SUBCOMMUTATED)
- o BATTERY INPUT (CHARGING) CURRENT
- o BATTERY OUTPUT CURRENT
- o SOLAR ARRAY VOLTAGE
- o TEMP SENSORS (SUBCOMMUTATED)
- o SUN SENSOR OUTPUT
- o MAGNETOMETER OUTPUT

DIGITAL

- o COMMAND REGISTER CONTENT

I. COMMAND LISTINGS (CONT'D)

TYPICAL

- o SELECT TRANSPONDER 1 ON, 2 OFF
- o SELECT TRANSPONDER 2 ON, 1 OFF
- o TRANSPONDER BOTH OFF
- o CONVERTER 1 ON, 2 OFF
- o CONVERTER 2 ON, 1 OFF
- o TORQUE COIL A POSITIVE
 - A NEGATIVE
 - B POSITIVE
 - B NEGATIVE
- o COMMAND EXECUTE
- o BATTERY HIGH CHARGE RATE ON
- o BATTERY LOW CHARGE RATE ON
- o BATTERY CHARGE OFF
- o BATTERY RECONDITION
- o BATTERY A CONNECT, B DISCONNECT
- o BATTERY B CONNECT, A DISCONNECT
- o COMMAND EXECUTE #1 (WITH TIME DELAY)
- o COMMAND EXECUTE #2 (WITH TIME DELAY)
- o EXTEND GRAVITY GRADIENT BOOM
- o RETRACT GRAVITY GRADIENT BOOM

6.

PRELIMINARY COST ESTIMATES

QTY	CAPITAL COST ITEMS	NON-REC COST \$K	UNIT COST \$K	SYSTEM COST \$M
	<u>SPACE SEGMENT</u>			
	-SYSTEM DESIGN/MANAGEMENT	1000	110	
	-STRUCT/THERMAL	340	340	
	-POWER SUBSYSTEM	50	100	
	-TRANSPONDER	300	400	
	-T&C	100	230	
	-ANTENNAS	120	40	
	-ATT. CONTROL	305	256	
	-WIRE HARNESS	30	30	
	-SPACECRAFT INTEGRATION	175	75	
	-GROUND SUPPORT			
	EQUIPMENT - MECHANICAL	100	-	
	-SYSTEM TEST EQUIPMENT	250	-	
	-SYSTEM TEST	355	130	
	-LAUNCH CHECKOUT	-	100	
4	SPACECRAFT	3125	1811	10.369
	<u>MISSION CONTROL CENTER</u>			
	-FACILITIES (FURNISHINGS)	5	20	
	-MISSION SOFTWARE	600	-	
	-COMMUNICATIONS & DATA DISPLAY	50	100	
1	MISSION CONTROL	655	120	0.775
	<u>GROUND STATIONS</u>			
	-ANTENNA	10	80	
	-RF EQUIPMENT	15	60	
	-T&C EQUIPMENT	10	30	
	-DC PROCESSOR	250	150	
	-FS PROCESSOR	350	150	
	-COMPUTER	240	600	
	-COMMUNICATIONS INTERFACES	30	50	
	-CIVIL WORKS	100	150	
2	GROUND STATIONS	1005	1270	3.545

PRELIMINARY COST ESTIMATES

(CON'T)

QTY	CAPITAL COST ITEMS	NON-REC COST \$K	UNIT COST \$K	SYSTEM COST \$M
2000	DCP'S (NOT INCL. SENSORS)	150	2.8	5.750
1000	LIP'S	350	.9	1.250
3	SCOUT LAUNCH	-	4.5 (M)	13.500
	TOTAL SYSTEM COST			35.165
	-WITHOUT LAUNCH COST (-13.5 M)			21.665
	-WITH 500 DCP'S ONLY (= 4.2 M)			17.465

OPERATIONAL COSTS WILL BE COMPUTED IN PHASE III

81976

P
91
C655
D639
1976

DATE DUE
DATE DE RETOUR[illegible]

LOWE-MARTIN No. 1137

