Master in Space and Satellite Technology

SPACE PROJECT
Communication Satellite Project
(Solidaridad Mexican Satellite)

Salvador Landeros, Miguel Calvo, Ramón Martínez

Scope

- **Topic 1: Mission Objectives**
- **Topic 2: General Requirements**
- **Topic 3: Payload solution**
- **Topic 4: Subsystems solution**
- **Topic 5: Integration and tests**
- **Topic 6: Launch**
- **Topic 7: Earth segment solution**
- **Topic 8: Training and operations**

ACRONYMS

ACE	attitude control electronics
ACS	attitude control subsystem
ACSS	acquisition sun sensor
A/D	analog-to-digital
AEIRP	aggregate effective isotropic radiated power
AGC	automatic gain control
ALC	automatic level control
AlGaAs	aluminum gallium arsenide
ARC	Atlantic Research Corporation
ASWA	adjustable solar wing actuator
BCC	battery charge controller
BCVM	battery cell voltage monitor
BDC	battery discharge controller
BER	bit error rate
BIT	built-in test
BOL	beginning of life
BPDU	bus power distribution unit
BPF	bandpass filter
BVL	bus voltage limiter
CCU	channel control unit
CDU	command decoder unit
cg	center of gravity
C/I	carrier-to-interference power
CIC	cell interconnect cover
C/3IM	carrier-to-third-order intermodulation
CM	center of mass
CMOS	complementary metal-oxide semiconductor
C/No	carrier-to-noise power ratio
CP	center of pressure
CPW	commanded pulse width
CSG	Guiana Space Center
CTE	coefficient of thermal expansion
CT&R	command, telemetry, and ranging
D/A	digital-to-analog
DAB	deployable aft blanket
DCI	Dossier de Contrôle Interfaces
DOD	depth of discharge

Ac-1

EIRP	effective isotropic radiated power
EMF	electromotive force
EMI	electromagnetic interference
EOL	end of life
EPC	electronic power conditioner
EPS	electrical power subsystem
EPW	effective pulse width
ER	east reflector
ESA	earth sensor assembly
ESD	electrostatic discharge
E-W	east-west
FDV	flight development vehicle
FET	field effect transistor
FIFO	first in, first out
FIST	final integrated system test
FOV	field of view
FSK	frequency shift keying
GaAs	gallium arsenide
GSE	ground support equipment
G/T	gain to noise temperature ratio
GTO	geosynchronous transfer orbit
HCI	horizon crossing indicator
HEMT	high electron mobility transistor
HPA	high power amplifier
IF	intermediate frequency
IMUX	input multiplexer; current multiplexer
I/O	input/output
IP3	third-order intercept point
IRU	inertial reference unit
Is/It	spin-to-transverse inertial ratio
ITO	indium tin oxide
LAM	liquid apogee motor
LIFO	last in, first out
LIM/LIN	limiter/linearizer
LNA	low noise amplifier
LO	local oscillator
LOS	line of sight
LPF	low pass filter
LPPS	low-power power supply
LSB	least significant bit

LSFT	launch site functional test
LV	latch valve
MEOP	maximum expected operating pressure
MIC	microwave integrated circuit
MLI	multilayer insulation
MMH	monomethylhydrazine
MMIC	microwave monolithic integrated circuit
MON	mixed oxides of nitrogen
MOSFET	metal oxide-silicon field effect transistor
MPS	mobile power stand
MRO	memory readout
MSB	most significant bit
MT	magnetic torquer
MWA	momentum wheel assembly
MWP	momentum wheel platform
NASA	National Aeronautics and Space Administration
NF	noise figure
NRZL	nonreturn to zero level
NRZM	nonreturn to zero mark
N-S	north-south
NSI	NASA standard initiator
NSW	north solar wing
NTO	nitrogen tetroxide
NTSC	National Television Systems Committee
ODA	omni deployment actuator
OMUX	output multiplexer
OTS	optimal thruster select
PCM	pulse code modulation
PDA	PIN diode attenuator
PDU	power distribution unit
PGS	propellant gauging system
PIM	passive intermodulation
PKM	perigee kick motor
PMD	propellant management device
PPDU	propulsion power distribution unit
PROM	programmable read-only memory
PVA	perigee velocity augmentation
PWB	printed wiring board
PWM	pulse width modulator
RADA	receive antenna deployment actuator
RAM	random access memory

RCS	reaction control subsystem
RDA	reflector deployment actuator
RPM	reflector positioning mechanism
RRF	receive reject filter
rss	root sum square
RTCI	real time clock interrupt
RTI	real time interrupt
RTP	range tone processor
RTV	room temperature vulcanization
RZ	return to zero
SADA	step attenuator/driver amplifier
SAW	surface acoustic wave
SCC	stress corrosion cracking
SCP	spacecraft control processor
SDU	squib driver unit
SIT	system integrated test
S/No	signal-to-noise power ratio
SOC	state of charge
spst	single pole, single throw
SRD	step recovery diode
SSPA	solid state power amplifier
SSW	south solar wing
STE	system test equipment
SV	squib valve
SWA	solar wing actuator
SWD	solar wing drive
TBR	to be resolved
T&C	telemetry and command
TCR	track command receiver
TDMA	time division multiple access
TEU	telemetry encoder unit
TLM	telemetry
TOA	time of arrival
TOSS	transfer orbit sun sensor
TT&C	telemetry, tracking, and command
TV	thermal-vacuum
TWT	traveling wave tube
TWTA	traveling wave tube amplifier
ULPC	uplink power control
URD	unit reference designator
VCC	variable command count
VCM	volatile condensable material

Ac-4

VDA	vacuum deposited aluminum
VDU	valve driver unit
VPD	variable power divider
VSAT	very small aperture terminal
VSWR	voltage standing wave ratio
WDE	wheel drive electronics
WHECON	wheel control
WR	west reflector

Topic1: Mission objectives

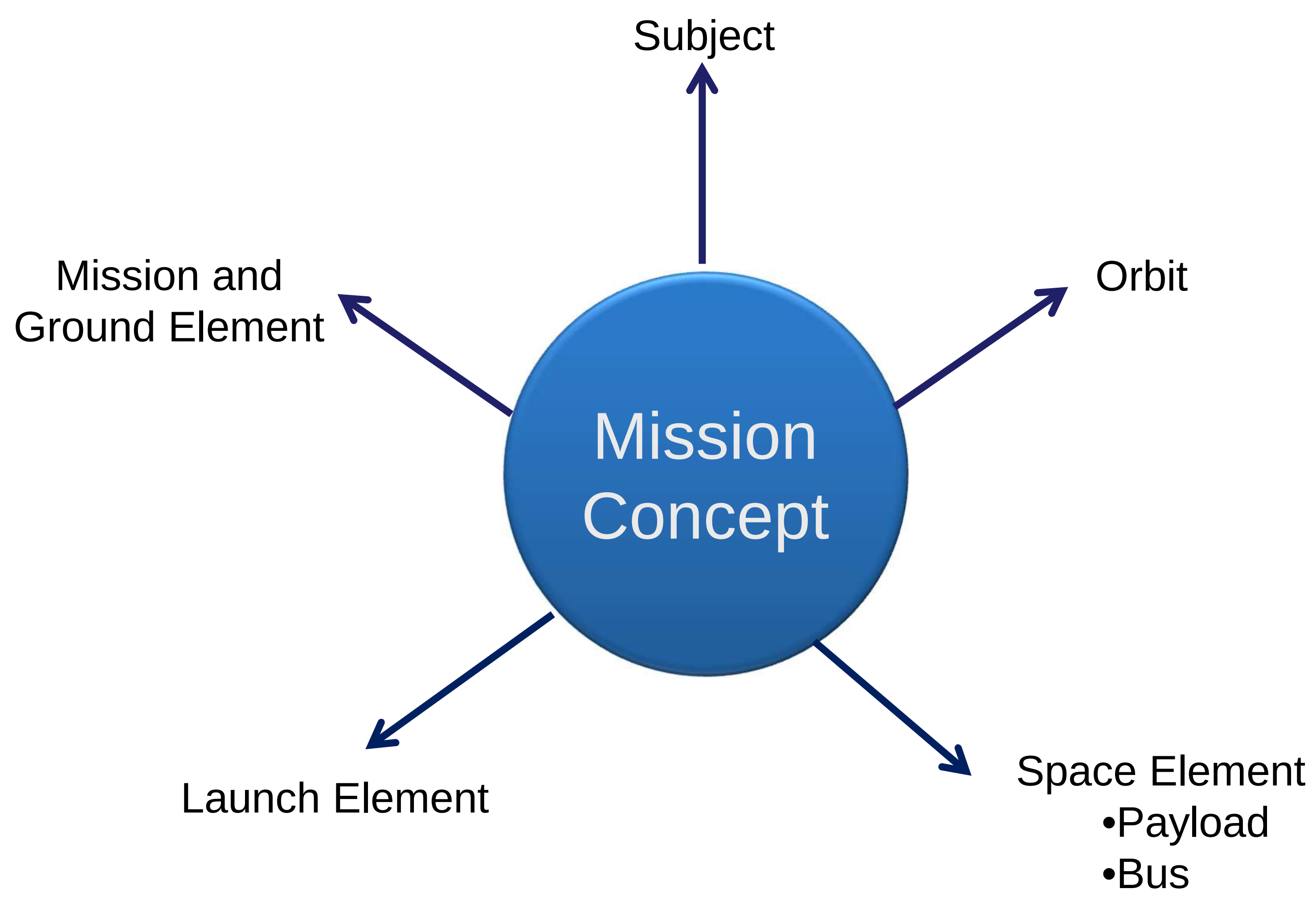
- **General objective**

  To provide telecommunications solutions in Mexico,USA and LatinAmerica

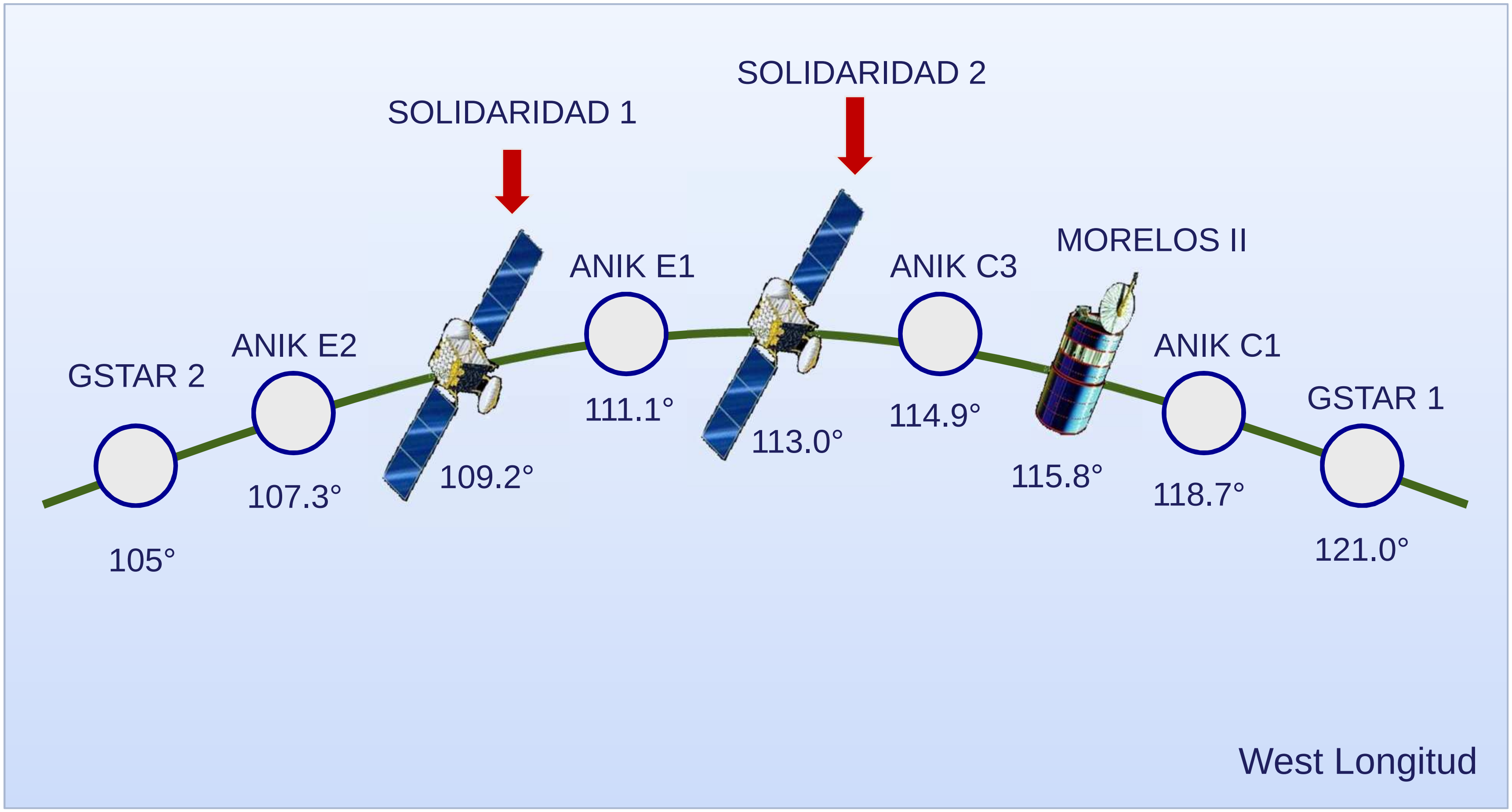
- **Specific objectives**

  To offer C, Ku and L band services(FSS, DBS, Mobil)

Space Mission Architecture



Position and neighboring of the Solidaridad Satellites



Spacecraft

Stabilization

Transfer/drift orbit	Stable spinner	
Geosynchronous	3-axis body stabilized	
Stationkeeping performance	**Limit, deg**	**Correction Interval (Nominal), Days**
North – south	±0.05	>14
East – west	±0.05	>14
Mission/design life	14 yr	
Weight	< 3000 kg	

Master in Space and Satellite Technology

Topic 2: General requirements

Communications

The Satellite Communications subsystem shall include all necessary antennas and microwave transponder hardware to receive, amplify and transmit microwave signals within the Ku–band services areas, the C–band services areas and the L–band services areas.

This subsystem shall comprise 16 linearised 14/12 GHz transponders(54 MHz bandwith), 18, 6/4 GHz transponders(12, 36 MHz bandwith and 6, 72 MHz bandwidth) and one 1.6/1.5 GHz transponder of 31 MHz bandwith

Communications(Cont)

The transponders shall be capable of being operated in either single carrier or multicarrier per transponder modes including:

a) Single carrier or two-carrier FM television.
b) Single carrier FM television mixed with a number of narrowband SCPC carriers or a wideband digital carriers.
c) Multicarriers such as FM/FDM
d) SCPC/ FM/ FDMA
e) SCPC/ PSK/ FDMA
f) TDM/ PSK/ TDMA
g) CDMA

Frequency Bands

The subsystem shall receive and transmit in the following frequency bands:

Frequency Band	Receive			Transmit		
C	5.925	to	6.425 GHz	3.7	to	4.2 GHz
Ku	14.0	to	14.5 GHz	11.7	to	12.2 GHz
L	1626.5	to	1660.5 MHz	1525	to	1559 MHz

Polarization C band

Transponder	Receive Polarization	Transmit Polarization
1-12(Narrow Band) 1-6(Wide Band)	Horizontal Vertical	Vertical Horizontal

Polarization Ku band

Transponder	Receive Polarization	Transmit Polarization
1-8 9-16	Vertical Horizontal	Horizontal Vertical

Polarization L band

Transponder	Receive polarization	Transmit polarization
1	Right-hand circular	Right-hand circular

Communications

	C Band (36 MHz)	C Band (72 MHz)	Ku Band (54 MHz)
EIRP (dBW) (EOC)	R1: 37.0 R2: 36.2 R3: 36.6	R1:40.1	R4:47.0 R5:46.40
Capacity(transponders)	12	6	16
Principal cities, USA	Los Angeles San Antonio Miami	Los Angeles and San Antonio	Los Angeles, New York, Miami, Houston, Dallas and San Francisco
Latin America	Mexico, Argentina, Chile Venezuela, Colombia and Central America	Mexico, Belice and Guatemala	Mexico, Guatemala, Belice and Cuba
G/T /(dB/K) EOC	R1=2.5 R2=-0.5 R3=1	R1: 2.0	R4: 2.2 R5: 2.5

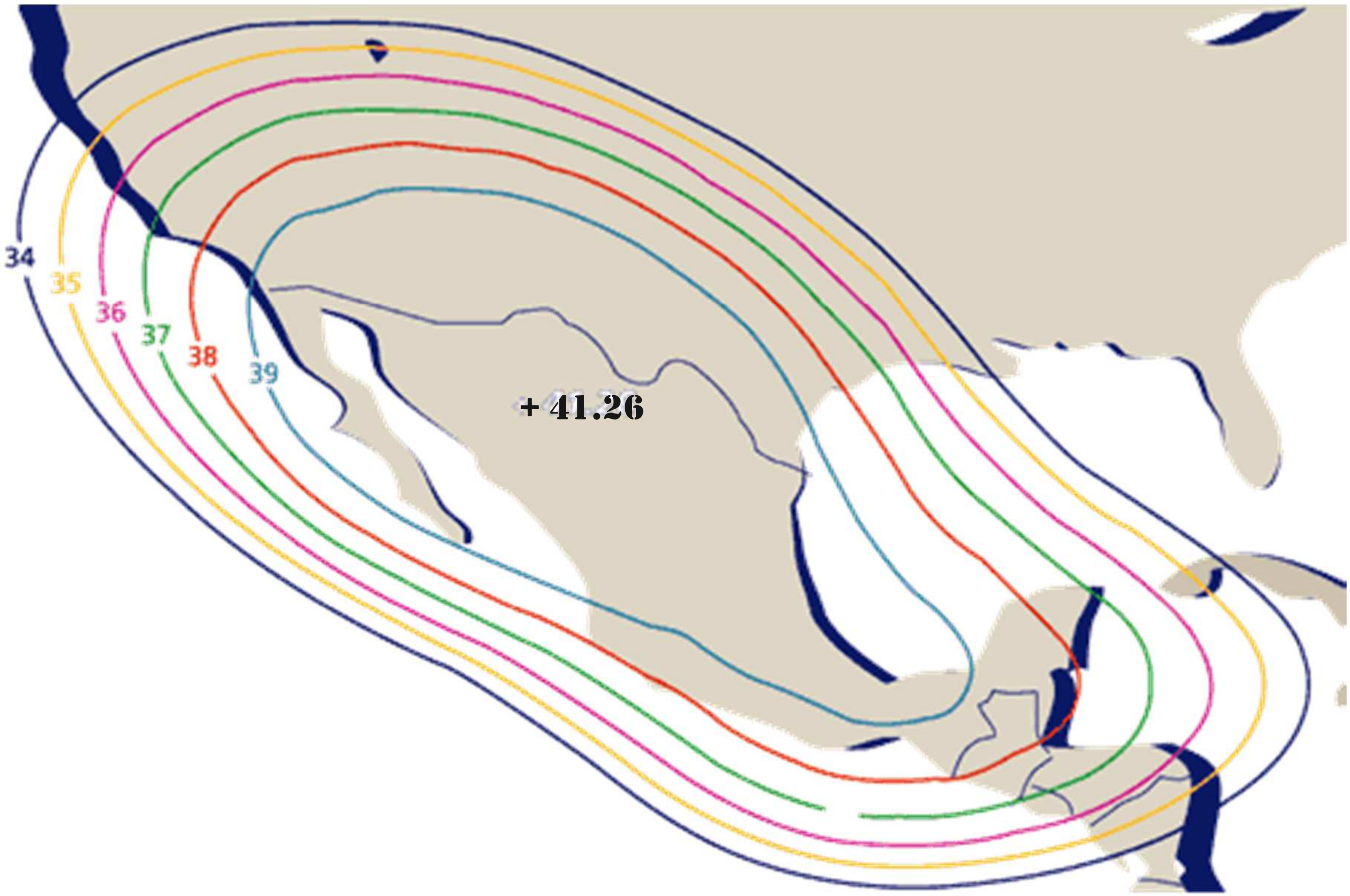
Communications (Cont.)

Solidaridad 1	C Band (36 MHz)	C Band (72 MHz)	Ku Band (54 MHz)
Saturation density flux	R1 : -92.0 R2 : -92.0 R3 : -89.0	R1 : -89.0	R4 : -95.0 R5 : -95.0
Redundancy	14 SSPAs for 12 channels	8 SSPAs for 6 channels	20 TWTAs for 16 channels
Amplifiers Power	SSPA of 10 and 16 Watts	SSPA of 14.4 Watts	TWTA of 45 Watts
Input attenuation range	0 to 14 dB in 2dB steps	0 to 14 dB in 2dB steps	0 to 22 in 2 dB steps
Degrees of tolerance in the stationkeeping	±0.05º N-S ±0.05º E-W	-	-
Fuel at december 1st, 1998		271.821	
Operation Life: 14 years		Start Operation: January,1994	

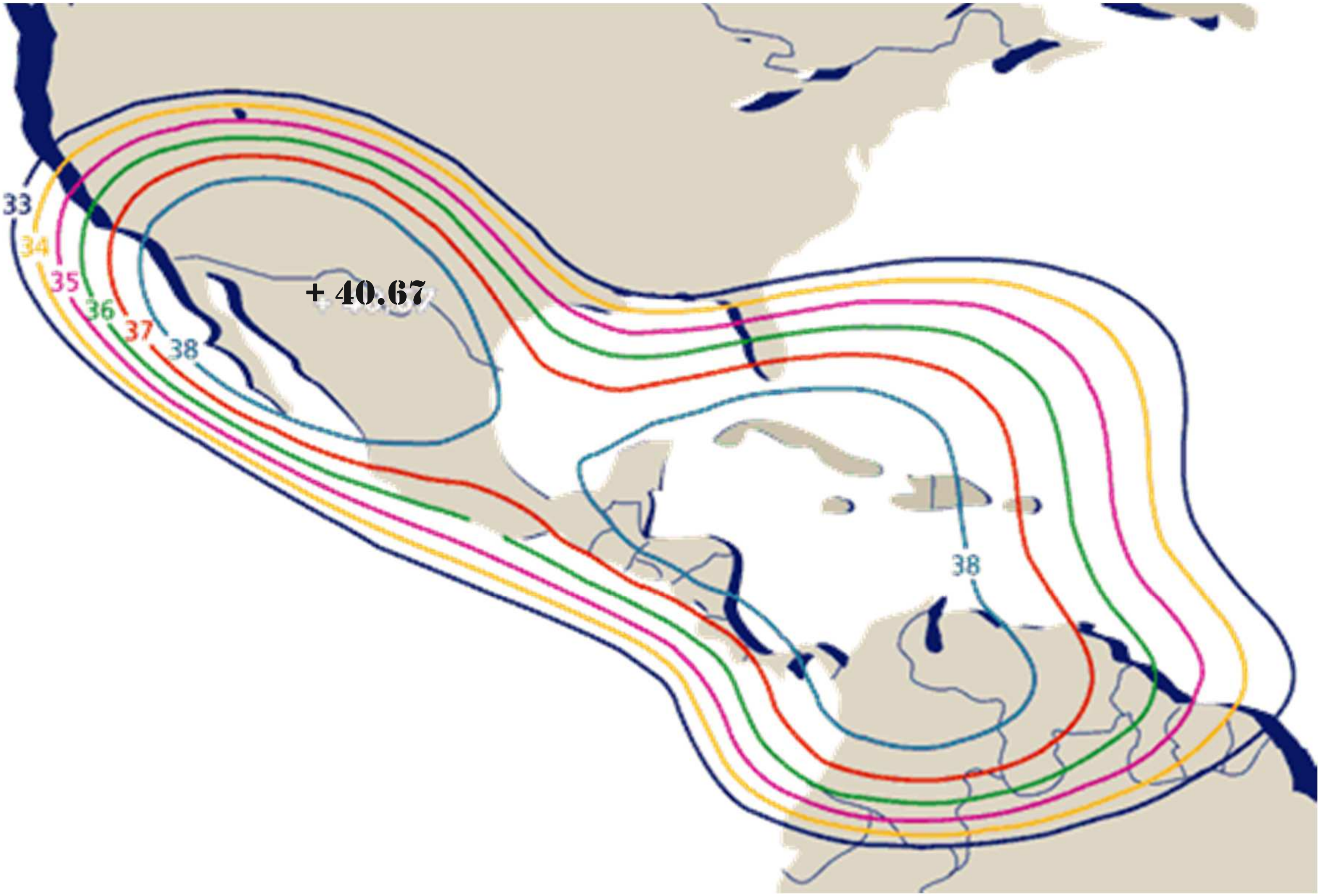
Communications(Cont)

- **The tenderer shall provide detailed calculations of predicted EIRP, including justification for all assumed output RF losses and degradations to cater for RF variations over temperature and spacecraft life. Predicted worst-case end-of- life EIRP performance shall include a minimum margin of 0.5 dB relative to these specifications.**
- **In calculating G/T values, a spacecraft antenna noise temperature of 290º K shall be assumed, all noise services generated within the spacecraft shall be included, and a minimum margin of 0.5 dB relative to especifications under worst-case predicted end-of-life conditions shall be included.**
- **The SFD at any selected gain step shall not vary more than ±0.5 dB over any 24 hour period and ±2 dB over the spacecraft service life.**

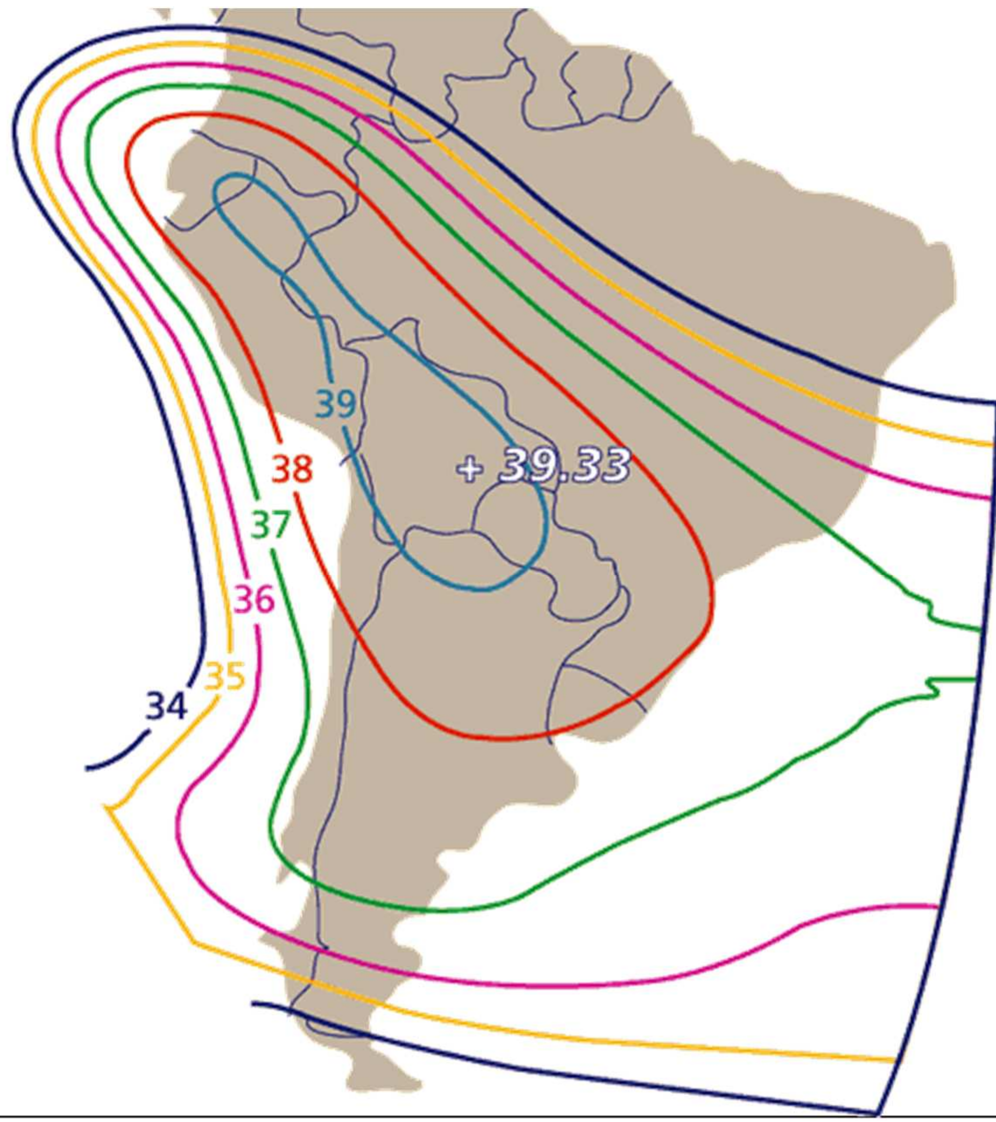
Solidaridad C1 Band



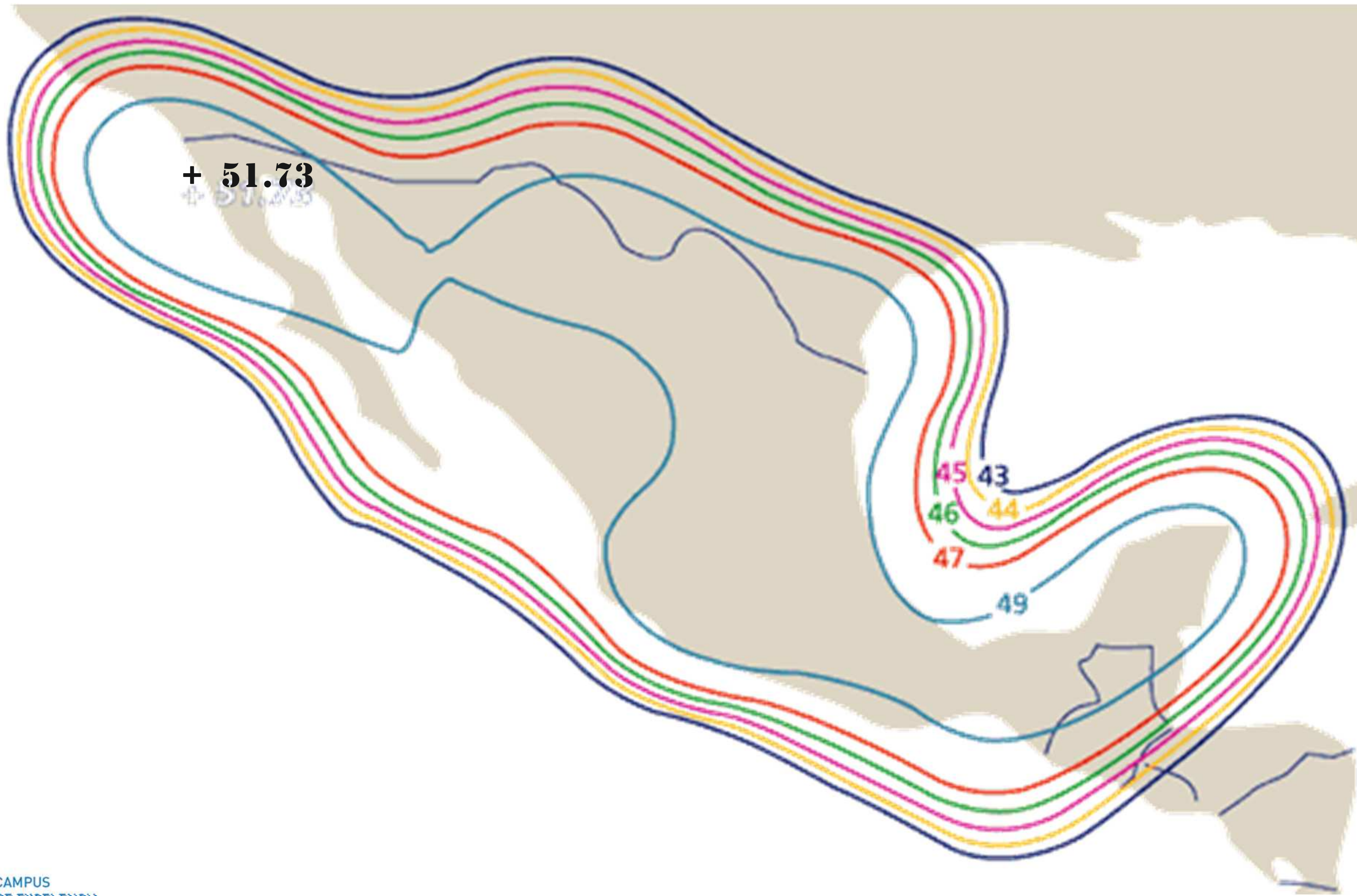
Solidaridad C2 Band



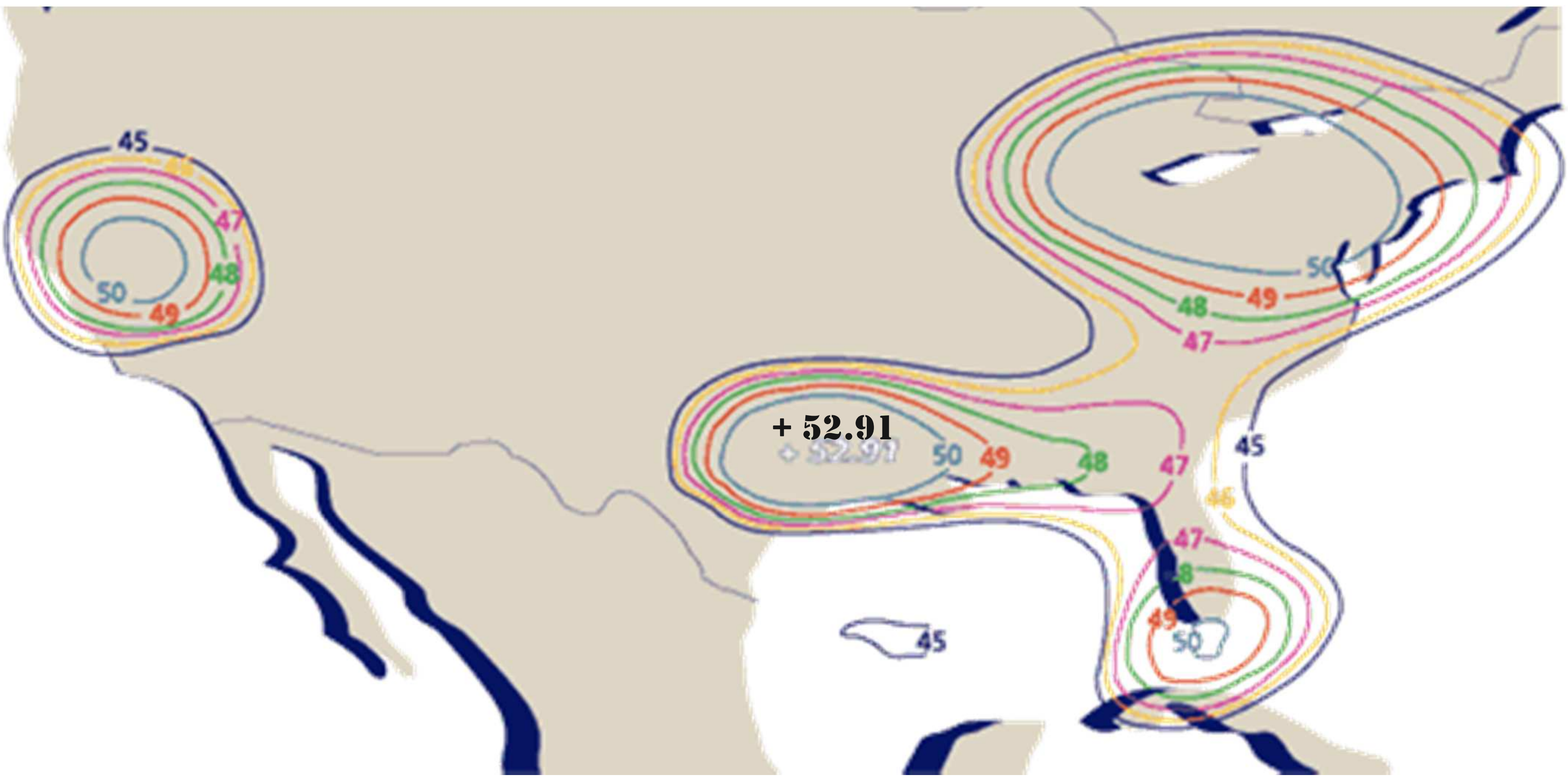
Solidaridad C3 Band



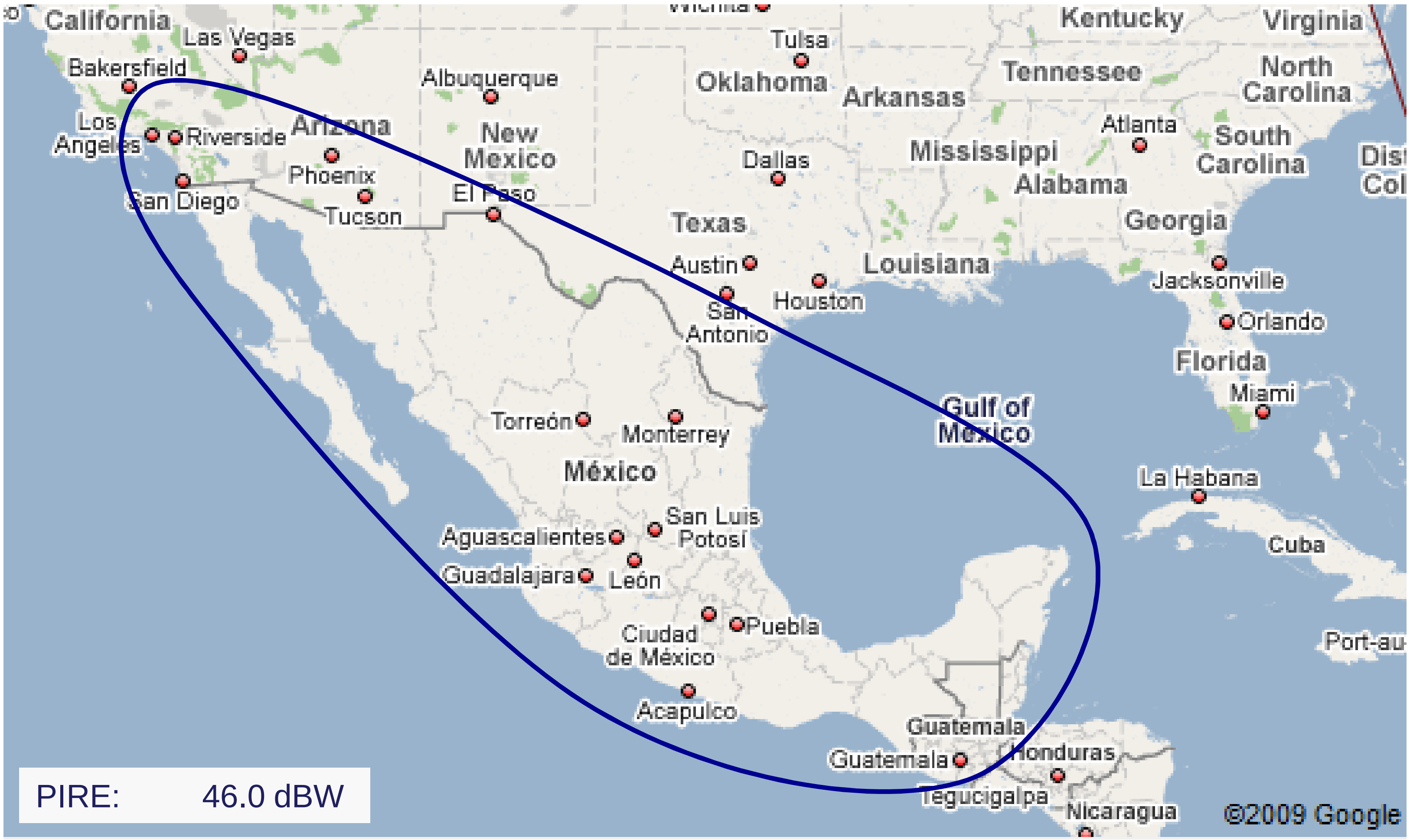
Solidaridad Ku4 Band



Solidaridad Ku5 Band



Solidaridad Satellite
Region 6 (R6) “L” Band



C – Band Repeater

- Coverage:

R1	Mexico, US southern border and Central America northern part.
R2	R1 + Southern Florida, the Caribbean, Central America, Colombia and Venezuela.
R3	Most of the remaining parts of south America with the exception of Brazil.

- Life: 15 years
- EIRP: R1: 37dBw, R2: 36dBw, R3: 36dBw
40dBw
- No. Channels: 18
- Amplifiers: TWT's or SSPA's
14 for 12
8 for 6
- 3 for 2 C Band receivers
- 16 for 12 C Band Channel Control Units
- 8 for 6 C Band Channel Control Units
- 18 Input Multiplexers
- 18 Output Multiplexers

Ku Band Repeater

– Coverage:

R4 Mexico, Los Angeles and San Antonio.

R5 Major United States cities and parts of Canada and Cuba.

– Life: 15 years

– EIRP: R4: 47dBw, R5: 46dBw

– No.Channels: 16

– TWT's: 20 for 16 Ku band

– 5 for 3 Ku band receivers

– 10 for 8 Band channels Control Units

– 10 for 8 Band channels Control Units

– 16 Channel Input Multiplexers

– 16 Channel Output Multiplexers

L band repeater

-Coverage: México and territorial waters

-Life: 15 years

-Number of channels: 7 sub-bands

-PIRE: 45 dBw

-Amplifiers: 6(4 operating, 2 redundant)

-Antennas: Diplexed phased array

Telemetry, Tracking and Command(TTC)

The TTC subsystem shall provide the capabilitiy to monitor and control the spacecraft so that it meets all performance requirements and shall be suitable for controlling the spacecraft during periods of attitude instability for any attitude and attitude rate that is theoretically achievable by the spacecraft.

The TTC system shall not prevent the spacecraft being launched as co-passenger with another spacecraft using C band telemetry and command frequencies at similar signal levels. As a minimum it is requiered to have one TTC channel available in transfer orbit on a full time basis up untill apogee motor fire or until the two spacecraft can be spatially isolated by the TTC earth station antennas

TTC(Cont)

- **Command requirements**

The probability of successfully executing a command shall be at least 99.98% for single entry attemt under all nominal transfer orbit and on-station operating conditions.

The command subsystem shall serve as an uplink receiver for ranging signals.

The command subsystem shall consist of redundant command receivers operating at the same frequency and redundant decoders, all of which shall be active whenever the electrical power bus is supplying power.

The command subsystem shall operate at C band

TTC(Cont)

- **Telemetry requirements**

The telemetry subsystem shall collect and transmit data pertaining to all spacecraft subsystems in quantities, accuracies and at time intervals sufficient to determine spacecraft performances, to identify the necessity to take corrective action and to enable analysis of failures.

The telemetry subsystem shall also provide a downlink capability for ranging system.

The Telemetry system shall comprise, as a minimum, two fully redundant subsystems, each operating at the same frequency.

The Telemetry subsystem shall operate at C band.

TTC(Cont)

Both the command and telemetry subsystems shall interface with the omnidirectional antenna for transfer orbit an on-station backup capability. Both subsystems shall also interface with the high gain communications antenna for normal on-station operations.

The TTC subsystem shall provide a facility to carry out ranging for spacecraft orbit determination operations.

Attitude Subsystem

The tenderer shall provide a full description of the proposed spacecraft attitude determination and control subsystem including analysis of spacecraft dynamic stability and attitude subsystem performance during all operational phases. Any included contingencies and margins(eg, for qualification testing) shall be identified.

The design of all sensors shall minimise the effects of seasonal, thermal, optical, RF and diurnal variations.

The design of the attitude determination of the nominal thrust axis of the apogee motor can be determinated, through appropriate ground processing, to an accuracy of 1.2 degrees, after no more then one half hour of continuous observation, and to an accuracy of 0.5 degrees, after no more than two hours of observation, either continuous or cumulativa

Electrical Subsystem

The electrical subsystem shall generate, store, condition and distribute the electrical power required for all spacecraft loads to fulfill the mission requirements during all mission phases and expected modes of operation. The subsystem shall consist of:

a) Solar arrays as primary power source
b) Batteries for energy storage as secondary power source
c) Power control, conditioning and protection circuits

No single part failure in the power subsystem shall prevent the subsystem from satisfying the load requirements.

No single part or insulation system failure in the spacecraft shall open or short a main electrical power bus.

Electrical Subsystem (Cont.)

TWTAs shall be automatically disconnected from the power bus if an undervoltage condition develops on the power bus. In order to ensure the ability to exercise command control of the spacecraft, the TC&R susystem and all other housekeeping loads, as a minimum, shall continue to meet all performance requirements at a bus voltage 10% less than the TWTA undervoltage conditions, it is required that essential loads are kept operational for as long as practicable, and that non-essential loads ie. loads not needed to re-acquire spacecraft function after a temporary failure are disconnected. After any zero bus voltage condition, the TC&R equipment shall recover automatically in a safe configuration with unimpaired performance.

The tenderer shall provide a full description of the proposed spacecraft power subsystem inlcuding a detailed power budget for the spacecraft , showing actual or apportioned power requirements for each unit subsystem under steady-state and transient conditions and identifying any included contingencies and margins.

Electrical Subsystem (Cont.)

Solar Array

The primary on-board electric power source shall consist of n-on-p silicon solar cells with fused silica (or equivalent) cover slides having adequate ultraviolet filtering. The active area of each solar cell shall be fully covered by either the cover slide or other suitable material to provide radiation protection. The ungrounded ends of the strings shall be isolated from the bus by diodes. Adequate measures shall be taken to allow for the safe dissipation of excess solar array power. Telemetry associated with the solar array shall permit accurate determination of solar array output power to within 1% or better.

At the end of the spacecraft service life, the usable power output of the main array under the worst-case condition in sunligth shall be 5% greater than the maximum load requirement, the tenderer shall assume all transponders to be operational throughout the spacecraft lifetime with 6 narrow band and 3 wideband C band transponders and eight Ku band transponders operating at 2.5 dB output backoff, the L band system operating at the drive levels and all other transponders saturated. In sizing the solar array, array degradation shall be predicted using the space radiation environment specification, and nominal end of life predicted array temperatures.

Electrical Subsystem (Cont.)

The tenderer shall provide a detailed account of all array degradation factors together with a solar array power profile covering the life of spacecraft. These shall include, but are not limited to:

- **Radiation degradation (including detailed calculations and measurement data)**
- **Optical transmission loss**
- **Seasonal declination intensity**
- **Measurement accuracy (standard cell calibration, etc.)**
- **Diode and harness losses**
- **Fabrication and process losses**
- **Temperature effects**
- **Mismatch losses**
- **Thermal cycling losses**

Electrical Subsystem (Cont.)

Batteries

The secondary power source for supplying all power during eclipse and supplementary power prior to arrival on-station shall be either nickel-cadmium or nickel-hydrogen batteries.

The battery system shall comprise at least two batteries, with reconditioning capability, unless the tenderer can demonstrate that alternative battery configurations without reconditioning can meet mission requirements.

Adequate battery capacity shall be available to provide full satellite performance through all eclipses during spacecraft service life.

The tenderer shall demonstrate that the battery subsystem proposed is full compatible with the mission requirements and shall select battery characteristics incluing number of cells, number of battery packs, battery temperature, depth of discharge, charging rates, etc, to ensure that the spacecraft meets specification under worst-case conditionsover the service life. As a guideline, the maximum depth of discharge on NiCd cells should be less than 50% and on NiH2 cells, less than 60%. Higher depths of discharge must be justified.

Electrical Subsystem (Cont.)

The battery subsystem design shall be such that full mission capability over the spacecraft service life is retained with any single cell short circuit or open circuit. If Nickel-Cadmium battery cells are used, the contractor may consider only short circuit cell failure modes in this design, provided he can demonstrate that the battery design and operating procedures preclude open circuit failures.

The battery subsystem shall include a constant current charging system which can adequately recharge the batteries between eclipses. Individual battery reconditioning circuitry shall be provided. Circuitry for automatic end of charge control shall be provided, which preferably shall be based on a selectable set of battery voltage/temperature limits or pressure limits. However, the tenderer should feel free to propose alternative end of charge determination schemes. The spacecraft design shall allow for removaland replacement of batteries whitout affecting the acceptance status of other equipment on the spacecraft.

Telemetry associated with the battery subsystem shall permit accurate determination of battery characteristics and operation (temperature, overall battery voltage, etc.). Individual cell voltage monitoring shall be provided.

Electrical Subsystem (Cont.)

Power Conditioning, Control and Distribution

The power conditioning, control and distribution electronics shall transfer electrical power between the solar array, batteries and all spacecraft loads in manner which is compatible with the electrical inteface of the spacecraft loads, the solar array and the batteries.

The design of all electronic circuits shall be such as to provide appropriate control loop stability margins and adequate thermal and electrical derating under critical conditions. The tenderer shall state the respective stability margins and derating characteristics to be adopted in his spacecraft design.

Protection provisioning shall be included to prevent a failure in a load from permanently degrading the power subsystem performance.

It shall be possible to override by telecommands any automatic changeover or fault isolation provision. Appropriate measures shall be taken to prevent conducted or radiated electromagnetic interference from degrading spacecraft performance.

It shall not be possible to simultaneously disconnect all batteries from the spacecraft power bus.

Propulsion

The propulsion subsystem shall be an integrated, storable bipropellant design to performs orbital insertion, attitude control and station keeping functions by providing the necessary translational impulse and moment in all three axes. The subsystem shall be designed, and the bipropellant supply sized, for an operational liftime equal to or greater than the spacecraft service liftime.

An analysis of the bipropellant requirements of the spacecraft for all phases of the mission shall be performed to demostrate the adequancy of the propellant load provided.

The contractor shall provide details of the performance prediction techniques to predict fuel life and assess remaining fuel on board accounting for pressure, temperature, pressurant solubility, tank expansion and initial conditions.

Thermal

The tenderer shall provide a full description of the spacecraft thermal control subsystem. The spacecraft shall be constructed to maitain all equipment and structure within design temperature ranges under all expected conditions of prelaunch, launch transfer orbit and geostationary orbit environments and operations modes.

For each unit of the spacecraft, the thermal control subsystem shall be designed to provide adequate margins between the temperature extremes expected in flight(based on worst case environmental conditions and operating modes) and the temperature range used for unit level acceptance testing. The worst case temperature extremes shall take into account degradation effects of the thermal control items specially low solar absorptance radiator surfaces and heat pipes

Thermal(Cont)

During qualification and system level protoflight tests, satisfactory performance shall be demonstrated at 10º C above and 10º C below predicted in-orbit temperatures. For acceptance-level tests, the margin shall be 5º C.

Provisions shall be made to obtain sufficient data at adequate sampling rates for monitoring the thermal control subsystem performance, temperatures of spacecraft units, heater operation, and for performing failure analysis if nedded. Temperature sensors shall be designed to provide adequate resolutions in the desired ranges, which shall be approved by the operator

Structural

The spacecraft structure shall provide the mechanical support for other subsystems in a configuration meeting the system requirements of thermal control, mass properties, alignment, launch vehicle interface, and assembly, integration and test. The design shall be based on an envelope of the environments, safety and fracture mechanics requirements specified by the selected launch vehicle contractors.

The structure shall be capable of sustaining all direct and cumulative load combinations occuring during qualification testing, spacecraft environmental exposure testing, ground handling, launch, and orbital manoeuvres(including apogee and perigee motor firing) without exceeding the limit of elactic deformations.

Structural(Cont)

In final orbit, the structure shall have, and maintain throughout the spacecraft service life, the necessary dimensional relationship to satisfy all mision requirements, including, for spin-stabilised spacecraft, the ability to survive, without exceeding the ultimate desigan loads, a flat spin and the subsequent recovery actions.

A safety factor of 1.5 times limit loads shall be used to determine ultimate design loads for structure not classed as pressure vessels

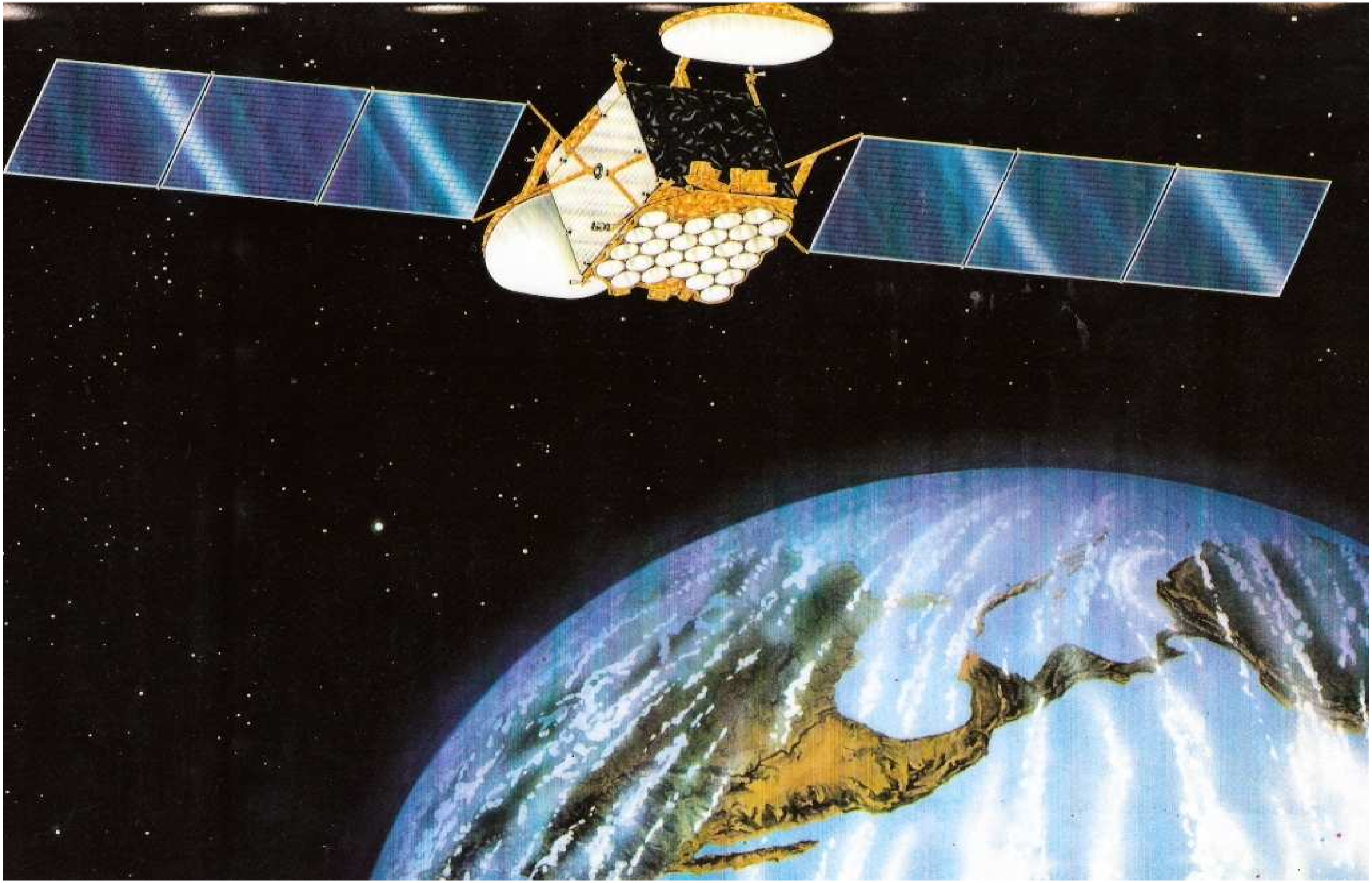
Launch

The spacecraft shall be technically compatible with at least three different launch systems as usable alternatives for launching the Solidaridad satellite

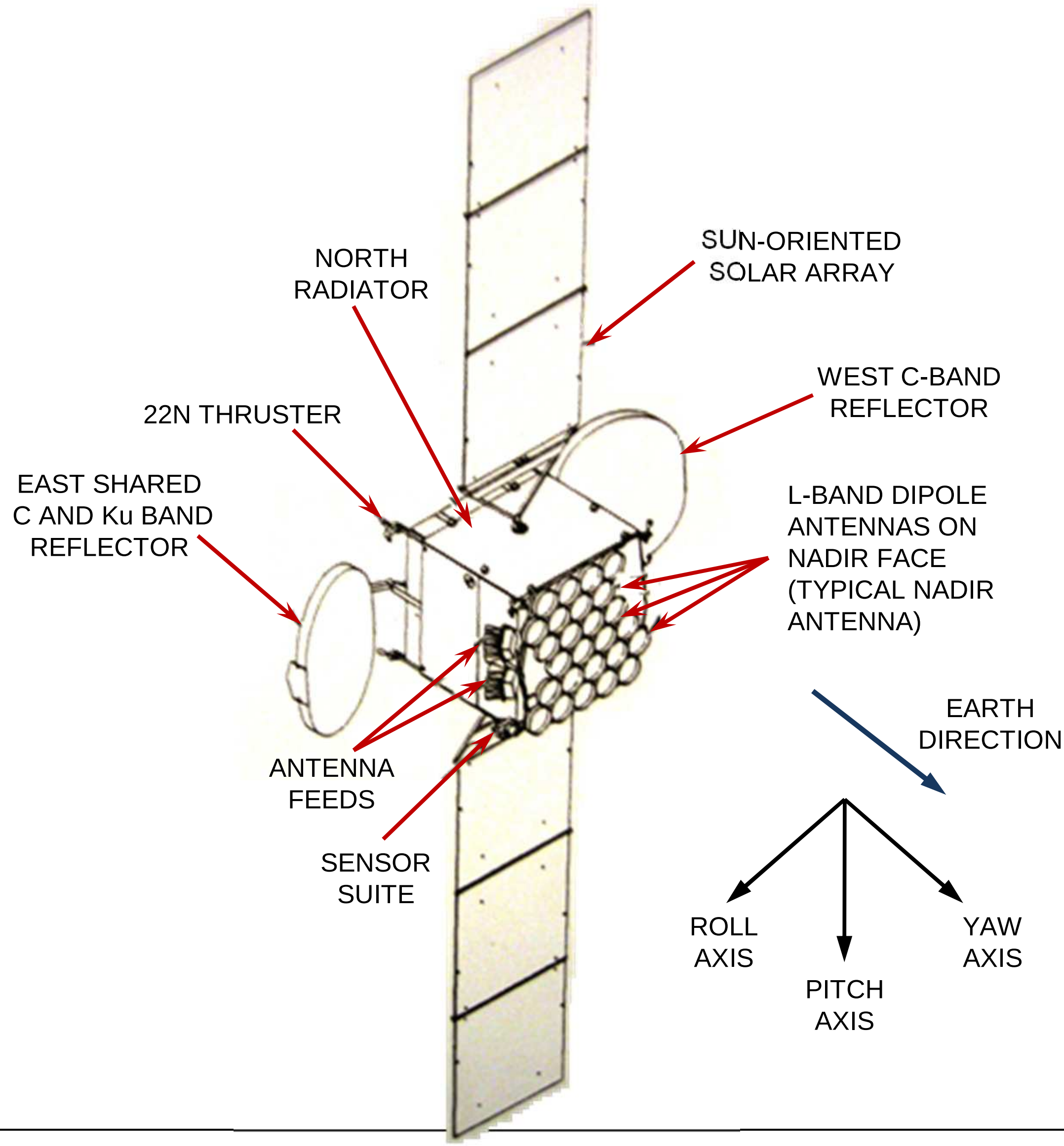
Master in Space and Satellite Technology

Topic 3: Payload solution

Solidaridad Satellite



Spacecraft coordinate system definition



Communication Subsystem

C – band

System		
	Frequency range	5.925 to 6.425 GHz receive
		3.7 to 4.2 GHz transmit
Coverage		R1: Mexico and southwest U.S.
		R2: Mexico plus Central America, excluding Brazil
Channel bandwith		36 and 72 MHz
No. of channels		6 x 72 MHz (R1 only) and 12 x 36 MHz (4 for R1 only; 8 individually switchable to receive from R1, R2 or R3; can each transmit to R1 or R2; 4 can each transmit to R1 or R3)
Performance		
	Min EIRP	72 MHz: 40 dBW 36 MHz: 37 dBW
	Min G/T	72 MHz: 2.5 dB/K 36 Mhz: R1 =2.0, R2=-0.5 and R3=1.0 dB/K
Antenna		Dual aperture
	Size	1.83 x 2.44 m (72 x 96 in.)
	Focal legth	2.03 m (80 in.)
	Polarization	Linear (vertical and horizontal)

Communication Subsystem (Cont.)

Receive	
LNA/receiver	HEMT LNA
Redundancy	3-for-2
Saturation flux density	72 MHz: -75 to -89 dBW/m^2 36 MHz: -78 to -92 dBW/m^2
Transmit section	
No. of SSPAs	72 MHz: 8, 36 MHz: 16
SSPA power level	72 MHz: 14.4 W 36MHz: 10.3/16.0 W switchable
Channel multiplexing	72 MHz: contiguous, 36 MHz: noncontiguous
Ku – band	
System	
Frecuency range	14.0 to 14.5 GHz receive 11.7 to 12.2 GHz transmit 11.701 ULPC transmit
Coverage	R4: Mexico and southwest U.S.
	R5: selected U.S. cities
Channel bandwith	54 MHz
No. of channels	16, with 2 receive and 1 transmit switchable to R5

Communication Subsystem (Cont.)

Performance	
Min EIRP	R4: 47.0 dBW R5: 46.4 dBW, ULPC:7 dBW
Min G/T	R4: (100% coverage): 2.2 dB/K R4: (98% coverage) and R5 2.5 dB/K
Antenna	Dual aperture
Size	1.83 x 2.44 m (72 x 96 in.)
Focal legth	2.03 m (80 in.)
Polarization	Linear (vertical and horizontal)
Receive	
LNA/receiver	HEMT LNA
Redundancy	5-for-3
Noise figure	<2.0 dB
Saturation flux density	-73 to -95 dBW/m^2
Transmit section	
No. of TWTAs	20
TWTA power level	45 W
Channel multiplexing	Contiguous

Communication Subsystem (Cont.)

L – band

System	
Frecuency range	
Forward	14.248 to 14.265 GHz receive 1.528 to 1.559 GHz transmit
Return	1.6295 to 1.6605 GHz receive 11.9515 to 11.9685 GHz transmit
L-band Coverage	Mexico and territorial waters
Channel bandwith	31 MHz
No. of channels	7 sub-bands
Performance of L-band	
Fordward EIRP	45 dBW (100% coverage)
Return G/T	-1,5 dB/K (100% coverage)
Antenna	
Type	Diplexed phased array
Elements	26 short backfire parabolic cups
Polarization	Right-hand circular polarization

Communication Subsystem (Cont.)

Receive	
LNA	HEMT with 1.2 dB noise figure
Redundancy	2-for-1
Noise figure	<2.0 dB
Saturation flux density	-123 dBW/m^2 total
Transmit section	
No. of SSPAs	6 (4 operating, 2 redundant)
SSPA power level	24 W

Payload Power, Watts

Unit	Qty	Unit power	Power	Comments
C – band				Efficiency 38.64%
Low noise amplifier	2	0.7	1.4	
Downconverter	2	7	14.0	
Receiver	2	7	14.0	
Channel control unit	18	1.3	23.4	
SSPA	18	P RF:	602.5	
	4	16.0		
	6	14.4		
	8	10.3		
Subtotal			655.3	
Ku – band				EPC Efficiency 91.4%
Low noise amplifier	3	0.9	2.7	TWT efficiency 55.6%
Downconverter	3	6.0	18.0	
ULPC beacon	1	5.5	5.5	
Channel control unit	16	1.0	30.4	
Linearizer	3	1.5	4.5	
TWTA - FSS	15.45	42.6	1295.1	Eclipse at 49.85 Sunlight unit power at 50.4 V=1309.4
Subtotal			1356.2	

Payload Power, Watts (Cont.)

Unit	Qty	Unit power	Power	Comments
L – band				Efficiency 24.1%
Ku/IF	1	5.3	5.3	
IF/L	2	10.5	21.0	
Low noise amplifier	1	1.7	1.7	
L/IF	2	7.8	15.6	
IF/Ku	1	5.2	5.2	
Reg generator	1	13.5	13.5	
SSPA	4	21.6	358.5	
Subtotal			420.8	
Total				
Eclipse			2432.3	
Sunlight			2442.4	

Solidaridad Satellite Regions conectivity

Up link	Band	Down link	Band	Transponder
R1	C	R1	C	1N – 12N 1W – 6W
R2	C	R2 R3	C C	6N, 8N, 10N, 12N 11N (UL), 12N (DL)
R3	C	R3 R2	C C	5N, 7N, 9N, 11N 11N (DL), 12N (UL)
R4	Ku	R4 R5 R6	Ku Ku L	1K – 16K 6K 5K – LP (UL-Ku), 5K (DL-L)
R5	Ku	R5 R4	Ku Ku	6K 6K (UL), 8K (DL)
R6	L	R4	Ku	5K – LP (UL-L), 5K (DL-Ku)

LP: Low part

* Band L is used for mobil terminals-satellite links.
Ku band is used for Hub-Satellite links

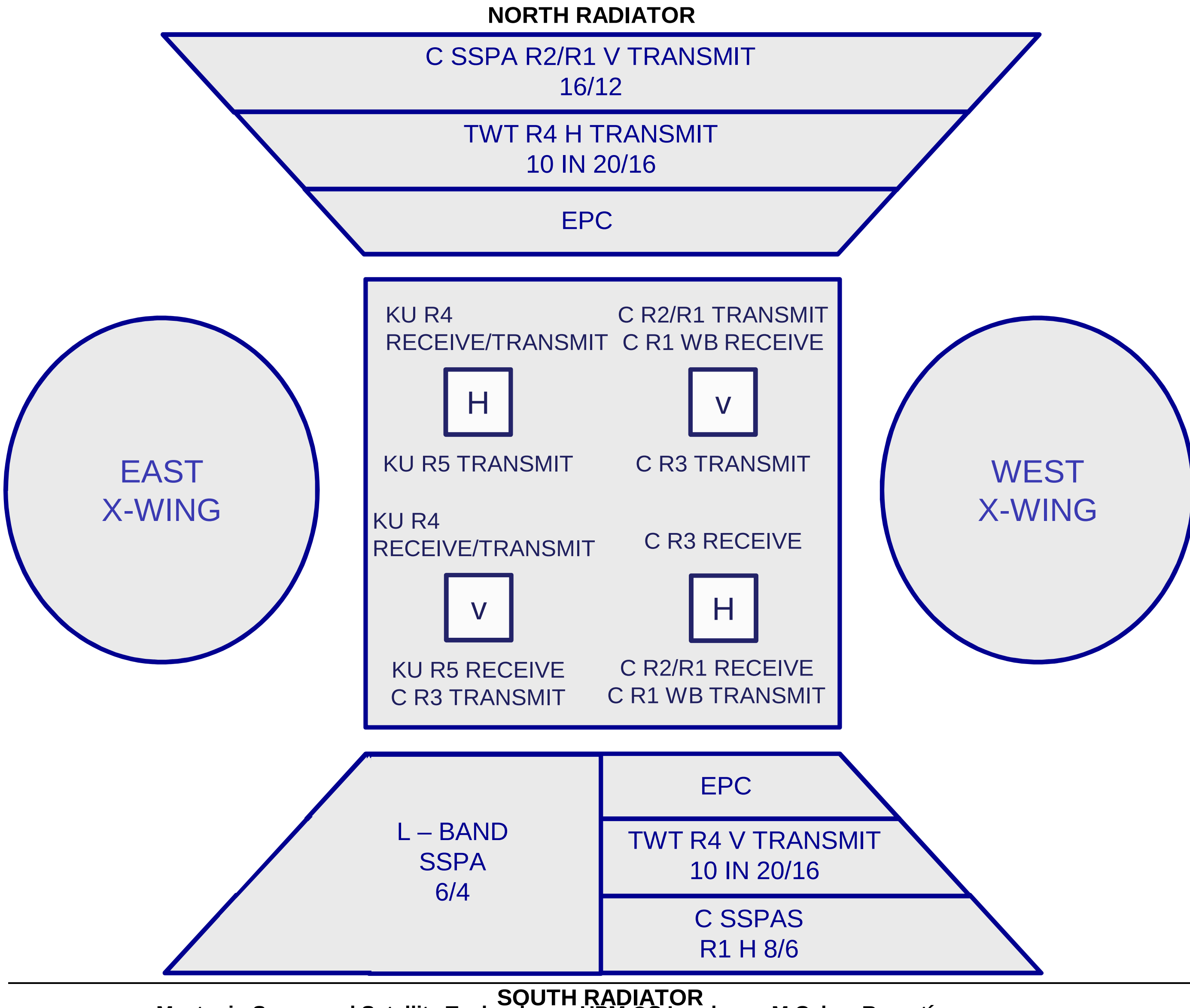
Solidaridad Satellites Transponders Characteristics

Band	Transponders	BW (MHz)	Coverage (Region)	Polarization		
				Uplink	Downlink	Transponder
C	12 6	36 72	R1, R2, R3 R1	Horizontal Vertical	Vertical Horizontal	All All
Ku	16	54	R4, R5	Vertical Horizontal	Horizontal Vertical	1K – 8K 9K – 16K
L*	1	15	R6	Vertical (Ku) Right Circular	Right Circular Horizontal (Ku)	5K 5K

BW = Bandwith

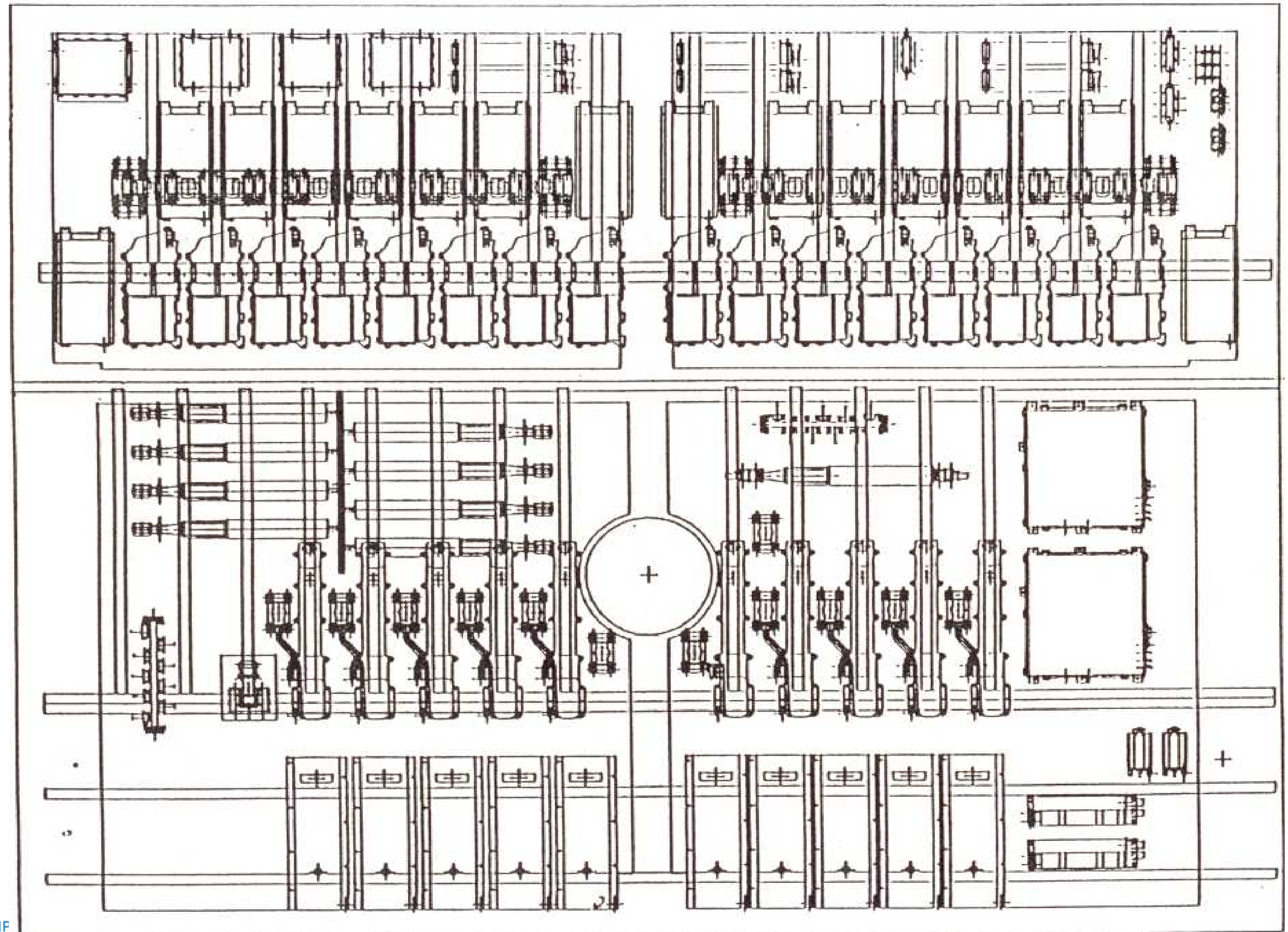
* For L band traffic, transponder 5K (low part) is used

Solidaridad Satellite Layout

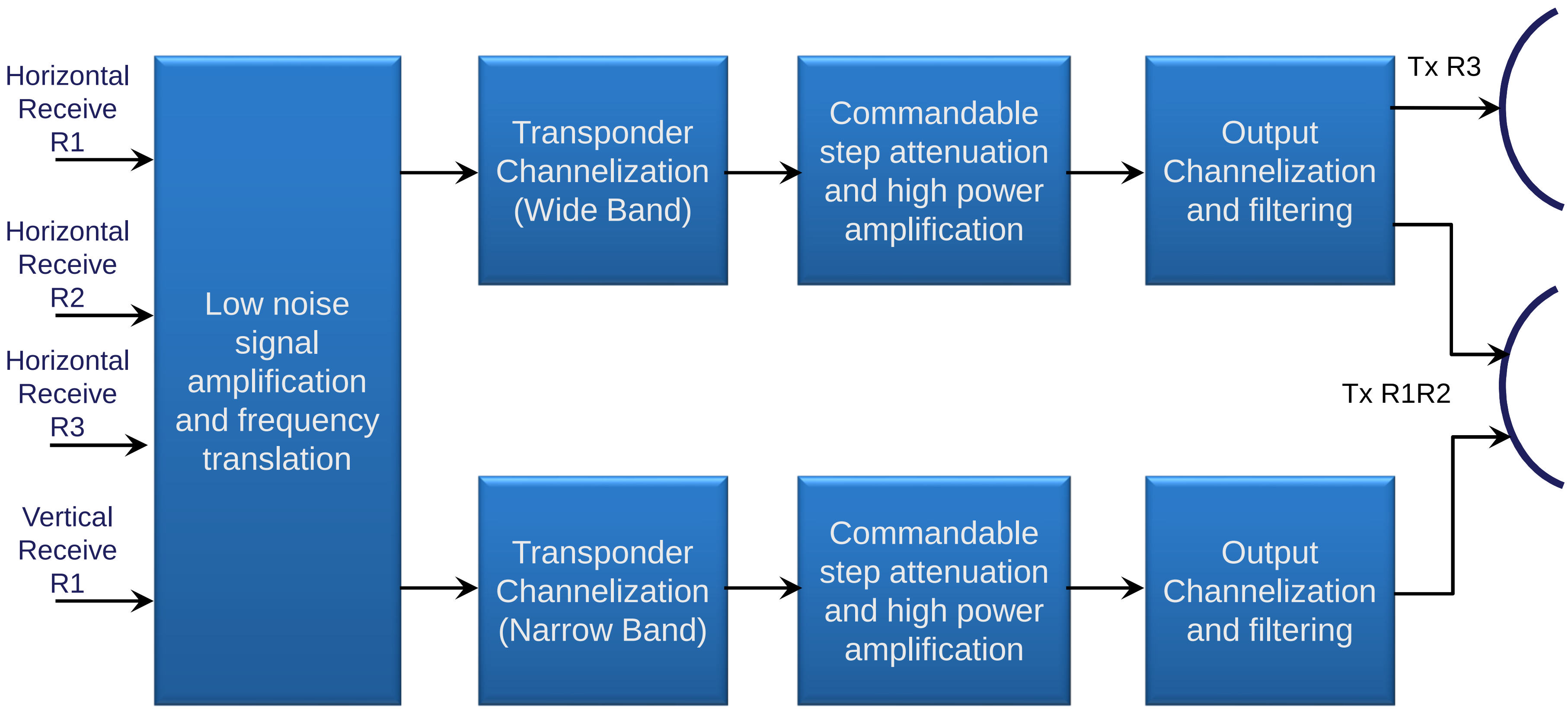


Solidaridad Repeater Layout

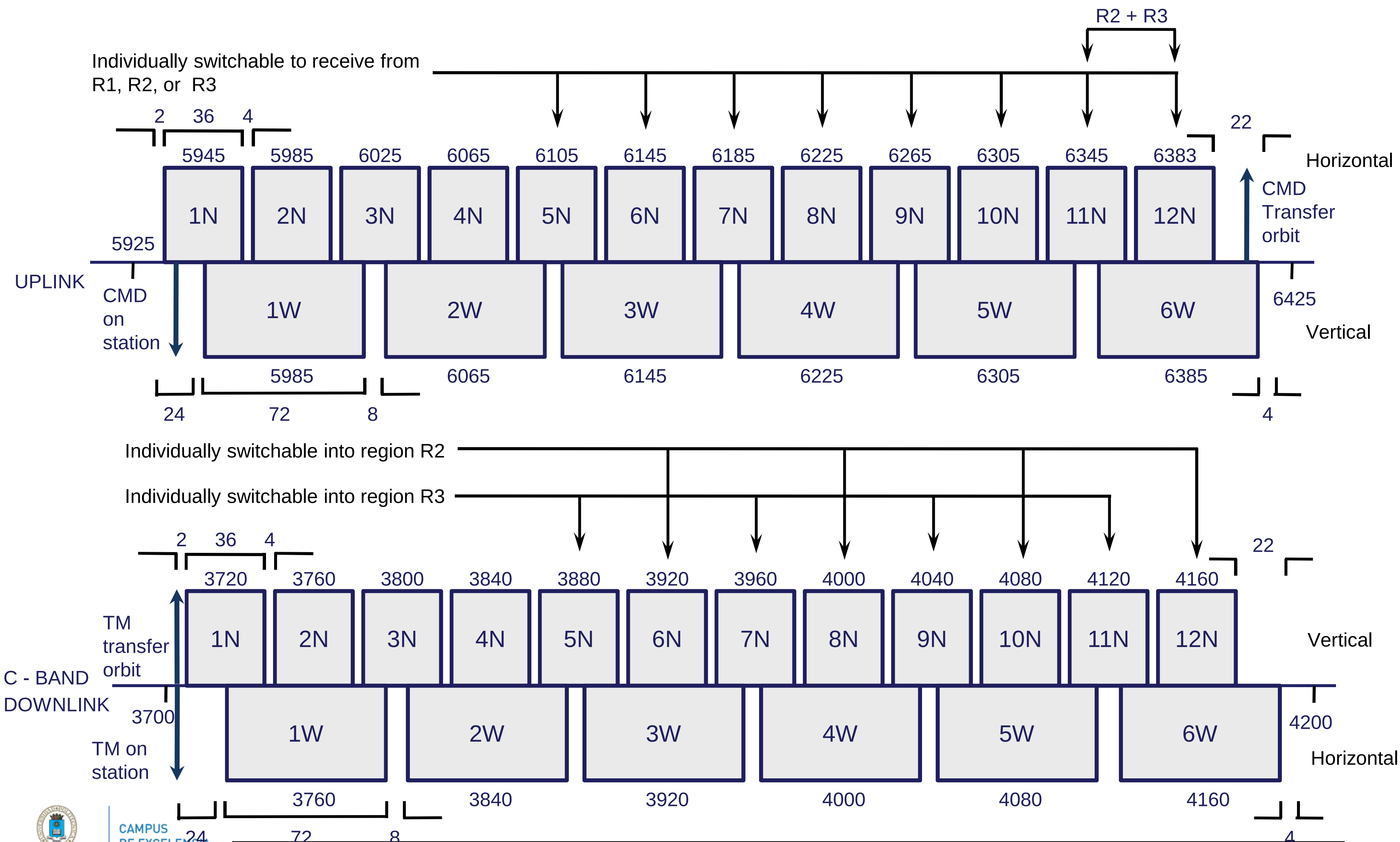
North Panel



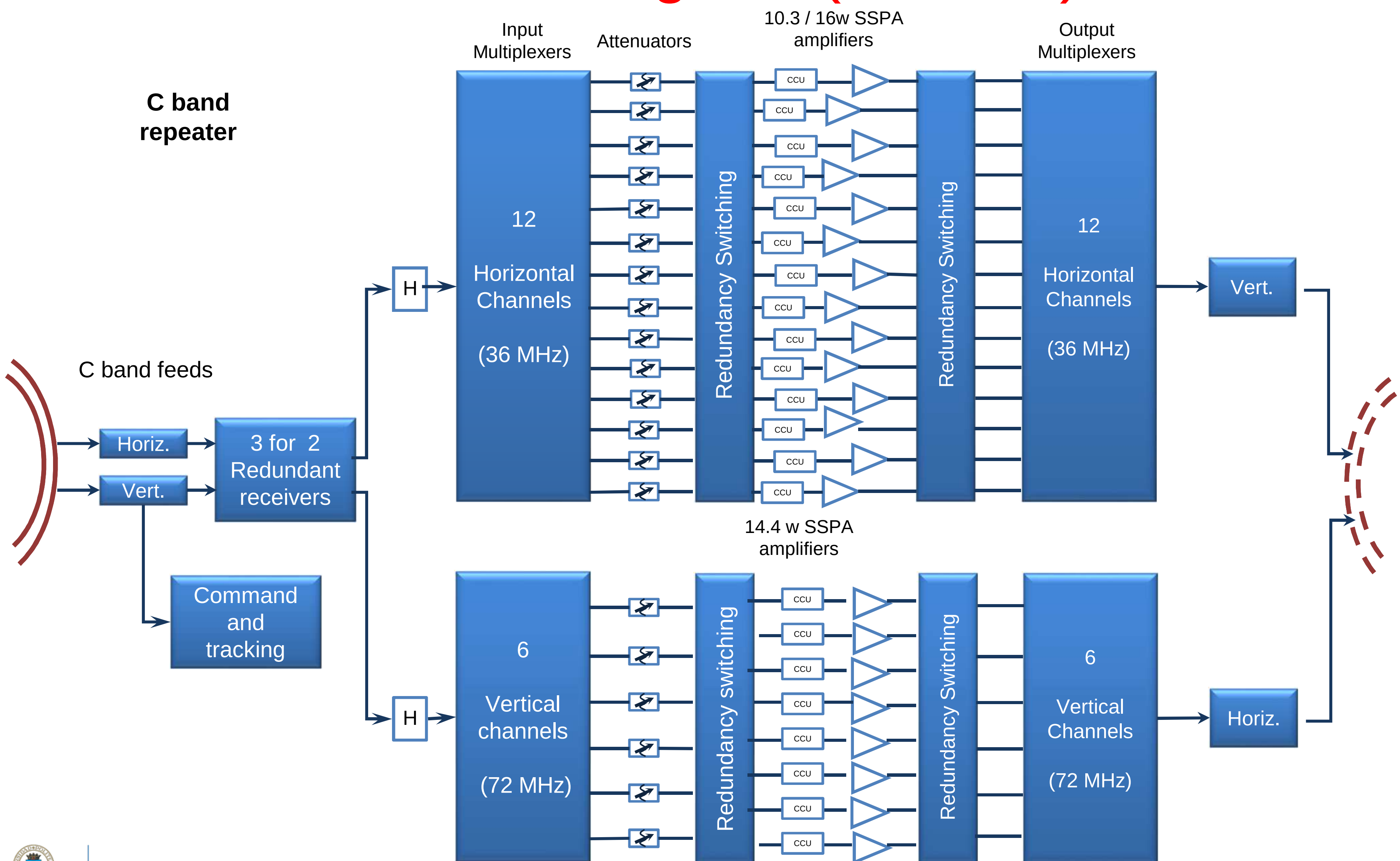
C – Band Block Diagram



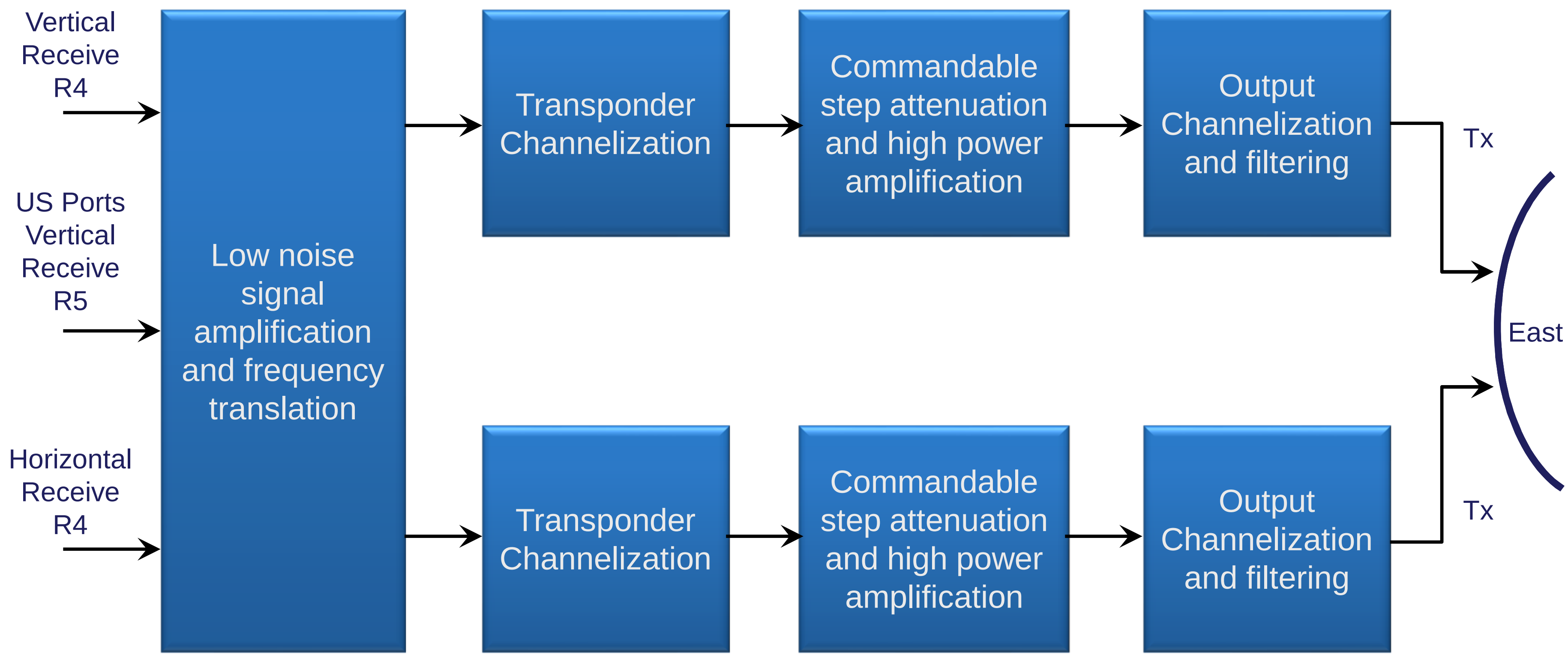
C-Band Frequency Plan



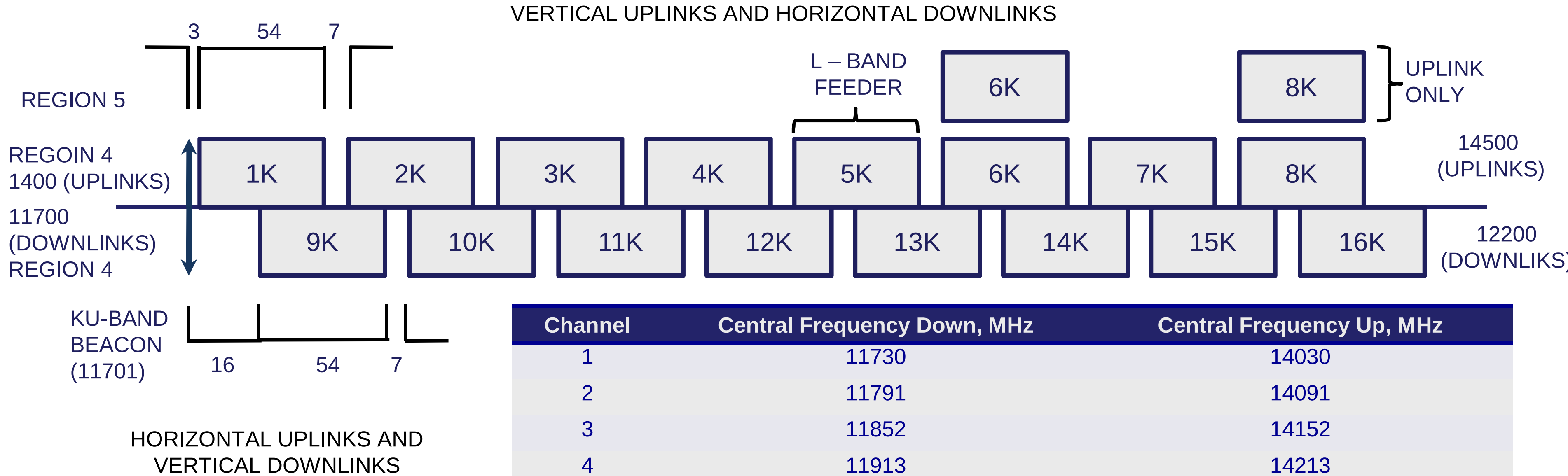
Communication subsystem functional diagram (C Band)



Ku – Band Block Diagram

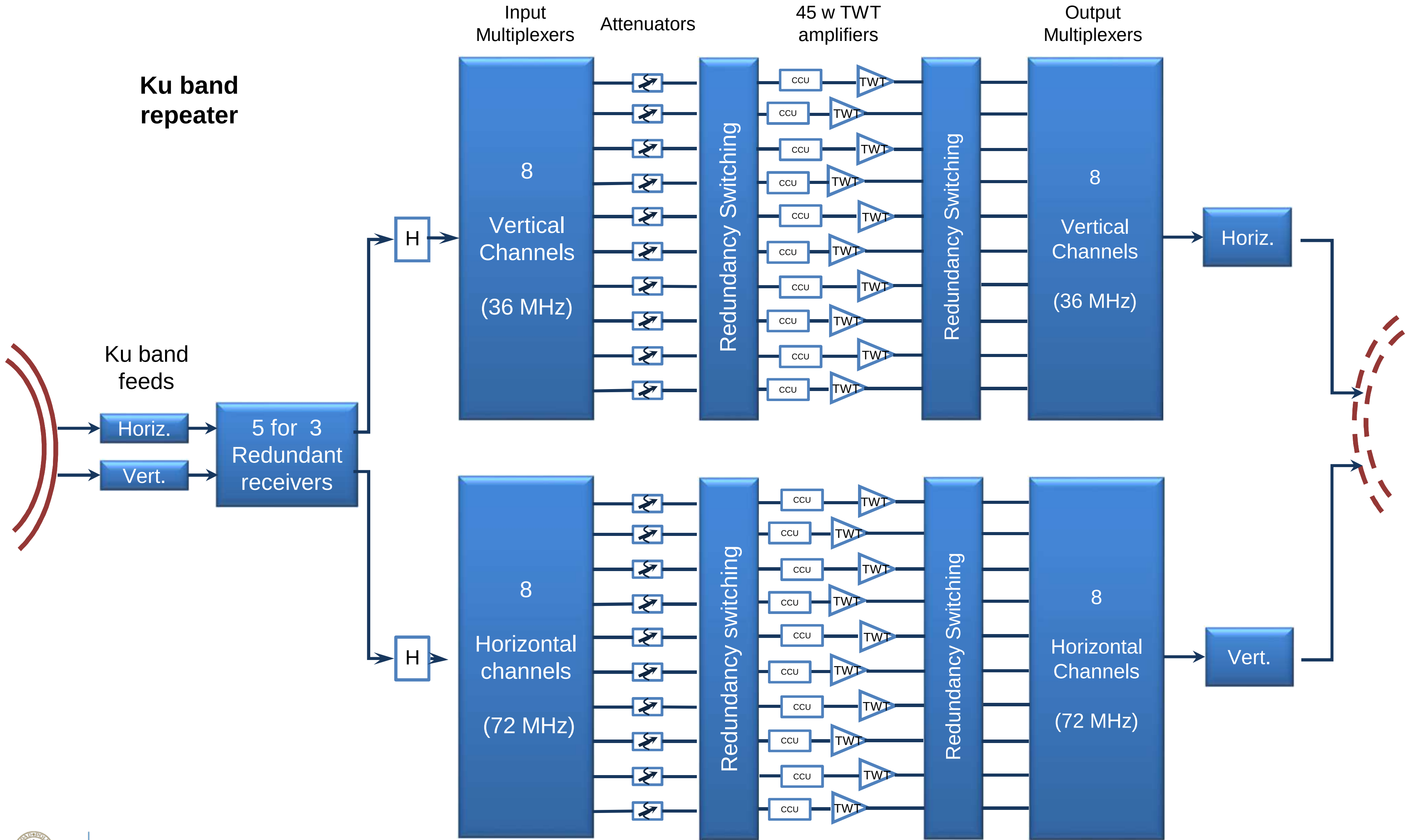


Ku – Band Frequency Plan

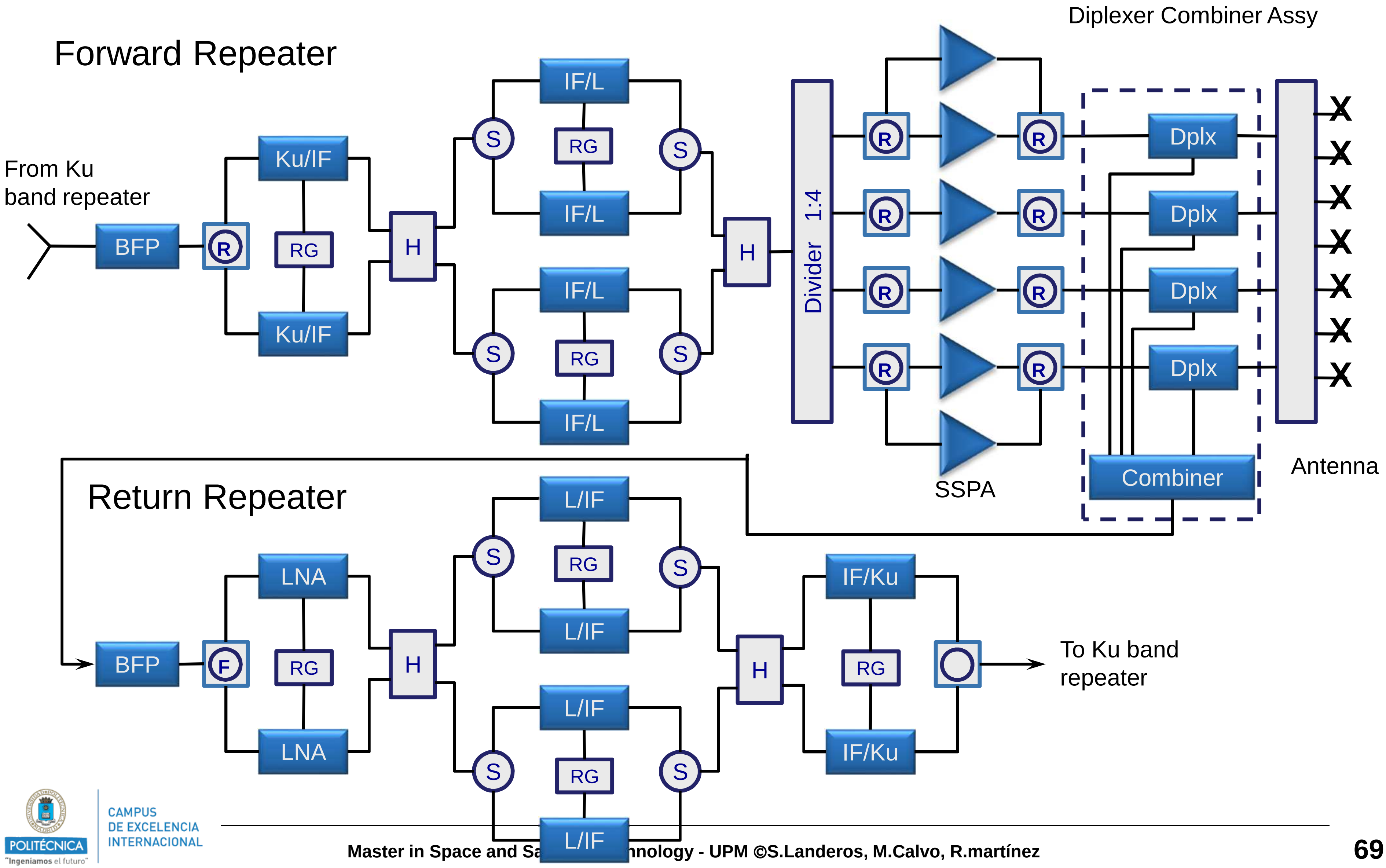


Channel	Central Frequency Down, MHz	Central Frequency Up, MHz
1	11730	14030
2	11791	14091
3	11852	14152
4	11913	14213
5	11974	14274
6	12035	14335
7	12096	14396
8	12157	14457
9	11743	14043
10	11804	14104
11	11865	14165
12	11926	14226
13	11987	14287
14	12048	14348
15	12109	14409
16	12170	14470

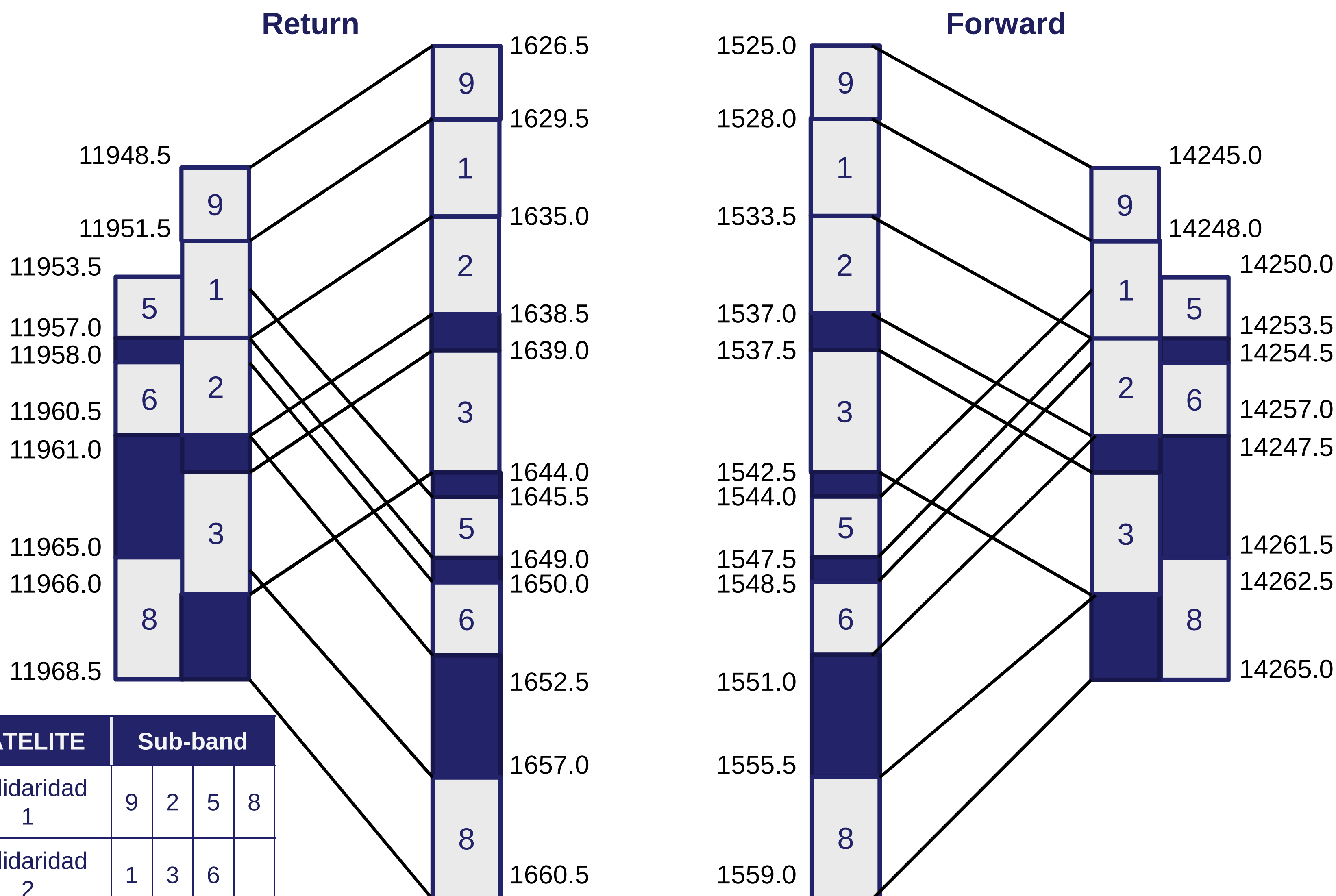
Communication subsystem functional diagram (Ku Band)



L-band repeater block diagram



Frequency bands, L band

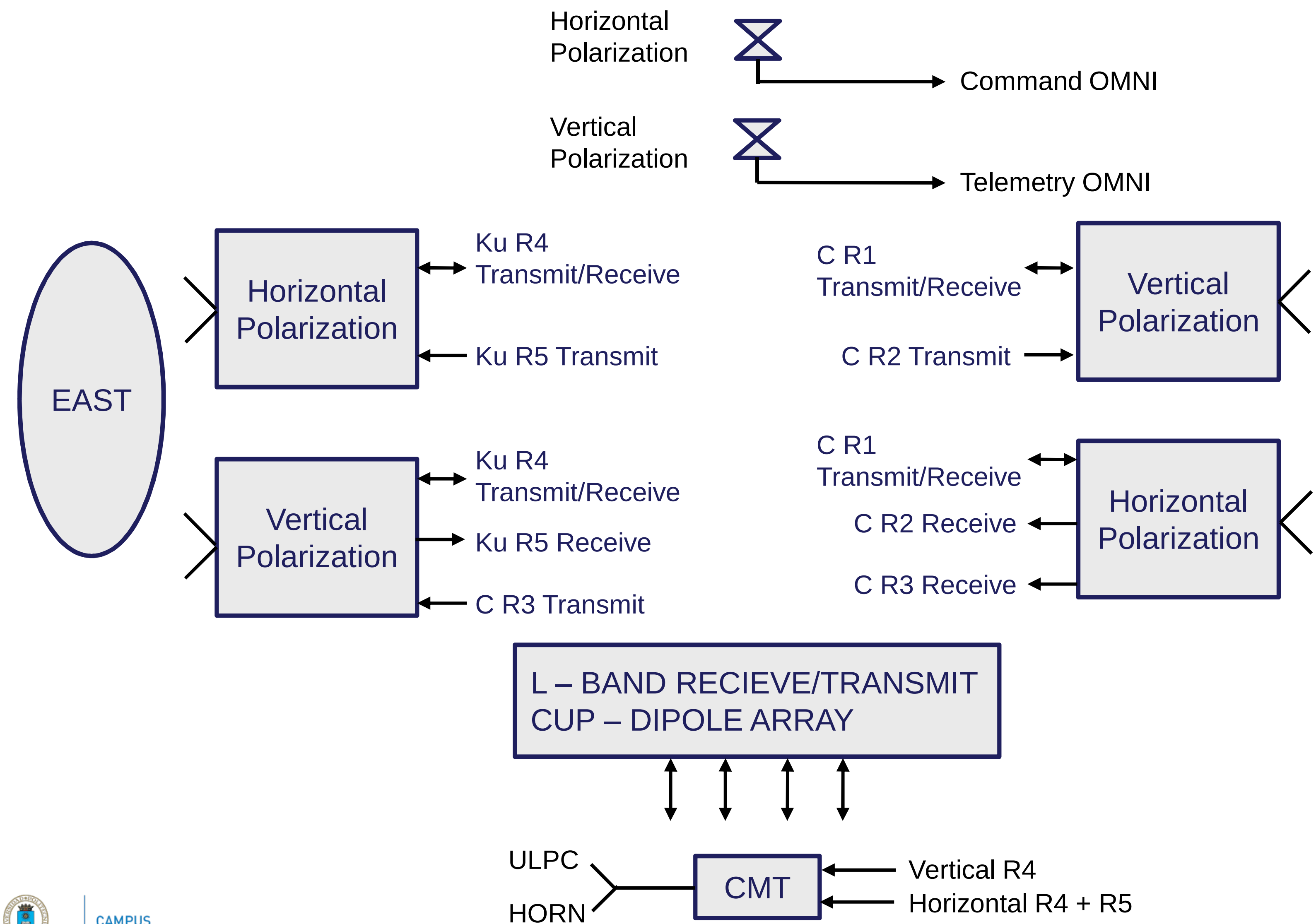


SATELITE	Sub-band			
Solidaridad 1	9	2	5	8
Solidaridad 2	1	3	6	

POLARIZATION

Region 1	**Tx Vertical** **Rx Horizontal**	**Tx Horizontal** **Rx Vertical**
Region 2	**Tx Vertical** **Rx Horizontal**	
Region 3	**Tx Vertical** **Rx Horizontal**	
Region 4	**Tx Vertical** **Rx Vertical**	**Tx Horizontal** **Rx Horizontal**
Region 5	**Tx Vertical** **Rx Horizontal**	
Region 6	**Tx L – Band** **Rx L – Band** **Circular**	

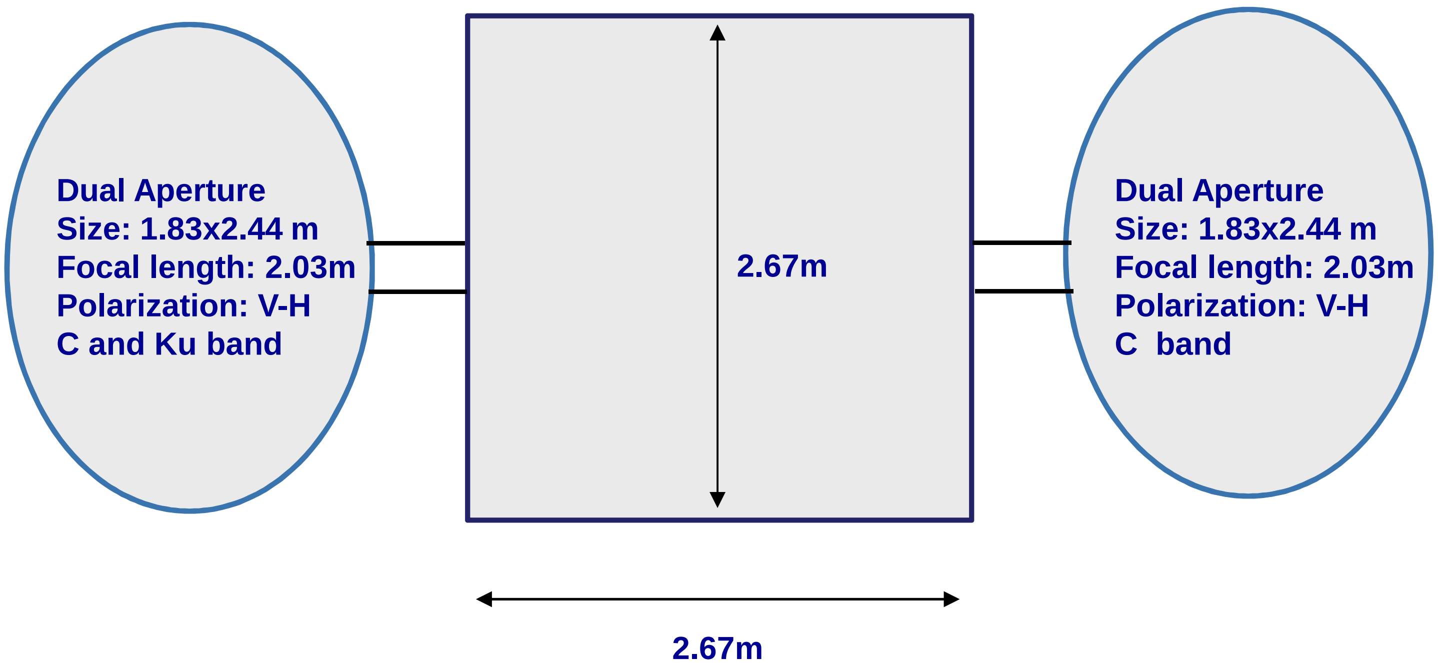
Antenna System Functional Diagram



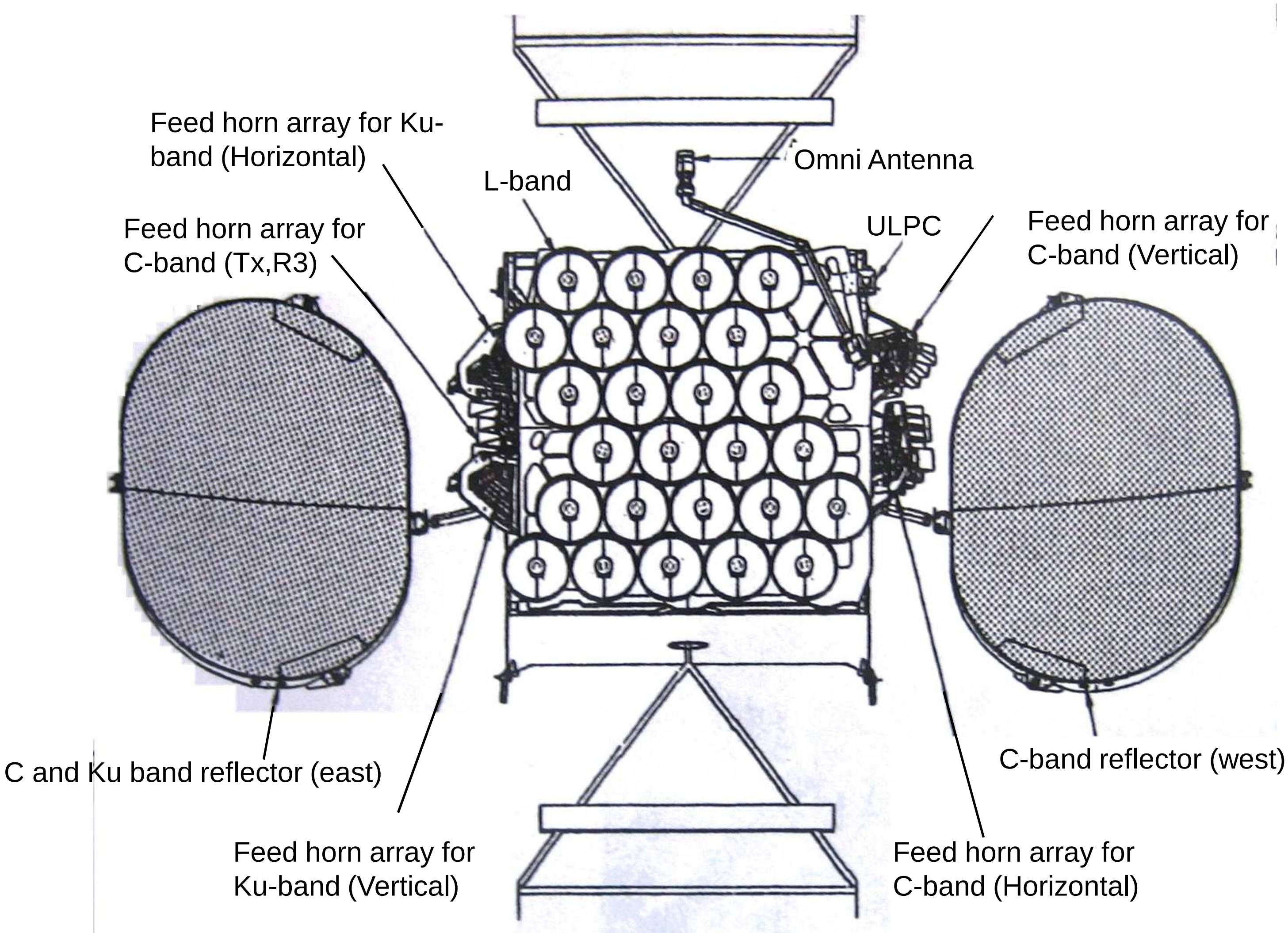
Key Design Features

Features	*Benefit*
Large X-wing reflectors (C-band and Ku-band)	High gain, compact stowage, simple deployment, shared aperture, and feed array separation
Gridded apertures	Excellent polarization purity
Reflector sunshield	Reduced temperature gradients
Single mode transmit feed networks	Lightweight and low loss
Diplexed transmit /receive	Feed horn reuse and lower weight
Squareax feed network	Light, rigid, low loss, accurate, and stable
Planar waveguide feed network	Rigid, lightweight, and low loss
Cup dipole feeds for L-band array	Excellent performance, design heritage, and low PIM

Antennas

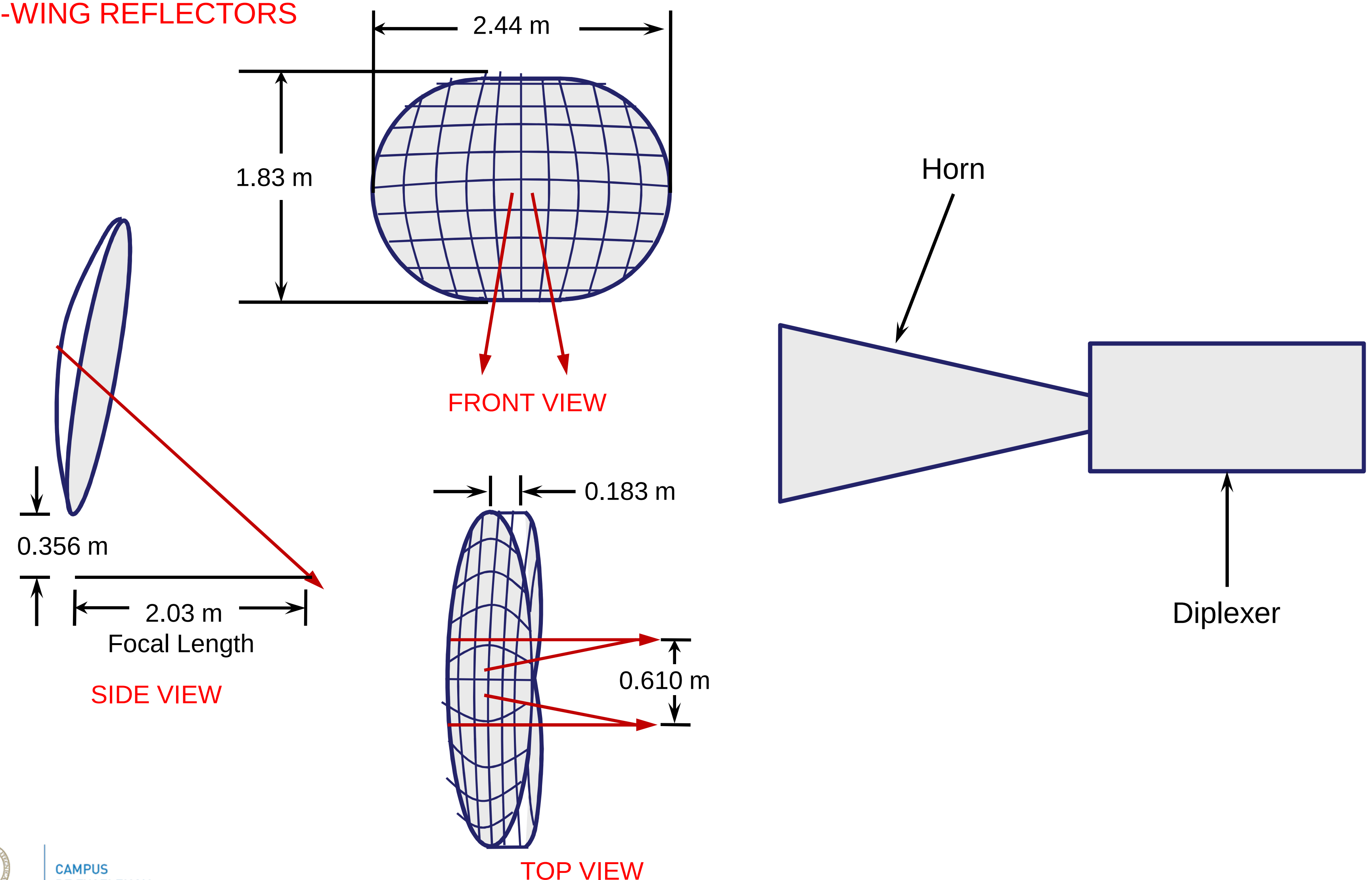

Dual Aperture
Size: 1.83x2.44 m
Focal length: 2.03m
Polarization: V-H
C and Ku band
2.67m
Dual Aperture
Size: 1.83x2.44 m
Focal length: 2.03m
Polarization: V-H
C band
2.67m

Antennas Configuration



Antennas (Cont.)

X-WING REFLECTORS



Feed Network Losses

Frequency	Region Coverage	Beam	Loss, dB
C – band	R1	Horizontal transmit	0.40
	R1	Vertical transmit	0.50
	R2	Vertical transmit	0.50
	R3	Vertical transmit	0.40
	R1	Vertical receive	0.75
	R1	Horizontal receive	0.75
	R2	Horizontal receive	0.75
	R3	Horizontal receive	0.45
Ku – band	R4	Horizontal transmit	0.40
	R4	Vertical transmit	0.40
	R5	Horizontal transmit	0.40
	R4	Horizontal receive	0.70
	R4	Vertical receive	0.70
	R5	Vertical receive	0.70
L – band	R6	RHCP transmit	0.40
	R6	RHCP receive	0.40

NOTE: Does not include waveguide loss from BFN to repeater interface

C – Band Vertical Array Location and Dimension

WEST REFLECTOR

Horn No.	Principal Plane Dimension, cm		Location, cm	
	E	H	X	Y
1	5.23	22.76	-5.97	6.86
2	5.49	22.25	-0.51	-0.13
3	4.98	7.01	4.83	-12.70
4	5.99	9.04	5.33	-4.57
5	7.52	6.25	-1.52	-14.48
6	7.01	6.76	3.81	-21.08
7	4.98	20.32	9.91	-19.81
8	5.99	17.27	15.49	-19.81

EAST REFLECTOR

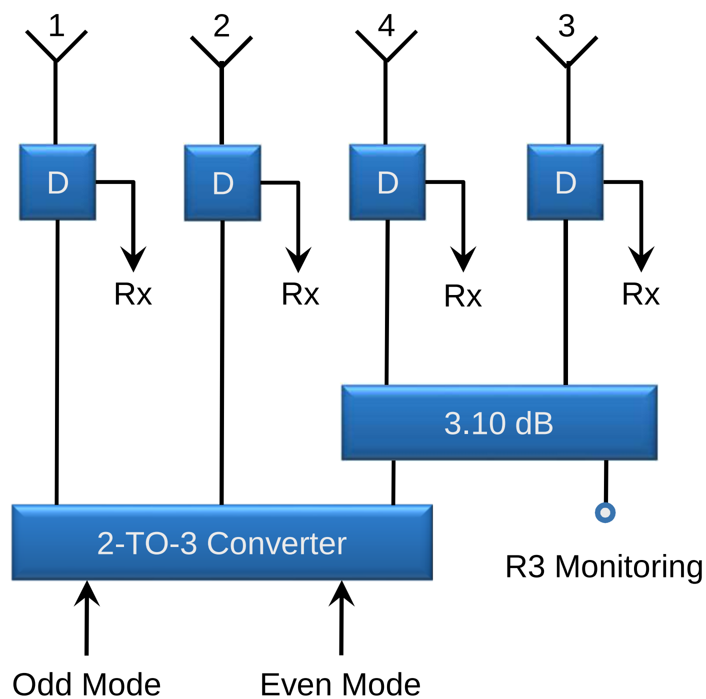
Horn No.	Principal Plane Dimension, cm		Location, cm	
	E	H	X	Y
8	13.68	20.32	15.88	-15.88
9	8.79	19.30	25.27	-18.92
10	8.79	20.32	34.16	-19.94
11	8.79	18.80	43.05	-11.81

Region R1

VERTICAL TRANSMIT HORN EXCITATIONS

No.	Relative Power		Location, cm	
	Even	Odd	Even	Odd
1	0.333	0.333	0	0
2	0.333	0.333	60	-60
3	0.163	0.163	120	-120
4	0.170	0.170	120	-120

VERTICAL TRANSMIT NETWORK



NETWORK SCHEMATIC

Region 1 Vertical Transmit Directivities

City	Directivity (109.2°)	Directivity (113°)	Expected EIRP, dBW (109.2°)	Expected EIRP, dBW (113°)
a) Channels 1 to 4				
Puebla, Pue.	31.80	31.83	40.0	40.0
San Luis Potosi	31.85	31.87	40.1	40.1
Toluca	31.55	31.60	39.8	39.8
Leon	31.60	31.65	39.8	39.9
Mexicalli	31.00	30.94	39.2	39.1
Aguascalientes	31.59	31.63	39.8	39.8
Coatzacoalcos	32.03	32.01	40.2	40.2
Tampico	31.90	31.90	40.1	40.1
Torreón	31.94	31.93	40.1	40.1
Chihuahua	32.21	32.21	40.4	40.4
Campeche	31.40	31.43	39.6	39.6
Oaxaca	31.43	31.45	39.6	39.7
Los Angeles	29.54	29.41	37.7	37.6

Region 1 Vertical Transmit Directivities (Cont.)

City	Directivity (109.2º)	Directivity (113º)	Expected EIRP, dBW (109.2º)	Expected EIRP, dBW (113º)
a) Channels 1 to 4				
San Antonio	29.62	29.72	37.8	37.9
Tijuana	30.34	30.28	38.5	38.5
Monterrey	31.47	31.47	39.7	39.7
Mexico	31.73	31.76	39.9	40.0
Guadalajara	30.99	31.08	39.2	39.3
Veracruz	32.11	32.11	40.3	40.3
Acapulco	30.35	30.46	38.6	38.7
Hermosillo	32.08	32.09	40.3	40.3
Ciudad Juarez	31.78	31.81	40.0	40.0
Matamoros	30.70	30.74	38.9	38.9
Merida	30.77	30.83	39.0	39.0
Cancul	29.38	29.58	37.6	37.8
Chetumal	30.82	30.86	39.0	39.1

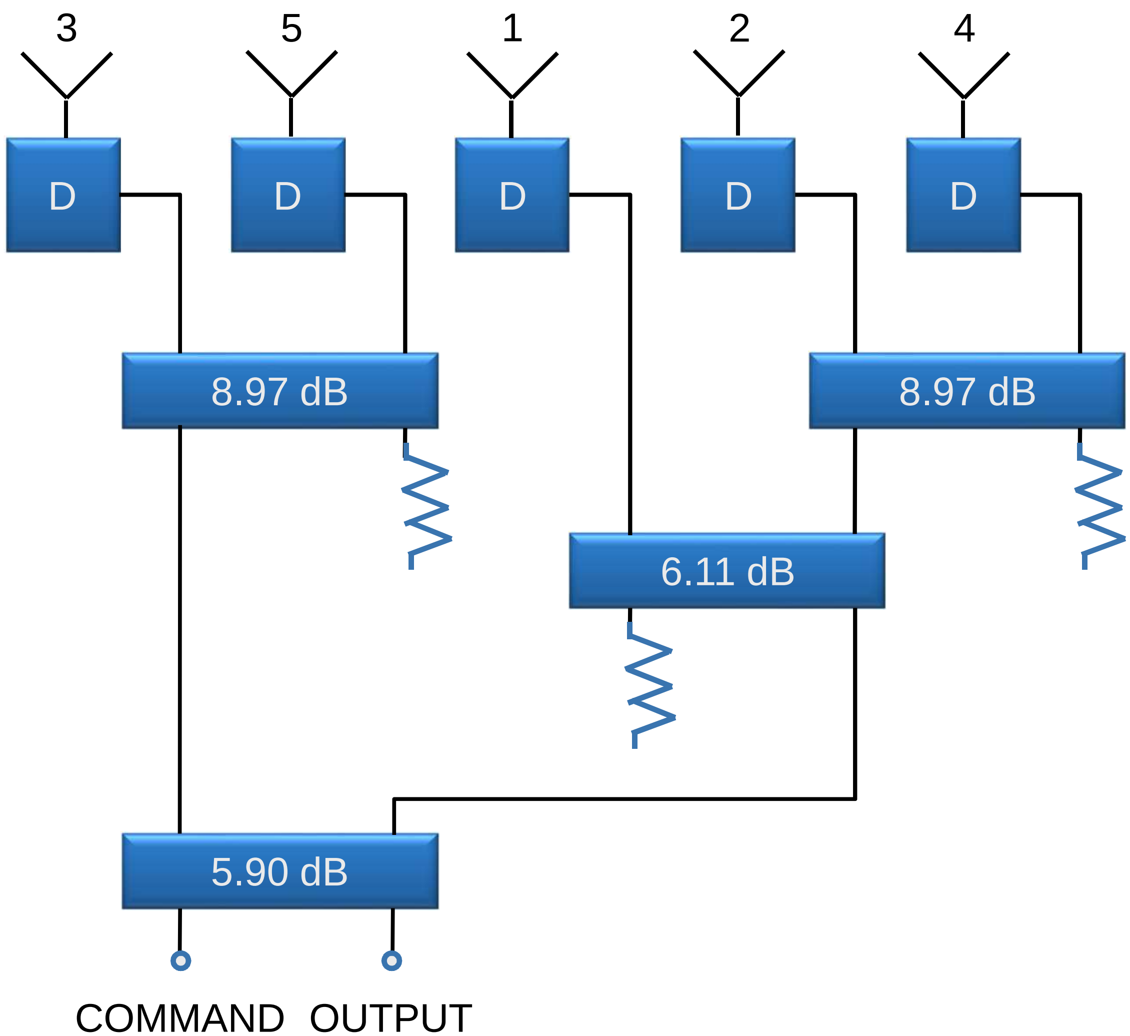
Region 1 Vertical Transmit Directivities (Cont.)

City	Directivity (109.2°)	Directivity (113°)	Expected EIRP, dBW (109.2°)	Expected EIRP, dBW (113°)
a) Channels 1 to 4				
Ensenada	30.55	30.51	38.8	38.7
La Paz	30.38	30.47	38.6	38.7
Nuevo Laredo	30.79	30.82	39.0	39.0
Puerto Escondido	30.72	30.76	38.9	39.0
Puerto Vallarta	30.24	30.37	38.4	38.6
Tapachula	30.70	30.63	38.9	38.8
Tuxtla Gutierrez	31.65	31.62	39.9	39.8
Villahermosa	31.97	31.94	40.2	40.1
Guatemala	30.09	30.01	38.3	38.2
Average			39.3	39.3
Specified			38.3	38.3
Margin, dB			1.0	1.0

Region R1 Vertical Receive Horn Excitations

No.	Relative Power	Phase, deg
1	0.195	0
2	0.463	20
3	0.163	-20
4	0.138	-20
5	0.041	-50

R1 Vertical Receive Network

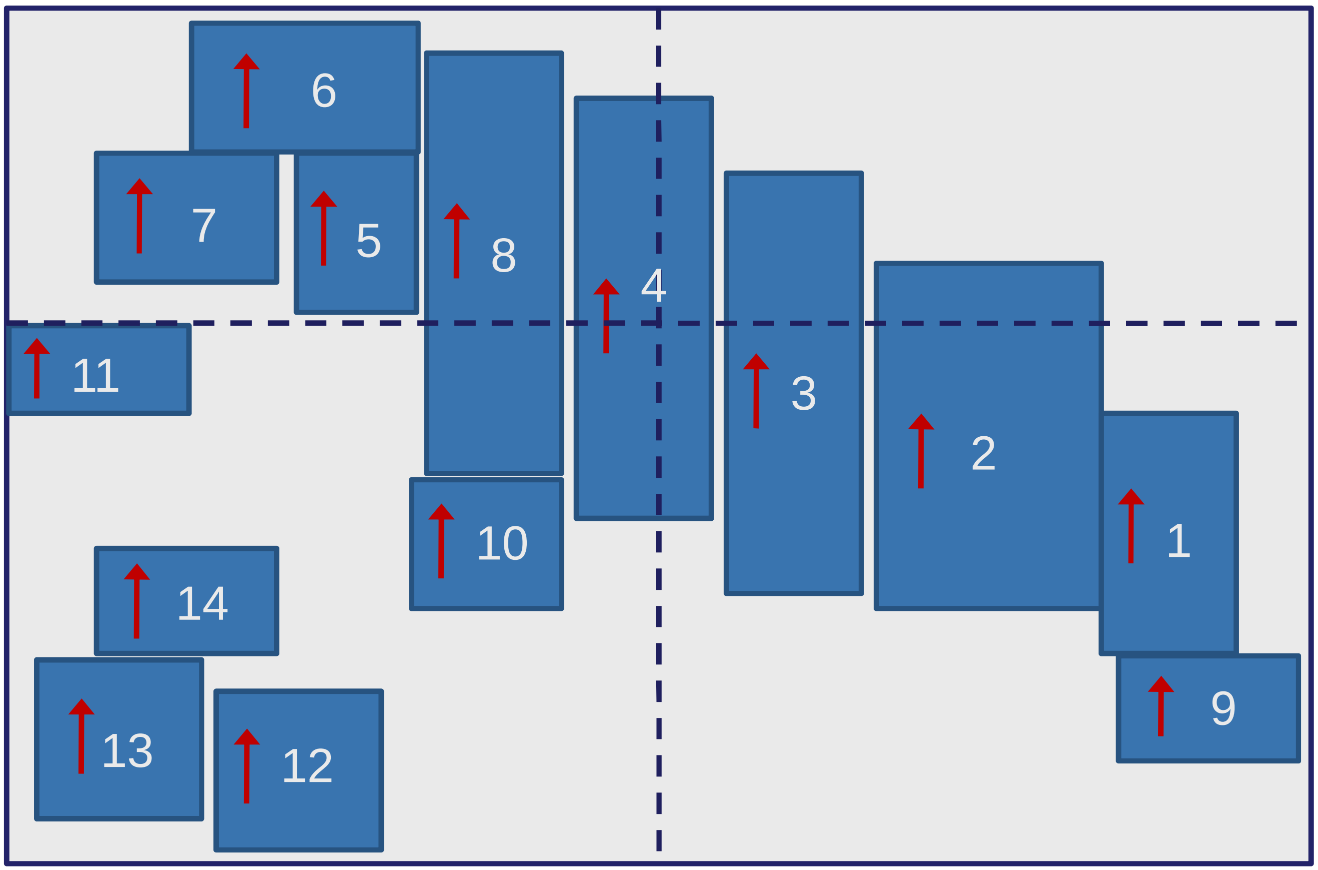


Ku – Band Vertical Array

LOCATION AND DIMENSION

Horn No.	Principal Plane Dimension, cm		Location, cm	
	E	H	X	Y
1	5.46	3.05	-4.71	9.60
2	7.62	4.06	-2.67	5.94
3	10.16	2.67	-1.02	2.47
4	11.18	2.67	0.02	-0.30
5	3.56	2.79	1.93	-5.92
6	3.43	5.21	5.52	-7.12
7	3.05	4.06	2.18	-9.70
8	9.91	2.67	1.47	-3.08
9	2.03	4.06	-8.56	10.46
10	2.29	3.68	-4.72	-3.58
11	2.03	4.06	-0.71	-11.61
12	4.06	4.06	-9.32	-7.09
13	4.06	4.06	-8.28	-11.25
14	2.54	4.57	-4.88	-9.40

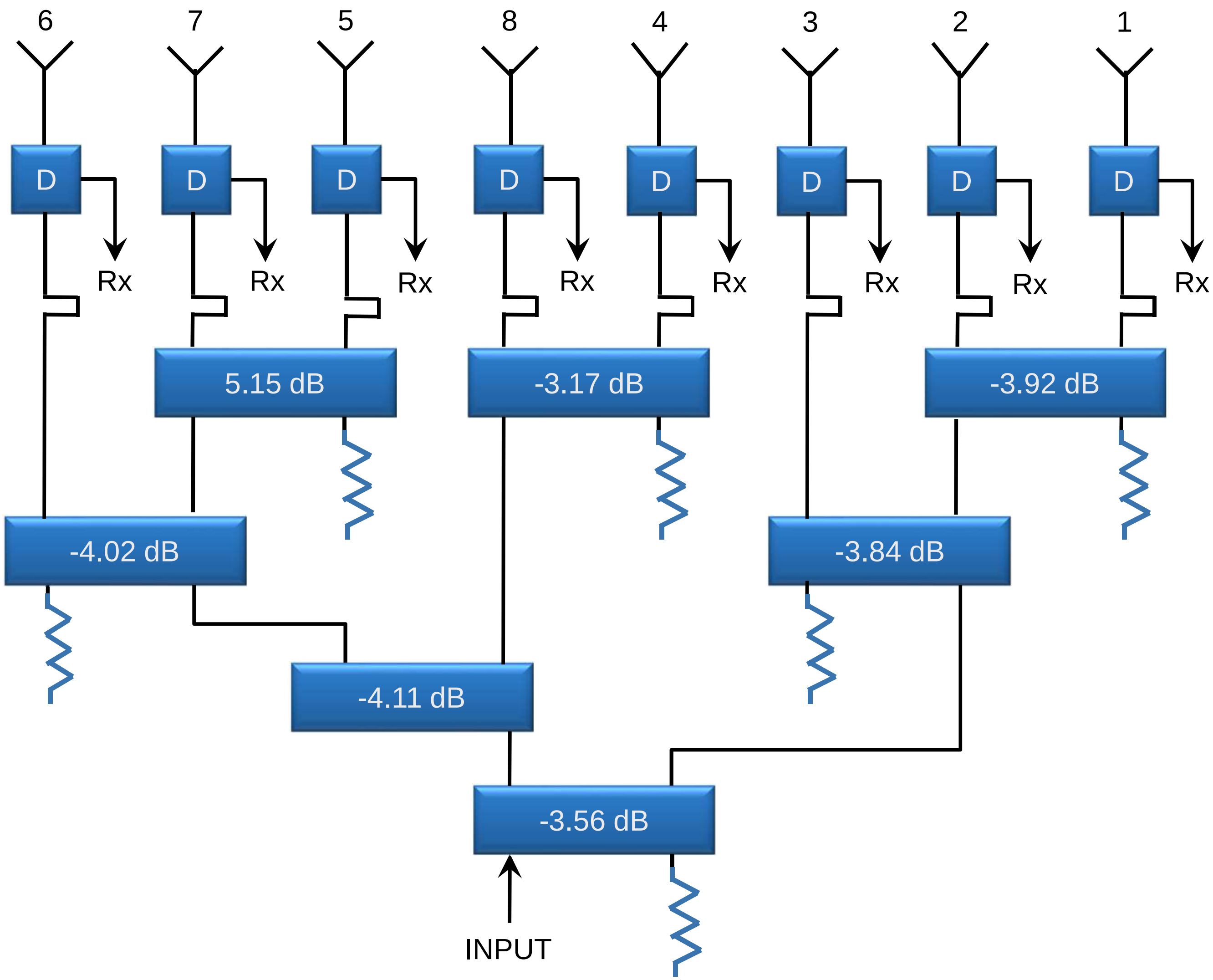
Ku – Band Vertical Horns Aperture Layout



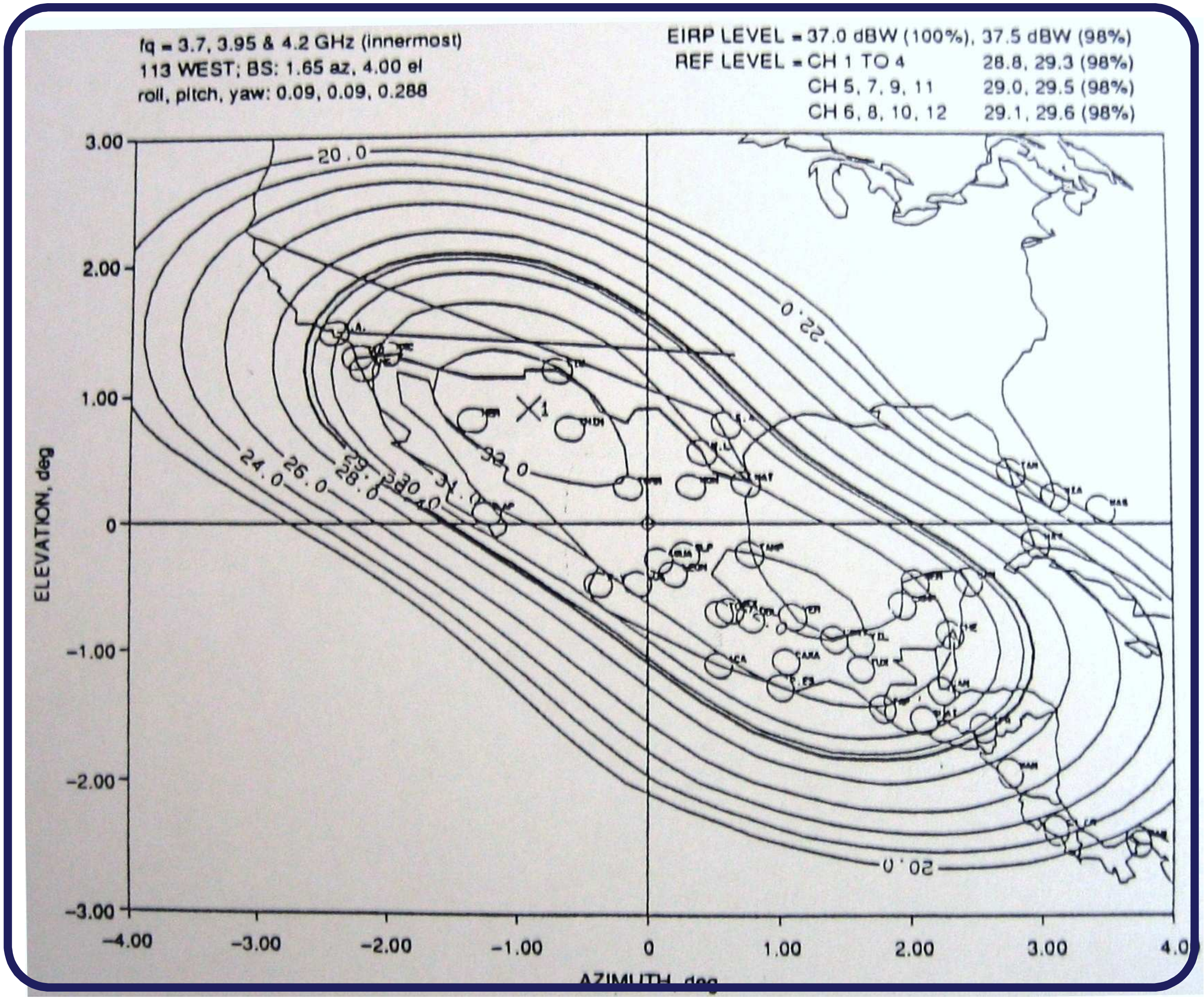
Region R4 Vertical Transmit Horn Excitations

No.	Relative Power	Phase, deg
1	0.105	0
2	0.154	0
3	0.182	0
4	0.165	-10
5	0.040	0
6	0.086	0
7	0.091	0
8	0.177	0

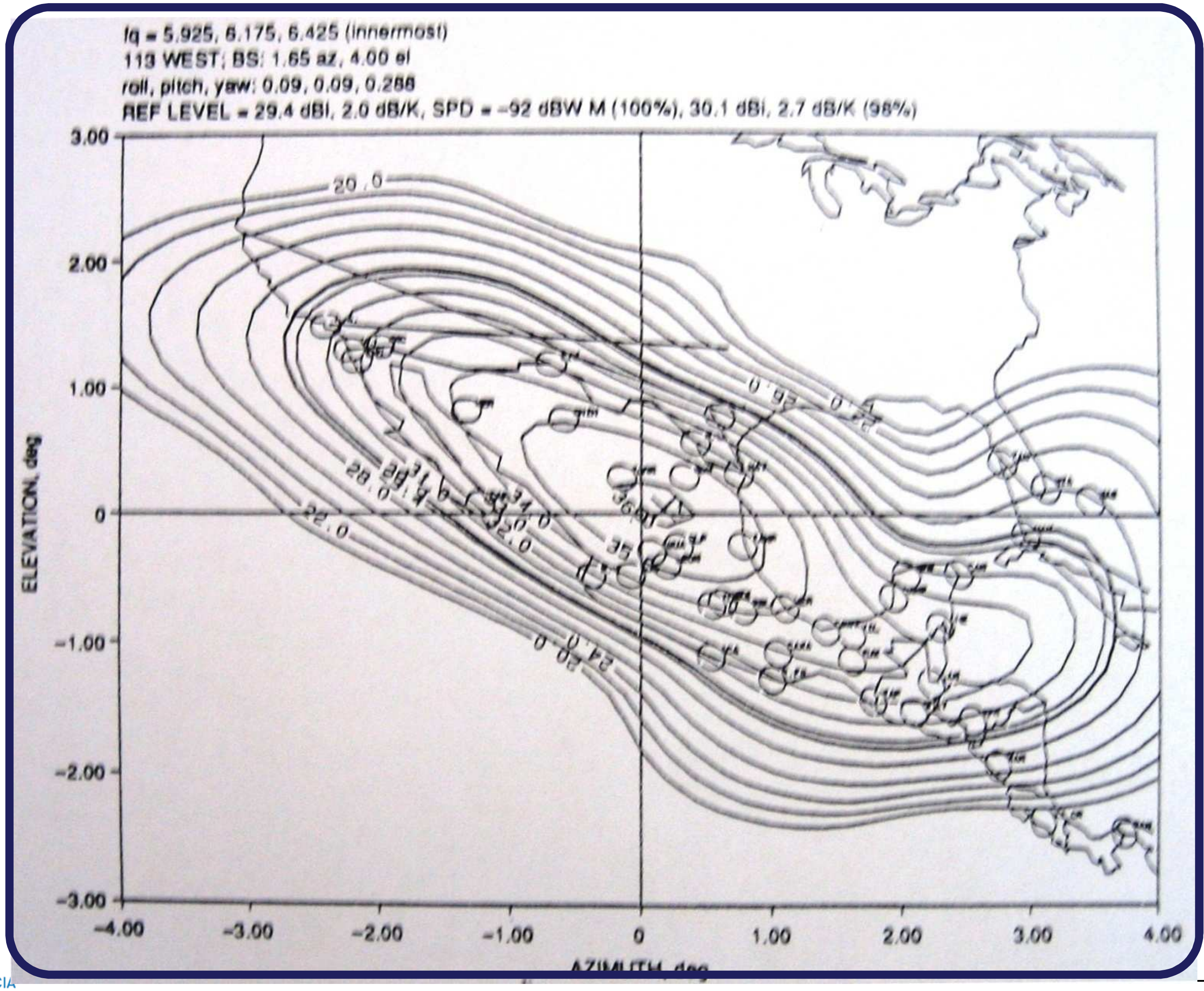
Region R4 Vertical Transmit Network



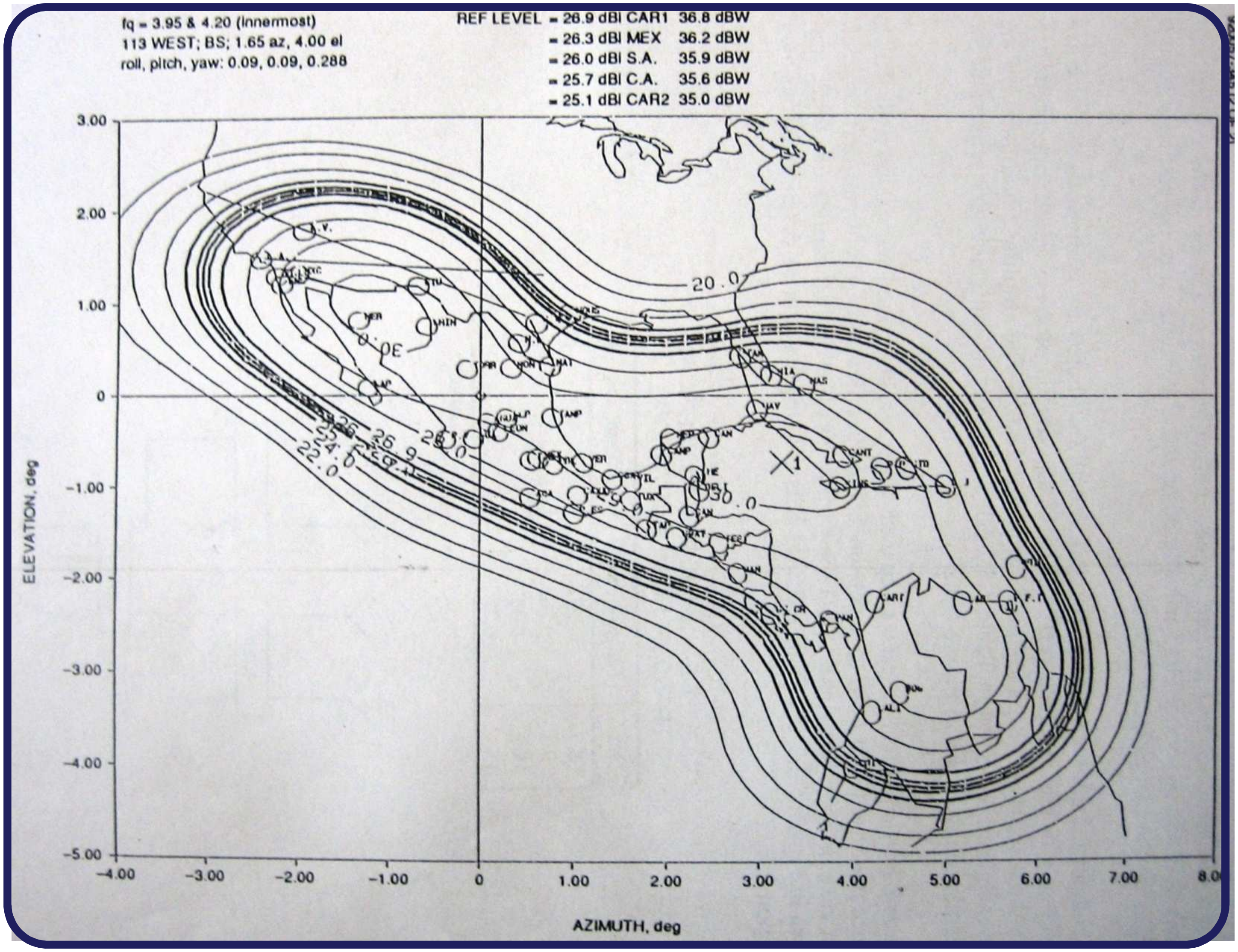
Region R1 Vertical Transmit Contours



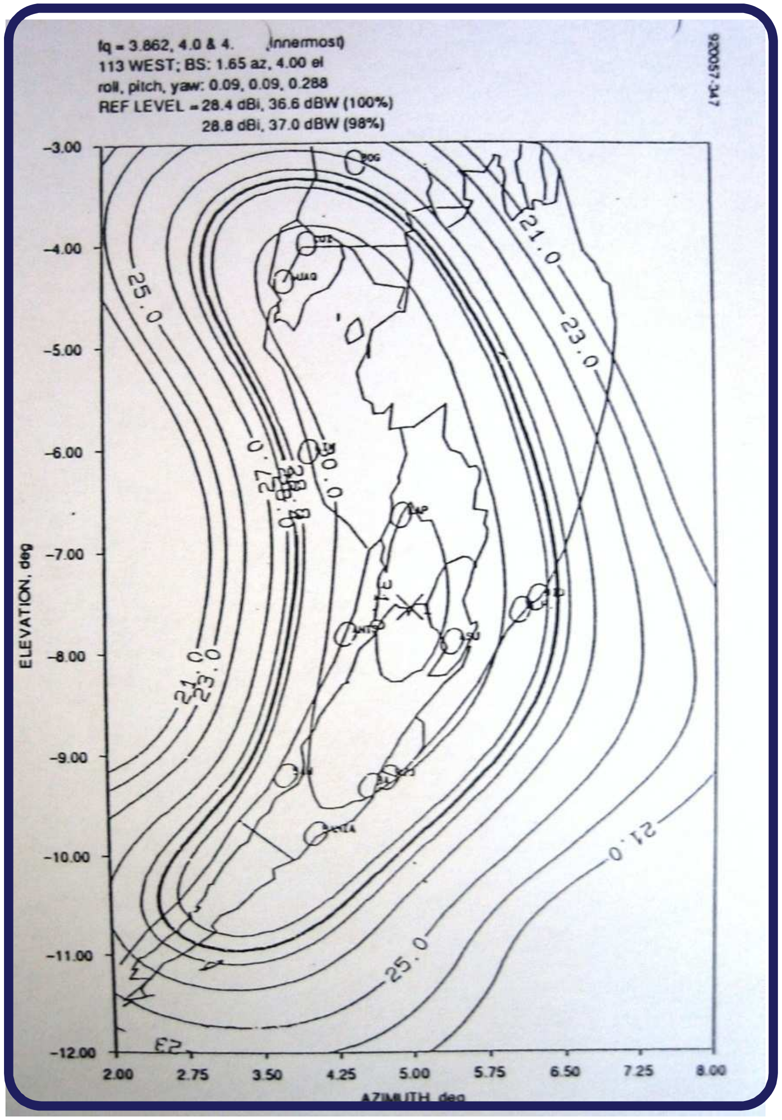
Region R1 Vertical Receive Contours



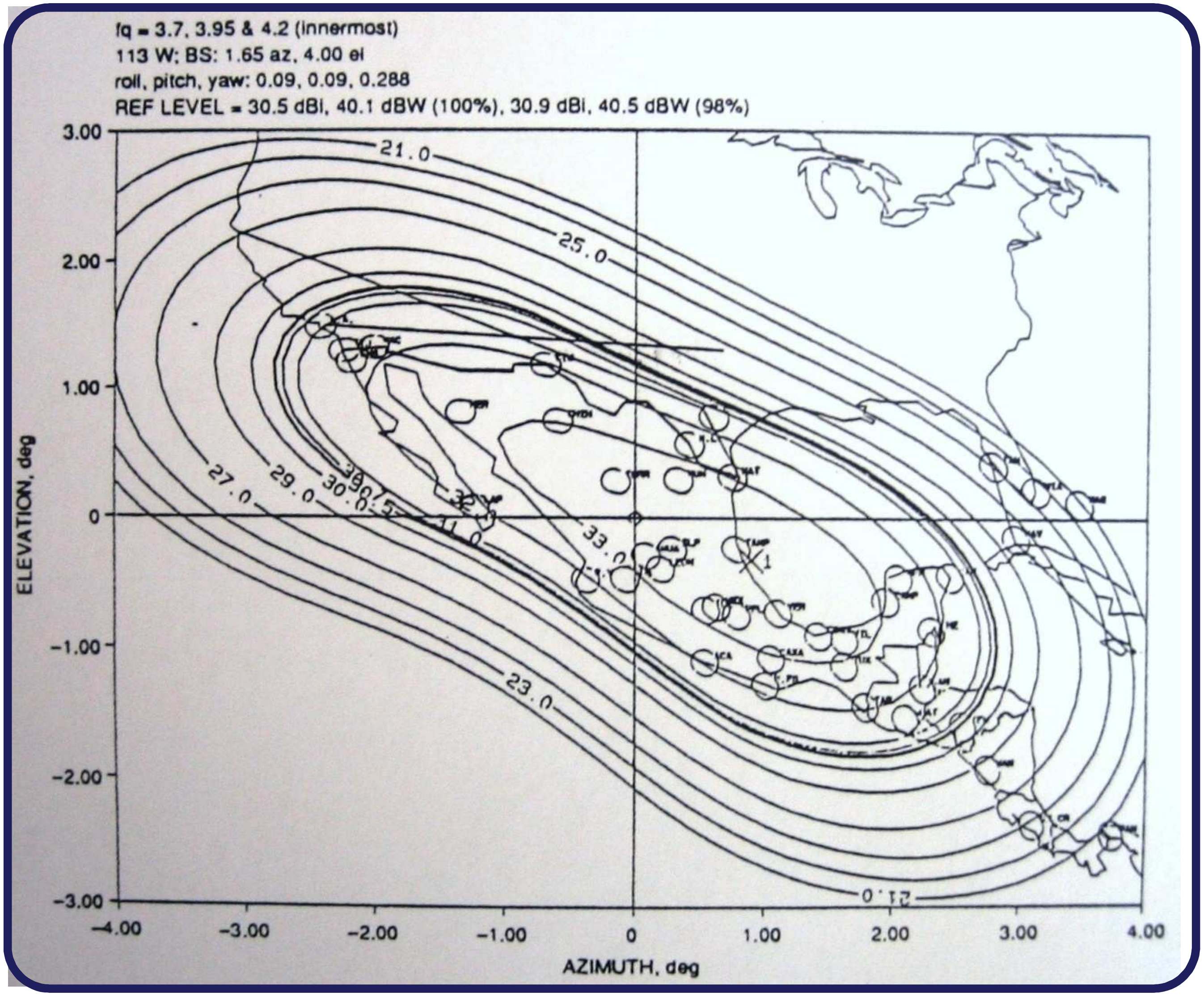
Region R2 vertical Transmit Contours



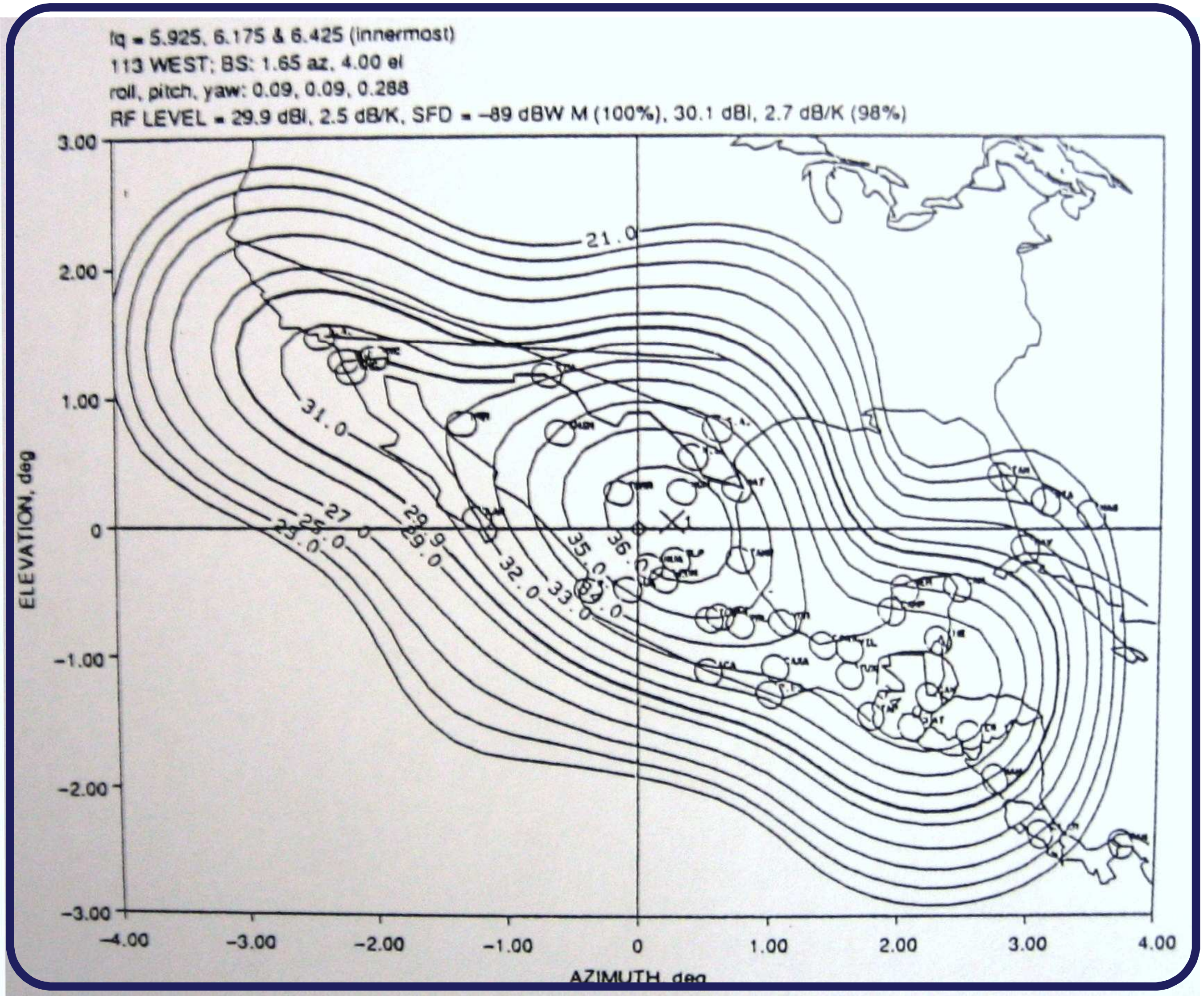
Region R3 Vertical Transmit Contours



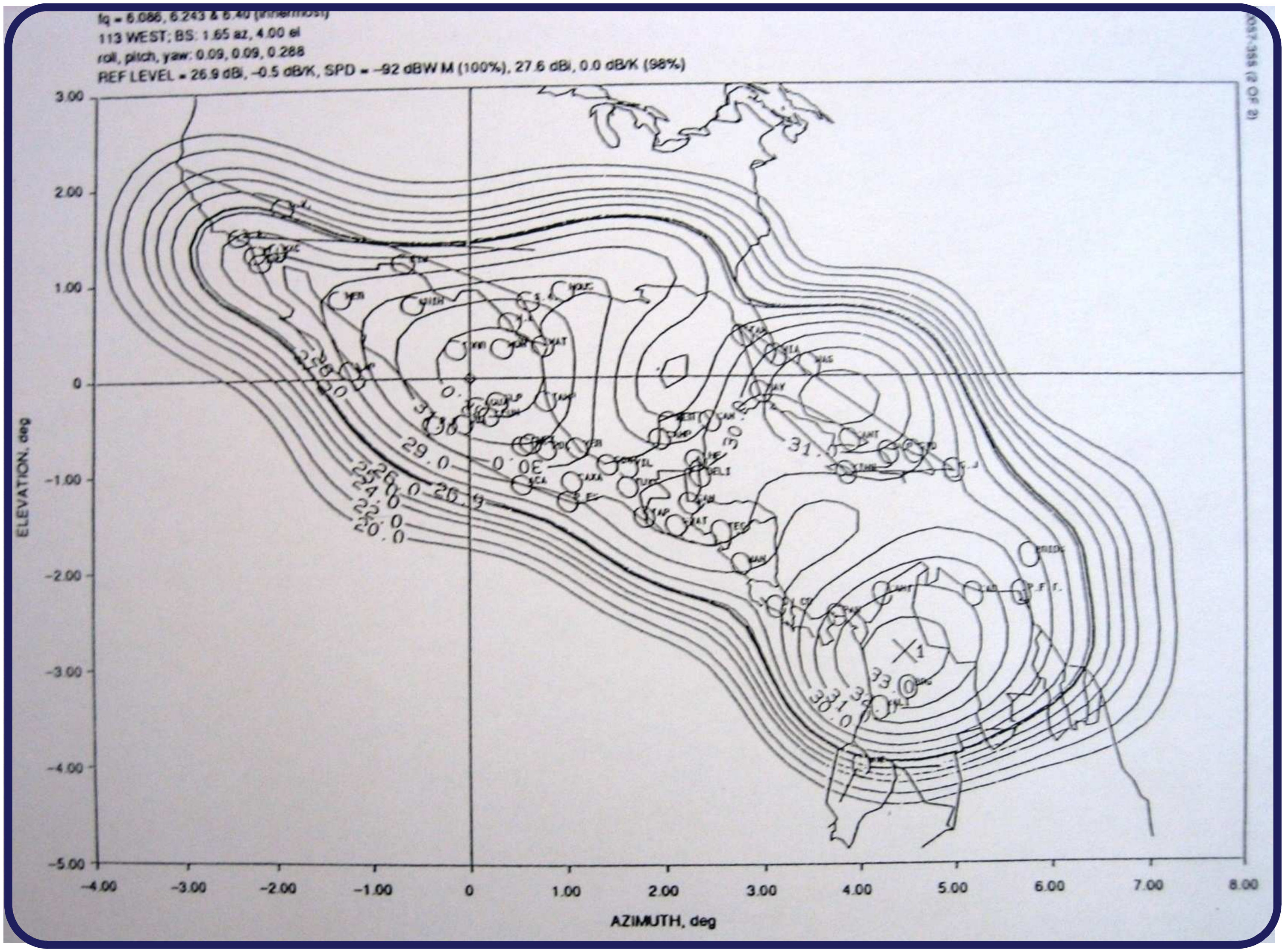
Region R1 Horizontal Transmit Contours



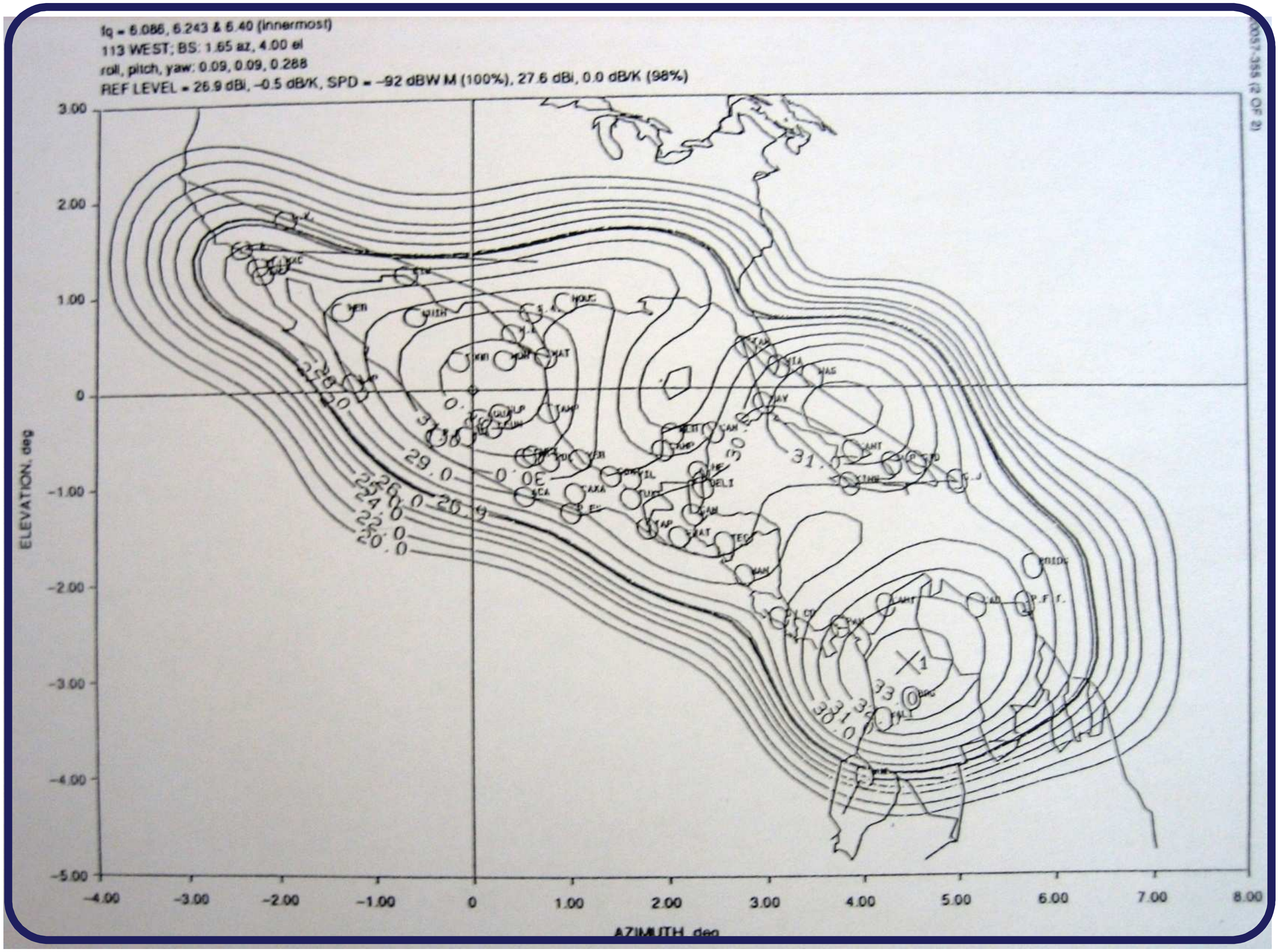
Region R1 Horizontal Receive Contours



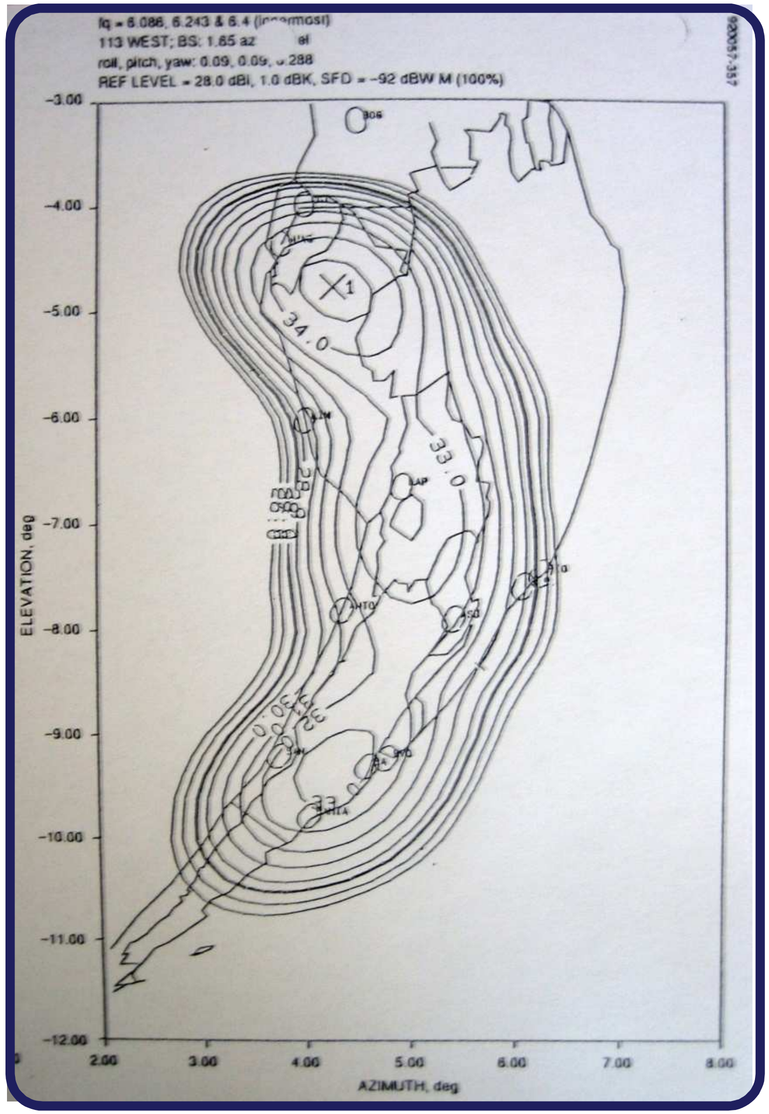
Region R2 Horizontal Receive Contours



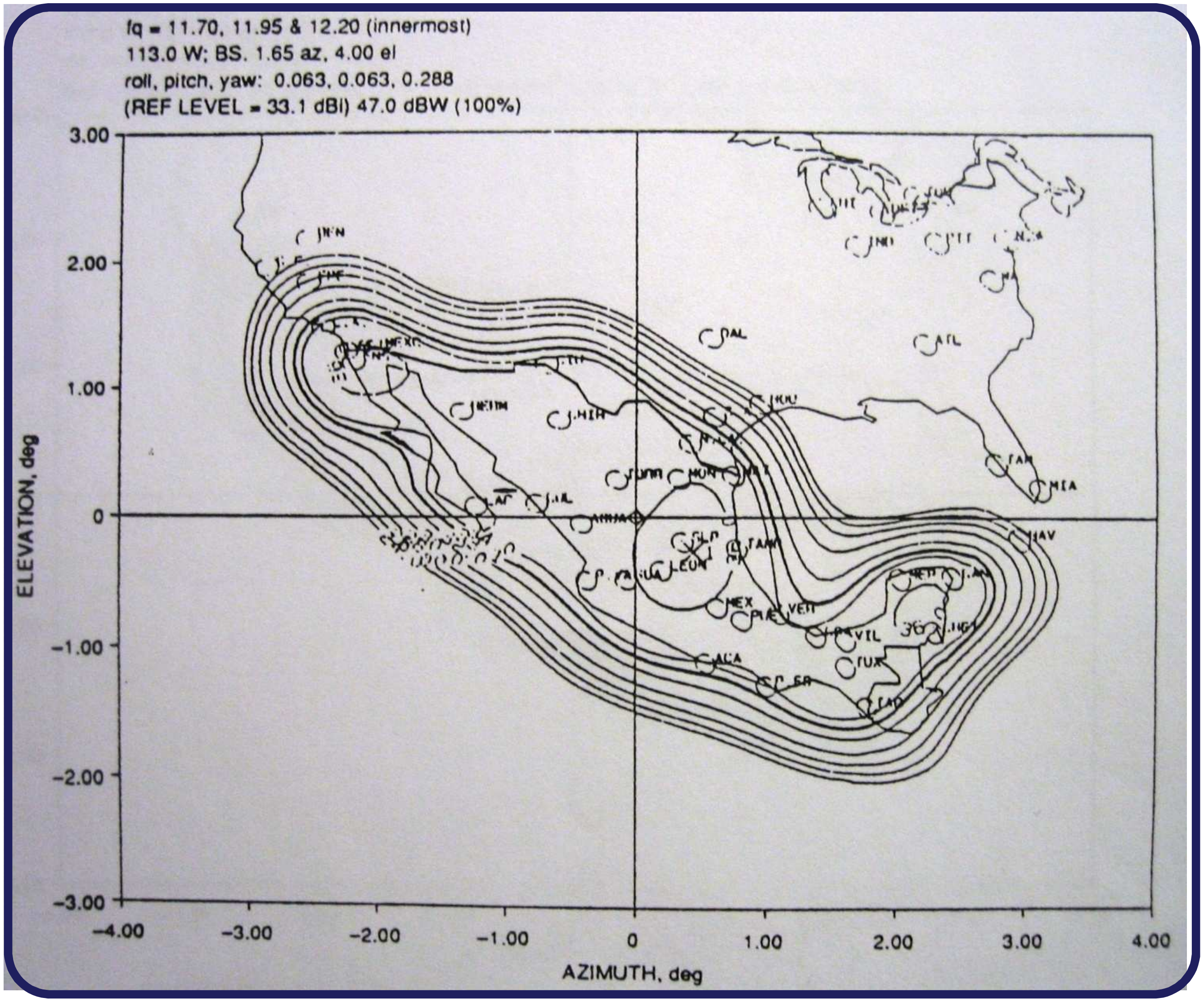
Region R2 Horizontal Receive Contours



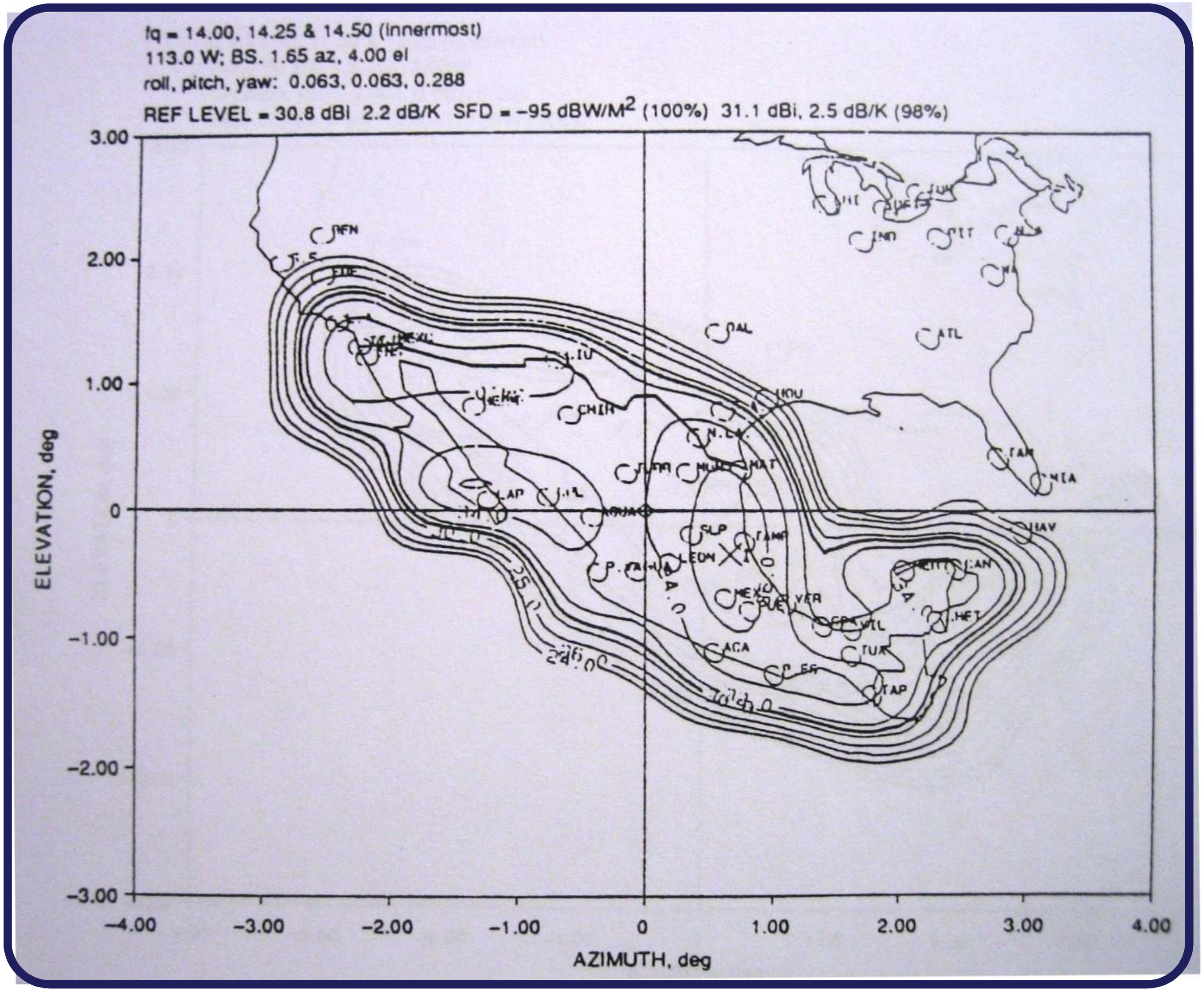
Region R2 Horizontal Receive Contours



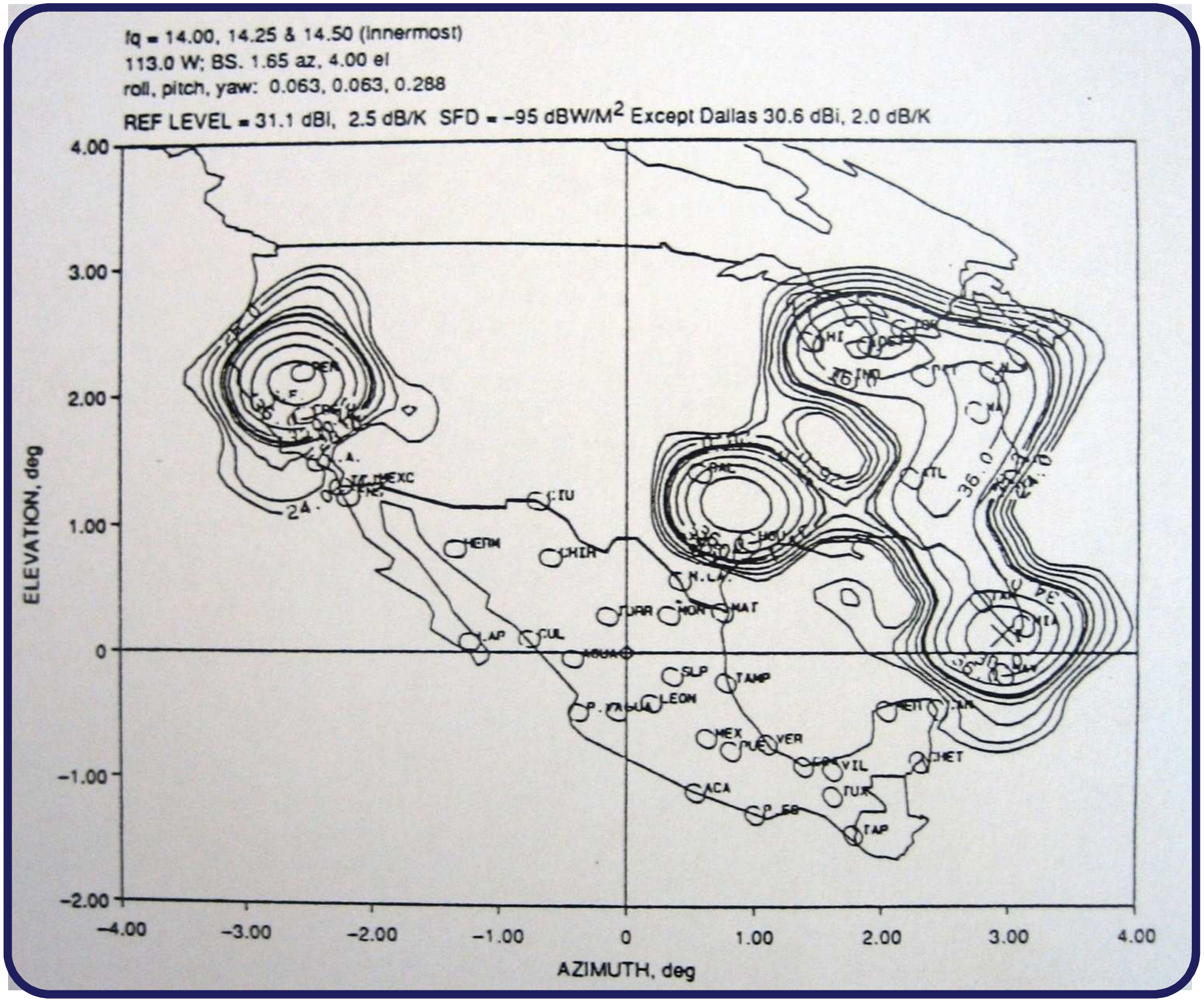
Region R4 Vertical Transmit Contours



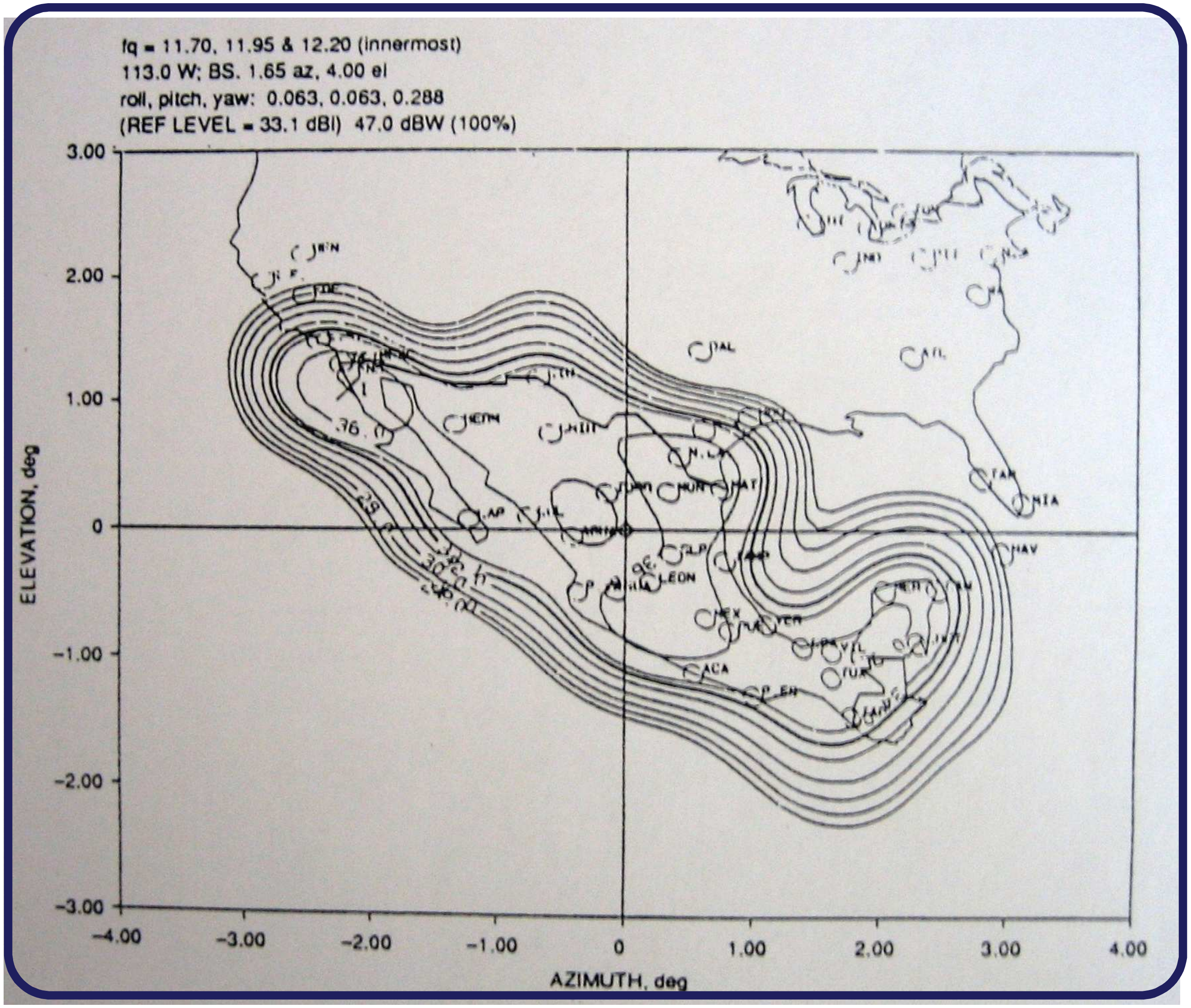
Region R4 Vertical Receive Contours



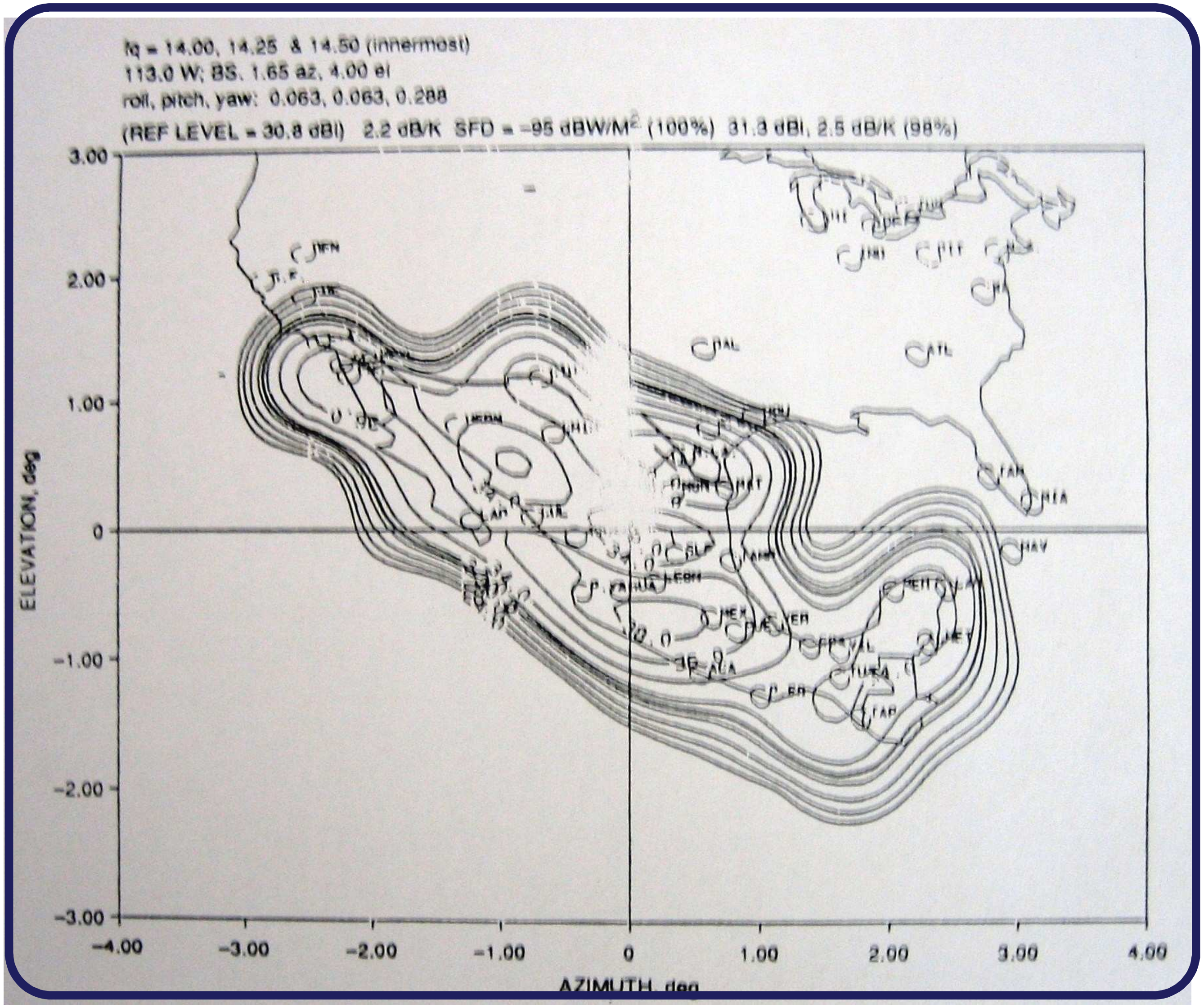
Region R5 Vertical Receive Contours



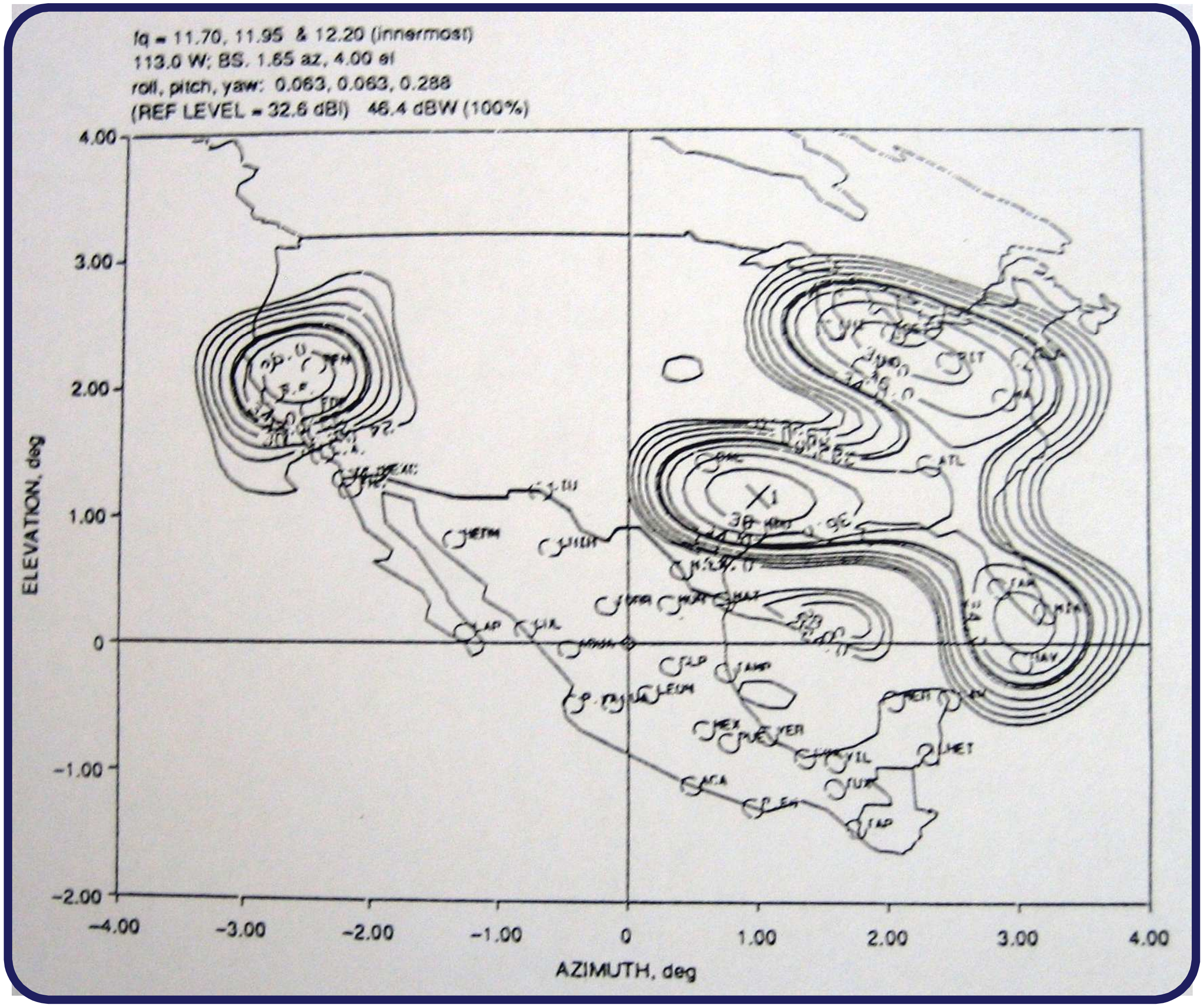
Region R4 Horizontal Transmit Contours



R4 Horizontal Receive Contours

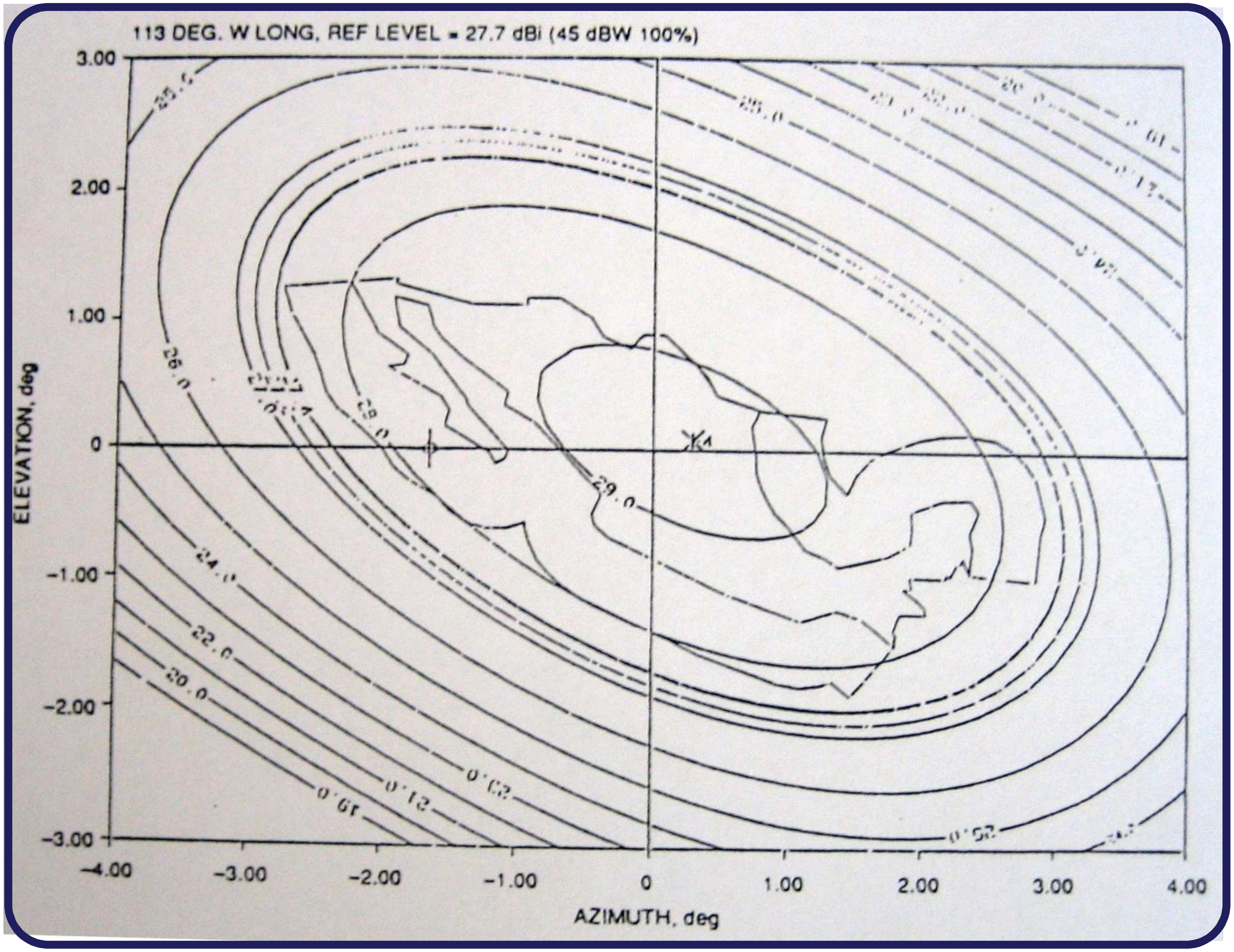


Region R5 Horizontal Transmit Contours

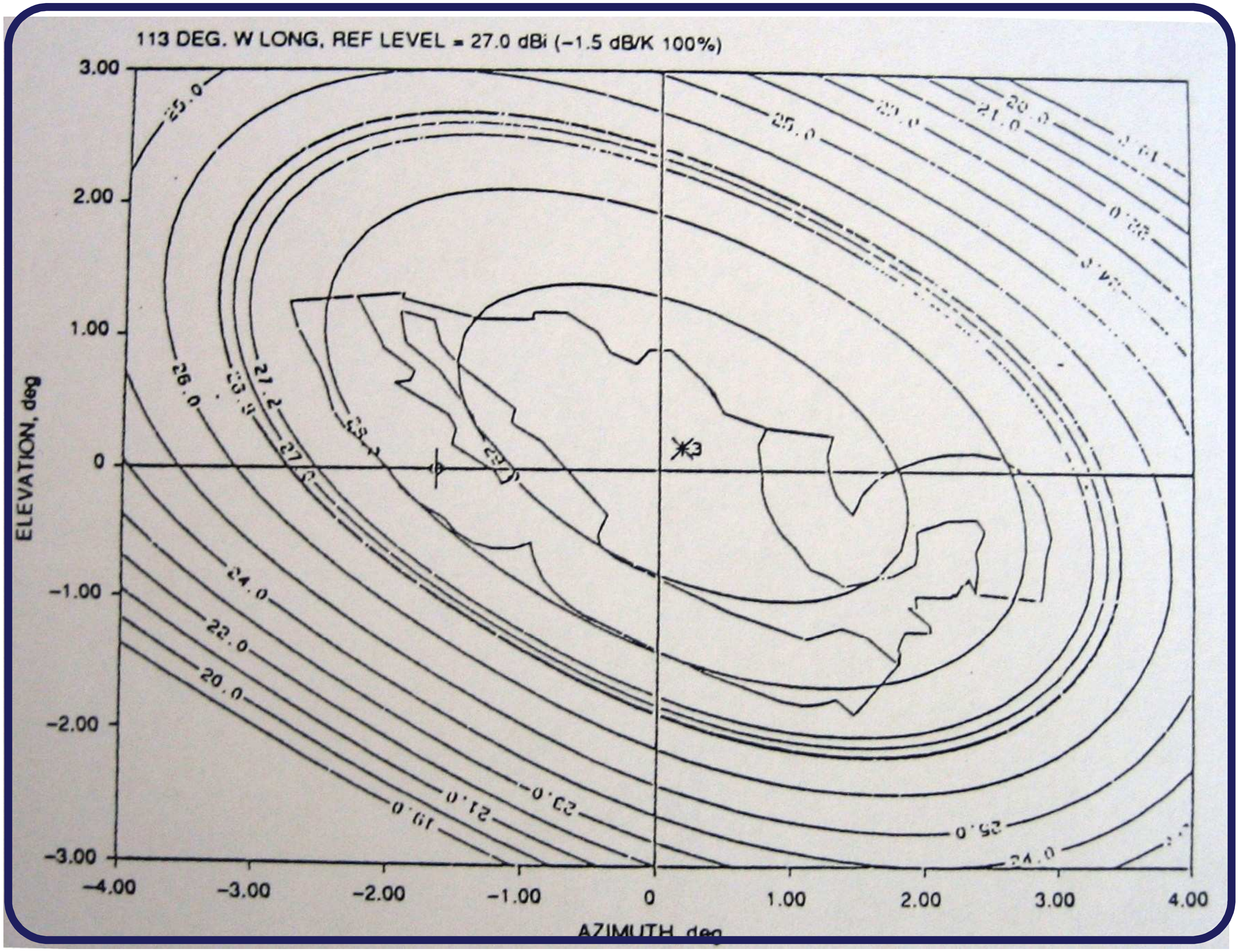


CAMPUS DE EXCELENCIA INTERNACIONAL

L-band Transmit Contours



L-band Receive Contours



Solidaridad I
(109.2°W)

REGION 4 (MEXICO)
Ku BAND

LOCATION	LONGITUD (deg)	LATITUD (deg)	Pol V/H PIRE (dBw)	D.F.S. (dBw/m$_2$)	G/T (dB/°k)	Pol H/V PIRE (dBw)	D.F.S. (dBw/m$_2$)	G/T (dB/°k)
Acapulco, Gro.	99.55	16.51	48.10	-98.05	5.05	47.30	-98.20	5.20
Aguascalientes, Ags.	102.03	21.86	47.80	-98.45	5.45	49.30	-99.30	6.30
Cancún, Q. Roo	86.46	21.05	47.60	-97.25	4.25	48.70	-97.30	4.30
Cd. Juárez, Chich.	106.29	31.44	48.40	-97.95	4.95	47.95	-100.70	7.70
Chetumal, Q. Roo.	88.18	18.30	48.60	-98.05	5.05	48.16	-98.35	5.35
Chihuahua, Chih.	106.06	28.65	49.30	-97.10	4.10	49.35	-98.70	5.70
Coatzacoalcos, Ver.	94.45	18.20	49.00	-96.00	3.00	47.92	-97.80	4.80
Culiacán, Sin.	107.40	24.82	48.90	-99.22	6.22	49.62	-99.15	6.15
Ensenada, B. C. N.	116.37	31.52	51.10	-99.90	6.90	50.32	-101.30	8.30
Guadalajara, Jal.	103.20	20.40	49.80	-97.25	4.25	49.97	-101.50	8.50
Hermosillo, Son.	110.58	29.04	48.90	-96.90	3.90	49.25	-97.70	4.70
La Paz, B. C. S.	110.18	24.10	49.30	-98.75	5.75	48.65	-99.90	6.90
León, Gto.	101.25	21.07	50.20	-98.00	5.00	50.20	-100.00	7.00
Los Ángeles, Cal.	118.15	34.03	48.00	-97.70	4.70	47.75	-98.10	5.10
Matamoros, Tamps.	97.30	25.53	50.60	-99.27	6.27	48.10	-101.10	8.10
Mérida, Yuc.	89.37	20.58	48.70	-97.60	4.60	48.20	-97.90	4.90

Solidaridad I (109.2°W) (Cont.)

REGION 4 (MEXICO) Ku BAND			Pol V/H			Pol H/V		
LOCATION	**LONGITUD (deg)**	**LATITUD (deg)**	**PIRE (dBw)**	**D.F.S. (dBw/m$_2$)**	**G/T (dB/°k)**	**PIRE (dBw)**	**D.F.S. (dBw/m$_2$)**	**G/T (dB/°k)**
Mexicali, B.C.N.	115.45	32.65	49.00	-98.85	5.85	49.35	-98.10	5.10
México, D.F.	99.01	19.24	50.70	-100.55	7.55	49.45	-102.10	9.10
Monterrey, N.L.	100.19	5.40	50.80	-99.00	6.00	49.60	-99.90	6.90
Nuevo Laredo, Tamps.	99.31	27.30	51.00	-98.65	5.65	48.35	-102.50	9.50
Pto. Escondido, Oax.	97.10	15.50	47.30	-98.45	5.45	47.15	-96.70	3.70
Pto. Vallarta, Jal.	105.15	20.37	48.60	-97.60	4.60	48.20	-100.10	8.10
Puebla, Pue.	98.20	19.03	49.90	-100.45	7.45	48.20	-100.80	7.80
San Antonio, Tex.	98.31	29.28	47.70	-95.57	2.57	47.00	-95.50	2.50
San Luis Potosi, S.L.P.	100.98	22.15	50.00	-99.45	6.45	50.50	-96.00	3.00
Tampico, Tamps.	97.85	22.21	48.70	-101.25	8.25	49.52	-98.90	5.90
Tapachula, Chia.	92.17	14.54	48.10	-98.05	5.05	47.87	-97.90	4.90
Tijuana, B.C.N.	117.01	32.32	50.50	-99.60	6.60	49.95	-100.60	7.60
Torreón, Coah.	103.45	25.53	47.80	-97.45	4.45	49.05	-99.10	6.10
Tuxtla, Gtz. Chia.	93.07	16.45	49.70	-97.20	4.20	49.37	-98.40	5.40
Vareacruz, Ver.	96.08	19.12	48.40	-97.77	4.77	47.85	-98.50	5.50
Villahermosa, Tab.	92.55	17.59	49.40	-95.65	2.65	48.60	-97.90	4.90

LINK BUDGET

LINK BUDGET

Satellite Data

SATELLITE:	SOLIDARIDAD 2	
LONGITUD:	113.0 º	WESTERN
OPERATION BAND:	C	
TRANSPONDER TYPE:	12N (36 MHz)	
REGION:	R3-R2	
UPLINK FREQUENCY	6.385	GHz
DOWNLINK FREQUENCY:	4.160	GHz
IBO:	7.5	dB
OBO:	5.0	dB
PAT:	6.0	dB

Signal Data

RATE:	4000 Kbps
MODULATION:	QPSK
ROLL OFF:	14 %
FEC:	0.69
BER:	$10E^{-7}$

Satellite Parameters in locations

LOCATION	QUITO, ECUADOR	MIAMI, USA	
DFS	-94.00	dBW/m^2	
G/T	2.90	dB/K	
PIREsaturation		37.60	dBW

E/T Transmision and Recepcion Data

LOCATION	QUITO, ECUADOR	MIAMI, USA	
LATITUD	0.22	25.77	ºN
LONGITUD	78.50	80.20	ºO
ANTENNA DIAMETER	3.80	4.20	m
ANTENNA GAIN Tx	45.88		dBi
ANTENNA GAIN Rx		43.03	dBi
TOTAL SYSTEM TEMP		89.99	ºK
Eb/No RECEIVER MODEM		4.0	dB

BANDWITH

BW = Vinf. $(FEC)^{-1}$ (FM) (1 + ROLL OFF) (Hz)

Vinf =Information Rate

FEC =Forward Error Correction

FM =Modulation Factor, it depend of used modulation.

If modulation is	BPSK	FM = 1.0
If modulation is	QPSK	FM = 0.5

ROLL OFF = Spread Spectrum Factor (modem feature)

Replacing:

USED BANDWITH

BW = 4000.000 $*(0.69)^{-1}$ *(0.5) *1.14

BW = 3304.35 KHz

ANTENNA POINTING AND DISTANCE E/T-SATELLITE

AZIMUTH ANGLE FOR QUITO E/T :

A' = Tan^{-1} (Tan [ABS (LONGSAT - LONGE/T)] / Sin LATE/T)

Where: LONGSAT = Satellite Longitude

LONGE/T = E/T Longitude.

LATE/T = E/T Latitude.

ABS = Absolute Value

If E/T location is in North Hemisphere and:

E/T west from the satellite : A = 180 - A´

E/T east from the satellite : A = 180 + A´

If E/T location is in South Hemisphere and :

E/T west from the satellite : A = A´

E/T east from the satellite A = 360 - A´

replacing for QUITO:

A' = Tan^{-1} (Tan[ABS (113.0 - 78.50)] / Sin 0.22)

A' = 89.68

such E/T is in south hemisphere and east of satellite

A = 360 - 89.68

A = 270.32º

ELEVATION ANGLE FOR QUITO E/T :

$$E = \text{Tan}^{-1} \left[(R - Re(w) / (Re \ \text{Sin}(\text{Cos}^{-1} w)))\right] - \text{Cos}^{-1} w$$

Where: R = Mean Distance from Earth Center to geostationary orbit (42164.2 Km)

Re =Mean Radio of Earth (6378.155 Km)

w =Cos LATE/T (Cos [LONGSAT - LONGE/T])

replacing:

w = (Cos 0.22)*(Cos [113.0 - 78.50])

w = 0.82142

$$E = \text{Tan}^{-1} \left[(42164.2 - 6378.155 (0.82142)) / (6378.155 (\text{Sen} (\text{Cos}^{-1} 0.82142)))\right] - \text{Cos}^{-1} 0.82142$$

E = 49.91º

DISTANCE BETWEEN QUITO E/T AND SOLIDARIDAD 2

$$D = \{R^2 + Re^2 - (2\ Re\ (R)\ Sen\ (E + Sin^{-1}\ ((Re / R)\ Cos\ E)))\}^{1/2}$$

Where:

R = Mean distance from Earth center to Satellite (42164.2 Km)

Re = Mean Radius of Earth (6378.155 Km)

E = Elevation angle

Replacing:

$$D = \{42164.2^2 + 6378.155^2 - (2\ (6378.155\ (42164.2))\ Sin\ (49.91 + Sin^{-1}\ ((6378.155 / 42164.2)\ Cos\ 49.91)))\}^{1/2}$$

D = 37084.22 Km

AZIMUTH ANGLE FOR MIAMI E/T :

$A' = Tan^{-1}\ (Tan[\ ABS\ (\ 113.0 - 80.20\ )\ ] / Sin\ 25.77)$

A' = 56.00

E/T location is in north hemisphere and east from the satellite

A = 180 + 56.00

A = 236.00º

ELEVATION ANGLE FOR MIAMI E/T :

$$w = \cos 25.77 \ \cos \ [113.0 - 80.20]$$

$$w = 0.75697$$

$$E = \tan^{-1} [(42164.2 - 6378.155 (0.75697)) / (6378.155 (\text{Sen} (\cos^{-1} 0.75697)))] - \cos^{-1} 0.75697$$

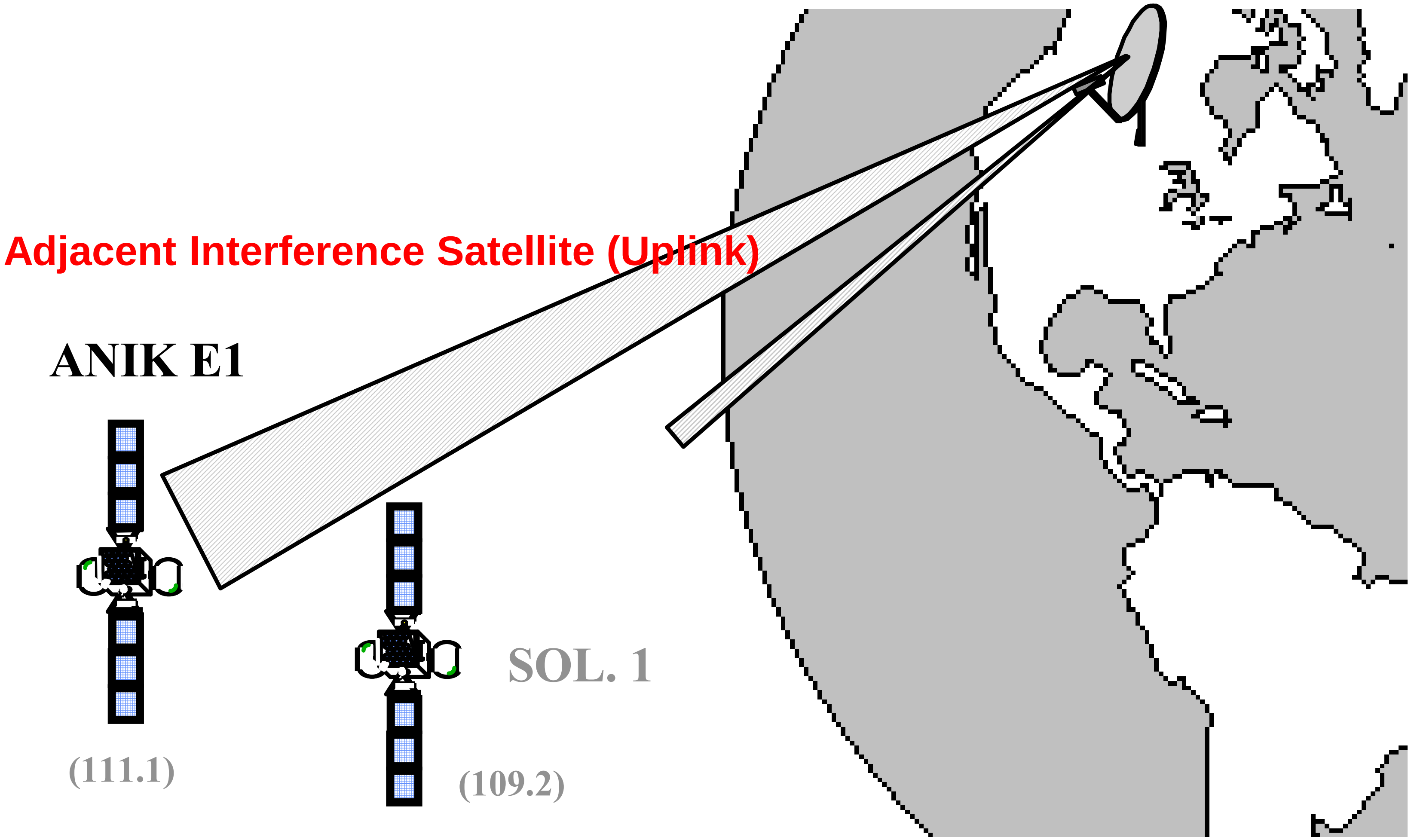
$$E = 42.83^{\circ}$$

DISTANCE BETWEEN E/T MIAMI AND SOLIDARIDAD 2

$$D = (42164.2^2 + 6378.155^2 - (2 (6378.155 (42164.2)) \sin (42.83 + \sin^{-1} ((6378.155 / 42164.2) \cos 42.83)))) ^{-1/2}$$

$$D = 37567.88 \ \text{Km}$$

UPLINK



Adjacent Interference Satellite (Uplink)
ANIK E1
(111.1)
SOL. 1
(109.2)

CARRIER TO NOISE DENSITY RATIO UPLINK

$$(C/No)asc = EIRP\ E/T + (G/T)SAT - K - Ls\ asc - \mu asc - L\Delta asc$$

Where:

EIRP E/T	= Equivalent isotropically radiated power from the E/T.
(G/T)SAT	= Satellite characteristics.
K	= Boltzman Constant = -228.6 (dBJ/ºK)
Ls asc	= Free Space Losses (Uplink)
µasc	= Rain Atenuation Margin, uplink
LΔasc	= Miscelaneous losses , it is the summatory of atmospheric losses, pointing and polarization losses and is approximately 1dB

replacing:

µasc = 0, For 99.98 availability in C band

PROPOSED VALUE OF 57.83 dBW FOR E/T EIRP .

Free Spece Losses (Uplink)

Ls asc = 20 Log ((4p*F*D) / C)

Where: F = Uplink Frequency (Hz)

D = Distance between E/T and satellite (m)

C = Ligth speed (3 E8 m/s)

replacing:

Ls asc = 20 Log ((4p(6.385 E9)(37084.22 E3))/ 3 E8)

Ls asc = 199.93 dB

(C/No)asc = 57.83+ 2.90 - (-228.6) - 199.93 - 1.0 (dB Hz)

(C/No)asc = 88.40 dB-Hz

CARRIER TO NOISE RATIO UPLINK

(C/N)asc = (C/No)asc - 10 Log (AB)

replacing:

(C/N)asc = (88.40) - 10 Log (3304.35 E3)

(C/N)asc = 23.21 dB

TOTAL CARRIER TO NOISE RATIO

$$\left(\frac{C}{N}\right)_{ASCTOTAL} = 10 \log \left[\frac{1}{\frac{1}{a \log\left(\frac{C/N asc}{10}\right)} + \frac{1}{a \log\left(\frac{C/I}{10}\right)} + \frac{1}{a \log\left(\frac{C/X pol}{10}\right)} + \frac{1}{a \log\left(\frac{C/X satady}{10}\right)}} \right]$$

Where:

C/I Ascending Intemodulation: C/I = - HPA INT - IPBO - 10 LOG(AB)

C/X Ascending cross polarization : C/X pol = - INTASCCPOL - IPBO - 10 LOG(AB)

C/X Ascending adjacent Satellite : C/Xsatady =- INTASCSADY - IPBO -10 LOG(AB)

CARRIER IPBO

IPBO = DFS - EIRPE/T + Lp asc + ATP + LATM + µasc

replacing:

IPBO = DFS - PIREE/T + Lp asc + ATP + LATM + µasc

Where:

Lp asc = 10 Log (4 * p * D^2)

Lp asc = 10 Log ((4p)(37084.22 E3) ^{2})

Lp asc = 162.38 dB

IPBO = -94.00 – 57.83 + 162.38 + 6 + 0.5 + 0

IPBO = 17.05 dB

C/I ASCENDING INTERMODULATION

C/I Intermodulation=-(-106.0) – 17.05 - 10*log(3304.35 E3) =106 – 17.05 – 65.19

C/I = 23.77 dB

C/X ASCENDING CROSS POLARIZATION

C/X Cross polarization = - (-112.5) – 17.05 – 65.19

C/X Pol = 30.27 dB

C/X ASCENDING ADJACENT SATELLITE

C/X AdJacent Satellite = - (-110.0) – 17.05 – 65.19

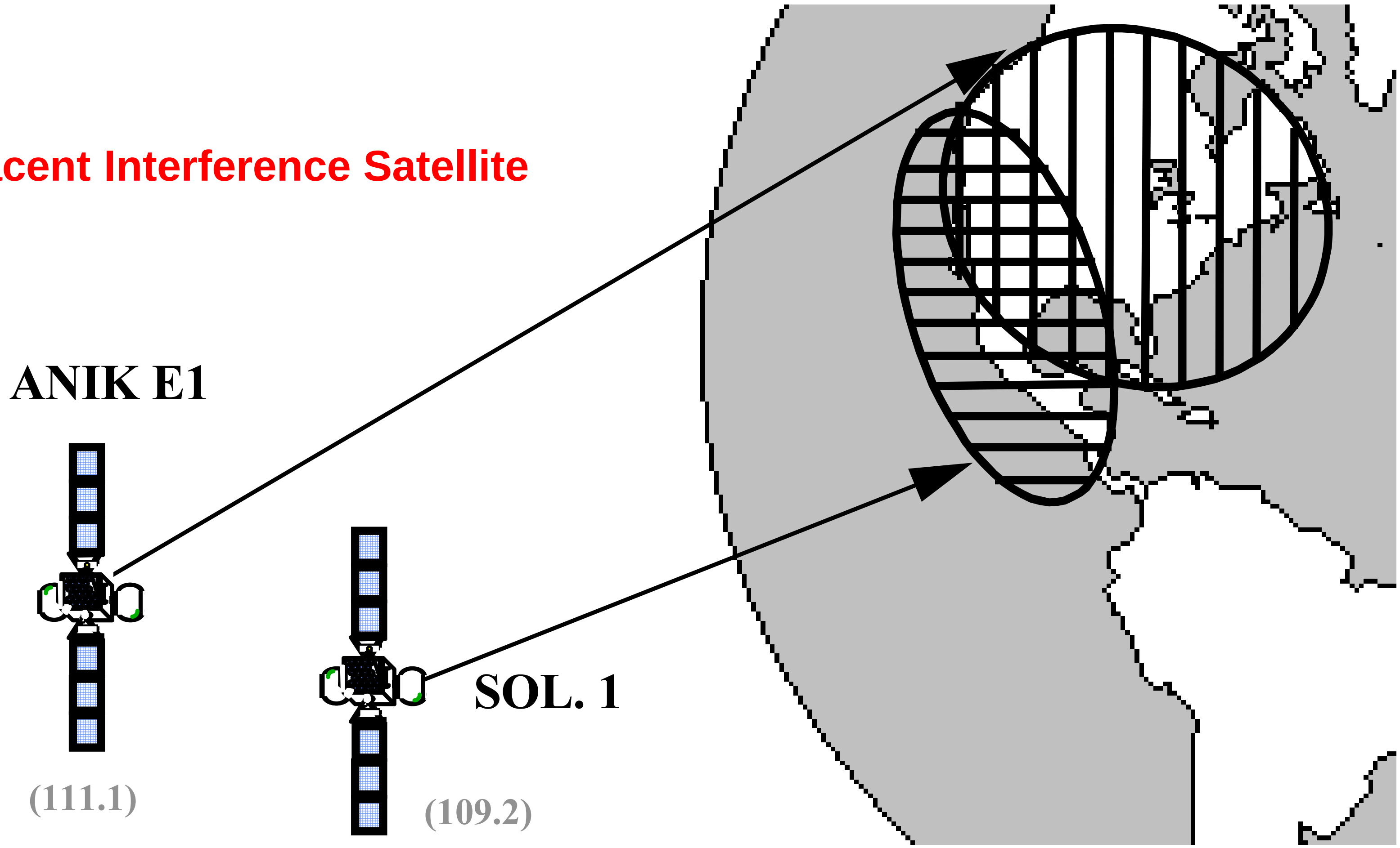
C/X Satady = 27.77 dB

$$\left(C/N\right)_{ASCTOTAL} = 10\log\left[\frac{1}{\frac{1}{a\log\left(23.21/10\right)}+\frac{1}{a\log\left(23.77/10\right)}+\frac{1}{a\log\left(30.27/10\right)}+\frac{1}{a\log\left(27.77/10\right)}}\right]$$

(C/N) ASC TOTAL = 19.36 dB

DOWN LINK

Adjacent Interference Satellite



CARRIER TO NOISE DENSITY RATIO DOWN LINK

(C/No)desc = EIRPSAT + (G/T)E/T - K - Ls desc - μ desc - LΔ desc

Donde:

EIRPSAT	=	EIRP of satellite for carrier
(G/T)E/T	=	Earth station Rx
K	=	Boltzman Constant = -228.6 (dBJ/ºK)
Ls desc	=	Free Space Losses (Downlink)
μ desc	=	Rain atenuation Margin, uplink
L Δ desc	=	Other losses, it is the summatory of athmospheric losses, pointing and polarization losses and is approximately 0,8dB

replacing:

μ desc = 0, For 99.98 availability in C band

SATELLITE EIRP

EIRPSAT = - SDFTX - ATP + IBO - Lp asc + EIRPE/T - OBO + PIRESATU(RX) - Latm

Where: SDFTX is the Saturation Density flow to locality Tx

EIRPSATU(RX) is the saturation EIRP to location Rx replacing:

$$EIRPSAT = -(-94.00) - 6 + 7.5 - 162.38 + 57.83 - 5.0 + 37.60 - 0.5$$

$$EIRPSAT = 23.05 \text{ dBW}$$

FREE SPECE LOSSES (DOWNLINK) :

$$Ls\ desc = 20 \text{ Log } ((4p\ (4.160\ E9)(37567.88\ E3))/ 3\ E8)$$

$$Ls\ desc = 196.32 \text{ dB}$$

MERIT FIGURE OF THE MIAMI E/T

$$(G/T) = GRX - 10 \text{ LOG } (Ts)$$

$$Ts = T\ LNA + T\ ANTENNA = 65 + 24.99\ (K)$$

:

$$(G/T)E/T = 43.03 - 10 * \text{Log } (89.99)$$

$$(G/T)E/T = 23.49 \text{ dBºK}$$

replacing in (C/No)desc:

$$(C/No)desc = 23.05 + 23.49 - (-228.6) - 196.32 - 0.8$$

$$(C/No)desc = 78.02 \text{ dB-Hz}$$

CARRIER TO NOISE RATIO(DOWN LINK)

(C/N)desc = (C/No)desc - 10 Log (AB)

replacing:

(C/N)desc = (78.02) - 10 Log (3304.35 E3)

(C/N)desc = 12.82 dB

TOTAL CARRIER TO NOISE RATIO

$$\left(\frac{C}{N}\right)_{DESCTOTAL} = 10\log\left[\frac{1}{\frac{1}{a\log\left(\frac{C/Ndesc}{10}\right)}+\frac{1}{a\log\left(\frac{C/I}{10}\right)}+\frac{1}{a\log\left(\frac{C/Xpol}{10}\right)}+\frac{1}{a\log\left(\frac{C/Xsatady}{10}\right)}}\right]$$

Where:

C/I Intermodulation desc : C/I = - SAT INT - OPBO - 10 LOG(AB)

C/X Cross Polarization desc : C/X pol = - INTDESCPOL - OPBO - 10 LOG(AB)

C/X Adyacent Satellite desc: C/X satady = EIRPSAT -(INTDESSADY- GANT RX) -10 LOG(AB)

<u>OPBO CARRIES</u>

OPBO = MOBO - MIBO + IPBO

replacing:

OPBO = 5.0 - 7.5 + 17.05

OPBO = 14.55 dB

<u>C/I INTERMODULATION DESCENDENT</u>

C/I Intermodulation = - (-97.2)- 14.55 – 65.19

C/I = 17.47 dB

C/X CROSS POLARIZATION DESCENDENT

C/X Cross Polarization = - (-107.5) – 14.55 – 65.19

C/X pol = 27.77 dB

C/X ADJACENT SATELLITE DESCENDENT

C/X Adyacente Satellite = 23.05 - (-15.00 – 43.03) - 65.19

C/X satady = 15.89 dB

replacing:

$$\left(C/N\right)_{DESCTOTAL} = 10\log\left[\frac{1}{\frac{1}{a\log\left(12.82/10\right)}+\frac{1}{a\log\left(17.47/10\right)}+\frac{1}{a\log\left(27.77/10\right)}+\frac{1}{a\log\left(15.89/10\right)}}\right]$$

(C/N) DESC TOTAL = 10.11 dB

Link Evaluation

TOTAL CARRIER TO NOISE RATIO

$$\left(\frac{C}{N}\right)_{TOTAL} = 10\log\left[\frac{1}{\dfrac{1}{a\log\left(\dfrac{\frac{C}{N}_{ASCTOTAL}}{10}\right)}+\dfrac{1}{a\log\left(\dfrac{\frac{C}{N}_{DESCTOTAL}}{10}\right)}}\right]$$

Replacing:

$$\left(\frac{C}{N}\right)_{TOTAL} = 10\log\left[\frac{1}{\dfrac{1}{a\log\left(\frac{19.36}{10}\right)}+\dfrac{1}{a\log\left(\frac{10.11}{10}\right)}}\right]$$

(C/N)TOTAL = 9.63 dB

CARRIER TO NOISE RATIO REQUIRED

(C/N)REQ. = Eb/No + 10 Log (Vel inf) - 10 Log (AB)

replacing:

(C/N)REQ. = 4.0 + 10 Log (4000 E3) - 10 Log (3304.35 E3)

(C/N)REQ = 4..83 dB

LINK MARGIN

ME = (C/N)TOTAL - (C/N)REQ.

replacing:

ME = 9.63 - 4.89

ME = 4.74 dB

PERCENTAGE OF POWER CONSUMPTION BY CARRIER IN THE SATELLITE

$$\% \, POT = \left[ALog \left\{ \left(\frac{EIRPSAT - EIRPSATU + OBO}{10} \right) \right\} \right] * 100$$

replacing:

$$\% \, POT = \left[ALog \left\{ \frac{(23.05 - 37.60 + 5)}{10} \right\} \right] * 100$$

$$\% \, POT = 11.1100 \; \%$$

POWER CONSUMPTION IN HPA

$$POTHPA = EIRPE/T - GTx + LHPA \; Y \; ANT$$

Replacing values:

$$POTHPA = 57.83 - 45.88 + 0.5$$

$$POTHPA = 12.45 \; dBW$$

In Watts:

$$POTHPA = ALOG(12.45 \; dBW / 10)$$

$$POTHPA = 17.58 \; W$$

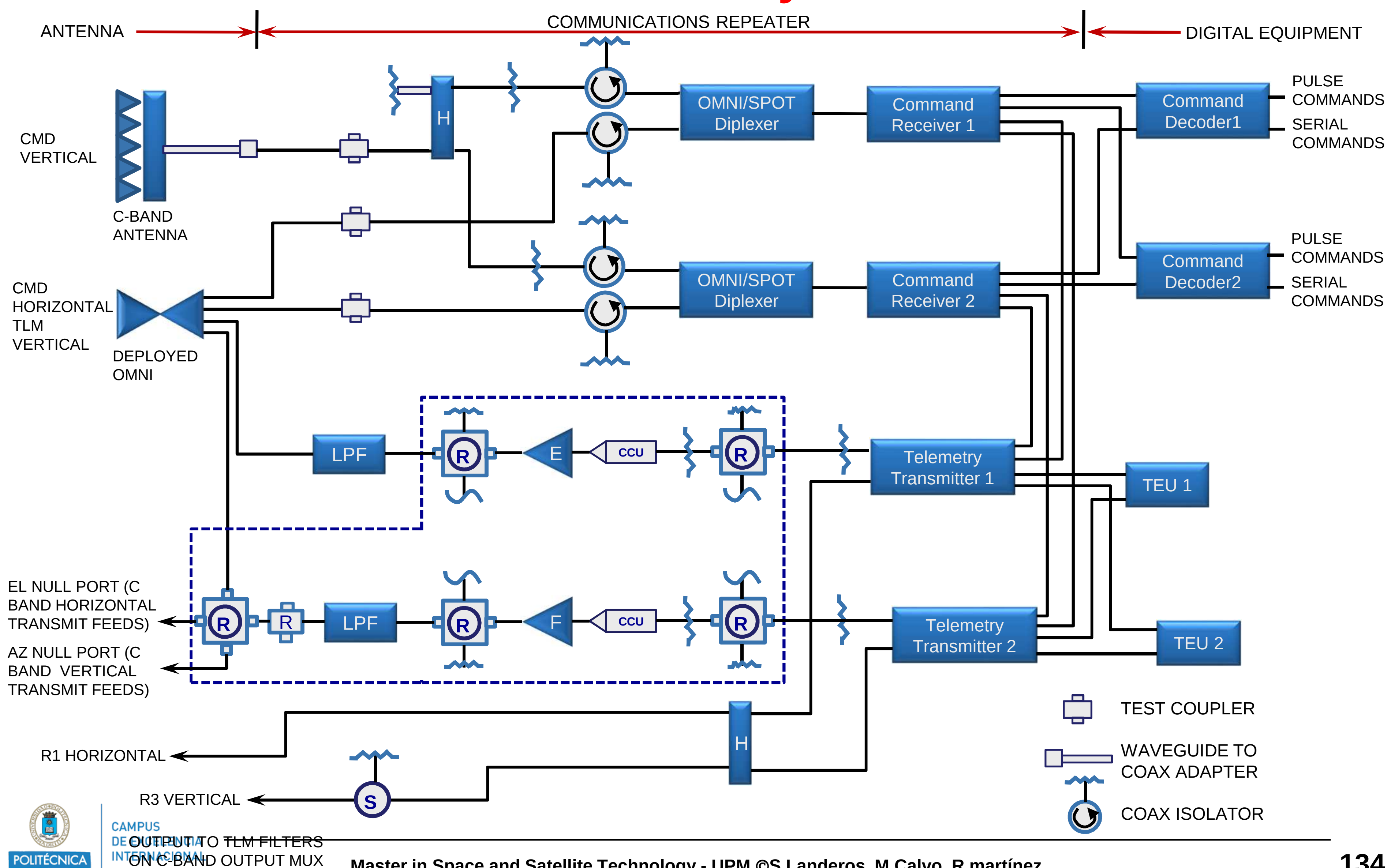
Master in Space and Satellite Technology

Topic 4: Subsystems solution

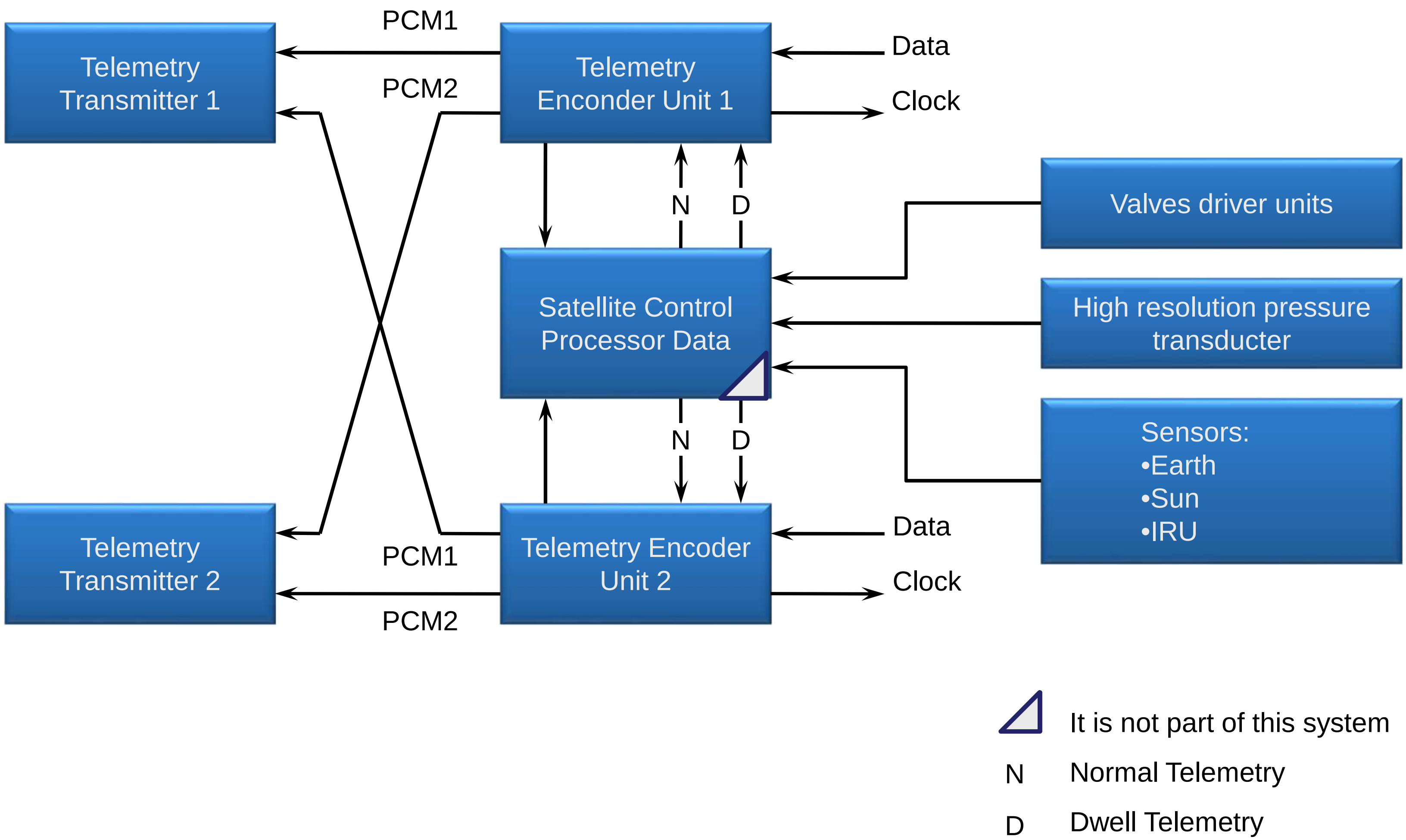
Telemetry, Tracking and Command

	Telemetry	Command	Tracking
Frequency	3701.1 MHz	5935 MHz for dish antenna	5943 MHz
Capacity	256 words for minor frame 32 minor frames for major frame 1 major frame every 65.5 seg	768 pulse commands 16 serials	
Polarization	For dish antenna: vertical For OMNI antenna: horizontal	For dish antenna: vertical For OMNI antenna: horizontal	
EIRP	10 dBw for dish antenna	-	-
Technique	-	-	Transponder range
accuracy	-	-	15 m

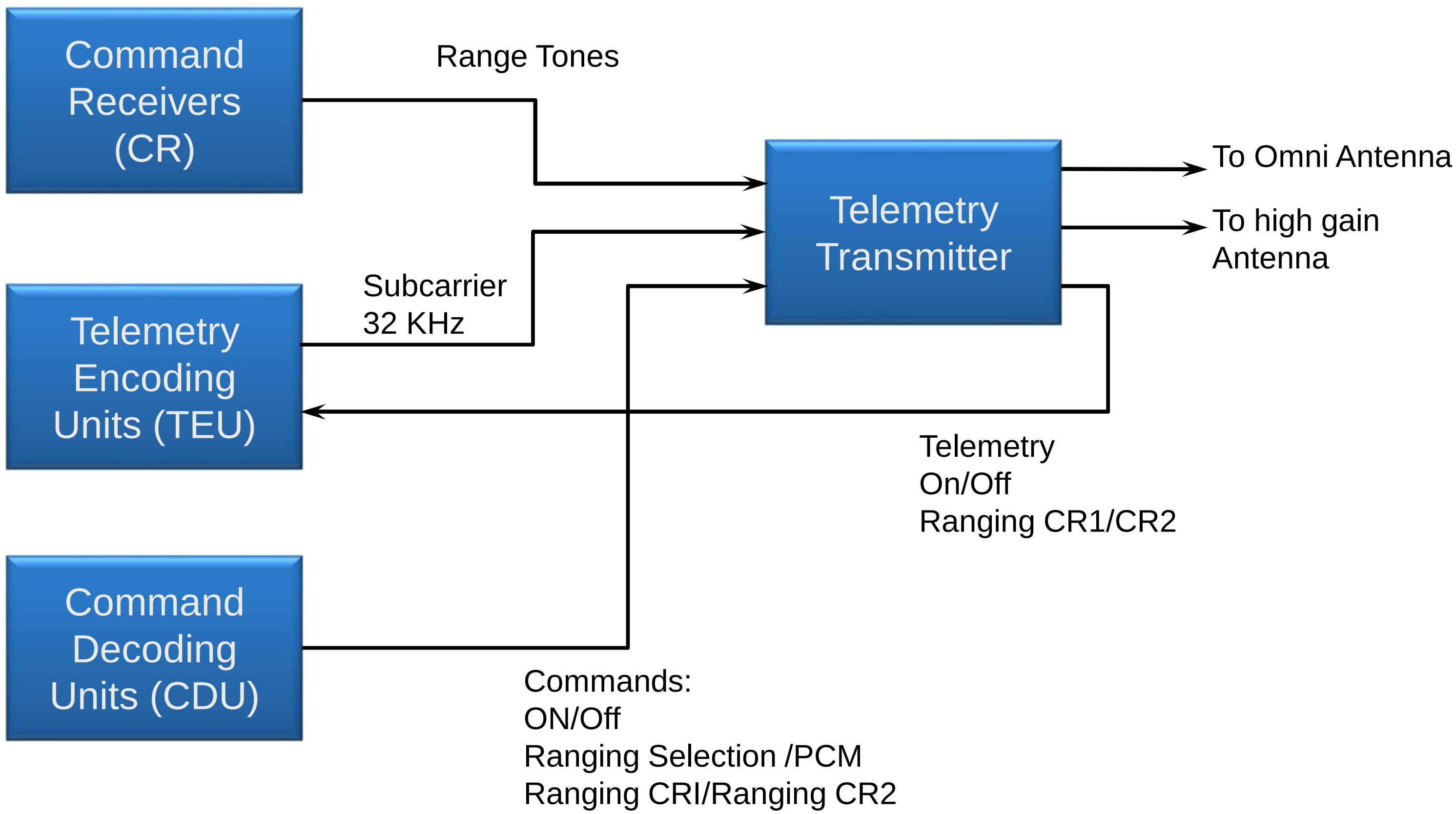
Telemetry, Tracking and Command Subsystem



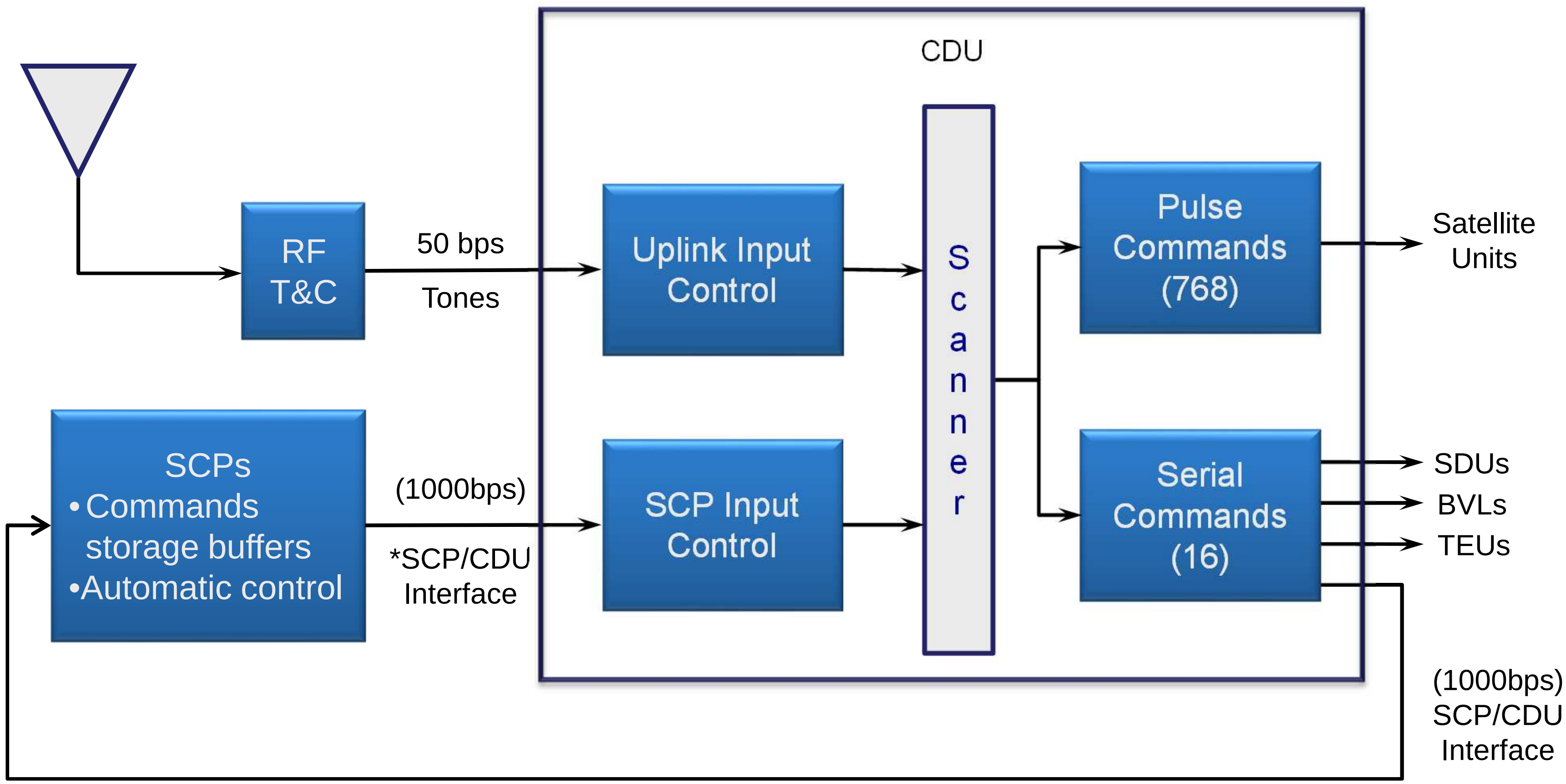
Telemetry Subsystem Block Diagram



Telemetry transmitter Input/Output interfaces



Command Simplified Block Diagram



* It is fitted out from earth by a command when only one the SCP's is turn on.

Telemetry, Tracking and command subsystem

Telemetry, Tracking and Command	
Telemetry	
Frequency	3700.1 to 3701.1 MHz
Modulation index	1.0 ± 0.15 rad
PCM data	
Major frame rate	65.536 sec/frame
Minor frame rate	2.048 sec/frame
Minor frame length	256 words (8bits/word)
Subcarrier	32 kHz, phase modulated
Capacity	256 channels
Bilevel (digital)	69
Conditioned bilevel	9
Analog	108
Conditioned analog	62
Serial	8

Telemetry, Tracking and command subsystem (Cont.)

Polarization	
Transfer orbit and on-station (reflector)	Vertical command, horizontal telemetry
On-station (omni)	Horizontal command, vertical telemetry
EIRP	
Transfer/drift orbit	4.0 dBW (±20°)
On-station	10.0 dBW min
Command	
Frecuency range	6415 MHz (transfer orbit), 5935 MHZ (on-station)
Coverage	
Transfer orbit	±35°
On-station	Spot beam Mexico
Polarization	
Transfer orbit and on-station(reflector)	Horizontal
On station (omni)	Vertical
Capacity	768 pulse; 16 serial

Telemetry, Tracking and Command subsystem (Cont.)

Threshold flux density	
Transfer/drift orbit	-91.5 dBW/m^2
On-station	-93.9 dBW/m^2
Peak deviation	300 kHz
Format	RZ tone digital, sync tone
Tracking	
Transfer orbit	Via bicone antenna
On-station	Via reflector
Modulation index	1.0 ±0.15 rad
Peak deviation	300 kHz
Accuracy	15 m

Attitude Subsystem

- ***Attitude Processor :*** Managements and processes the information of all the units for the self- control of the satellite.

- ***Momentum Wheels :*** Provide attitude control in the three reference axis of the satellite (Roll, Pitch and Yaw)

- **Inertial reference unit**: 3-for-1 redundancy in pitch and roll
  2-for-1 redundancy in yaw

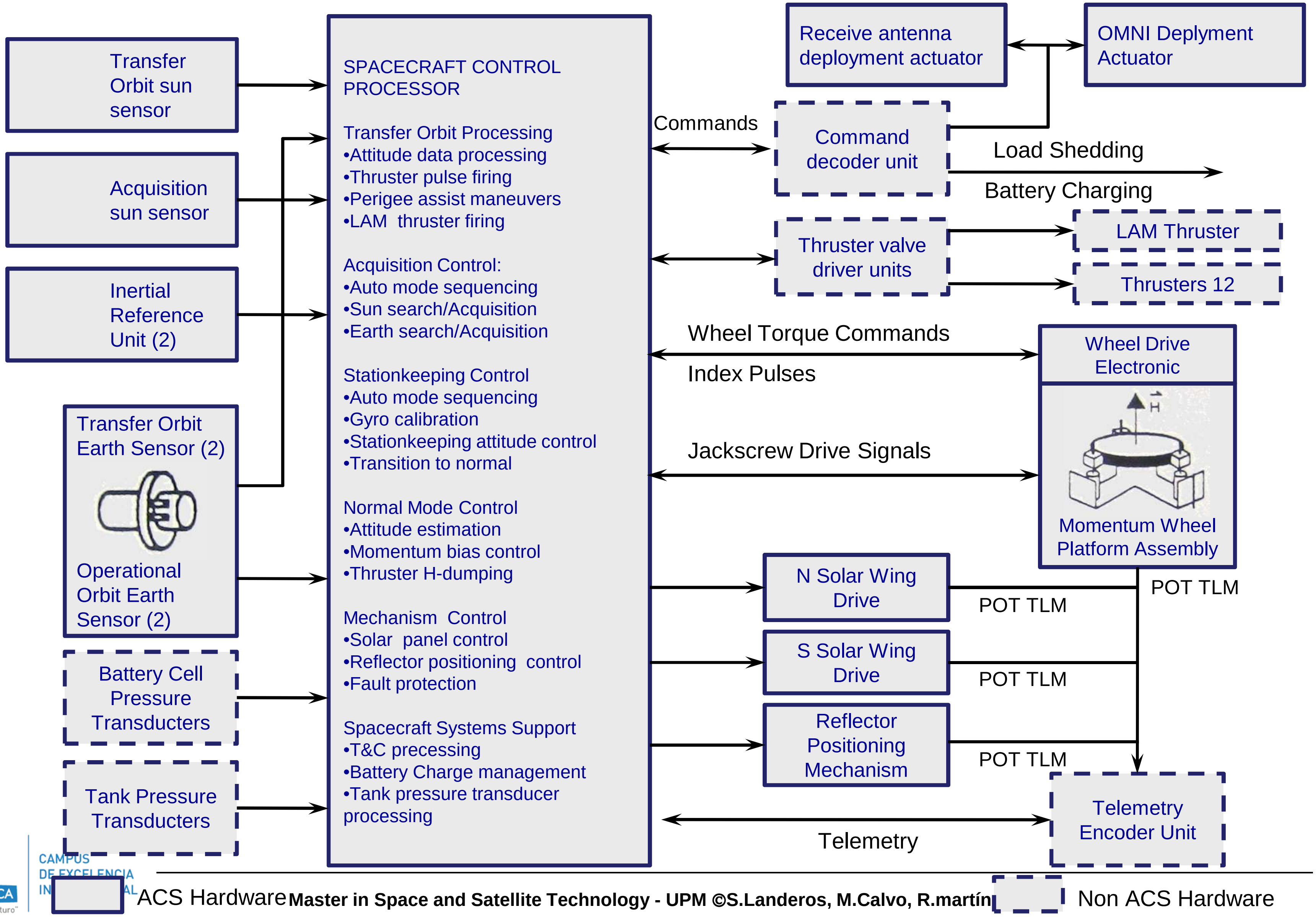
- ***Operation Range :*** /Pitch/ + /Roll/ < 0.4º

- ***Gyroscope:*** Measures the angular velocity in Roll, Pitch and Yaw.

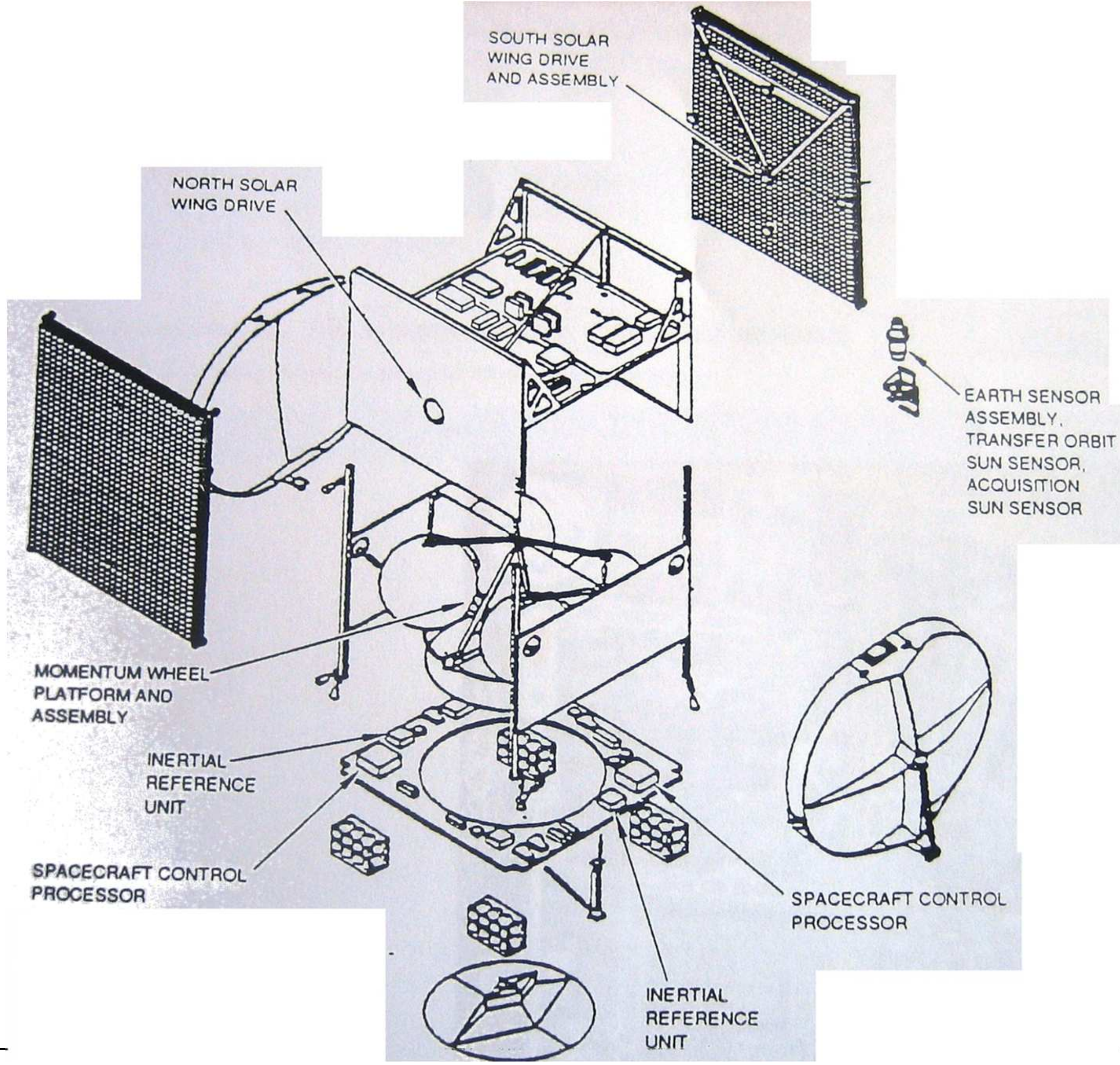
- ***Sun sensors:*** Silicon photovoltaic elements

- ***Earth Sensors:*** Detectors in the infrared

Attitude Control Subsystem Block Diagram



ACS Component Locations



Spacecraft Body Control Modes

Mode	Sensors	Actuators	Phase / Configuration	Mode/Phase Function
Standby	None	None	Inactive, ground control	Default at turnon, or eq failure Ground mechanism control
Ascent	Transfer orbit sun sensor HCI earth sensors	Thrusters	Passive stable spin	Ground transfer orbit operations
Gyro pointing	3-axis IRU	Thrusters	Gyro rate configuration Rate Integrate gyro	Hold rate; IRU range high or low Hold rate and position; IRU low range
Sun pointing	Acquisition sun sensor Transfer orbit sun sensor 3-axis IRU	Thrusters	Pitch sun acquisition Yaw sun acquisition Sun hold	Search for sun in pitch Search for sun in yaw Hold sun pointing
Earth pointing	Static earth sensor 3-axis IRU	Thrusters	Earth search Capture Lockon Earth hold	Around roll to find earth Center earth in FOV Null earth sensor errors Hold nadir pointing
Normal	Static earth sensor	MWA, MWP. SWD	Capture Steady state	Rapid capture entering Normal mode >99% of operational life
Momentum dump	Static earth sensor	As Normal mode plus thrusters	Pitch dump Roll/yaw dump	Dump pitch momentum Dump roll/yaw momentum
Station keeping	3-axis IRU Static earth sensor	Thursters		Attitude Control during maneuvers
Transition	Static earth sensor 3-axis IRU	Thrusters MWA, MWP	Thruster Whell	Reduce rates for wheel capture Reduce rates before Normal mode

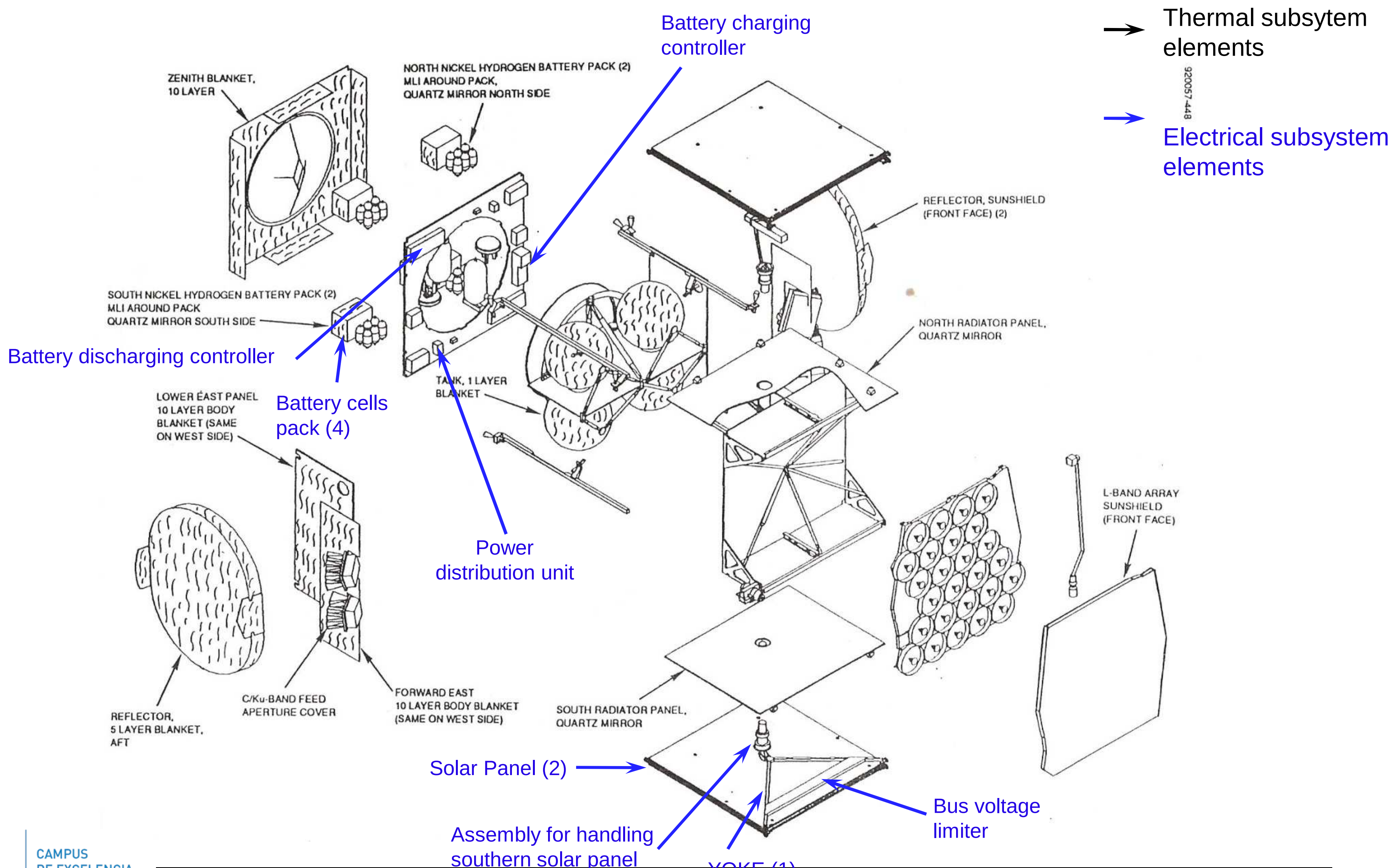
Electrical subsystem

Electrical Power		
System		Single regulated bus
	Solar cel array type efficiency	High
	Cells	Thickness
	Total array power	
	On-station (EOL)	
	Jun solstice	3156 W
	Sep equinox	3370 W
	Battery system	1 nickel-hydrogen battery
	Capacity	160 A-hr (EOL)
	DOD, EOL	70% max
	Recharge time at EOL	< 16 hr

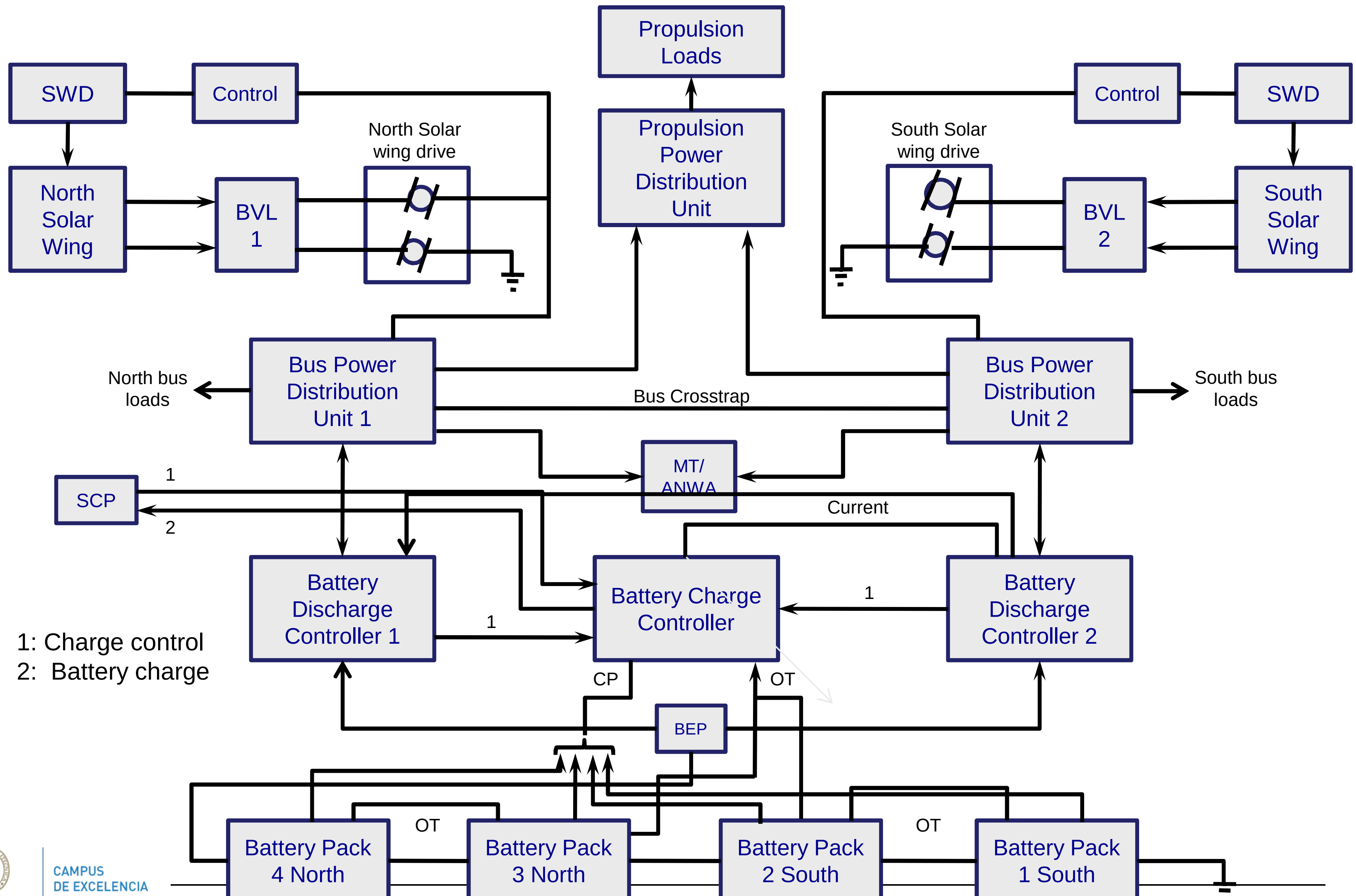
Electrical Power Subsystem Key Features

Purpose	Provide regulated power to all active payload and bus units
Operational phases	Transfer orbit On station Sunligth operation Eclipse operation
Requirements	Maintain tightly regulated bus voltage Provide sufficient current for nominal loads Provide additional current for transient loads Provide fusing for units loads Provide commandable switched power Provide current/voltage telemetry

Thermal and Electrical design elements



Power Subsystem Block Diagram

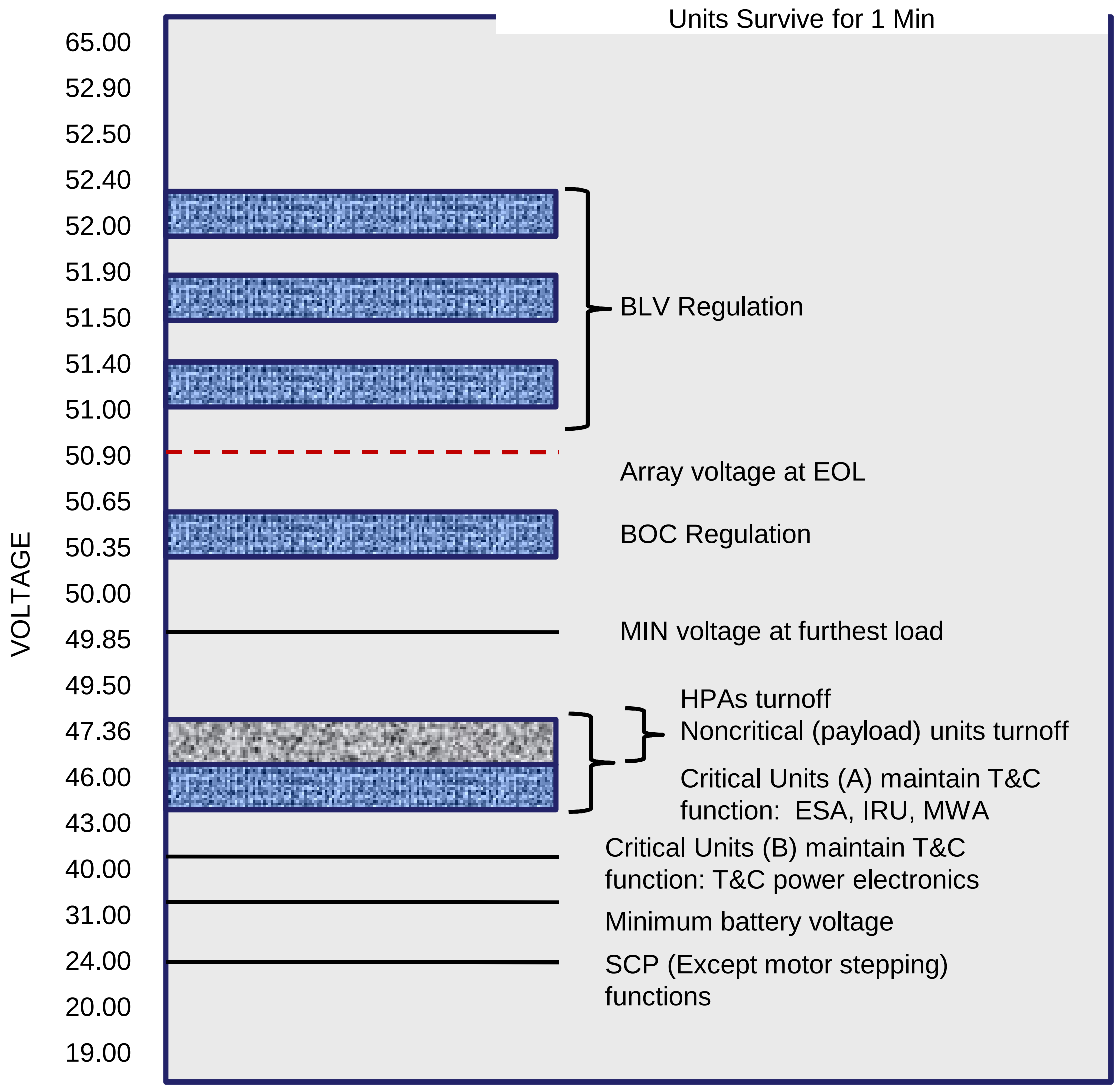


1: Charge control
2: Battery charge

Electrical Power Subsystem Performance Characteristics

Bus voltage regulation range	51.0 to 52.4 V	
Sunlight	50.35 to 50.65 V	
Eclipse	49.85 V	
Minimum bus voltage at farthest load	2 three panel deployable wings	
Solar array power at 50.9V (nominal temp) ±5℃	BOL	14 Yr
21 Jun solstice	3674 W	3156 W
21 Sep equinox	4083 W	3370 W
Solar array power margin	BOL	14 Yr
21 Jun solstice	692 W	206 W
21 Sep equinox	742 W	61 W
Battery	Single nickel-hydrogen battery	
Number of cells	27	
Capacity	160 A-hr (EOL)	
Average eclipse voltage	33.5 V (EOL)	
Cell bypass	Thermostatically actuated relays for open circuit cell protection	
Depth of discharge	BOL	14 Yr
All cells good	66.6%	66.9%
One cell failed	69.5%	69.8%
Two cells failed	72.6%	73.0%
Battey discharge controller	Constant power boost regulator Internally redundant units	
Number of units	2 per spacecraft	
Efficiency	94%	
Bus voltage limiter	Full shunt switching regulators Solar wing yoke mounted Provides shunted current telemetry	
Battery charge control	Regulated constant cuurrent power Provides battery pressure telemetry	
Charge rates available	0.8, 8.0, 13.0 A	
Efficiency at high rate	95.0%	
Efficiency at trickle	80.0%	

Key Bus Voltages

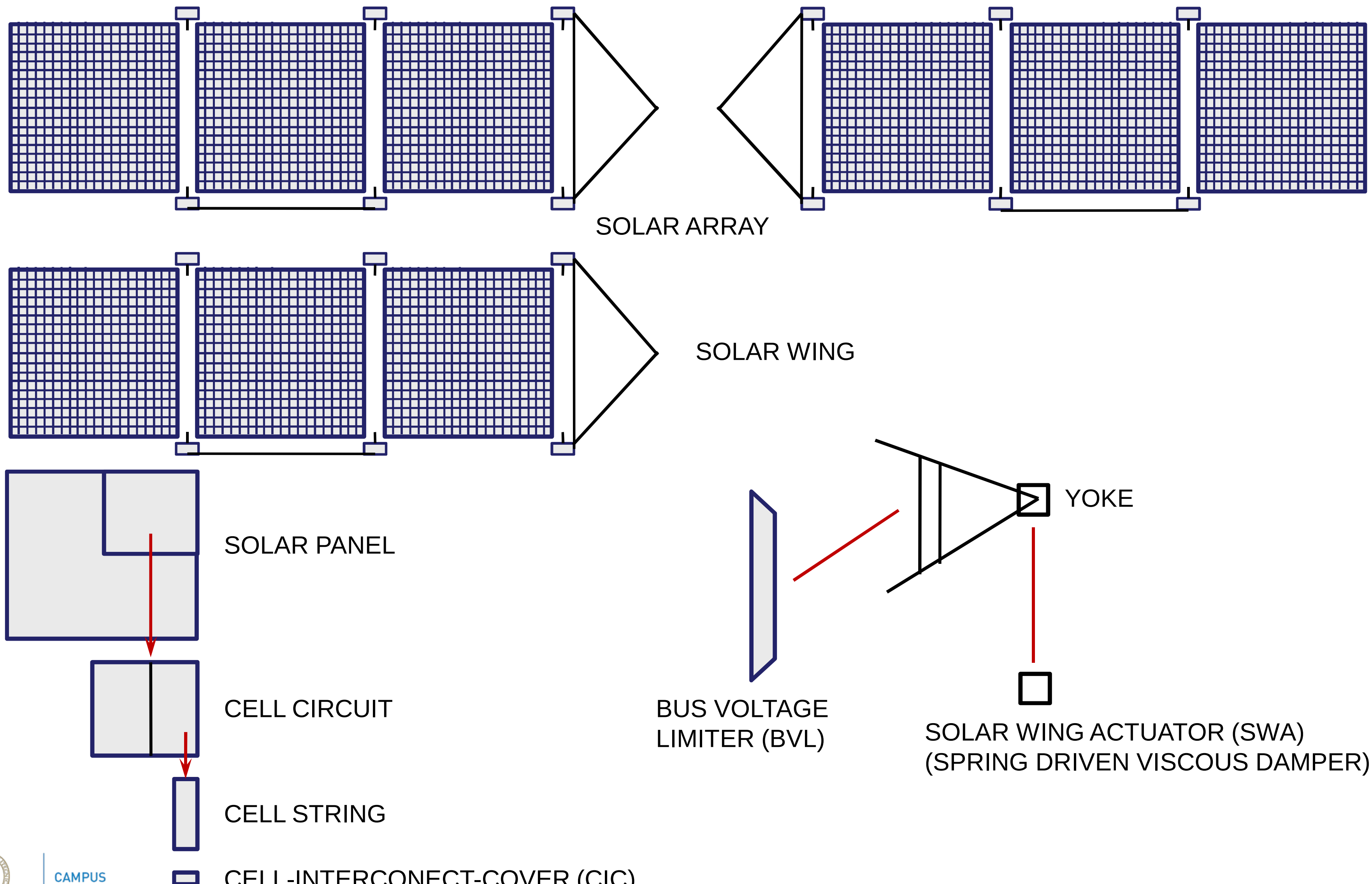


On station end of life power budget

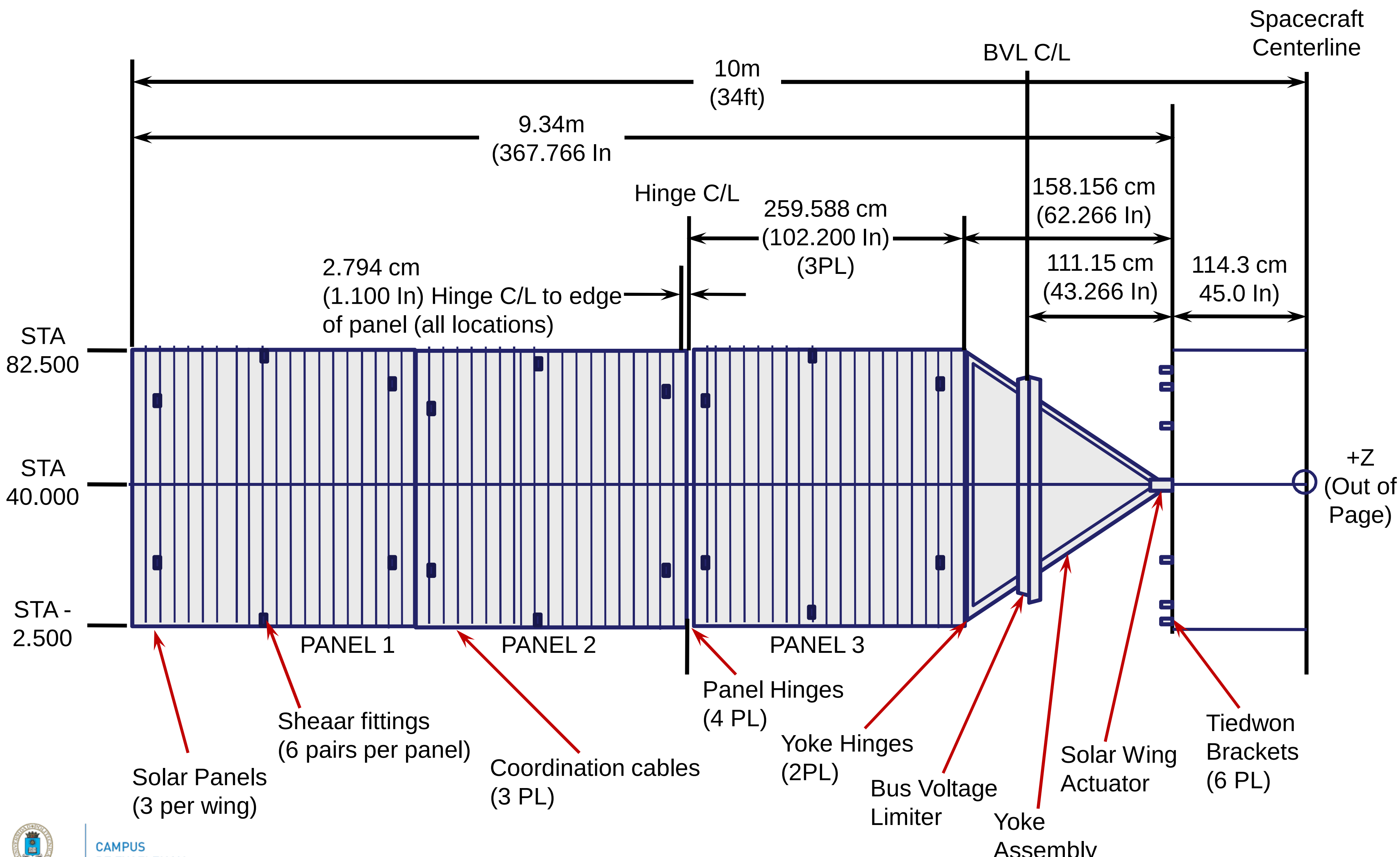
Item	Jun. Solstice	Sep. Equinox	Eclipse
a) Payload			
Repeater			
C-band	656	656	656
Ku-Band	1370	1370	1356
L-Band	421	421	421
T&C	54	54	54
Attitude control	46	46	46
Thermal	226	254	194
Power electronics	59	68	38
Battery charge	32	324	
Total loads (at 49.85 V)	2865	3194	2765

Subsystem/Unit	Active Units	Season		
		Jun. Solstice	Sep. Equinox	Eclipse
a) Bus				
T & C				
Decoders	2	13	13	13
Encoders	1	10	10	10
Squib driver	1	2	2	2
Valve driver units	2	0	0	0
T & C receivers	2	18	18	18
Telemetry transmiters	2	11	11	11
Subtotal		54	54	54
Attitude control				
SCP	1	22	22	22
Earth sensor		4	4	4
Momentum wheel		20	20	20
Subtotal		46	46	46
Thermal				
Thruster heaters		22	22	27
Line heaters		17	17	21
Battery heaters		28	56	0
Sensor suite heater		27	27	22
Reflector actuator heaters		0	0	0
SSPA/output multiplexer heater		112	112	112
LNA heater		12	12	12
ASWA heater		8	8	0
Subtotal		226	254	194
Power electronics				
Battery charge controller	1	8	17	6
Bus voltage limiters	2	8	8	8
BDCs	2	4	4	0
PDU current sensors	4	4	4	4
Heater controllers	46	20	20	20
Magnetic torquer		15	15	0
Subtotal		59	68	38

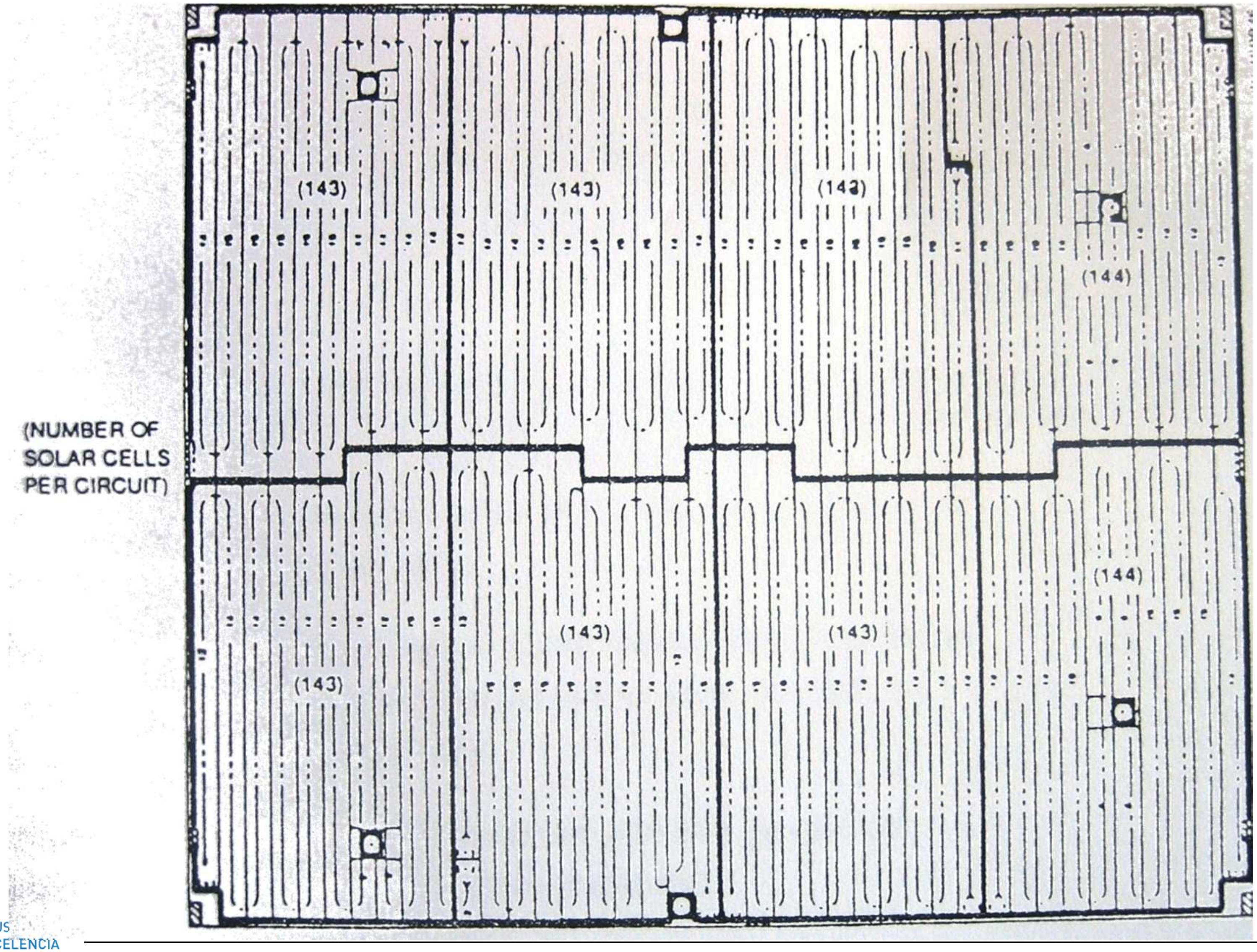
Solar Array Construction



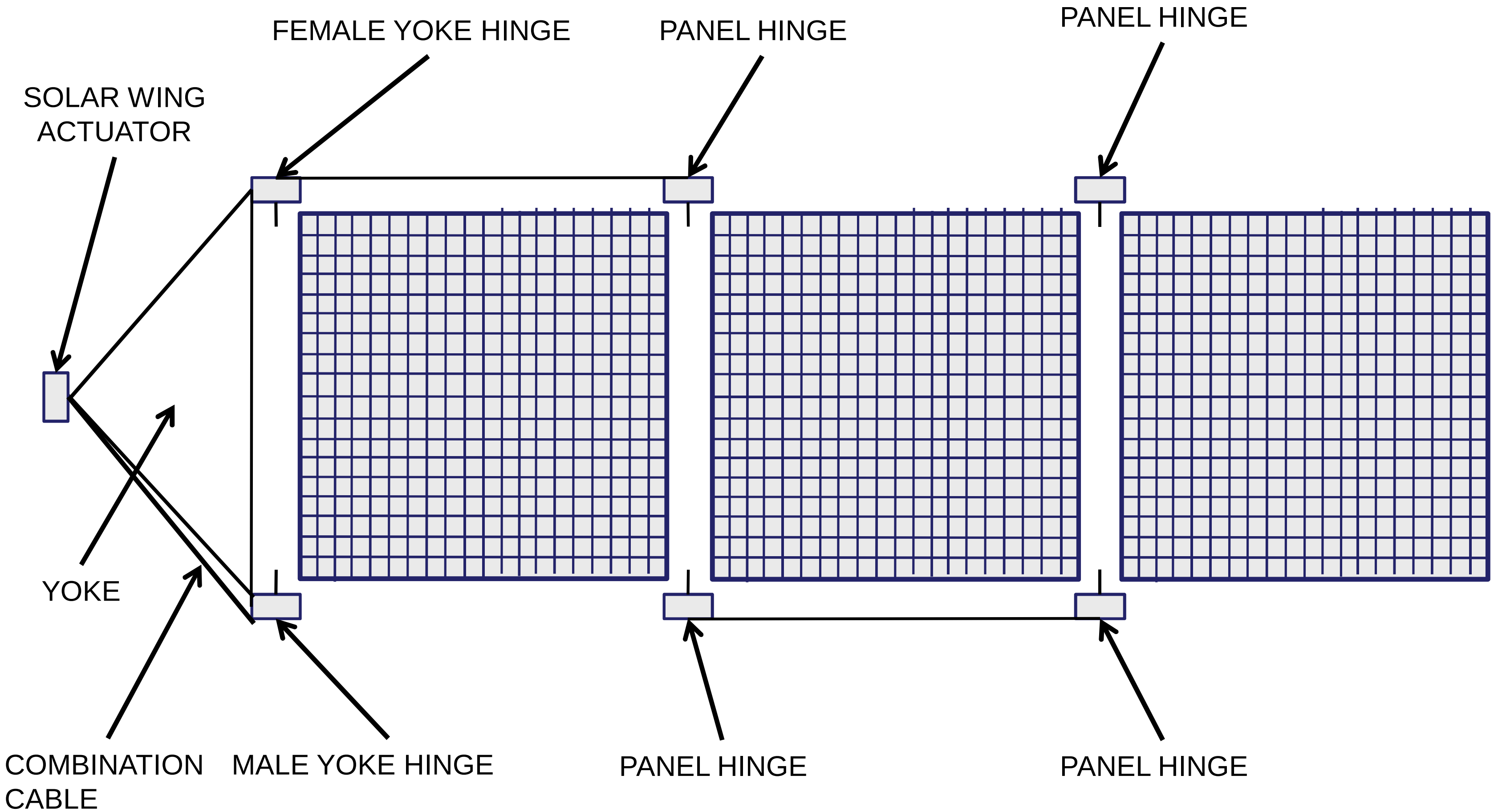
Deployed Solar Wing Dimensions



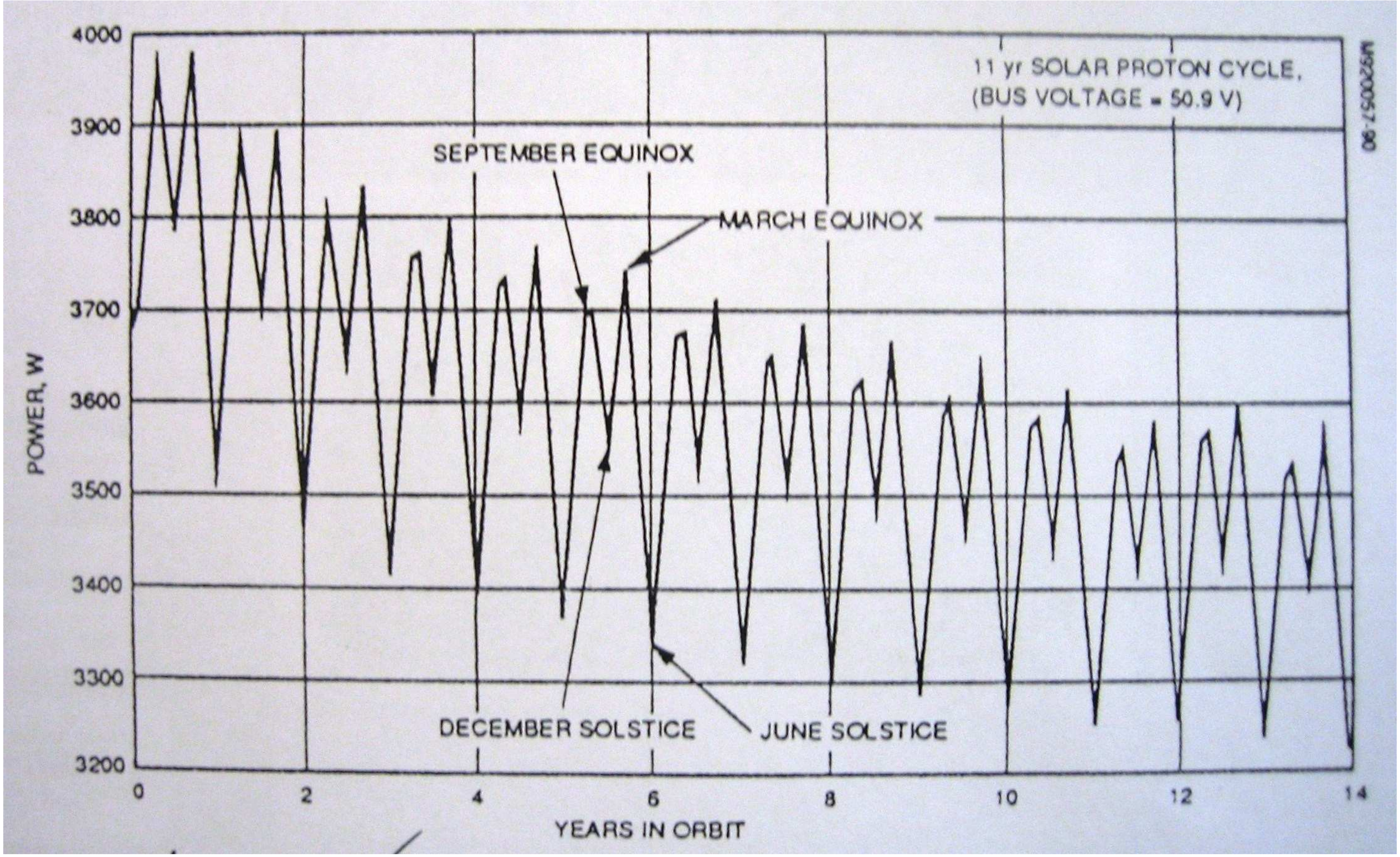
Typical Solar Panel Layout



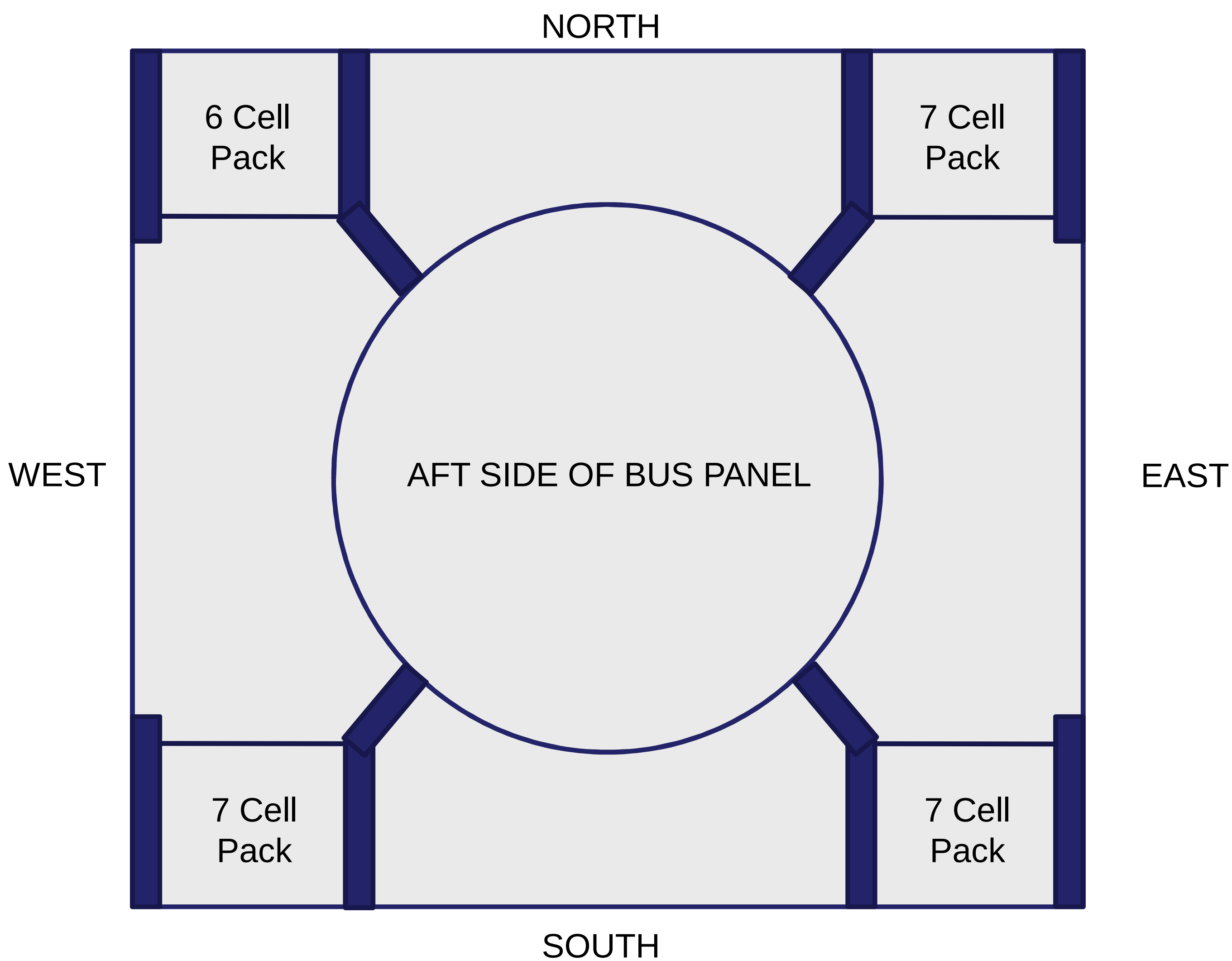
Solar Wing Deployment Mechanism



Predicted Solar Array Power Mission Profile



Battery Cell Location



All four packs mounted in standard (corner) position

Battery Parameters

Nameplate capacity	160 A-hr
Number of cells in series	27
Number of cells per pack	6, 7, 7, 7
Heater size	2 x 14 W maximum
Heater control	2 electronics thermostats
Mounting locations	
Northeast pack	Standard position
Northwest pack	Standard position
Southwest pack	Standard position
Southeast pack	Standard position

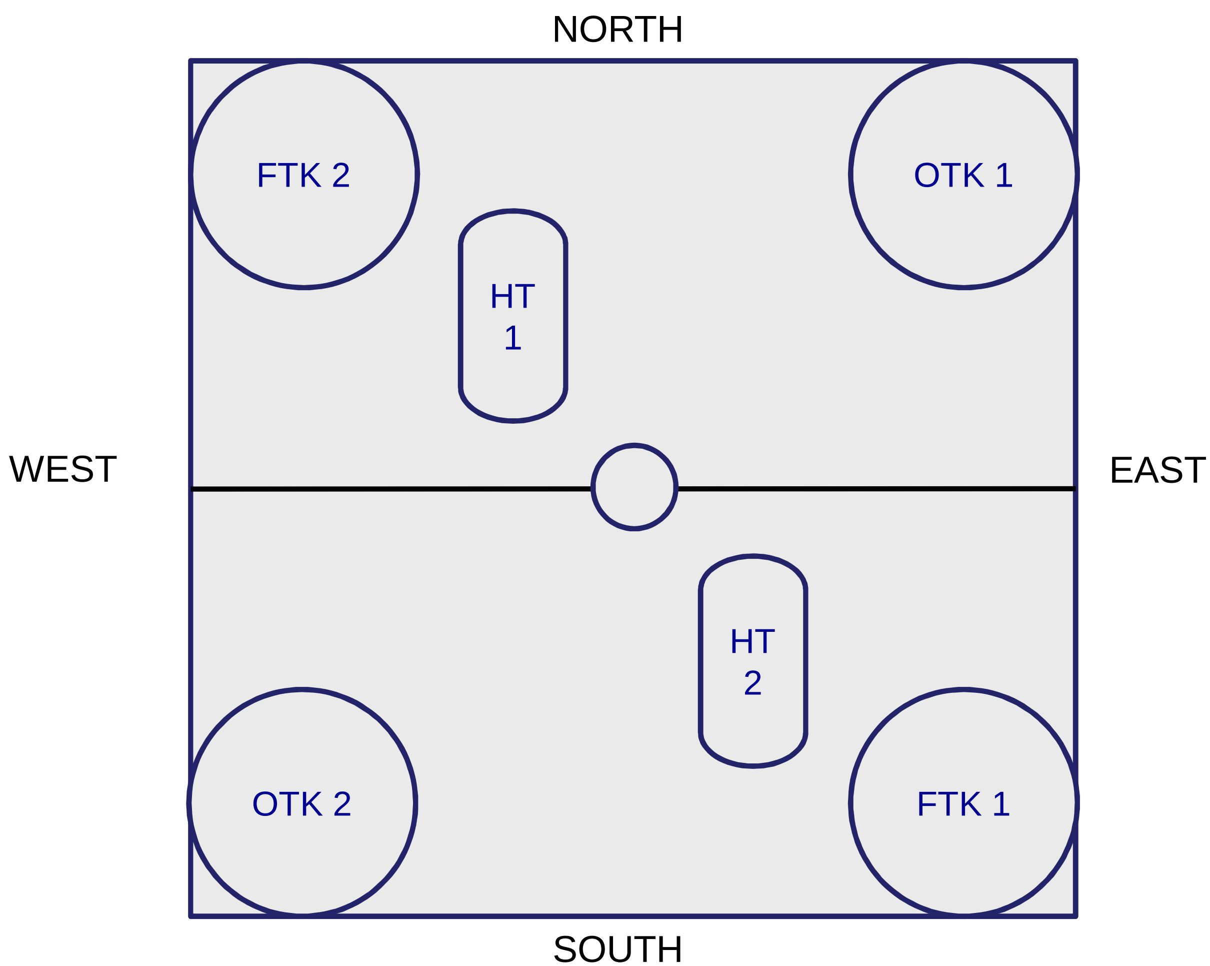
Propulsion Subsystem

- ***Thrusters:*** 12 thrusters with a thrust of 22 Nw with the following distribution:
  - 4 axials
  - 4 north-south
  - 4 east-west

- ***Helium tanks:*** 2 tanks of aluminum liner with graphite epoxy overwrap to support a maximum pressure of 4,200 psia and a capacity of 2650 In^3 min

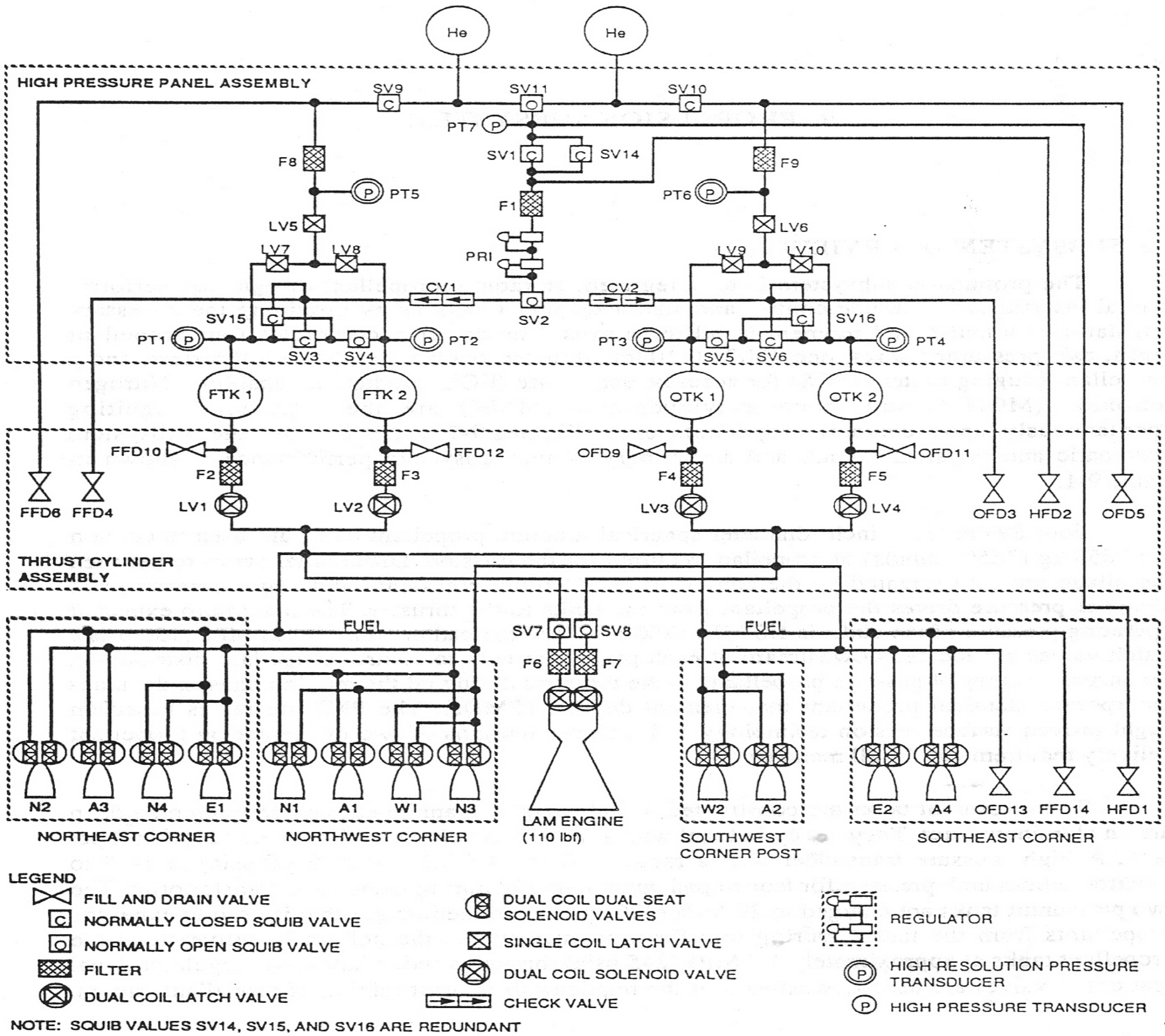
- ***Propellant tanks:*** 2 fuel tanks (monometyl hydrazine) and 2 oxidizer tanks (nitrogen tetroxide) to support a maximum pressure of 1,800Kpa and a capacity of 367,89 dm^3

Propulsion Subsystem Layout

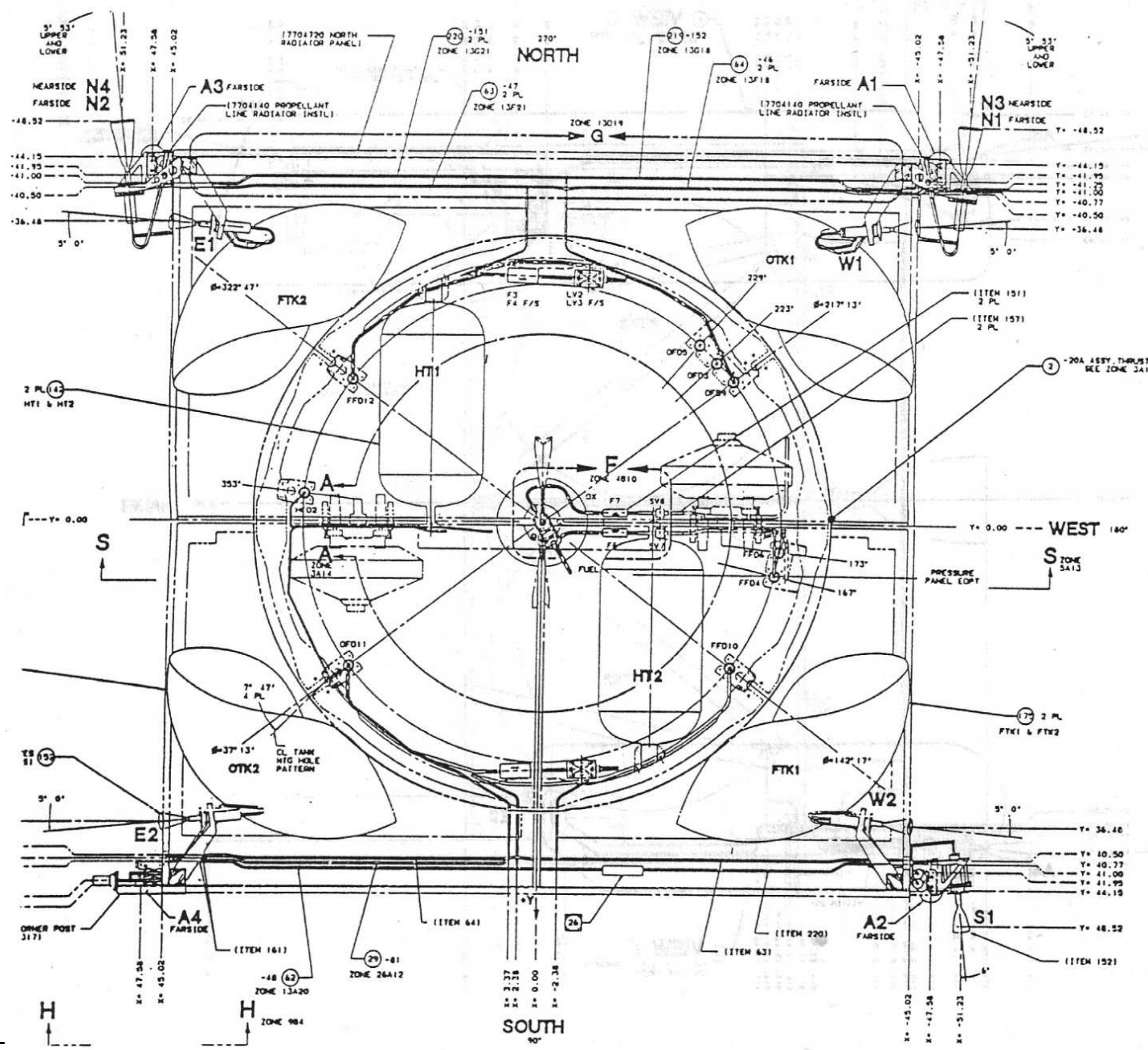


FTK=Fuel Tank   OTK=Oxidant Tank   HT=Helio Tank

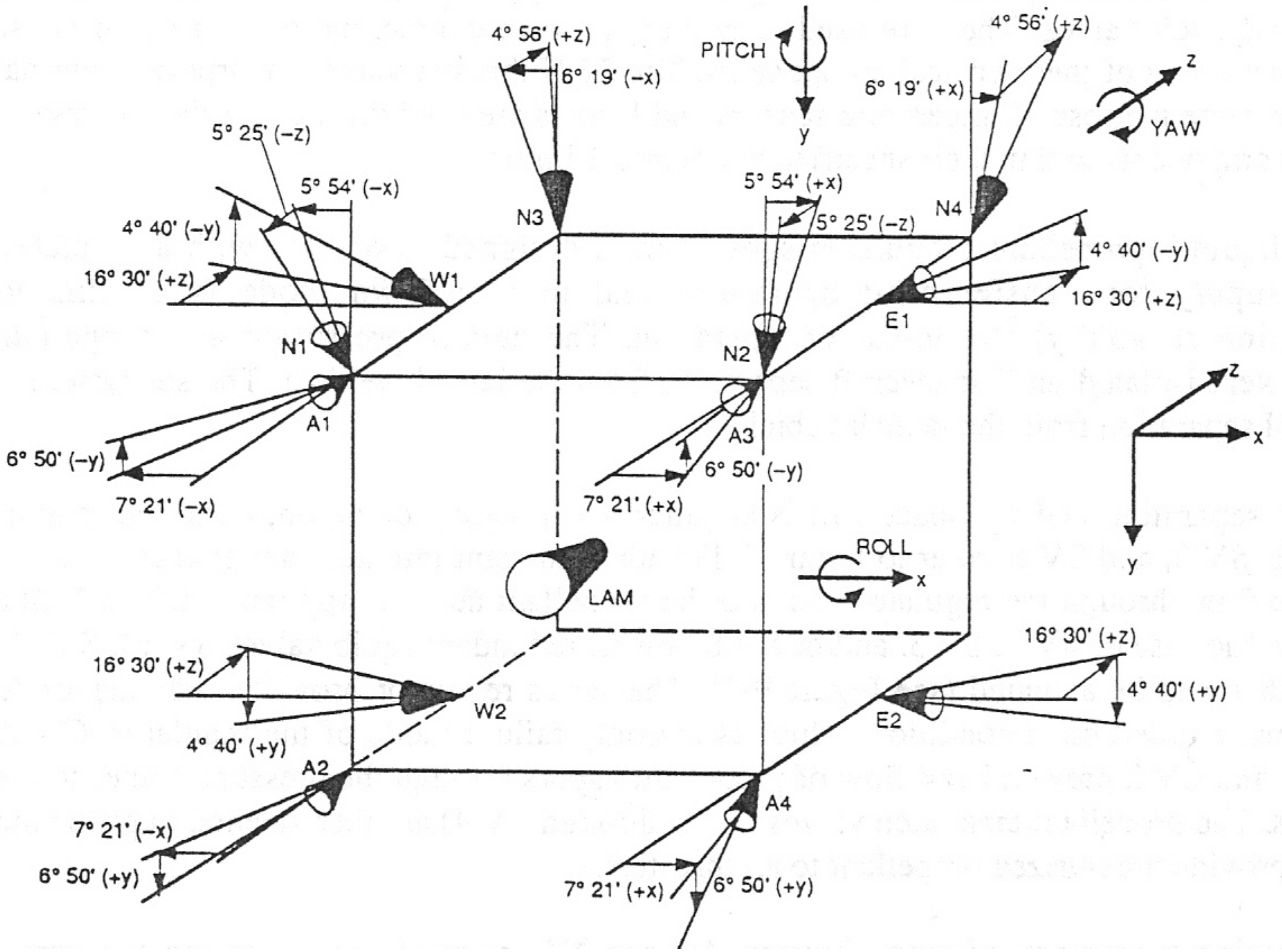
Propulsion Subsystem Schematic



Propulsion Subsystem Layout



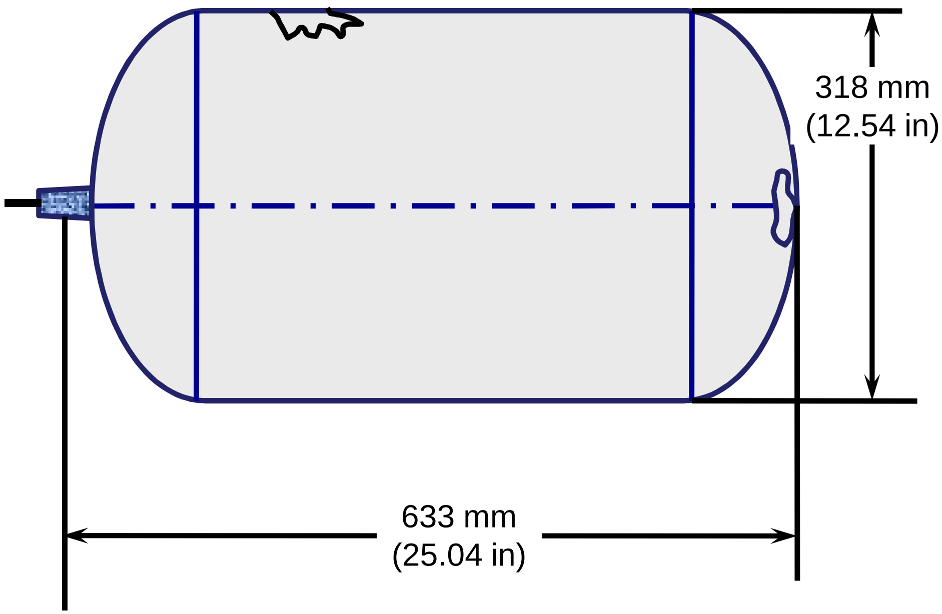
Thruster Configuration and Usage



Thruster Configuration and Usage (Cont.)

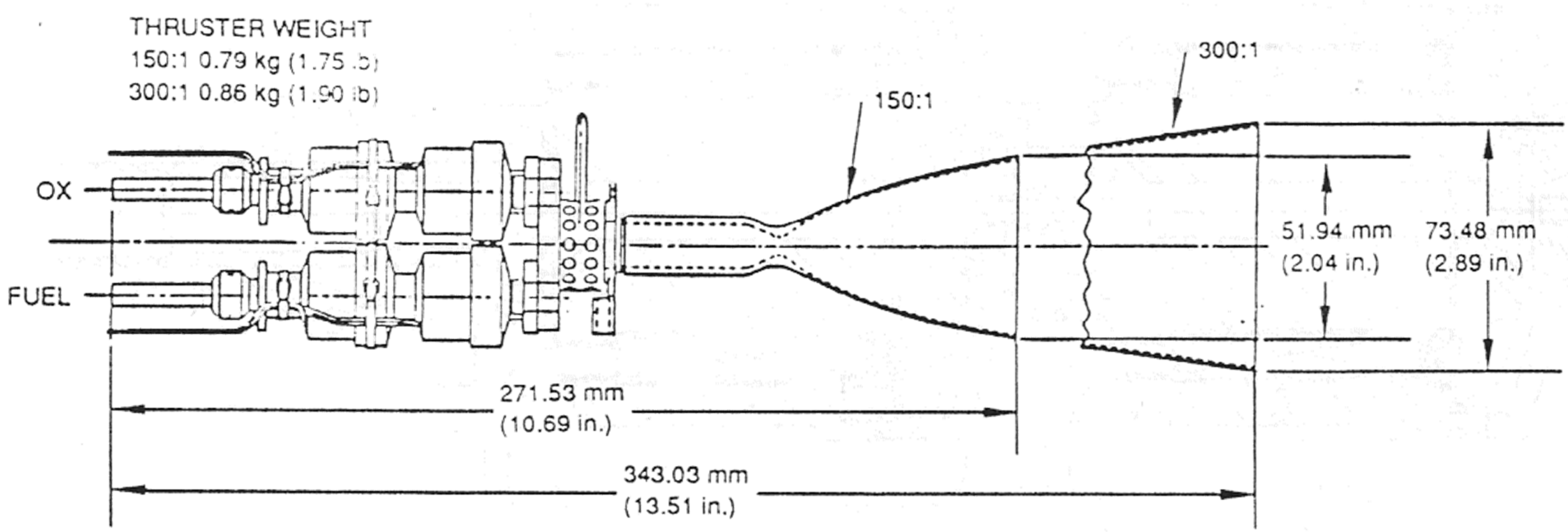
Torque or ΔV	Thruster Usage		
	Stationkeeping	**Non-Stationkeeping**	**Backup options for thruster failures**
+ ROLL	N1 + N2	A2 + A4	N2 + E1: N1 + W1: N2 + W2: N1 + E2
-ROLL	N3 + N4	A1 + A3	N4 + E1: N3 + W1: N4 + W2: N3 + E2
+ PITCH	A1 + A2	A1 + A2	A2+(N3+N4): A1+(N1+N2): A2+N4+E1: A1+N2+E1:…
-PITCH	A3 + A4	A3 + A4	A4+(N3+N4): A3+(N1+N2): A4+N4+E1: A3+N2+E1:…
+YAW	N2 + N4	E2	W1
-YAW	N1 + N3	E1	W2
SOUTH ΔV	N1 + N4	-	N2 + N3
EAST ΔV	W1 + W2	-	W1 + (N1 + N3): W2 (N2+N4)
WEST ΔV	E1 + E2		E1 + (N2 + N4): E2 + (N1 + N3)
SPINUP	-	N2 ≠ N4	N2: N4

Presurant Tank and Characteristics

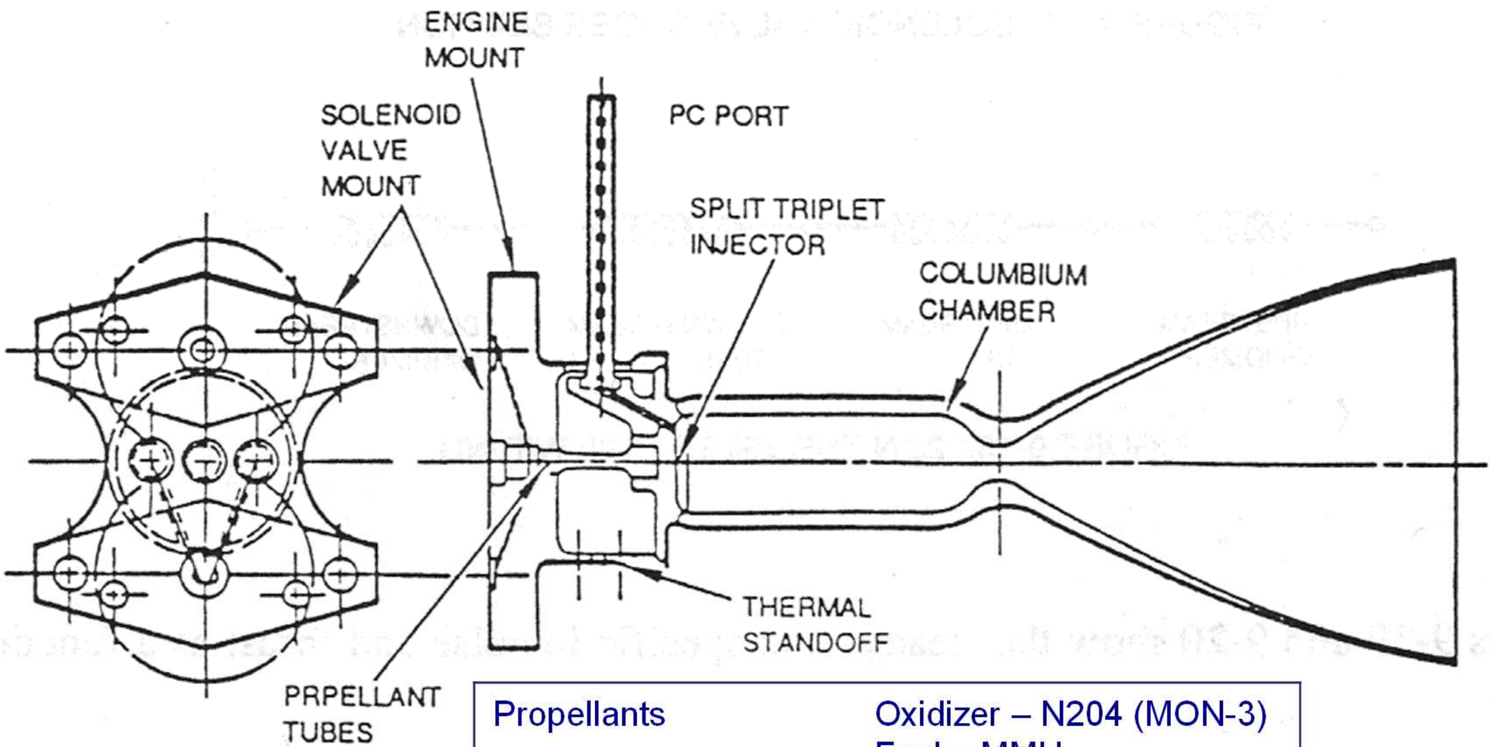


•Manufacturer:	Structural composites ind
•Safety Factor:	1.5 to 1
•Pressure range.	MPa
Operating	28.95 (4200psi)
Proof	36.19 (5250psi)
Burst	43.43 (6300psi)
•Temperature range	-65 to 60℃
	(-85 to 140℉)
•Volume	43.42 liter (2650 in)
•Weight	7.44kg (16.40 lb)
•Material	
Liner	6061 aluminum
Overwraps	Graphite/Carbon

Atlantic Research Corporation 22 N Thruster

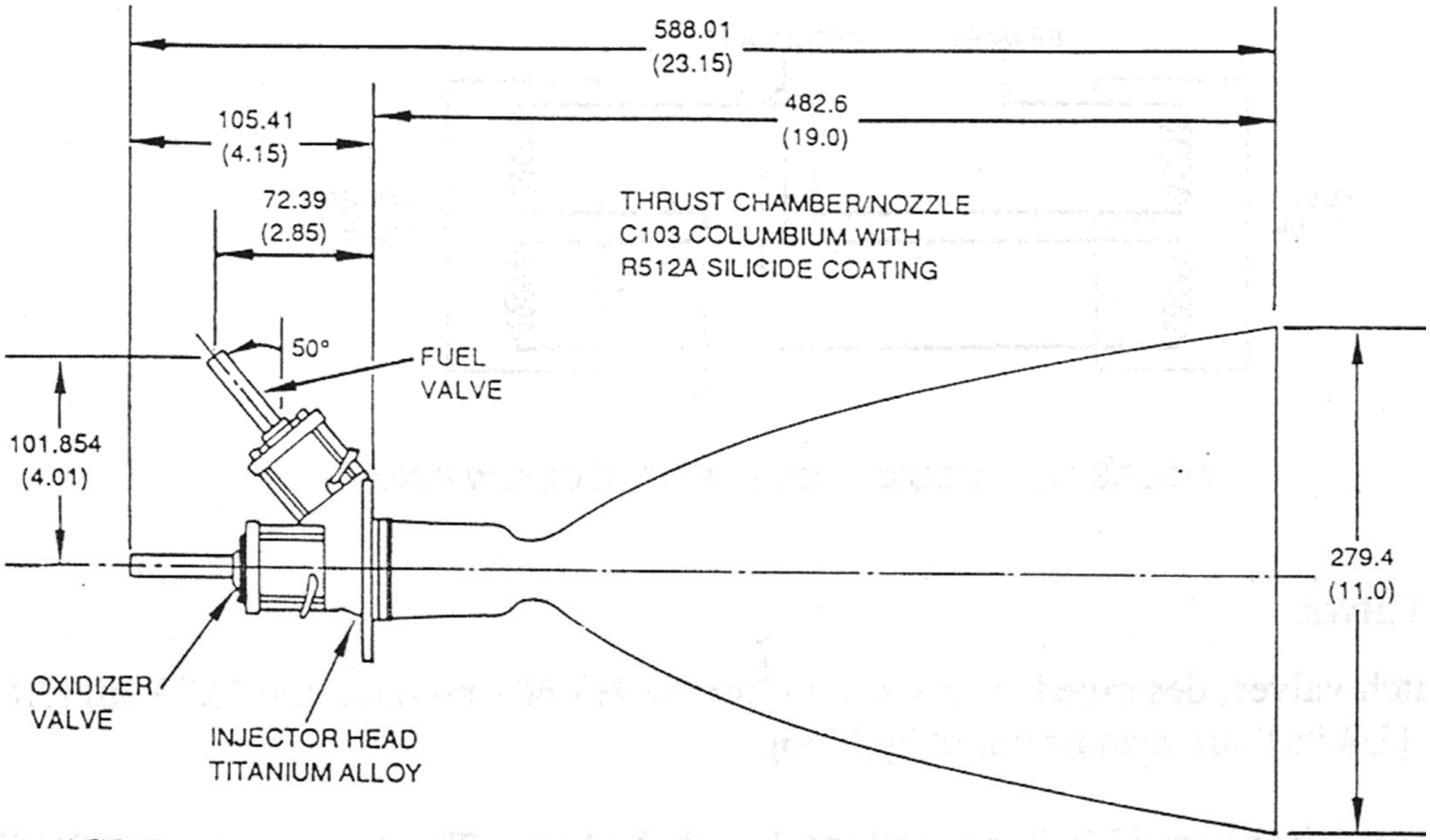


Atlantic Research Corporation 22 N Thruster (Cont.)



Propellants	Oxidizer – N204 (MON-3) Fuel – MMH
Feed pressure	1620 kPa (235 psid)
Thrust	22N (5.0 lbf)
Chamber Pressure	862 kPa (125 psid)
Mixture Ratio	1.65
Area Ratio	150:1, 300:1
Specific Impulse	285 sec, 290

Marquardt 490 N Thruster and Performance Data



- WEIGHT = 3.80 kg (8.38 lbm) INCLUDING 1219..2 mm (48 in.) OF CABLES
- DIMENSIONS IN MILLIMETERS (INCHES)

Thrust	492 ±5 N (110.6 ±1.1 lbf)
Isp	311 ± 1.2 sec
Mixture Ratio	1.625 ± 0.002
Combustor Temperature	1229 ± 20℃ (2245±36℉)

Thermal subsystem

- ***Heat pipes:*** They uniformly distribute the heat generated from the interior of the satellite.

- ***Heaters:*** They maintain in a pre-established level the temperature of certain units.

- ***Thermal blankets:*** Passive control of temperature of certain units using special covers.

- ***Mirrors:*** 2 radiators, one in the north face and another one in the south

HS 601 Mission Environments

Environment		*Nominal Value*
Transfer orbit		
	Solar radiation	1369 ± 50 W/m^2
	Earth albedo	0.3
	Earth IR	243 W/m^2
	Space sink temp	-273 ℃
	Attitude	Sun 60° to 115° from spin axis normal (except during maneuvers)
	Eclipse	Satellite spin stabilized (0.3 to 0.7 rpm) 72 min max
On orbit		
	Solar radiation	1369 ± 50 W/m^2
	Space sink temp	-273℃
	Orbit	Geosynchronous
	Attitude	Orbit normal – 3 axis stabilized
	Sun Angle	23.5 max out of orbit plane
	Eclipse	72 min max

Thermal Control Finish Requirements

Suface Area	Chosen Finish	Solar ABS BOL/EOL	Infrared Emittance	Other Requirements
External				
N-S radiators	Ag/quartz mirror*	0.08/0.24	0.80	Indium coat plus Ni edge coat (ESD)
E-W MLI	Black/Kapton	0.90/0.90	0.85	ITO (ESD), PIM
Nadir MLI	Kapton		0.53	
Aft barrier MLI	ITO Kapton	0.36/0.59	0.53	
LAM plume shield	Sperex VHT white	0.40/0.70	0.85	
LAM light shield	Sperex VHT white	0.40/0.70	0.85	
SWD VCM barrier	Conductive Keviar	0.95/0.95	0.91	
SWD housing	Black painted Be	0.95/0.95	0.83	ESD
Solar wing yoke MLI	ITO/Kapton	0.36/0.59	0.53	
Solar Array	Solar cells	0.74/0.74	0.83	
BVL radiator	White	0.40/0.60	0.85	
MLI VCM barriers	Conductive Kevlar	0.95/0.95	0.91	
Launch locks	White painted aluminium	0.40/0.60	0.85	
Ku- band antenna sun shield	Ge/Kapton/VDA	0.42/0.60	0.65	ESD, E = 0.16 inside
L- band antenna sun shield	Ge/Kapton/black	0.55/0.66	0.72	ESD
Thruster shield	Sperex VHT black	0.95/0.95	0.85	
Earth sensor MLI	Black/Kapton	0.90/0.90	0.85	ESD, PIM
Earth sensor radiator	Ag/quartz mirror	0.80/0.24	0.80	
Battery MLI	ITO Kapton	0.36/0.59	0.65	
Feed array aperture cover	Ge/Kapton/VDA	0.42/0.60	0.65	ESD, E=0.16 inside

Thermal Control Finish Requirements (Cont.)

Suface Area	Chosen Finish	Solar ABS BOL/EOL	Infrared Emittance	Other Requirements
Line radiator	Ag/quartz mirror	0.80/0.24	0.80	
Type I MLI	Cond black/Kapton	0.90/0.90	0.85	
Type II MLI	ITO/Kapton	0.36/0.59	0.53	
Type III MLI	ITO/Kapton	0.36/0.59	0.53	
Type IV MLI	Kapton/VDA	0.36/0.59	0.53	
Type V MLI	Nickel foil	– / –	0.10	
Type VI MLI	Kapton VDA (2 sides)	– / –	0.16	
	Black painted Be	– / –		
Internal				
Structure	Conductive black	– / –	0.85	R<10^9 Ω, Z<10
Units	Conductive black	– / –	0.85	R<10^9 Ω, Z<10
MLI	VDA/Kapton	– / –	0.16	
Aft barrier shield	Nickel foil/quartz mat	– / –	0.10	
Thruster shield	Nickel foil/quartz mat	– / –	0.10	
Battery	Bare aluminium	– / –	0.10	
Earth sensor	Conductive black	– / –	0.85	R<10^9 Ω, Z<10
Propellant tank MLI	VDA/Kapton	– / –	0.16	
Helium tanks	Graphite	– / –	0.85	
Propulsion lines	Alumunium tape	– / –	0.10	
Propulsion componenets	Bare metal	– / –	0.10 to 0.15	
Thruster valves	Bare stainless steel	– / –	0.15	ESD, E=0.16 inside

Unit Thermal Control Finish Requirements

Subsystem Unit	*Surface Property*
C – Band	
Input coaxial cables	Bare copper
Test coupler, 6 GHz	Conductive black
Receive low pass filter	Conductive black *
LNA	Conductive black
Switch, coax 3/2	Conductive black
Hybrid, 6 GHz	Conductive black *
Receiver bandpass filter	Conductive black *
Receiver, 6/4 GHz	Conductive black
Input filter R2V	Low emittance
Input filter R1H	Low emittance
Input filter R1V	Low emittance
R-switch, coax	Conductive black
Switch drivers	Conductive black *
CCU	Conductive black
SSPA nonswitchable (14.4W)	Conductive black
SSPA power supply (14.4W)	Conductive black
SSPA switchable (10.3/16.0W)	Conductive black
SSPA power supply (10.3/16.0W)	Conductive black
R-switch waveguide 4 GHz	Conductive black
Variable power divider	Conductive black
Output multiplexer, 7 channels, horizontal	Conductive black
Output multiplexer, 5 channels, vertical, R2	Conductive black
Output multiplexer, 6 channels, vertical	Conductive black
Output multiplexer, 5 channels, vertical, R3	Conductive black
Receiver reject filter	Conductive black
Test coupler, 4 GHz	Conductive black
Output coaxial cables	Conductive black

* Permissible to leave unpainted.

Unit Thermal Control Finish Requirements (Cont.)

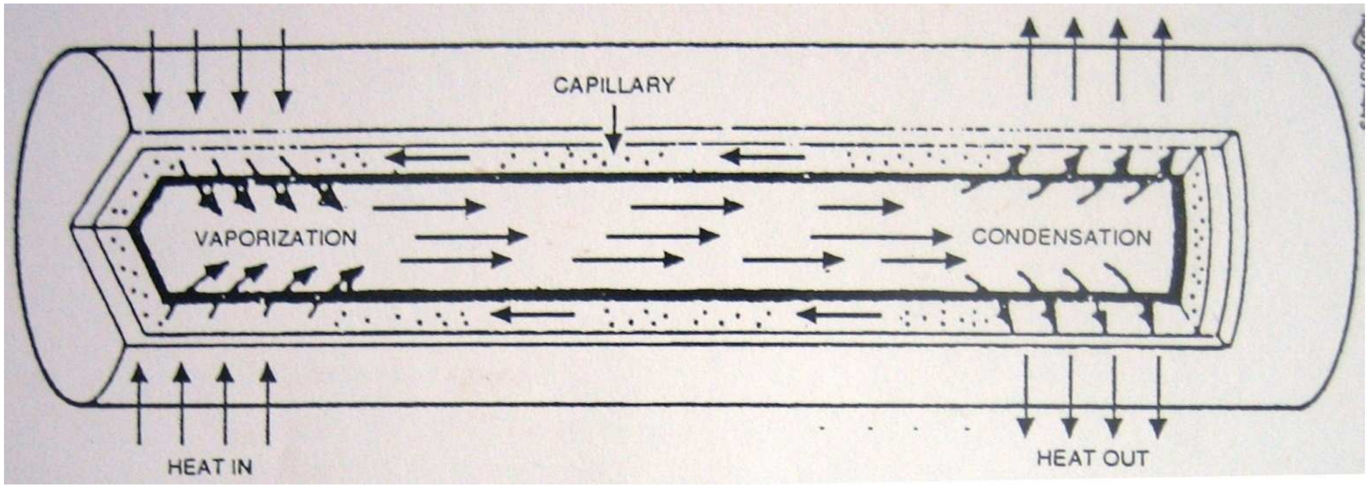
Subsystem Unit	*Surface Property*
Ku – Band	
Receiver bandpass filter (WR-75)	Conductive black *
LNA 14 GHz	Conductive black
Switch drivers	Conductive black *
Receiver, 14/12 GHz	Conductive black
Input filter channels 1,2,4,5,6,7,8	Low emittance (gold)
Input filter channels 9,10,11,12,14,15,16	Low emittance (gold)
CCU driver amplifier	Conductive black
Limiter / linearized	Conductive black
TWT (42.5 W)	Low emittance (Bare aluminium)
EPC (42.5 W)	Conductive black
R-switch waveguide 12 GHz	Conductive black
Output multiplexer, 8 channels, horizontal	Conductive black
Output multiplexer, 8 channels, vertical	Conductive black
Output multiplexer, 1 channel, U.S. port	Conductive black
Harmonic Filter	Conductive black
Isolator, output	Conductive black
Isolator, WR-75 (High power)	Conductive black
Notch filter	Conductive black
Test coupler, WR- 75GHz	Conductive black
Bacon transmitter (ULPC)	Conductive black

* Permissible to leave unpainted.

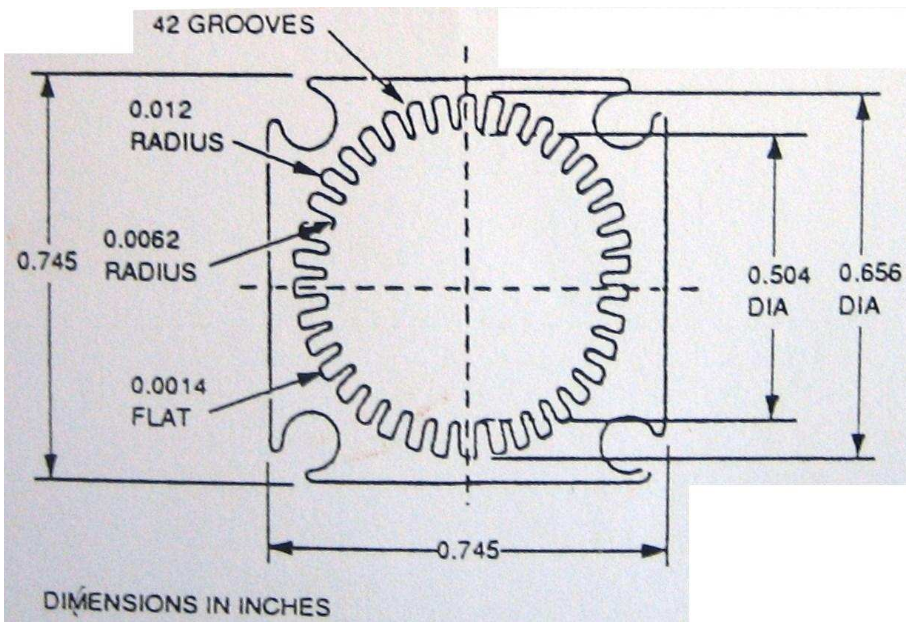
Thermal Control Design Issues and Elements

System/Subsystem	Design Issue	Thermal Control Element
Main body	Minimize solar heating due to diurnal solar impingement	East-west blankets Nadir-aft blankets Morrored north-south radiators (low solar absortance) Locate high dissipating units on radiators
High dissipating electronics	Reduce temperatures	Mirrored radiators Heat sinks/doublers Heat pipes High emittivity black paint
Batteries	Reduce upper temperatures Minimize lifetime operating temperature	Mirrored radiators Conductive brackets Heaters Blankets
Propulsion	Control low end temperatures to avoid frezing	Low emissivity aluminium tape Heaters Blankets
Antennas	Minimize upper temperatures Reduce operating temperature range	High emissivity black paint (internal reflectors) Sunshield (germanium coated Kapton exterior, gridded VDA interior)

Heat Pipes



CAPILLARY
VAPORIZATION
CONDENSATION
HEAT IN
HEAT OUT



42 GROOVES
0.012
RADIUS
0.0062
RADIUS
0.745
0.0014
FLAT
0.504
DIA
0.656
DIA
0.745
DIMENSIONS IN INCHES

Spacecraft Blanket Design

Blanket Location	No. of Layers	Blanket Type	Emmitance Inner/Outer*	Effective Through Emmitance	Outer Absorption BOL/ECL
Nadir blanket	10	MLI Kapton	0.85/0.85	0.010	
East-west sides	10	MLI Kapton	0.53/0.85	0.025	0.90/0.90
Battery packs	10	MLI Kapton	0.53/0.53	0.025	0.36/0.90
Aft barrier closeout	10	MLI Kapton	0.16/0.53	0.025	0.36/0.59
Thrust cylinder flat section closeout	9 layers +0.003 Al foil	MLI Kapton plus Kapton outer layer	0.16/0.53	0.025	0.36/0.59
490 N (110lbf) thruster shield (pyramid panel)	4 quartz / 5 foil	Nickel foil/quartz mat	0.10/0.85	0.002	0.40/0.70
Propellant tanks	1	Kapton	0.16/0.53	0.48	-
Interior of TWT radiator	3	Kapton	0.16/0.53	0.03	-
Reflector antenna blankets	5	MLI Kapton	0.16/0.65	0.015	0.36/0.59
Separation ring	1	Kapton	0.16/0.53	-	0.36/0.59
Deployable aft blanket	5	Kapton	0.16/0.53	0.060	0.36/0.59
Interior of L-band radiator aft of subnadir	1	Kapton	0.16/0.53	-	-

Spacecraft Blanket Configuration

Type	Description	Location
I	10 layer, carbon Kapton exterior	Battery, east-west launch locks, north-south internal porpellant lines along bus panel, propellant line radiators, sensor suite, 22N (5lbf) thrusters, antenna tripods.
II	Not used	-
III	5 layer, mylar, VDA on side	Aft deployable shield, solar panel yoke, bus voltage limiter
IV	1 layer, ITO Kapton exterior	TWT collector (aft subnadir), fordward SSPA radiator, entire fordware side subnadir shelf (decouplers subnadir from hot TWT zone) propellant tanks
V	Not used	-
VI	11 layer, ITO Kapton exterior with Kevlar separators	Aft closeout outside thrust cylinder, umbilical bracket closeout
VII	11 layer, nickel foil, quartz cloth	East-west thruster plume shields, LAM plume shield
VIII	11 layer, carbon Kapton exterior with internal aluminium foil	East-west side blankets
IX	12 layer, Kapton exterior with internal aluminium foil/Kevlar separators	Aft barrier closeout internal to thrust cylinder
X	10 layer, ITO Kapton exterior	Battery radiator frame, sensor suite radiator frame

Flight Temperature Sensors

Unit	Number
PAYLOAD	
Communication electronics	
C-band OMUX 4 plex even temp 2	
C-band OMUX 4 plex odd temp 1	
C-band OMUX 6 plex even temp 3	
C-band OMUX 6 plex odd temp 2	
C-band OMUX 6 plex temp 1	
C-band OMUX receiver 4	
C-band SSPA north panel temp 5 V	
C-band SSPA north panel temp 6 V	
C-band SSPA south panel temp 3 H	
C-band SSPA south panel temp 6 H	10
Ku-band EPC 6	
Ku-band EPC 15	
Ku-band LNA 1	
Ku-band OMUX filter temp 1	
Ku-band OMUX filter temp 2	
Ku-band receiver 2	
IF/Ku-band upconverter 1	
IF/Ku-band upconverter	
Ku-band/IF downconverter 1	
CCU/driver amplifier 6 Ku-band temp 2	
CCU/driver amplifier 15 Ku-band temp 1	11

Flight Temperature Sensors (Cont.)

Unit	Number
TWT north panel temp 2	
TWT north panel temp 6	
TWT south panel11	
TWT south panel temp 15	4
L-band LNA	
L-band output filter assembly	
L-band ref generator temp 1	
L-band ref generator temp 2	
L-band SSPA 1	
L-band SSPA 2	
L-band SSPA 3	
L-band SSPA 4	
L-band/IF downconverter	9
Command receiver 2 temp	
ULPC beacon 2	2
Total	36
BUS	
Telemetry	
Propulsion	
A1 thruster (primary = TEU 1)	
A1 thruster (redundant = TEU 2)	
A2 thruster (primary = TEU 1)	
A2 thruster (redundant = TEU 2)	
A3 thruster (primary = TEU 1)	
A3 thruster (redundant = TEU 2)	

Flight Temperature Sensors (Cont.)

Unit	*Number*
A4 thruster (primary = TEU 1)	
A4 thruster (redundant = TEU 2)	
E1 thruster (primary = TEU 1)	
E1 thruster (redundant = TEU 2)	
E2 thruster (primary = TEU 1)	
E2 thruster (redundant = TEU 2)	
N1 thruster (primary = TEU 1)	
N1 thruster (redundant = TEU 2)	
N2 thruster (primary = TEU 1)	
N2 thruster (redundant = TEU 2)	
N3 thruster (primary = TEU 1)	
N3 thruster (redundant = TEU 2)	
N4 thruster (primary = TEU 1)	
N4 thruster (redundant = TEU 2)	
W1 thruster (primary = TEU 1)	
W1 thruster (redundant = TEU 2)	
W2 thruster (primary = TEU 1)	
W2 thruster (redundant = TEU 2)	
Total	24
Fuel tank 1 temp 1	
Fuel tank 1 temp 2	
Fuel tank 1 temp 3	
Fuel tank 2 temp 1	
Fuel tank 2 temp 2	
Fuel tank 2 temp 3	
	6
Helium tank 1 temp 1 (TEU 1 only)	
Helium tank 1 temp 2 (TEU 2 only)	

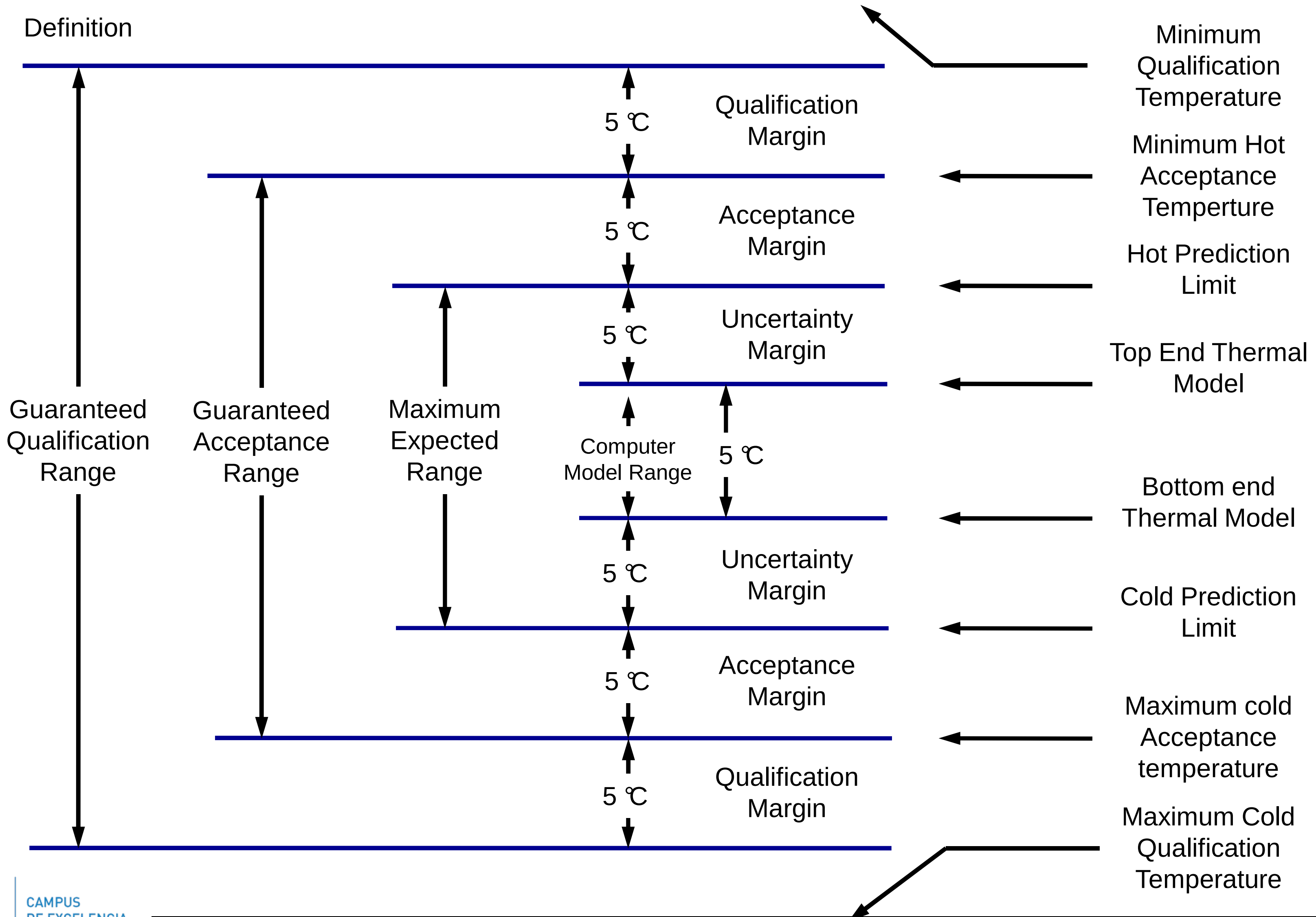
Flight Temperature Sensors (Cont.)

Unit	Number
Helium tank 2 temp 1	
Helium tank 2 temp 2	
High resolution pressure transducer 5 (helium 1)	
High resolution pressure transducer 6 (helium 2)	
	6
Oxidizer tank 1 temp 1	
Oxidizer tank 1 temp 2	
Oxidizer tank 1 temp 3	
Oxidizer tank 2 temp 1	
Oxidizer tank 2 temp 2	
Oxidizer tank 2 temp 3	
	6
LAM oxidizer valve	
LAM thruster	2
Propellant line 1 (southeast aft panel)	
Propellant line 1 (southeast bus panel)	
Propellant line 2 (norhwest aft panel)	
Propellant line 2 (northwest bus panel)	
Propellant line radiator northeast	
Propellant line radiator northwest	6
Total	25
Power	
Battery pack 1	
Battery pack 2	
Battery pack 3	
Battery pack 4	

Flight Temperature Sensors (Cont.)

Unit	Number
BDC 1	
BDC 2	
BVL 1 (splice to TEU 1/2)	
BVL 2(splice to TEU 1/2)	
Solar wing 1 north back splice to TEU 1/TEU 2	
Solar wing 2 south back splice to TEU 1/TEU 2	
SWD 1 (north) housing	
SWD 2 (south) housing	12
Attitude control	
ESA channel 1	
ESA channel 2	
IRU 1 gyro	
IRU 2 gyro	
MWA 1 (north) (primary = TEU 1)	
MWA 1 (north) (redundant = TEU 2)	
MWA 2 (south) (primary = TEU 1)	
MWA 2 (south) (redundant = TEU 2)	
SPC 1	9
Telemetry nad command	
VDU 1	
Transfer 1	2
Antenna	
RDA 1 (west C-band)	
RDA 2 (east Ku-band)	
East reflector RPM	
West reflector (back) (C-band)	
ODA	5
Total	28

Unit Qualification/Acceptance Temperatures



Expected Flight Temperature Limits

Subsystem / Unit	On-orbit Predicted Temperature, ℃		Qualification Limits, ℃		Unit Operating Survival Limits, ℃		Unit Nonoperating Survival Limits, ℃	
	Min	Max	Min	Max				
Communication electronics								
TWT	14	51	4	80	3	85	-20	85
SSPA	13	47	-3	57	-20	60	-20	85
EPCs	3	50	3	60	-18	71	-23	71
Communication receivers	17	43	3	54	-20	70	-20	85
Output multiplexer panels north, south	24	73	24	83	-20	99	-20	99
L/Ku-band upconverter	25	42	0	54	-20	70	-20	85
Antenna/feeds								
Reflectors east, west	-112	119	-125	138	-150	149	-150	149
Ku/band feeds	-38	117	-56	135	-65	140	-65	140
Power								
Solar wing north	-148	57	-181	79	-190	100	-190	100
Solar wing south	-148	57	-181	79	-190	100	-190	100
BVLs	-16	49	-39	75	-39	83	-39	83
Battery packs	-10	27	-15	37	-19	40	-19	40
BCDs	-2	51	-34	71	-34	71	-34	71
Telemetry and command								
TCR	21	46	2	56	-20	70	-20	70
VDU	4	31	-34	71	-34	71	-34	71
Telemetry transmitter 1	17	44	-5	55	-20	70	-20	70

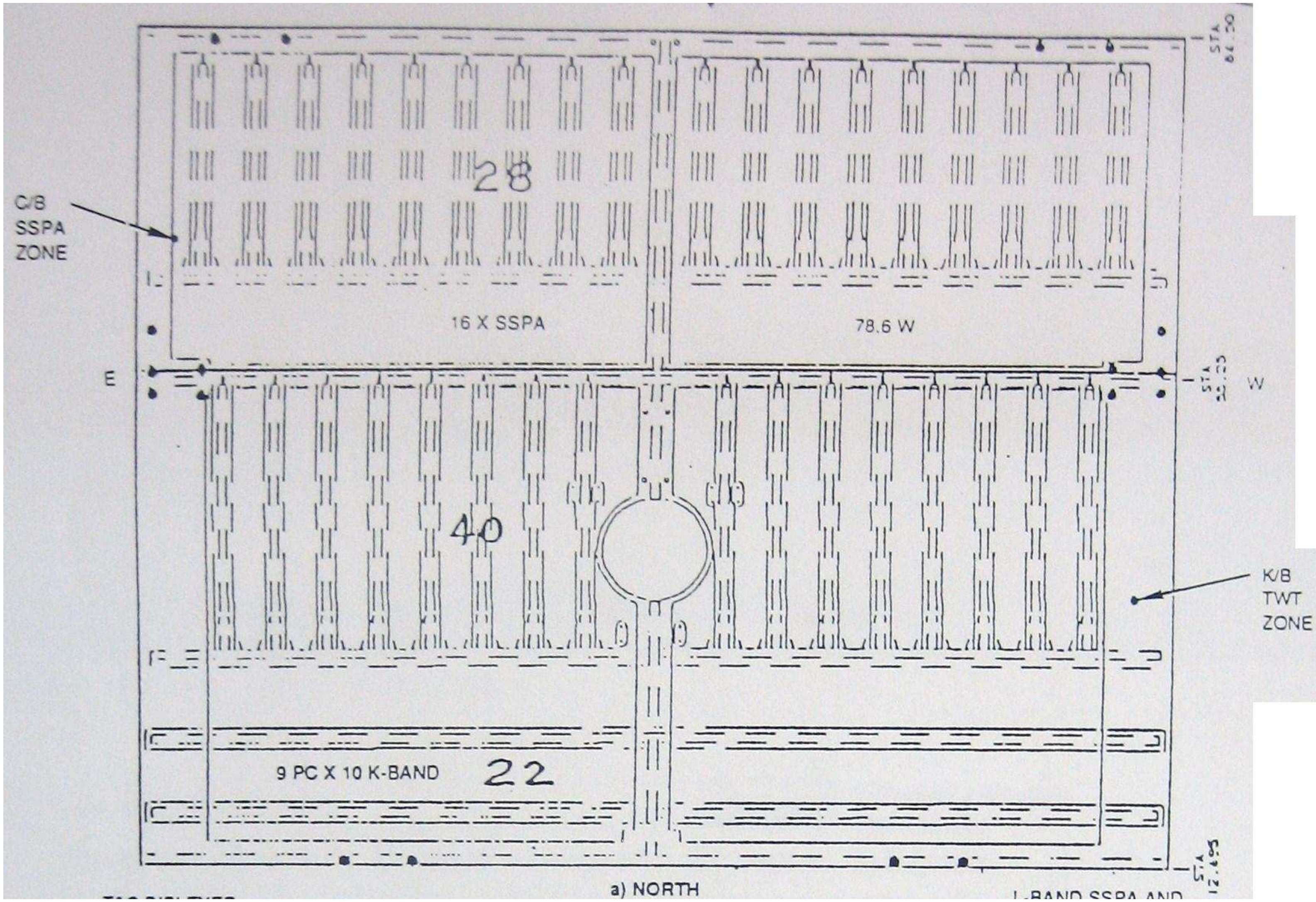
Expected Flight Temperature Limits (Cont.)

Subsystem / Unit	On-orbit Predicted Temperature, ℃		Qualification Limits, ℃		Unit Operating Survival Limits, ℃		Unit Nonoperating Survival Limits, ℃	
	Min	Max	Min	Max				
Attitude Control								
SCP	20	49	-34	70	-34	71	-34	71
IRUs	7	33	-34	71	-34	71	-34	71
MWAs	15	50	-34	71	-34	71	-34	71
ESA	24	26	-34	71	-50	81	-50	81
SWDs	-7	42	-34	71	-34	81	-34	71
RDA 1 west	-15	47	-34	71	-50	85	-50	85
RPM 2 east	-25	47	-34	71	-50	85	-50	85
Propulsion								
22 N thrusters	9	70	-7	121	-12	N/A	-12	N/A
LAM thruster injector	N/A	N/A	-7	121	-12	N/A	-12	N/A
Oxidizer tanks	7	35	-7	41	-12	54	-12	54
Fuel tanks	7	35	-7	41	-12	54	-12	54
Helium tanks	8	34	-65	60	-65	60	-65	60
Porpellant line 1 southeast aft	4	47	-7	41	-12	54	-12	54
Porpellant line 2 northwest bus	4	47	-7	41	-12	54	-12	54
Porpellant line 1 southeast bus	4	47	-7	41	-12	54	-12	54
Porpellant line 2 northwest aft	4	47	-7	41	-12	54	-12	54
Porpellant line radiators northwest, norteast	4	47	-7	41	-12	54	-12	54
High resolution pressure transducter 5, 6	12	39	-7	71	-12	107	-12	107

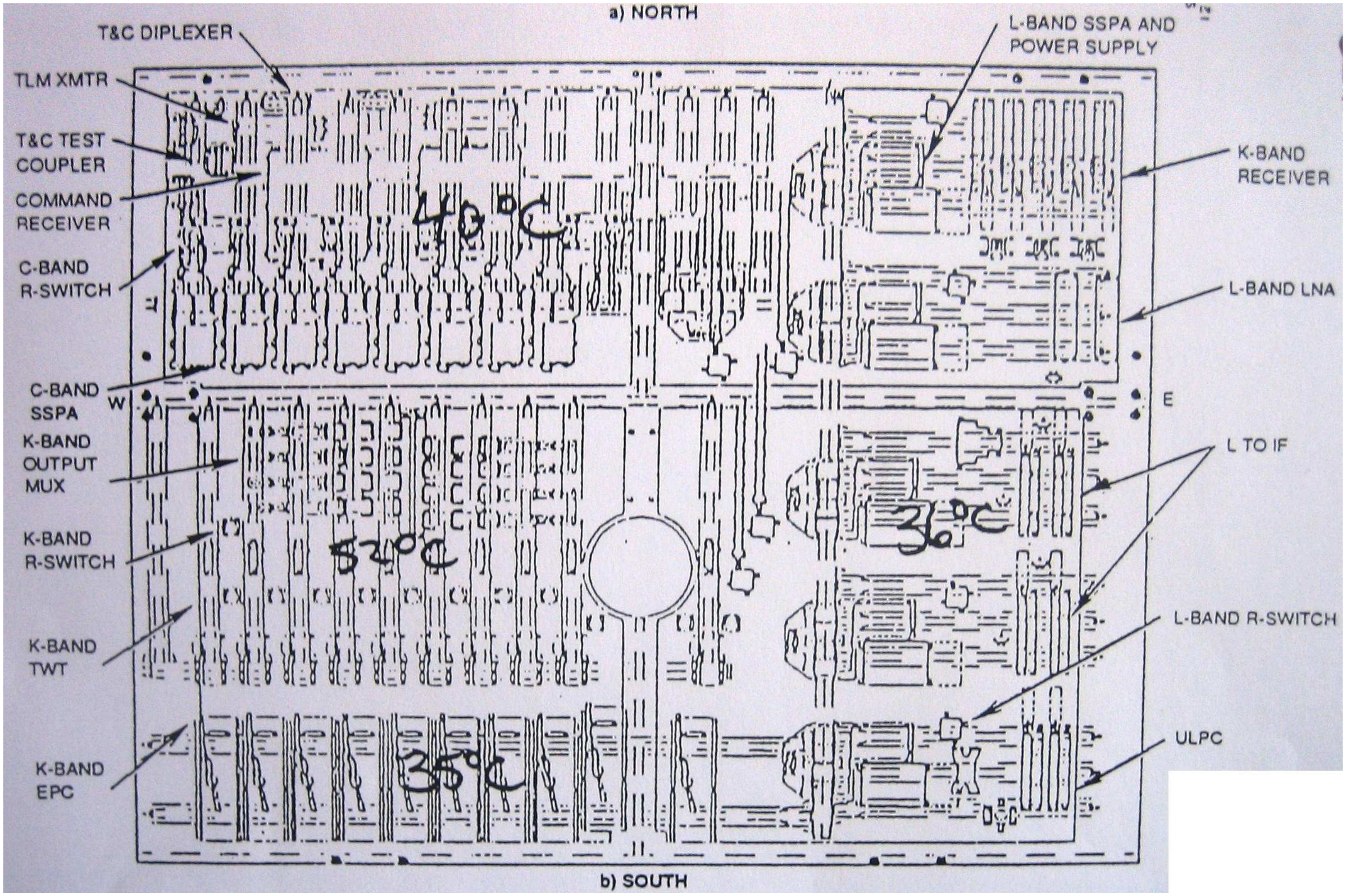
Blanket Requirements for North-South Radiator Panels

Blenket	Blanket Type	Emittance In/Out	Efficiency through θ
TWT			
South-north (inboard)	3 layer Kapton	0.16/0.53	0.03
North radiator (outboard)	3 layer Kapton	0.16/0.53	0.03
L-band			
South (inboard)	1 layer Kapton	Bare/0.16	--

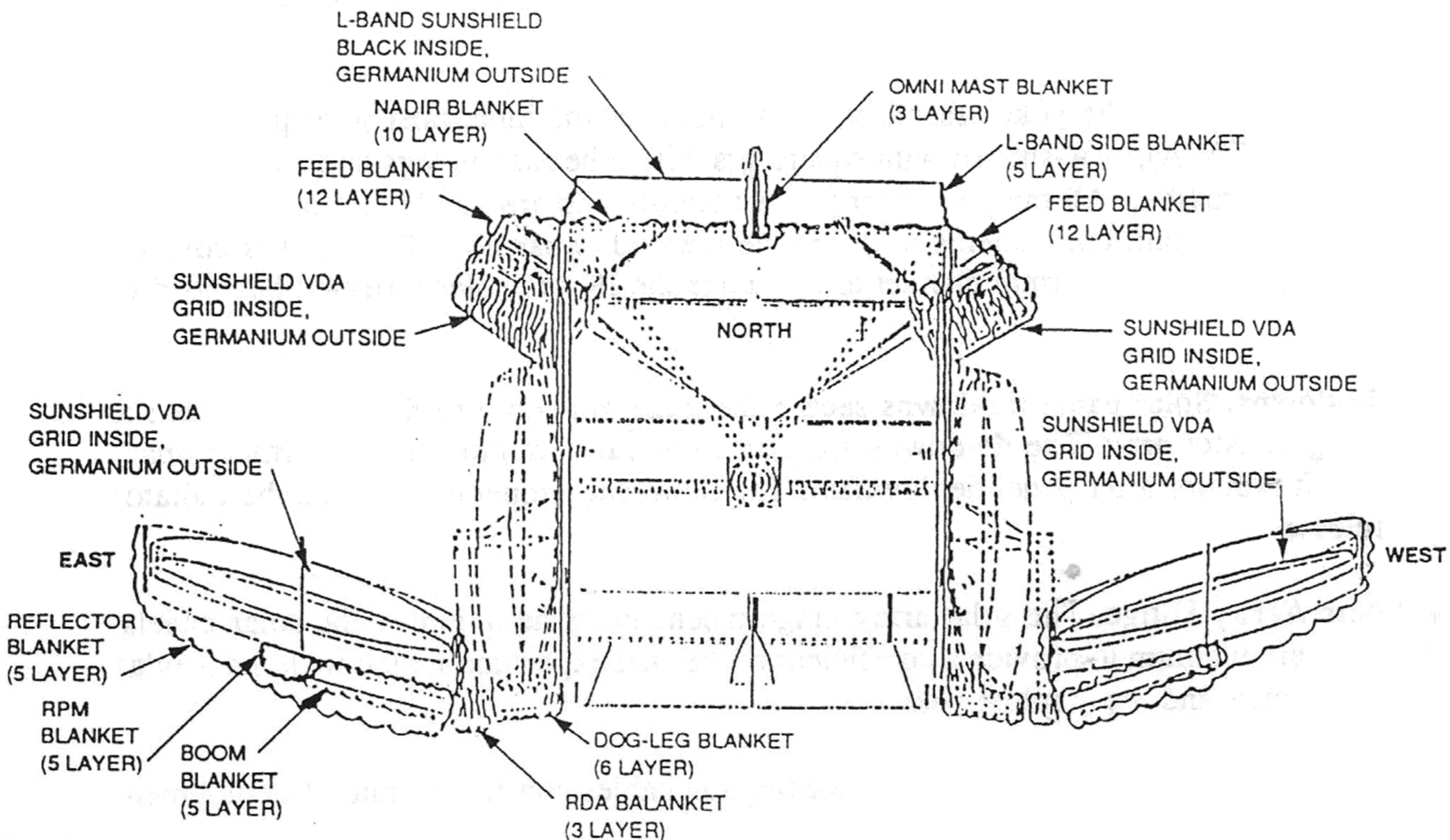
Solidaridad Panel Layout (units and heat pipes)



Solidaridad Panel Layout (units and heat pipes) (Cont.)



Reflector Blanket Design



On Orbit Thermal Dissipation Summary

Radiator Node	Case, W								
	Hot 1	Hot 2	Hot 3	Hot 4	Hot 5	Hot 6	Hot 7	Cold 1	Cold 2
North C-band zone	254	350	361	350	361	361	361	294	294
Aft	(65.4)	(80)	(81)	(80)	(81)	(81)	(81)	(49)	(49)
Forward	(188)	(270)	(280)	(270)	(280)	(280)	(280)	(245)	(245)
North TWT zone	404.3	404.3	404.3	404.3	404.3	404.3	404.3	382.4	382.4
North EPC zone	80.2	80.2	80.2	80.2	80.2	80.2	80.2	56	56
Total north	(738)	(834)	(845)	(834)	(845)	(845)	(845)	(732)	(732)
South C-band zone	240	265	299.3	200	299	234	210	127.3	194.8
Aft	(51)	(57)	(52)	(51)	(52)	(51)	(52)	(32)	(32)
Forward	(188)	(208)	(247)	(149)	(147)	(183)	(158)	(95)	(163)
South L-band zone	304	304	304	370	239	304	393.4	288	220.5
South TWT zone	350	350	350	350	350	350	350	322.4	322.4
South EPC zone	74.4	74.4	74.4	74.4	74.4	74.4	74.4	51	51
Total south	(968)	(994)	(1028)	(994)	(963)	(963)	(1028)	(788.7)	(788.7)
Total radiator	(1704)	(1828)	(1873)	(1828)	(1808)	(1808)	(1873)	(1521)	(1521)
Total subnadir	154.3	124.1	122.5	124.1	122.5	122.5	122.5	135.2	135.2
Feeds									
C-band	27.7	3	0	3	0	0	0	27.7	27.7
Ku-band	63.8	63.8	63.8	63.8	63.8	63.8	63.8	0	0
L-band	0	3	0	3	13.6	13.6	0	13.6	13.6
Bus shelf	48	48	48	48	48	48	48	48	48
Cruciform panel	40	40	40	40	40	40	40	40	40
Total internal	(334)	(282)	(275)	(282)	(288)	(288)	(275)	(264)	(264)
Harness loss	33	33	33	33	33	33	33	30	30
Total spacecraft dissipation	2071	2143	2181	2143	2129	2129	2181	1815	1815

Structural subsystem

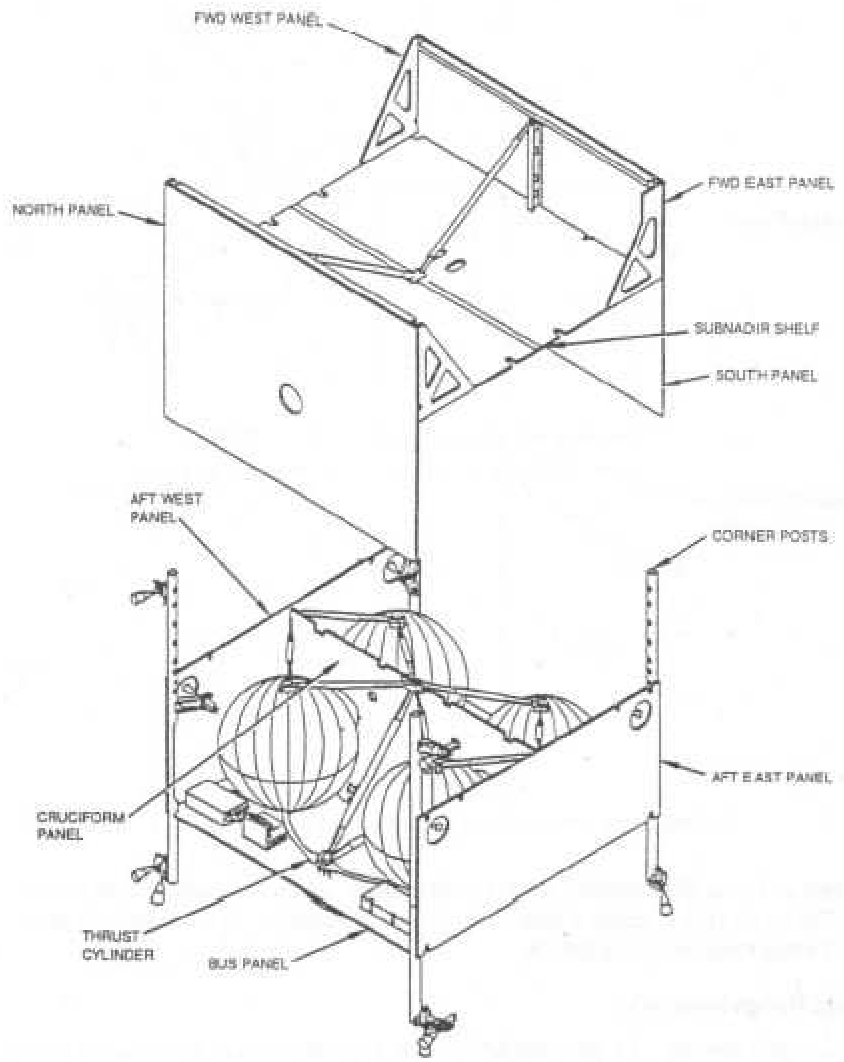
Structure

Bus/propulsion module	**Honeycomb with strut stabilization for tanks, shelves**
Payload module	**Honeycomb with strut stabilization**

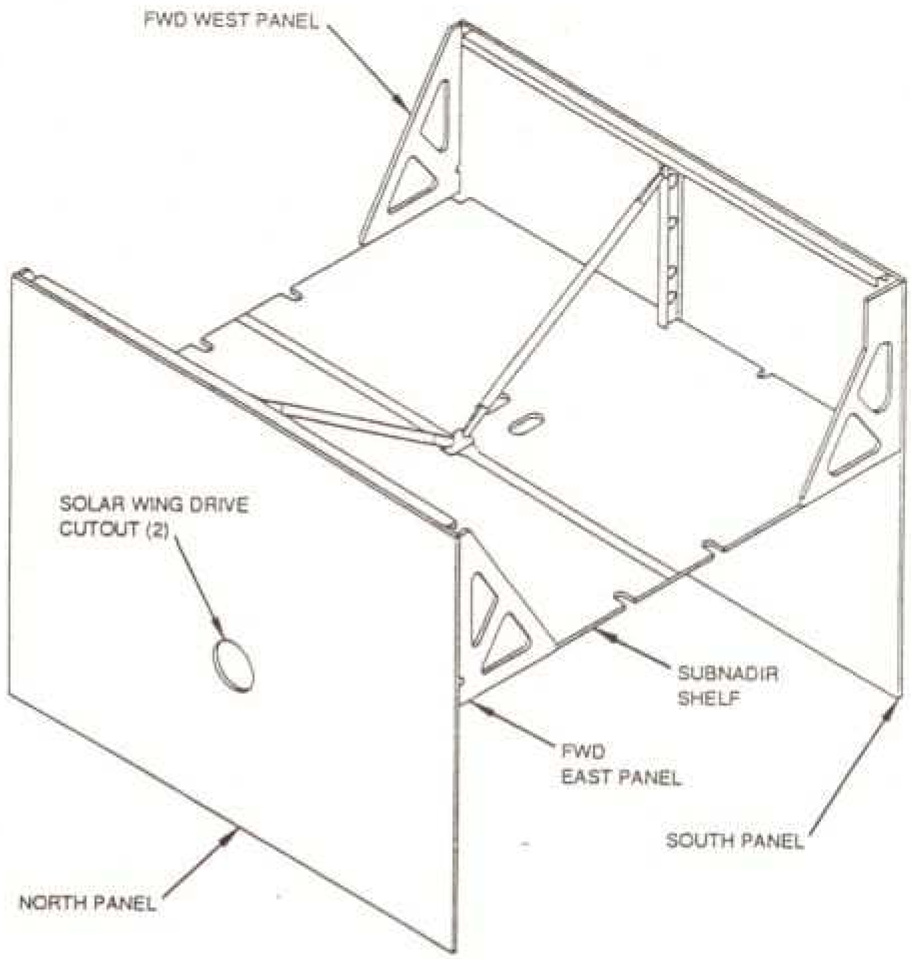
Structure design description

- **Distribution of all mechanical loads**
- **Support of all payload flight hardware**
- **Support of all bus flight hardware**
- **Support thermal control elements**
- **Maintenance of proper dimensional relationships among flight hardware**
- **Provision of a ground plane for flight electronics**
- **Provision of a faraday cage for flight electronics**
- **Provision of a mechanical interface with the Ariane booster**

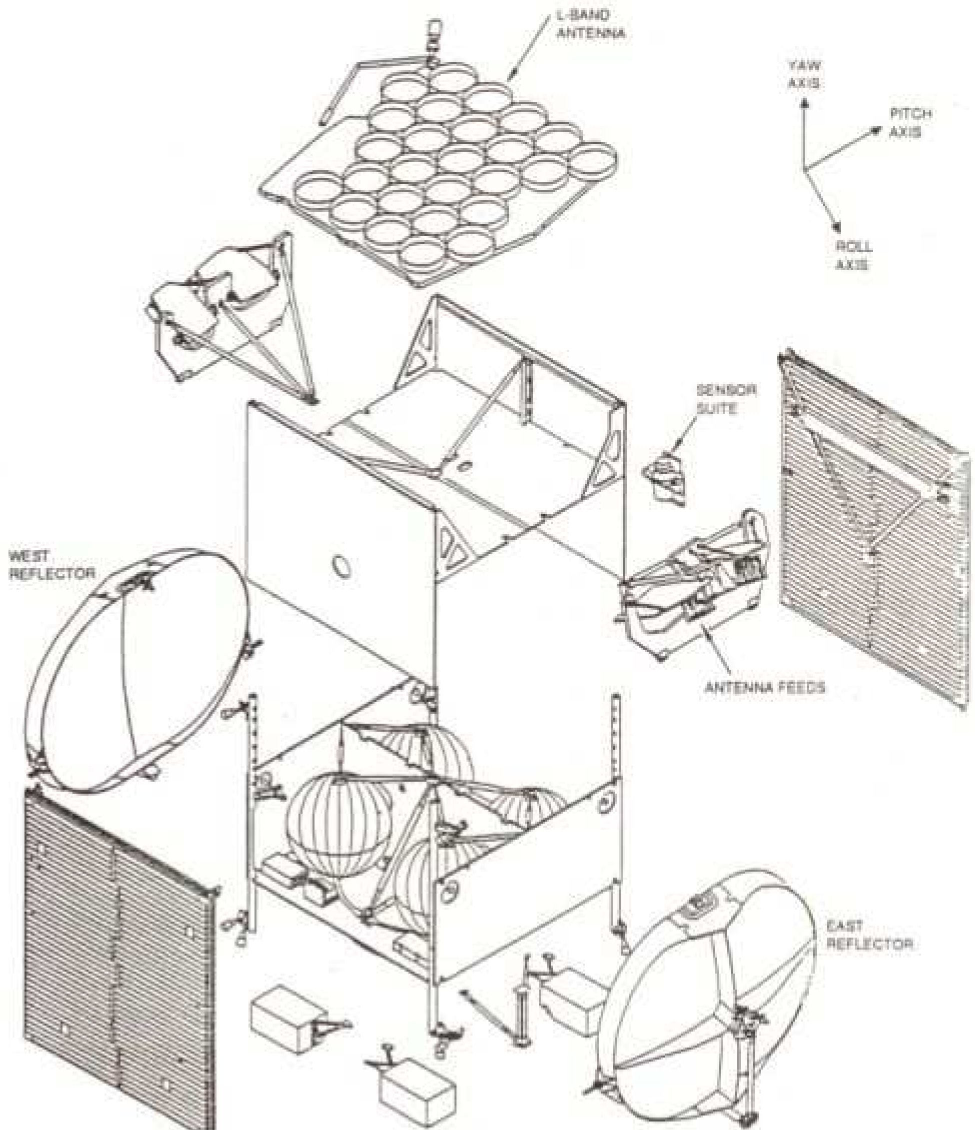
Solidaridad primary structure



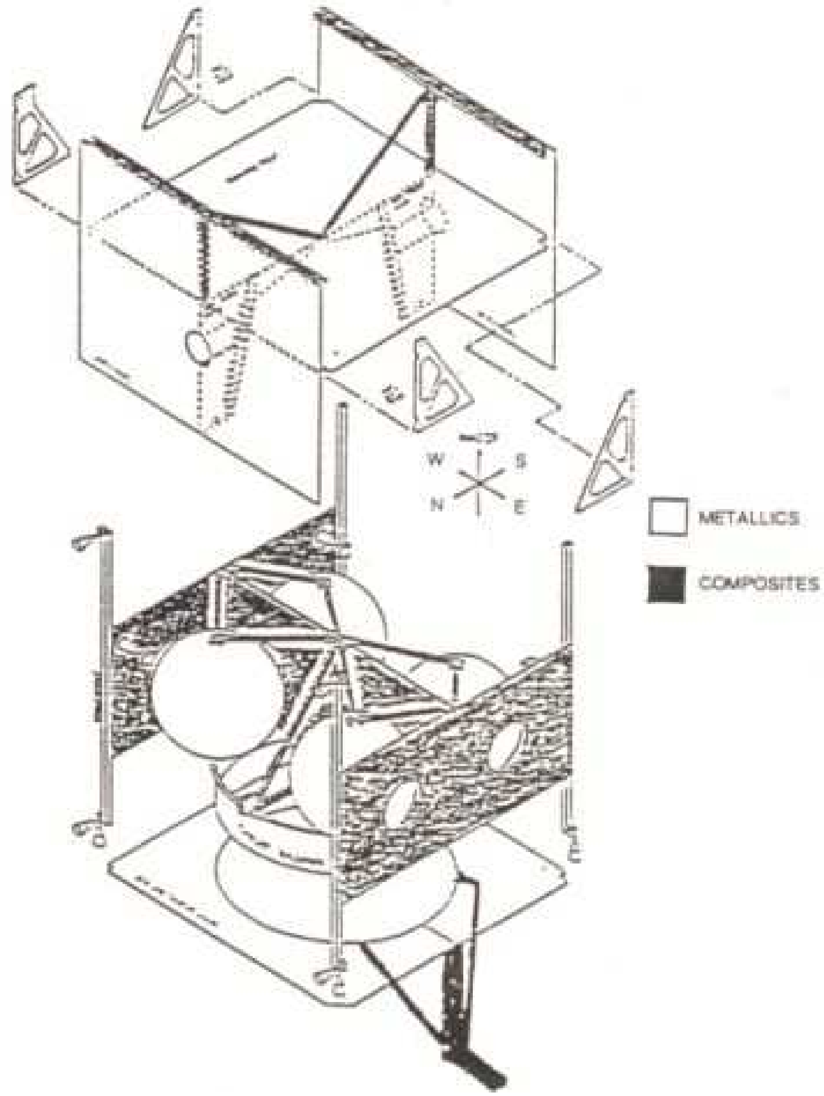
Payload module primary structure



Overall integrated configuration



Materials Use



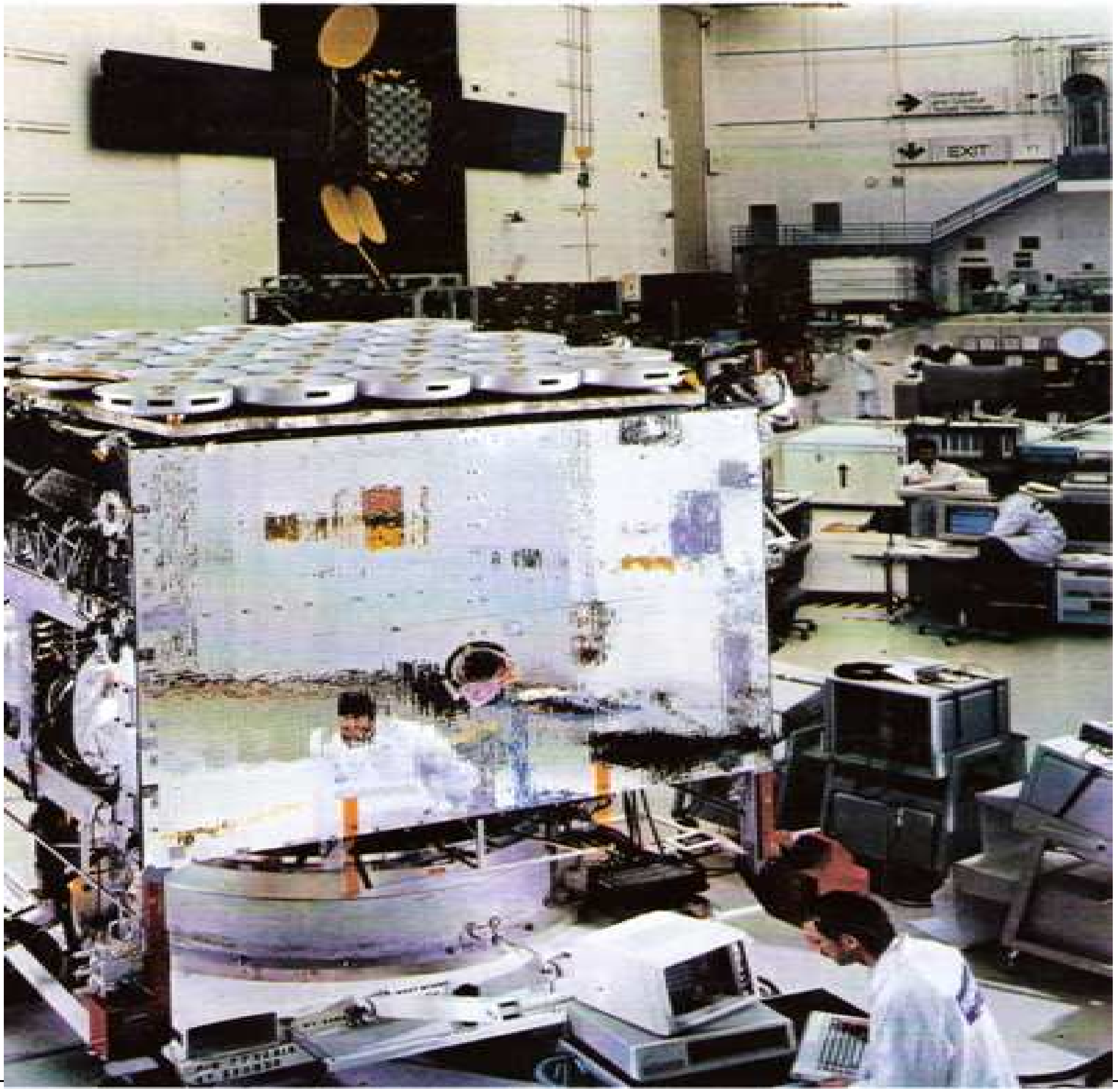
Subsystem Weight Summary

Title	Total Mass (Kg)
Antenna	143.83
Ku Band Repeater	114.81
C Band Repeater	119.57
L Band Repeater	58.39
T & C RF	11.29
TT & C Digital	30.43
Attitude Control	80.71
Propulsion	97.72
Electrical Power	278.98
Thermal Control	67.96
Structure	175.02
Wire Harness	80.34
Growth	14.33
S/C Unbal Dry	1259.26
Prop in lines	2.49
S/C Unbal (W/TRPD PROP)	1261.75
Bal Weight Pre Split	5.26
Bal Weight Split	6.63
S/C Bal (W/TRPD PROP)	1268.38
S/C Dry (W/Bal WT)	1265.88
PYLD Subtotal	447.88
Bus Subtotal	811.15

Master in Space and Satellite Technology

Topic 5: Integration and Test

Solidaridad tests



Solidaridad Satellite Tests, General Plan

- Initial test
- Environmental test (Build up)
- Full up integrated system test
- Functional test at launch site

Communication Subsystem Test

Unit acceptance test	Functional and environmental test
Antenna test	PIRE, G/T, SFD Polarization Isolation Radiation Patterns
Hardline (Communications Electronics)	End to end transponder test
Initial test of the integrated Subsystem	Verify the electronics and antenna intefaces with platform. Characterization of gain transference and frecuency response in band (pre-environmental)
Thermal Test	End to end electronics performance under severe conditions
Full-up integrated system test	Test and compare. Post environmental
On orbit test	See next slide

On orbit test

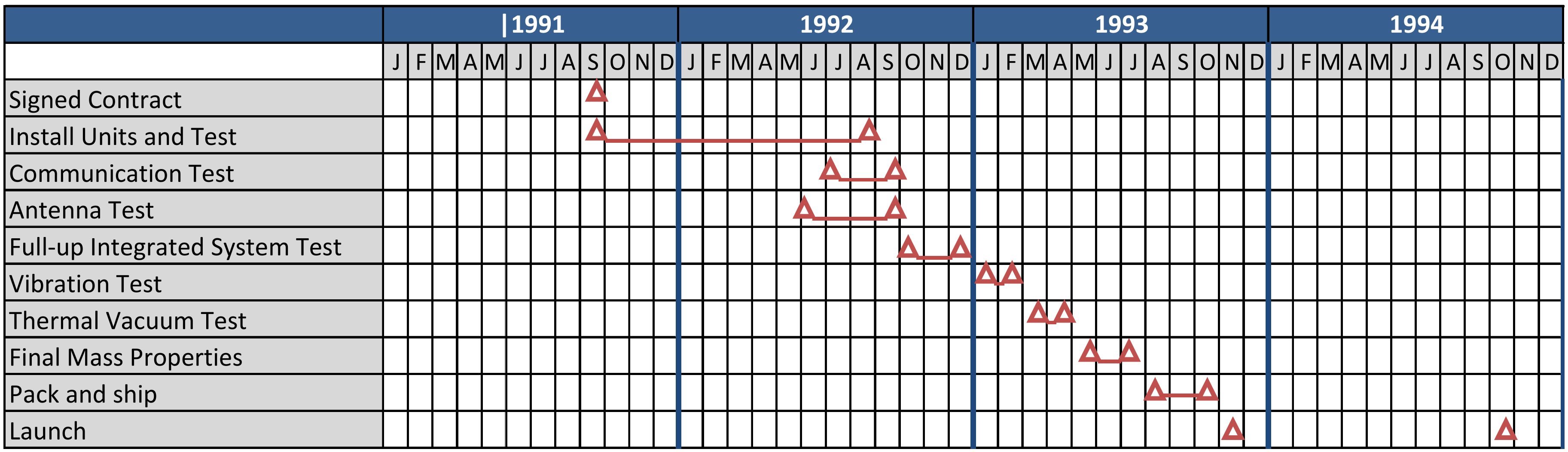
Communications

- Transfer Characteristic
- PIRE and SFD
- G/T
- Radiation Patterns
- Frequency Convertion
- Co –Polarization
- Frequency Response (out band and in band
- Cross Polarization Discrimination

TTC

- Commands functionality
- Commands sensibility
- Telemetry PIRE
- Telemetry modulation index
- Authomatic Control Gain calibration of the telemetry receiver
- Telemetry carrier frequency

Solidaridad Satellite
Test and Integration Schedule



Solidaridad launch request for tender participants

- General dynamics(Atlas)
- Arianespace(Ariane)
- China Great Wall Industry(Long march)

Propellant consumption

Useful life

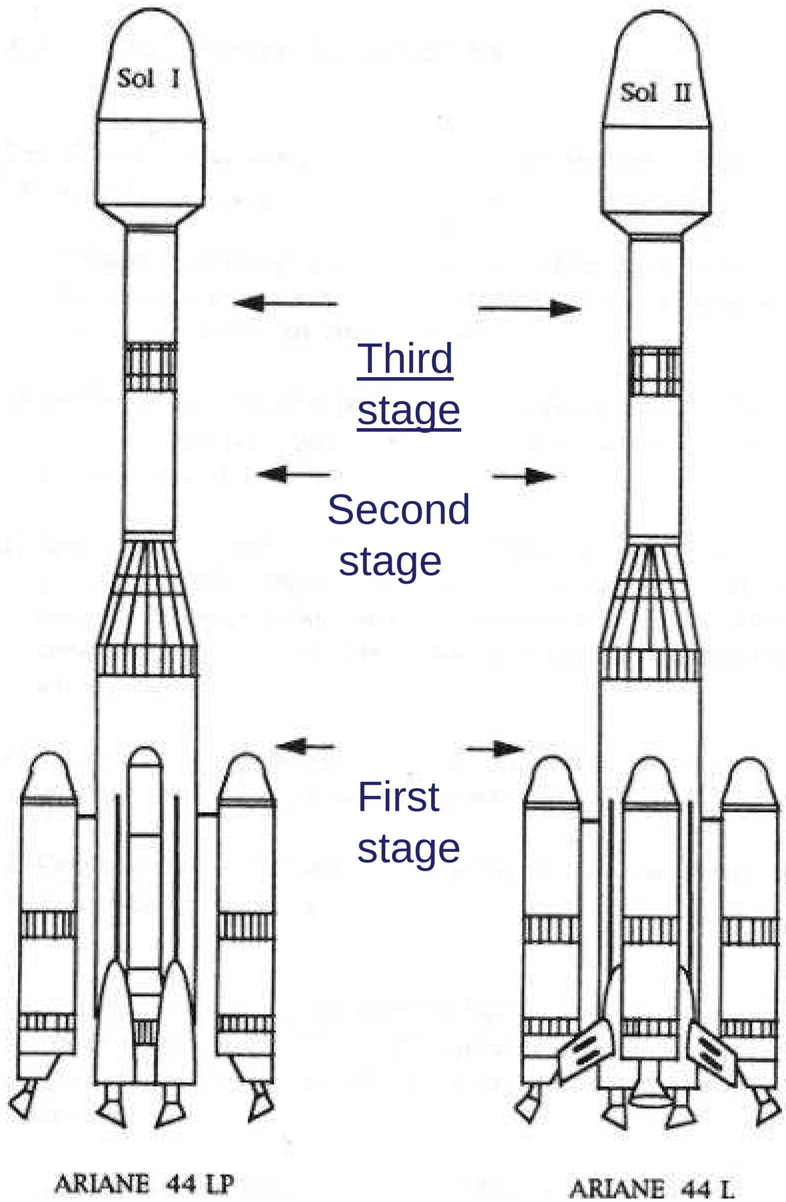
Cost

Launch windows

Master in Space and Satellite Technology

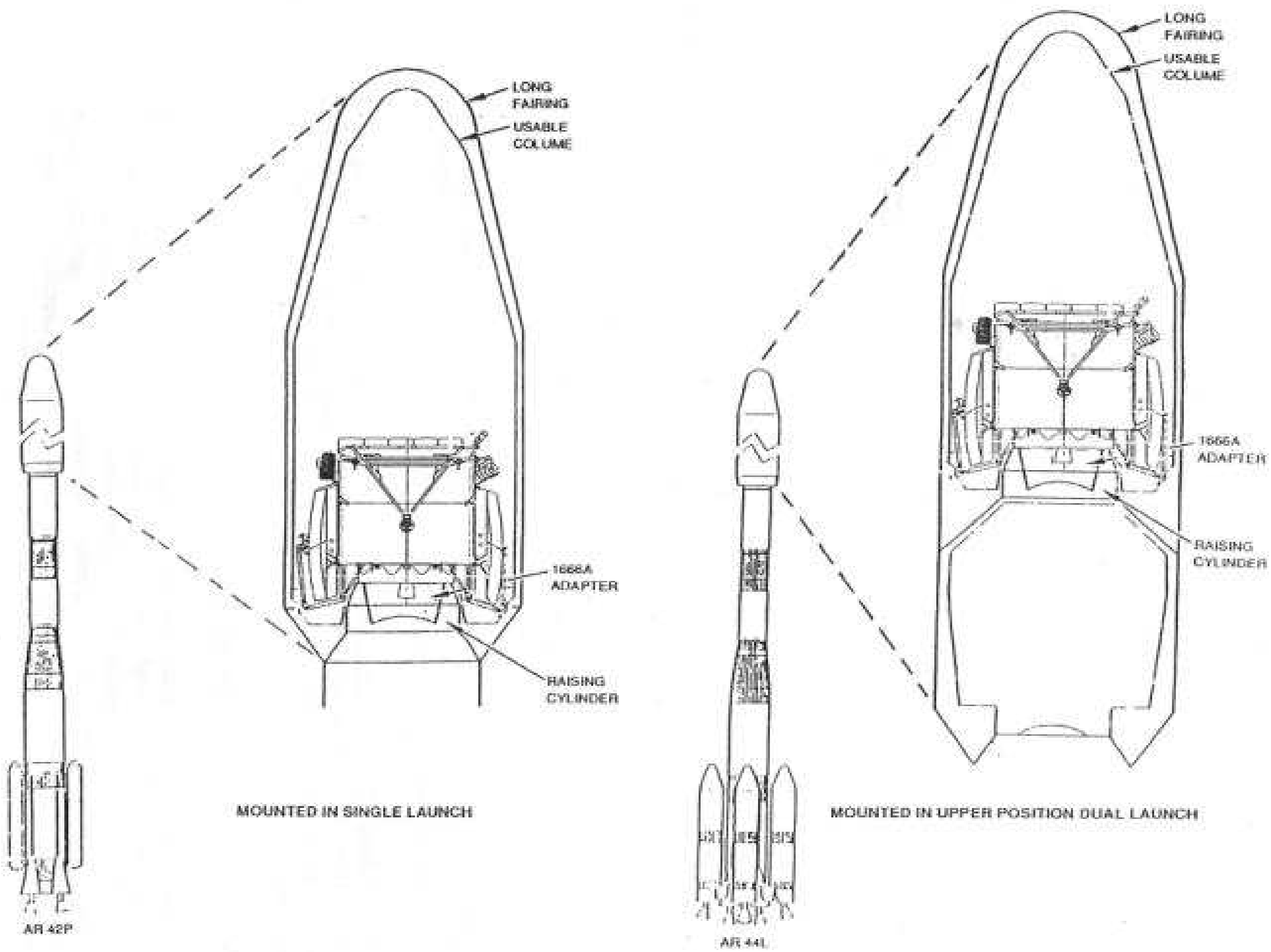
Topic 6: Launch

Ariane and Solidaridad



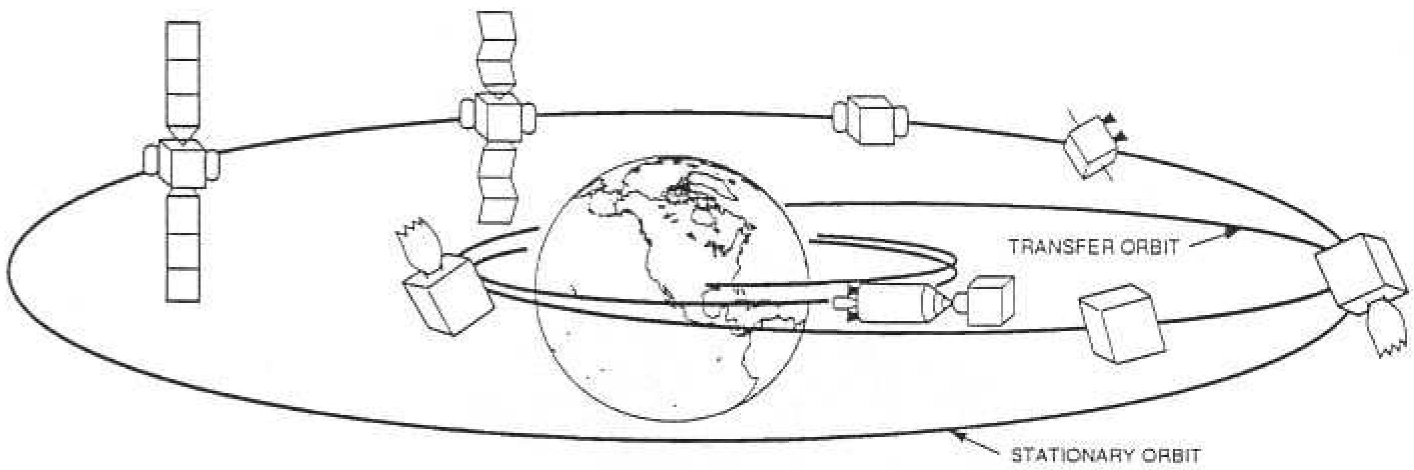
Solidaridad Launch

Ariane single and dual launch configutations



TRANSFER AND STATIONARY ORBITS MISSION PHASES

Solidaridad sequency



Solidaridad launch characteristics

Perigee altitude: 20

Apogee altitude: 35,786 Km

Inclination: 7º

Argument of the perigee: 178º

Right ascension of the ascending node: 11º

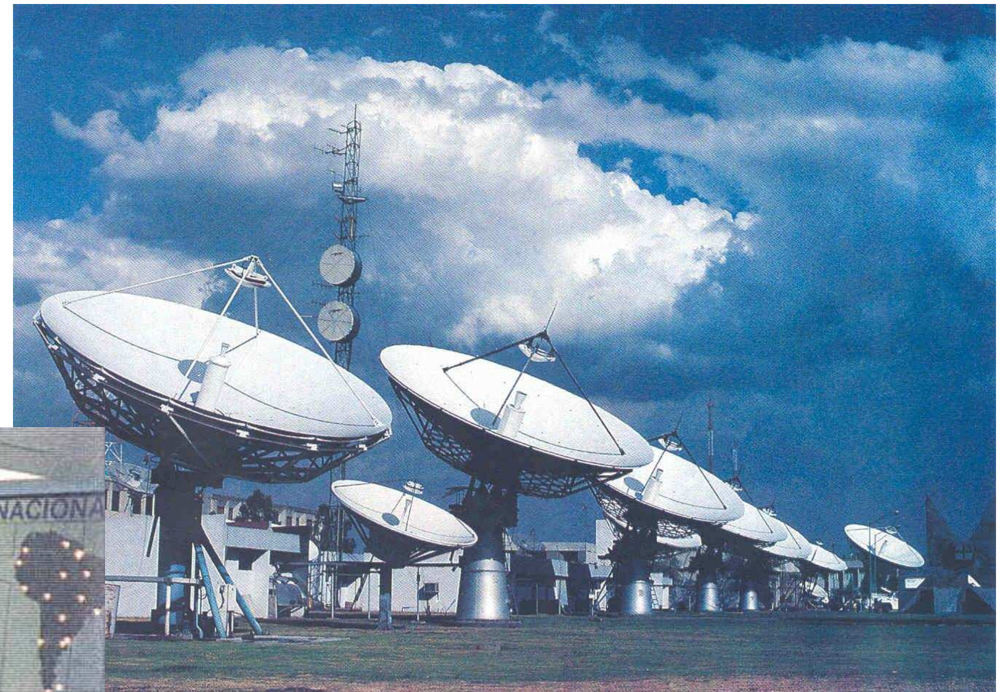
Solidaridad launch stages

- **0 seconds: Ignition**
- **4,4 seconds: Lift-off**
- **3,5 minutes: First stage separation and second stage ignition**
- **5,5 minutes: second stage separation and third stage ignition**
- **18 minutes: GTO orbit injection**
- **22 minutes: Solidaridad2 separation**
- **27 minutes: Thaicom2 separation**

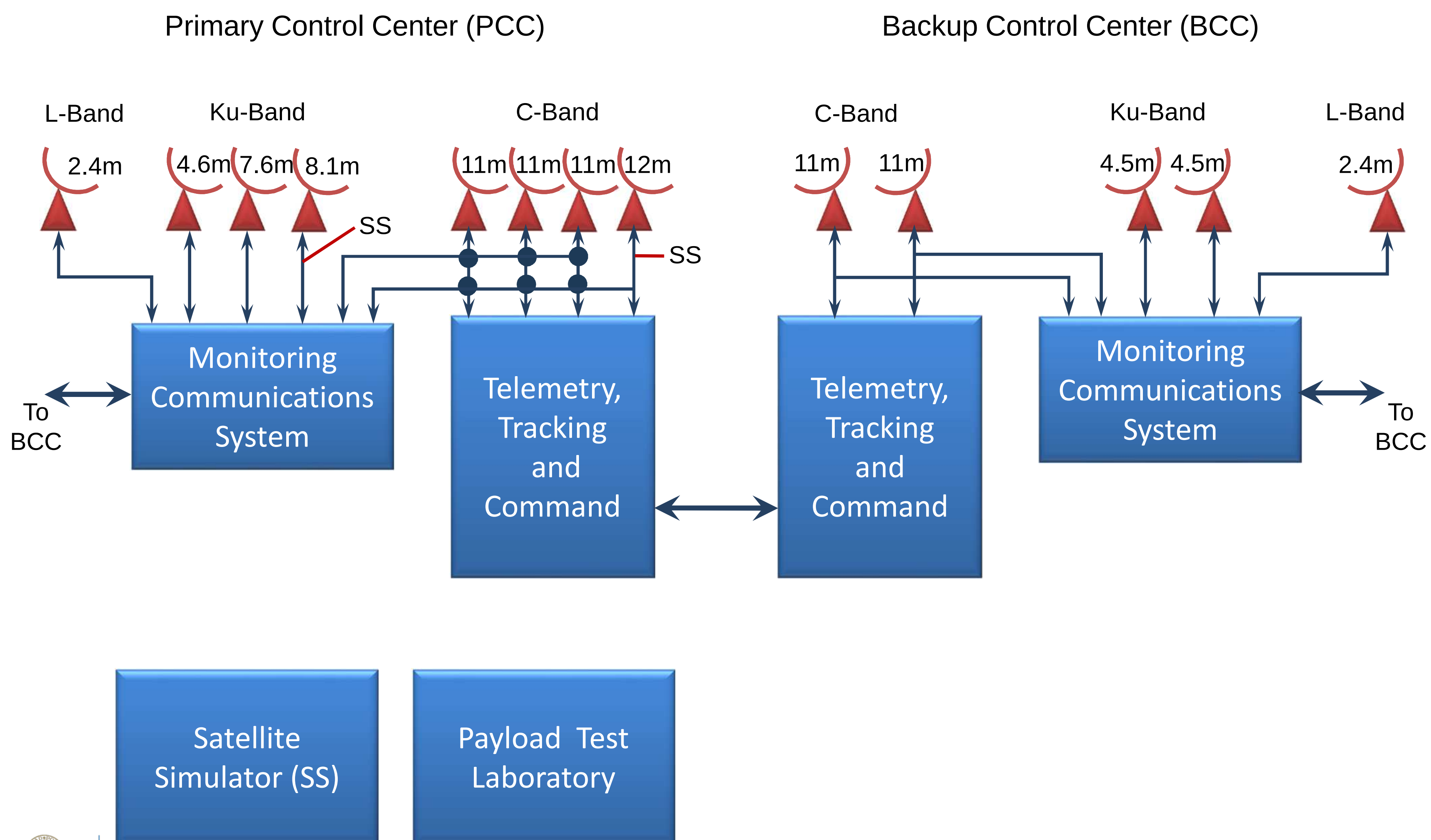
Master in Space and Satellite Technology

Topic 7: Earth segment solution

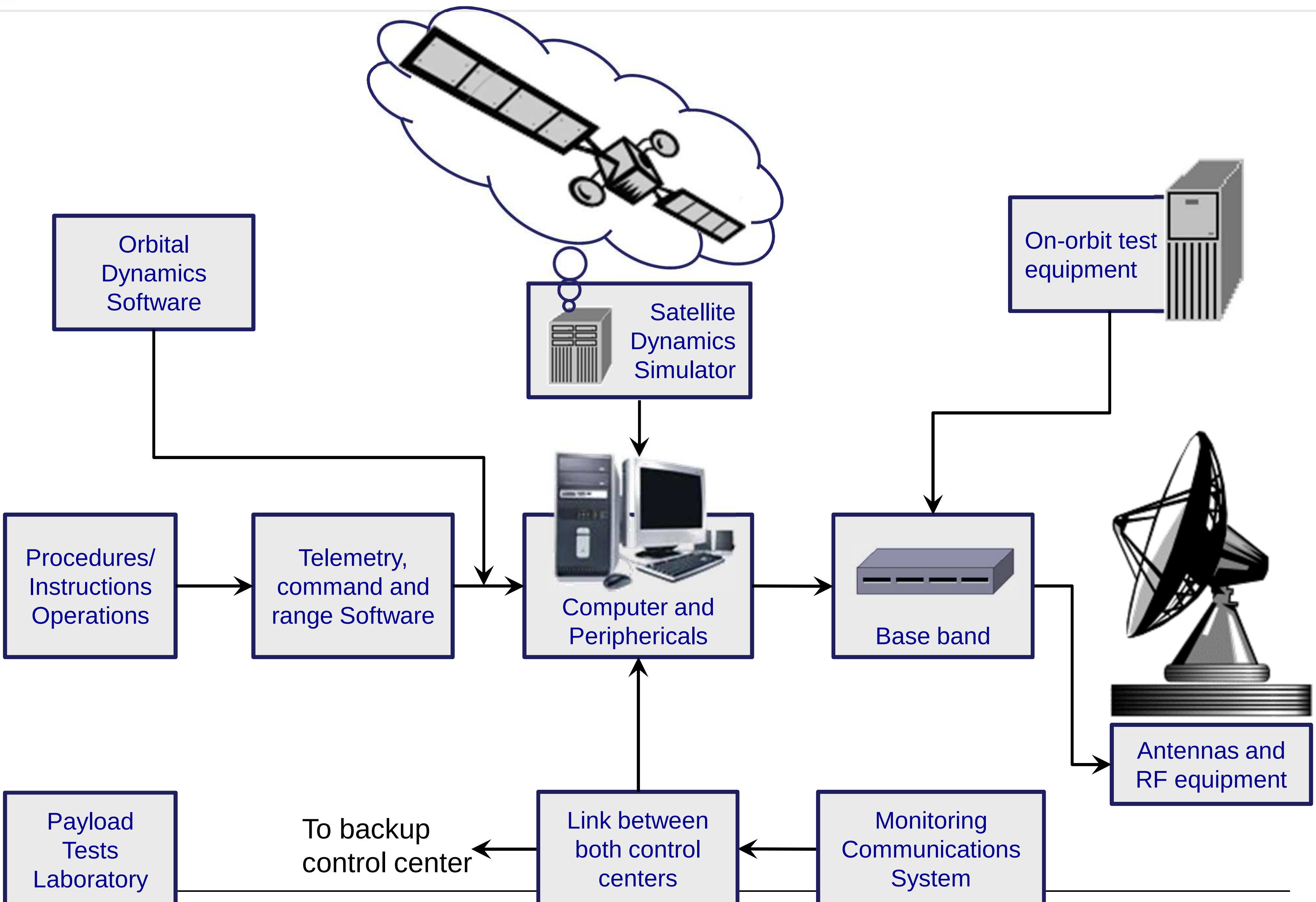
Control Center



Control Centers



Primary Control Center



Telemetry and Command Characteristics of the Mexican Satellites

	Morelos II	Solidaridad 1	Solidaridad 2
Orbital Longitude	116.8°	109.2°	113.0°
Command:			
Dish	6422 MHz (Vertical)	5935 MHz (Vertical)	5935 MHz (Vertical)
Omni	5928 MHz (Horizontal)	6415 MHz (Horizontal)	6415 MHz (Horizontal)
Modulation	R-FSK, 5 to 15 KHz FM, 75 to 173 KHz	RZ-FSK, 5 to 15 KHz FM, 75 to 173 KHz	RZ-FSK, 5 to 15 KHz FM, 75 to 173 KHz
Deviation	300 KHz 2.5 MHz Peak-Peak	300 KHz 2.5 MHz Peak-Peak	300 KHz 2.5 MHz Peak-Peak
Data Rate	0 to 50 BPS	0 to 50 BPS	0 to 50 BPS
Telemetry			
Dish (Horizontal)	4198.625 MHz 4199.625 MHz	3700.1 MHz 3700.6 MHz	3700.1 MHz 3700.6 MHz
Omni (Vertical)	4198.625 MHz 4199.625 MHz	3700.1 MHz 3700.6 MHz	3700.1 MHz 3700.6 MHz
RF Modulation	Phase	Phase	Phase
Mod. Index	1.00 ± 0.1 RAD	1.00 ± 0.15 RAD	1.00 ± 0.15 RAD
Subcarrier	Biphase/32 KHz	Biphase/32 KHz	Biphase/32 KHz

Users. Request for testing

- Cross-polarization isolation
- Verification of the antenna pattern (if requested)
- Power level adjustment
- Optimal antenna pointing
- Coordination for carrier activation/deactivation
- Signal absence
- Interference
- Verification of technical parameters

Required information

- Registered name of the company, name and telephone number of the E/S operator
- Satellite to access
- Transponder and polarization
- Transmission and reception frequencies
- Transmission rate
- Type of modulation
- Brand name and antenna diameter
- Access technique
- Name of the locations that will be connected at the transmission and reception

Preliminary adjusments to the reception

The user must previously carry out the following actions without transmitting any carrier to the satellite

•Pointing the antennas correctly in the azimuth and elevation angle towards desired satellite

•Adjust the cross-polarization isolation of the antennas through the observation of signals coming from the satellite. The user can ask the CCC to ask for a reference signal to obtain a maximum level of reception

•Calculate and adjust the transmission power, which, at the time of transmission, it must not exceed the assigned power

•Verify the configuration and the operating status of the baseband and RF equipments of the E/S before activating the carrier**.**

Transmission radio frequency tests

The carrier will be transmitted, under the guidance of the CCC, in the assigned frequency, by using a low power level in order to perform the following measurements:

•Orthogonal cross-polarization isolation

•Antenna pattern (its execution depends on the antenna diameter)

•Carrier frequency

•Dispersal energy, audio subcarrier (for TV/FM/FDMA analog carriers)

•Transmission rate and FEC

•Modulation

•Bandwidth

•Spectral shape

•Satellite EIRP

•Spurious emissions

***NOTE*: If the CCC does not detect a carrier on the satellite, the user will be advice to deactivate the carrier, since this could indicate an anomaly in the operation and the possibility that a wrong satellite may be accessed. The user will need to check the E/S and correct the anomaly and then establish contact again with the CCC.**

General guidalines

•Orthogonal cross-polarization isolation

The orthogonal cross-polarization isolation of the antenna must be > 30dB and have no induction over the opposite channel

•Antenna pattern

All the antenna transmitting to the SATMEX satellites must meet the following envelope for side lobes

$$29-25\log(\theta)$$

For antennas ≥ 3.6m it is neccesary to perform an antenna pattern test under SATMEX guidance

•A non modulated carrier(CW)

The E/S needs to have the capability to transmit a non modulated carrier(CW), sinthesizable and stable in frequency as well as in amplitude

Report and interference management

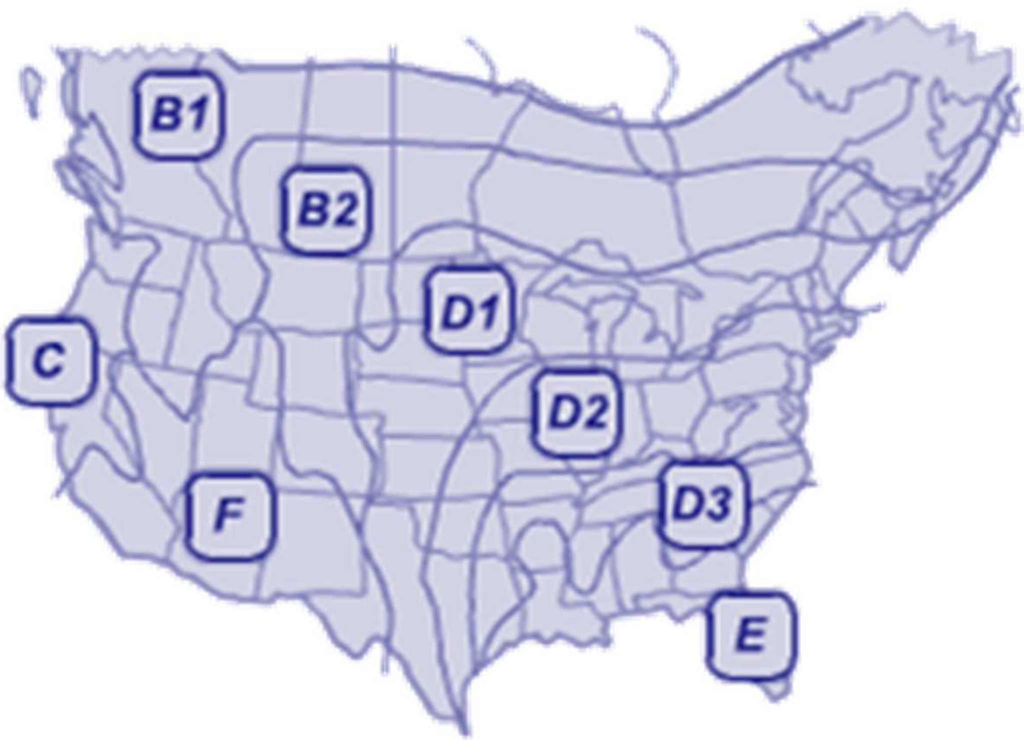
All incidents regarding radio frequency interference (RFI) must be reported to the CCC

- Before starting an RFI report, the E/S operator must verify the transmission equipment (master and VSAT's stations) in order to be sure that the interference is not generated by themselves.
- If possible, the RFI should be verified with a second E/S to confirm it. In case that the user does not have a second station, the CCC will verify through a reference station.

Rain margins R4

Rain Fade		99.50% (dB)	99.80% (dB)	99.90% (dB)
North Wes NW	Tx	1.50	3.00	3.50
	Rx	0.00	1.00	1.50
North Central NC	Tx	0.00	1.00	1.30
	Rx	0.00	0.00	0.00
Gulf North GN	Tx	3.60	6.80	9.20
	Rx	1.60	4.80	7.20
Central C	Tx	2.20	4.20	6.30
	Rx	0.20	2.20	4.30
Pacific Central PC	Tx	3.60	5.90	8.50
	Rx	1.60	3.90	6.50
Isthmus IT	Tx	2.50	5.80	8.20
	Rx	0.50	3.80	6.20
Yucatan YU	Tx	2.90	6.00	8.90
	Rx	0.90	4.00	6.90

Rain margins R5



Rain Fade		99.50% (dB)	99.80% (dB)	99.90% (dB)
B1	Tx	0.14	0.29	0.46
	Rx	0.10	0.20	0.32
B2	Tx	0.21	0.40	0.65
	Rx	0.15	0.28	0.46
C	Tx	0.39	0.72	1.15
	Rx	0.27	0.51	0.81
D1	Tx	0.70	1.44	1.95
	Rx	0.49	1.02	1.39
D2	Tx	1.17	2.34	3.74
	Rx	0.83	1.66	2.67
D3	Tx	1.59	3.47	5.69
	Rx	1.12	2.48	4.08
E	Tx	2.10	5.66	9.79
	Rx	1.49	4.06	7.07
F	Tx	0.29	0.49	0.70
	Rx	0.20	0.34	0.50

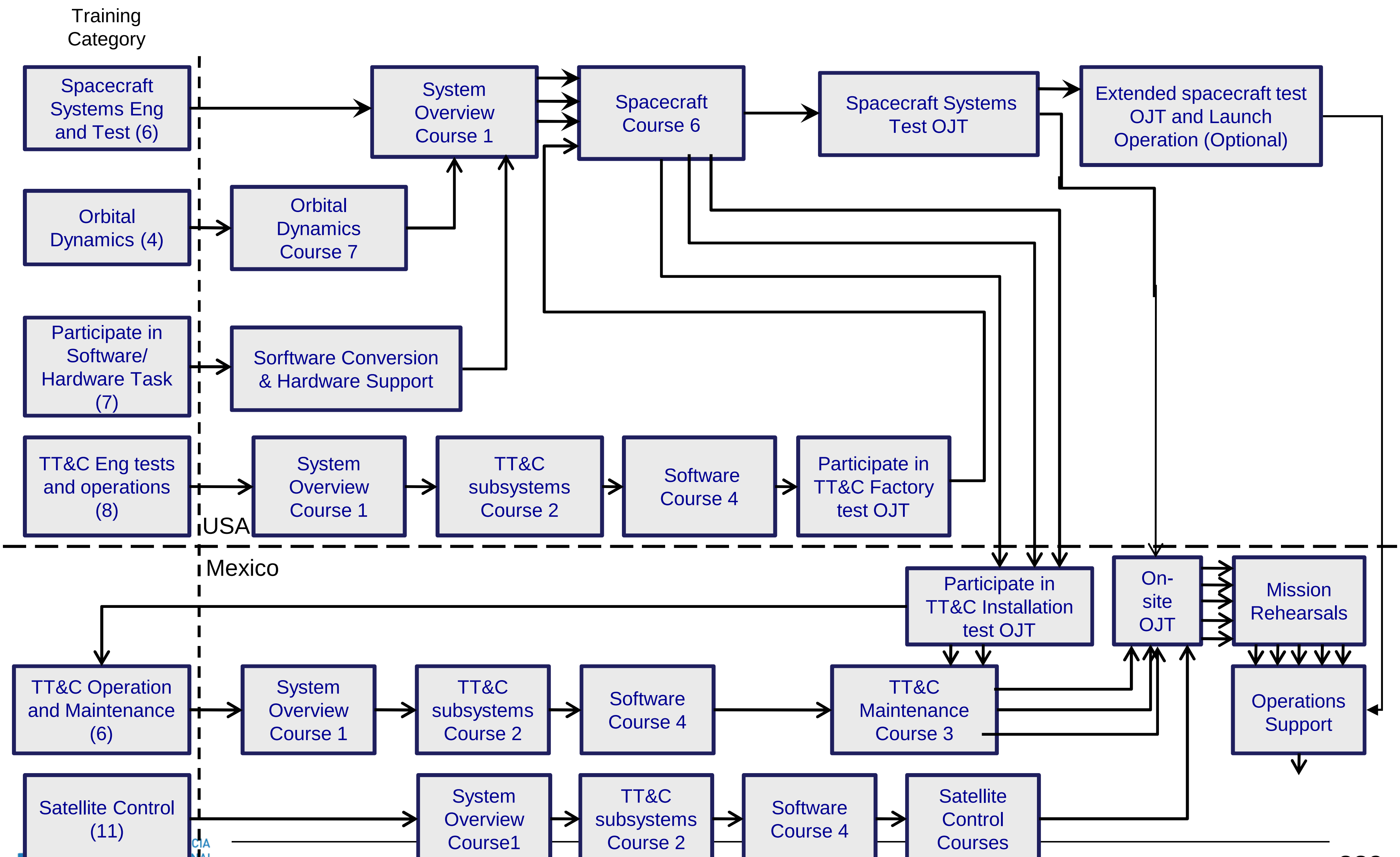
Rain margins
Central and SouthAmerica

Rain Fade		99.50% (dB)	99.80% (dB)	99.90% (dB)
C'	Tx	0.15	0.48	0.66
	Rx	0.11	0.34	0.47
D	Tx	1.36	2.04	2.84
	Rx	0.95	1.44	2.02
IT	Tx	2.50	5.80	8.20
	Rx	0.50	3.80	6.20
E'	Tx	0.28	0.73	1.10
	Rx	0.19	0.51	0.77
K	Tx	2.37	4.06	6.14
	Rx	1.67	2.88	4.38
N	Tx	2.65	5.38	8.98
	Rx	1.89	3.86	6.48
P	Tx	6.73	11.37	17.25
	Rx	4.84	8.23	12.55
Y	Tx	2.90	6.00	8.90
	Rx	0.90	4.00	6.90

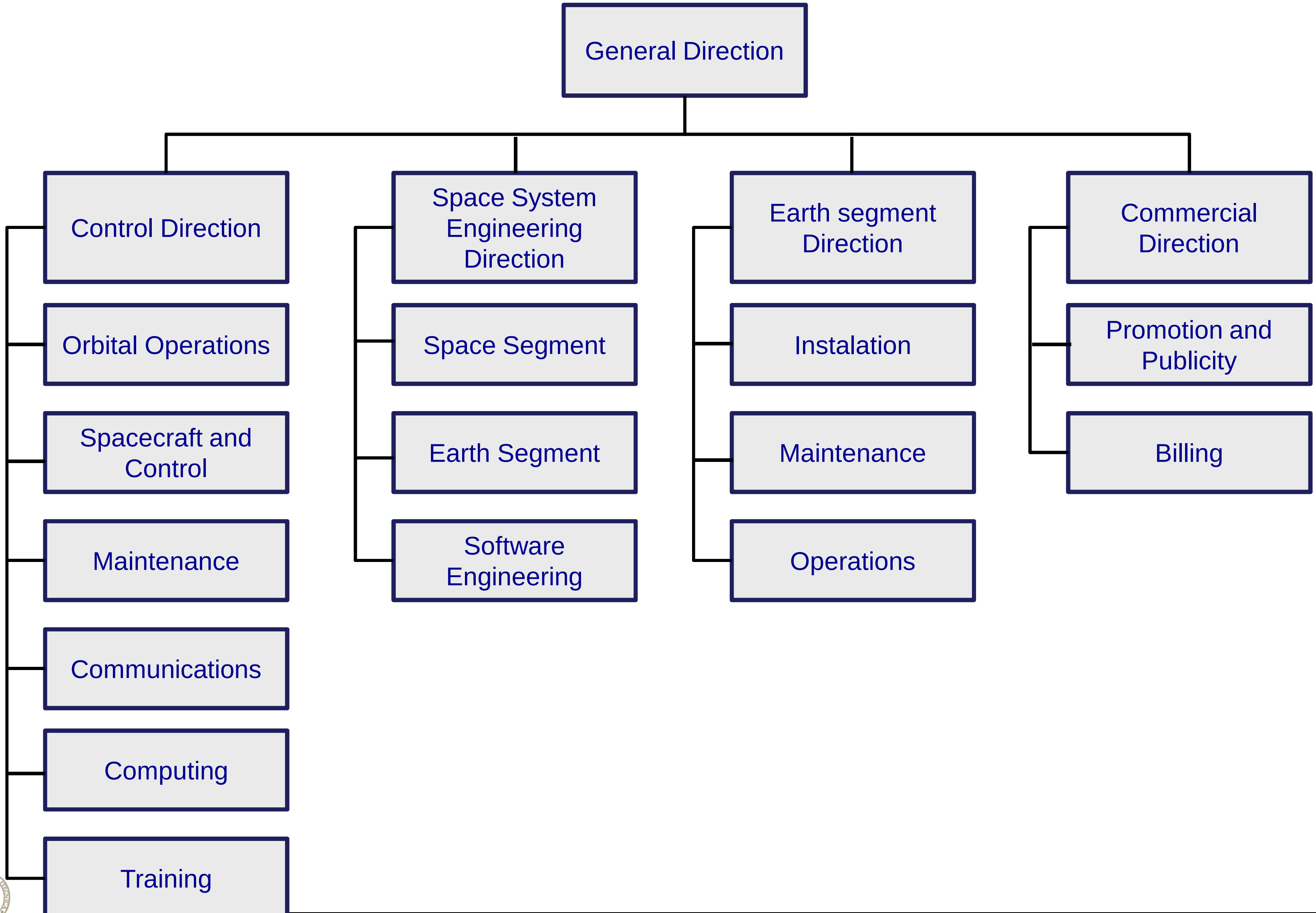
Master in Space and Satellite Technology

Topic 8: Training and operations

Training Activity



Organization



C band tariffs(USA dollars)

Speed (KBPS) up to	Assigned power (dBw) up to	Morelos II	Assigned power (dBw) up to	Solidaridad Region I
32.0	4.22	123.0	4.72	130.0
64.0	7.23	245.0	7.73	260.0
128.0	10.24	490.0	10.74	520.0
256.0	13.25	980.0	13.75	1,040.0
384.0	15.01	1,470.0	15.51	1,560.0
512.0	16.32	1,986.0	16.82	2,108.0
768.0	18.02	2,940.0	18.52	3,120.0
1,544.0	21.21	6,125.0	21.71	6,500.0
2,048.0	22.00	7,350.00	22.50	7,800.0
3,200.0	24.22	12,250.00	24.72	13,000.0
4,096.0	25.01	14,700.00	25.51	15,600.0

Ku band tariffs(USA Dollars)

Speed (KBPS) up to	Assigned power (dBw) up to	Morelos II	Assigned power (dBw) up to	Solidaridad Region I
32.0	6.92	193.0	13.39	350.0
64.0	9.93	386.0	16.40	700.0
128.0	12.94	772.0	19.41	1,400.0
256.0	15.96	1,547.0	22.42	2,811.0
384.0	17.73	2,325.0	24.22	4,234.0
512.0	18.97	3,094.0	25.45	5,622.0
768.0	20.77	4,680.0	27.28	8,574.0
1,544.0	24.00	9,853.0	30.51	18,052.0
2,048.0	24.75	11,700.0	31.26	21,437.0
3,200.0	26.58	17,829.0	33.30	34,300.0
4,096.0	27.50	22,024.0	33.76	38,110.0

INVESTMENT PROJECT

Cash Flow													
Concept	**Years**												
	1995 $	1996 $	1997 $	1998 $	1999 $	2000 $	2001 $	2002 $	2003 $	2004 $	2005 $	2006 $	2007 $
Income	87,514.16	104,167.98	123,200.93	123,411.65	137,686.36	154,340.18	159,098.42	168,614.89	173,373.13	182,889.60	185,268.72	190,026.95	194,785.19
Financial cost	19,546.15	19,546.15	19,546.15	38.368.38	38.368.38	38.368.38	38.368.38	38.368.38	38.368.38	38.368.38	38.368.38	38.368.38	38.368.38
Costs	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00
Depreciation	25,384.62	25,384.62	25,384.62	25,384.62	49,829.06	49,829.06	49,829.06	49,829.06	49,829.06	49,829.06	49,829.06	49,829.06	49,829.06
Taxable Base	59,129.54	75,783.37	94,816.31	95,027.03	84,857.30	101,511.12	106,269.36	115,785.83	120,544.07	130,060.54	132,439.66	137,197.89	141,956.13
Income Tax IT 40%	23,651.82	30,313.35	37,926.52	38,010.81	33,942.92	40,604.45	42,507.74	46,324.33	48,217.63	52,024.22	52,975.86	54,879.16	56,782.45
Taxable Base – IT	35,477.72	45,470.02	56,889.79	57,016.22	50,914.38	60,906.67	63,761.61	69,471.50	72,326.44	78,036.32	79,463.79	82,318.74	85,173.68
Assets investment	330,000.00	0.00	0.00	220,000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net cash flow(NCF)	(269,137.66)	70,854.64	82,274.40	(137,599.17)	100,743.44	110,735.73	113,590.67	119,300.56	122,155.50	127,865.38	129,292.85	132,147.80	135,002.74
Discount Rate(DR)	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%
1 + Discount Rate	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Accumulated DR	1.000	1.120	1.254	1.405	1.574	1.762	1.974	2.211	2.476	2.773	3.106	3.479	3.896
Discounted NCF	(269,137.66)	63,263.07	65,588.55	(97,940.37)	64,024.28	62,834.43	57,548.57	53,965.51	49,336.56	46,209.54	41,628.84	37,989.33	34,651.84
Accumulated DNCF	(269,137.66)	(205,874.59)	(140,285.94)	(238,226.31)	(174,202.04)	111.367.61)	(53,819.04)	146.48	49,483.04	95,592.57	137,221.41	175,210.75	209,882.59

DR= 12.00%	NPV	$209,862.59
Transponder Cost = $1,699.37	IRR	20.02%
Transponder Price = $2,379.12	PP	8.99 years

Note: All values are in thousands of dollars

POLITÉCNICA "Ingeniamos el futuro" CAMPUS DE EXCELENCIA INTERNACIONAL