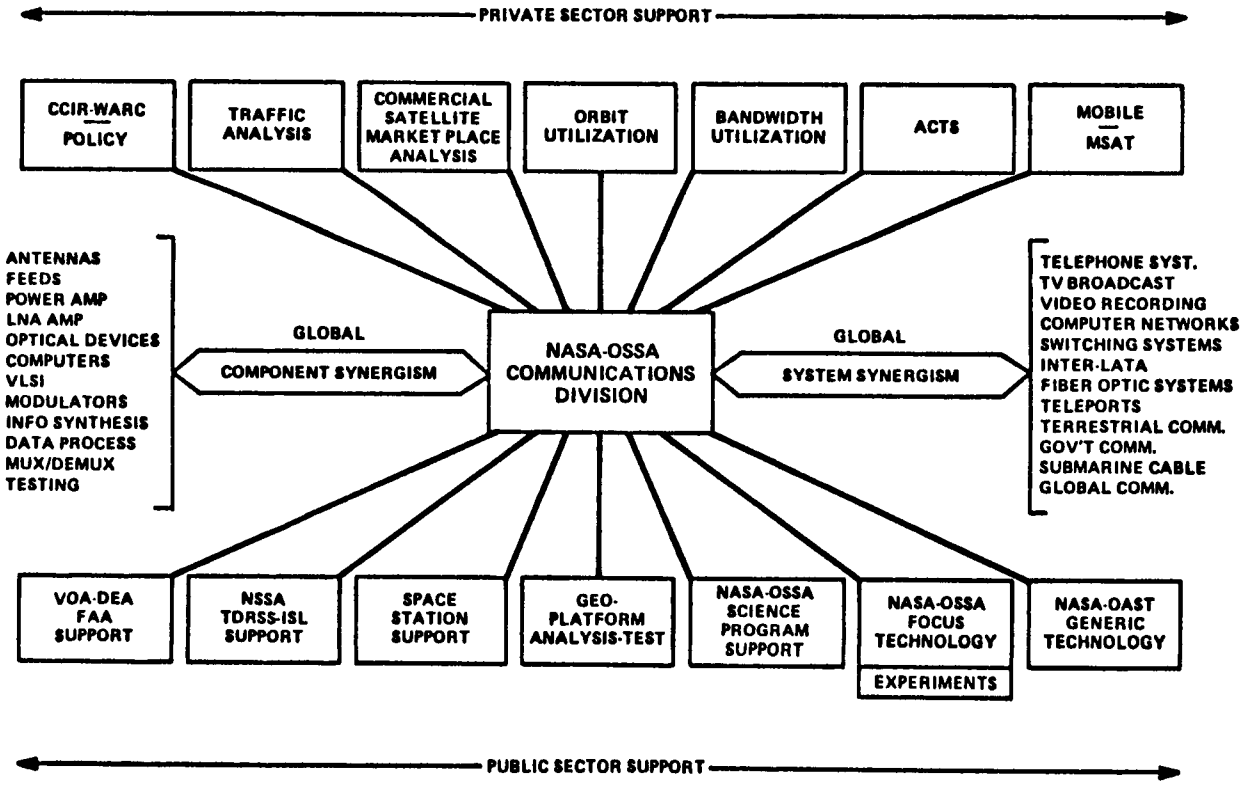
COMMUNICATION SATELLITE TECHNOLOGY TRENDS

Louis Cuccia
NASA Headquarters

A CHRONOLOGY OF SPACE-EARTH INTERCONNECTIVITY

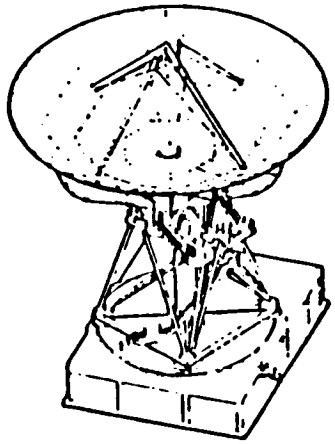
- o THE 1960's- INTERNATIONAL COMMUNICATIONS
- o THE 1970's- INTERNATIONAL AND NATIONAL DOMESTIC COMMUNICATIONS
- o THE 1980's- INTERNATIONAL, NATIONAL, AND REGIONAL SATELLITE COMMUNICATIONS
- o THE 1990's- GLOBAL INTERCONNECTIVITY BY LASER LINKS INTERCONNECTING SATELLITES IN THE ORBITAL ARC
- o 2000+ SPACE NETWORK INTERCONNECTIVITY FOR EARTH, LOW EARTH ORBIT, AND GEOSTATIONARY ORBIT COMMUNICATION SYSTEMS



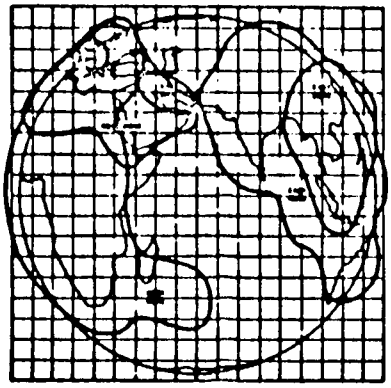
PERSPECTIVE ON THE 1960'S- INTERNATIONAL COMMUNICATIONS

	INTELSAT I	INTELSAT II	INTELSAT III
YEAR OF FIRST LAUNCH	1965	1967	1968
HEIGHT (CM)	60	67	104
WEIGHT IN ORBIT (KG)	38	86	152
ELECTRICAL POWER (KW)	0.04	0.075	0.120
CAPACITY (TELEPHONE CIRCUITS)	240	240	1,200
DESIGN LIFETIME (YEARS)	1.5	3	5
INVESTMENT COST PER CIRCUIT YEAR	$32,500	$11,400	$2,000
COST PER S/C ON ORBIT (MILLIONS OF $)	11.7	8.2	12.2

30 METER STANDARD A

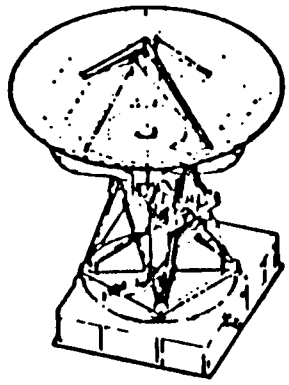


INTERNATIONAL SYSTEMS

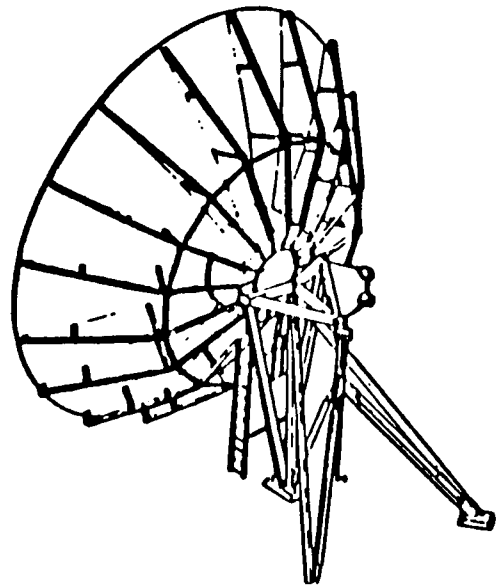


INTELSAT V Indian Ocean Coverage

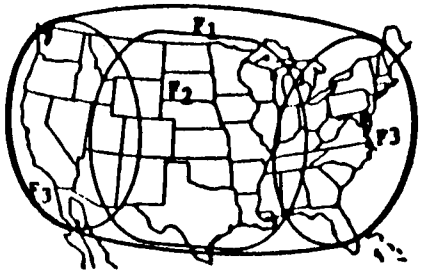
30 METER
STANDARD A



10-13 METER
STANDARD B

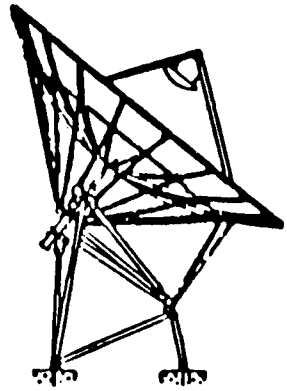


NATIONAL SYSTEMS

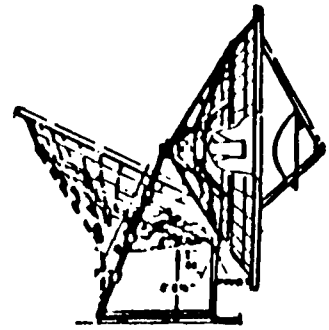


GROUP OF FREQUENCIES F_3 REUSED

9-10 METER
CA-TV

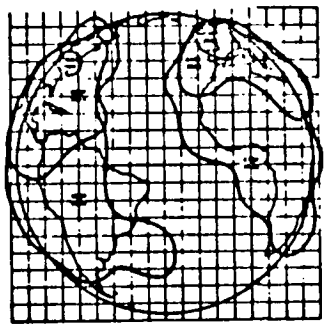


4.5 METER
CA-TV

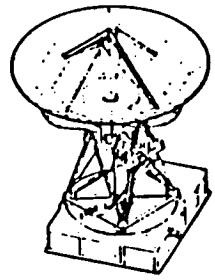


PERSPECTIVE ON THE 1980'S

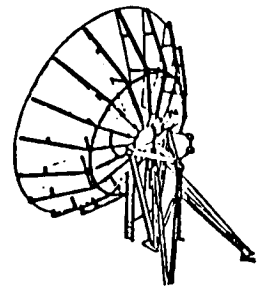
INTERNATIONAL SYSTEMS



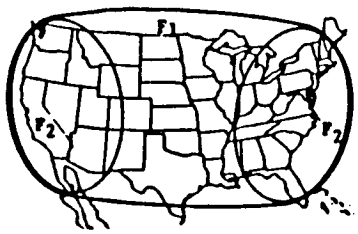
30 METER
STANDARD A



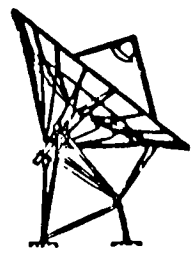
10-13 METER
STANDARD B



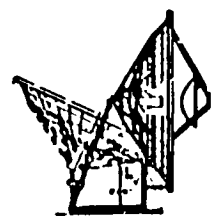
NATIONAL SYSTEMS



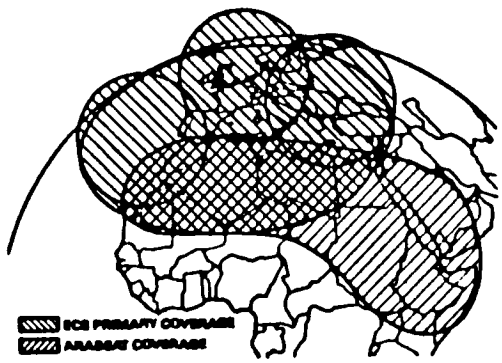
9-10 METER
CA-TV



4.5 METER
CA-TV



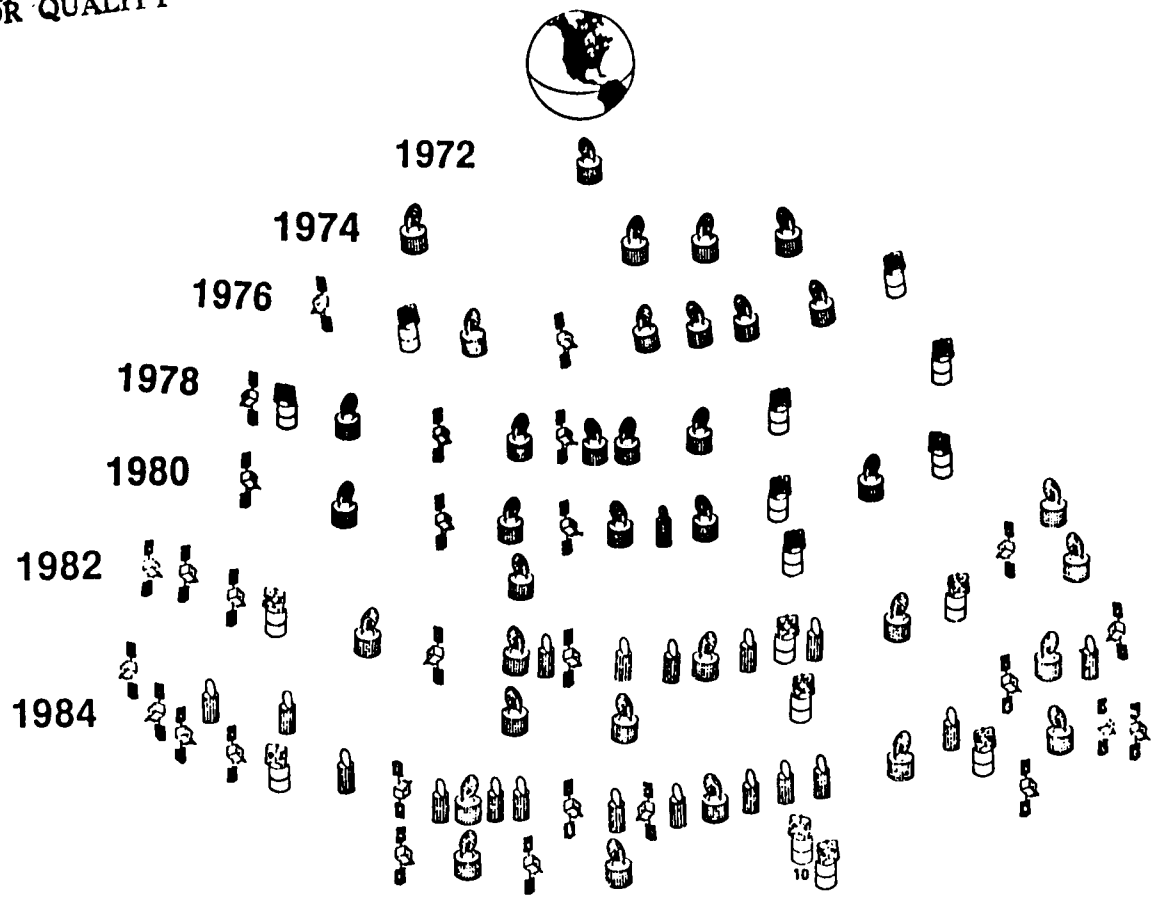
REGIONAL SYSTEMS



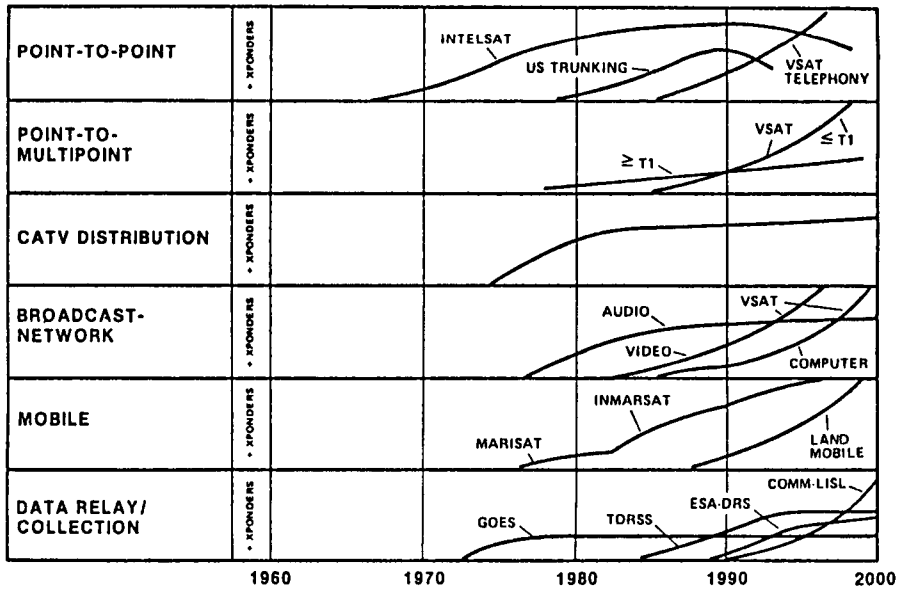
Coverage of Arabsat and Eutelsat

3 METER
MEDIA
DISTRIBUTION

NO. AMERICAN DOMSATS IN GEOSTATIONARY ORBIT



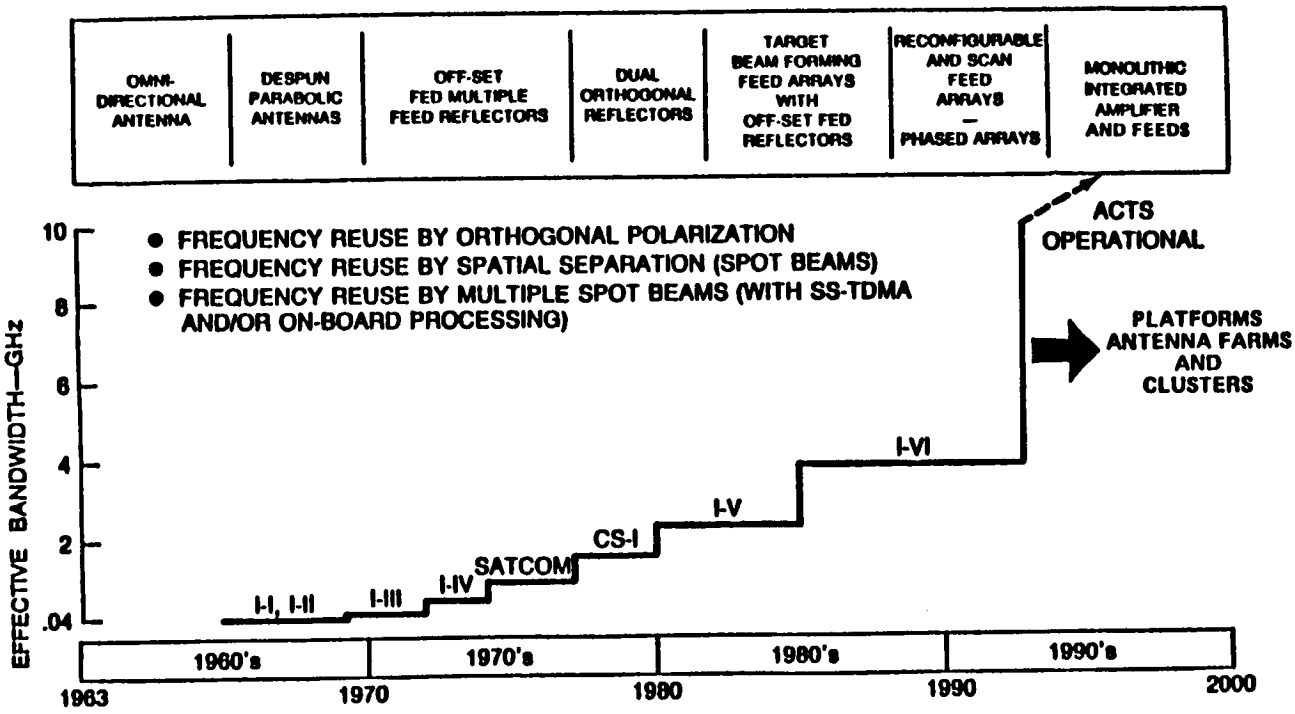
COMMUNICATIONS SATELLITE TRENDS AND OPPORTUNITIES



FUTURE ROLES OF COMMUNICATIONS SATELLITES

- SATCOMS ARE A NATURAL MEDIUM FOR BROADCAST OR INFORMATION/ENTERTAINMENT
- SATCOMS PROVIDE AN OPTIMUM SOLUTION FOR MANY TYPES OF MOBILE COMMUNICATIONS
- SATCOMS PROVIDE FOR EFFICIENT POINT-TO-MULTIPOINT COMMUNCIATIONS
- SATCOMS CAN EFFECTIVELY REACH THIN ROUTE LOW POPULATION DENSITY AREAS NOT ECONOMICALLY SERVED BY TERRESTRIAL NETWORKS
- SATCOMS CAN EFFECTIVELY SERVE ISDN AND LOW DATA RATE/CAPACITY USERS IN THE 50 KBPS TO T1 (1.544 MBPS) RANGE

PERSPECTIVE ON THE INCREASE IN SATCOM BANDWIDTH IN THE GEOSTATIONARY ARC



NASA PROGRAMS IN ADVANCED TECHNOLOGY AND SPACE SYSTEM DEVELOPMENT

- o ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)
- o MOBILE SATELLITE SYSTEM MSAT
- o SHUTTLE-ACTS LASER LINK
- o SPACE STATION COMMUNICATIONS/ANTENNA TEST RANGE
- o GEOSTATIONARY COMMUNICATIONS PLATFORM

THE ENABLING TECHNOLOGIES FOR SPACE SWITCHING CENTERS AND GEOSTATIONARY INTERCONNECTION

TECHNOLOGY	WHERE IN DEVELOPMENT	TIME FRAME
• NARROW BAND (≈5 KBPS) SUBSCRIBER COMMUNICATION	MOBILE SATELLITE	1988 ON
• WIDE BAND (56 KBPS) TRUNK SWITCHING	ACTS SATELLITE	1990
• INTERSATELLITE LINK	ACTS - SHUTTLE EXPERIMENT	1990
• SUPER COMPUTER FOR SPACE	IN DEVELOPMENT IN PRESENT MARKET PLACE	1995

ACTS SYSTEM

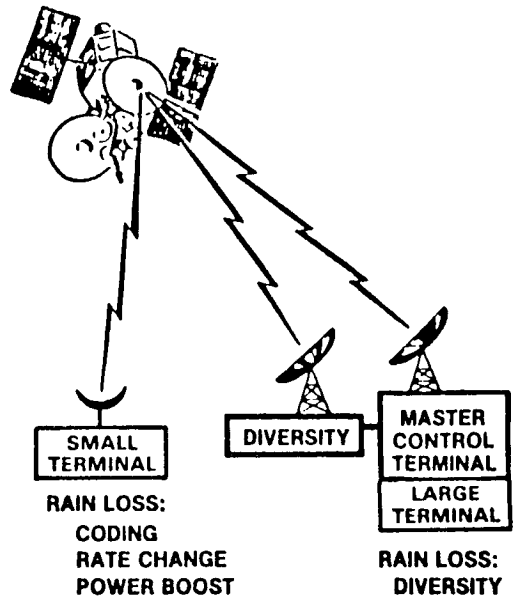
PRIMARY OBJECTIVES:

TO PROVE THE FEASIBILITY OF ADVANCED COMMUNICATIONS SATELLITE TECHNOLOGIES IN THE ENVIRONMENT OF SPACE AND REPRESENTATIVE EARTH ATMOSPHERIC CONDITIONS:

- FIXED AND SCANNING SPOT BEAMS
- FREQUENCY REUSE
- BEAM INTERCONNECTING VIA SATELLITE SWITCHING
- SYSTEM NETWORKING
- RAIN COMPENSATION TECHNIQUES

SECONDARY OBJECTIVE:

OPTICAL INTER-SATELLITE LINK RESEARCH FACILITY

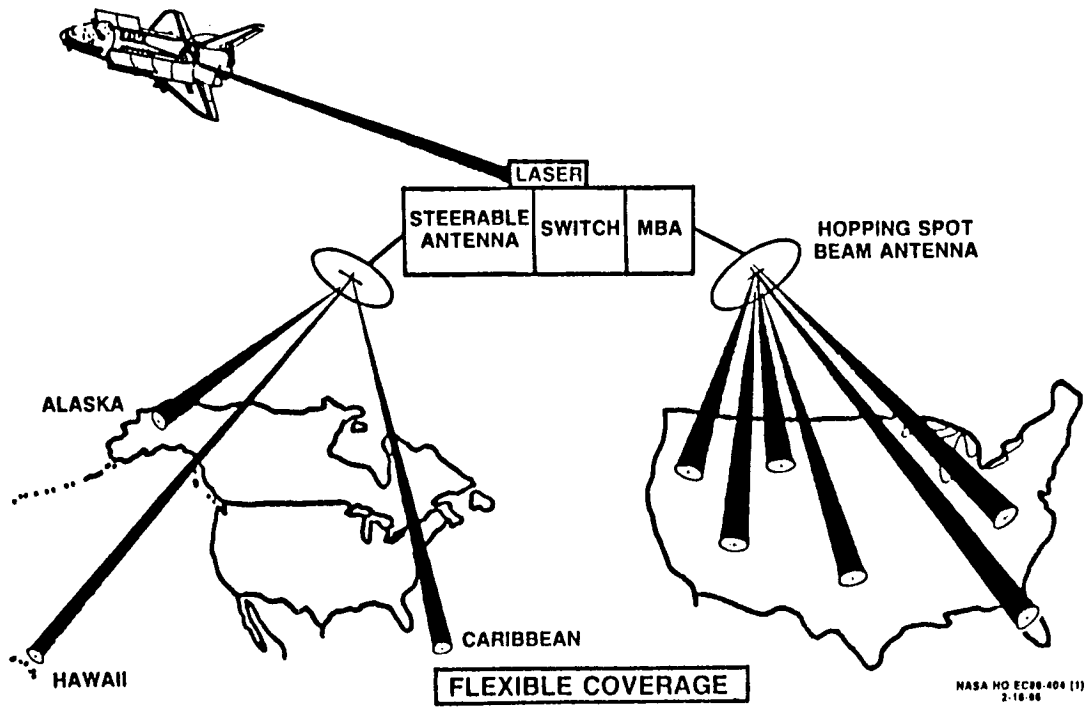


MAX. BURST RATE CAPABILITY: 550 MB/S

FLIGHT EXP. BURST RATES: 110 OR 220 MB/S

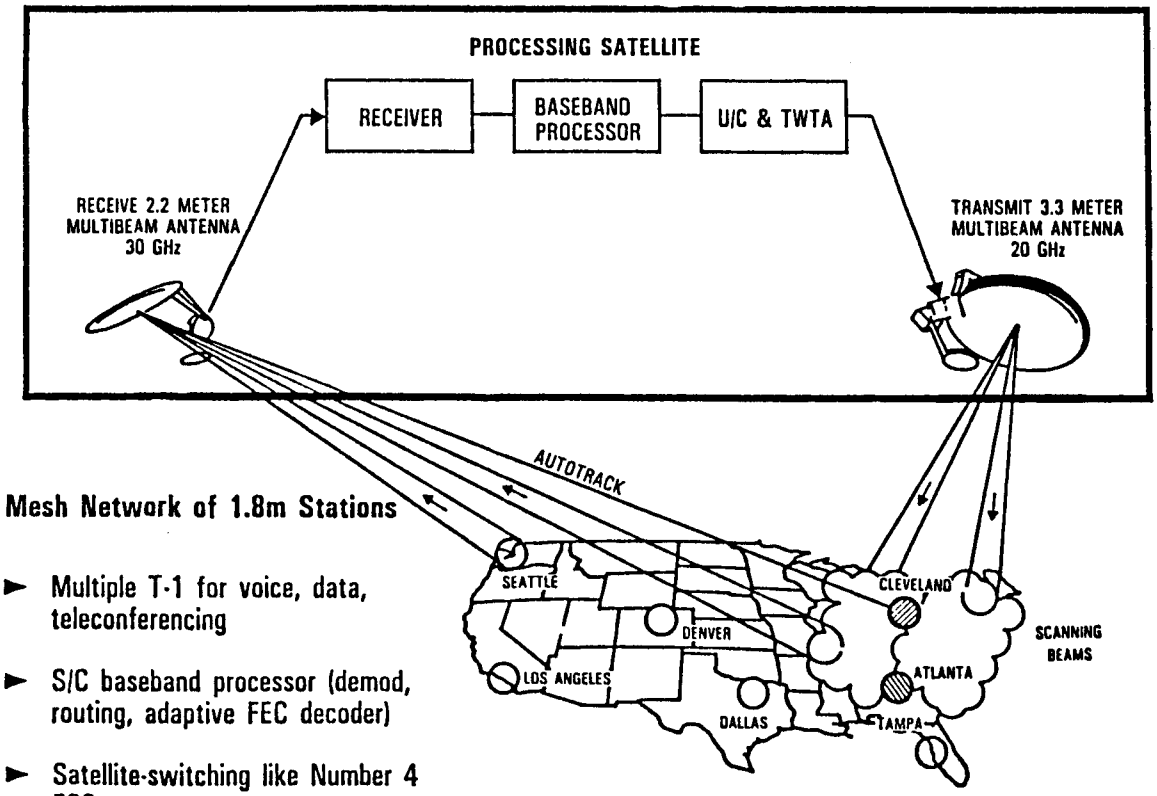
NASA HQ E82-1112(1)
REV. 7-21-82

ACTS SYSTEM COVERAGE



NASA HQ EC88-404 (1)
2-18-88

ACTS 30/20 GHz Experimental System (CPS Mode)

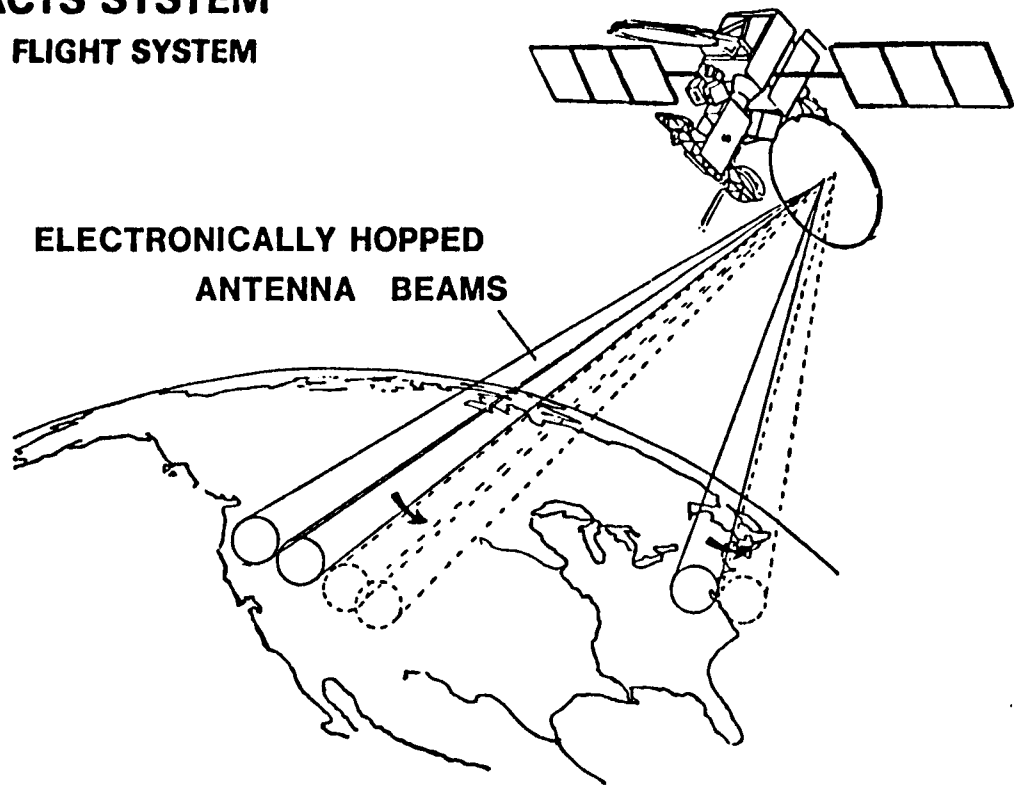


Mesh Network of 1.8m Stations

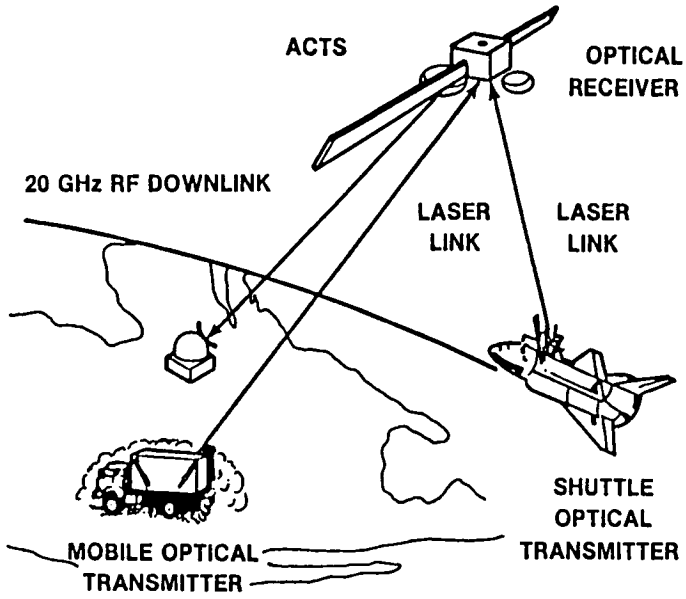
- Multiple T-1 for voice, data, teleconferencing
- S/C baseband processor (demod, routing, adaptive FEC decoder)
- Satellite-switching like Number 4 ESS

ACTS SYSTEM

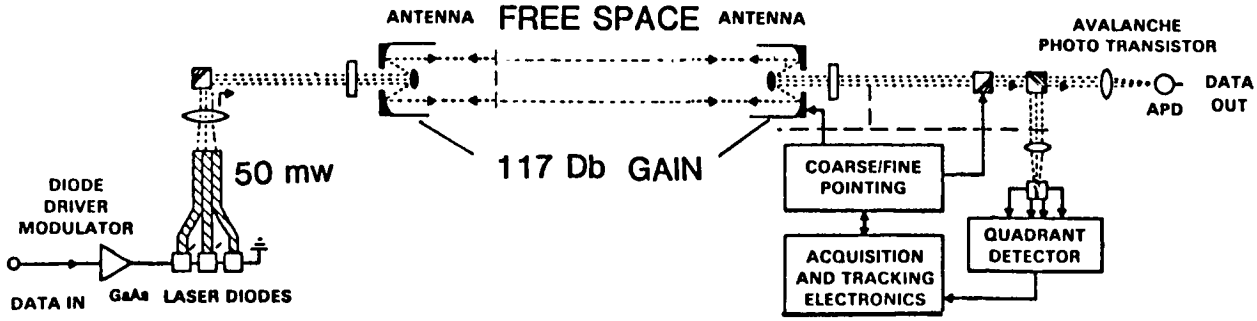
- **FLIGHT SYSTEM**



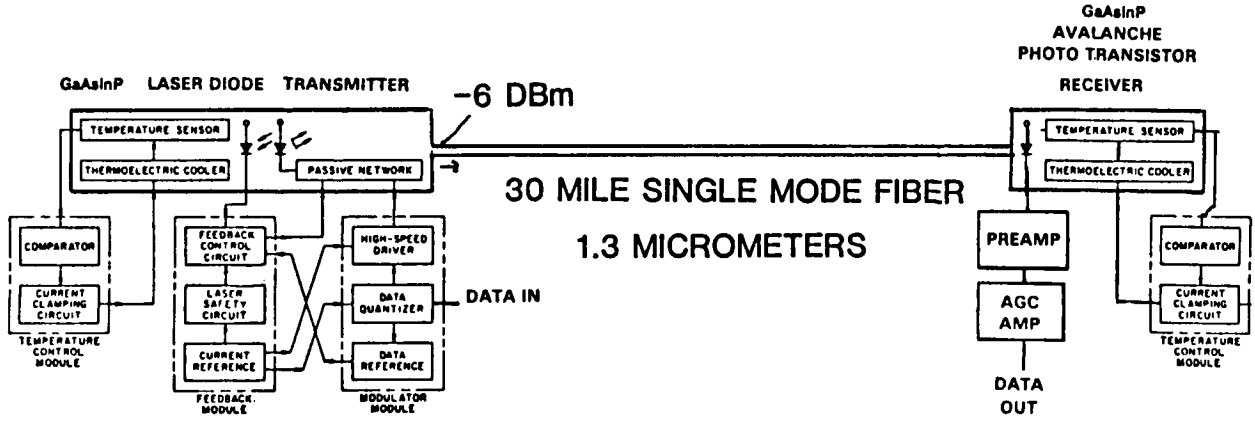
OPTICAL INTER-SATELLITE LINK



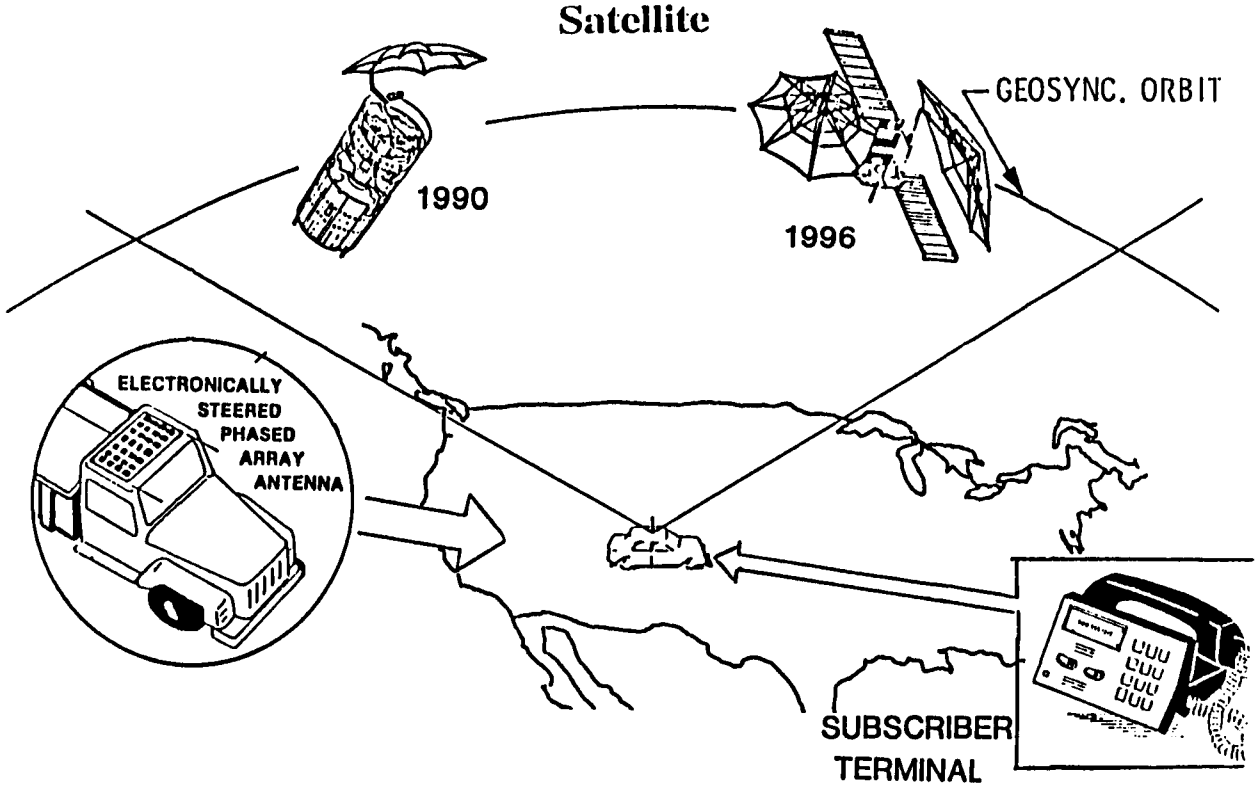
SHUTTLE TO ACTS LASER LINK -220 MBPS 0.86 MICROMETERS



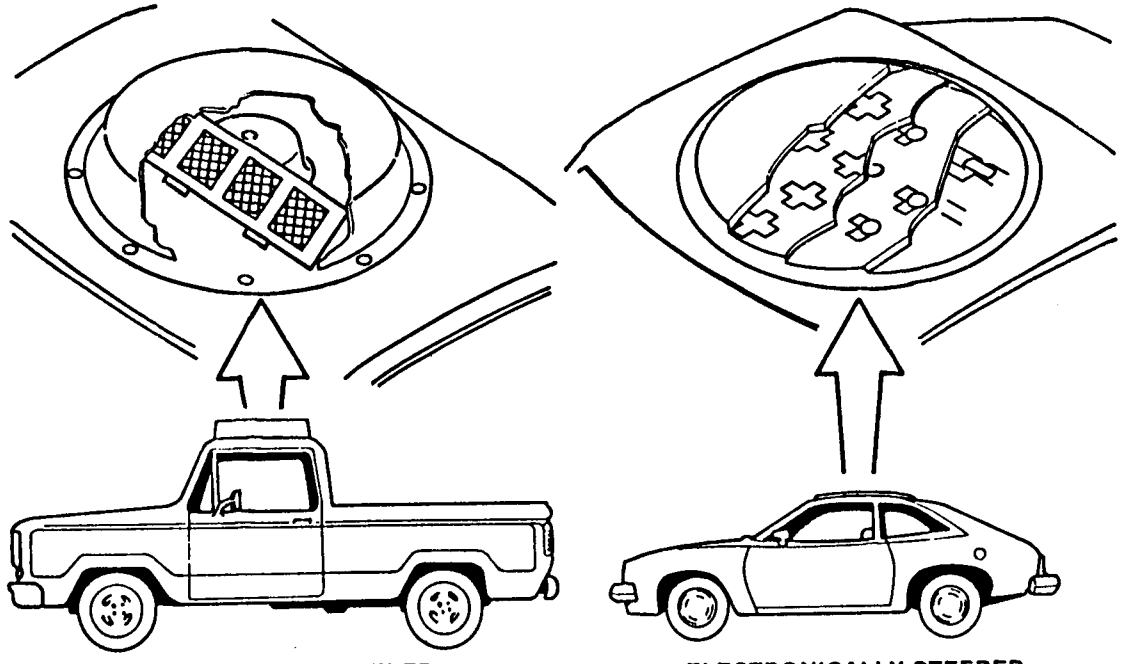
TYPICAL AT&T FTX TERRESTRIAL FIBER OPTIC 430 MBPS LINK



Land Mobile Satellite



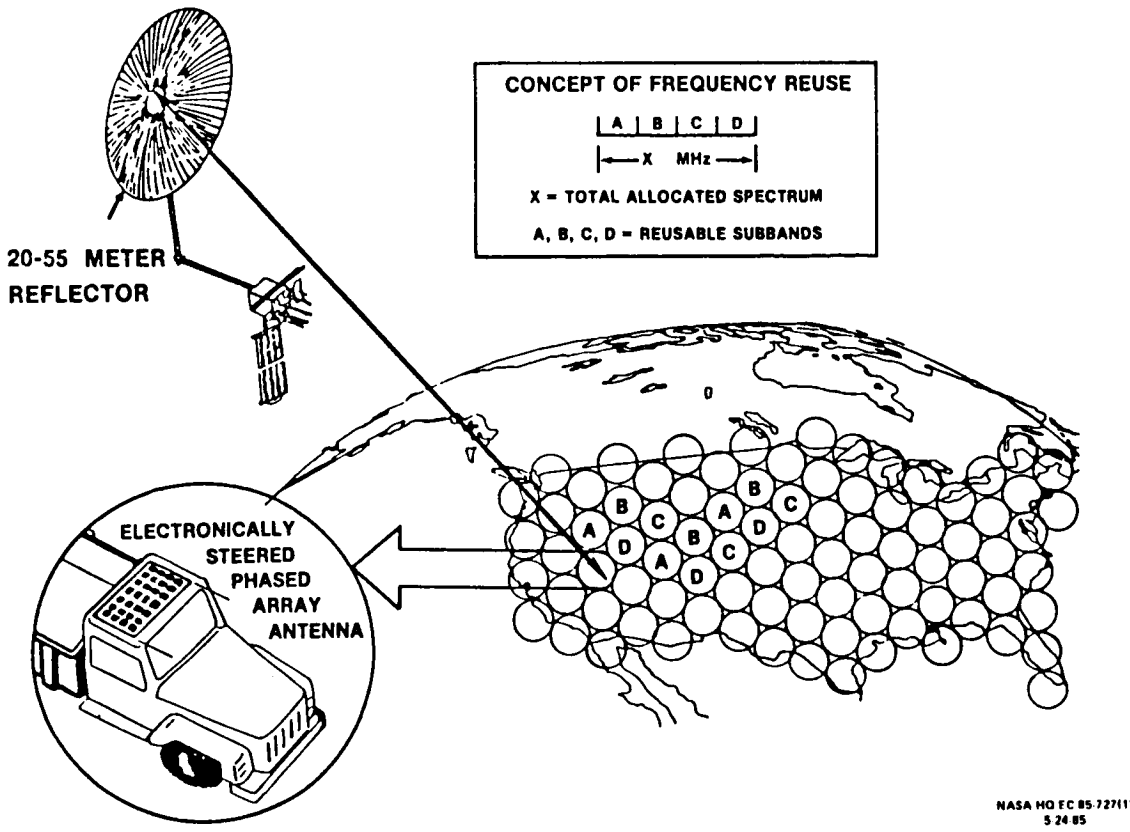
CANDIDATE VEHICLE ANTENNAS FOR MOBILE SATELLITE COMMUNICATIONS



MECHANICALLY STEERED
TILTED MICROSTRIP ARRAY
(7" HEIGHT, 38" DIA.)

ELECTRONICALLY STEERED
PHASED ARRAY
(1.5" HEIGHT, 38" DIA.)

LATER GENERATION SYSTEMS



EVOLUTION OF CRAY COMPUTER*

- SUPER COMPUTER GENERATION IS 3 YEARS
- IN 1987 - CRAY 3 WILL HAVE
  - 16 PROCESSORS
  - EACH 1/2 BILLION 64 BIT WORDS
  - 12'' x 8'' x 4''
- BY THE TIME WE GET TO CRAY-6,-- 1995---, CRAY-3 WILL BE HAND HELD
- PROCESSING POWER WILL BE IN GREATER DEMAND THAN BANDWIDTH AS IT BECOMES AVAILABLE IN SPACE APPLICATIONS

*MR. BRETT BERLIN, 1985

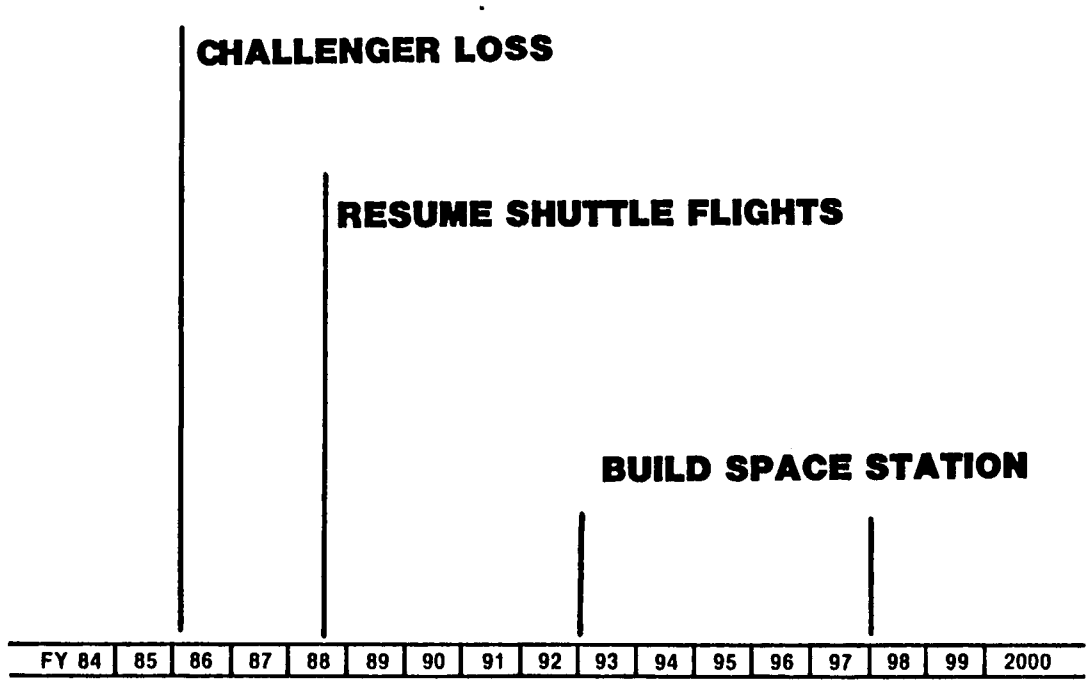
EVOLUTION OF TERRESTRIAL SWITCH TECHNOLOGY

TO SIZE AND POWER COMPATIBLE WITH SPACECRAFT

ITEM	YEAR 65	71	77	78	81	89
RELATIVE VOLUME	3840	320	80	20	2	1
POWER μWATT/BIT	2800	175	70	20	4	1
SPEED μSEC	5.5	5.5	1.4	.7	.55	.55
MEMORY IN MEGABYTES	1.18	1.18	1.18	.79	1.05	1.0
	SHEET FARRITE	CORE	SEMICON-DUCTOR	SEMICON-DUCTOR	SEMICON-DUCTOR	SEMICON-DUCTOR
	104 FT. LONG		4K RAM	16K RAM	64K RAM	256K RAM

NASA HQ EC86-20011
10-28-85

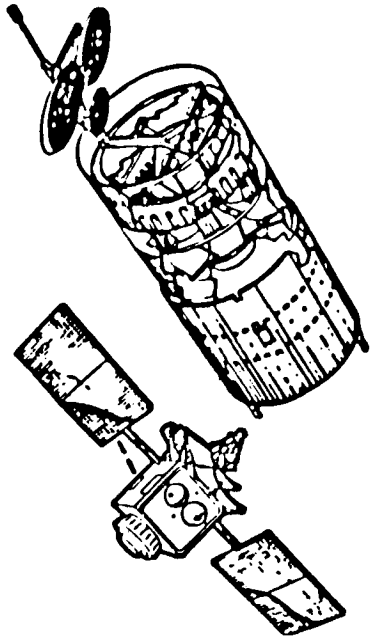
IMPACT OF CHALLENGER DISASTER



THE PATHS OF INTERCONNECTIVITY SPACE-EARTH ANTENNA BEAMS

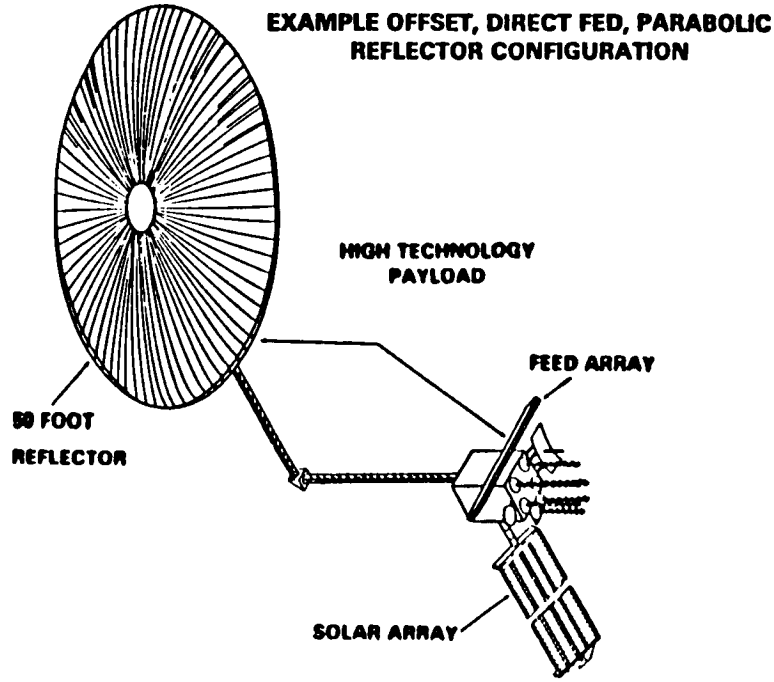
CONVENTIONAL

SATELLITE DESIGN



FUTURE SATELLITE DESIGN USING SPACE STATION

AS ASSEMBLY BASE

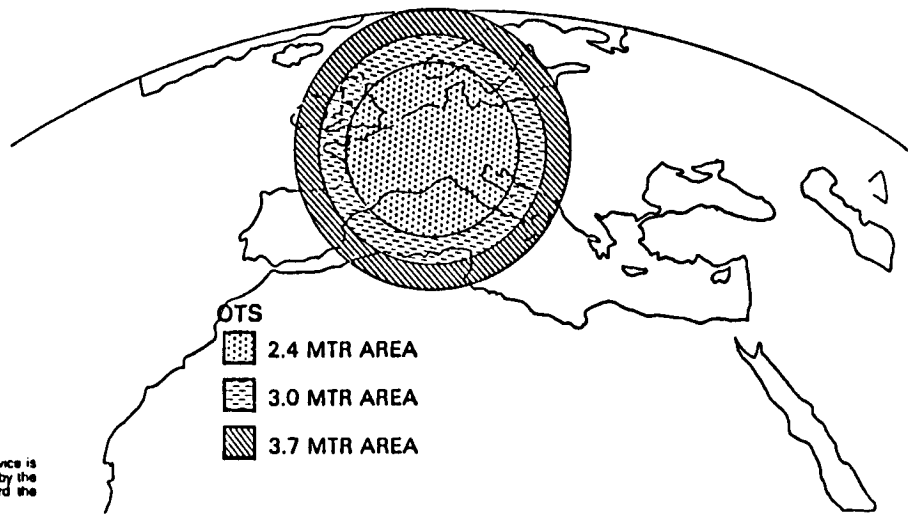


WILL NOW CONTINUE

WILL BE DELAYED

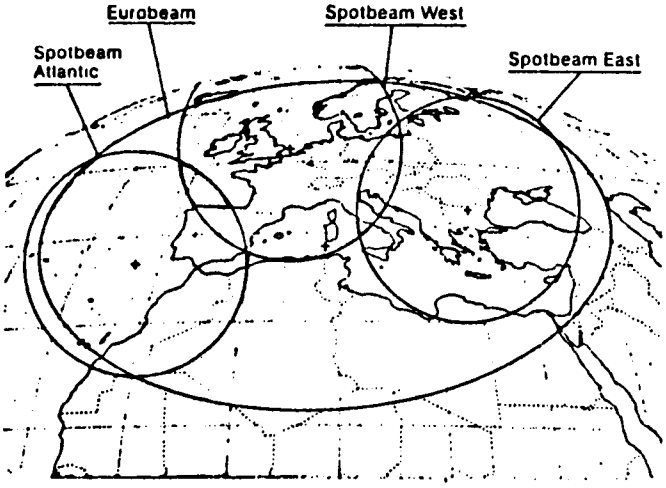
EUROPEAN SATELLITES WITH CENTER FED SPOT BEAM ANTENNAS - OTS

O.T.S. GROUNDPRINT-SPOT BEAM



Satellite Television's new service is directed throughout Europe by the European Space Agency bird the "OTS" Satellite"

EUROPEAN SATELLITES WITH CENTER FED SPOT BEAM ANTENNAS-ECS

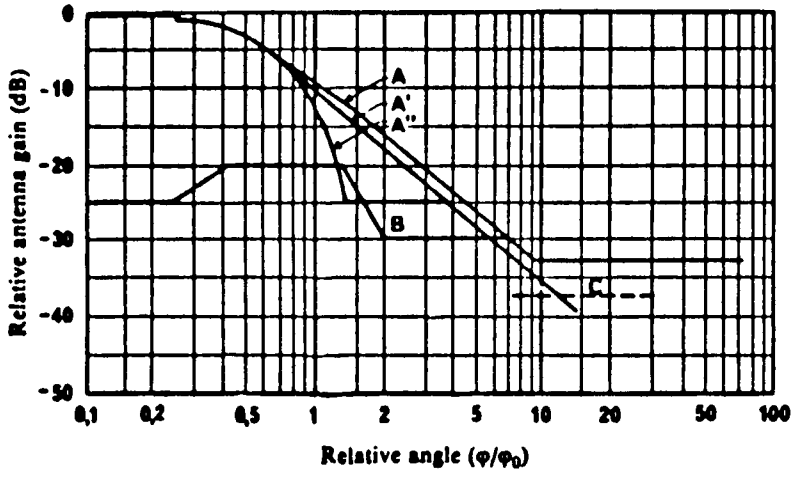


The TV and telecommunications beams of ECS

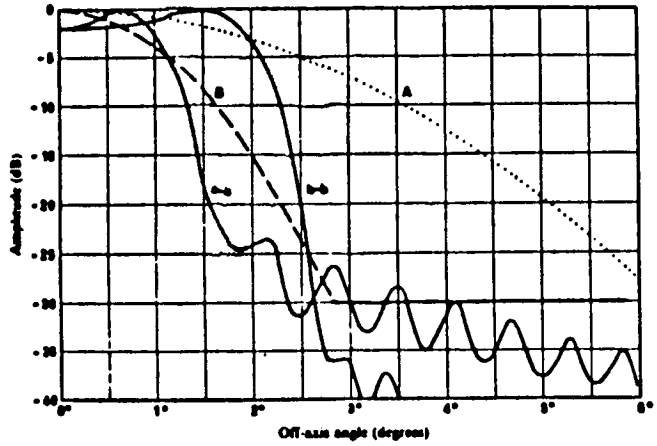
INVESTMENT IN ECS

Country	ECS Share
Austria	1.97
Belgium	4.92
Cyprus	0.97
Denmark	3.28
Finland	2.73
France	16.40
West Germany	10.82
Greece	3.19
Ireland	0.22
Italy	11.48
Luxembourg	0.22
Netherlands	5.47
Norway	2.51
Portugal	3.06
Spain	4.64
Sweden	5.47
Switzerland	4.36
Turkey	0.93
United Kingdom	16.40
Yugoslavia	0.96
	100.00%

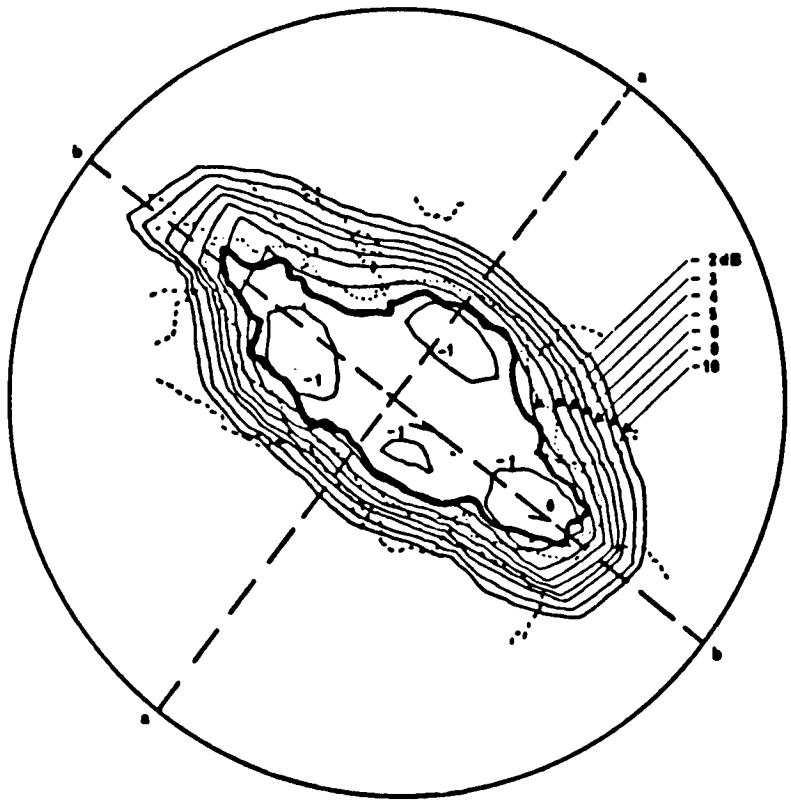
WARC-77 ANTENNA PATTERN



CONTOURED ANTENNA PATTERN



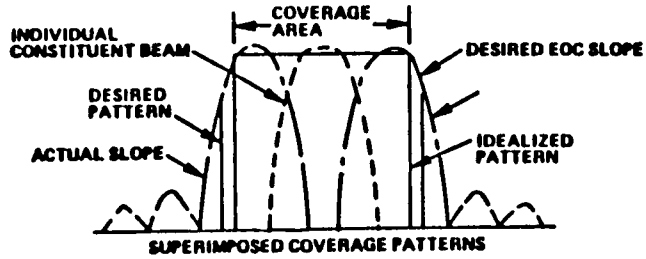
MULTI-BEAM ANTENNA CONTOURING A COUNTRY

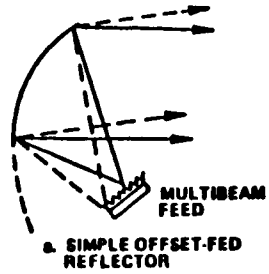


Computed shaped beam pattern at 11.379 GHz for a 21-horn offset-fed parabolic reflector system

ORIGINAL PAGE IS
OF POOR QUALITY

MULTIPLE-FEED OFFSET FED SATELLITE ANTENNA AND SUPERIMPOSED BEAM PATTERNS FOR SHAPED AREA COVERAGE ON EARTH





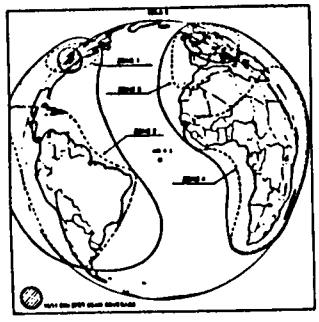
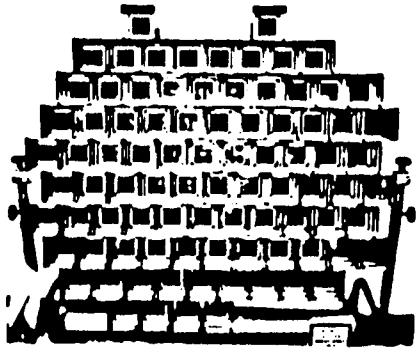
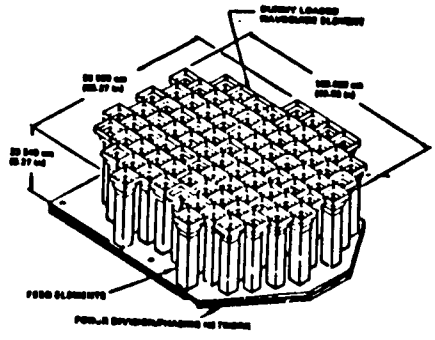


Figure 8. INTELSAT VI COVERAGE CONTOURS FOR THE AOR FROM 335.5 DEGREES EAST LONGITUDE

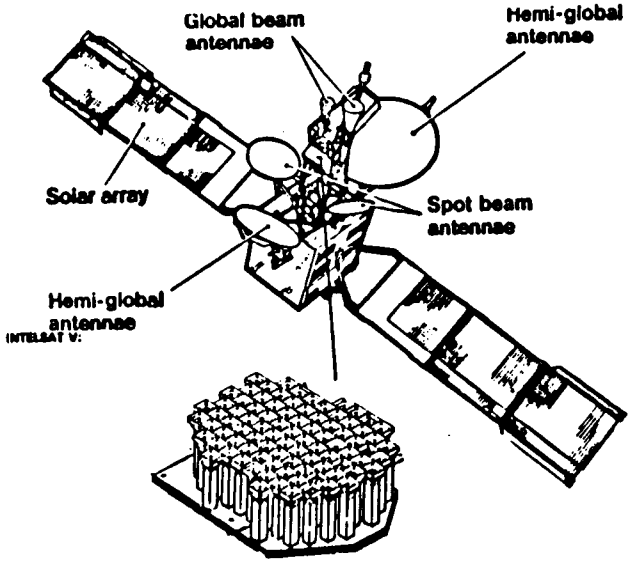


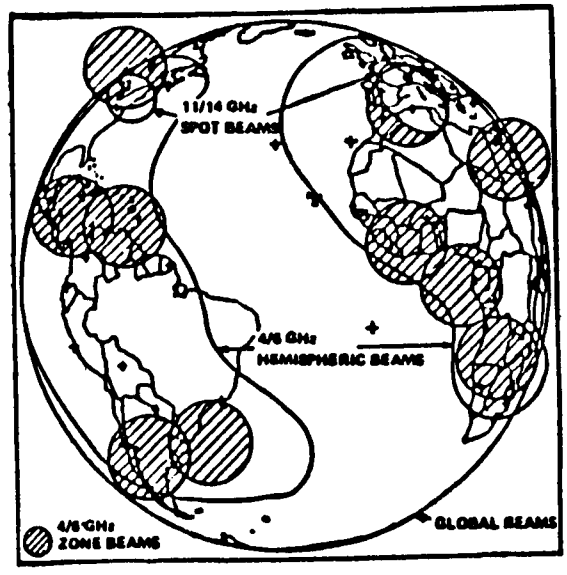
Transmit Feed Array



Intelsat V Antenna Feed Assembly

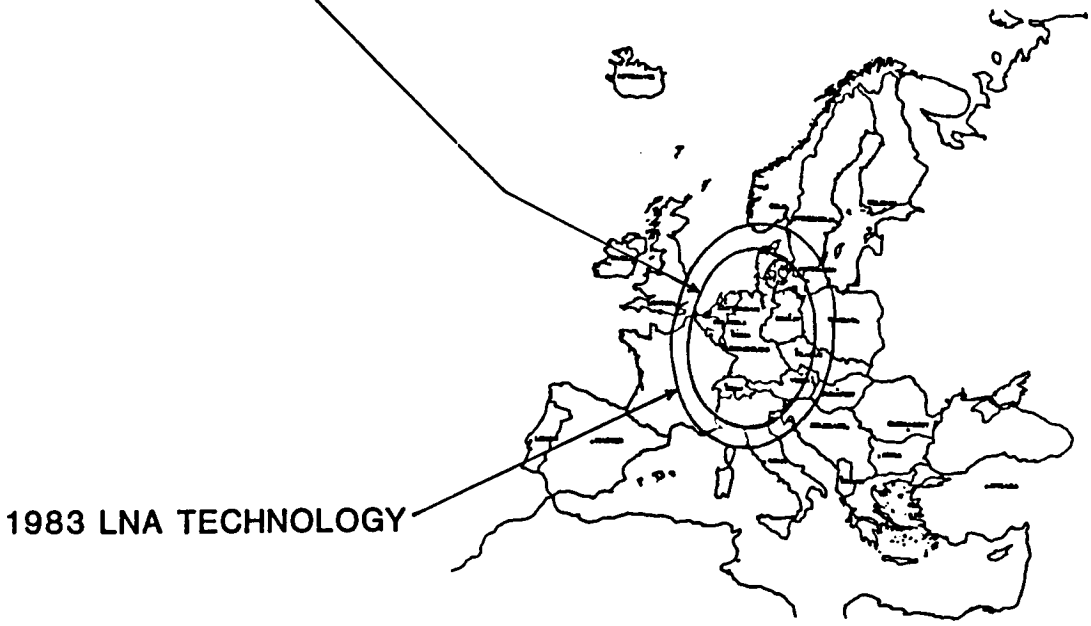
MULTIPLE AREA COVERAGE INTELSATS IV IVA V VA VI





HAZARDS OF APRIORI PLANNING

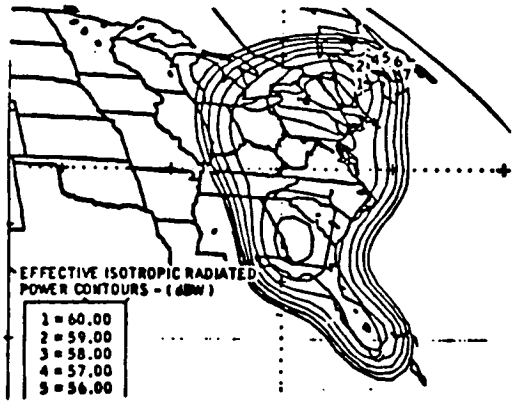
WARC-77 COVERAGE WITH1977 LNA TECHNOLOGY IN EARTH STATION



1983 LNA TECHNOLOGY

CONTOURED ANTENNA BEAM EXAMPLES

COMSAT STC DBS



ARABSAT

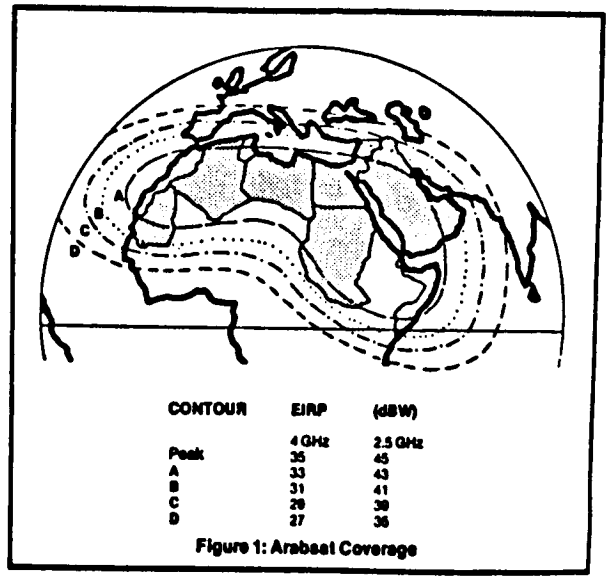
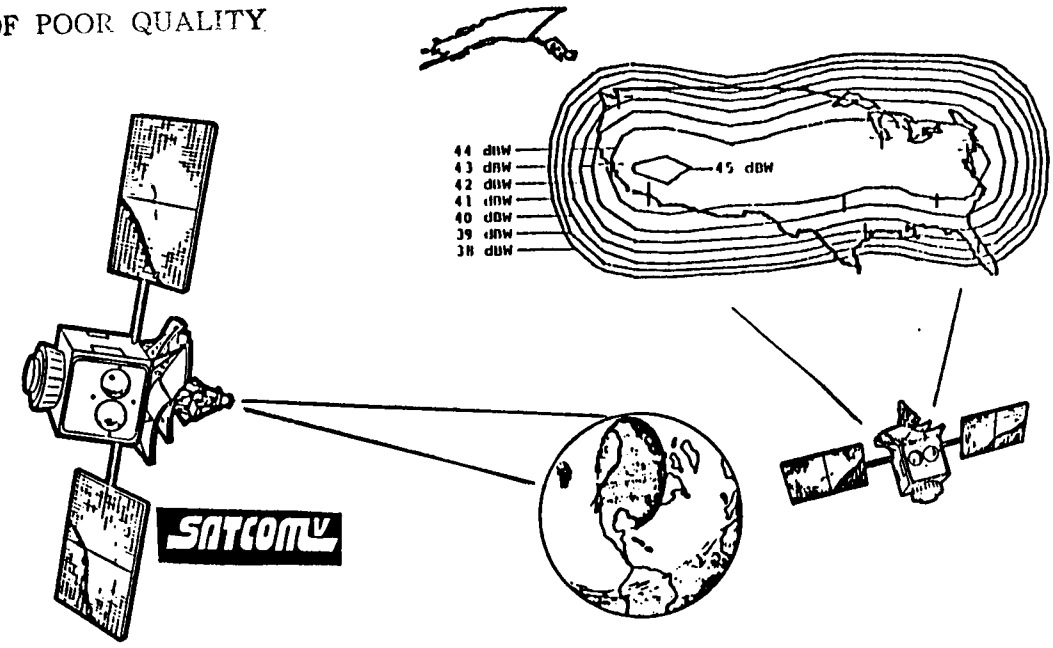


Figure 1: Arabsat Coverage

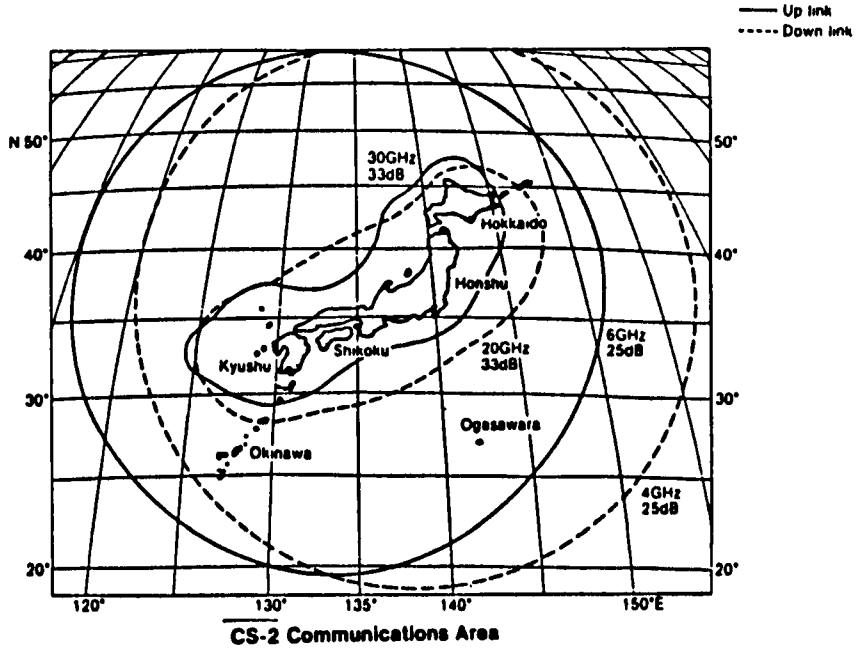
SATELLITES WITH CONTOURED BEAM ANTENNAS

RCA SATCOMS

ORIGINAL PAGE IS
OF POOR QUALITY



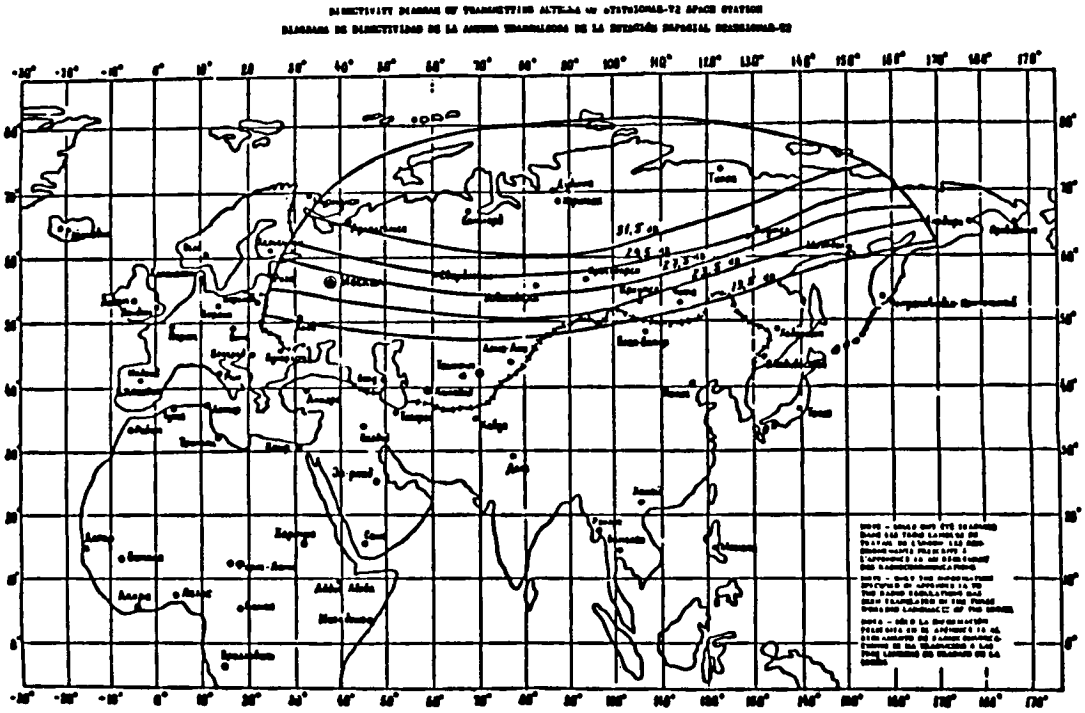
JAPAN CS-2A 30/20 GHZ ANTENNA PATTERN



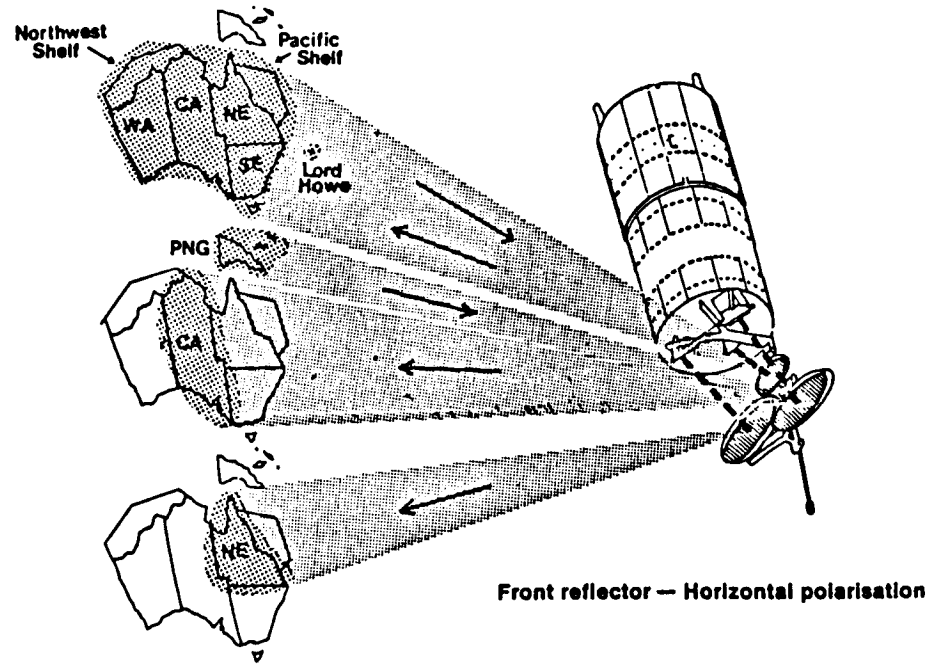
CS-2 Communications Area

USSR STATSIONAR T2 CONTOURED 716 MHZ BEAM

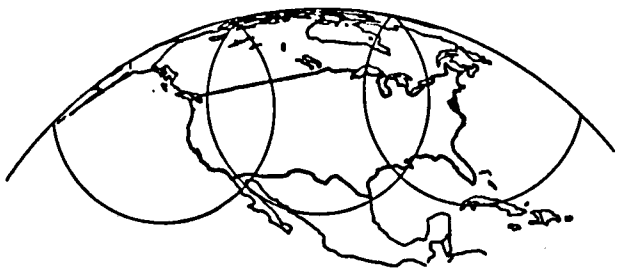
USING 96 HELICAL ANTENNA ARRAY



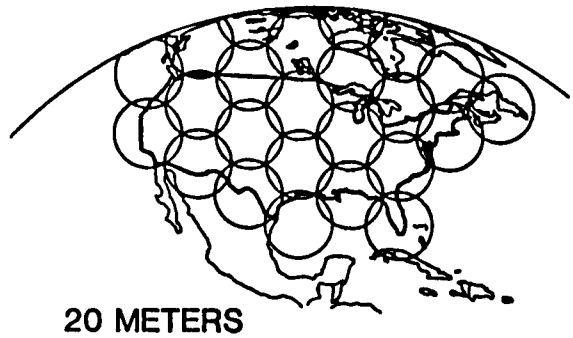
MULTIPLE BEAM AUSSAT



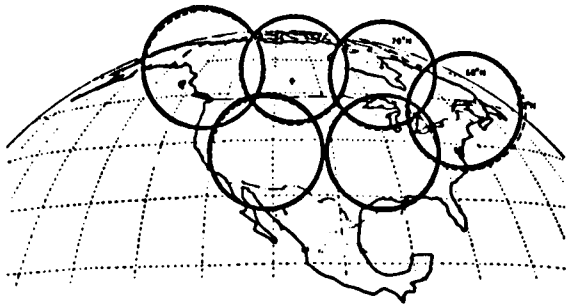
IMPACT OF ANTENNA SIZE ON U S COVERAGE AT 860 MHZ



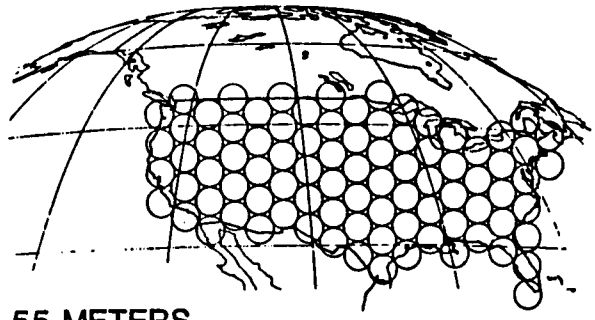
5.5 METERS



20 METERS



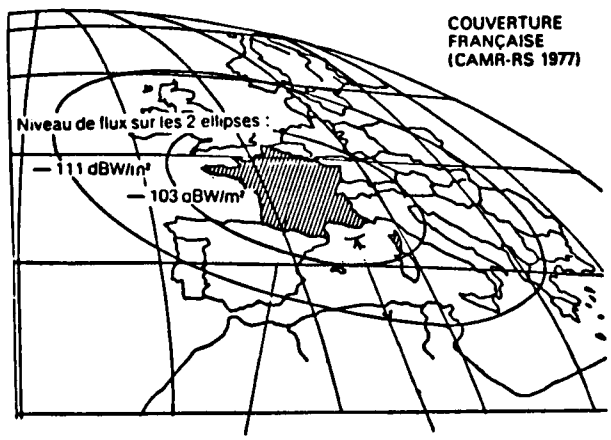
9 METERS



55 METERS

87 CELLS

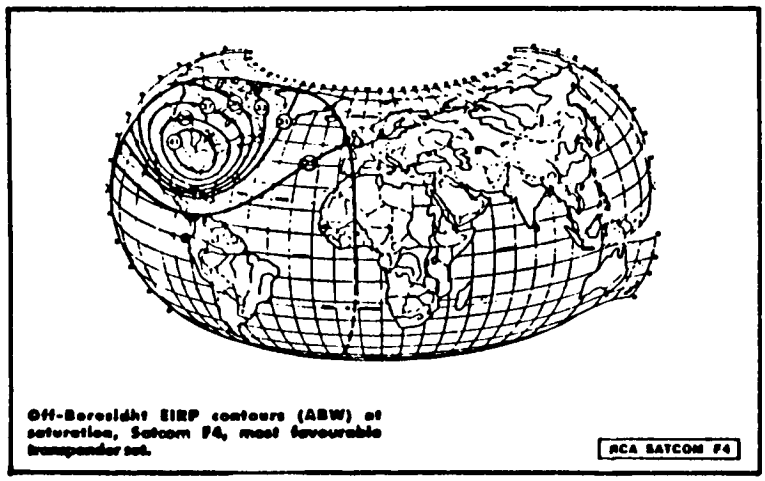
THE POLITICS OF ANTENNA COVERAGE AND SPILLOVER



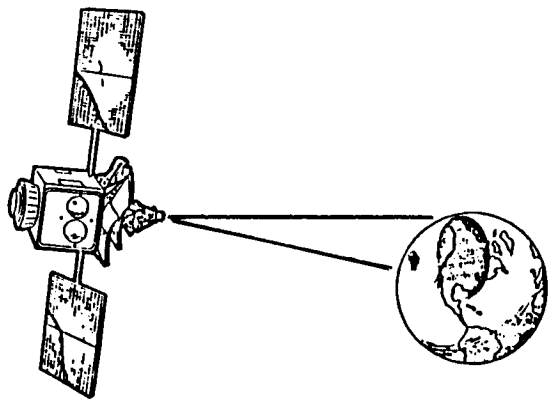
PRIMARY COVERAGE AREA

ADJACENT COUNTRY SPILLOVER

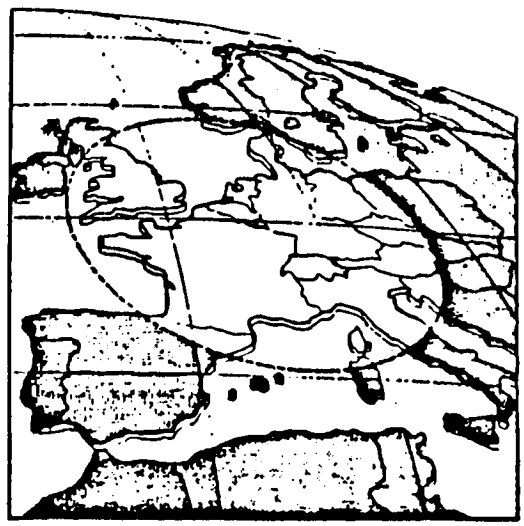
SATCOM F4 SPILLOVER TO EUROPE



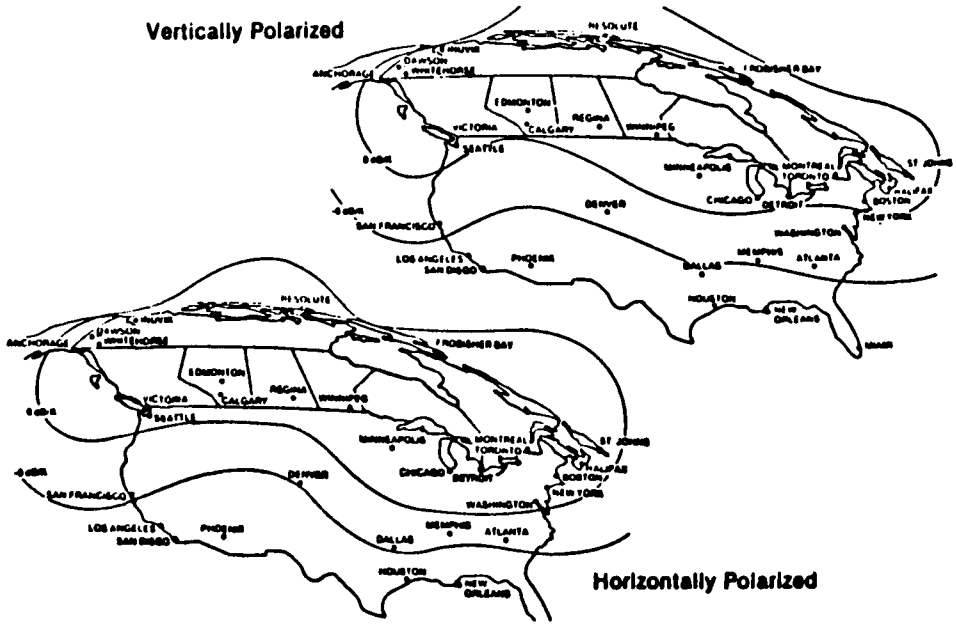
Off-Boresight EIRP contours (ABW) at saturation, Satcom F4, most favourable transponder set.



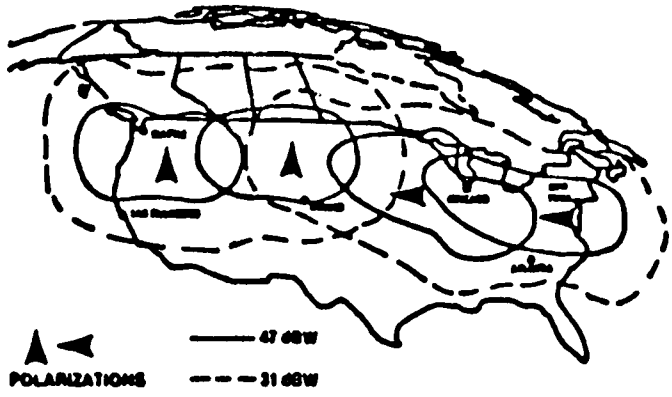
FRENCH TELCOM 1 SPILLOVER TO WARSAW PACT NATIONS



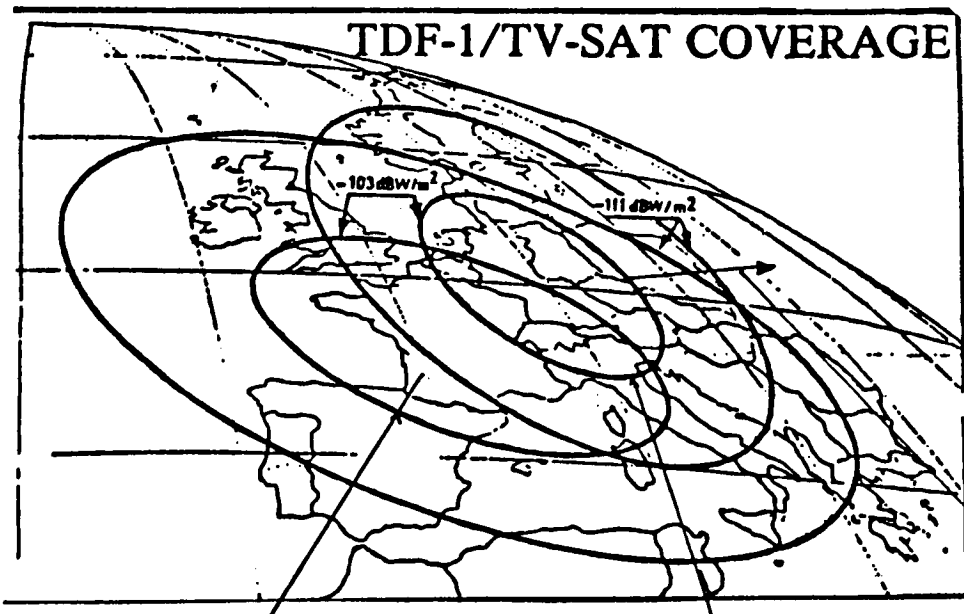
CANADIAN SPILLOVER TO U S



Anik D 6 GHz Receive Pattern (G / T) (Typical)



ANIK C3 12GHz TRANSMIT PATTERN (EIRP)
(TYPICAL)

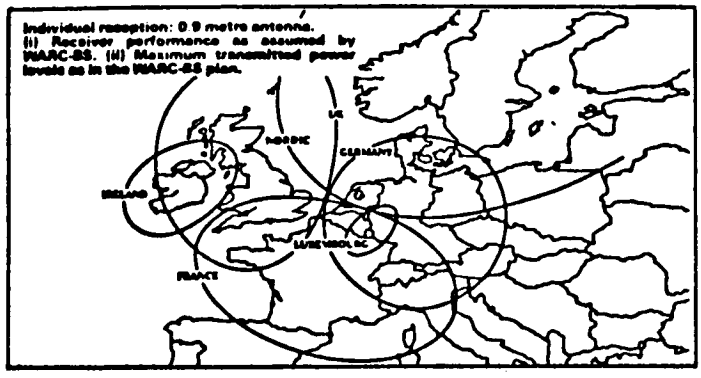


FRENCH TDF DBS PRIMARY COVERAGE

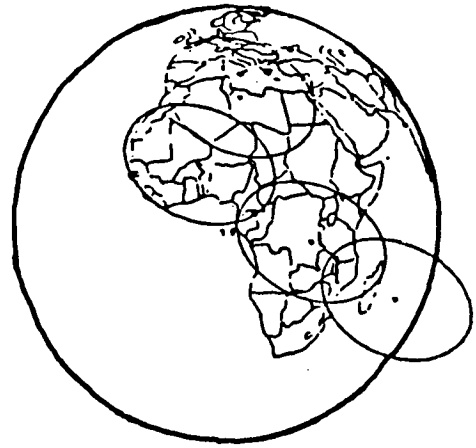
GERMANTV-SAT DBS PRIMARY COVERAGE

SPILLOVER TO GDR POLAND USSR

WARC-77 DBS SPILLOVER IN EUROPE



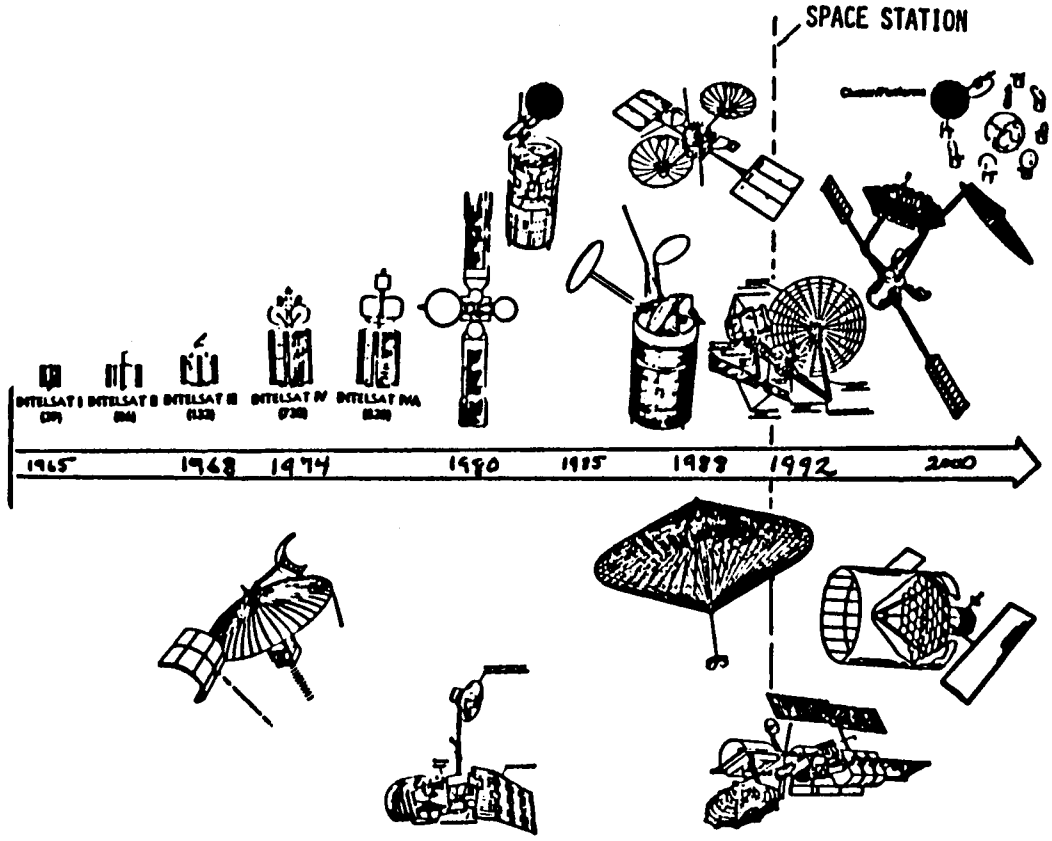
FRENCH "SPILLOVER" TO CENTRAL AFRICA



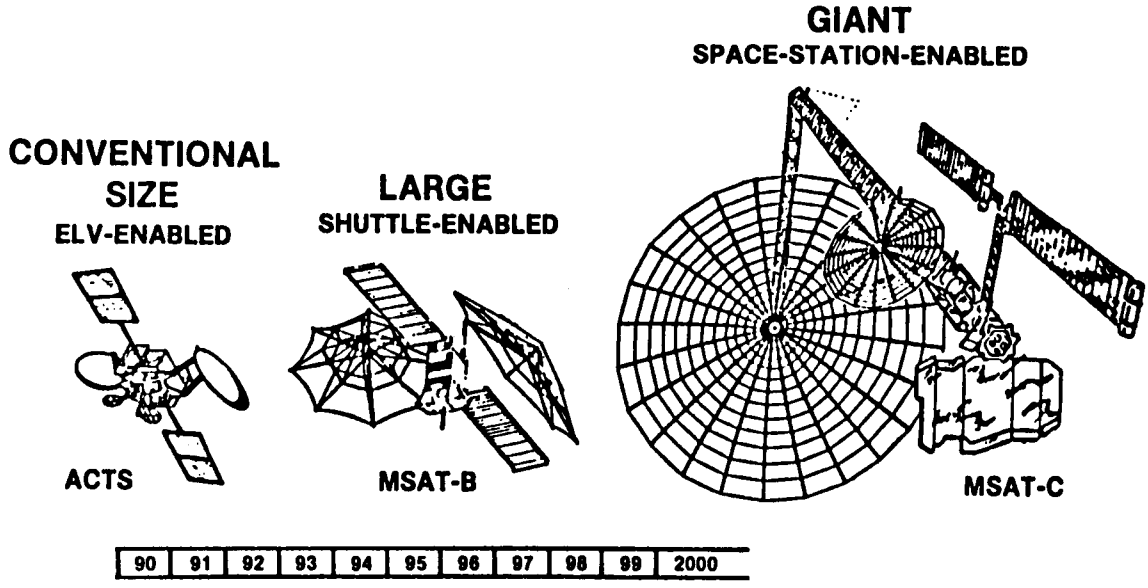
ATHOS 6/4 GHz coverage zones

TRANSITION TO GIANT ANTENNAS IN THE SPACE STATION ERA

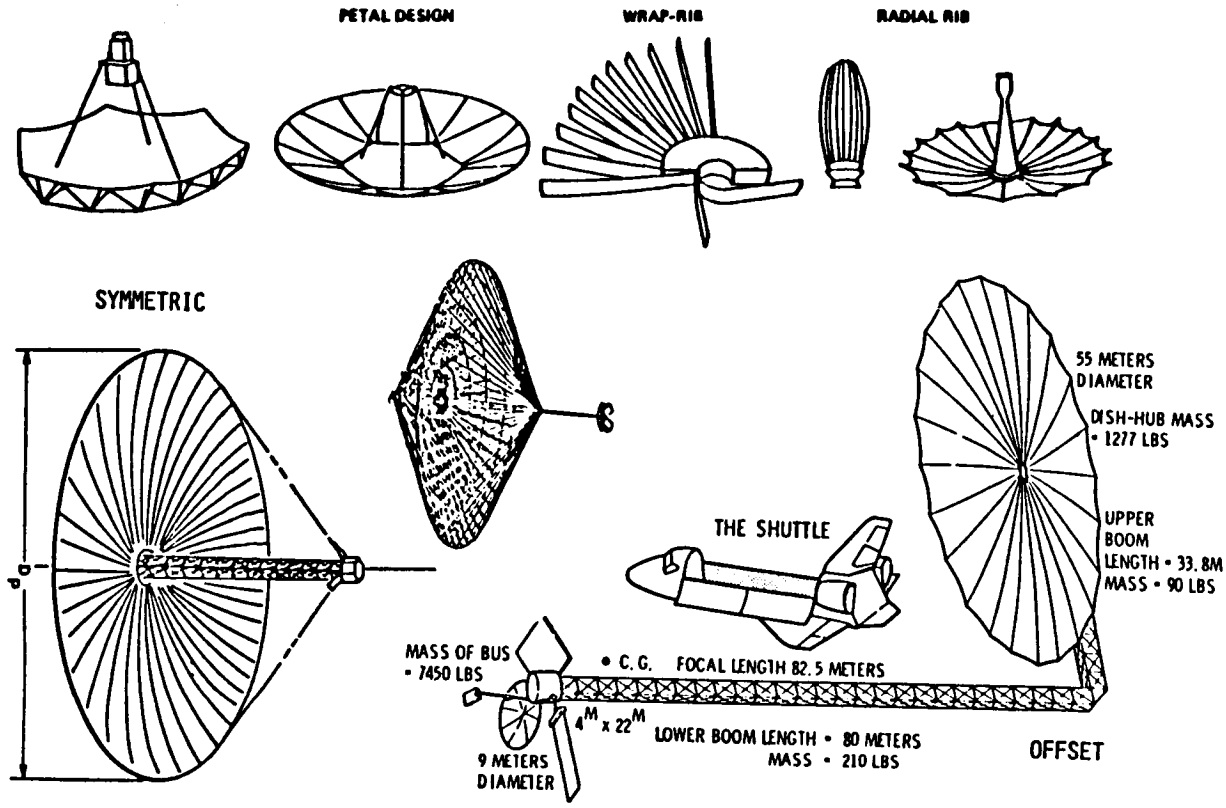
NOW DELAYED



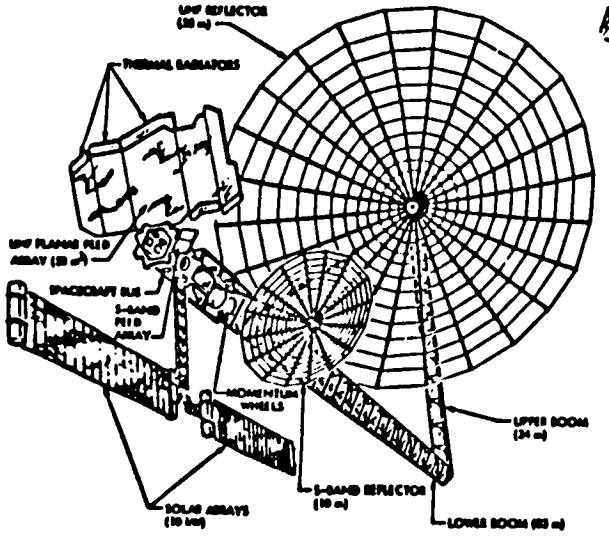
GROWTH IN ANTENNA SIZE



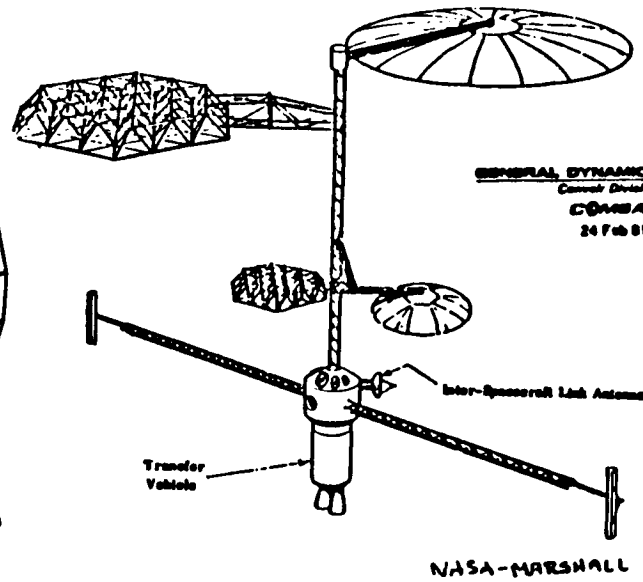
TYPES OF GIANT ANTENNAS FOR UNFURLING



CANDIDATE GEOSTATIONARY PLATFORMS



A Conceptual Drawing Depicting a Time-of-the-Century Mobile Satellite (JPL)

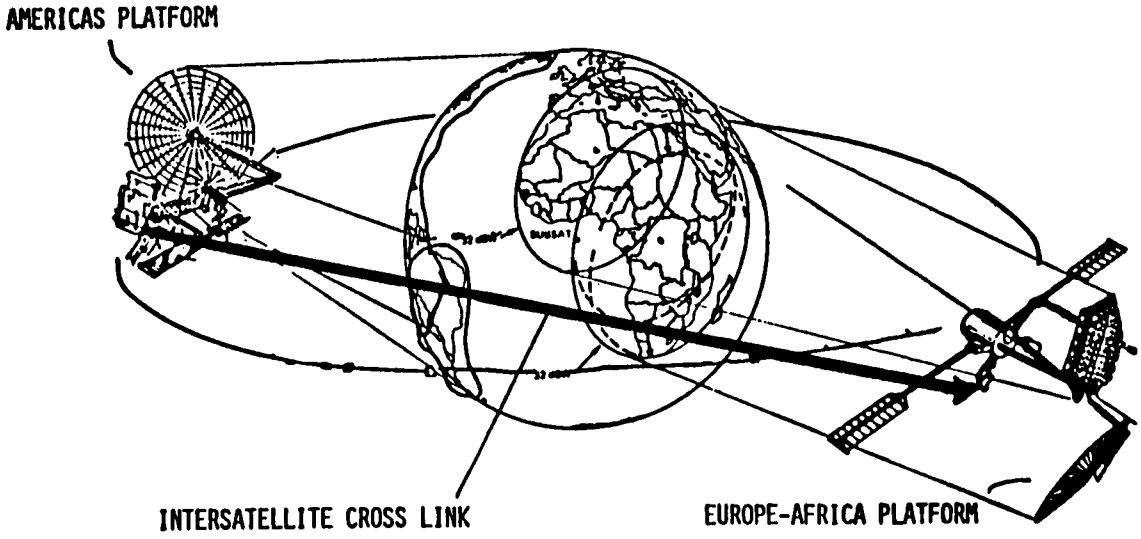


Ready for Transfer. Here LEO deployment has been completed and the Transfer Vehicle, with the module on top of it, has separated. The solar arrays are still in their canisters. It may be possible to partially deploy the arrays before transfer.

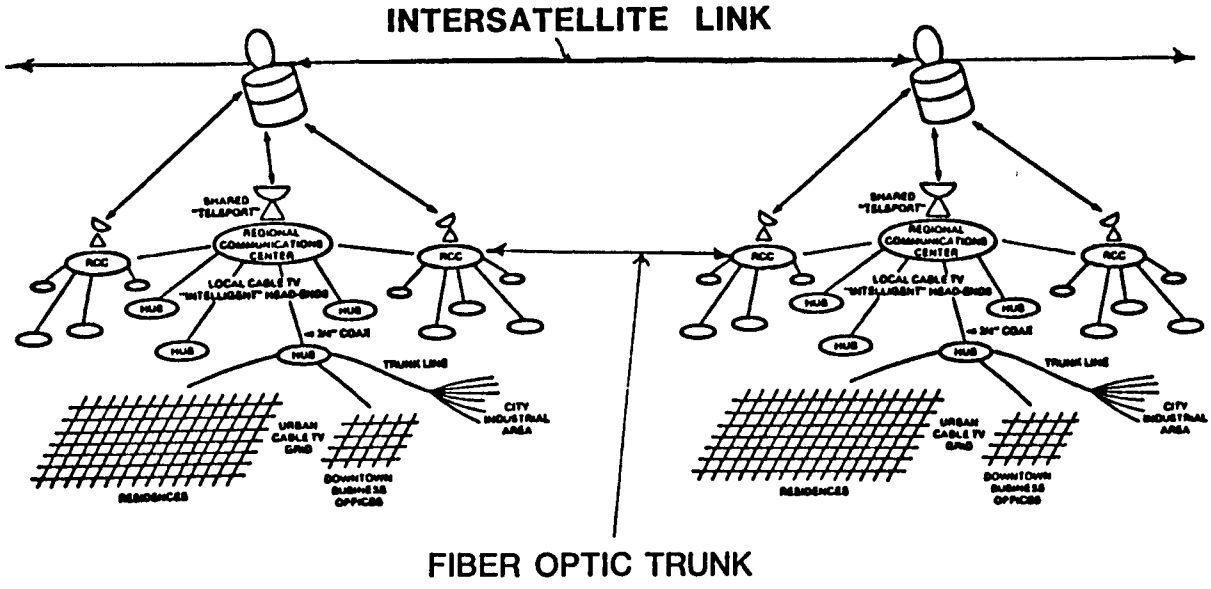
PERSPECTIVE OF THE 2000's

INTERCONNECTIVITY OF REGIONAL PLATFORMS BY INTERSATELLITE LINKS

PERSPECTIVE OF THE 1990'S- INTERCONNECTIVITY OF REGIONAL PLATFORMS BY INTERSATELLITE LINKS

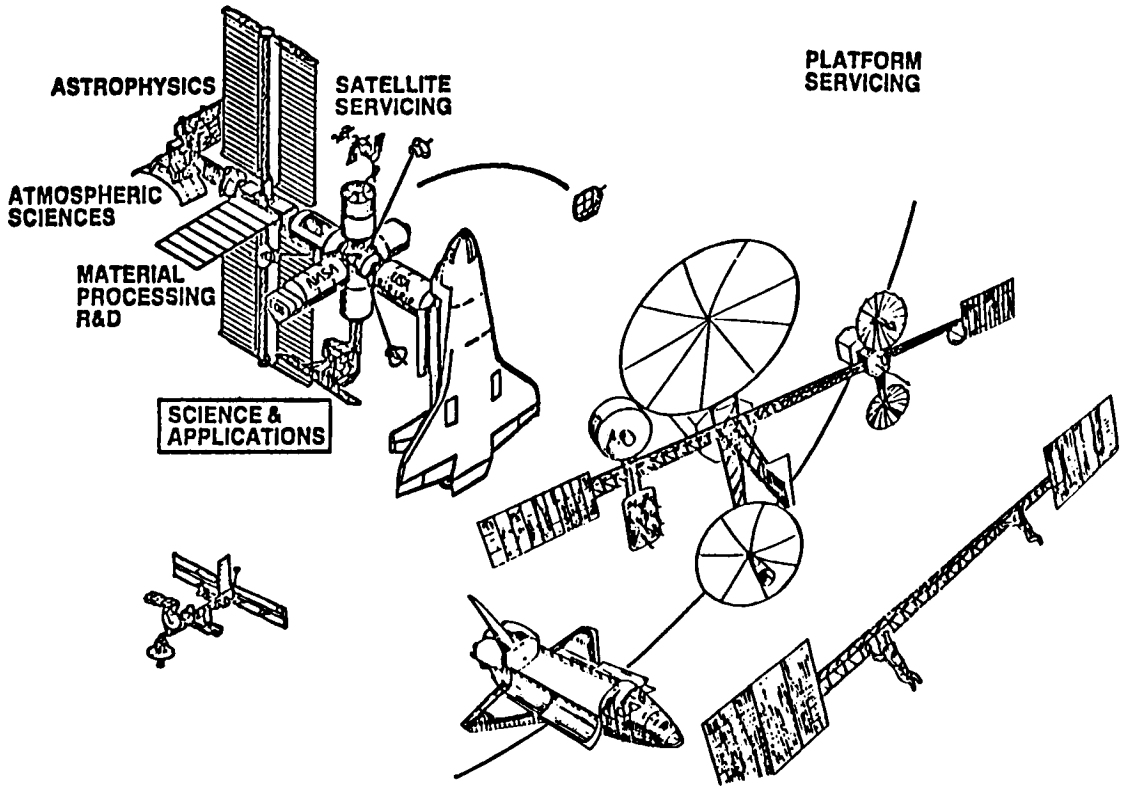


SPACE TERRESTRIAL COMMUNICATION SYSTEM 1990'S

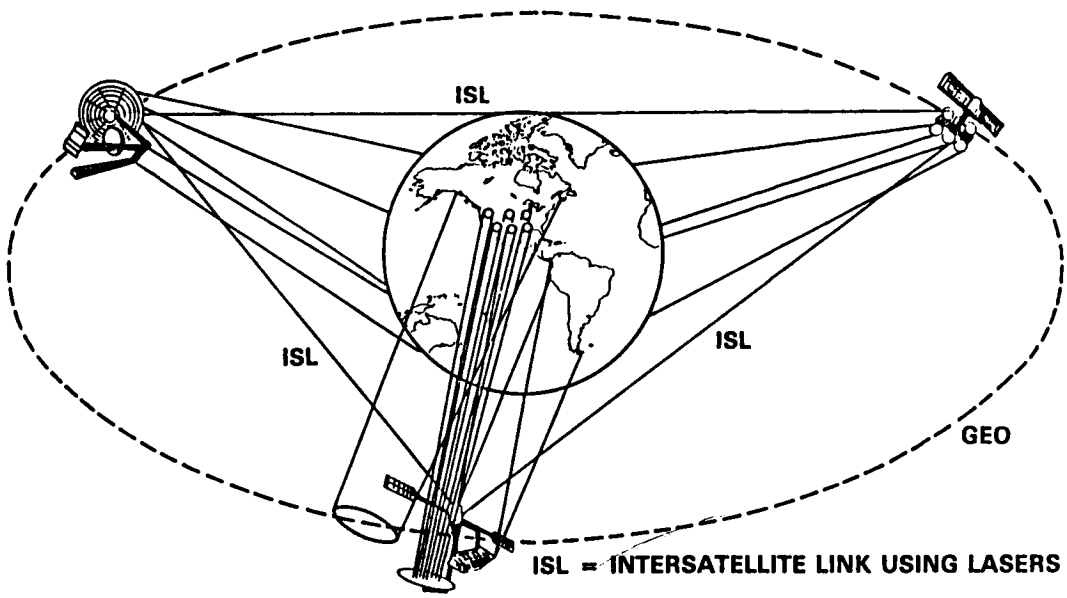


SPACE STATION COMMUNICATIONS

OSSA TECHNOLOGY EC



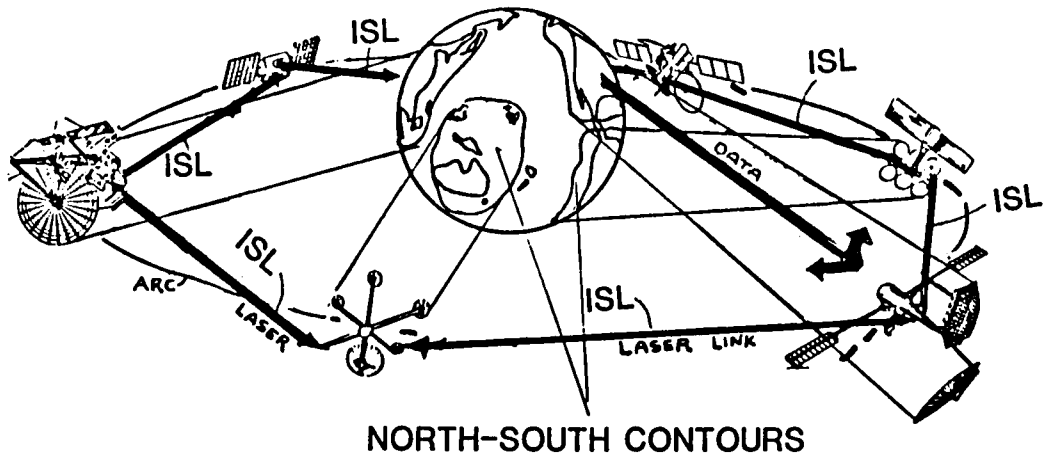
NORTH SOUTH REGIONAL SATELLITE NETWORK FOR GLOBAL INTERCONNECTIVITY



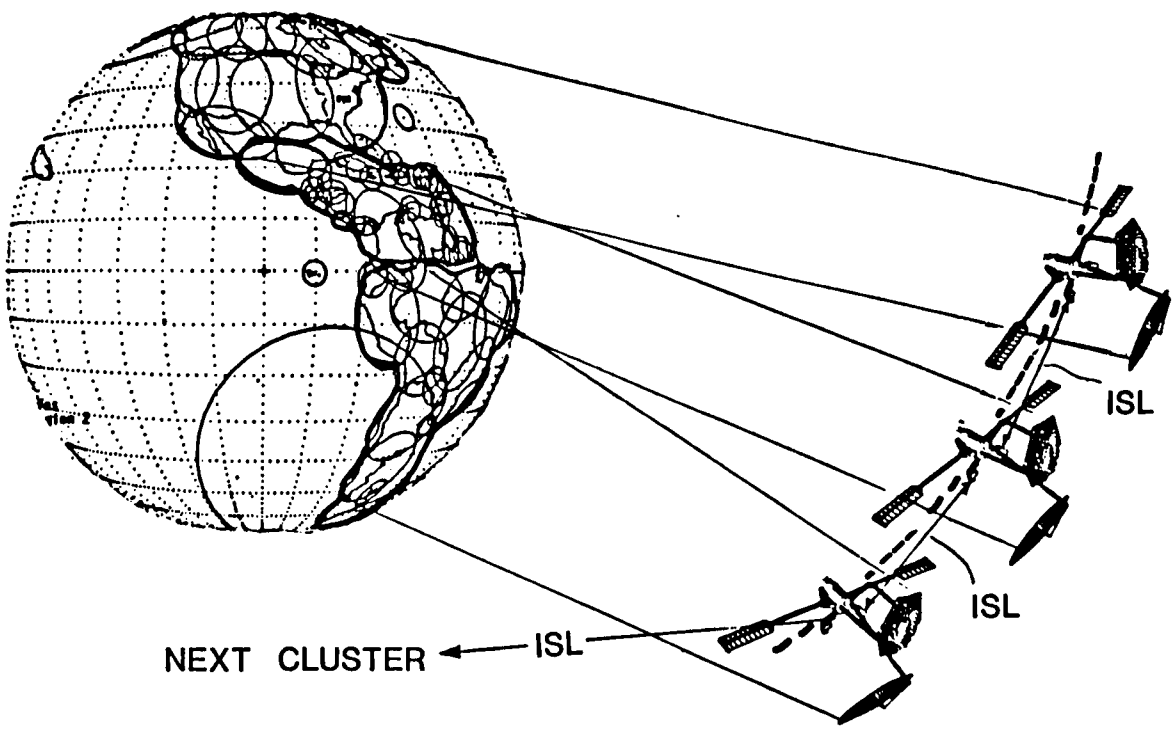
GLOBAL INTERCONNECTIVITY IN THE EARLY 21ST CENTURY

GLOBAL INTERSATELLITE (ISL)

COMMUNICATION SYSTEM 1990's

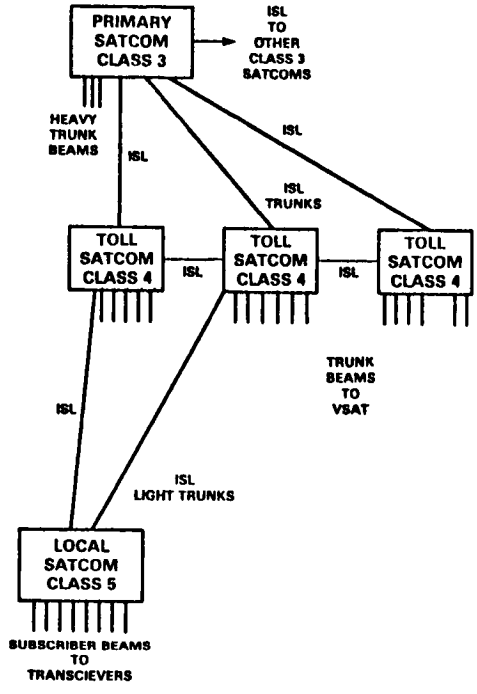


GEOPLATFORM CLUSTER 2000's



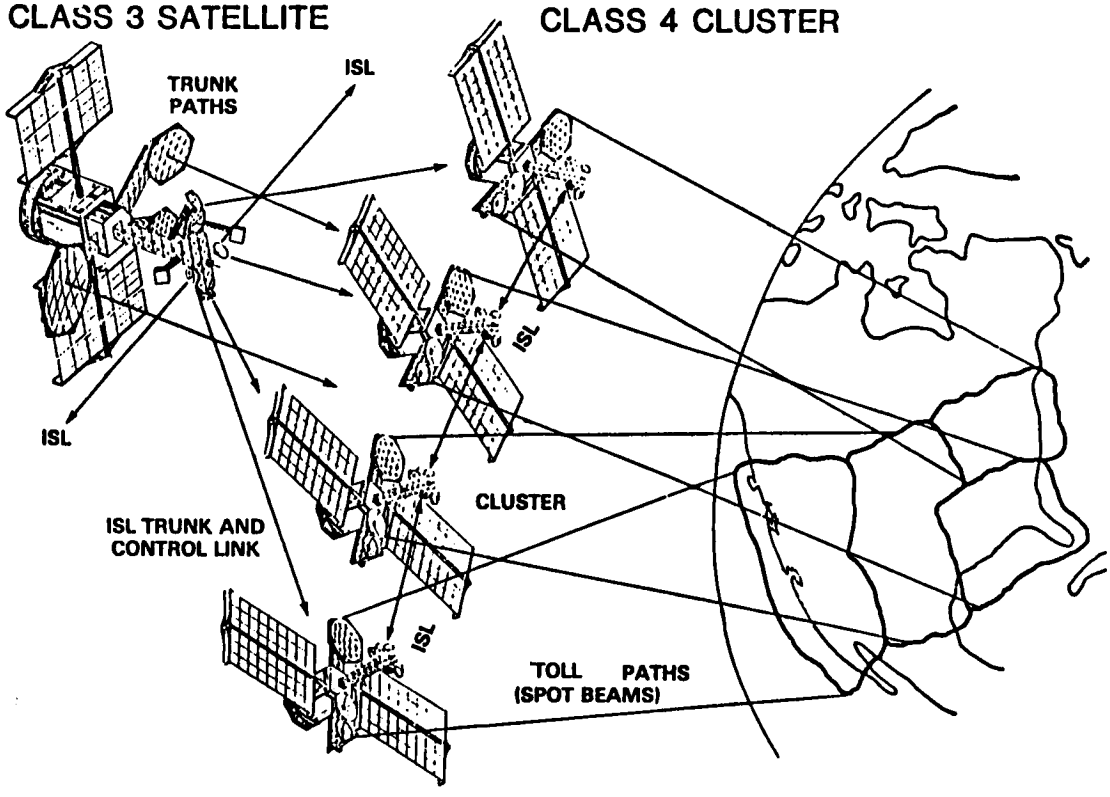
SATELLITE EQUIVALENT DIGITAL SWITCH HIERARCHY

CLASS	USERS	SIGNAL TYPE	EARTH STATION
3	HEAVY TRUNK INTERCONNECTS WITH CLASS 4 SATELLITES OR WITH GLASS 3/4 STATIONS ON GROUND	T3 (43 Mbps) — 565 Mbps — 1.8 Gbps (COMPATIBLE) WITH EARTH FIBER TRUNK NETWORKS	EXPENSIVE 13 METER HEAVY ROUTE STATIONS <$1M
4	PBX-TO-PBX OR EQUIVALENT	5b Kbps TO T1 (1.54 Mbps) T2 (6.2 Mbps)	VSAT TERMINALS <$10K
5	SUBSCRIBER TO SUBSCRIBER — MOBILE USERS — PC-TO-PC — WRIST-RADIO — PAGING	75 Bps TO 9.6 Kbps — VOICE: — SSB — 2.4 Kbps	VERY LOW COST EARTH TRANSCIEVERS <$1K



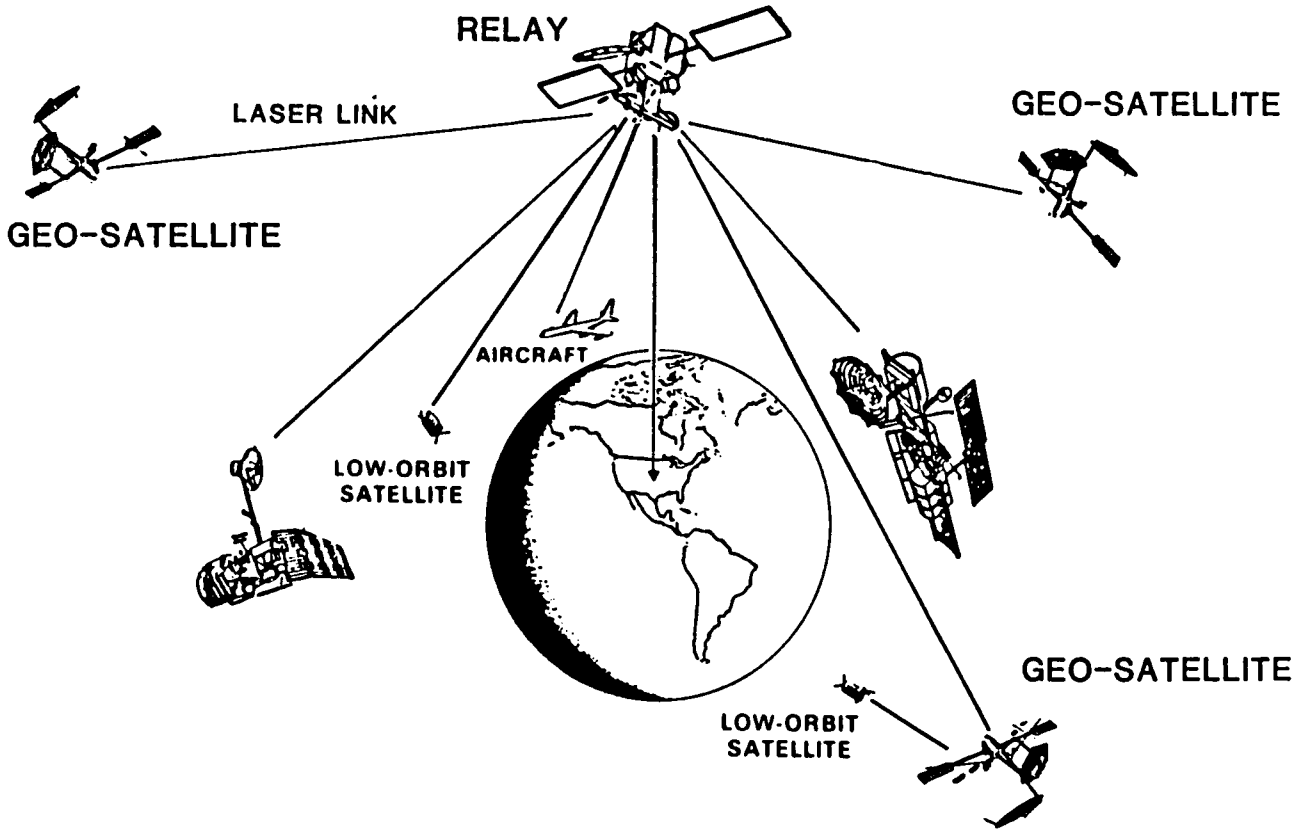
CLASS 3 SATELLITE

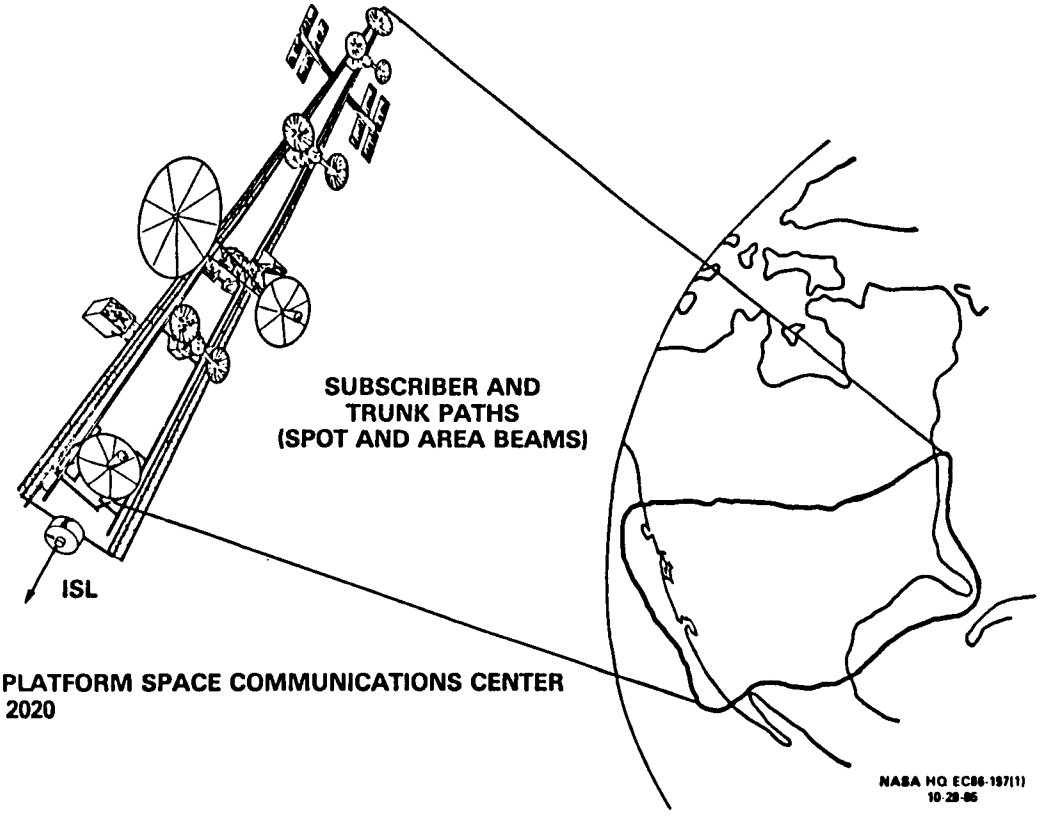
CLASS 4 CLUSTER



ISL = INTERSATELLITE LINK

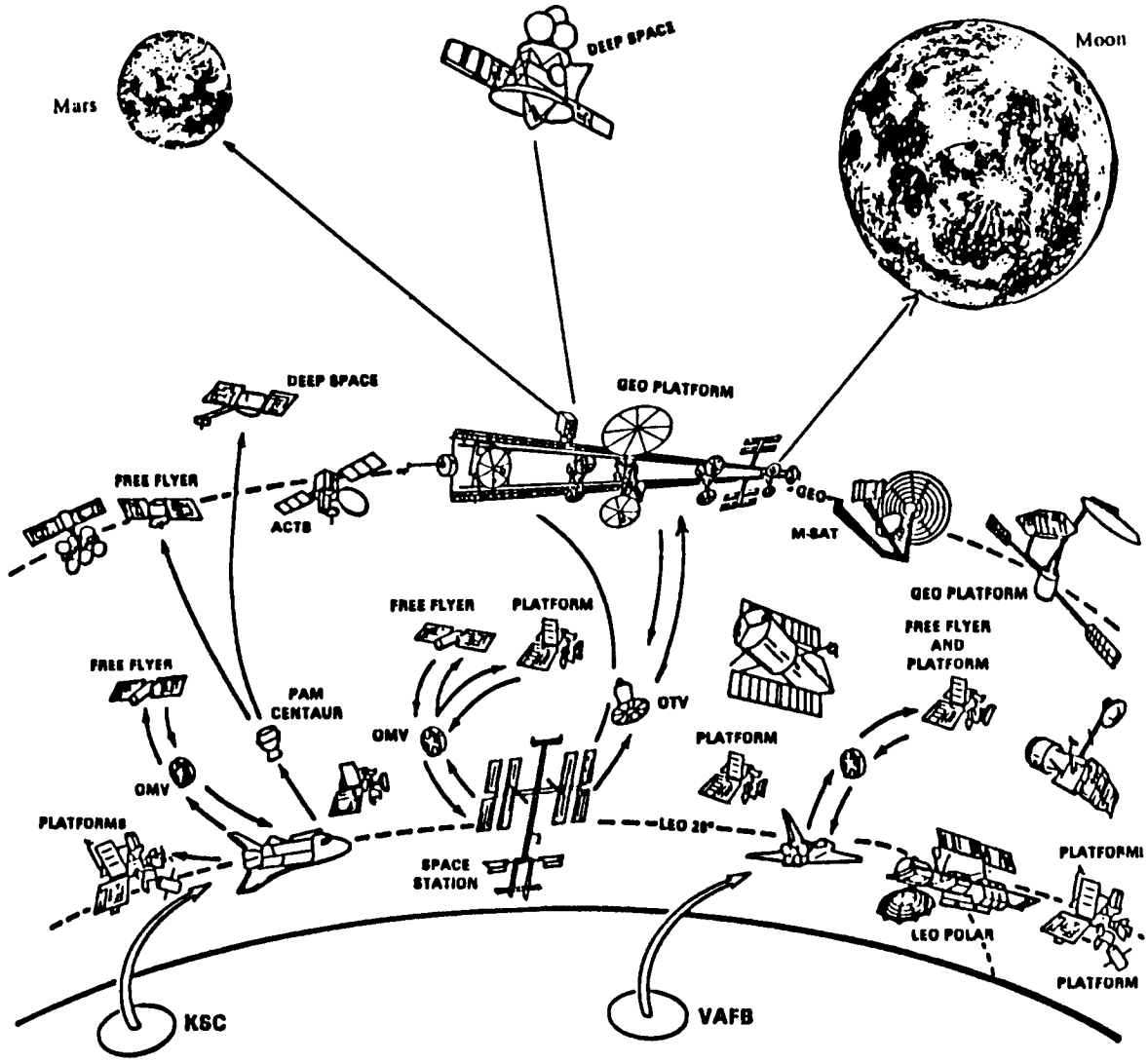
OPTICAL FREQUENCY COMMERCIAL GEOSTATIONARY RELAY SATELLITE





SINGLE PLATFORM SPACE COMMUNICATIONS CENTER
CIRCA - 2020

NASA HQ EC86-197(1)
10-29-86



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