General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

CR-119888

REPORT NO. GDC-DCF70-002
CONTRACT NAS 8-21036

TELEVISION BROADCAST SATELLITE STUDY

VOLUME III • SERVICE DESCRIPTIONS

N71-31408
(ACCESSION NUMBER)
63
(PAGES)
CR-119888
(NASA CR OR TMX OR AD NUMBER)
(THRU)
03
(CODE)
31
(CATEGORY)
FACILITY FORM 602

GENERAL DYNAMICS
Convair Aerospace Division

JUL 1971
RECEIVED
NASA STI FACILITY
INPUT BRANCH

REPORT NO. GDC-DCF70-002

TELEVISION BROADCAST SATELLITE STUDY

TVBS SYSTEM

SERVICE DESCRIPTIONS

VOLUME III

CONTRACT NAS8-21036

31 December 1970

Prepared for
E. C. Hamilton, COR
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama

Prepared by
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
San Diego, California

PRECEDING PAGE BLANK NOT FILMED

FOREWORD

This report was prepared by the San Diego operation of the Convair Aerospace Division of General Dynamics under Contract NAS8-21036, Television Broadcast Satellite Study, for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Astrionics Laboratory of the George C. Marshall Space Flight Center.

PRECEDING PAGE BLANK NOT FILMED

TABLE OF CONTENTS

Section			Page
1	U.S. ARMED FORCES RADIO AND TELEVISION SERVICE		1-1
	1.1	OBJECTIVE	1-1
	1.2	SERVICE REQUIREMENTS	1-1
	1.3	COMMUNICATION SYSTEM DESIGN REQUIREMENTS	1-3
	1.4	SUPPORTING DATA	1-3
	1.5	COMMUNICATIONS SYSTEM DESCRIPTION	1-3
	1.6	SCHEDULE	1-15
	1.7	COST	1-1
2	U.S. ETV/ITV SYSTEM		2-1
	2.1	SERVICE DESCRIPTION	2-1
	2.2	COMMUNICATION SYSTEM DESCRIPTION	2-7
3	ALASKA AND WESTERN STATES		3-1
	3.1	REQUIREMENTS	3-2
	3.2	COMMUNICATIONS SYSTEM DESCRIPTION	3-9
	3.3	SCHEDULE AND COST SUMMARY	3-25

1

U.S. ARMED FORCES RADIO AND TELEVISION SERVICE

1.1 OBJECTIVE

The U.S. Armed Forces Radio and Television Service reaches approximately ten million persons world wide with radio, television, teletype, voice and data communications services. Two hundred and eighty-one radio and seventy-one television stations offering twenty-three channels are operated. This extensive service lacks the advantage of network television coverage. It is the purpose of this study to describe a minimum cost system employing geostationary satellite relays to provide television service.

1.2 SERVICE REQUIREMENTS

1.2.1 INFORMATION TRANSFER. This service will transfer television data from two originating stations, near Washington D.C. and Los Angeles, California to virtually a worldwide service area by way of two satellites with five down beams for the Pacific regions and four down beams for the Atlantic regions.

1.2.2 QUANTITY OF DATA. Five television channels with one audeo channel per video channel will be operated through each of the 9 satellite to ground beams.

1.2.3 DATA SCHEDULE. The duty cycle for the system is three channels assigned 24 hours/day and 2 additional channels from 5:00 to 8:00 a.m. and also from 5:00 p.m. to midnight. This schedule of operation offers programming freedom for providing entertainment, news, educational and instructional services.

1.2.4 QUALITY OF DATA. Full color TV service will be provided on each channel with a quality of TASO Grade 1. A possible option is combination with CATV in which case CCIR relay grade would be available.

1.2.5 COVERAGE. The area of coverage, specifically excluding the continental United States, covers nine regions of the world of approximately one million square miles each

providing television service to nearly all of United States military personnel and their dependents outside CONUS.

Table 1-1 and Figure 1-1 summarize the service brought to the above mentioned nine regions.

Table 1-1. U.S. Armed Forces Radio & TV Services.

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
GLOBAL COVERAGE (SPECIFICALLY EXCLUDING U.S.) 9,2 SATELLITES 1,5 BEAMS/SATELLITE 5 CHANNELS/BEAM 10^6 SQ. MI./BEAM	10×10^6 PEOPLE (MILITARY PERSONNEL PLUS DEPENDENTS & ON-BASE STAFF) ASSUME: UNIFORM DISTRIBUTION 5 PEOPLE/RECEIVER	TWO ORIGINATING STATIONS WASHINGTON LOS ANGELES	3 CHANNELS 100% 2 CHANNELS 5:00 - 8:00 A.M. 5:00 P.M. - MIDNIGHT

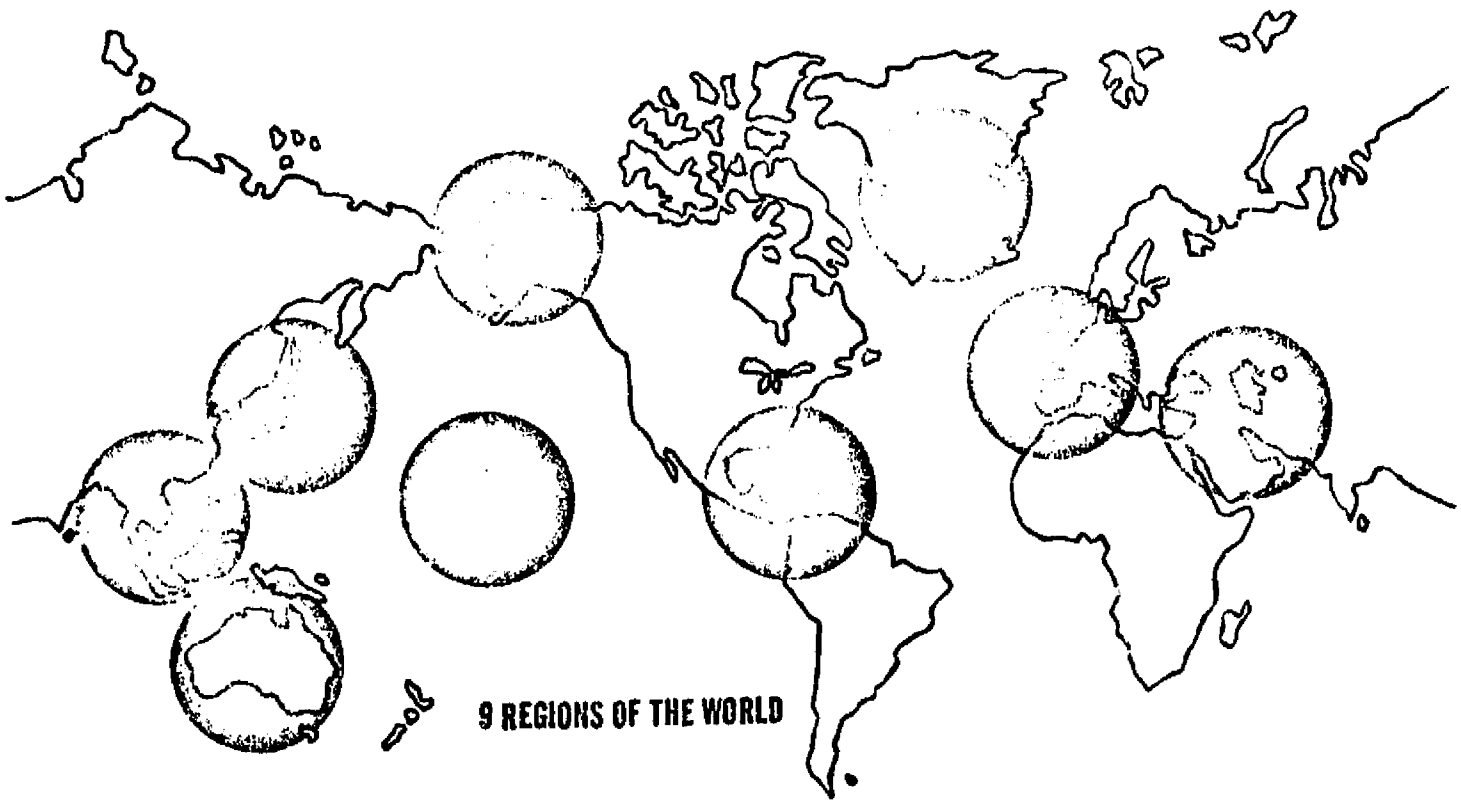


Figure 1-1. U.S. Armed Forces Radio & TV Services.

1.3 COMMUNICATION SYSTEM DESIGN REQUIREMENTS

Design requirements for this system are shown in Table 1-2.

Table 1-2. User Requirements.

	Pacific Area	Atlantic Area
Area of Coverage*		
Major Axis (mi.)	2669	2669
Minor Axis (mi.)	1236	1236
Area (10^6 mi.^{2})		
Receiver Population	5.5×10^6	4.45×10^6
Beam Center Latitude	5 beams	4 beams
Beam Center Longitude	See Fig. 5-1	See Fig. 5-1
Spacecraft Longitude	~-170°	~-10°
Taso Grade	1	1
No. of Video Channels	5	5
No. of Audio Channels/Video	1	1
No. of Uplink Facilities	1	1
No. of Video Channels/Facility	25	20
Total System Lifetime	10 years	10 years
Satellite Lifetime	2 @ 5 years	2 @ 5 years
Downlink Frequency (GHz)	0.8	0.8
Duty Cycle	Up to 24 Hrs.	Up to 24 Hrs.

*Typical beam coverage.

1.4 SUPPORTING DATA

1.4.1 CONTACTS — The following contacts have been made in relation to the need for a television system for AFRTS. All contacts were within DOD.

a. J. Broger (Director AFRTS)

b. H. Valentino

c. Col. L. Cruciana

d. Lieut. Col. Souville

1.5 COMMUNICATIONS SYSTEM DESCRIPTION

The user requirements detailed in Table 1-2 were encoded into the TVBS synthesis program and a minimum cost solution, consistent with configuration constraints was determined. The resulting solution is discussed in this section.

1.5.1 SATELLITE SYSTEM DESCRIPTION. The lowest cost satellite system among the cases analyzed consists of nine five year life satellites of concept B. Concept B is a multiple satellite payload in which each individual satellite contains no provisions for docking and life support. Any maintenance accomplished requires EVA. The satellite is equipped with a small aperture (0.3 ft. × 0.3 ft.) antenna for uplink operation at 12.0 GHz and a deployable truss parabola of 29.7 ft. diameter for the down link. Figure 1-2 and Table 1-3 illustrate this concept. Table 1-4 defines the terms used. Table 1-5 allows a cursory comparison between different satellite concepts studied.

The solar array prime power panels would likely be of a roll out type attached to the truss antenna periphery. These are sized to supply 7 kw of power at the end of the satellite lifetime. Nickel-cadimum batteries provide 15 kilowatt hours of energy storage.

Redundant high efficiency UHF crossed field amplifiers produce the required 550 watts per channel transponder output. Figure 1-3 is a block diagram of the satellite communication system.

Table 1-6 gives the subsystem types, cost, weight and volume.

1.5.2 GROUND UPLINK SYSTEM DESCRIPTION. The AFRTS analysis presents two originating (Class 1) stations, one in the Washington, D.C. area and one near Los Angeles, California. These are used as likely locations. There is nothing in the synthesis that restricts Class 1 stations to these two locations. The service offers five channels to each user area. Thus the Washington, D.C. and Los Angeles stations would have 20 and 25 1.1 kilowatt transmitters respectively to permit complete freedom of scheduling programs to each area. The antenna is rigid parabola approximately 45 feet in diameter. Video-tape recorders, physical plant, stand-by power, test equipment and a telemetry and command subsystem are included in the synthesis. The cost of program generation and studios is not included. Table 1-7 describes the items making up the ground originating station and their costs.

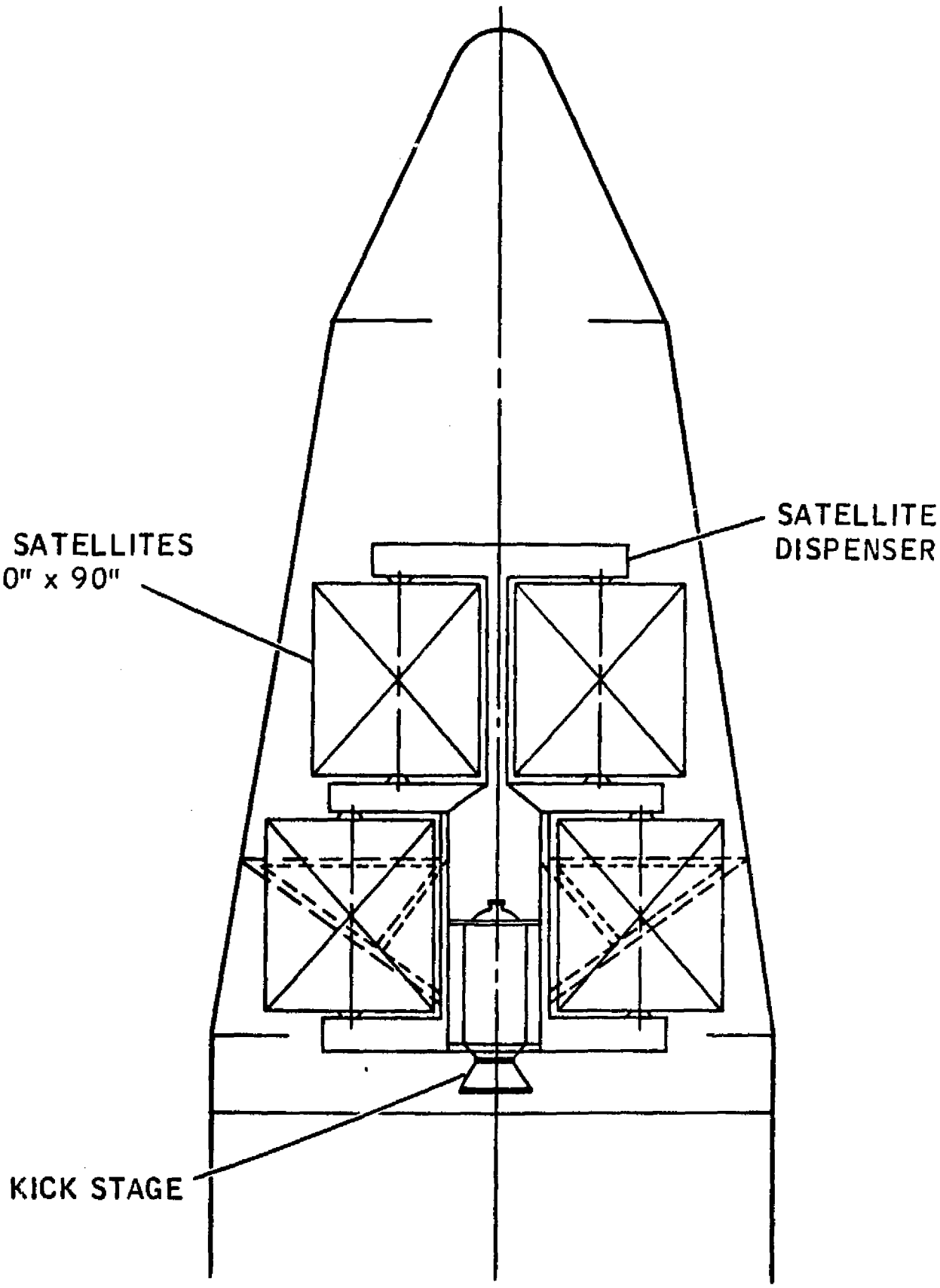


Figure 1-2. Concept B packaging.

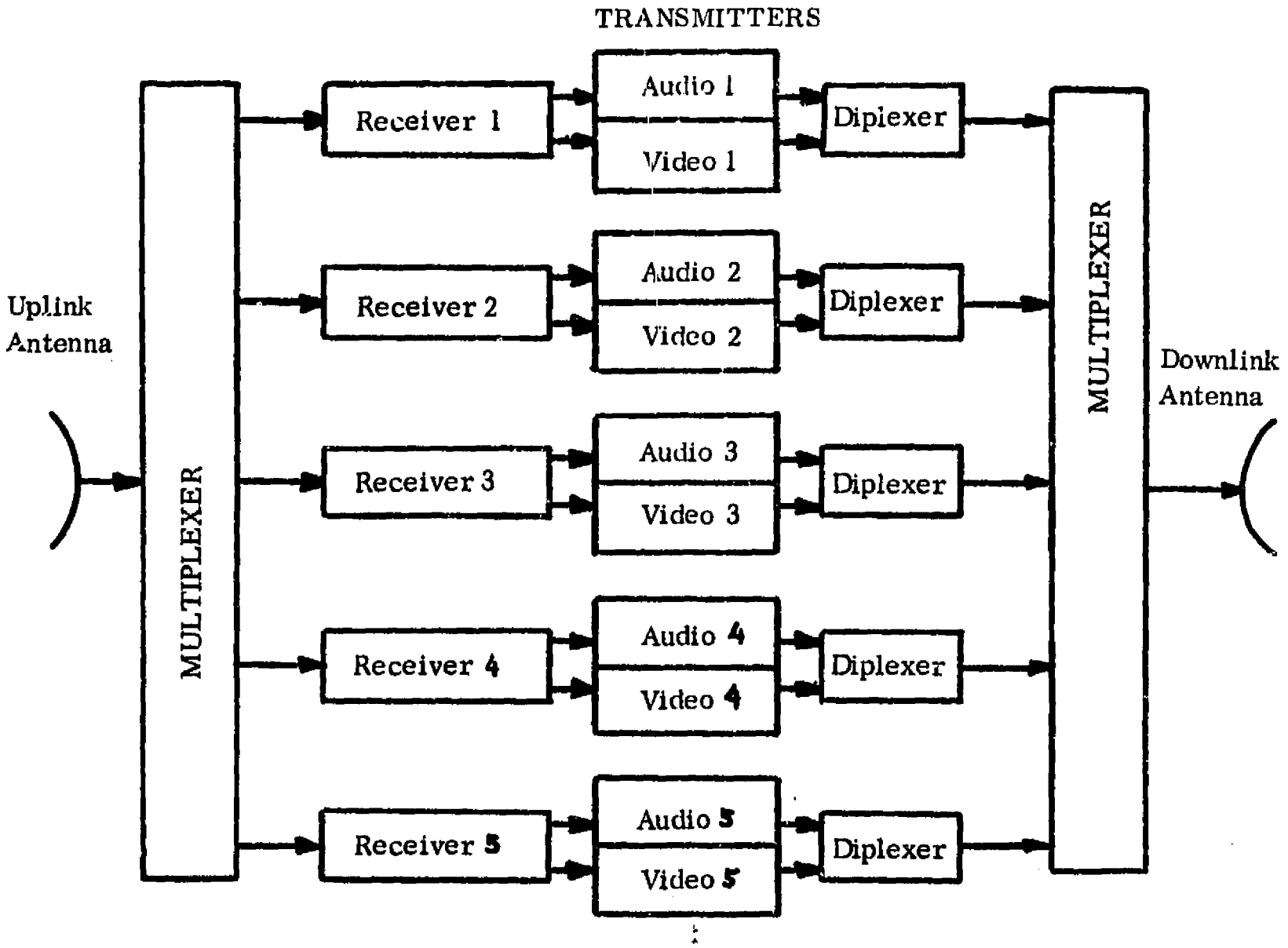


Figure 1-3. Communications Sytem Block Diagram.

Table 1-3. Geometry, Weight and Volume Constraints — Concept B.

1. Antenna: Rigid Dish for $D_A \leq 6.67$
   PETA for $6.67 < D_A \leq 30.0$

2. Feed: Cassegrain, Rigid or Hinged

3. Packaged Length:
   a. $\ell_{EM} + \ell_F + 0.5 \leq 7.5$ for $D_A \leq 6.67$
   b. $\ell_{EM} + \ell_A + 0.5\ \ell_F \leq 7.5$ for $6.67 < D_A \leq 30$

4. Feed Length: $\ell_F = (.2 D_A + .25)$

5. PETA Package Length: $\ell_A = .12 D_A$

6. Module Diameter = 5.67

7. Module Available Volume:
   $V_{EM} = 25.3\ \ell_{EM}$

8. Total Volume:
   a. $V_{EM} + V_{RD} + V_{SA} + 34.9\ (\ell_F + 0.5) \leq 262$; $D_A \leq 6.67$
   b. $V_{EM} + V_{RD} + V_{SA} + 34.9\ (\ell_F + \ell_A) \leq 262$; $6.67 < D_A \leq 30$

9. Total Weight $\leq 5,200$

Table 1-4. Nomenclature.

ℓ_{EM}	=	Length of Equipment Module
D_{EM}	=	Diameter of Equipment Module
P_{PRIME}	=	Power Source Output in Watts
N	=	Satellite Life in Years
A	=	Area of Solar Array in Square Feet
ℓ_F	=	Length of Feed in Feet
ℓ_A	=	Height of Stowed Antenna in Feet
D_A	=	Diameter of Deployed Antenna in Feet
W_S	=	Weight of Spacecraft Less Stationkeeping
P_{DIS}	=	Power Dissipated by Thermal Control Subsystem in Watts
P_{XMTR}	=	RF Power Radiated by Transmitter in Watts
V_{EM}	=	Volume of Equipment Module in Cubic Feet
P_{DIST}	=	Power Generated by Transmitter to be Dissipated in Watts
P_{DISS}	=	Power Generated by Other Subsystems to be Dissipated in Watts
η	=	Transmitter Efficiency
V_{RD}	=	Volume of Radiator
V_{SA}	=	Volume of Stowed Solar Array
D_U	=	Diameter of the Uplink Antenna
V_F	=	Volume of Feed
V_U	=	Volume of Uplink Antenna
ℓ_U	=	Height of Stowed Uplink Antenna
V_{PP}	=	Volume of Prime Power System

Table 1-5. Concept Summary.

SATELLITE CONCEPT COMPARISON

CONCEPT	NUMBER POTENTIAL USERS *	FREQUENCY RANGE (GHz)	MAX.NO. BEAMS	WEIGHT RANGE (LB.)	VOLUME RANGE (CU.FT.)	SATELLITE COST RANGE ($M)	RANGE OF COST/RCVR/YR ($)	ORBITAL REFURB. POSSIBLE?	RANK	REASON FOR RANKING
A	0 **							NO	6	TOO SMALL
B	5	2.5 to 12.7	1	1,100 to 3,200	< 262	6 to 9	385 to 191,000	NO	2	WIDE USER RANGE GOOD SINGLE-PURPOSE CONCEPT
C	2	2.5 to 12.7	1	4,000 to 5,000	< 810	10 to 11	50 to 71	NO	4	VOLUME LIMITED, SELDOM OPTIMUM
D	6	2.5 to 12.7	4	32,000 to 42,000	< 6,000	28 to 40	12 to 743	YES	3	WIDE USER RANGE, GOOD MULTI-PURPOSE CONCEPT (HIGH VOLUME)
E	0 ***	UHF ONLY						YES	5	ANTENNA TOO LARGE, VOLUME TOO SMALL
F	9	UHF to 12.7	6	16,000 to 42,000	< 6,000	18 to 40	14 to 245,000	YES	1	SATISFIES WIDEST USER RANGE

* CONCEPT WAS FIRST OR SECOND CHOICE

** SIZE INSUFFICIENT FOR ALL SYSTEMS CONSIDERED

*** APPLICABLE ONLYAT UHF, WHICH IS NOT OPTIMUM FREQUENCY

Table 1-6. Satellite Subsystems Description.

SATELLITE SUBSYSTEMS	COSTS (MILLIONS) ACQUISITION	R+D	TOTAL	WEIGHT (LBS.)	VOLUME (CU FT)	TYPE	DESCRIPTIVE PARAMETERS
POWER SUBSYSTEM							
PRIME POWER	2.29	.95	2.34	1015.4	169.57	SOLAR	POWER = 6.996 KW
SECONDARY POWER	.03	.16	.04	749.3	5.93	NI-CAD	CAPACITY = 15.001 KW-H
CONDITIONING	.09	.28	.11	345.5	4.63		
DISTRIBUTION	.21	.40	.23	99.7	8.45		
ANTENNA	.29	1.08	.35	120.7	77.21		2 BEAMS
TRANSMITTER	.95	.67	.99	358.5	6.69	CFA	5 TRANSMITTERS
MULTIPLEXER	.07	.46	.10	47.8	1.59	COAX	
RECEIVERS	.21	.28	.23	70.0	1.25	LIN TRNS	NOISE FIG = 3.0 DB
STRUCTURE	.06	.20	.07	29.2	42.57		H = .9, D = 10.0 FT
THERMAL CONTROL	.07	.53	.10	51.9	10.38	HEATPIPE	PWR RAD = 5.148 KW
STATION KEEPING	.46	3.38	.65	86.3	.26	ION PROP	
ATTITUDE CONTROL	.68	4.46	.92	96.0	1.35	ION PROP	AM/L = 4026.6 SQ FT
TELEMETRY + COMMAND	.17	.85	.22	70.0	2.00		
PROTOTYPE	-	3.63	.20				1 PROTOTYPE(S)
INTEG, ASSY + CHECK	.42	-	.42				
DESIGN, INTEG + MGMT	-	6.84	.38				
CENTER SUPPORT	.90	1.03	.96				9 SATELLITE(S)
GRD SUPPORT EQUIP	-	2.79	.16				
TOTAL/SATELLITE	6.90	1.55	8.45	3140.3	331.93		
SYSTEM TOTAL	124.19	27.98	152.17				

Table 1-7. Class 1 Ground Station Costs.

GROUND STATIONS - BEAM 1 (THOUSANDS)

CLASS 1 FACILITIES	ACQUISITION	INSTALL	OPER/YEAR	MAINT/YEAR	TOTAL
FACILITY	530.00	-	-	10.60	636.00
TERMINAL EQUIP-VIDEO	3000.00	600.00	450.00	300.00	*100.00
TRANSMITTERS-VIDEO	1581.17	316.23	1.46	158.12	3493.21
ANTENNA + MUX	212.38	0.00	-	21.24	424.76
STANDBY POWER	201.75	4.04	-	10.09	306.67
TEST EQUIPMENT	50.00	-	-	-	50.00
PERSONNEL	-	-	150.00	-	1500.00
DESIGN, INTEG + MGMT	-	719.03	-	-	719.03
TOTAL/FACILITY	5575.30	1639.30	601.46	500.04	18229.67

1.5.3 GROUND RECEIVING SYSTEM DESCRIPTION. The ultimate user is assumed to have a conventional VHF-UHF television receiver. The modification for the AFRTS application includes an antenna and a pre-amplifier converter. The incident beam is frequency modulated at 0.8 GHz carrier frequency. The 5.4 dB noise figure converter provides FM demodulation and channel selection. The converter output is directly to the existing receiver video and audio circuits. The antenna of 3.4 feet equivalent diameter would most likely be a low cost ribbed parabolic type. Table 1-8 gives the costs of the two major parts of the modification kit, the antenna and the preamplifier-converter.

Table 1-8. Direct Receiving Station Costs.

GROUND STATIONS - BEAM 2

DIRECT STATIONS	ACQUISITION	INSTALL	MAINT/YR	TOTAL
ANTENNA	11.60	36.87	1.16	60.08
RECEIVER	39.73	19.87	3.97	99.33
	51.33	56.74	5.13	159.40

1.5.4 GROUND COVERAGE. The nine concentrations of receivers are shown in Figure 1-4. Each of these is supplied by a beam from a satellite or by a beam from a multi-beam antenna if two satellite coverage is used. Figure 1-4 illustrates the coverage for the five Pacific region user areas as provided by a satellite with a five beam antenna. The Atlantic area satellite is at approximately 10°W longitude to cover the easterly four regions shown in Figure 1-1.

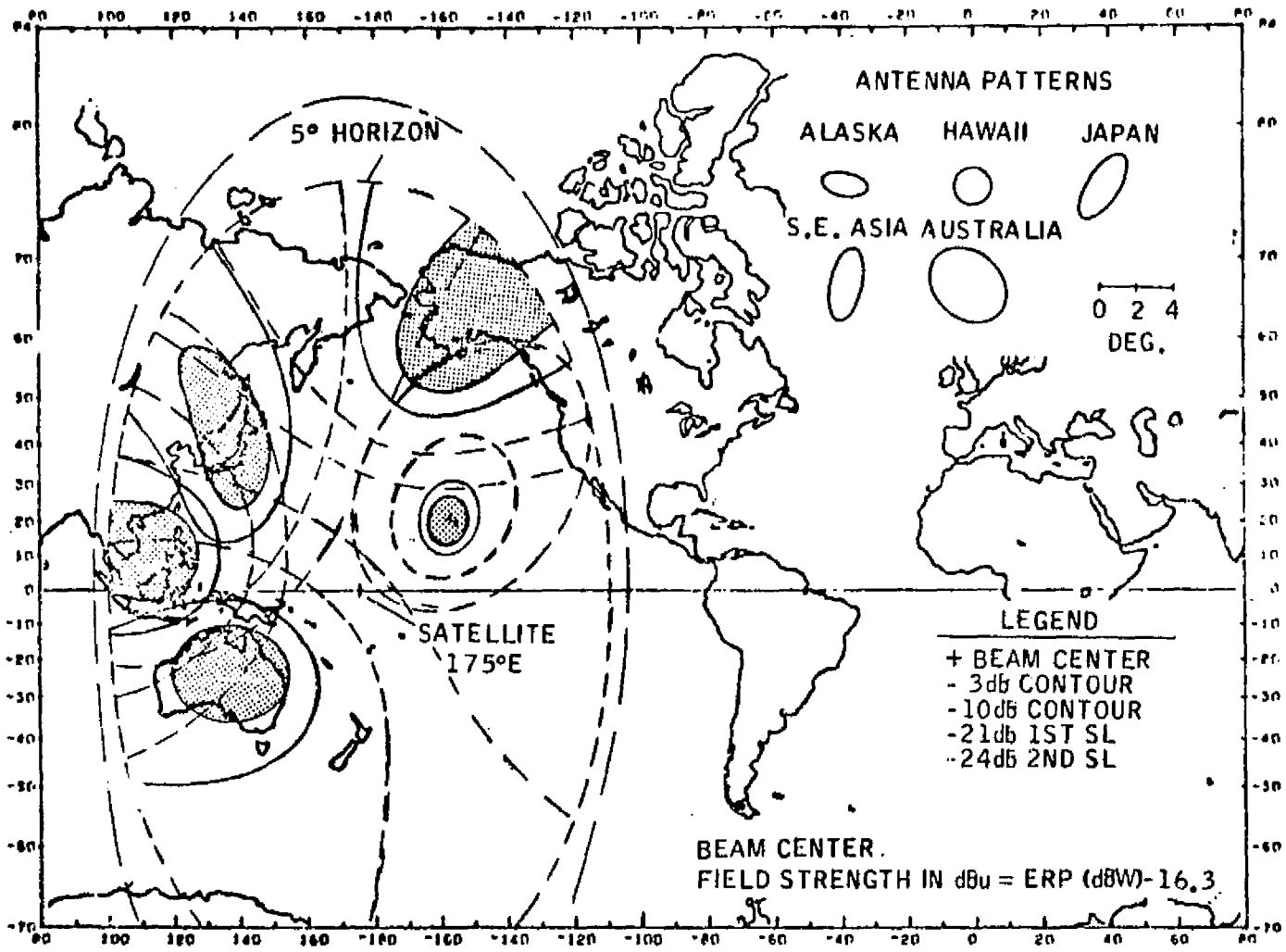


Figure 1-4. Pacific Area Coverage, AFRTS.

1.5.5 POWER BUDGET CALCULATIONS. The Pacific and Atlantic distribution systems are sufficiently similar that one uplink and one downlink are analyzed in detail for power budgeting to provide the desired service. The minimum cost system using 9-B concept satellites is analyzed. It will be noted that an uplink receiver location loss of -2.0 db is allowed. This permits the originating station (Class 1) to be located anywhere since the satellite receiving antenna gives full earth coverage. Table 1-2 summarizes the user requirements reflected in the link analysis in the following paragraphs.

UPLINK POWER BUDGET, 12.0 GHz

a.	Transmitter power (1, 1 kW)		+ 30.4 dBW
b.	Trans. antenna gain (43.8 ft. diam).		+ 59.9 dB
c.	Trans, circuit losses		- 3.0 dB
d.	EIRP		+ 87.3 dBW
e.	Total propagation losses		
	1) Free space (23,700 Stat. Mi),	-205.7 dB	
	2) Atmosphere and rain (36.6° elev),	- 5.4 dB	
	3) Location and pointing,	- 2.2 dB	
f.	Sat. receiving ant. gain (0.3 ft. x 0.3 ft.),		+ 19.6 dB
g.	Receiver circuit losses		- 1.0 dB
h	Total available carrier power,		-107.4 dBW
i.	Total system noise power (kTB),		-125.9 dBW
	1) Receiver (3.0 dB N.F.),	290.0°K	
	2) Receiver input circuitry	59.6°K	
	3) Antenna (-1.0 dB, item g),	230.0°K	
	4) Effective system temperature,	579.6°K	
	5) Noise bandwidth,	32.63 MHz	
j.	Available carrier-to-noise ratio		18.5 dB

DOWNLINK POWER BUDGET, 0.8 GHz

a.	Transponder output power (550W),		+ 27.4 dBW
b.	Trans. ant. gain (29.7 ft. diam)		+ 35.0 dB
c.	Trans. circuit loss,		- 1.7 dB
d.	EIRP		+ 60.7 dBW
e.	Total propagation losses		-188.4 dB
	1) Free space (25,700 Stat. Mi),	-182.8 dB	
	2) Atmosphere and rain (6.4° elev),	- 0.4 dB	
	3) Location and pointing	- 2.2 dB	
	4) Polarization (circ. to lin),	- 3.0 dB	
f.	Direct receiving ant. gain (3.4 ft. diam. equiv.)		+ 16.2 Db
g.	Direct Rcvr. circ. loss,		- 2.9 dB
h.	Total available carrier power,		-113.5 dB
i.	Total system noise power (kTB),		-123.6 dBW
	1) Receiver (5.4 dB N.F.),	706.2°K	
	2) Receiver input circuitry	107.0°K	
	3) Antenna (-2.0 dB, item g),	80.8°K	
	sky, 0.537 x 68.3 = 36.7		
	envir, 0.036 x 72.1 = 2.6		
	earth, 0.305 x 290.0 = 88.5		
		127.8	
	4) Uplink contribution,	89.4°K	
	5) Effective system temperature,	983.4°K	
	6) Noise bandwidth,	32.63 MHz	
j.	Available carrier-to-noise ratio		10.1 dB
k.	Total improvement factors		+ 34.5 dB
	1) Weighting (EIA/BELL)	+ 7.0 dB	
	2) Peaking & TASO conversion	+ 7.6 dB	
	3) FM, $3m^2(m+1)$, m=2.88,	+19.9 dB	
l.	Available signal-to-noise ratio		+ 44.6 dB

1.6 SCHEDULE

The schedule for development of a dedicated broadcast satellite for Alaska and the Western States is controlled primarily by the pacing items shown in Table 1-9.

Table 1-9. Schedule Pacing Items.

	PACING ITEM	DEVELOPMENT TIME (YRS)
1.	Antenna Truss Assembly, including: 1 ea. 29.7 ft. diameter antenna for each satellite	3
2.	Transmitters: 2-1.1 kw for Washington D.C. and Los Angeles areas	2
3.	Solar Array: 7.0 kw Fold-Out Panel (end-of-life rating)	
	a. Solar Cells	2
	b. Panels and Mechanisms	3
	c. Assembly	1

1.7 COST

The U.S. Armed Forces Radio and Television services study has been based upon ten million viewers requiring two million direct receivers. The weight of the smallest cost item, the receiver, in large quantities shows clearly in Table 1-10 where the total costs of all major system subparts are compared for two frequencies. This data applies to the first two cases as summarized in Table 1-11. It may be noted that the Class 1 station and launch vehicle costs are the same while the satellite, direct receiver and total system costs increase when the downlink frequency is increased from 0.8 to 2.5 GHz. However, the satellite cost increased by only nine

Table 1-10. Cost Dependence Upon Frequency.

Freq, GHz	Cost in Millions of Dollars				
	Total System	2 Class 1 Stations	All Launch Vehicles	Total For All Satellites	Total for 2×10^6 Receivers
$f_1 = 2.5$	1206	36.5	401	166	602
$f_2 = 0.8$	909	36.5	401	152	319
Ratio of f_1 costs to f_2 costs	1.33	1	1	1.09	1.89

per cent while the eighty-nine per cent receiver cost increase brought the total system cost up thirty-three per cent showing the large effect of the receivers whose unit costs are only $301 and $159 respectively. Costs and further discussion of different parts of the system follow.

1.7.1 COST OF SATELLITES. The satellite analysis considers numerous cost contributing items as structure, power generation and storage, electronics, station keeping and other factors. Table 1-6 shows spacecraft subsystem costs.

1.7.2 COST OF GROUND UPLINK SUBSYSTEM. The originating station costs include all significant items. As previously mentioned, costs do not include production of programs. Table 1-7 summarizes these costs.

1.7.3 COST OF DIRECT RECEIVING STATION. Paragraph 1.5.3 described the ultimate using station. The cost associated with this analysis was indicated to be only those to modify conventional television receiving sets. Table 1-8 gives the associated costs.

1.7.4 TOTAL SYSTEM COST. The total system costs are tabulated in Table 1-11. The cases listed are the same as in Table 1-12. The top case is the one detailed in the link analysis and cost summaries for USAFRTS.

Table 1-11.

User: U.S. Armed Forces Radio & TV (Direct Distribution)
Service: 5 Channels, 2 Stations, 24-Hour, Color
Coverage: $1.26 \times 10^6 \times 9 = 11.3$ Million Square Miles
Life: 10-Year System, 2-5 Year Satellites

CONCEPT	TASO GRADE	DOWNLINK FREQ (GHz)	No. SATELLITES REQUIRED	RATE TYPE	MODULATION	RECEIVING STATION			SAT. WEIGHT (lbs)	SATELLITE PRIME POWER (END OF LIFE) (KW)	UNIT COSTS			TOTAL SYSTEM COST ($M)	TOTAL COST/ YEAR/ RECEIVER ($)
						ANT. GAIN (dB)	ANT DIA (ft)	RCVR NOISE FIGURE (dB)			SAT ($M)	UPLINK ($M)	RCVR ($)		
B	1	0.8	(2)x9	CFA	FM	16.3	3.4	5.4	3140	7.0	8.45	18.27	159	908.8	45.40
B	1	2.5	(2)x9	TWT	FM	25.1	3.0	6.3	4201	10.9	9.24	18.24	301	1206.0	60.30
D	1	0.8	(2)x2	CFA	FM	16.3	3.4	5.3	19446	35.4	50.51	18.22	160	960.3	48.00
D	1	2.5	(2)x2	TWT	FM	25.4	3.1	7.5	28596	69.7	59.61	18.26	292	1637.5	81.90
F	1	0.8	(2)x2	CFA	FM	16.3	3.4	5.3	20894	35.3	49.88	18.22	161	957.6	47.90
F	1	2.5	(2)x2	TWT	FM	24.6	2.9	6.8	29839	68.9	58.70	18.27	292	1633.2	81.70

Table 1-12. Total System Costs in Millions of Dollars.

SAT. CONCEPT	FREQ. IN GHz	UNIT COSTS				TEN YEAR SYSTEM COSTS				TOTAL SYSTEM
		CLASS I	DIRECT *	SAT.	L.V.	CLASS I	DIRECT	SAT.	L.V	
B	0.8	18.23	159	8.45	213.2	36.46	318.8	152.2	401.4	908.8
B	2.5	18.24	301	9.24	213.2	36.48	601.9	166.3	401.4	1206.0
D	0.8	18.22	160	50.5	213.2	36.44	320.4	202.0	401.4	960.3
D	2.5	18.26	292	59.6	213.2	36.52	584.7	238.4	777.8	1637.5
F	0.8	18.22	160	49.9	213.2	36.44	320.2	199.5	401.4	957.6
F	2.5	18.27	292	58.7	213.2	3654	584.1	234.8	777.8	1633.2

* DIRECT RECEIVER UNIT COST IS IN DOLLARS

2.0 U.S. ETV/ITV SYSTEM

2.1 SERVICE DESCRIPTION

2.1.1 OBJECTIVE

The objective of this system is to provide a multi-channel TV system to be used for instructional purposes during normal school hours and for non-commercial (adult education, special interest, cultural, etc.) purposes during early morning and evening hours. If required, the "down time" (midnight to 4 a.m.) could be used for program previewing and selection. The service can reach 300,000 elementary and secondary schools in 30,000 school districts throughout the U.S. It can also reach the existing ETV stations.

2.1.2 SERVICE REQUIREMENTS

2.1.2.1 Information Transfer

The service will provide a multi-channel TV service to each U.S. time zone to be shared as follows:

ITV --- Nominal school hours 8:00 A.M. to 5:00 P.M.

ETV--- Early Morning and Evening
4:00-8:00 A.M. 5:00 - Midnight

The remaining portion of the day is available for program previewing, selection, and local management.

ETV is the generally accepted nomenclature used to describe noncommercial TV. It embraces National Educational TV (NET), Public Borad-cast Laboratory (PBL), and local operations of social and cultural interest (Figure 2-1). It is funded through federal, state and/or local taxes, and private endowments.

The range of application of Classroom Instructional Television (ITV) is very broad - all academic levels, industrial training, adult education, military training and so on.

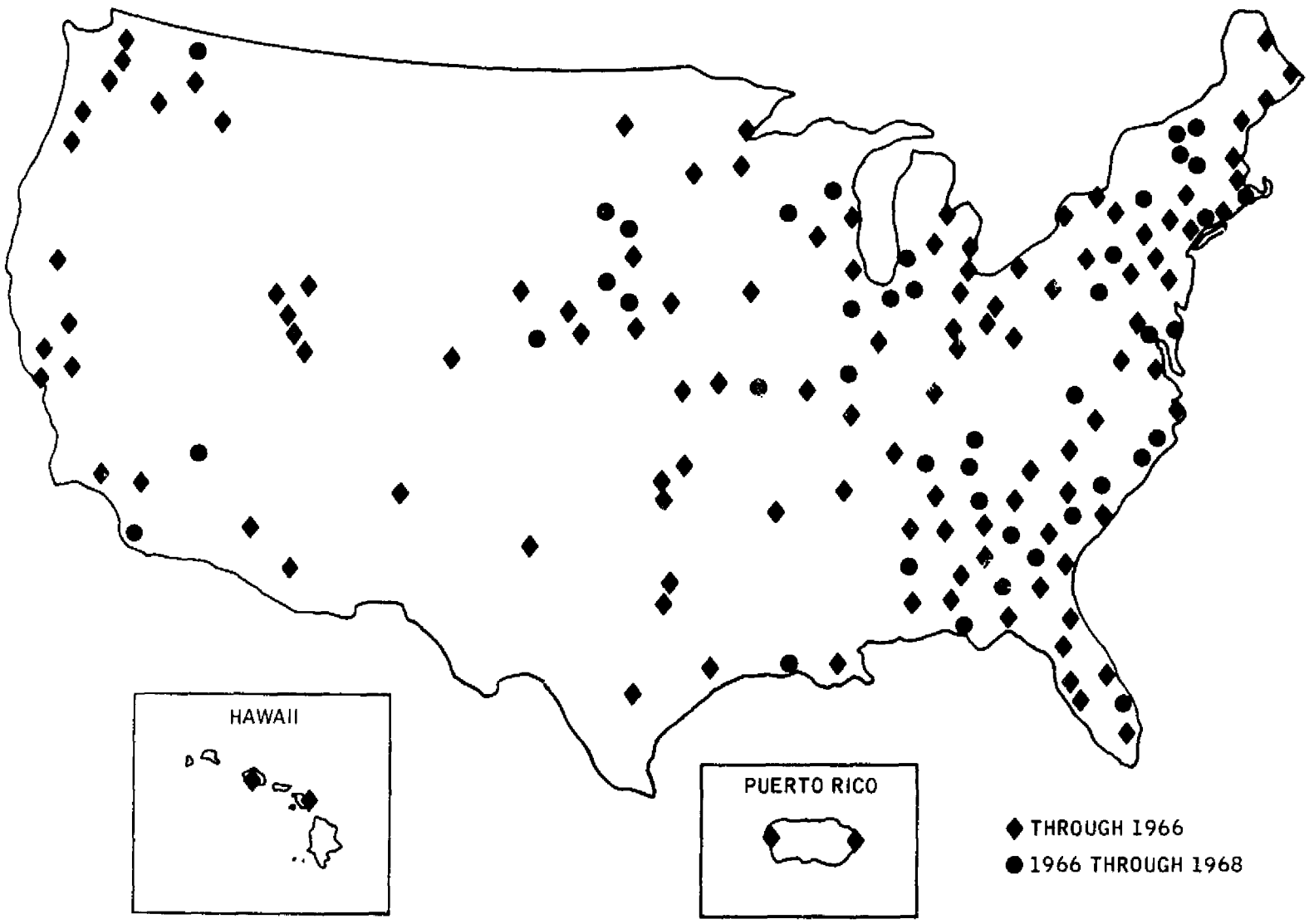


Figure 2-1. Distribution of ETV Stations in U.S. [1, 2]

2.1.2.2 Quantity of Data

This service description has considered 1, 5, 11, and 20 television channels per downlink beam with one audio per video channel.

2.1.2.3 Quality of Data

Data quality is defined for a redistribution mode and a direct mode. Two different quality levels are considered for each mode:

Redistribution Mode

CCIR Relay (54 db) yields TASO 1 at receiver

36.5 db yields TASO 3 at the receiver

Direct Mode

44.5/TASO 1

27 db/TASO 3

2.1.2.4 Service Area

The example system postulated for this service is:

1. Sources -- Two sources are shown for ETV, corresponding to NET in New York City and Los Angeles. Fifty sources for ITV, at one per state, are selected to provide local control and programming.

2. Destinations -- The number of ETV stations is projected to 223 to capture the major metropolitan markets or more than 90% of the U.S. population. A downlink system is provided for each school district. This will ensure control, programming, scheduling, and review at the most local level.

3. Description -- Eleven channels of TV are provided in each time zone. The satellite configuration includes one beam for each time zone. With eight channels of ITV a high degree of flexibility is offered. The system could grow to one or more channels per grade level serviced. Three channels of ETV are provided. In all cases a high quality TV signal is provided to permit redistribution to individual schools and homes.

Several of the states have their own network systems. Nevada, for example, has a microwave interconnection between Las Vegas, Carson City, and Reno linking the campuses of the University of Nevada. It also includes state general services -- Highway Patrol, Dept. of Health, etc. The intent is to make the network available to the entire educational community.

Educational laboratories exist in several key areas. These organizations are dedicated to improving the services in their areas by use of modern technology and innovative teaching methods. They are also trying to improve educational standards in the homes in their areas.

Much of this activity is sponsored by the U.S. Dept. of Health, Education & Welfare under the Public Broadcasting Act of 1967 and Networks For Knowledge of 1968. Private foundations as shown, are strong supporters of noncommercial TV operations.

2.1.2.5 Growth Projections

2.1.2.5.1 Educational Television (ETV)

Growth in the number of ETV stations[1, 2] since the first system went on the air in 1953 is shown in Figure 2-2, which also shows projected growth through 1980. At that time, it is anticipated that ETV stations will cover the same marketable metropolitan areas as commercial TV. As can be seen, until 1966 the stations tended to be located in the most densely populated areas. In the interval from 1966 through 1968, additional stations tended to reinforce the existing systems. Nevada and Vermont were the only additional states to acquire ETV systems. Finally, it should be noted that large areas of the Central and Western states do not now enjoy ETV coverage and would, therefore, welcome the advantages this service has to offer.

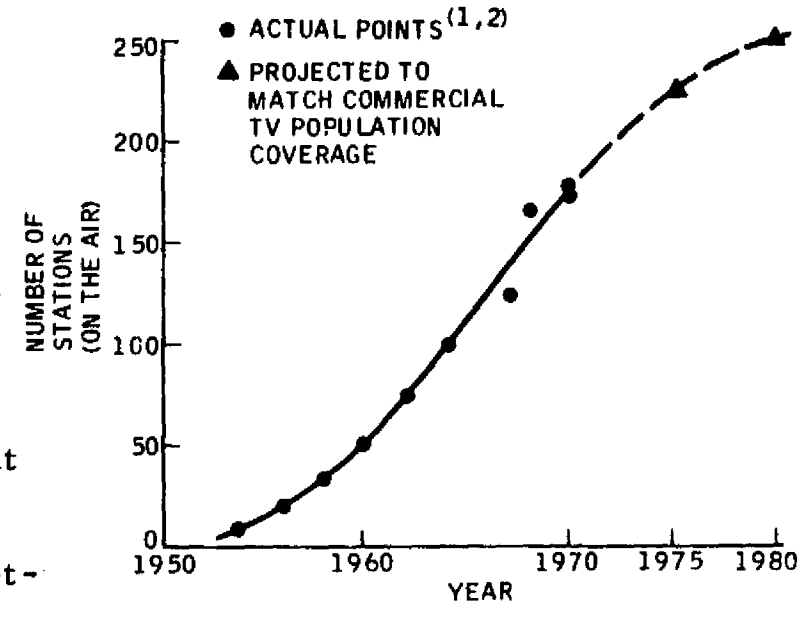


Figure 2-2. Growth of ETV

ETV systems have demonstrated their capability to capture audiences of six to eight million TV households. There is no particular reason to presume that, given a high interest program at a premium time, they could not be highly competitive with commercial TV.

2.1.2.5.2 School Enrollment

Figure 2-3 shows the growth in enrollment in elementary and secondary schools since 1956[3, 4]. In recent years, enrollment in elementary schools has accelerated; this surge is not yet reflected in secondary school enrollments, but the increased rate will be picked up when these pupils are graduated to high school. Two totals are shown -- one for public schools only, and one including private schools. The latter curve represents a 12% increase over the previous curve. Projection of the total enrollment

shows an anticipated increase of 25% by 1975. Conservative estimates show a student population of 70 to 75 million by 1980[3].

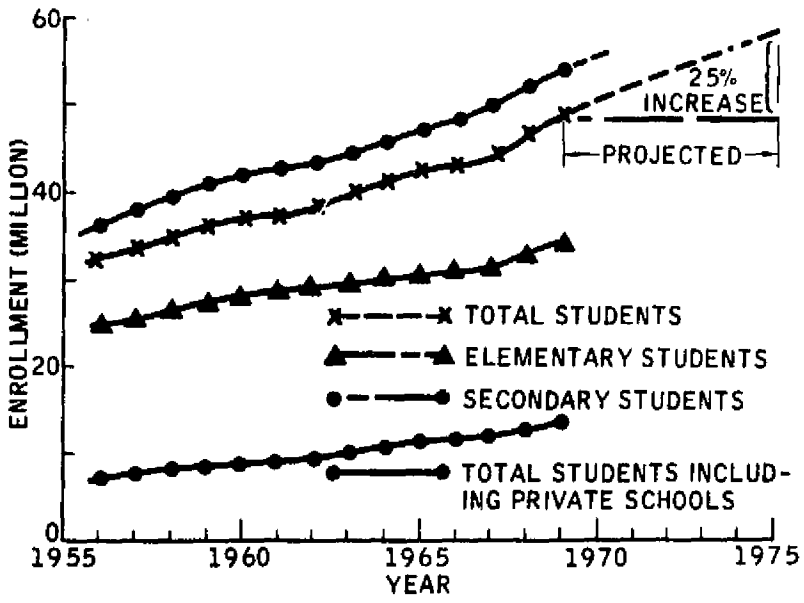


Figure 2-3. Enrollment in Elementary and Secondary Schools

Organizationally, this educational system is composed of school districts, usually controlled by locally elected school boards and managed by professional administrators. Figure 2-4 shows the decline in the total number of school districts since World War II (1946)[3, 5]. It can be seen that 78% of the schools districts were eliminated. The main reason for this decline has been consolidation of districts into unified school districts for reasons of functional and financial efficiency; 1,400 school districts in densely populated areas account for more than 58% of pupil enrollment. In contrast, seven Midwestern states account for 40% of the school districts. This continuing trend toward unification greatly enhances the acceptability of a national ETV/ITV system.

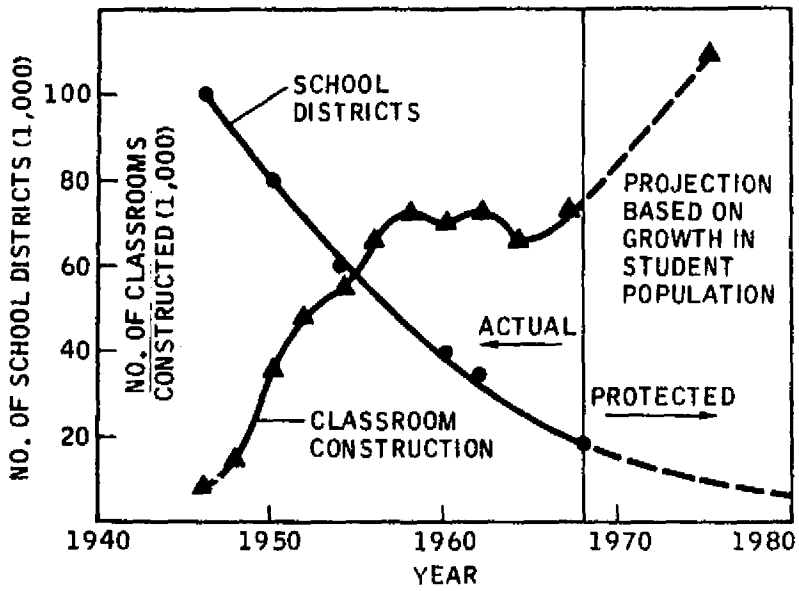


Figure 2-4. Number of Public School Districts and New Facilities

Whatever else might be said about education in the U.S. it must be categorized as "Big Business." Figure 2-5 shows the expenditures for public elementary and secondary education[3]. Before 1940, only about $2 billion was spent annually. Immediately thereafter, expenditures began to increase and have continued to do so ever since. Current annual expenditures are $34 billion, with a projected increase to $50 billion in 1975 (just for elementary and secondary education).

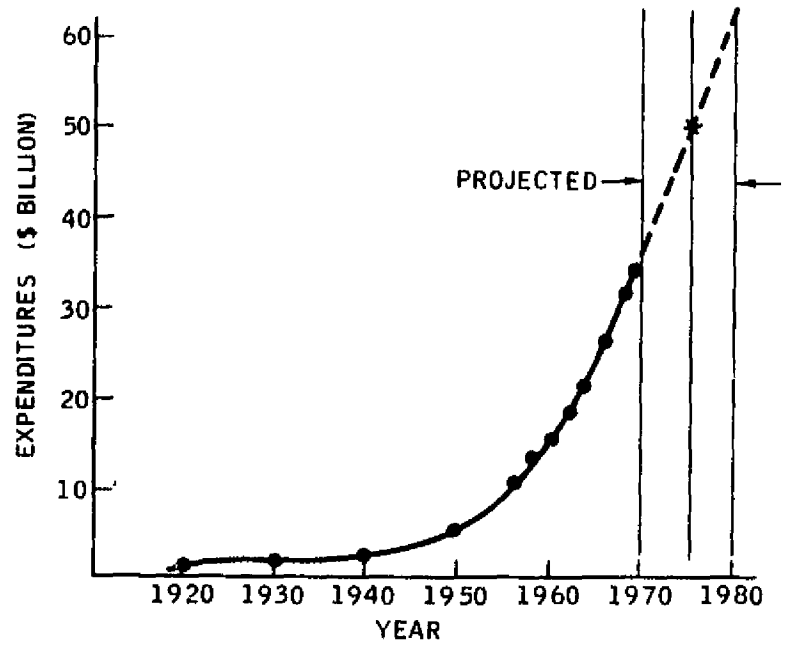


Figure 2-5. Summary of Expenditures for Public Elementary and Secondary Education(3)

2.1.3 COMMUNICATION SYSTEM DESIGN REQUIREMENTS

The design requirements for the television broadcast system are shown in Table 2-1. The assumptions for each of the system components are given below.

2.1.3.1 Ground Uplink Facilities

Two uplink facilities, one in New York City and one in Los Angeles are provided for ETV. Fifty uplink facilities, one per state, are assumed for ITV to provide local control and programming.

Table 2-1. U.S. Educational/Instructional Television System Design Requirements

SOURCE LOCATIONS	DESTINATIONS
● ETV-2 FACILITIES	● ETV - 223 METROPOLITAN AREAS
● ITV - 50 FACILITIES	● ITV - 27,000 SCHOOL DISTRICTS

SYSTEM DESCRIPTION

- 4 DOWNLINK BEAMS
- 11 VIDEO CHANNELS PER BEAM (NOMINAL)
  - 8 INSTRUCTIONAL
  - 3 EDUCATIONAL
- CCIR RELAY QUALITY $\frac{S}{N}$ = 54 dB (PREFERRED)
- 10 YEAR SYSTEM LIFE

2.1.3.2 Spacecraft -- The satellite will be positioned on a geostationary orbit. One uplink antenna and four downlink antennas, one for each time zone, are required.

2.1.3.3 Ground Receiving System

2.1.3.3.1 Redistribution Mode

10,000 to 30,000 downlink facilities are considered for analysis.

2.1.3.3.2 Direct Mode of Operation

The number of downlink facilities for this mode, based upon growth projections, is 60.4 million.

2.1.3.4 Interconnecting Systems

Interconnecting systems and networks to be considered are shown in Table 2-2.

Table 2-2. Interconnection Systems

- STATE NETWORKS -
  - GEORGIA
  - FLORIDA
  - NEBRASKA
  - NEVADA
- EDUCATIONAL LABORATORIES -
  - N.Y. SUPPLEMENTARY EDUCATIONAL CENTER
  - APPALACHIA EDUCATIONAL LABORATORY
  - ROCKY MOUNTAIN STATED EDUCATIONAL LABORATORY
- NETWORKS -
  - NET
  - EEN
- SPONSORS -
  - HEW
  - FORD FOUNDATION
  - CORP. FOR PUBLIC BROADCASTING
  - KETTERING FOUNDATION
  - JOHNSON FOUNDATION

2.2 COMMUNICATION SYSTEM DESCRIPTION

The user requirements detailed in Table 2-3 were encoded into the TVBS synthesis program and a minimum cost solution, consistent with configuration constraints, was determined. The resulting solution and the sensitivities about this solution will be discussed in the following sections.

Table 2-3 lists the general input requirements used for all cases analyzed. Twenty-five cases were run for the Redistribution mode of operations. In this mode, a fairly complex receiving station was used to distribute the signal to the users: an NET/ETV station or the equivalent for a school district. This mode was also used for a wider range of variations. Fifty cases were run for the Direct mode of operation where the signal was received directly at the viewer's facility. In the case of ITV, this was considered to be a school where internal CCTV would provide classroom coverage.

Table 2-3. System Parameters and Variations for Analysis

SYSTEM PARAMETERS	FIXED VALUES	VARIATIONS	FIXED VALUES	VARIATIONS
Satellite Longitude	—	-95° & -105°	-95°	—
Satellite Life	10 yr.	—	10 yr.	—
System Life	10 yr.	—	10 yr.	—
Uplink Frequency (GHz)	12.2	—	12.2	—
Downlink Frequency (GHz)	—	0.8, 2.5, 8.4 & 12.2	—	0.8, 2.5, 8.4 & 12.2
No. Uplink Beams (Antenna on Sat.)	1	—	1	—
No. Downlink beams	—	4,6	4	—
No. Uplink Facilities	—	1, 10, 20, 35, 50	—	12, 50
No. Receivers (1,000)	—	10, 30, 100, 300	60,400	—
Signal-to-Noise Ratio (at Receiver)	—	CCIR Relay: 54 db/ TASO 1 36.5 db/ TASO 3	—	Direct: 44.5/ TASO 1 27 db/ TASO 3
Modulation	FM	—	FM	—
No. Channels	—	1, 5, 11, 15, 20	—	1, 5, 11, 20
Receiving Antena Type	Parabolic	—	—	Parabolic, YAGI
No. Cases	25		30	

2.2.1 Redistribution Mode of Operation

Data for this mode is summarized in Table 2-4 and plotted in Figures 2-6 through 2-10. Several features are noteworthy:

1. In every instance, the largest contributor to total system cost is total receiver cost. Two basic reasons underlie this situation:
   a. First, a relatively large number of receivers is considered -- 30,000 is the nominal case.

Table 2-4. Results of Analysis of Redistribution Mode of Operation

CASE NO.	f (GHz)	ΣSystem ($M/Yr) T-1	ΣSystem ($M/Yr) T-3	ΣSAT ($M/Yr) T-1	ΣSAT ($M/Yr) T-3	U-SAT $M	U-SAT Wt. Lb	U-SAT Vol Cu Ft	ΣRCVR ($M/Yr) T-1	ΣRCVR ($M/Yr) T-3	U-RCVR Ant + R	U-RCVR Total	ΣGND UP ($M/Yr) T-1	ΣGND UP ($M/Yr) T-3	ΣLV ($M/Yr)	No. TV Channels	No. of Downlink Fac. (Thousands)	No. DN Beams	No. UP Facility
1	12.2	2,105.63		4.44		8.25	3,248.8	277	2,077.1		547.26	8,923	21.95		2.13	1	10	4	50
2	12.2	6,257.20		5.13		9.91	5,081.0	404	6,227.80		426.89	6,887	21.95		2.13	1	30	4	50
3	12.2	20,782.65		5.97		12.22	7,793.0	594	20,751.69		546.65	8,921	21.95		3.04	1	100	4	50
4	12.2	62,282.08		10.93		29.08	29,958.0	2223	62,238.54		306.47	2,074	21.95		10.66	1	300	4	50
5	12.2	5,270.04		7.63		20.52	10,623.0	872	5,213.41		884.58	5,213	37.94		4.26	5	10	4	50
6	12.2	52,133.07		10.91		32.82	24,990.0	2058	62,079.56		882.99	5,207	32.94		10.66	5	100	4	50
7	12.2	8,842.0		10.01		30.41	19,204.0	1592	8,766.55		1736.86	8,766	56.85		8.52	11	10	4	50
8	12.2	87,659.78		11.67		37.03	27,044.0	2247	87,580.60		1734.24	8,758	56.85		10.66	11	100	4	50
9	12.2	10,992.77		11.21		35.55	29,588.0	1948	10,899.39		2302.67	10,899	71.51		10.66	15	10	4	50
10	12.2	108,994.73		12.01		38.76	27,419.0	2275	108,900.0		2299.81	10,890	71.51		10.66	15	100	4	50
11	12.2	13,541.47		12.26		40.08	26,852.0	2235	13,429.44		3008.77	13,429	89.12		10.66	20	10	4	50
12	12.2	134,305.45		12.42		40.72	27,615.0	2301	134,193.25		3005.70	13,419	89.12		10.66	20	100	4	50
1	12.2	26,308.21		11.25		35.32	24,988.0	2071	26,284.55		1735.36	8,761	1.75		10.66	11	30	4	1
2	12.2	26,320.00		11.24		35.31	24,977.0	2071	26,284.55		1735.36	8,761	13.54		10.66	11	30	4	10
3	12.2	26,333.12		11.24		35.28	24,946.0	2068	26,284.57		1735.36	8,761	26.65		10.66	11	30	4	20
4a	12.2	26,352.78		11.24		35.29	24,955.0	2063	26,284.56		1735.36	8,761	46.32		10.66	11	30	4	35
4b	12.2	26,345.04		11.53		36.46	26,363.0	2189	26,283.96		1735.28	8,761	39.89		10.66	11	30	4	35
1	0.8	26,320.18		10.08		27.51	10,158.0	3460	26,248.99		1731.40	8,749	56.86		4.26	11	30	6	50
2	0.8		26316.65		9.09	24.05	7,318.0	3242		26248.45	1731.35	8,749		55.08	3.04	11	30	6	50
3	2.5	26,335.28		8.95		24.59	9,300.0	734	26,265.22		1733.20	8,755	56.86		4.26	11	30	6	50
4	2.5		26329.70		8.78	24.02	8,712.0	686		26262.80	1732.95	8,754		55.08	4.26	11	30	6	50
5	8.4	26,349.60		10.68		33.25	19,445.0	1748	26,273.53		1734.10	8,757	56.86		8.52	11	30	6	50
6	8.4		26338.22		8.41	24.70	9,858.0	956		23270.46	1733.78	8,756		55.08	4.26	11	30	6	50
7	12.2	26,365.26		12.32		39.94	27,385.0	2305	26,285.42		1735.39	8,761	56.86		10.66	11	30	6	50
8	12.2		26350.38		8.71	25.86	11,110.0	944		26282.33	1735.10	8,760		55.08	4.26	11	30	6	50

b. Second, the total receiving system includes not only the basic antenna and receiver but also facilities, video tape recorders, inatallations, operations, and maintenance.

2. Implementation costs (defined as the summation of ground uplink, satellite and launch vehicle costs) are considerably less than total system cost. They range from approximately 30 to 100 million dollars per year.

3. Total system costs increase with increased services -- number of TV channels and number of receivers.

4. Total system cost is almost completely insensitive to the change in the number of uplink facilities. This, again, relates to the dominance of receiver costs in the system.

5. Total system cost is again fairly insensitive to change in frequency. For a TASO Grade 1 system, the total satellite cost shows a minimum of $8.95 million per year at 2.5 GHz. This changes to a minimum of $8.41 million at 8.4 GHz for TASO Grade 3.

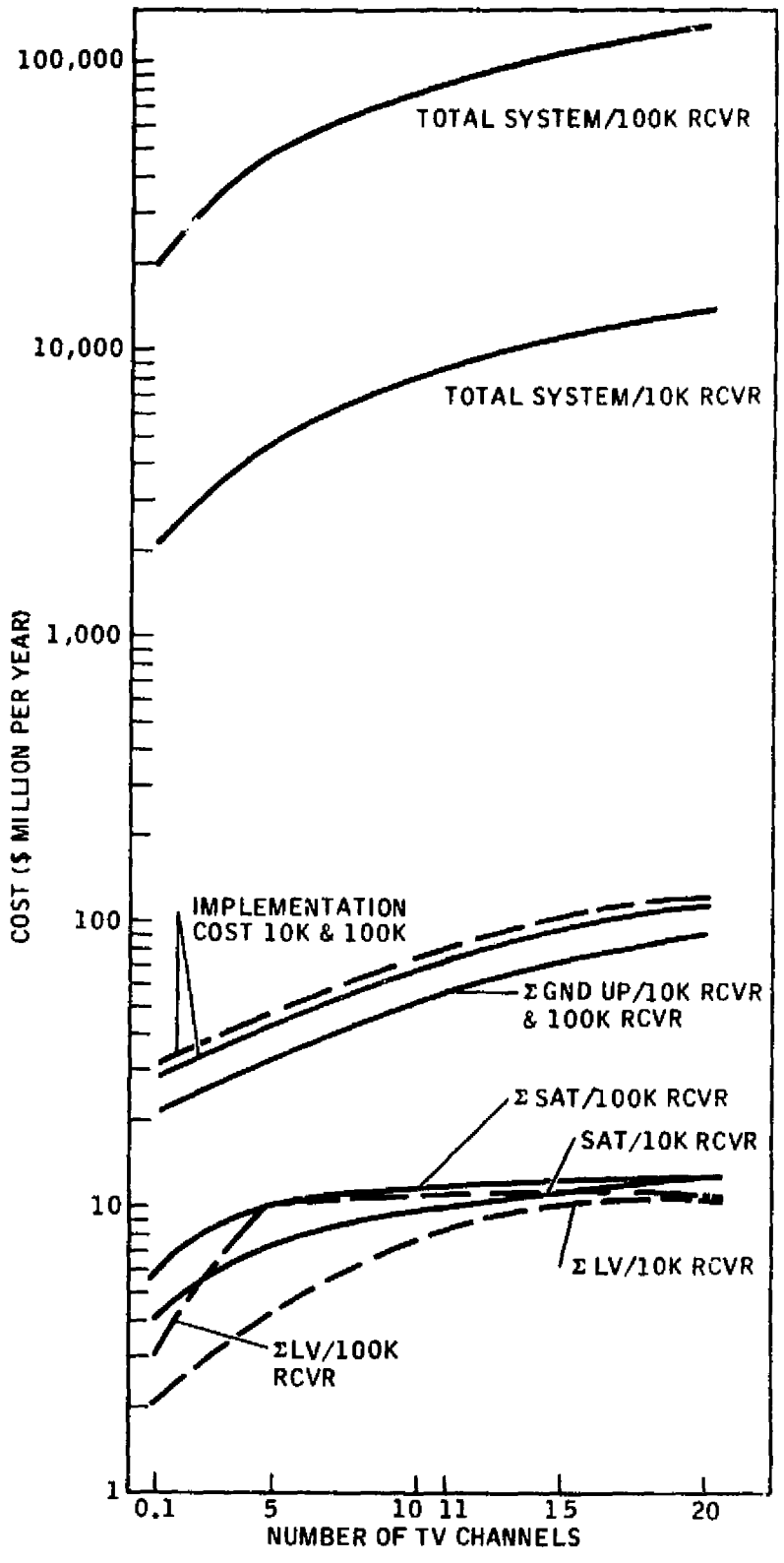


Figure 2-6. ETV/ITV Redistribution Mode of Operation -- Total Costs vs. Number of TV Channels

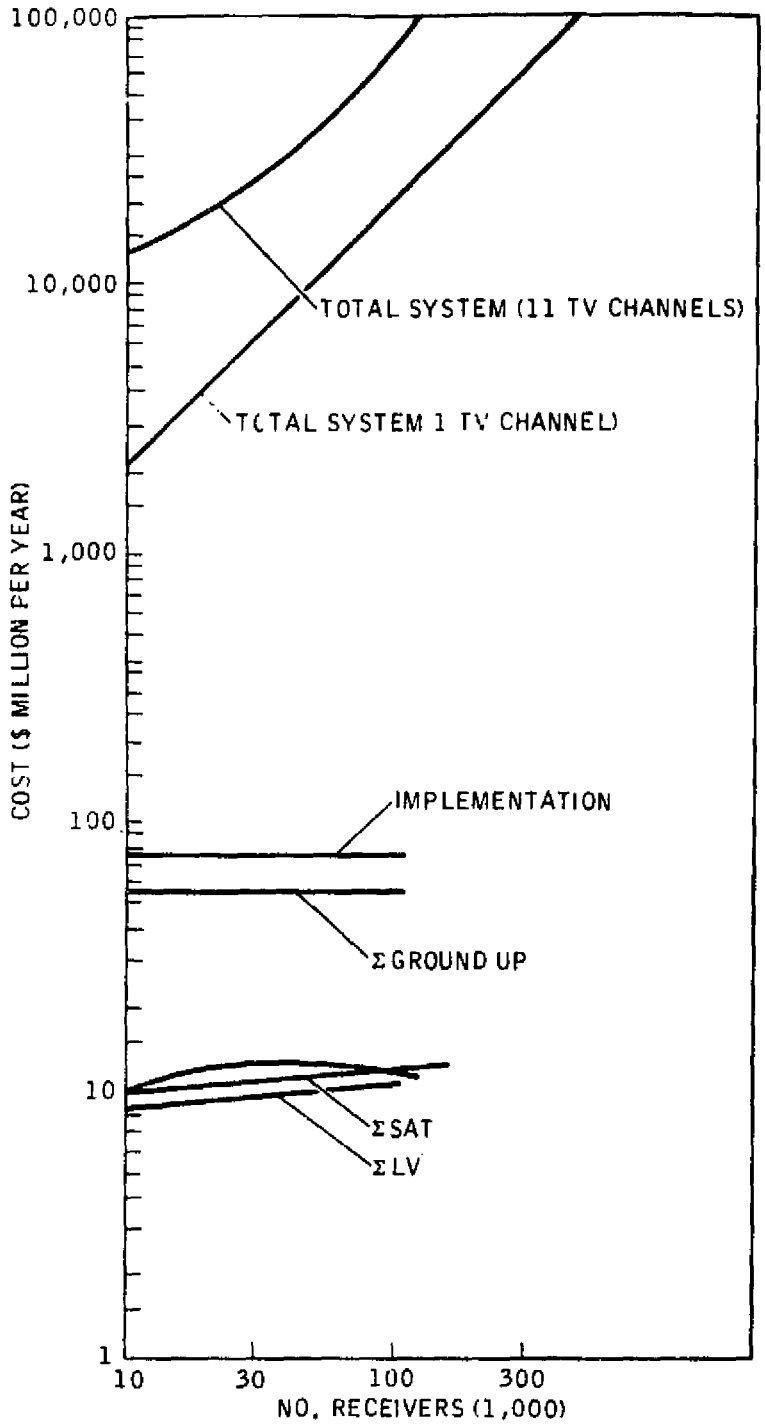


Figure 2-7. ETV/ITV Redistribution Mode of Operation -- Total Costs vs. Number of TV Receivers

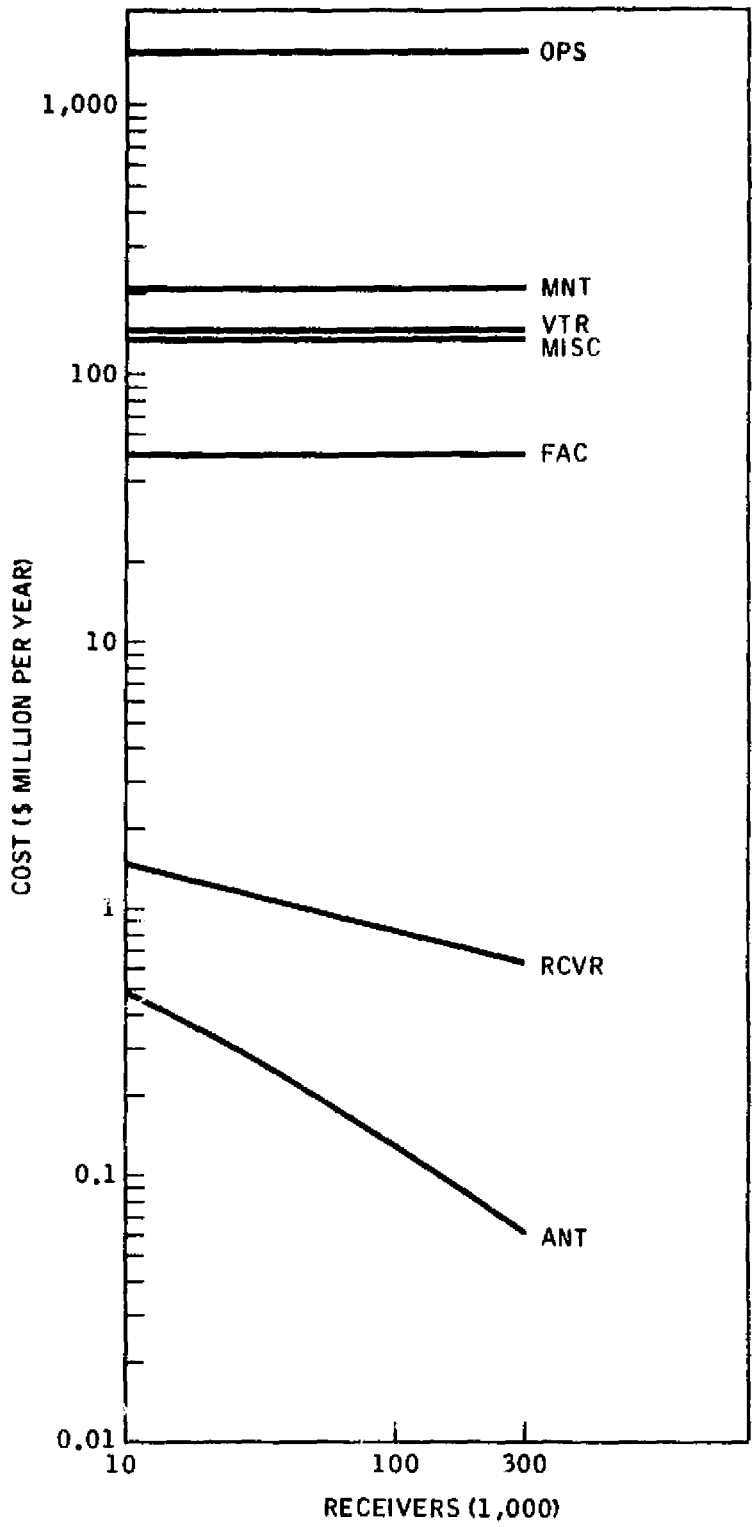


Figure 2-8. ETV/ITV Redistribution Mode of Operation -- Unit Receiving System Cost Elements

2.2.2 Direct Mode of Operation

Table 2-5 summarizes data for this mode, which is plotted in Figures 2-11 through 2-13. Several features are immediately discernable.

1. Direct systems are considerable less costly than redistribution systems -- by a factor of 20 for comparable systems (Table 2-4, Case 1).

2. Total system cost increases with frequency and is not significantly sensitive to variations in number of up-link facilities or signal/noise ratio.

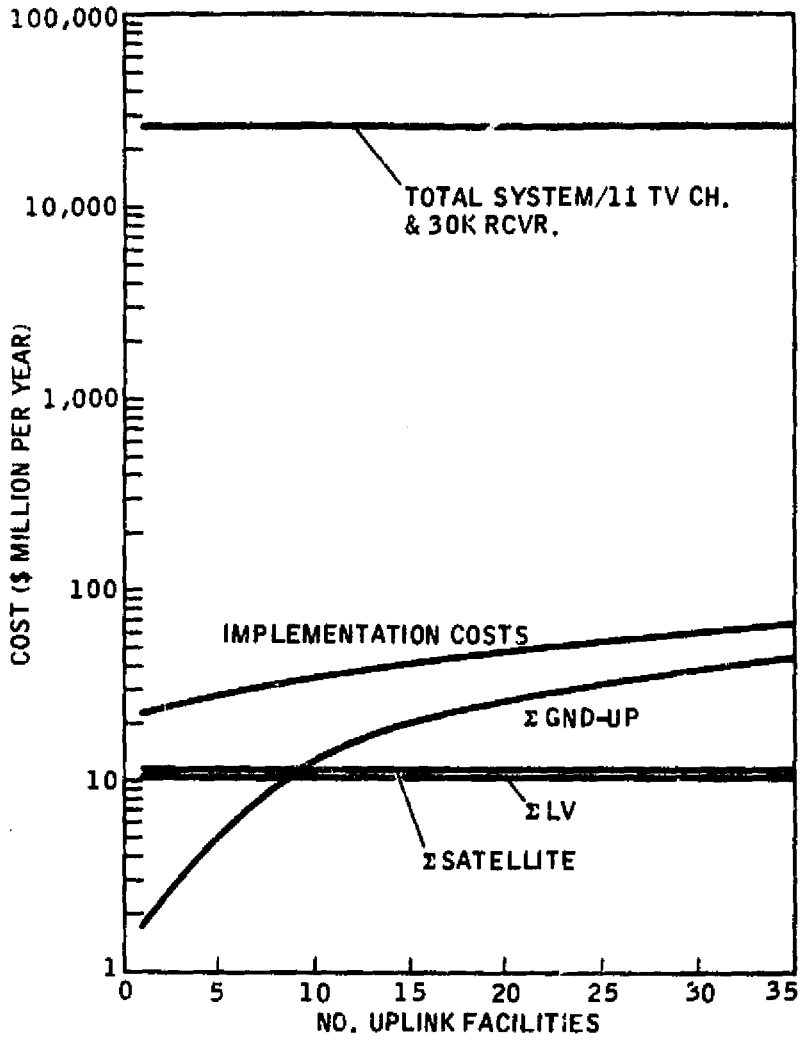


Figure 2-9. ETV/ITV Redistribution mode of operation -- total costs vs. number of uplink facilities

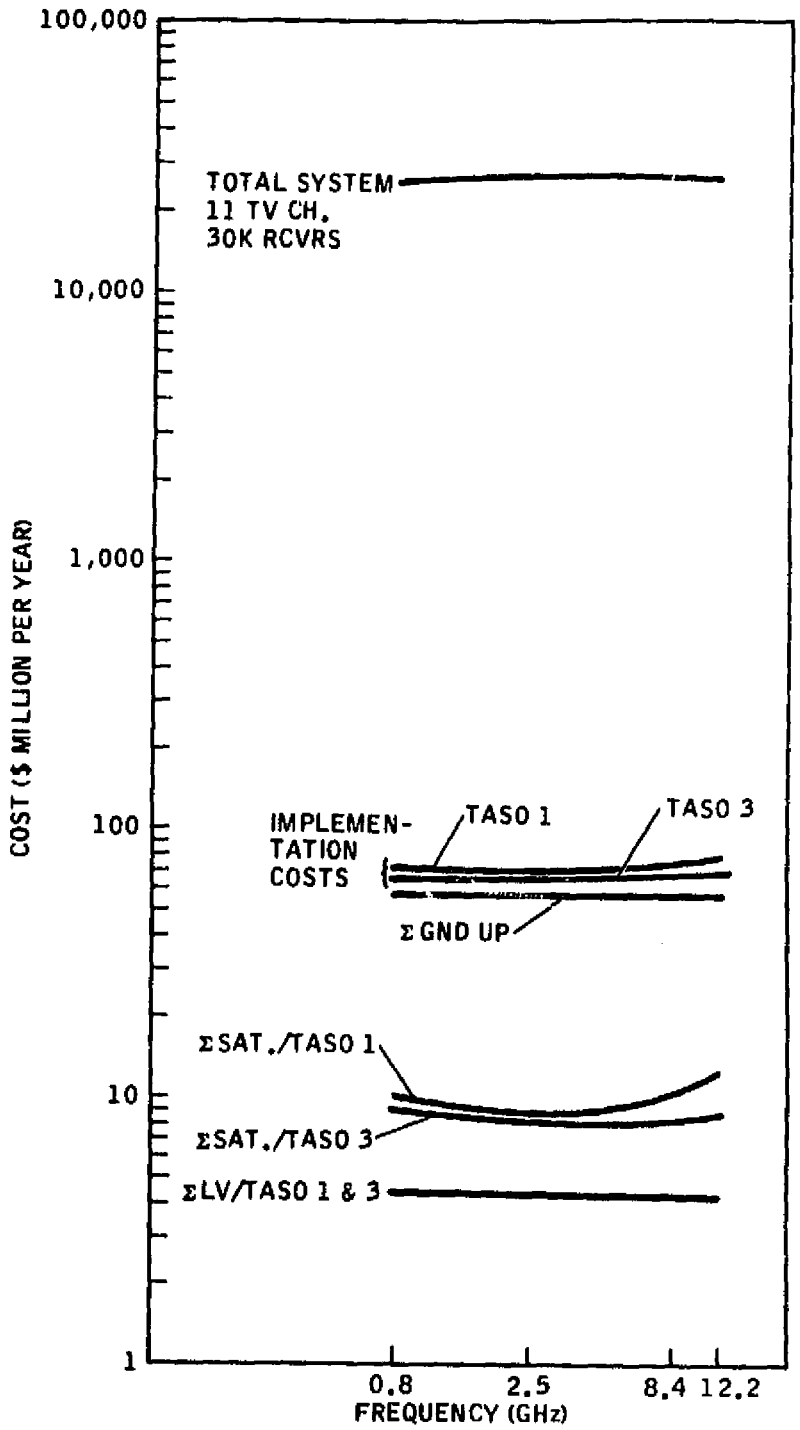


Figure 2-10. ETV-ITV Redistribution mode of operation -- total costs vs. frequency

Table 2-5. Results of Analysis of Direct Mode of Operation

CASE NO.		f (GHz)	ΣSystem ($M/Yr) T-1	ΣSystem ($M/Yr) T-3	ΣSAT ($M/Yr) T-1	ΣSAT ($M/Yr) T-3	U-SAT $M	U-SAT Wt. Lb	U-SAT Vol. Cu. Ft.	ΣRCVR ($M/Yr) T-1	ΣRCVR ($M/Yr) T-3	U-RCVR Ant + R	U-RCVR Total	ΣGND UP ($M/Yr) T-1	ΣGND UP ($M/Yr) T-3
1	12 Uplink Facilities	0.8	1391.1		13.16		42.34	29,014	3120	1343.28		80.78	222.40	13.53	
3		0.8		1362.16		13.16	42.34	29,014	3120		1314.27	79.51	217.59		13.40
5		2.5	1741.5		12.37		38.07	27,680	2236	1694.28		103.83	280.51	13.53	
8		2.5		1701.43		12.37	38.07	27,680	2236		1654.34	102.05	273.90		13.40
6		8.4	1890.23		11.68		37.06	27,092	2304	1843.71		112.18	305.25	13.53	
9		8.4		1798.42		11.68	37.06	27,092	2304		1752.02	108.06	290.07		13.40
7		12.2	1947.80		11.68		37.05	27,069	2249	1900.98		115.23	314.73	13.53	
10		12.2		1824.78		11.68	37.05	27,069	2249		1778.39	109.64	294.43		13.40
17	50 Uplink Facilities	0.8	1433.12		13.16		42.34	29,014	3120	1343.28		80.78	222.40	55.36	
19		0.8		1403.61		13.16	42.34	29,014	3120		1314.27	79.51	217.59		54.85
11		2.5	1783.33		12.37		38.07	27,680	2235	1694.28		103.83	280.51	55.36	
14		2.5		1742.88		12.37	38.07	27,680	2235		1654.34	102.05	273.90		54.85
12		8.4	1932.07		11.68		37.06	27,092	2304	1843.71		112.18	305.25	55.36	
15		8.4		1839.87		11.68	37.06	27,092	2304		1752.02	108.06	290.07		54.85
13		12.2	1989.33		11.68		37.05	27,069	2249	1900.98		115.23	314.73	55.36	
16		12.2		1866.23		11.68	37.05	27,069	2249		1778.39	109.64	294.43		54.85
1	1 CHANNEL	0.8	886.58		9.329		26.14	23,214	2531	852.74		49.24	141.18	3.19	
3		0.8		884.14		7.85	20.08	15,313	1949		851.81	49.20	141.03		3.16
5		2.5	1222.35		11.60		30.62	30,032	2217	1186.24		71.48	196.40	3.19	
8		2.5		1219.09		8.59	19.34	15,657	1154		1186.24	71.47	196.36		3.16
6		8.4	1292.25		10.92		29.09	29,978.2	2278	1256.82		76.23	208.08	3.19	3.16
9		8.4		1288.33		10.80	28.65	29,362	2232		1253.05	76.05	207.46	3.19	3.16
7		12.2	1302.68		10.93		29.08	29,957	2223	1267.25				3.19	3.16
10		12.2		1297.65		10.93	29.08	29,958	2223		1262.24	76.79	208.98	3.19	3.16
11	5 CHANNELS	0.8	1056.30		12.19		38.78	28,156	3090	1014.88		59.70	168.03	7.91	
13		0.8		1046.20		12.19	38.28	28,156	3090		1004.85	59.25	166.37		7.83
15		2.5	1395.85		11.98		35.32	27,045	2203	1354.65		82.23	224.28	7.91	7.83
18		2.5		1381.91		11.98	35.32	27,045	2203		1340.78	81.60	221.98	7.91	7.83
16		8.4	1490.21		11.29		34.33	26,843	2267	1449.70		88.12	240.02	7.91	7.83
19		8.4		1458.82		11.29	34.33	26,843	2267		1418.37	86.69	234.83	7.91	7.83
17		12.2	1515.26		11.29		34.32	26,821	2212	1474.74		89.63	244.16	7.91	7.83
20		12.2		1473.39		11.29	34.32	26,821	2212		1432.94	87.69	237.24	7.91	7.83
21	20 CHANNELS	0.8	1905.75		14.47		47.76	29,958	3166	1845.85		112.92	306.10	21.11	
23		0.8		1869.88		14.47	47.76	29,958	3166		1783.17	110.08	295.23		20.92
25		2.5	2274.6[illegible]		13.13		41.77	28,202	2286	2219.13		136.87	367.40	21.11	20.92
28		2.5		2186.60		13.13	41.77	28,202	2286		2131.24	133.00	352.85	21.11	20.92
26		8.4	2529.73		12.43		40.78	27,691	2361	2474.87		150.35	409.75	21.11	20.92
29		8.4		2323.23		12.43	40.78	27,691	2361		2268.56	140.80	375.59	21.11	20.92
27		12.2	2643.47		12.43		40.76	27,668	2306	2588.62		156.09	428.58	21.11	20.92
30		12.2		2372.80		12.43	40.76	27,668	2306		2318.14	143.49	393.80	21.11	20.92

3. The overwhelming expense is in total ground receiving cost, which is driven by the potentially large number of receivers: 60.4 million. This element is, in fact, a consumer cost for ETV and may be for ITV, depending upon the way in which school participation is handled.
4. Considering only the receiving antenna and the receiver, unit receiver cost increases with frequency, but is on the order of $100. However, when operations and maintenance are included, this value increases by a factor greater than two for just one year, as shown in Figure 2-12.
5. Implementation costs for the system are represented by summing the ground uplink, satellite, and launch vehicle costs. This cost is approximately $46 million per year for a system with 12 uplink facilities or $88 million per year for 50 uplinks. The remaining portion of the total system costs would be assumed incrementally as receivers are added to the system.
6. As expected, the total system cost increases with the number of channels, as shown in Figure 2-13. The major contributor to the total cost is the receiving system -- again because of the large population considered.

As above, implementation costs are derived by summing the ground uplink satellite and launch vehicle costs. This cost increases with the number of channels, as shown. The minimum cost system is a single-channel system at $33.84 million per year.

2.2.3 Conclusions

The primary conclusions to be drawn from this study are:

1. This mission is technically feasible within current technology. For the smaller satellites, launch vehicles up to the Titan III/Centaur can be used; larger satellites require the Saturn V. Since they do not completely fill the Saturn V, additional payloads may be carried on the same launch.
2. As shown in Figure 2-14, the Redistribution mode of operation is more costly than the Direct mode. This is primarily due to the additional expense items in the ground receiving system (video tape recorders, operations, etc.).

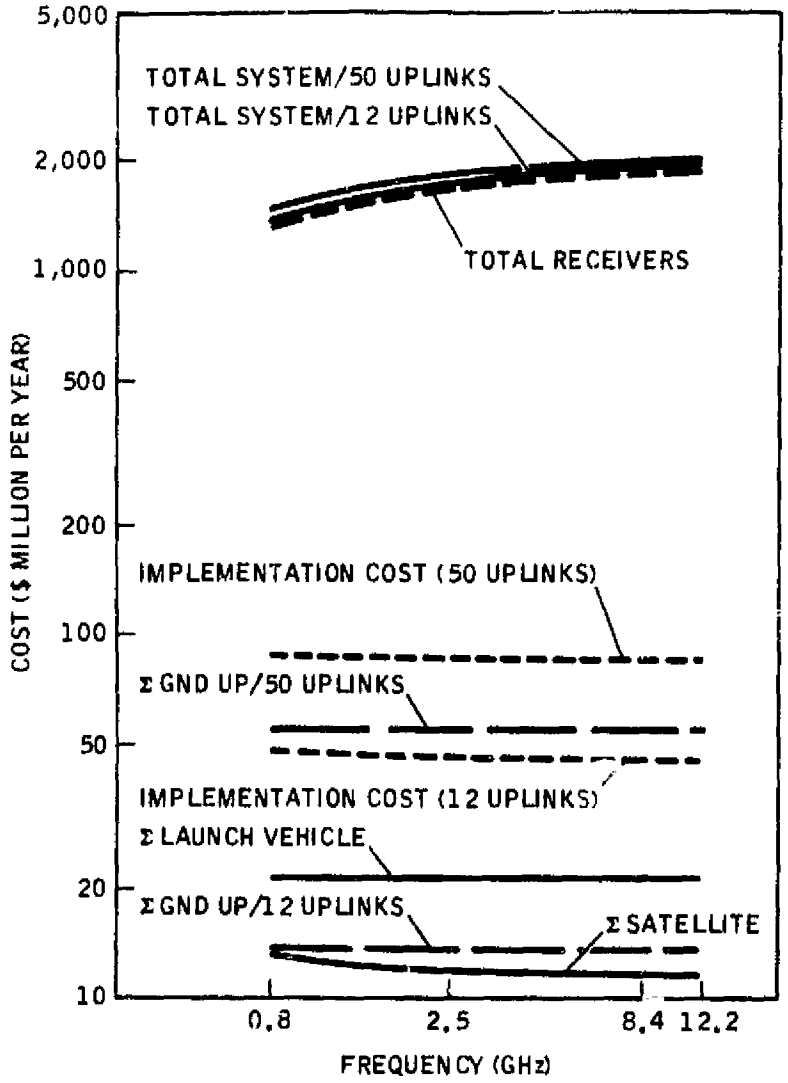


Figure 2-11. ETV/ITV Direct Total Cost vs. Frequency

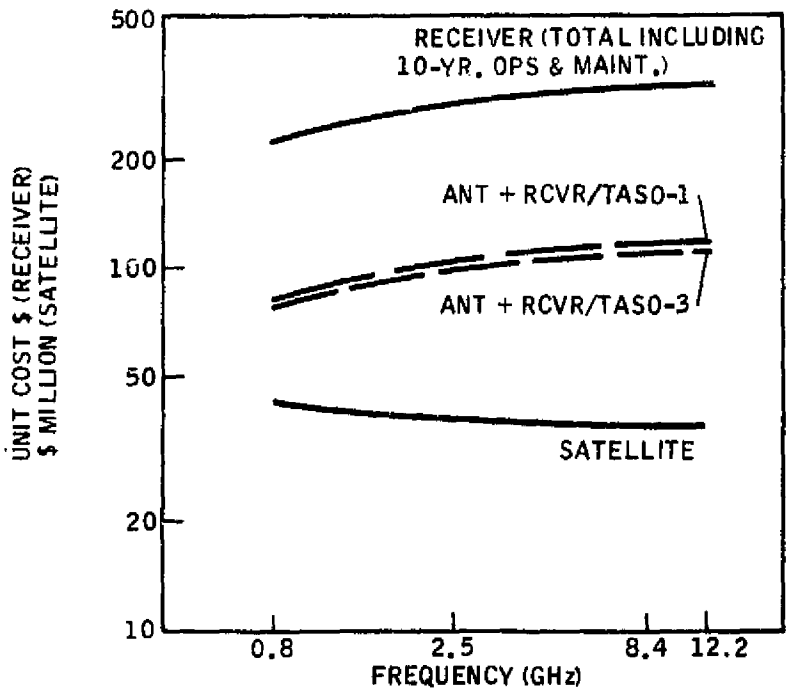


Figure 2-12. ETV/ITV Direct Mode of Operation -- Unit Costs vs. Frequency

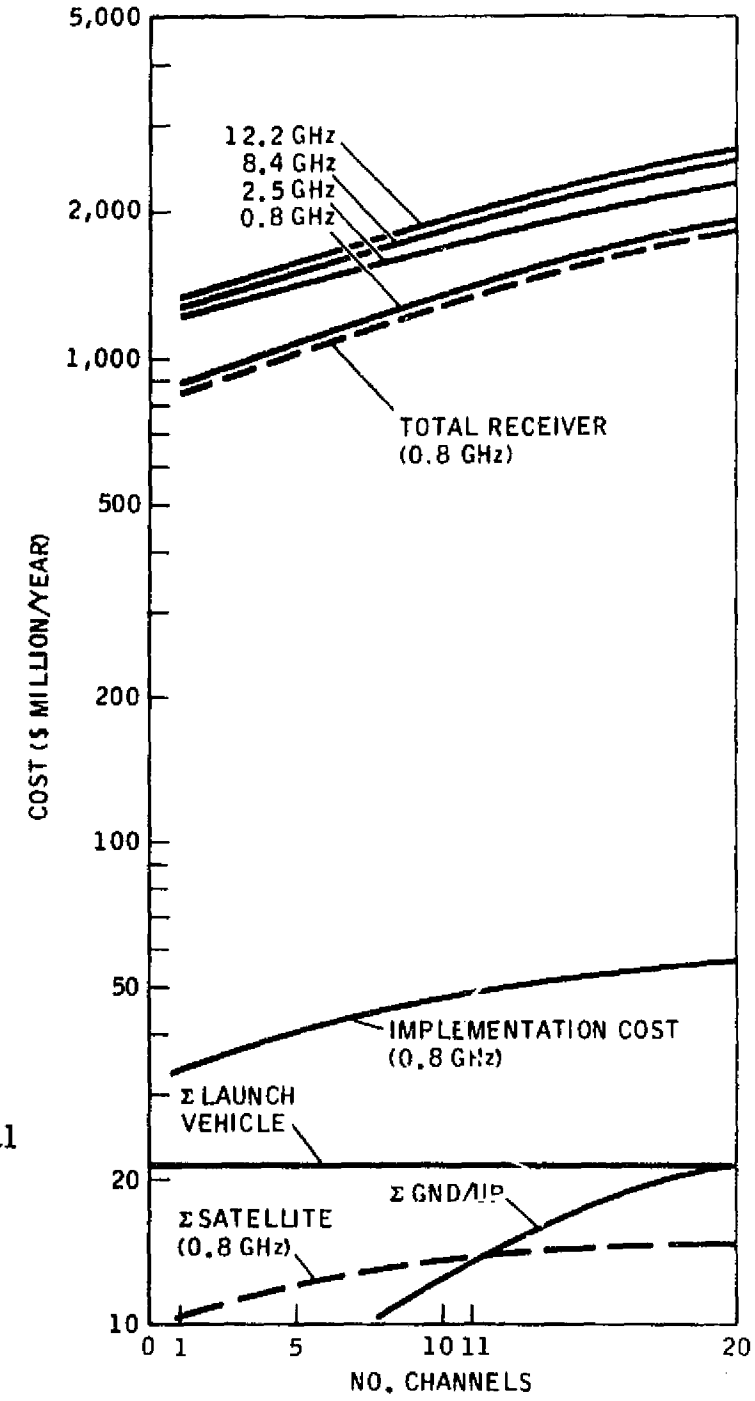


Figure 2-13. ETV/ITV Direct Total Costs vs. Number of Channels

3. Generally, the systems can be arranged in an ascending order of costs (Figure 2-14) for an increasing order of service. As the combination of number of TV channels and uplinks increases, Direct mode costs increase because it is broadcasting to a

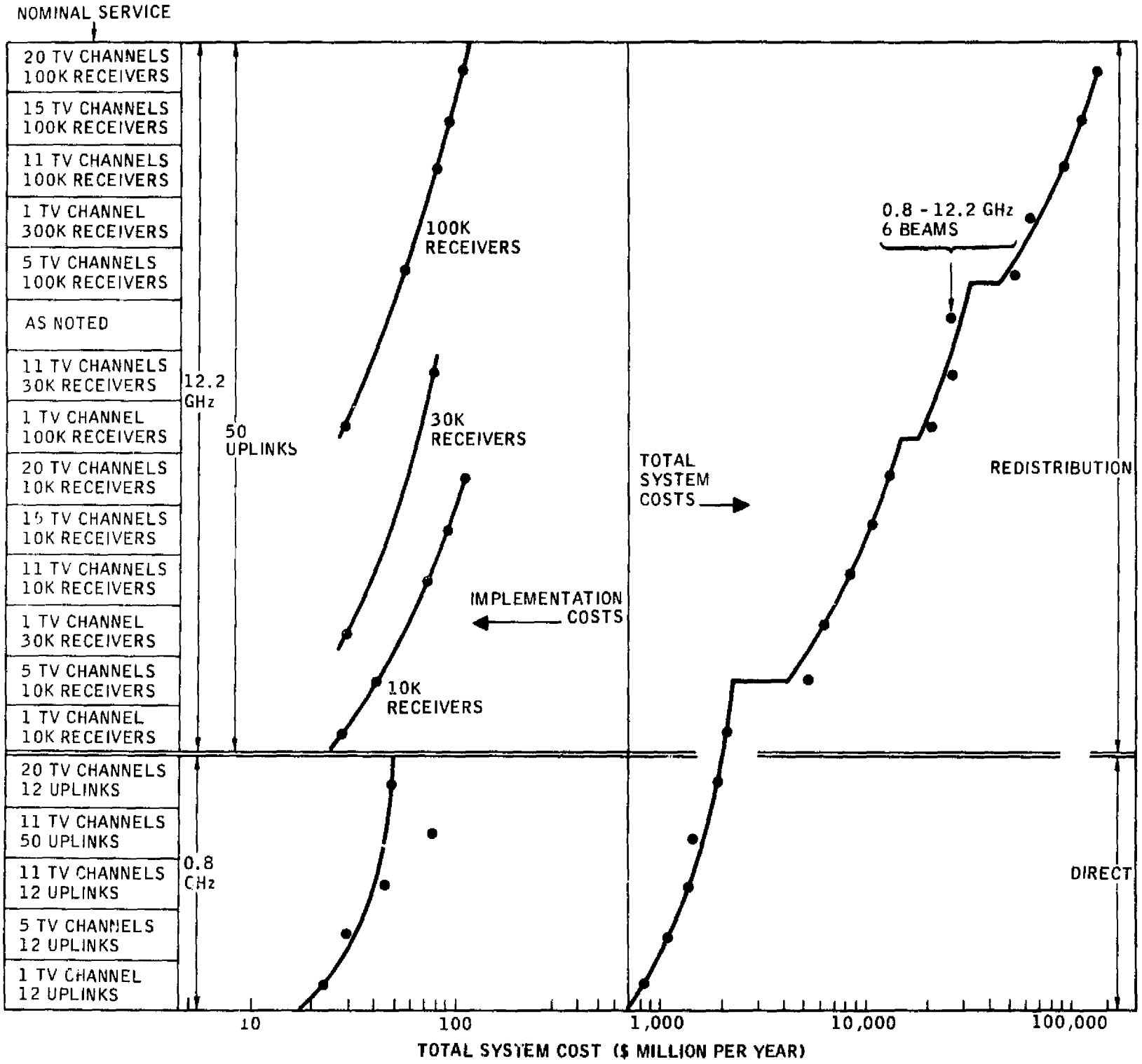


Figure 2-14. Cost Summary

fixed population (60.4 million). The combination of TV channels and number of receivers is used for the Redistribution mode.

4. A particular point is shown, representing a range of downlink frequencies. Total system cost is not sensitive to this variation.

5. As shown in Figure 2-15, a variety of multiple-beam satellites result from this analysis. The unit cost varies with number of TV channels supplied. For the Direct mode, the range of unit cost is from 26 to 47 million dollars; for Redistribution the range is from 12 to 38 million dollars. These costs are considerably less than the total system cost.

6. Finally, it should be noted from the System Analysis section that the total receiver costs constitute the largest portion of total system cost. This is contrary to most other analyses, but is consistent with the real-world situation where the following items must be considered:

    Antenna costs
    Receiver costs
    Installation costs
    Video tape recorder costs
    Facilities costs
    Operations costs
    Maintenance costs
    Personnel costs

Indications are, in general, that student populations are increasing, operating costs are increasing, school facilities are marginal, and available funds are decreasing. Coupling this with a strong trend toward a reduced number of school districts suggests a need to exploit every available technique for bringing effective instruction to students at all levels. Similarly, while the benefits are not so clearly discernible, the demand for educational/cultural television can be readily satisfied by a satellite system.

2.2.4 References

1. Public Television -- A Program For Action, Bantam Books PZ3552, January 1967.
2. Television Factbook, Stations Volume, 1968-69 Edition, No. 38.
3. OE-10024-68, "Digest of Educational Statistics," 1968 Edition; November 1968, U.S. Dept. HEW -- Office of Education.
4. Fact Sheet on Catholic Schools in the U.S., December 1968, The National Catholic Educational Association.
5. "Education -- An Investment in People," Chamber of Commerce of the U.S., 1964 (Library of Congress Catalog Card No. 64-25401).



DIRECT/4 BEAMS/60.4 MILLION RECEIVERS				REDISTRIBUTION/4 BEAMS/100K RECEIVERS			
	SATELLITE				SATELLITE		
NO. TV CHANNELS	WT. (LB.)	VOL. (CU. FT.)	UNIT COST ($M)	NO. TV CHANNELS	WT. (LB.)	VOL. (CU. FT.)	UNIT COST ($M)
1	23,214	2,531	26.14				
5	28,156	3,090	38.78				
11	29,014	3,120	42.34				
20	29,958	3,166	47.76				
1	30,032	2,217	30.02				
5	27,045	2,203	35.32				
11	27,680	2,236	38.07				
20	28,202	2,286	41.77				
1	29,978	2,278	29.09				
5	26,843	2,267	34.33				
11	27,092	2,304	37.06				
20	27,691	2,361	40.78				
1	29,957	2,223	29.08	1	7,793	594	12.22
5	26,821	2,212	34.32	5	24,990	2,058	32.82
11	27,069	2,239	37.05	11	27,044	2,247	37.03
20	27,668	2,306	40.76	20	27,615	2,301	40.72
				15	27,419	2,275	38.76

Figure 2-15. Summary of Satellite Characteristics

3

ALASKA AND WESTERN STATES

This analysis served to define the requirements for a total non-commercial educational and instructional television service (ETV/ITV) for Alaska. The present coverages of the commercial television services and the CATV systems are presented.

The system described in this study will provide three channels of color television reception to every village in the state. Up-link facilities have been located in both Alaska and in the South 48 to provide both state-wide and national real-time transmission. The system described will cost the state government 10.8 million dollars per year and each large community 1,300 dollars per year. Small villages (less than 100 people) may receive the same service for about 300 dollars per year. These costs are based upon a total system lifetime of ten years.

In addition to the description of the selected configuration, system sensitivities are presented which illustrate the impact of perturbations of design requirements upon the system. It is shown in these sensitivities that, if desirable, 1,100 two-way telephone channels may be included for an additional government cost of 1 million dollars per year and a community cost increase of 200 dollars per year. These costs do not include, however, the additional ground uplink facilities.

Continuing analysis by Convair of these communications requirements will refine the total requirements and will result in the definition of an expanded information transfer system for Alaska.

3.1 REQUIREMENTS

3.1.1 OBJECTIVE - The objective of this service is to provide a complete educational and instructional television (ETV/ITV) broadcast and reception capability for Alaska. It is intended that this service will be available to all homes, communities, schools, colleges and institutuions in the state.

3.1.2 SERVICE REQUIREMENTS

3.1.2.1 Information Transfer - This service will transfer real-time or recorded television data from either of the originating stations to the entire state. At this time, it is assumed that only one-way transmission is required. Continuing activity in this area will define the requirements for other types of information transfer, both one-way and two-way.

3.1.2.2 Quantity of Data - Three television channels, with one audio channel per video channel, will be supplied.

3.1.2.3 Quality of Data - Full color television service will be provided on each channel at C.C.I.R. Relay Quality (Signal-to-Noise Ratio of 53dB) to the redistribution head-end equipment and TASO Grade 1 (Signal-to-Noise Ratio of 44.5dB) to community receivers.

3.1.2.4 Service Area - The service area will be the entire state of Alaska. A population distribution of Alaskan communities is given in Figure 3-1. It is assumed that a minimum of one receiver per community will be used for populations less than 100, and a redistribution system (CATV) will be required for the larger communities. Each school may either have a separate receiving system or be connected via cable to the community receiving systems.

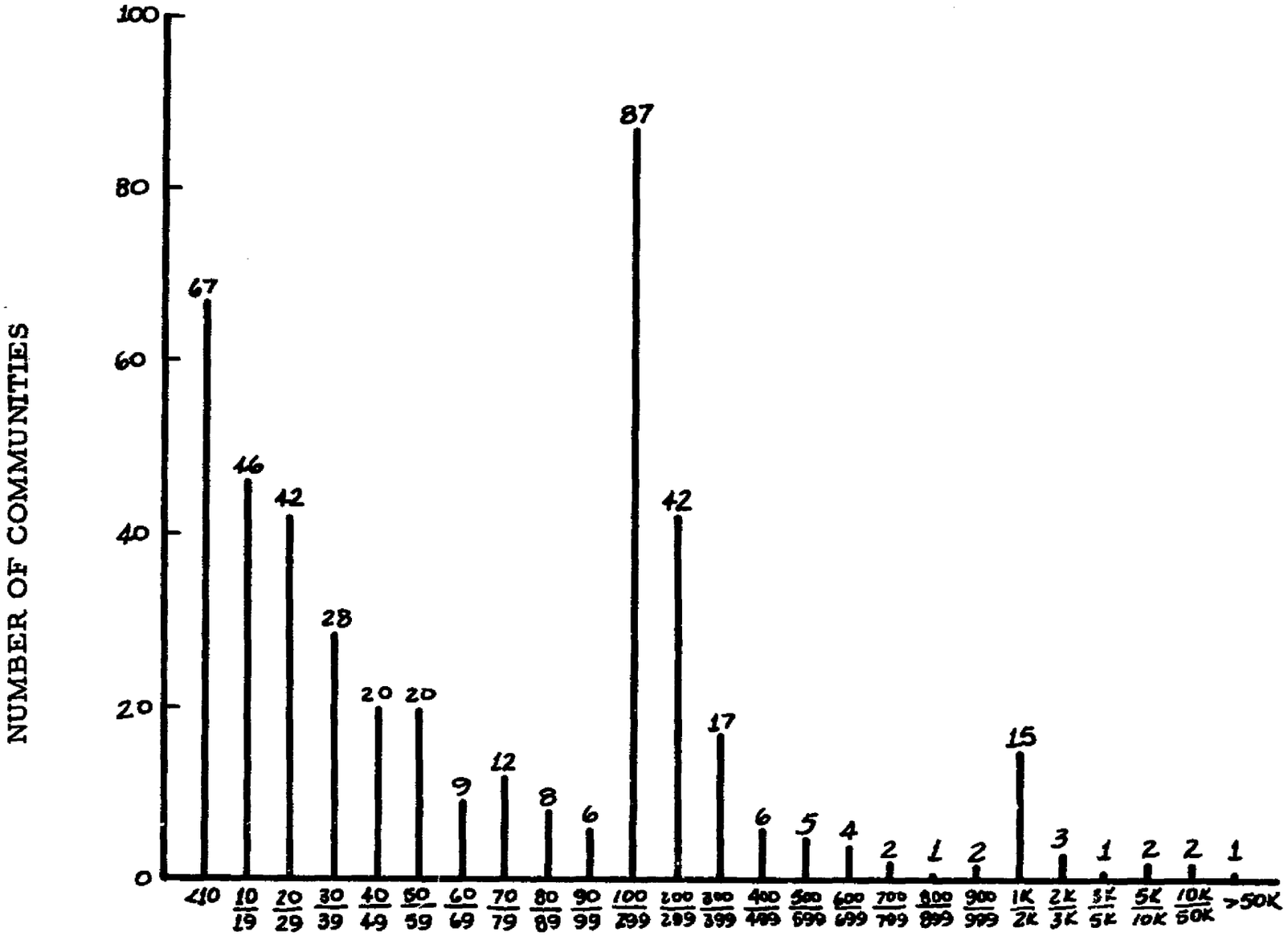


Figure 3-1. Population Distribution of Communities in Alaska

3.1.2.5 Schedule of Operation - The duty cycle for the system is assumed to be 24 hours per day based upon the following load requirements:

5:30 a.m. to 9:00 a.m.

ETV for the general public - 3 channels

9:00 a.m. to 5:00 p.m.

ITV for school use - 3 channels

5:00 p.m. to Midnight

ETV for the general public - 2 channels

ITV for program previewing - 1 channel

Midnight to 5:30 a.m.

ITV for program previewing, selection, and recording - 3 channels

3.1.2.6 Existing Facilities - The existing commercial television service contours for Alaska are given in Figure 3-2. At present there are no ETV facilities. Existing CATV systems are listed in Table 3-1, showing present and projected services.

Table 3-1. Existing CATV Systems in Alaska

COMMUNITY	NUMBER OF SUBSCRIBERS	POTENTIAL AUDIENCE	POPULATION	NO. OF CHANNELS	MILES IN PLANT		HOMES FRONT OF PLANT	SUBSCRIBER FEE
					EXISTING	PLANNED		
Cordova	125		1128					$17/mo.
Juneau	300	3000	6797	6	5	20	1700	$55+$12/mo.
Ketchikan	1000	1500	6483	5	30	7	2000	
Kodiak	300		2628					
Petersburg	390		1501					$15/mo.
Barrow	1800		1314					
Sitka	1000	1600	3237	5			1300	
Skagway	107		659					$17/mo.
Wrangell	325		1315					$15/mo.

Table 3-2. Design Requirements

AREA OF COVERAGE	
MAJOR AXIS (mi)	1175
MINOR AXIS (mi)	2090
AREA (10^6 mi^2)	1.93
RECEIVING POPULATION	500
SET POPULATION	100,000
BEAM CENTER LATITUDE	59.75°N
BEAM CENTER LONGITUDE	150.00°W
SPACECRAFT LONGITUDE	150.00°W
SIGNAL QUALITY	C.C.I.R.
SIGNAL-TO-NOISE RATIO	53.0dB
NO. OF VIDEO CHANNELS	3
NO. OF AUDIO CHANNELS/VIDEO	1
NO. OF UPLINK FACILITIES	2
NO. OF VIDEO CHANNELS/FACILITY	3
TOTAL SYSTEM LIFETIME	10 years
DUTY CYCLE	24 hrs/day

3.1.3 COMMUNICATION SYSTEM DESIGN REQUIREMENTS - The design requirements for the television broadcast system are shown in Table 3-2. The assumptions made for each of the system components are given below.

3.1.3.1 Ground Uplink Facilities - Two uplink facilities, one near Fairbanks and the other on the West Coast, are provided to allow both local and national participation in the system. Each facility has the capability for three time-shared video channels.

3.1.3.2 Spacecraft - The satellite will be positioned in a geo-stationary orbit at 150^{o} West longitude. Two uplink antennas and one downlink antenna will be required.

3.1.3.3 Ground Receiving System - The ground receiving system is composed of one receiving antenna and a low-noise preamplifier/ modulation, and frequency converter. The redistribution systems will be required at each receiving system, but was not included in this analysis. Future analysis of this system will address the advantages and disadvantages of CATV and rebroadcast distribution.

3.1.4 SUPPORTING DATA

3.1.4.1 Contacts - The following contacts have been made in relation to the need for an ETV/ITV system for Alaska and the Western States:

1. L. Madison Coombs
   Bureau of Indian Affairs
2. Ray Reid
   ETV Coordinator for California
3. D. R. Quale
   Corporation for Public Broadcasting

4. W. Briscoe
   National CATV Association

5. J. W. Powell
   Office of Economic Opportunity

6. J. C. Broger
   DOD

7. Very Rev. F. A. Quinn, Ed.D.
   Archdiocese of San Francisco

8. Rev. J. Pindar
   The National Catholic Office for Radio and TV

3.1.4.2 References

1. Katherine Johnsen, "Action Believed Imminent on Domestic Satcom Plan", Aviation Week and Space Technology, 14 July, 1969.

2. Herman Lowenhar, "TV Distribution From Space", Space/ Aeronautics, March 1969.

3. Television Broadcast Satellite Study, NAS 3-9708, Final Briefing, G.E., 5 February 1969.

4. Commercial Atlas and Marketing Guide 1969 ed., Rand-McNally and Co.

5. CATV and Station Coverage Atlas, 1968-1969 edition, TV Digest, Inc.

3.2 COMMUNICATIONS SYSTEM DESCRIPTION

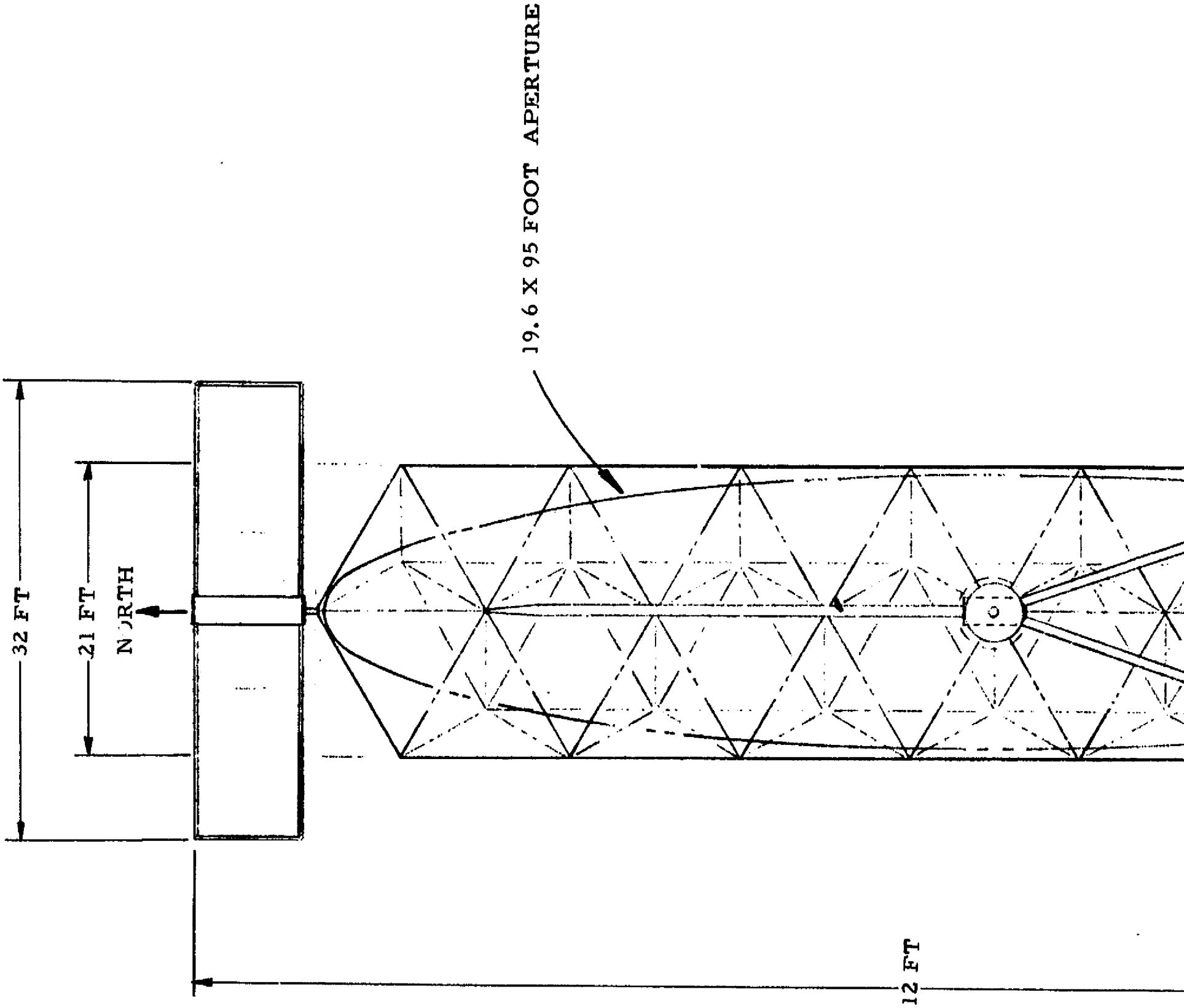
The user requirements detailed in Table 3-2 were encoded into the TVBS synthesis program and a minimum cost solution, consistent with configuration constraints, was determined. The resulting solution and the sensitivities about this solution will be discussed in the following sections.

3.2.1 SATELLITE SYSTEM DESCRIPTION - Selected from six different configurations, the minimum cost system consists of a 10 year spacecraft launched by a Titan IIID. The satellite downlink antenna is 19.6 feet by 95 feet and is fabricated using the Parabolic Expandable Truss Antenna (PETA). This antenna was chosen to take advantage of the rigidity of the deep truss structure for mounting the solar array. Prime Power is supplied by four roll-up solar arrays producing 3.1 kilowatts at end of life. Batteries are provided to allow full 3 channel operation during solar eclipse. See Figure 3-2 for satellite configuration. Table 3-3 lists subsystems.

Redundant high efficiency UHF crossed-field amplifiers (CFA's) p produce the required 320 watts per channel. The channels are multiplexed into the single downlink antenna. The communications subsystem block diagram is given in Figure 3-3.

3.2.2 GROUND UPLINK SYSTEM DESCRIPTION - The two uplink facilities are located near Fairbanks and one on the continental West Coast, will provide the necessary program recording transmission functions. Each is capable of the full three channel output and will time-share uplink duties. The Fairbanks station will, in addition, perform the telemetry and command operations. Each facility consists of 3-600 watts per channel transmitters feeding a 36 foot parabolic antenna, 3 video-tape recorders, the physical plant, standby

FOLDOUT FRAME



Figure

FOLDOUT FRAME 2

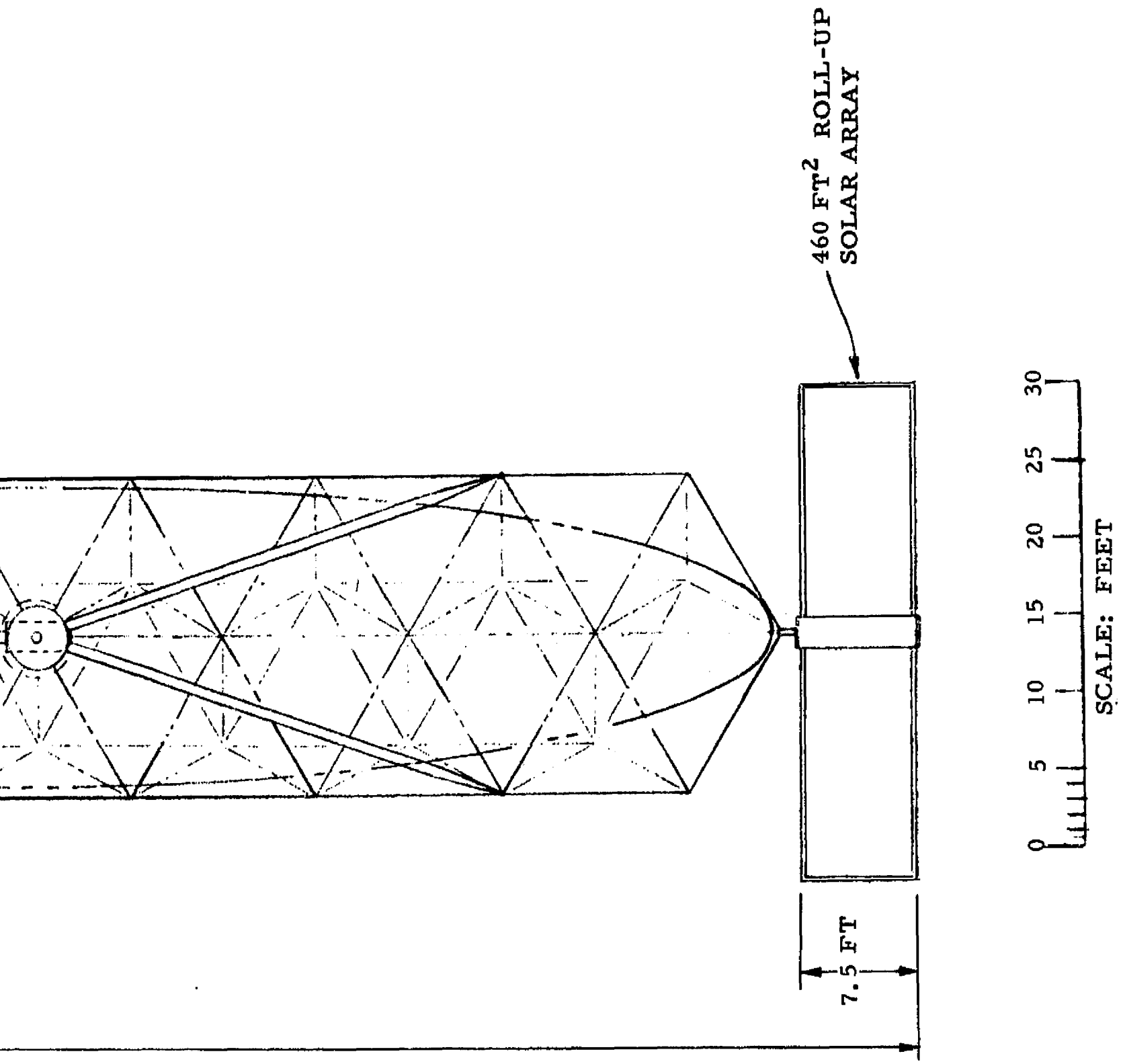


Figure 3-2(a). UHF Alaska ETV/ITV Satellite Configuration (a) Front View

FOLDOUT FRAME 1

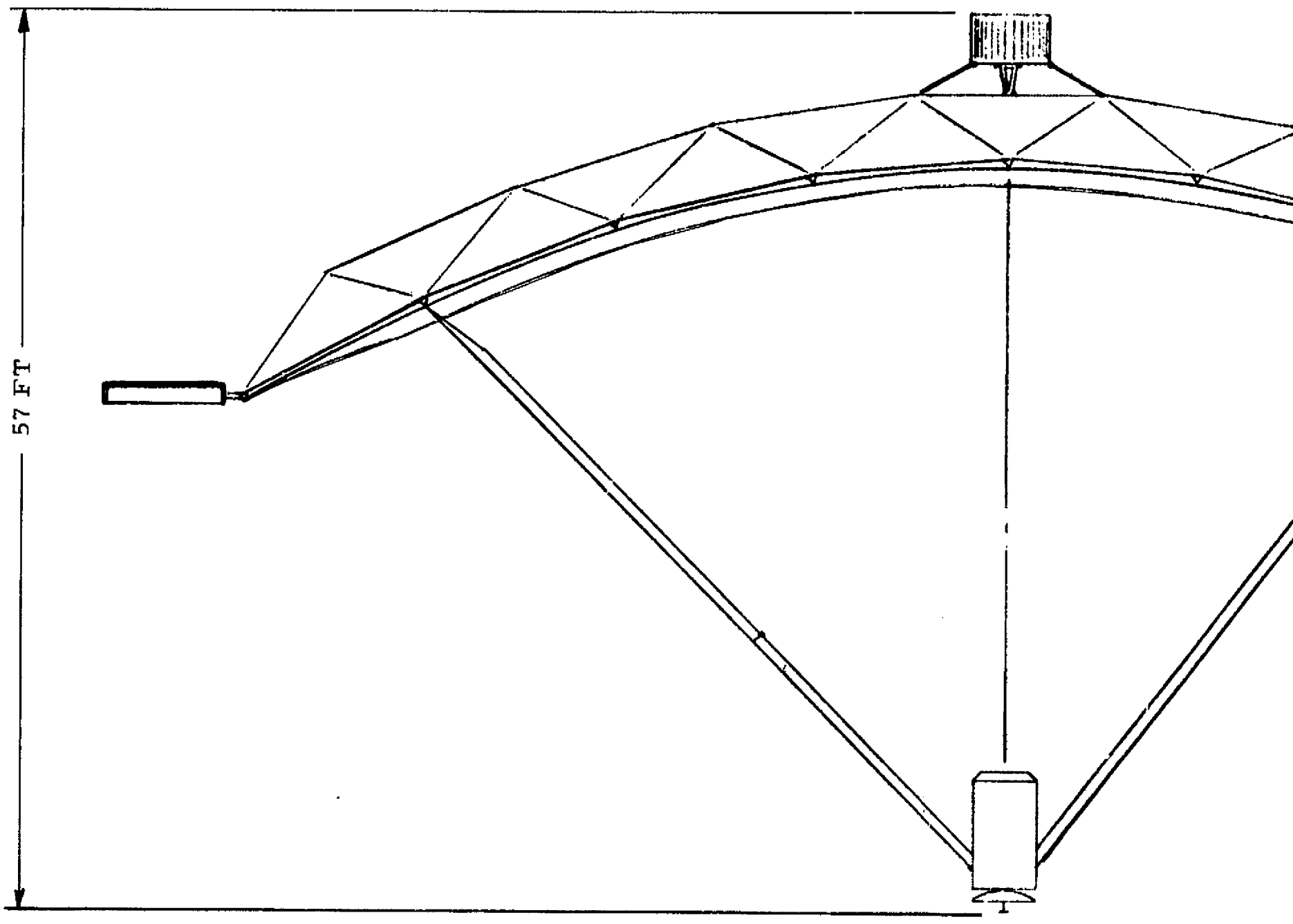


Figure 3-2(b). UHI

FOLDOUT FRAME 2

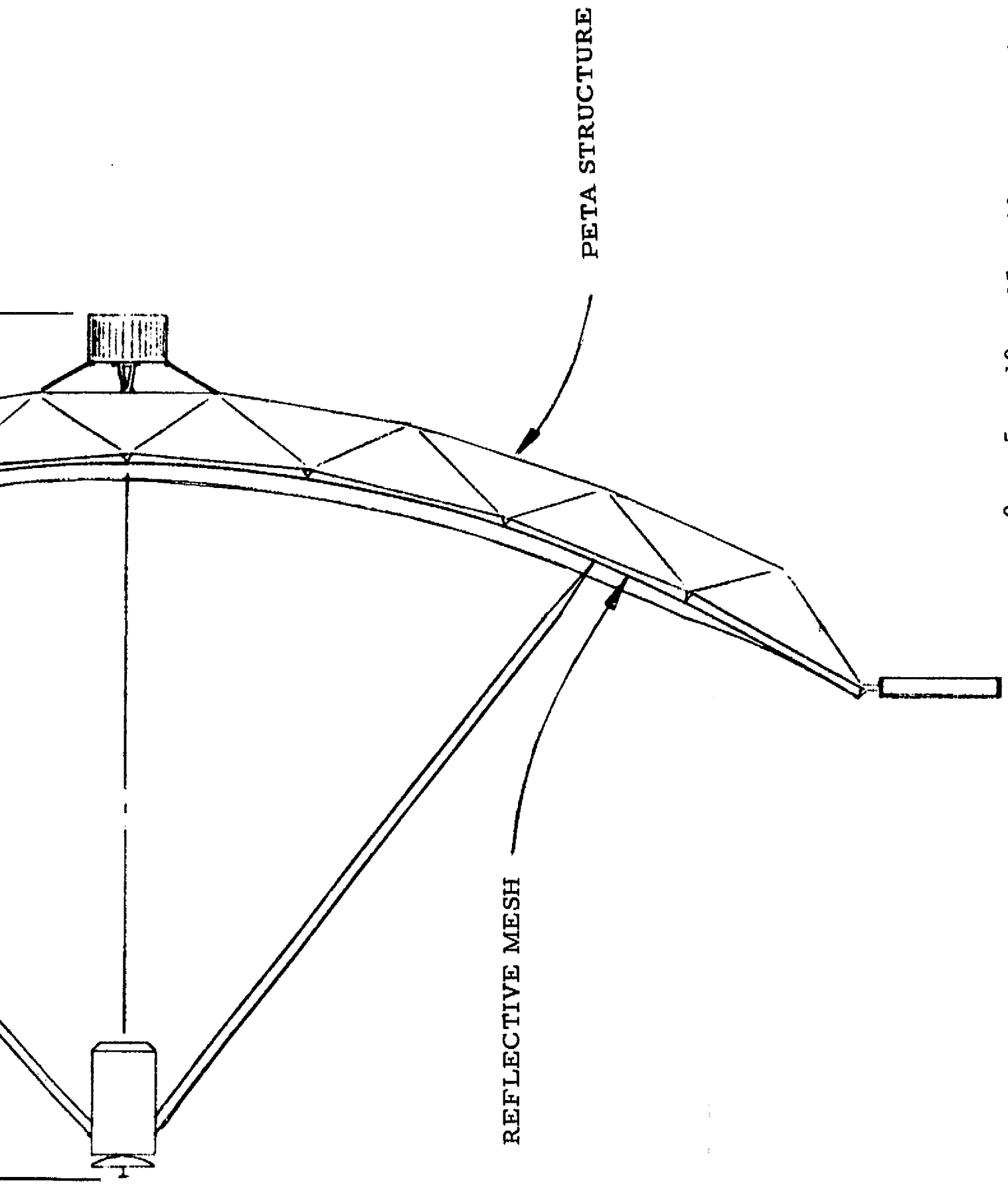
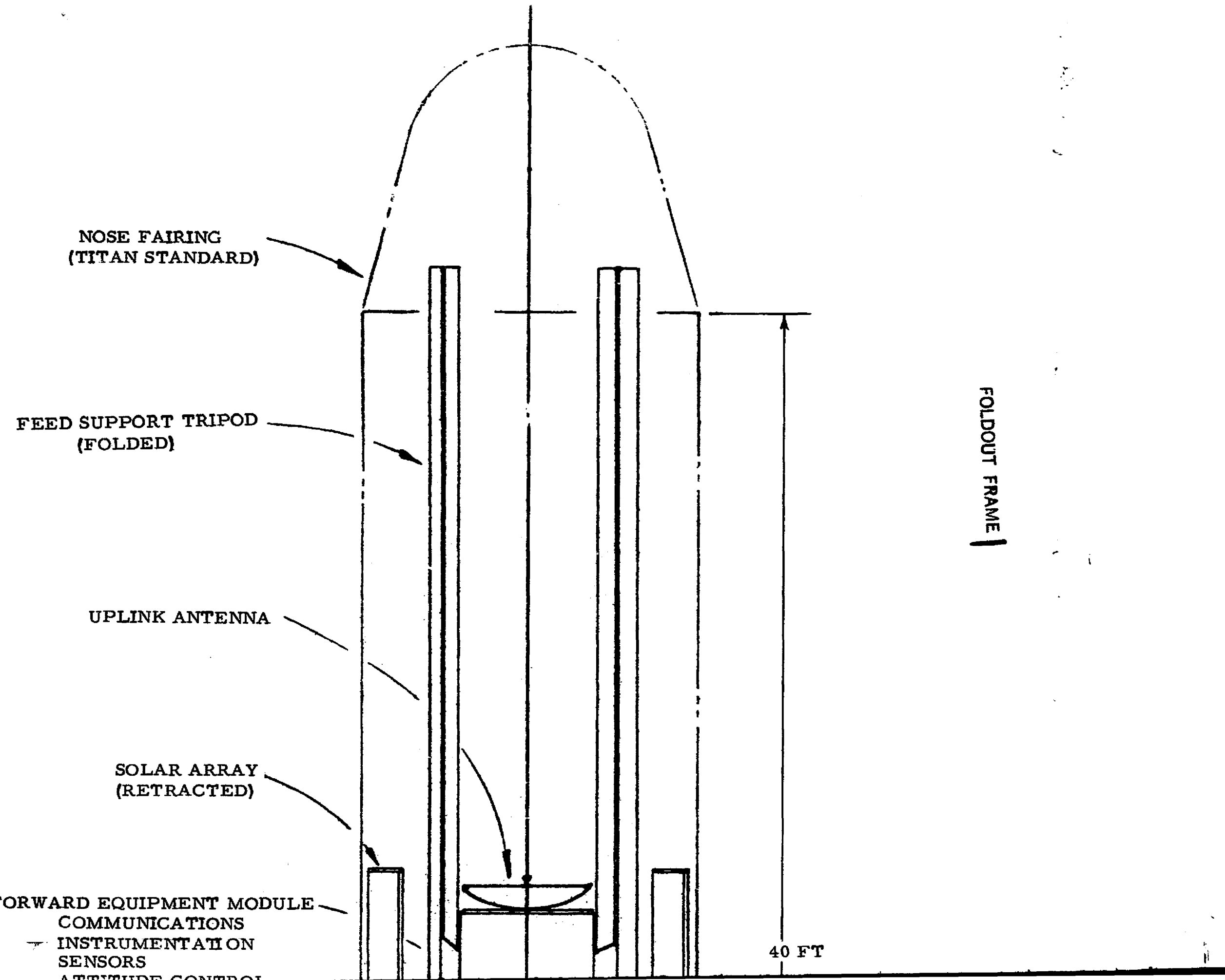


Figure 3-2(b). UHF Alaska ETV/ITV Satellite Configuration (b) Side View


NOSE FAIRING
(TITAN STANDARD)
FEED SUPPORT TRIPOD
(FOLDED)
UPLINK ANTENNA
SOLAR ARRAY
(RETRACTED)
FORWARD EQUIPMENT MODULE
COMMUNICATIONS
INSTRUMENTATION
SENSORS
ATTITUDE CONTROL
FOLDOUT FRAME
40 FT

Figure

(RETRACTED)

FORWARD EQUIPMENT MODULE
COMMUNICATIONS
INSTRUMENTATION
SENSORS
ATTITUDE CONTROL
ANTENNA FEED

PETA STRUCTURE
(FOLDED)

AFT EQUIPMENT MODULE
BATTERIES
POWER CONDITIONING

LAUNCH ADAPTER

40 FT

0 50 100
SCALE: INCHES

FOLDOUT FRAME 2

Figure 3-2(c). UHF Alaska ETV/ITV Satellite Configuration

(c) Launch Configuration

Table 3-3. Spacecraft Subsystem Tabulation

	SUBSYSTEM COST (Millions) Aquisition	R&D	TOTAL	WEIGHT (lbs)	VOLUME (cu ft)		
Power Subsystem							
Power Source	1.50	1.64	3.13	457	76.3	Array	3.1
Batteries	0.01	.11	.12	668	4.5	Ni-Cd	6.7 KWH
Conditioning	1.02	2.05	3.07	478	15.2		
Antenna (Downlink)	.98	3.50	4.48	373	334.0	Truss	19.6 x 95 Ft.
Antenna (Uplink)	.00	.05	.05	26	30.6	Rigid	
Transmitter	2.39	4.50	6.89	638	16.8	CFA	320 Watts
Multiplexer	.92	2.55	3.47	32	.1	COAX	
Receiver	.29	.70	.98	70	1.3		2db NF
Sturucture	.09	.53	.62	44	21.0	Conv.	
Thermal Control	.04	.49	.53	20	3.9	Hybrid	1.8 KW
Stationkeeping	.57	7.54	8.11	122	.3	ION	
Attitude Control	4.23	27.41	31.64	100	1.4	ION $\pm$ 0.1°	
Telemetry & Command	1.05	1.58	2.63	70	2.0		
Test Equipment	-	.75	.75	-	-		
Total/Satellite	13.10	53.38	66.48	3099	507.4		

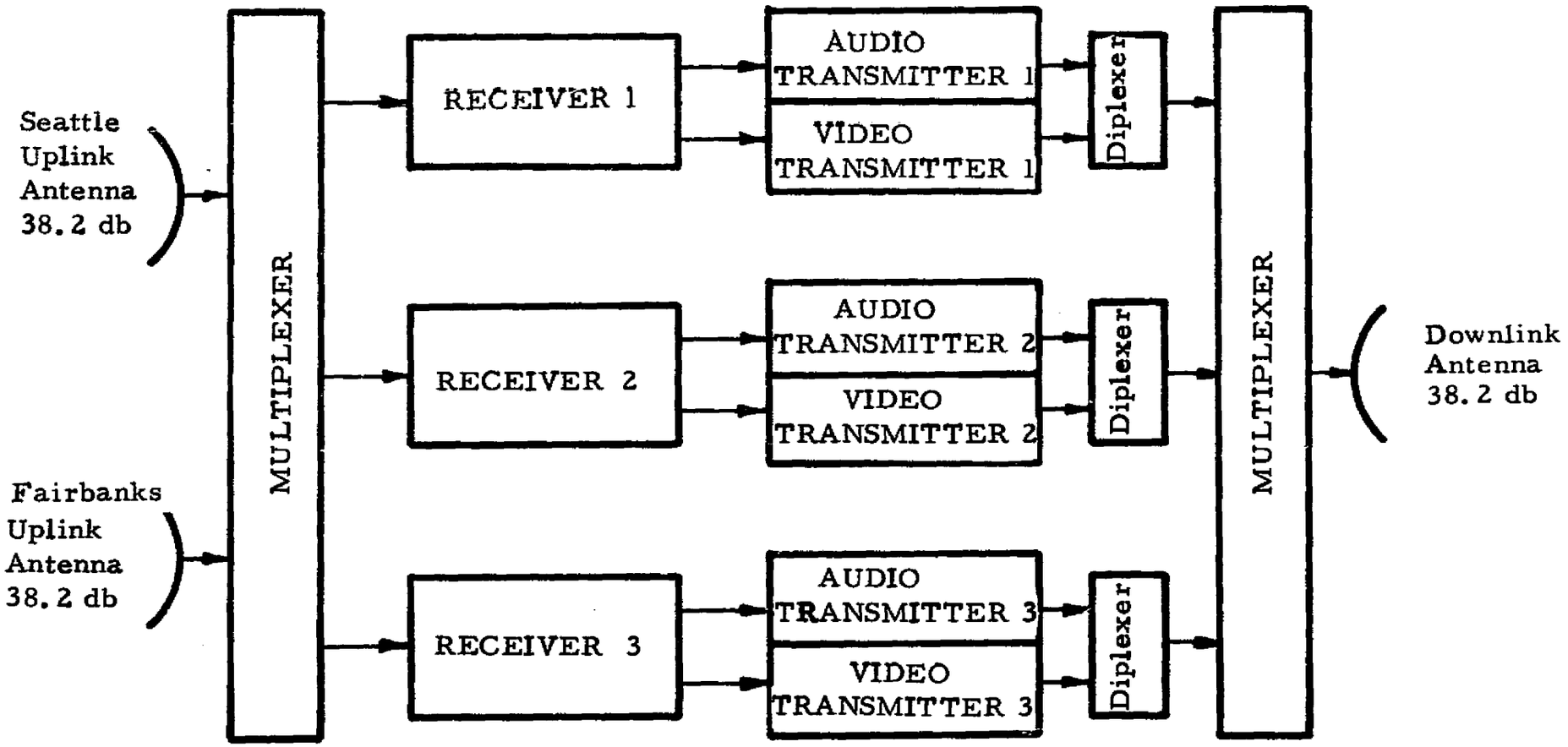


Figure 3-3. Communications Subsystem Block Diagram

power and test equipment. Specifically excluded in the analysis was the cost of program generation and studios. System characteristics are listed in Table 3-4.

3.2.3 GROUND RECEIVING SYSTEM DESCRIPTION - It was assumed in the analysis that the consumer had a standard UHF-VHF television set and the redistribution will require a cable drop into each home. The head-end equipment will consist of a 18.5 foot parabolic reflector and one uncooled parametric amplifier (1.2 dB Noise Figure) and modulation converter per channel in addition to the standard frequency converters and distribution amplifiers. The signal quality at the consumer set will be on the order of TASO Grade 1.

The community receiving systems require only limited redistribution and will require a 7.5 ft. antenna for a TASO Grade 1 signal. One preamplifier/modulation converter per channel will allow independent reception of all three channels.

Table 3-4. Ground Uplink Subsystem Tabulation

	COST (MILLIONS)				
	ACQUISITION	R&D	OPS/YR	TOTAL	
Facilities	.06	.01	.00	.08	
Prog., Rec., & Contr. Equip.	.43	.00*	.22	2.62	3 channels
Transmitter	.41	.00*	.05	.91	600 watts
Antenna	.11	.00*	.01	.18	
Standby Power	.04	.00*	.00	.06	
Test Equipment	.20	.00*	-	.20	
Sys. Des. Integ. & Mgmt.	-	.59	-	.59	
Sys. Oper. Mgmt.	-	-	.16	1.56	
Total/Facility	1.25	.59	.44	6.20	
Telemetry & Command	.29	.20	.33	3.79	
TOTAL FOR SYSTEM	2.79	.786	1.20	15.60	

* Available Hardware

3.2.4 LINK CALCULATIONS

3.2.4.1 Uplink from Fairbanks

Transmitter Power - (600 Watts)		27.8 dBw
Xmitter Antenna Gain - (36 feet)		56.0 dB
Transmitter Circuit Losses		- 2.0 dB
		81.8 dBw
EIRP		
Total Propogation Losses	-204.1 dB	
Free Space (24,800 statue miles)	-	202.8 dB
Atmospheric (Elev. = 17°)	-	1.1 dB
Pointing (Xmit and Recvr.)	-	0.2 dB
S/C Receiving Antenna Gain		38.2 dB
TOTAL AVAILABLE CARRIER POWER		- 84.1 dBw
Noise Temperatures:		
Receiver (2 dB Noise Figure)	170.0°K	
Antenna	290.0°K	
RF Bandwidth = 33.6 MHz		- 126.7 dBw
TOTAL SYSTEM NOISE POWER		- 126.7 dBw
Available Carrier to Noise Ratio at Input to Spacecraft Receiver		42.6 dB

20

3.2.4.2 Uplink from Seattle, Washington

Transmitter Power (600 watts)		27.8 dBw
Xmitter Antenna Gain (36 feet)		56.0 dB
Transmitter Circuit Losses		- 2.0 dB
EIRP		81.8 dBw
TOTAL PROPOGATION OSSES		-203.7 dB
Free Space (24,000 Statute Miles)	- 202.8 dB	
Atmospheric (Elev. = 29°)	- 0.7 dB	
Pointing (Xmit & Rcvr)	- 0.2 dB	
Spacecraft Receiving Antenna Gain (2' x 9.75')		38.2 dB
TOTAL AVAILABLE CARRIER POWER	- 83.7 dBw	
Noise Temperatures:		
Receiver (2 dB Noise Figure)	170° K	
Antenna	290° K	
TOTAL SYSTEM NOISE POWER	- 126.7 dBw	
Available Carrier-to-Noise Ratio at Input to Spacecraft Receiver		43.0 dB

3.2.4.3 Downlink to CATV System

Transmitter Output Power (320 Watts)		25.1 dBw
S/C Antenna Gain (18.6' X 95')		38.2 dB
Transmitter Circuit Losses		- 1.6 dB
EIRP		61.7 dBw
Total Propagation Losses:		- 190.3 dB
Free Space Loss (25,400 st. mi.)	- 183.9 dB	
Atmospheric Loss (Elev. = 8°)	- 0.3 dB	
Pointing Loss (Xmit and Rcvr.)	- 2.1 dB	
Typical Rcvr. Location Loss	- 2.0 dB	
Polarization Loss (Circular-to-Linear)	- 3.0 dB	
Receiving Antenna Gain (18 ft)		30.8 dB
Receiver Transmission Line Loss (2 ft)		- 0.1 dB
AVAILABLE CARRIER POWER		- 97.9 dBw
SYSTEM NOISE POWER (seen at Rcvr. Input)		- 130.6 dBw
Antenna Temperature	71°K	
Xmission Line Temperature	7°K	
Receiver Temperature	90°K	
Temperature Contributed by Uplink	17°K	
Noise Bandwidth	33.6 MHz	
AVAILABLE CARRIER-TO-NOISE RATIO		32.7 dB
FM Imporevement Threshold		12.0 dB
Margin Above Threshold		20.7 dB
FM Improvement (Mod Index = 3)		20.3 dB
AVAILABLE SIGNAL-TO-NOISE RATIO		53.0 dB

3.2.4.4 Downlink to Community Receivers

Transmitter Output Power (320 Watts)			25.1 dBw
S/C Antenna Gain (19.6' X 95')			38.2 dB
Transmitter Circuit Losses		-	1.6 dB
EIRP			61.7 dBw
Total Propagation Losses:		-	190.3 dB
Free Space Loss (25,400 St. Mi.)	- 182.9		
Atmospheric Loss Elevation = 8°)	-1 0.3		
Pointing Loss (Xmit. &Rcvr.)	2.1		
Typical Rcvr. Location Loss	- 2.0		
Polarization Loss (Circular-to-Linear)	- 3.0		
Receiving Antenna Gain (7.5 ft)			23.3 dB
Receiver Transmission Line Loss (2 ft)		-	0.1 dB
AVAILABLE CARRIER POWER		-	105.4 dBw
SYSTEM NOISE POWER (seen at input to Rcvr)		-	119.6 dBw
Antenna Temperature	117°K		
Xmission Line Temperature	7°K		
Receiver Temperature	90°K		
Temperature Contributed by Uplink	21°K		
Noise Bandwidth	33.6 MHz		
AVAILABLE CARRIER-TO-NOISE RATIO			24.2 dB
FM Improvement Threshold			12.0 dB
Margin Above Threshold			12.2 dB
FM Improvement (Mod Index = 3)			20.3 dB
AVAILABLE SIGNAL-TO-NOISE RATIO			44.5 dB

3.2.5 SYSTEM SENSITIVITIES TO DESIGN PARAMETERS - By an iterative process, the system design paramters are successively perturbed in arriving at the selected system. The minimum cost solution is a balanced system considering the ground uplink, the spacecraft, the launch vehicle, and the ground receiving system. Sensitivities about this design can also be investigated by modifying the user requirements.

The number of ground receiving systems and the downlink frequency was varied in Figure 3-4 to determine the impact upon the system cost. The government cost includes the ground facilities, the satellite and the launch vehicle while the receiving system cost includes the total 10 year cost of the receiving equipment and maintenance. The curves in Figure 3-4 is for a 3 downlink channel system with a C.C.I.R. relay quality signal at the ground receiver. The government costs for both frequency bands reach a maximum cost on the order of $10M per year. As the receiver population increases, the percentage of the total system cost drives the satellite to higher transmitter powers and higher costs. Once the satellite reaches a configuration constraint, in this case a weight of 9000 pounds, no more power can be generated in the satellite. The options are then to select a larger satellite to allow more power generation or to increase the ground receiving system cost. In this case, the ground receiver noise figure was reduced and the receiving antenna gain was increased resulting in a change in slope of the receiving system cost. At low populations, less than 1000, the 0.8 gigahertz levels at about $10M per year. This is due to the almost constant costs of the uplink facilities and the launch vehicle. The 12 gigahertz curve will also reach a minimum cost at populations less than 100.

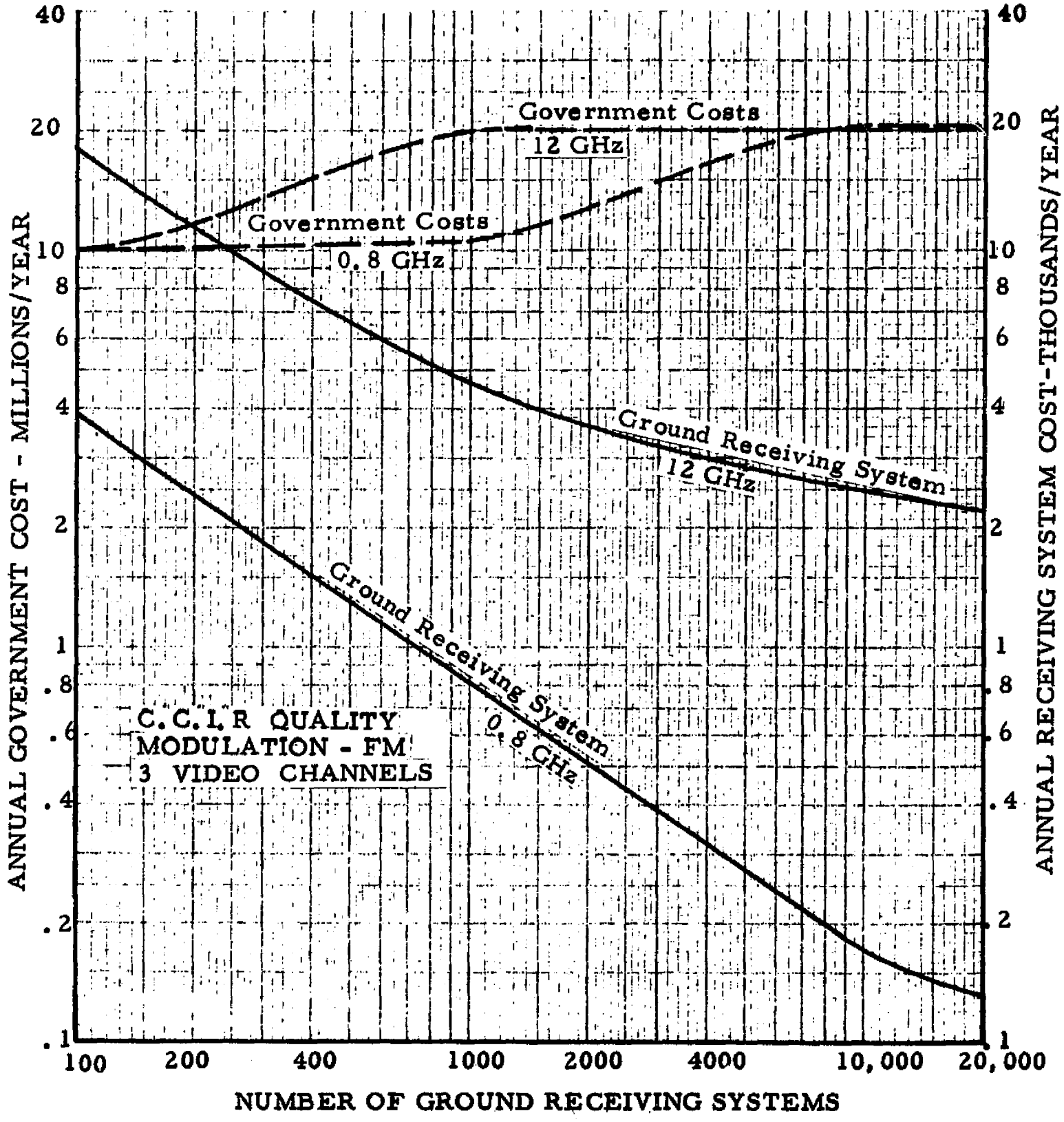


Figure 3-4. Cost Sensitivity to Number of Receiving Systems

Also of interest are the cost sensitivities tc the number of downlink channels (Figure 3-5). As expected both receiver cost as well as government cost increases with the number of channels, however the receiver cost has a steeper slope. The large increase from three to four channels in the 12 gigahertz case is a result of the satellite requiring a Saturn IB/Centaur rather than a Titan IIID/Centaur. It is interesting to note that the government cost is minimized 2.5 gigahertz due to the "microwave window", the range of frequencies where man-made noises and atmospheric attenuation are minimized. In this region the demands upon the transmitter power reduce the satellite cost. On the otherhand ground receiving systems in this band are more complex and low noise receivers are more expensive.

Although not considered directly in this analysis, it can be drawn from Figure 3-5 that telephone channels may be added to the system by increasing the number of downlink video channels. For 2200 telephone channels - the equivalent of one FM video channel - the additional government cost at UHF would be about $1M per year and the ground receiving system cost would increase by about $2K per year. These costs, however, do not include the additional uplink facilities or ground and spacecraft switching complexes. These areas will be covered in greater detail in future analyses.

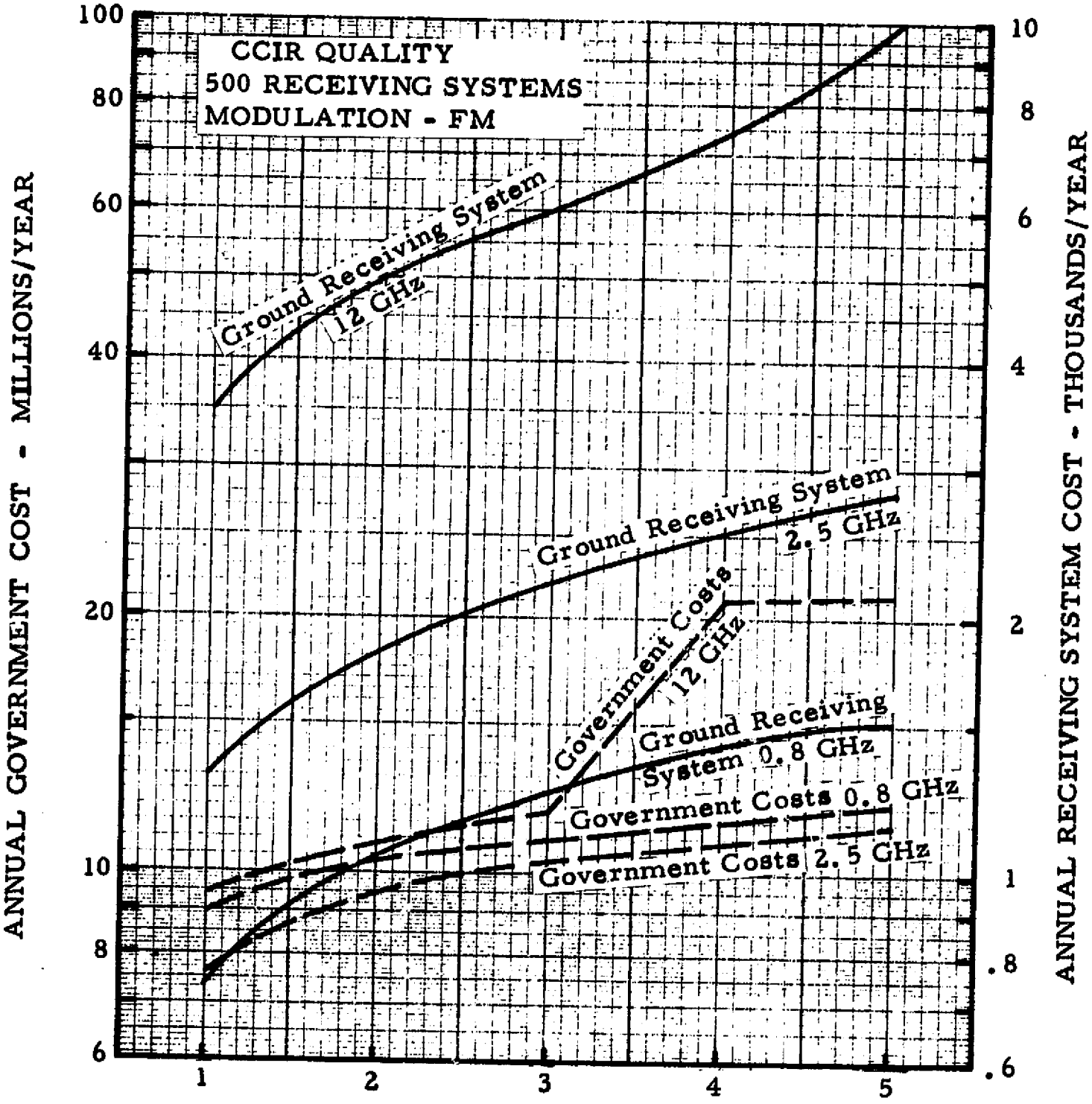


Figure 3-5. Cost Sensitivities to Number of Downlink Channels

3.3 SCHEDULE AND COST SUMMARY

3.3.1 SCHEDULE - The schedule for development of a dedicated broadcast satellite for Alaska is controlled primarily by the pacing items shown in Table 3-1. Table 3-5 also shows the development time for each item.

Table 3-5 Schedule Pacing Items

	PACING ITEM	DEVELOPMENT TIME YEARS
1.	Antenna Truss Assembly 1 ea. 95 X 19.6 - Ft. antenna	3
2.	Transmitters: 320 watts	2
3.	Solar Array: 4.6 KW Roll-up Panel	
	a. Solar Cells	2
	b. Panels and Mechanisms	2
	c. Assembly	1

From this table it can be seen that the longest lead time is the antenna assembly. This sets the R & D schedule at 3 years. Development of solar cells, panels and mechanisms will be conducted concurrently so that the solar array lead time is two years.

3.3.2 COST - The itemization of the system costs is given in Table 3-6. Specifically excluded is the standard TV set and the redistribution system. The government cost includes both ground uplink facilities, the satellite, and the launch vehicle. The receiving system cost includes the receiving antenna and three preamplifier/converters. In addition, the community receivers are costed to receive TASO Grade 1 while the CATV systems are costed for CCIR Relay quality.

Table 3-7 lists the three major systems comprising the government portion and Table 3-8 is a tabulation of each type of receiving system.

Table 3-6. System Cost Summary

3 Color Channels; TASO 1 at Viewer's Set 10 yr. System Life	Government Cost (Millions)	Receiving System Cost Community (Dollars)	Receiving System Cost CATV (Dollars)
Acquisition Cost	36.8	981	4410
Research & Development	59.6	-	-
Installation	-	920	2160
Opers. & Maintenance	12.0	1066	6210
10 YEAR TOTALS	108.4	2967	12780

Table 3-7. Government Cost Summary

	Acquisition (Millions)	R&D Cost (Millions)	Annual Operations (Millions)	Total (Millions)
Satellite	13.1	53.4	-	66.5
Launch Vehicle	21.0	5.4	-	26.4
Ground Uplinks Prog. (2)	2.5	0.6	.87	11.8
Telemetry & Command	0.3	0.2	.33	3.8
				108.4

Table 3-8. Ground Receiving System Cost Summary

	Acquisition Dollars	Installation (Dollars)	Total Initial (Dollars)	Annual Maintenance (Dollars)	Total (Dollars)
CATV					
Antenna	3600	1350	4950	540	
Receiver	810	810	1670	81	
	4410	2160	6570	621	12, 780
Community					
Antenna	171	110	280	25.6	
Receiver	810	810	1620	81.0	
	981	920	1900	106.6	2967