14-DSS-P-90

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

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Domestic Facilities Division
Satellite Radio Branch

Application of

HUGHES COMMUNICATIONS GALAXY, INC.

for

One C/Ku Band Hybrid
Domestic Communications Satellite
to Serve as a Ground Spare
for the Galaxy Satellite System

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January 10, 1990

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BY HAND DELIVERY

Ms. Donna R. Searcy
Secretary
Federal Communications Commission
1919 M Street, N.W., Room L-18
Washington, D.C. 20554

Re: Hughes Communications Galaxy, Inc.
Application for Authority to Construct a Ground
Spare Satellite for the Galaxy Satellite System

Dear Ms. Searcy:

On behalf of Hughes Communications Galaxy, Inc. ("HCG") enclosed is one original and eleven copies of an application to construct a hybrid domestic communications satellite to serve as a ground spare for the Galaxy satellite system.

A check for $1,800 is also enclosed. This amount is appropriate because the application does not seek launch authority or any orbital assignment.

Please direct any inquiries concerning this application to me.

Very truly yours,

James F. Rogers
James F. Rogers
of Latham & Watkins

Enclosure

cc (w/encl.): Cecily Holiday
Fern Jarmulnek

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* The references below are intended to follow the Commission's guidelines as set out in Appendix B. "Information Required for Domestic Satellite Space Station Applications," 93 F.C.C.2d 1260, 1265 (1983) (Appendix B).

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of the Application of HUGHES COMMUNICATIONS GALAXY, INC. For Authority to Construct One C/Ku Band Hybrid Domestic Communications Satellite to Serve as a Ground Spare for its Domestic Communications Satellite System	File No.

APPLICATION

Hughes Communications Galaxy, Inc. ("HCG") hereby applies for authority to construct a hybrid domestic communications satellite to serve as a ground spare for HCG's domestic communications satellite system. The proposed hybrid satellite will be able to operate in both the C and Ku bands. This ground spare will be a state-of-the-art satellite that will employ full frequency re-use in both frequency bands, while maintaining levels of power that are now standard on single-band satellites.

As explained below, the construction of a ground spare will better enable HCG to meet the needs of its customers that require a fully constructed satellite immediately available for launch to provide back-up protection in case of a launch failure of a given satellite. The construction of a hybrid ground spare will provide HCG the flexibility to use that satellite to back up any of HCG's currently operating or authorized C band satellites or any of its currently authorized Ku band satellites, as well as the hybrid Galaxy IV satellite for which HCG has recently requested authority, and any other single-band or hybrid C and Ku band satellite for which it may receive authorization in the future.

ITEM C. System Description

The ground spare will be an important element of HCG's Galaxy system of domestic communications satellites. HCG holds authorizations for six currently operating C band satellites: Galaxy I, Galaxy II, Galaxy III, Westar III, Westar IV and Westar V. HCG also holds authorizations to construct, launch, and operate replacements for each of these six satellites[1/] and has been authorized to construct two Ku band satellites (assigned to 99° W.L. and 131° W.L.)[2/] and one expansion C band satellite (assigned to the 64° W.L. location). In addition, HCG has recently requested authority to modify its authorizations for Galaxy A and Galaxy IV (formerly Westar IV R) to allow the construction of one hybrid satellite for the 99° W.L. location, instead of two

---

1/ These replacements are known as Galaxy I R, Galaxy II R, Galaxy III R, Galaxy IV (formerly Westar IV R), Galaxy V (formerly Westar V R), and Galaxy VI (formerly Westar VI-S).

2/ These satellites are currently known as Galaxy A and Galaxy B, respectively.

single-band satellites.[3/] HCG, however, is not currently authorized to construct a ground spare satellite.

Construction of a ground spare will allow HCG to replace (subject to Commission consent) any of its satellites that experience a launch failure or on-orbit failure far more promptly than would be possible without a fully constructed ground spare. Without a ground spare available for launch, restoral is possible only from otherwise available in-orbit capacity. To wait the two to four years it might take to construct a new satellite after a launch failure would cause intolerable disruption to the business plans of HCG, its customers, and their users.

Prompt replacement is particularly important given the current launch schedule for the satellites mentioned above. All of those nine satellites are scheduled for launch within the next four and one-half years. The construction of a ground spare will reduce the risk associated with those launches and will help ensure that service is provided to satellite users as soon as possible in the unlikely event of a launch failure.

3/ File No. 1-DSS-MP/ML-89, 2-DSS-MP/ML-89, 3-DSS-ML-89. This hybrid satellite will be known as Galaxy IV.

Also currently pending before the Commission is an application to transfer control of Satellite Transponder Leasing Corporation ("STLC") to HCG. File No. 1838-DSS-TC-89, 1839-DSS-TC-89, 1840-DSS-TC-89. STLC is the licensee of the Ku band satellites SBS-4, SBS-5, and SBS-6.

D. General Technical Information

1. Satellite Operational Characteristics

a. Frequency Plan

The ground spare will be constructed to operate in the C and Ku bands. The radio frequency and polarization plans are shown in Figures 1a and 1b; center frequency and polarization assignments are listed in Tables 1a and 1b.

The C band communications payload consists of 24 active transponder channels, each with a bandwidth of 36 MHz. The Ku band communications payload contains 24 active transponder channels, consisting of eight wideband (54 MHz bandwidth) channels and 16 narrowband (27 MHz bandwidth) channels.

Certain channels within the communications payload are equipped with "cross-strap" switches. These ground-controlled switches allow specific C band uplink channels to be retransmitted through Ku band downlink channels and, conversely, allow specific Ku band uplink channels to be retransmitted through C band downlink channels. The channels equipped with cross-strapping capabilities are listed in Table 2.

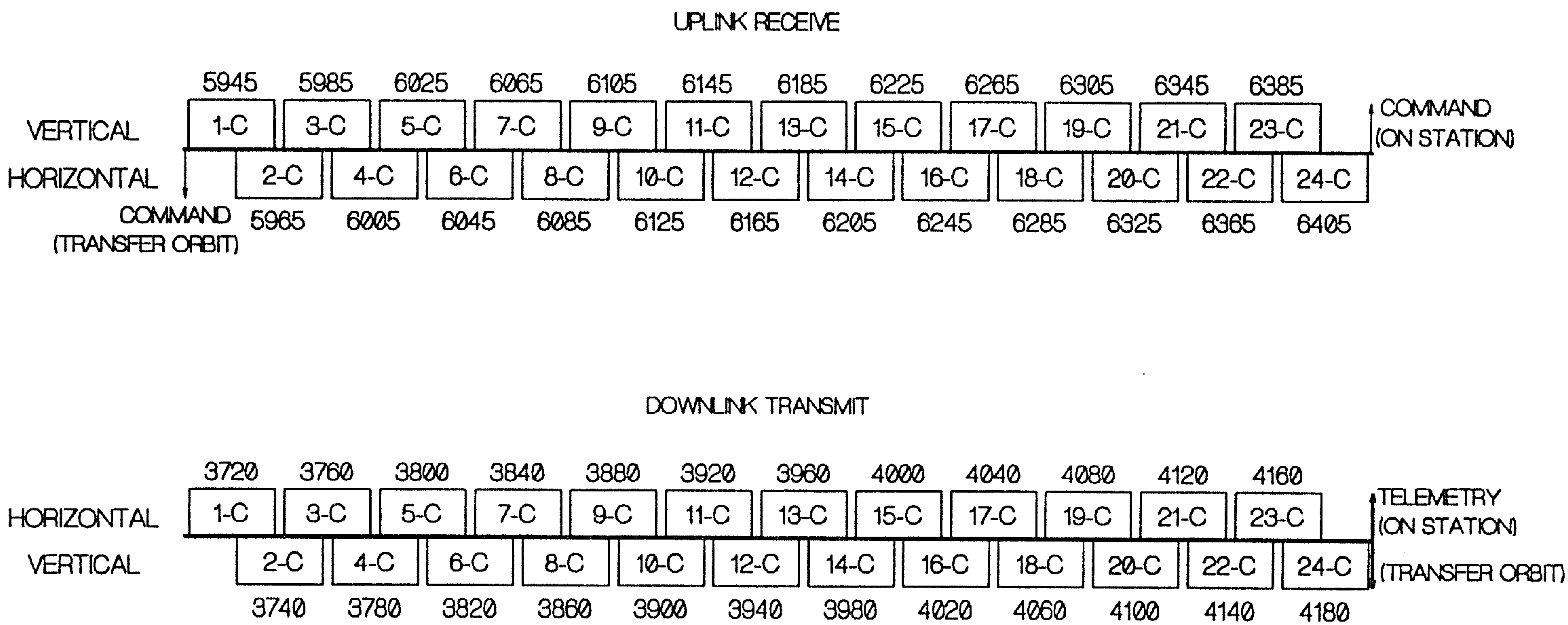

FIGURE 1a. C-Band FREQUENCY AND POLARIZATION PLAN

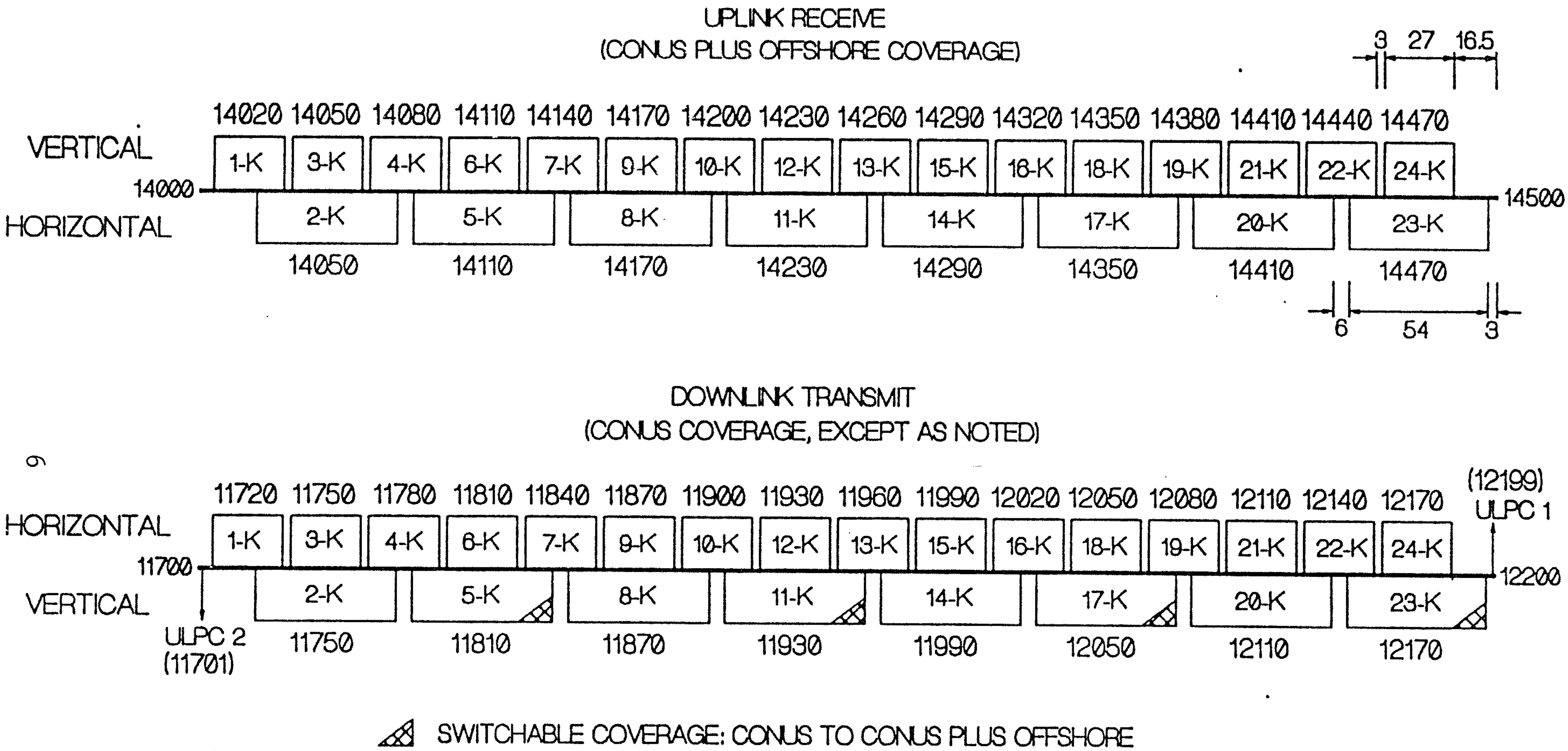

FIGURE 1b. Ku-BAND FREQUENCY AND POLARIZATION PLAN

TABLE 1a

C BAND FREQUENCY AND POLARIZATION ASSIGNMENTS

Channel	Uplink Polarization	Uplink Center Frequency (MHz)	Downlink Polarization	Downlink Center Frequency (MHz)	Transponder Bandwidth (MHz)
1	V	5945	H	3720	36
2	H	5965	V	3740	36
3	V	5985	H	3760	36
4	H	6005	V	3780	36
5	V	6025	H	3800	36
6	H	6045	V	3820	36
7	V	6065	H	3840	36
8	H	6085	V	3860	36
9	V	6105	H	3880	36
10	H	6125	V	3900	36
11	V	6145	H	3920	36
12	H	6165	V	3940	36
13	V	6185	H	3960	36
14	H	6205	V	3980	36
15	V	6225	H	4000	36
16	H	6245	V	4020	36
17	V	6265	H	4040	36
18	H	6285	V	4060	36
19	V	6305	H	4080	36
20	H	6325	V	4100	36
21	V	6345	H	4120	36
22	H	6365	V	4140	36
23	V	6385	H	4160	36
24	H	6405	V	4180	36

V = Vertical polarization
H = Horizontal polarization

TABLE 1b

KU BAND FREQUENCY AND POLARIZATION ASSIGNMENTS

Channel	Uplink Polarization	Uplink Center Frequency (MHz)	Downlink Polarization	Downlink Center Frequency (MHz)	Transponder Bandwidth (MHz)
1	V	14020	H	11720	27
2	H	14050	V	11750	54
3	V	14050	H	11750	27
4	V	14080	H	11780	27
5	H	14110	V	11810	54
6	V	14110	H	11810	27
7	V	14140	H	11840	27
8	H	14170	V	11870	54
9	V	14170	H	11870	27
10	V	14200	H	11900	27
11	H	14230	V	11930	54
12	V	14230	H	11930	27
13	V	14260	H	11960	27
14	H	14290	V	11990	54
15	V	14290	H	11990	27
16	V	14320	H	12020	27
17	H	14350	V	12050	54
18	V	14350	H	12050	27
19	V	14380	H	12080	27
20	H	14410	V	12110	54
21	V	14410	H	12110	27
22	V	14440	H	12140	27
23	H	14470	V	12170	54
24	V	14470	H	12170	27

V = Vertical polarization
H = Horizontal polarization

TABLE 2

FREQUENCY CROSS-STRAP CHANNELS

Uplink Channel	Downlink Channel Options*
18-C	18-C , 17-K
24-C	24-C , 23-K
17-K	17-K , 18-C
23-K	23-K , 24-C

* Selectable by ground command

In addition to the communications channel frequencies, two C band command uplink, two C band telemetry downlink, and two Ku band downlink beacon frequencies are shown in the plan. During transfer orbit, command signals will be received through a bicone antenna at the higher band-edge of the C band uplink frequencies. When the satellite is at final orbit position, the primary command uplink will be received at the lower band-edge of the C band frequencies through the large C band communications reflector, with the bicone link available as a backup. The command uplink will use government-approved command encryption. The two C band telemetry frequencies shown in the plan will allow simultaneous transmission of two separate or redundant telemetry data streams. The vertically and horizontally polarized Ku band downlink beacon signals will be continuously transmitted by the satellite and used by earth station operators as a calibrated reference to compensate for rain attenuation and to adjust antenna pointing.

The satellite communication subsystem will include appropriate filtering at the inputs and outputs of the satellite to minimize internal interchannel interference, noise effects outside the satellite frequency band, and out-of-band spurious transmissions.

b. <u>Emission Designators</u>

Commands to the satellite from the TT&C station will be angle-modulated with a large deviation on the uplink carrier. The satellite will be equipped with government-approved command encryption equipment in order to secure command transmissions. Telemetry data from the satellite will be angle-modulated on the downlink carrier. The emission designators for the communications, TT&C and downlink beacon signals are as follows:

Signal	Emission Designator
Command	300KF9DXX
Telemetry/Ranging	120KF9DXX
Downlink Beacon	25KONON
Single carrier TV	24M0F3FNN
Dual carrier TV	23M3F8FNF
High Speed Data	25M7G1WDN
Digital (T1) data	1M17G1WDF
Digital voice	24K3G1WDF
Digital (64 kbps) data	48K6G1WDF
FM Audio (Narrowband)	50K0F3EJF
FM Audio (Wideband)	150KF3EJF

c. Communications Coverage

The receive and transmit patterns of the C band antenna provide shaped beam coverage of the contiguous United States ("CONUS"), Alaska, Hawaii, Puerto Rico, and U.S. Virgin Islands. Representative C band receive gain-to-noise temperature ratio ("G/T") and Effective Isotropic Radiated Power ("EIRP") contours are shown in Figures 2a through 2d. Values for Saturation Flux Density ("SFD") for C band communications may be calculated by using the equations specified at the top of Figures 2a and 2b.

The receive pattern for Ku band communications provides coverage over CONUS, Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands. The Ku band transmit pattern provides CONUS coverage for all Ku band downlinks. In addition, the transmit beams of four specific Ku band channels can be switched into "Offshore" mode. In Offshore mode, CONUS coverage is expanded to include Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands. Representative Ku band G/T and EIRP contours are shown in Figures 3a through 3e. Satellite SFD may be calculated for Ku band communications by using the equations specified at the top of Figures 3a and 3b.

PEAK G/T = 3.42 DB/K, SFD = -(G/T + 86.5) (@ 4DB COMMANDABLE STEP ATTEN)

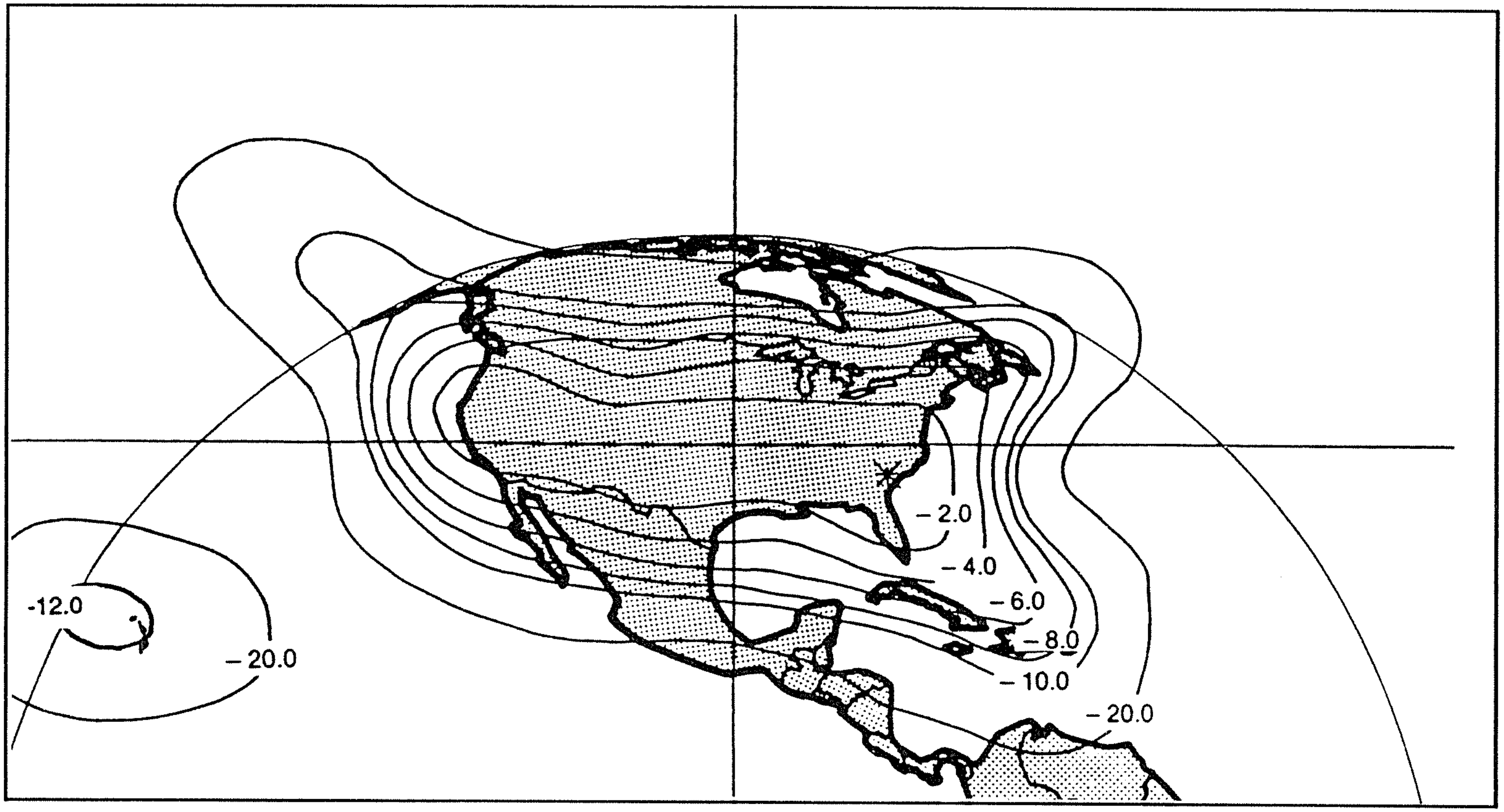

FIGURE 2a. C-BAND G/T COVERAGE AT 99° W.L. (HORIZONTAL RECEIVE)

PEAK G/T = 2.32 DB/K, SFD = -(G/T + 86.5) (@ 4DB COMMANDABLE STEP ATTEN)

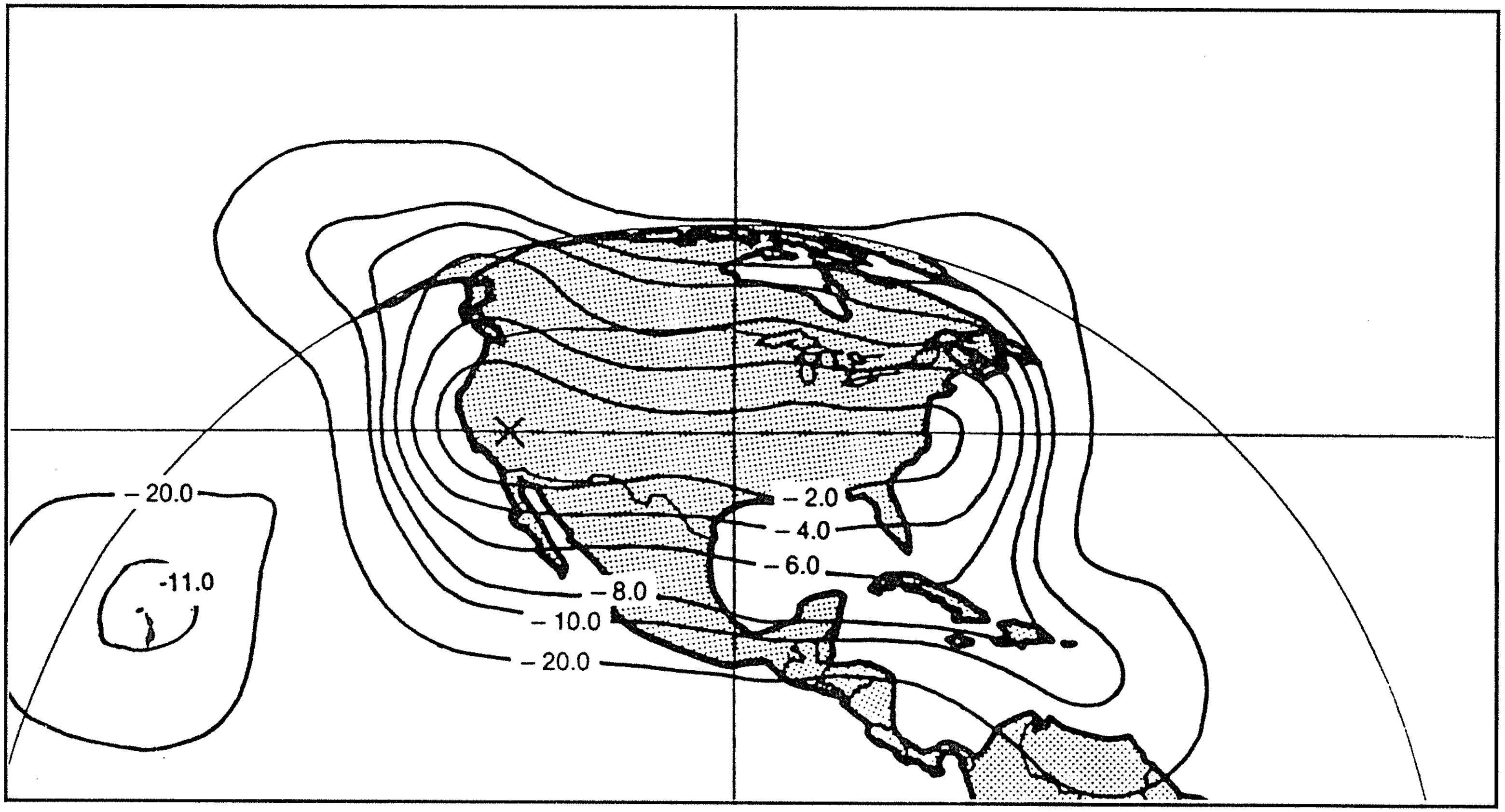

FIGURE 2b. C-BAND G/T COVERAGE AT 99° W.L. (VERTICAL RECEIVE)

HUGHES COMMUNICATIONS

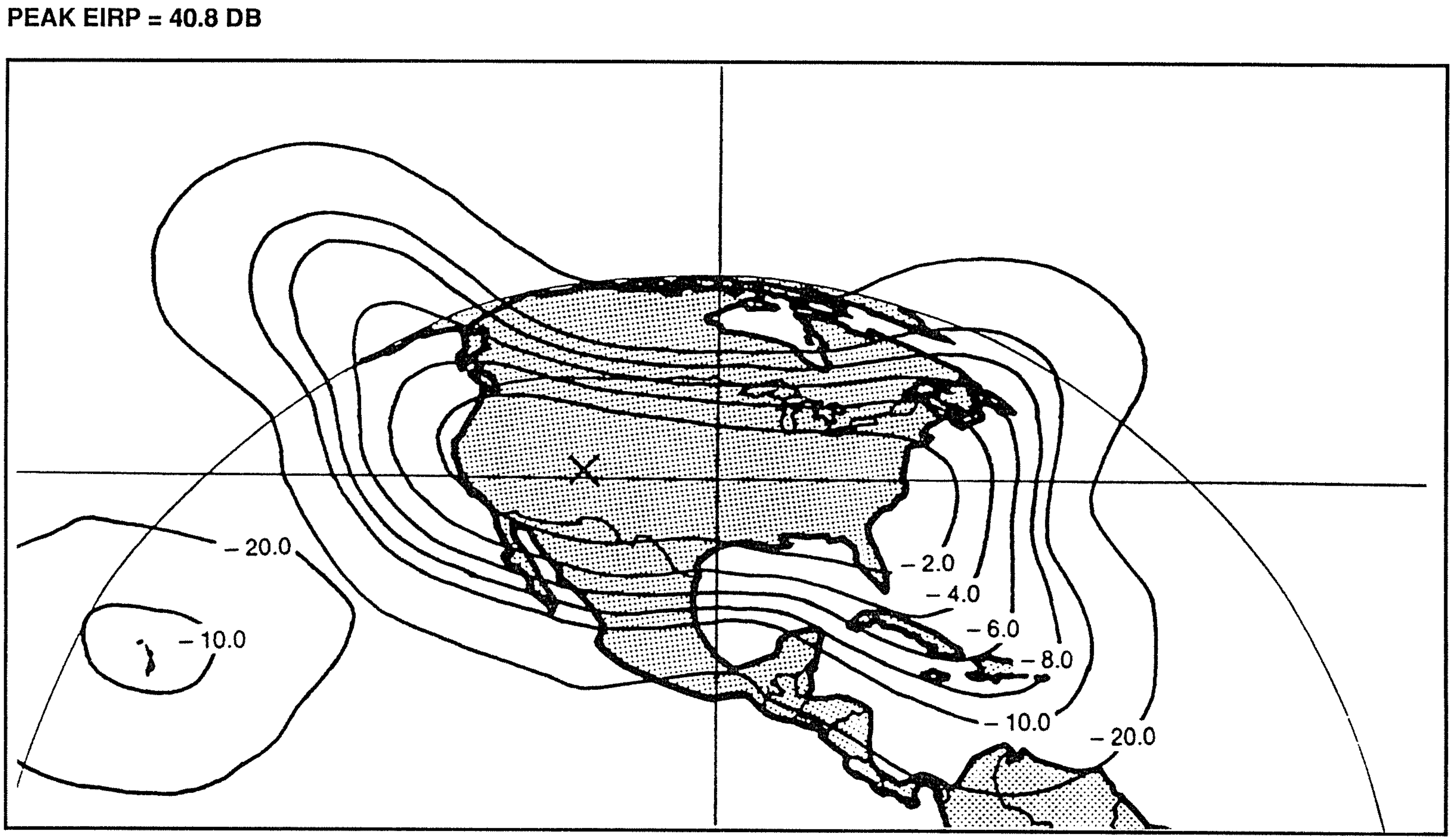

FIGURE 2c. C-BAND EIRP COVERAGE AT 99° W.L. (HORIZONTAL TRANSMIT)

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COMMUNICATIONS

PEAK EIRP = 40.61 DB

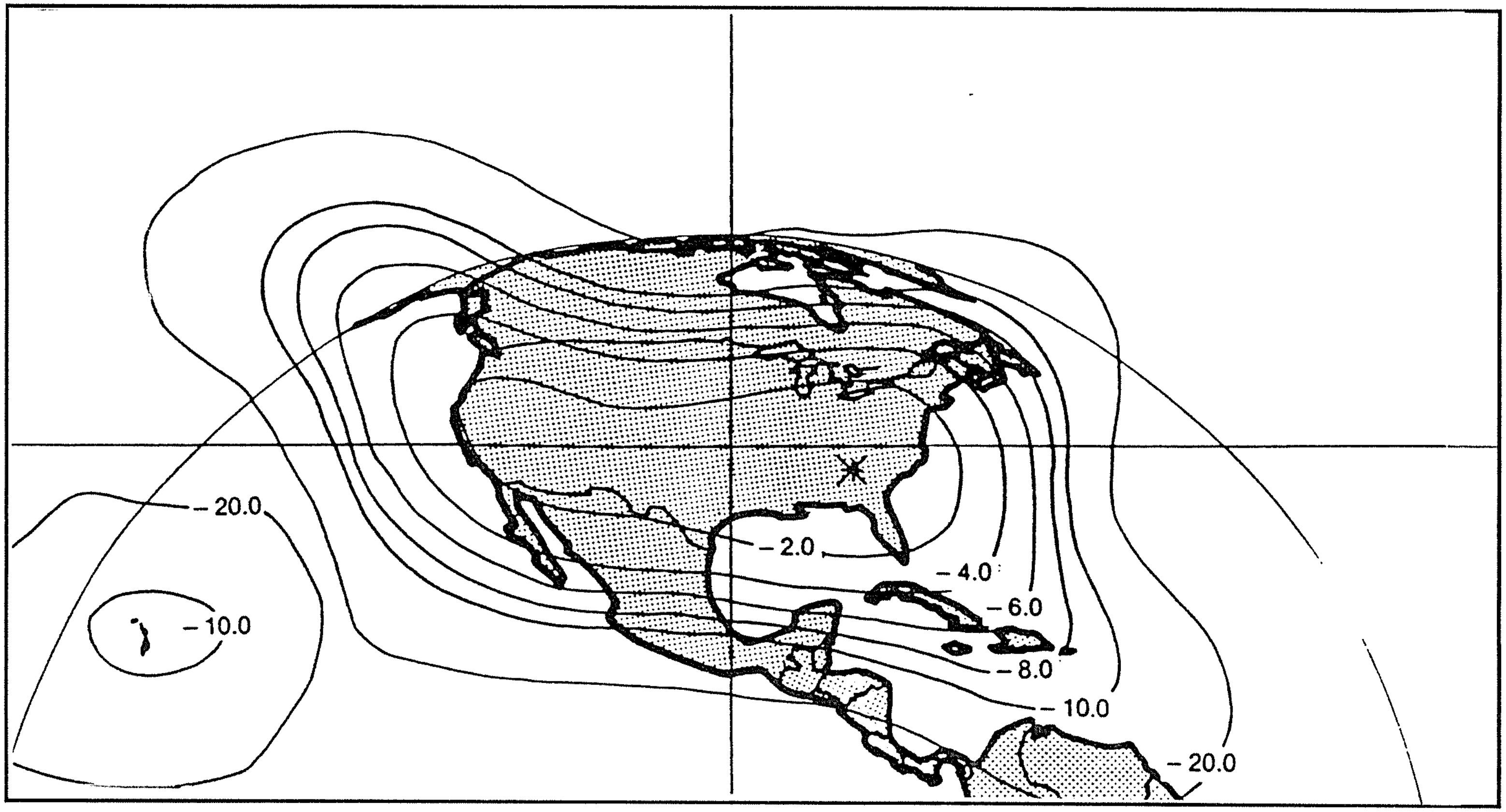

FIGURE 2d. C-BAND EIRP COVERAGE AT 99° W.L. (VERTICAL TRANSMIT)

PEAK G/T = 5.8 DB/K, SFD = -(G/T + 89.5) (@ 4DB COMMANDABLE STEP ATTEN)

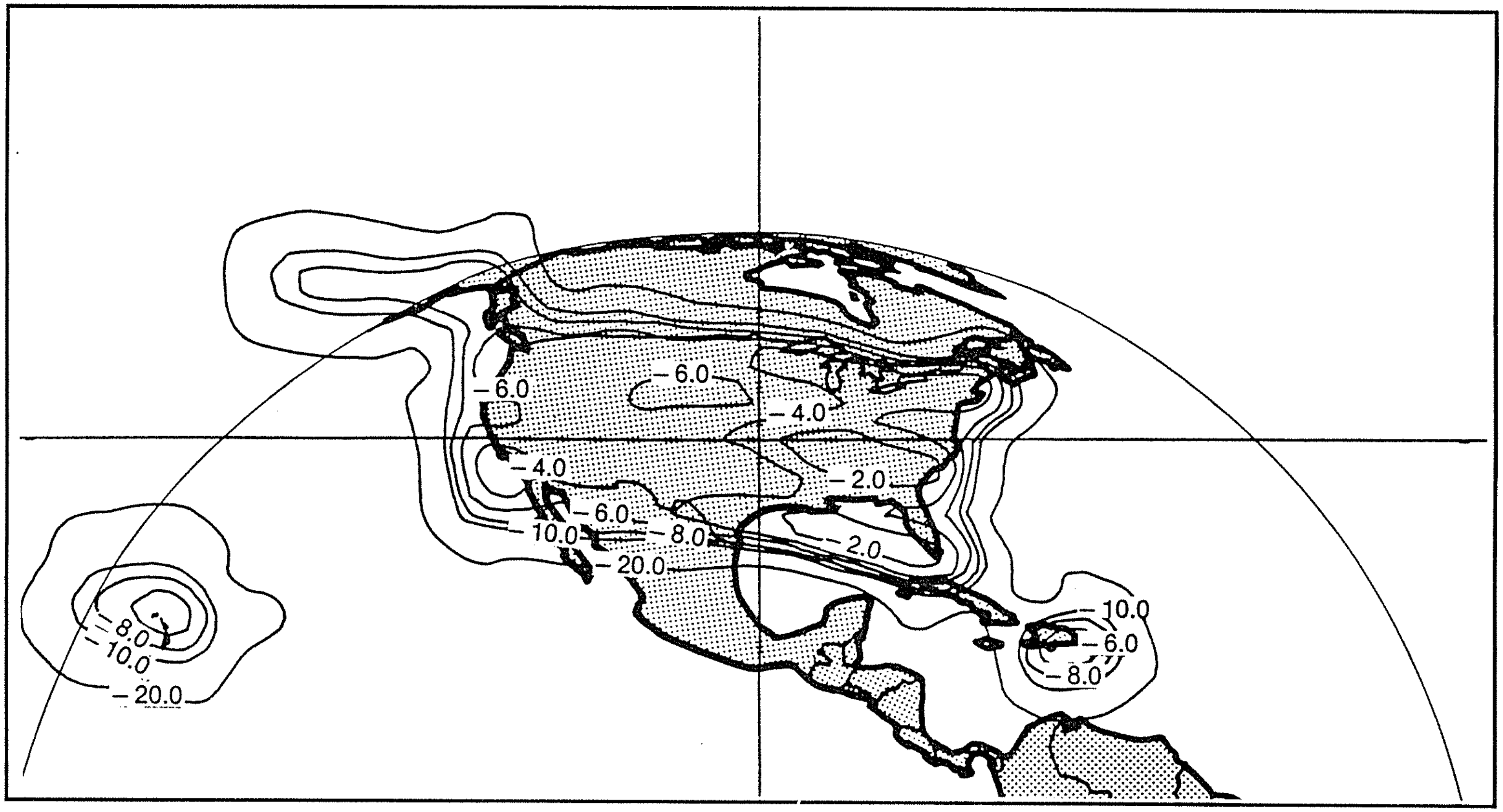

FIGURE 3a. Ku-BAND G/T COVERAGE AT 99° W.L. (HORIZONTAL RECEIVE)

PEAK G/T = 4.5 DB/K, SFD = -(G/T + 89.5) (@ 4DB COMMANDABLE STEP ATTEN)

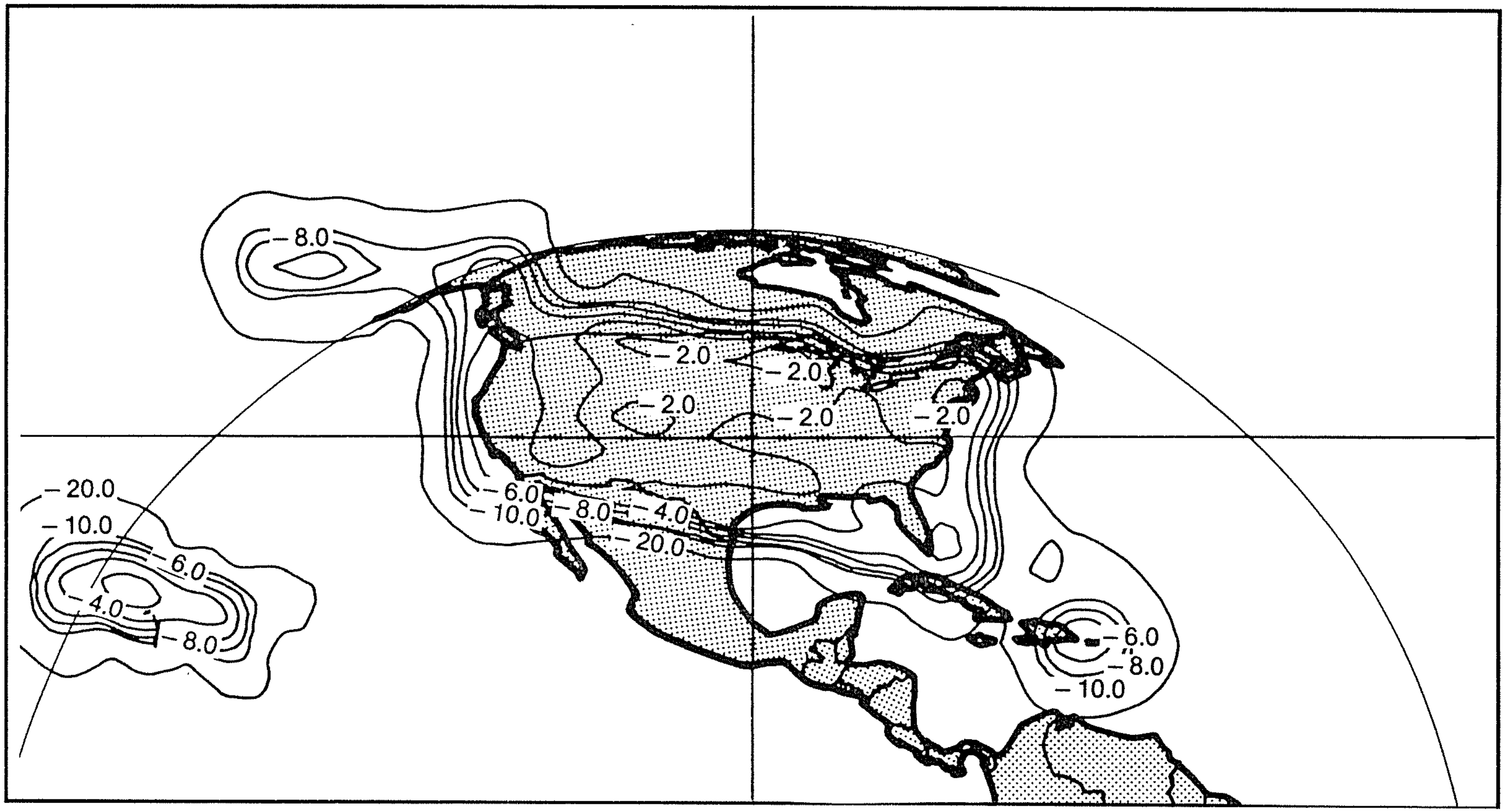

FIGURE 3b. Ku-BAND G/T COVERAGE AT 99° W.L. (VERTICAL RECEIVE)

PEAK EIRP = 48.7 DB

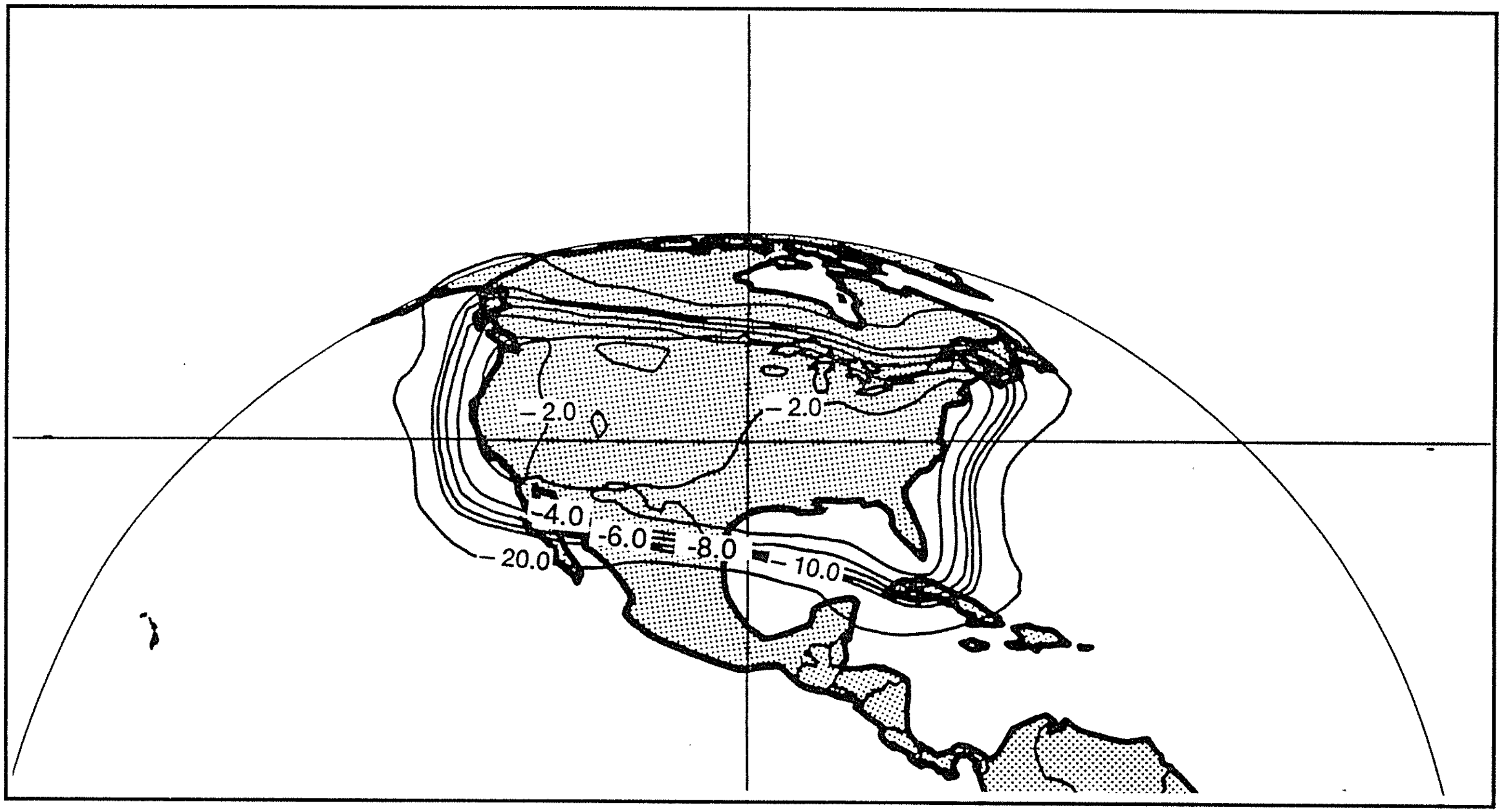

FIGURE 3c. Ku-BAND EIRP COVERAGE AT 99° W.L. (HORIZONTAL TRANSMIT)

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COMMUNICATIONS

PEAK EIRP = 48.3 DB

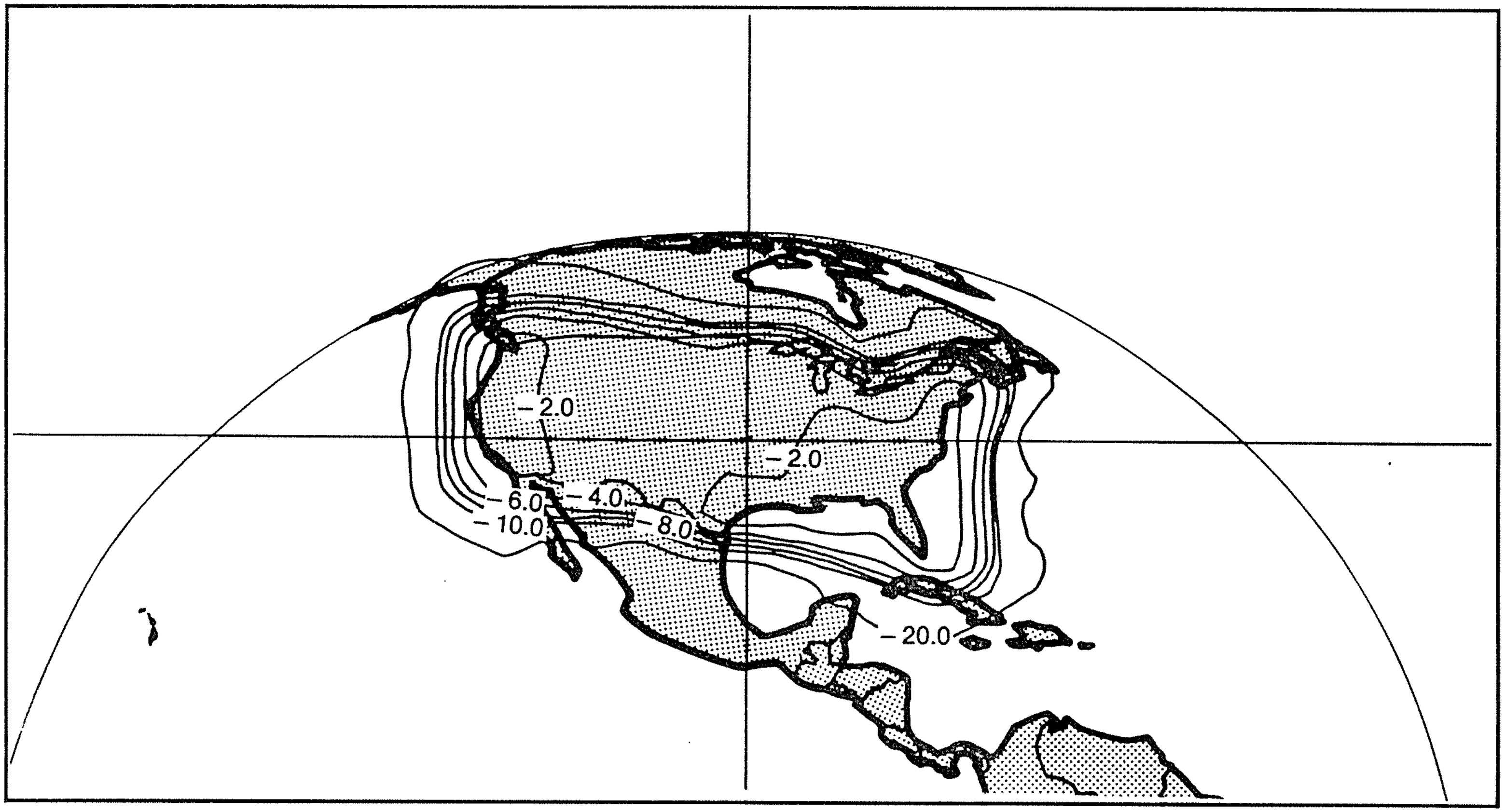

**FIGURE 3d. Ku-BAND EIRP COVERAGE AT 99° W.L.
(VERTICAL TRANSMIT, CONUS ONLY MODE)**

HUGHES
COMMUNICATIONS

PEAK EIRP = 48.3 DB

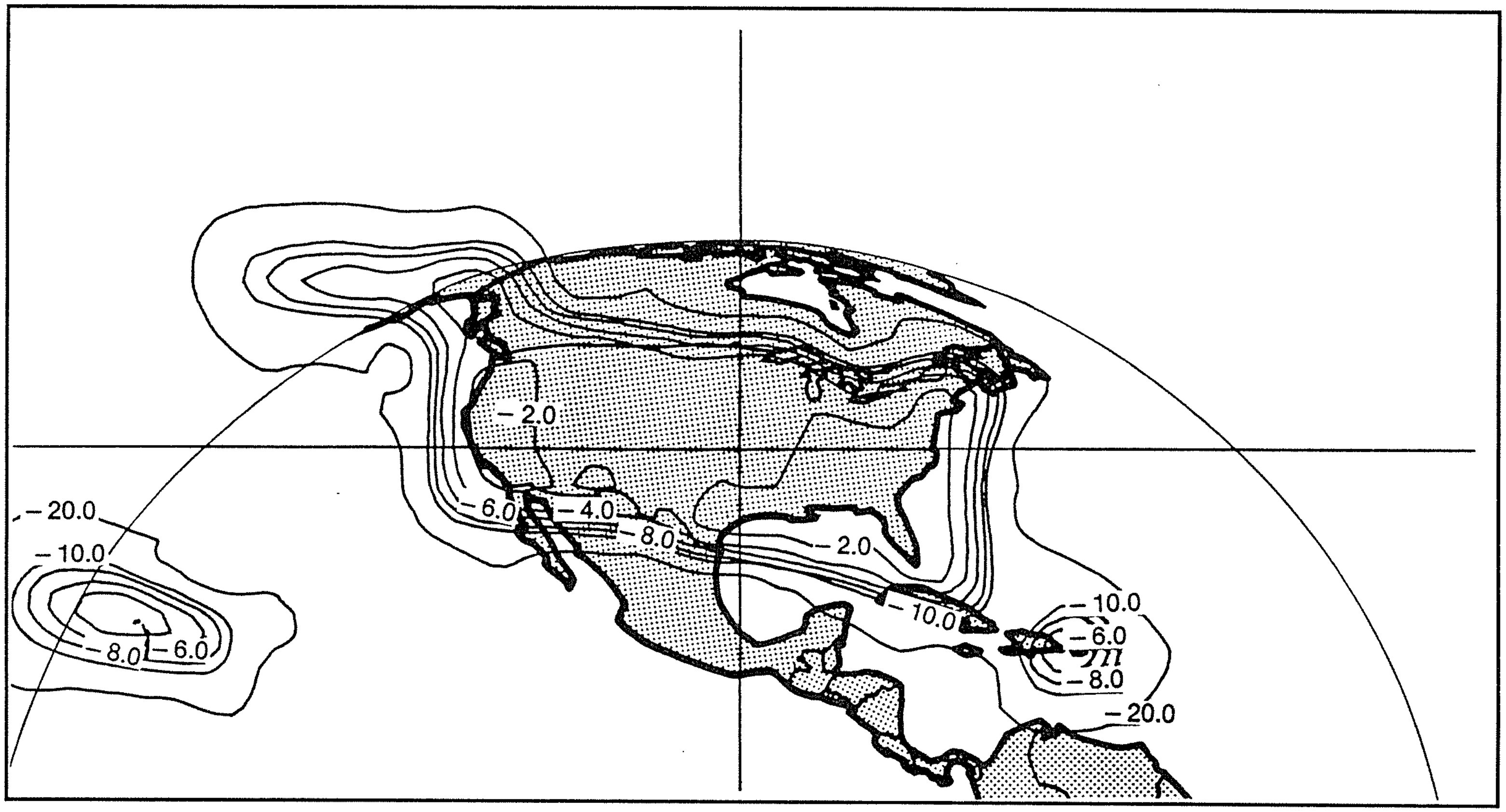

FIGURE 3e. Ku-BAND EIRP COVERAGE AT 99° W.L. (VERTICAL TRANSMIT, CONUS + OFFSHORE MODE)

2. Satellite Characteristics

The on-orbit configuration of the satellite is illustrated in Figure 4. The major spacecraft characteristics are shown below in Table 3. The estimated weight and power budgets, listed in Tables 4 and 5, are based on a mission life of 12 years and assume sufficient redundancy to allow for random failures.

Tables 6 and 7 show the estimated receive gain-to-noise temperature (G/T) and EIRP budgets, respectively.

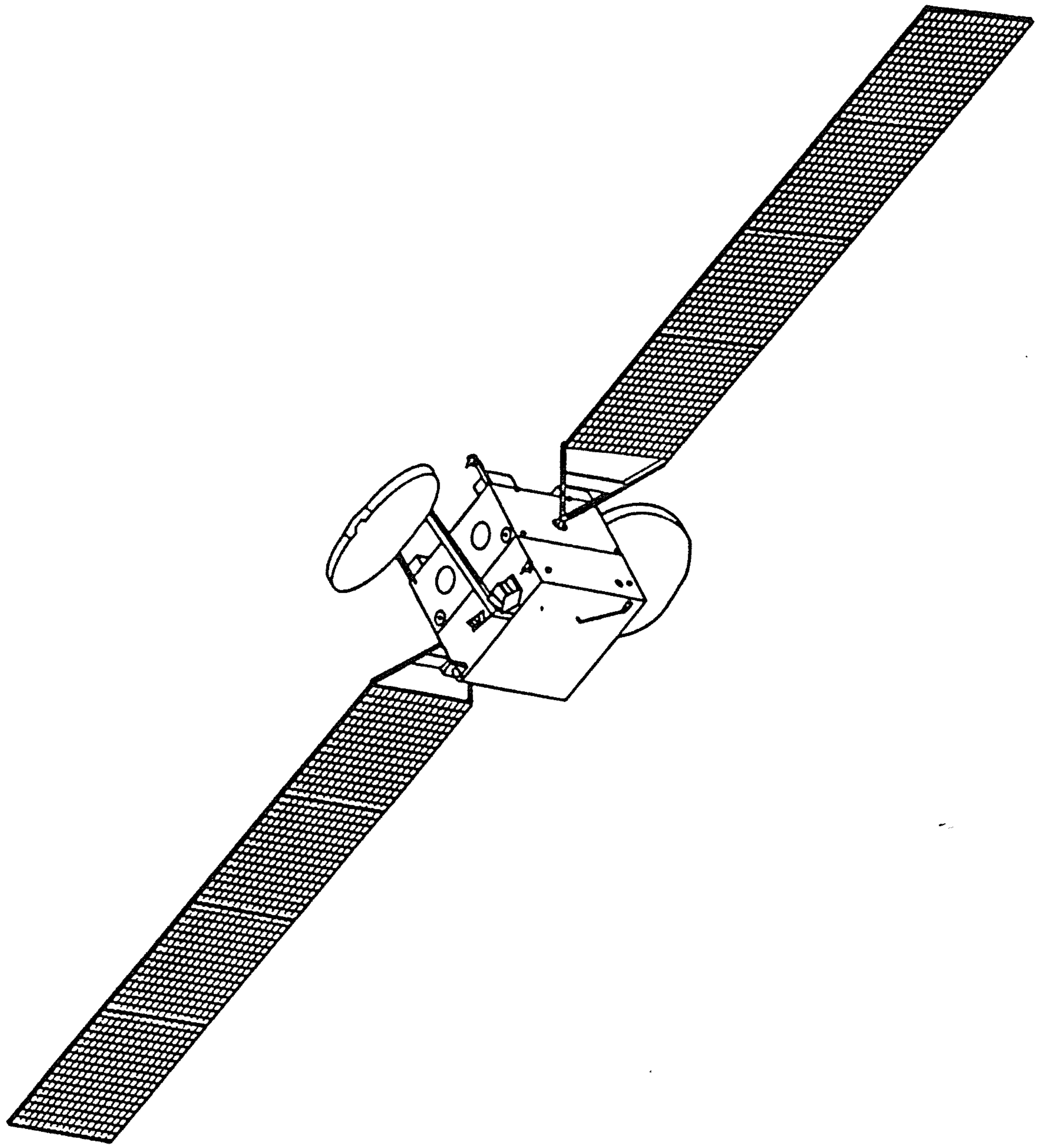

FIGURE 4. SATELLITE ON-ORBIT CONFIGURATION

TABLE 3

SPACECRAFT CHARACTERISTICS

General	
Spacecraft bus	Hughes, HS 601
Launch vehicle	Ariane, Titan, STS, Atlas
Stabilization	
Transfer orbit	Spin stabilized
On station	Body stabilized
Mission life	12 years
Design life	15 years
Eclipse capability	100 percent (48 channels)
Stationkeeping	
North-South (orbital inclination)	±0.05 degrees
East-West (longitudinal drift)	±0.05 degrees
Antenna pointing	
East-West North-South	±0.14 degrees azimuth ±0.14 degrees elevation
Beam rotation (antenna axis attitude)	±0.25 degrees

TABLE 3 (cont'd.)

Communications	C Band	Ku Band
Frequency		
Receive	5925-6425 MHz	14000-14500 MHz
Transmit	3700-4200 MHz	11700-12200 MHz
Polarization	Hor/Ver Linear	Hor/Ver Linear
Number of transponders	24	24
Transponder bandwidth	36 MHz	27 MHz (16 ch.) 54 MHz (8 ch.)
Receive G/T (CONUS)	-1.0 dB/K	1.0 dB/K
Transponder gain (@ 0dB attenuator step)	112 dB	123.0 dB
Receive Saturation Flux Density (CONUS)	-90 to -76 dBW/m^2 (2 dB increments)	-95.5 to -78 dBW/m^2 (2.5 dB increments)
Transmit EIRP (CONUS)	38 dBW	45 dBW
Transmitter RF power	16 Watts	50 Watts
Transmitter redundancy	30 for 24	30 for 24

Emission limitations (percentage of authorized bandwidth)	
50 to 100%	>25 dB attenuation in any 4 kHz
100 to 250%	>35 dB attenuation in any 4 kHz
Greater than 250%	>61 dB attenuation in any 4 kHz

Table 3 (cont'd.)

Tracking, Telemetry and Command		
Frequency		
Command, Ranging	5925 to 5930 MHz transfer orbit 6420 to 6425 MHz on station	
Telemetry and Ranging	2 signals within 4198 to 4200 MHz	
Polarization	Transfer Orbit	On Station
Command, Ranging	Horizontal, linear	Vertical, linear
Telemetry, Ranging	Vertical, linear	Horizontal, linear
Bandwidth		
Command, Ranging	300 kHz	
Telemetry/Ranging	120 kHz	
Telemetry EIRP		
Transfer Orbit	5.0 dBW	
On Station	4.5 dBW (CONUS)	
Command Threshold (flux density)		
Transfer Orbit	-91.0 dBW/m^2	
On Station	-105.0 dBW/m^2	

TABLE 4
WEIGHT BUDGET

Category	Weight, lbs.
Communications subsystem weight	560
Bus weight	1,980
Estimated spacecraft dry weight	2,540
Margin	90
Maximum allowable dry weight (Ariane IV, shared)	2,630
Fuel, expendables	2,875
Total launch weight	5,505

TABLE 5
POWER BUDGET

Category	Power, Watts
Communications subsystem power	3,437
Bus power	341
Total Power Requirement	3,778
End-of-Life array capability (12 years)	4,133
End-of-Life Margin	355

TABLE 6

SATELLITE UPLINK G/T BUDGET

Parameter	Value	
	C Band	Ku Band
Antenna gain (Edge of CONUS) (dB)	27.9	29.1
Losses between antenna and preamp (dB)	0.5	0.4
System noise temperature (dB-K)	28.4	27.7
G/T (dB/K)	-1.0	1.0

TABLE 7

SATELLITE DOWNLINK EIRP BUDGET

Parameter	Value	
	C Band	Ku Band
Amplifier output power (dBW)	12.0	17.0
Repeater output losses (dB)	1.0	1.5
Antenna Gain (Edge of CONUS) (dB)	27.0	29.5
EIRP	38.0	45.0

3. Satellite Description

The spacecraft bus is based upon the Hughes HS 601 series body stabilized bus. The satellite design is compatible for launch by the Ariane, Atlas and other expendable launch vehicles. The design also allows compatibility with the STS launch vehicle.

Deployment of antennas and solar cell arrays is performed in four separate steps. After launch vehicle separation and through transfer orbit operations, the bicone antenna is partially deployed in order to secure command, telemetry, and ranging functions. After the spacecraft has been injected into synchronous altitude, the bicone antenna is further deployed to its final on-orbit configuration and the solar cell array panels are extended. Finally the large communications antenna reflectors are deployed.

a. Power Subsystem

Satellite power will be provided by solar arrays of fused silica-covered silicon solar cells that convert solar energy to the required electrical power. The arrays are deployed after the satellite attains synchronous orbit.

Nickel-Hydrogen batteries provide sufficient electrical power during eclipse to operate the full communications and housekeeping loads throughout the mission life. Similar batteries are being used on Intelsat VI and other Hughes satellites. Nickel-Hydrogen battery cells have been under test since 1975. No failures have occurred at the design depth of discharge in these tests.

The electrical power subsystem has been designed so that no single failure in the subsystem will cause a spacecraft failure. Sufficient power will be available at the end of the satellite's life to support all 48 active transponder channels and the housekeeping loads.

b. Attitude Control Subsystem

The Attitude Control Subsystem (ACS) maintains the spacecraft attitude during the transfer orbit, initial acquisition period, and geostationary operations. The ACS employs sun and earth sensors to perform all attitude determination functions. The ACS will provide antenna pointing accuracy of ±0.14 degrees (North-South and East-West). Control of attitude and spacecraft orbit is accomplished by using momentum wheels and by pulsed or continuous firing of selected thrusters by the ACS during ground controlled maneuvers.

c. Propulsion Subsystem

The spacecraft will use a liquid bipropellent propulsion system. The liquid bipropellant system is based on proven technology from the Leasat and Intelsat VI programs. It provides high performance through the use of hypergolic propellant: nitrogen-tetroxide (N_2O_4) oxidizer and monomethyl-hydrazine (MMH) fuel.

d. Antenna Subsystem

The satellite antenna subsystem contains two parabolic reflectors each consisting of two polarization-selective gridded offset paraboloids sharing the same aperture. One of these reflectors is used for C band communications; the other reflector is used for Ku band communications. The four multihorn feed assemblies which feed the reflectors are frequency diplexed to allow each assembly to be used for transmit and receive functions. A minimum of 33 dB cross-polarization will be maintained over the satellite coverage area.

e. Communications Subsystem

The communications subsystem consists of two communications repeaters: a 24 channel C band repeater employing 16 watt solid state power amplifiers (SSPA's), and a 24 channel Ku band repeater employing 50 watt traveling wave tube amplifiers (TWTA's). Except for the limited frequency cross-strapping capabilities previously described, the C band and Ku band repeaters are essentially independent of each other. A functional block diagram of the C band and Ku band repeaters is presented in Figure 5.

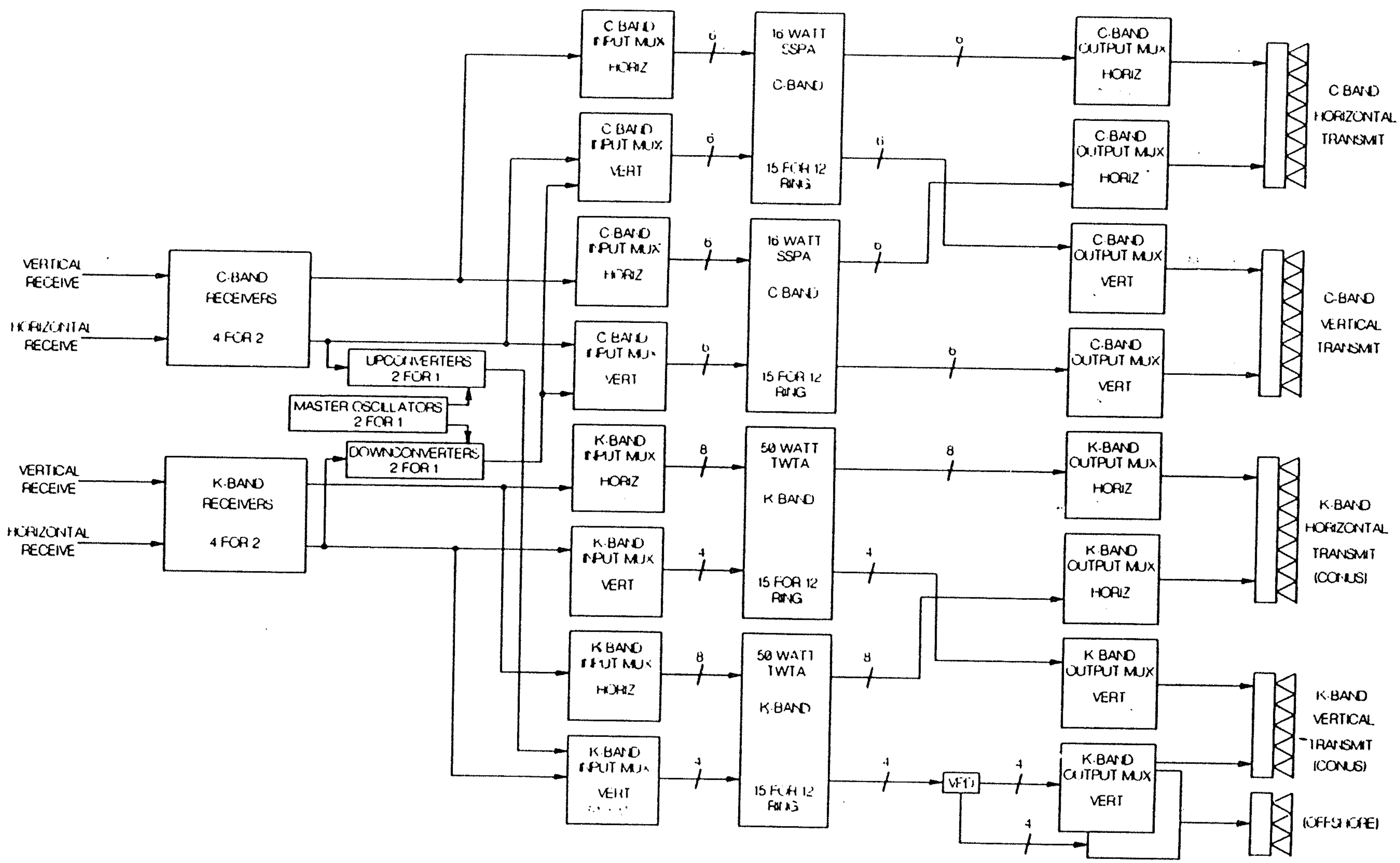

FIGURE 5. REPEATER BLOCK DIAGRAM

(i) Transponder Signal Path

The signal paths of the C band and Ku band repeaters are very similar. Horizontally and vertically polarized received signals are separately routed to a pair of wideband receivers. Each wideband receiver consists of a low noise amplifier followed by a downconverter which translates the input frequencies (6 GHz at C band, 14 GHz at Ku band) to the satellite transmit frequencies (4 GHz at C band, 12 GHz at Ku band). Following the downconverter is a medium-level amplifier which amplifies the translated signals to drive the final power amplifier in each transponder channel.

There are four receivers in each payload: two active receivers and two backup receivers. In case of a failure, any receiver can be switched to replace a failed receiver, thereby providing an overall four-for-two receiver redundancy.

The signals from each receiver are passed to separate channelized input multiplexers. Each input multiplexer contains twelve input filters arranged in two circulator-coupled chains fed by a hybrid splitter. Each channelized filter contains separate phase and amplitude equalization. A commandable gain step attenuator follows each input filter. In the C band repeater, the step attenuators allow each transponder's gain to be varied over a 14 dB range in 2 dB steps. For the Ku band repeater, the gain variation range is 17.5 dB in 2.5 dB steps.

Following the input filters is a bank of redundancy switches which allow spare amplifiers to be switched into the signal path as substitutes for failed amplifiers. 30 for 24 amplifier redundancy is provided in both the C and Ku band payloads. In the C band payload, amplification is provided by 16 watt SSPAs. At Ku band, amplification is provided by 50 watt TWTAs. Following the amplifier is an output redundancy network which is a mirror image of the input redundancy network.

Signals from the output redundancy switch network are routed to a set of output multiplexer assemblies. The output multiplexer provides channelized output filtering, as well as harmonic and receive-reject filtering. Signals from the output multiplexer are passed to the antenna feed network for transmission.

(ii) <u>Frequency Conversion and Stability</u>

Receive frequencies will be translated, without frequency inversion, to transmit frequencies through a net frequency subtraction of 2225 MHz at C band and 2300 MHz at Ku band. The net translation error, including initial tolerance, will not be greater than ±10 parts in 10^6 over the operating lifetime of the satellite. Variations in net translation frequency over 24 hours will not exceed a total of ±1 part in 10^6, including eclipse effects.

(iii) <u>Satellite Emission Limitations</u>

Spurious emissions that are beyond the usable bandwidth of each transponder and within the C and Ku transmission bands are attenuated by a combination of the input and output multiplex filters. Out-of-band emissions beyond the C and Ku transmission bands, including harmonics, are attenuated by a combination of the output multiplexer filter and harmonic filtering.

f. Satellite Useful Lifetime

The design lifetime of the satellite in orbit (excluding fuel limitations) is 15 years. This has been determined by a conservative evaluation of the effect of the synchronous orbit environment on the solar array, the effect of the charge-discharge cycling on the life of the batteries, and the wearout of the TWTAs. The mass allocation of propellant for spacecraft stationkeeping is 12 years. To enhance the probability of survival, spacecraft equipment will be redundant wherever possible. Materials and processes will be selected so that aging or wearing effects will not adversely affect spacecraft performance over the estimated life.

g. Satellite Stationkeeping

Inclination of the satellite orbit will be maintained to ±0.05 degree or less, and the satellite will be maintained to within ±0.05 degree of the nominal longitude position. Attitude of the satellite will be maintained to an accuracy consistent with the achievement of the specified communications performance, after taking into account all error sources (e.g., attitude perturbations, thermal distortions, misalignments, orbital tolerances, and thruster perturbations).

In addition to the propellant required for operational attitude and orbital control, extra propellant will be incorporated to provide correction of the initial orbit and initial attitude acquisition. Sufficient propellant will be included in the satellite to permit a 12-year operational life.

h. Telemetry, Tracking and Command ("TT&C")

The telemetry, tracking and command ("TT&C") subsystem will perform the monitoring and command functions necessary for spacecraft control.

(i) Telemetry

The telemetry system will have two identical links consisting of two encoders that modulate either of two transmitters via a cross-strap switch. Data pertaining to unit status, spacecraft attitude, and spacecraft performance will be transmitted continuously for spacecraft management and control. The telemetry transmitter will also serve as the downlink transmitter for ranging tones and command verification. The primary telemetry data mode will be PCM, but FM real time modes will be provided for sensor and accelerometer data. For normal on-station operation, the telemetry transmitters will be connected via a filter to the transmit feeds of the communications antenna.

In transfer orbit, each telemetry transmitter will drive one of two C-Band SSPAs selected to provide adequate

EIRP for telemetry coverage via the bicone antenna. Selection of this high level mode, which may also be used for emergency backup on station, will be by ground command.

(ii) Command

The command system will control spacecraft operation through all phases of the mission by receiving and decoding commands to the spacecraft. Additionally, it will serve as the uplink receiver for ranging signals. The command uplink will employ government-approved command encryption. The command signals will be fed through a filter diplexer into a redundant pair of command receivers. The composite signal of the receivers' total output will drive a pair of redundant decoders. The decoders will provide command outputs for all satellite functions. The command bicone antenna will be used in transfer orbit for command and ranging, while the reflector antenna will be used on-station for command and ranging.

(iii) TT&C Performance Characteristics

A telemetry and command summary is given in Table 3. The satellite system requires a command receiver input power of about -135 dBW for command execution. With a nominal ground station EIRP of 68 to 78 dBW, the command threshold requirements are met through the bicone and reflector antennas, respectively, as shown in Table 8. The telemetry link budget for on-station operation is given in Table 9.

TABLE 8. COMMAND LINK PERFORMANCE

Parameter	Transfer Orbit	On-Station
Command frequency	5928 MHz	6422 MHz
Uplink EIRP	78.0 dBW	68.0 dBW
Space loss	-200.0 dB	-200.7 dB
Antenna gain	-2.0 dBi	26.6 dBi
Received carrier power	-124.0 dBW	-106.1 dBW
Onboard losses	-3.7 dB	-12.4 dB
Command receiver input power	-127.7 dBW	-118.5 dBW
Receiver command threshold	-135.0 dBW	-135.0 dBW
Margin above command threshold	7.3 dB	16.5 dB

TABLE 9. TELEMETRY LINK BUDGET (ON-STATION)

Parameter	Value
Telemetry EIRP, minimum	4.5 dBW
Path loss	-196.1 dB
Atmospheric absorption (clear sky)	-0.2 dB
TT&C station G/T	30.0 dB/K
Link C/T	-161.8 dBW/K
Link C/N_o	66.8 dB-Hz
Subcarrier modulation index	-4.1 dB
Subcarrier C/N_o	62.7 dB-Hz
Telemetry Eb/N_o (bit rate = 1kbps)	32.7 dB
Eb/N_o required for 10^{-5} BER	13.4 dB
Margin	19.3 dB

i. Satellite Reliability

(i) Satellite

The satellite will be designed for an operational and mission life of 12 years. Mission lifetime is determined primarily by the amount of stationkeeping propellant that can be loaded into the tanks within the allowable launch weight and by the wearout mechanism of the TWTAs. To ensure highly reliable performance, 30 for 24 TWTA ring redundancy is provided.

Life and reliability will be maximized by using proven reliability concepts in equipment design. All subsystems and units have a minimum design life of 15 years; standby redundancy is used in the attitude control subsystem and in the communications receiver, and active redundancy is used in the power subsystem. All avoidable single-point failure modes will be eliminated. All components and subsystems will be flight-qualified, and all components will be derated in accordance with design guidelines.

Analysis indicates that there is a probability of greater than 80 percent that the spacecraft will retain 22 operational C Band and 22 operational Ku Band transponders after 12 years. This prediction assumes that the satellite is placed on-station without launch vehicle or spacecraft failure.

(ii) Eclipse Conditions

Eclipse conditions occur when a satellite passes through the earth's shadow. Satellite outages during eclipse conditions are avoided by providing each satellite with sufficient on-board battery capacity to power all required spacecraft and communications payload functions. The battery capacity will be more than adequate to power all 48 output amplifiers during eclipses throughout the mission life.

(iii) Sun Outages

During predictable twice-yearly periods of approximately eight days, the sun briefly transits the field of view of an earth station pointing at a geostationary satellite. The rise in thermal noise in the earth station receivers caused by the sun's radiation disrupts satellite reception (i.e., causes sun outage). Such disruption of satellite reception is predictable and is well understood by satellite users.

ITEM E. Performance Requirements and Operational Characteristics of the Satellite Services

As a potential replacement satellite, the ground spare has been designed to support all of the various services offered within HCG's satellite system. The characteristics and associated link analyses for representative C and Ku band services are presented in Appendix E. The link budgets demonstrate that the ground spare will allow all potential services to meet their respective performance objectives while maintaining sufficient link margin.

ITEM F. Adjacent Satellite Interference Analysis

The hypothetical interference levels generated between the ground spare and potentially adjacent satellite systems were evaluated using the computer program commonly known as the "George Sharp" program. The results of the interference analysis are presented in Appendix F.

The analysis results demonstrate that the ground spare does not generate any more interference than other satellite systems previously approved by the Commission. In addition, the sensitivity of the ground spare to adjacent satellite interference is substantially equivalent to that of previously approved satellite systems. In cases where the analysis indicates an incompatibility between specific service types of the ground spare and adjacent satellite services, such incompatibility is not due to the ground spare design, but is rather a fundamental characteristic of the two-degree spacing environment. Such interference situations are readily avoided or minimized through normal coordination arrangements made between the affected satellite operators.

In summary, the interference analyses establish that the design of the ground spare is in full compliance with the requirements of the Commission's two-degree spacing order.[4/]

ITEM G. Preferred Orbital Location

HCG currently is requesting authority only to construct a ground spare. If and when HCG applies for authority to launch and operate the ground spare, HCG will request a particular orbit location for that satellite,

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4/ Two Degree Spacing Order, 54 Rad. Reg. 2d (P&F) 577 (1983).

presumably the location assigned the failed statellite to be replaced by the ground spare.

ITEM H. Schedule

1. Contract Execution

The dates by which contracts are expected to be executed for the following matters are as follows:

a. Spacecraft RFP issued -- no RFP will be used to procure construction of the spacecraft.

b. Spacecraft contractor selected -- Hughes Aircraft Company has already been selected as the contractor.

c. Spacecraft contract executed -- appropriate authorizations executed within 30 days after grant of the construction permit by the FCC.

d. Financing completed -- as set forth in Item J, HCG's parent, GM Hughes Electronics Corporation, has sufficient current assets to fund the construction of the ground spare.

2. Spacecraft Milestones

The dates by which the following goals are scheduled to be achieved are as follows:

a. Spacecraft construction is expected to begin within 30 days of the grant of authorization from the FCC.

b. Spacecraft construction is expected to be completed within 30 months of commencement of construction and in no event later than 42 months.

ITEM I. System Costs

The total construction cost of the ground spare is estimated to be $79 million. This cost is based on estimates from the manufacturer, Hughes Aircraft Company, and includes an allocation of funds for research and development.

ITEM J. Financial Qualifications

HCG is a wholly owned subsidiary of Hughes Communications, Inc. ("HCI"). HCI is a wholly owned subsidiary of Hughes Aircraft Company ("HAC"), a large aerospace and electronics manufacturing company. HAC in turn is a wholly owned subsidiary of GM Hughes Electronics Corporation ("GMHE"). As demonstrated in Exhibit J, the consolidated financial statement of GMHE, GMHE has sufficient current assets to fund the construction of the ground spare applied for in this application.

ITEM K. Legal Qualifications

HCG has on file a current FCC Form 430. That form was attached as Attachment B to the application for consent to transfer control of Satellite Transponder Leasing Corporation, which was filed on July 21, 1989 (File No. 1838-DSS-TC-89, 1839-DSS-TC-89, 1840-DSS-TC-89).

ITEM L. Type of Operations

As a ground spare, this satellite is not intended to be operational. The type of in-orbit operations contemplated for the ground spare are expected to be the same as that of the satellite the ground spare replaces and will be specified if and when HCG applies for authority to launch and operate the ground spare. This application is merely for construction authority.

ITEM M. Public Interest Considerations

Grant of this application will serve the public interest in several respects. As indicated in Section C, above, construction of the ground spare will enable HCG promptly to replace any of the satellites HCG plans to launch in the next four and one-half years, in the event of a launch failure of any of those satellites.

Moreover, construction of the ground spare better enables HCG to meet the explicit requirements of its customers. Satellite customers today require multiple levels of back-up capacity from the satellite system that serves them. For example, customers often demand an ability to gain access to spare transponders in the event the transponder serving them fails. Customers also demand that satellite operators possess the capability to replace a satellite that has failed during launch (or before it has become operational). The ground spare provides HCG this very capability to meet its customers' needs.

The ground spare proposed in this application not only meets these needs, but does so in an efficient manner. The hybrid design of the ground spare makes it suitable to replace any of HCG's currently authorized C or Ku band satellites, as well as the hybrid satellite HCG has proposed to launch into 99° W.L.[5/] The state-of-the-art Hughes Aircraft HS 601 bus used for the ground spare allows full frequency re-use at both C and Ku bands with no reduction from the power levels currently standard on single-band satellites. This ensures a highly efficient use of the spectrum that was not possible with earlier hybrid designs.

In addition, the grant of this application is fully consistent with prior Commission decisions. The Commission has routinely granted satellite operators authority to construct ground spares as part of their satellite systems.[6/] HCG's request is no different from those previously granted.

Although the grant of this application will provide substantial benefits to customers of the Galaxy system, it will have no effect on current or potential satellite operators because this application does not seek the assignment to HCG of an additional orbit location.

CONCLUSION

In sum, the ground spare will provide significant protection to current satellite services and will help HCG meet customer demands, but will have no detrimental effects on any other satellite operator. Accordingly, HCG

5/ See File No. 1-DSS-MP/ML-89, 2-DSS-MP/ML-89, 3-DSS-ML-89.

6/ See, e.g., GTE Spacenet Corporation, 3 FCC Rcd 6986 (1988); National Exchange Satellite, Inc., 3 FCC Rcd 6992 (1988); Contel ASC, 3 FCC Rcd 6982 (1988); American Telephone and Telegraph Company, 3 FCC Rcd 6980 (1988).

respectfully requests that the Commission grant this application to construct a ground spare.

Respectfully submitted,

HUGHES COMMUNICATIONS GALAXY, INC.

By: ______________________________
Eddy W. Hartenstein
Senior Vice President

January 10, 1990

CERTIFICATION AND SIGNATURE

HCG waives any claim to the use of any particular frequency or of the electromagnetic spectrum as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise, and requests construction and launch and operating authority in accordance with this application. All statements made in the attached exhibits are a material part hereof, and are incorporated herein as if set out in full in this application.

The undersigned certifies individually and for HCG that the statements made in this application are true, complete, and correct to the best of his knowledge and belief, and are made in good faith.

HUGHES COMMUNICATIONS GALAXY, INC.

By: ______________________
Eddy W. Hartenstein
Senior Vice President

January 10, 1990

CERTIFICATION OF PERSON RESPONSIBLE

FOR PREPARING ENGINEERING INFORMATION

SUBMITTED IN THIS APPLICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's Rules, that I have either prepared or reviewed the engineering information submitted in this application, and that it is complete and accurate to the best of my knowledge.

BY: [signature]
Lawrence N. Chapman
Manager
Network Services
Hughes Communications, Inc.

January 10, 1990

DECLARATION OF EDDY W. HARTENSTEIN

I, Eddy W. Hartenstein, hereby declare under penalty of perjury that:

1. I am a Senior Vice President of Hughes Communications Galaxy, Inc.

2. The foregoing is a true and correct copy of the consolidated financial statements of GM Hughes Electronics Corporation for the year ended December 31, 1989, including the report of Deloitte Haskins & Sells, the Company's independant certified public accountants, as published in the 1989 annual report of GM Hughes Electronics Corporation.

Eddy W. Hartenstein
Senior Vice President

APPENDIX A

SATELLITE SERVICES - TECHNICAL CHARACTERISTICS AND LINK ANALYSES

This section presents the technical characteristics and associated link analyses for a representative sampling of services which the ground spare satellite, as a potential replacement spacecraft, may be used to support. The link analyses demonstrate that the ground spare satellite allows all of the potential services to achieve their respective performance objectives while maintaining sufficient link margin.

The following assumptions and models were used in the link analyses:

1. Earth Station and Satellite Locations

In the sample link budgets, earth stations (uplink and downlink) are assumed to be located in New York City and the satellite is at an assumed position of 99^{o} West Longitude.

2. Rain Effects

For the Ku band services, performance for clear weather, uplink rain and downlink rain conditions were calculated. For C band services, only clear weather performance was calculated since rain attenuation is relatively insignificant at C band frequencies. Rain attenuation predictions were derived using the rain model developed by R.K. Crane.* The predicted rain attenuation levels are dependent upon many factors including signal frequency, earth station location, and required link availability. In conditions of downlink rain, the link is degraded by both link attenuation as well as by an increase in the noise temperature of the receiving earth station. Both these factors are included in the link analyses.

3. Cross-Polarization Interference

The satellite antenna cross-polarization isolation is 33 dB or greater for both transmit and receive signals over the coverage regions. The earth station cross-polarization isolation values are assumed to be 35 dB for transmit and receive antennas larger than 1.2 meters and 30 dB for antennas smaller than 1.2 meters.

The link cross-polarization isolation value for channels of opposite polarization is calculated by power summing the earth station and satellite antenna polarization isolation values as modified by the depolarization effects of rainfall. The rainfall depolarization factors are a function of frequency, rain attenuation, incident wave polarization, and

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*/ Predictions of Attenuation by Rain, Robert K. Crane, IEE Trans. on Communication, Vol. COM-28, No. 9, September 1980, pp. 1717-1733.

elevation angle. The values used in the link budgets were calculated using the procedure described in CCIR Report 722.

In the link analyses, the cross-polarized interference signal is assumed to be identical to the desired signal. The resulting carrier-to-cross-polarized interference ratio is simply the composite link cross-polarization isolation value described above.

4. Intermodulation Interference

The values used for C/IM have been derived from a combination of laboratory measurements and computer simulations for those traffic modes in which several carriers are transmitted through a transponder.

5. Adjacent Satellite Interference

The model used for the calculation of potential interference into the ground spare satellite from adjacent satellites assumes a "worst case" constellation of homogeneous satellites at two-degree spacing. Each satellite of the constellation is assumed to be co-polarized with the ground spare satellite and to have an EIRP of 47 dBW. The adjacent satellites are assumed to be carrying FM-TV traffic uplinked from a 2.4 meter antenna. It is assumed that the adjacent satellite transponders are operated at saturation. For narrow-band digital SCPC carriers, the power spectral density of the TV interferor is assumed to be 72 db/HZ below an unmodulated carrier (with the narrow-band carriers located at least 3.5 MHz away from the interfering TV carrier).

A single-entry carrier-to-interference ratio (both on the uplink and on the downlink) is calculated for one of the closest adjacent satellites. All earth station antennas are assumed to comply with the current FCC sidelobe envelope requirement of "29 - 25 log (O)" for off-axis performance. The single-entry carrier-to-interference ratio value is decreased by 4 dB to account for the interference contributions of all other adjacent satellites.

These above assumptions, when compounded, result in a conservative estimate of adjacent satellite interference.

Table A.1.a

C-band FM-audio (wideband)

Signal Characteristics	
Modulation	FM-audio
Audio bandwidth	15 kHz
Noise bandwidth	150 kHz
Transponder Characteristics	
Frequency	C-band
Bandwidth	36 MHz
Single carrier saturated EIRP	37.0 dBW
G/T	-1.0 dB/K
Input Backoff (Output Backoff)	10 dB (5.03 dB)
Transmit Earth Station	
Antenna Diameter	6.0m
Receive Earth Station	
Antenna Diameter	3.5m
LNA Noise Temperature	100K
Performance Objectives	
C/N	13 dB

Table A.1.b Link Budget for C-band FM-audio

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-86.0	-86.0	-86.0	dBW/m2
	Agg Input B.O.	10.0	10.0	10.0	dB
	Input Backoff/Crr	21.4	21.6	21.4	dB
	Crr Flux Density	-107.4	-107.6	-107.4	dBW/m2
	Gain of a Sq meter	37.3	37.3	37.3	dBi
	Uplink Path Losses	200.2	200.4	200.2	dB
	Carrier Up EIRP	55.5	55.5	55.5	dBW
	Satellite G/T	-1.0	-1.0	-1.0	dB/K
	C/N Uplink	31.2	31.0	31.2	dB
DOWNLINK BUDGET	Saturation EIRP	37.0	37.0	37.0	dBW
	Agg Output B.O.	5.0	5.0	5.0	dB
	Output Backoff/Crr	16.4	16.6	16.4	dB
	Carrier Dn EIRP	20.6	20.4	20.6	dBW
	Dnlink Path Losses	196.0	196.0	196.1	dB
	Rx Pointing Losses	0.0	0.0	0.0	dB
	Cl Sky E/S G/T	19.5	19.5	19.5	dB/K
	Degradation in G/T	0.0	0.0	0.1	dB
	C/N Downlink	20.9	20.7	20.8	dB
COMPOSITE LINK	C/N Uplink	31.2	31.0	31.2	dB
	C/N Downlink	20.9	20.7	20.8	dB
	C/I Intermod (S/C)	30.5	30.3	30.5	dB
	C/I Uplink Adj Sat	28.9	28.7	28.9	dB
	C/I Dnlink Adj Sat	14.8	14.6	14.8	dB
	C/I Xpol	24.0	23.9	24.0	dB
	C/I Intermod (E/S)	99.0	99.0	99.0	dB
	C/(Nu,d)	20.5	20.3	20.4	dB
	C/(Nu,d,ims/c)	20.1	19.9	20.0	dB
	C/(Nu,d,im,i)Total	13.2	13.0	13.2	dB
	Minimum Reqd C/N	13.0	13.0	13.0	dB
	LINK MARGIN	0.2	0.0	0.2	dB

Table A.2.a

C-band FM-TV, cable quality

Signal Characteristics	
Modulation	FM-TV
Signals per transponder	1
Video bandwidth	4.2 MHz
Peak FM deviation	10.75 MHz
Pre emphasis and weighting	12.80 dB
Transponder Characteristics	
Frequency	C-band
Bandwidth	36 MHz
Single carrier saturated EIRP	37.0 dBW
G/T	-1.0 dB/K
Input Backoff (Output Backoff)	0.0 dB (0.0 dB)
Transmit Earth Station	
Antenna Diameter	6.0m
Receive Earth Station	
Antenna Diameter	3.5m
LNA Noise Temperature	250K
Threshold C/N	8.5 dB
Pre detection bandwidth	30 MHz
Performance Objectives	
End-to-end availability	99.5%
S/N (minimum under faded conditions)	47 dB

Table A.2.b Link Budget for C-band FM-TV

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-87.0	-87.0	-87.0	dBW/m2
	Agg Input B.O.	0.0	0.2	0.0	dB
	Input Backoff/Crr	0.0	0.2	0.0	dB
	Crr Flux Density	-87.0	-87.2	-87.0	dBW/m2
	Gain of a Sq meter	37.3	37.3	37.3	dBi
	Uplink Path Losses	200.2	200.4	200.2	dB
	Carrier Up EIRP	75.9	75.9	75.9	dBW
	Satellite G/T	-1.0	-1.0	-1.0	dB/K
	C/N Uplink	28.6	28.4	28.6	dB
DOWNLINK BUDGET	Saturation EIRP	37.0	37.0	37.0	dBW
	Agg Output B.O.	0.00	0.08	0.00	dB
	Output Backoff/Crr	0.0	0.3	0.0	dB
	Carrier Dn EIRP	37.0	36.7	37.0	dBW
	Dnlink Path Losses	196.0	196.0	196.1	dB
	Rx Pointing Losses	0.0	0.0	0.0	dB
	Cl Sky E/S G/T	16.1	16.1	16.1	dB/K
	Degradation in G/T	0.0	0.0	0.0	dB
	C/N Downlink	10.9	10.6	10.8	dB
COMPOSITE LINK	C/N Uplink	28.6	28.4	28.6	dB
	C/N Downlink	10.9	10.6	10.8	dB
	C/I Intermod (S/C)	99.0	99.0	99.0	dB
	C/I Uplink Adj Sat	35.8	35.6	35.8	dB
	C/I Dnlink Adj Sat	26.9	26.7	26.9	dB
	C/I Xpol	24.0	23.9	24.0	dB
	C/I Intermod (E/S)	99.0	99.0	99.0	dB
	C/(Nu,d)	10.8	10.5	10.7	dB
	C/(Nu,d,ims/c)	10.8	10.5	10.7	dB
	C/(Nu,d,im,i)Total	10.5	10.2	10.4	dB
	Minimum Reqd C/N	8.5	8.5	8.5	dB
	LINK MARGIN	2.0	1.7	1.9	dB
Video S/N (w/o Interference)		48.1	47.8	48.0	dB
Video S/N (with Interference)		47.8	47.5	47.7	dB

Table A.3.a

Ku-band FM-TV, Single Carrier per Transponder

Signal Characteristics	
Modulation	FM-TV
Signals per transponder	1
Video bandwidth	4.2 MHz
Peak FM deviation	9.75 MHz
Pre emphasis and weighting	12.8 dB
Transponder Characteristics	
Frequency	Ku-band
Bandwidth	27 MHz
Single carrier saturated EIRP	46.5 dBW
G/T	1.0 dB/K
Input Backoff (Output Backoff)	0.0 dB (0.0 dB)
Transmit Earth Station	
Antenna Diameter	6.1m
Receive Earth Station	
Antenna Diameter	1.2m
LNA Noise Temperature	250K
Threshold C/N	8.0 dB
Pre detection bandwidth	24 MHz
Performance Objectives	
End-to-end availability	99.5%
S/N (minimum under faded conditions)	44.5 dB

Table A.3.b Link Budget for Ku-band FM-TV, Single Carrier per Transponder

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-82.0	-82.0	-82.0	dBW/m2
	Agg Input B.O.	0.0	0.4	0.0	dB
	Input Backoff/Crr	0.0	0.4	0.0	dB
	Crr Flux Density	-82.0	-82.4	-82.0	dBW/m2
	Gain of a Sq meter	44.5	44.5	44.5	dBi
	Uplink Path Losses	207.4	209.8	207.4	dB
	Carrier Up EIRP	80.9	82.9	80.9	dBW
	Satellite G/T	1.0	1.0	1.0	dB/K
	C/N Uplink	29.3	28.9	29.3	dB
DOWNLINK BUDGET	Saturation EIRP	46.5	46.5	46.5	dBW
	Agg Output B.O.	0.00	0.07	0.00	dB
	Output Backoff/Crr	0.0	0.4	0.0	dB
	Carrier Dn EIRP	46.5	46.1	46.5	dBW
	Dnlink Path Losses	205.8	205.8	207.4	dB
	Rx Pointing Losses	0.0	0.0	0.0	dB
	Cl Sky E/S G/T	16.6	16.6	16.6	dB/K
	Degradation in G/T	0.0	0.0	1.2	dB
	C/N Downlink	12.0	11.6	9.3	dB
COMPOSITE LINK	C/N Uplink	29.3	28.9	29.3	dB
	C/N Downlink	12.0	11.6	9.3	dB
	C/I Intermod (S/C)	99.0	99.0	99.0	dB
	C/I Uplink Adj Sat	24.6	24.3	24.6	dB
	C/I Dnlink Adj Sat	16.8	16.5	16.8	dB
	C/I Xpol	20.9	20.4	20.6	dB
	C/I Intermod (E/S)	60.0	60.0	60.0	dB
	C/(Nu,d)	12.0	11.5	9.3	dB
	C/(Nu,d,ims/c)	12.0	11.5	9.3	dB
	C/(Nu,d,im,i)Total	10.2	9.8	8.2	dB
	Minimum Reqd C/N	8.0	8.0	8.0	dB
	LINK MARGIN	2.2	1.8	0.2	dB
Video S/N	(w/o Interference)	47.5	47.0	44.8	dB
Video S/N	(with Interference)	45.7	45.3	43.7	dB

Table A.4.a

Ku-band FM-TV, Two Carrier per Transponder

Signal Characteristics	
Modulation	FM-TV
Signals per transponder	2
Video bandwidth	4.2 MHz
Peak FM deviation	9.3 MHz
Pre emphasis and weighting	12.8 dB
Transponder Characteristics	
Frequency	Ku-band
Bandwidth	54 MHz
Single carrier saturated EIRP	46.5 dBW
G/T	1.0 dB/K
Input Backoff (Output Backoff)	5.8 dB (1.5 dB)
Transmit Earth Station	
Antenna Diameter	6.1m
Receive Earth Station	
Antenna Diameter	2.4m
LNA Noise Temperature	250K
Threshold C/N	8.0 dB
Pre detection bandwidth	24 MHz
Performance Objectives	
End-to-end availability	99.5%
S/N (minimum under faded conditions)	44.2 dB

Table A.4.b Link Budget for Ku-band FM-TV, Two Carrier per Transponde

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-82.0	-82.0	-82.0	dBW/m2
	Agg Input B.O.	5.8	6.2	5.8	dB
	Input Backoff/Crr	8.8	9.2	8.8	dB
	Crr Flux Density	-90.8	-91.2	-90.8	dBW/m2
	Gain of a Sq meter	44.5	44.5	44.5	dBi
	Uplink Path Losses	207.4	209.8	207.4	dB
	Carrier Up EIRP	72.1	74.1	72.1	dBW
	Satellite G/T	1.0	1.0	1.0	dB/K
	C/N Uplink	20.5	20.1	20.5	dB
DOWNLINK BUDGET	Saturation EIRP	46.5	46.5	46.5	dBW
	Agg Output B.O.	1.50	1.69	1.50	dB
	Output Backoff/Crr	4.5	5.0	4.5	dB
	Carrier Dn EIRP	42.0	41.5	42.0	dBW
	Dnlink Path Losses	205.8	205.8	207.4	dB
	Rx Pointing Losses	0.1	0.1	0.1	dB
	Cl Sky E/S G/T	22.6	22.6	22.6	dB/K
	Degradation in G/T	0.0	0.0	1.2	dB
	C/N Downlink	13.5	12.9	10.7	dB
COMPOSITE LINK	C/N Uplink	20.5	20.1	20.5	dB
	C/N Downlink	13.5	12.9	10.7	dB
	C/I Intermod (S/C)	99.0	99.0	99.0	dB
	C/I Uplink Adj Sat	21.6	21.3	21.6	dB
	C/I Dnlink Adj Sat	18.3	18.0	18.3	dB
	C/I Xpol	23.1	22.3	22.6	dB
	C/I Intermod (E/S)	60.0	60.0	60.0	dB
	C/(Nu,d)	12.7	12.2	10.3	dB
	C/(Nu,d,ims/c)	12.7	12.2	10.3	dB
	C/(Nu,d,im,i)Total	10.9	10.5	9.2	dB
	Minimum Reqd C/N	8.0	8.0	8.0	dB
	LINK MARGIN	2.9	2.5	1.2	dB
Video S/N (w/o Interference)		47.7	47.2	45.4	dB
Video S/N (with Interference)		46.0	45.5	44.2	dB

Table A.5.a

Ku-band Digital SCPC (512 kbps outroute)

Signal Characteristics	
Signal description	digital SCPC (outroute)
Information rate	512 kbps
Coding rate	1/2
Modulation	BPSK
Carrier spacing	1600 kHz
Transponder Characteristics	
Frequency	Ku-band
Bandwidth	27 MHz
Single carrier saturated EIRP	46.5 dBW
G/T	1.0 dB/K
Input Backoff (Output Backoff)	9.7 dB (4.0 dB)
Transmit Earth Station	
Antenna Diameter	6.1m
Uplink Power Control	yes
Receive Earth Station	
Antenna Diameter	1.8m
LNA Noise Temperature	250K
Minimum Required C_b/No	6.5 dB
Performance Objectives	
End-to-end availability	99.7%
Bit Error Rate	1×10^{-7}

Table A.5.b Link Budget for Ku-band Digital SCPC (512 kbps outroute)

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-88.4	-88.4	-88.4	dBW/m2
	Agg Input B.O.	9.7	9.7	9.7	dB
	Input Backoff/Crr	22.7	22.7	22.7	dB
	Crr Flux Density	-111.1	-111.1	-111.1	dBW/m2
	Gain of a Sq meter	44.5	44.5	44.5	dBi
	Uplink Path Losses	207.3	210.9	207.3	dB
	Carrier Up EIRP	51.7	55.3	51.7	dBW
	Satellite G/T	1.4	1.4	1.4	dB/K
	C/N Uplink	13.5	13.5	13.5	dB
DOWNLINK BUDGET	Saturation EIRP	43.2	43.2	43.2	dBW
	Agg Output B.O.	4.0	4.0	4.0	dB
	Output Backoff/Crr	17.0	17.0	17.0	dB
	Carrier Dn EIRP	26.2	26.2	26.2	dBW
	Dnlink Path Losses	205.5	205.5	208.6	dB
	Rx Pointing Losses	0.1	0.1	0.1	dB
	Cl Sky E/S G/T	19.9	19.9	19.9	dB/K
	Degradation in G/T	0.0	0.0	1.7	dB
	C/N Downlink	8.3	8.3	3.4	dB
COMPOSITE LINK	C/N Uplink	13.5	13.5	13.5	dB
	C/N Downlink	8.3	8.3	3.4	dB
	C/I Intermod (S/C)	20.1	20.1	20.1	dB
	C/I Uplink Adj Sat	19.7	19.7	19.7	dB
	C/I Dnlink Adj Sat	19.0	19.0	19.0	dB
	C/I Xpol	99.0	99.0	99.0	dB
	C/I Intermod (E/S)	24.2	17.0	24.2	dB
	C/(Nu,d)	7.1	7.1	3.0	dB
	C/(Nu,d,ims/c)	6.9	6.9	2.9	dB
	C/(Nu,d,im,i)Total	6.4	6.1	2.7	dB
	Minimum Reqd C/N	2.7	2.7	2.7	dB
	LINK MARGIN	3.7	3.4	-0.0	dB

Table A.6.a

Ku-band Digital SCPC (128 kbps inroute)

Signal Characteristics	
Signal description	digital SCPC
Information rate	128 kbps
Coding rate	1/2
Modulation	BPSK
Carrier spacing	400 kHz
Transponder Characteristics	
Frequency	Ku-band
Bandwidth	27 MHz
Single carrier saturated EIRP	46.5 dBW
G/T	1.0 dB/K
Input Backoff (Output Backoff)	9.7 dB (4.0 dB)
Transmit Earth Station	
Antenna Diameter	1.8m
Receive Earth Station	
Antenna Diameter	6.1m
LNA Noise Temperature	250K
Minimum Required E_b/No	6.5 dB
Performance Objectives	
End-to-end availability	99.5%
Bit error rate	1×10^{-7}

Table A.8.b Link Budget for Ku-band FM-audio

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-85.0	-85.0	-85.0	dBW/m2
	Agg Input B.O.	9.7	9.7	9.7	dB
	Input Backoff/Crr	34.4	36.7	34.4	dB
	Crr Flux Density	-119.4	-121.7	-119.4	dBW/m2
	Gain of a Sq meter	44.5	44.5	44.5	dBi
	Uplink Path Losses	207.4	209.8	207.4	dB
	Carrier Up EIRP	43.5	43.5	43.5	dBW
	Satellite G/T	1.0	1.0	1.0	dB/K
	C/N Uplink	19.7	17.3	19.7	dB
DOWNLINK BUDGET	Saturation EIRP	46.5	46.5	46.5	dBW
	Agg Output B.O.	4.0	4.0	4.0	dB
	Output Backoff/Crr	28.7	31.0	28.7	dB
	Carrier Dn EIRP	17.8	15.5	17.8	dBW
	Dnlink Path Losses	205.8	205.8	207.4	dB
	Rx Pointing Losses	0.7	0.7	0.7	dB
	Cl Sky E/S G/T	33.6	33.6	33.6	dB/K
	Degradation in G/T	0.0	0.0	2.2	dB
	C/N Downlink	27.5	25.1	23.8	dB
COMPOSITE LINK	C/N Uplink	19.7	17.3	19.7	dB
	C/N Downlink	27.5	25.1	23.8	dB
	C/I Intermod (S/C)	21.3	18.9	21.3	dB
	C/I Uplink Adj Sat	22.7	20.3	22.7	dB
	C/I Dnlink Adj Sat	32.3	29.9	32.3	dB
	C/I Xpol	23.1	22.4	22.5	dB
	C/I Intermod (E/S)	60.0	60.0	60.0	dB
	C/(Nu,d)	19.0	16.7	18.2	dB
	C/(Nu,d,ims/c)	17.0	14.6	16.5	dB
	C/(Nu,d,im,i)Total	15.1	13.0	14.7	dB
	Minimum Reqd C/N	13.0	13.0	13.0	dB
	LINK MARGIN	2.1	-0.0	1.7	dB

Table A.8.a

Ku-band FM-audio

Signal Characteristics	
Modulation	FM-audio
Audio bandwidth	7.5 KHz
Noise bandwidth	40 KHz
Transponder Characteristics	
Frequency	Ku-band
Bandwidth	27 MHz
Single carrier saturated EIRP	46.5 dBW
G/T	1.0 dB/K
Input Backoff (Output Backoff)	9.7 dB (4.0 dB)
Transmit Earth Station	
Antenna Diameter	2.4m
Receive Earth Station	
Antenna Diameter	6.0m
LNA Noise Temperature	250K
Performance Objectives	
C/N	13 dB

Table A.7.a

Ku-band Digital SCPC (56 kbps Gemini)

Signal Characteristics	
Signal description	digital SCPC (Gemini)
Information rate	56 kbps
Coding rate	1/2
Modulation	QPSK
Carrier spacing	100 kHz
Transponder Characteristics	
Frequency	Ku-band
Bandwidth	27 MHz
Single carrier saturated EIRP	46.5 dBW
G/T	1.0 dB/K
Input Backoff (Output Backoff)	9.7 dB (4.0 dB)
Transmit Earth Station	
Antenna Diameter	2.4m
Receive Earth Station	
Antenna Diameter	2.4m
LNA Noise Temperature	250K
Minimum Required E_b/No	6.5 dB
Performance Objectives	
Availability (each direction)	99.5%
Bit error rate	1×10^{-7}

Table A.6.b Link Budget for Ku-band Digital SCPC (128 kbps inroute)

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-87.0	-87.0	-87.0	dBW/m2
	Agg Input B.O.	9.7	9.7	9.7	dB
	Input Backoff/Crr	32.4	37.0	32.4	dB
	Crr Flux Density	-119.4	-124.0	-119.4	dBW/m2
	Gain of a Sq meter	44.5	44.5	44.5	dBi
	Uplink Path Losses	207.1	211.7	207.1	dB
	Carrier Up EIRP	43.2	43.2	43.2	dBW
	Satellite G/T	0.0	0.0	0.0	dB/K
	C/N Uplink	9.8	5.2	9.8	dB
DOWNLINK BUDGET	Saturation EIRP	42.8	42.8	42.8	dBW
	Agg Output B.O.	4.0	4.0	4.0	dB
	Output Backoff/Crr	26.7	31.3	26.7	dB
	Carrier Dn EIRP	16.1	11.5	16.1	dBW
	Dnlink Path Losses	205.7	205.7	208.1	dB
	Rx Pointing Losses	0.7	0.7	0.7	dB
	Cl Sky E/S G/T	30.9	30.9	30.9	dB/K
	Degradation in G/T	0.0	0.0	1.7	dB
	C/N Downlink	14.3	9.7	10.2	dB
COMPOSITE LINK	C/N Uplink	9.8	5.2	9.8	dB
	C/N Downlink	14.3	9.7	10.2	dB
	C/I Intermod (S/C)	16.4	11.8	16.4	dB
	C/I Uplink Adj Sat	17.2	12.5	17.2	dB
	C/I Dnlink Adj Sat	25.3	20.7	25.3	dB
	C/I Xpol	99.0	99.0	99.0	dB
	C/I Intermod (E/S)	99.0	99.0	99.0	dB
	C/(Nu,d)	8.5	3.9	7.0	dB
	C/(Nu,d,ims/c)	7.9	3.2	6.5	dB
	C/(Nu,d,im,i)Total	7.3	2.7	6.1	dB
	Minimum Reqd C/N	2.7	2.7	2.7	dB
	LINK MARGIN	4.6	-0.0	3.4	dB

Table A.7.b Link Budget for Ku-band Digital SCPC (56 kpbs Gemini Terminals)

	LINK PERFORMANCE	Cl Sky	Up Fade	Dn Fade	Unit
UPLINK BUDGET	Satellite SFD	-85.0	-85.0	-85.0	dBW/m2
	Agg Input B.O.	9.7	9.7	9.7	dB
	Input Backoff/Crr	37.5	37.9	37.5	dB
	Crr Flux Density	-122.5	-122.9	-122.5	dBW/m2
	Gain of a Sq meter	44.5	44.5	44.5	dBi
	Uplink Path Losses	207.4	207.9	207.4	dB
	Carrier Up EIRP	40.4	40.4	40.4	dBW
	Satellite G/T	1.0	1.0	1.0	dB/K
	C/N Uplink	14.3	13.9	14.3	dB
DOWNLINK BUDGET	Saturation EIRP	46.5	46.5	46.5	dBW
	Agg Output B.O.	4.0	4.0	4.0	dB
	Output Backoff/Crr	31.8	32.2	31.8	dB
	Carrier Dn EIRP	14.7	14.3	14.7	dBW
	Dnlink Path Losses	205.8	205.8	206.4	dB
	Rx Pointing Losses	0.1	0.1	0.1	dB
	Cl Sky E/S G/T	22.8	22.8	22.8	dB/K
	Degradation in G/T	0.0	0.0	0.5	dB
	C/N Downlink	11.9	11.5	10.9	dB
COMPOSITE LINK	C/N Uplink	14.3	13.9	14.3	dB
	C/N Downlink	11.9	11.5	10.9	dB
	C/I Intermod (S/C)	15.9	15.5	15.9	dB
	C/I Uplink Adj Sat	18.0	17.5	18.0	dB
	C/I Dnlink Adj Sat	19.6	19.1	19.6	dB
	C/I Xpol	22.3	22.3	22.3	dB
	C/I Intermod (E/S)	60.0	60.0	60.0	dB
	C/(Nu,d)	9.9	9.5	9.2	dB
	C/(Nu,d,ims/c)	9.0	8.5	8.4	dB
	C/(Nu,d,im,i)Total	8.0	7.5	7.5	dB
	Minimum Reqd C/N	7.5	7.5	7.5	dB
	LINK MARGIN	0.5	0.0	-0.0	dB

APPENDIX B

ADJACENT SATELLITE INTERFERENCE ANALYSIS

This section presents the results of an analysis performed to determine the levels of interference generated between the ground spare satellite and other potentially adjacent satellites. The analyses used the computer program commonly known as the "George Sharp Adjacent Satellite Interference Program" (4/85 version).

The George Sharp program calculates, on a service by service basis, the interference power generated into each listed satellite service by other satellite services. The program then compares the resulting adjacent satellite interference level to an established interference objective for the particular desired service. The interference objectives used in the analysis presented herein are based on the recommendations of of the FCC Advisory Committee on Reduced Spacing.

Separate C-band and Ku-band interference analysis were performed. Because of the large number of Ku-band services investigated, the Ku-band analysis is divided into two sections. Both the C-band and Ku-band analysis incorporate a worst-case assumption that the adjacent satellites are separated by two degrees. Spacings greater than two degrees will result in significant reductions in adjacent satellite interference. Other worst-case assumptions in the analyses are that all Ku-band services are cofrequency and copolarized to each other. These assumptions were made due to the nonuniformity of Ku-band satellite channel plans. In many cases, there will exist frequency offsets and/or polarization isolation between between adjacent Ku-band satellite services which will substantially reduce interference. In the case of C-band services, the uniform nature of C-band channel plans allow actual polarization orientations to be used in the interference analyses. C-band services are also assumed to be cofrequency with each other.

Each C-band and Ku-band interference analysis consists of three sections. The first section contains this input parameters for the interference analysis program. This section specifies the technical characteristics of the services supported by the potentially interfering satellites. The satellites included in the analyses are listed in Table B-1. The second section presents a computed thermal noise summary for each of the satellite links specified in the first section. The second section also specifies the carrier-to-intersatellite interference objective for each service type. The third section consists of a matrix which identifies the amounts by which the interference objectives of a particular service are exceeded when the service receives interference from another adjacent service.

The results of the analyses indicate that a significant interference potential (i.e. greater than 2dB) exists where television or wide-band data signals interact with narrowband SCPC (single-channel-per-carrier) signals. Such interference is not the result of the ground spare satellite's design or of the services it will carry, but is rather an inherent characteristic of the two-degree spacing environment. Such interference can be readily contained through coordination arrangements made between adjacent satellite operators. Such arrangements can include coordinated assignment of carrier frequencies, segmentation of the operating frequency bands for specific service types, and proper selection of the satellite input attenuation levels. It should be noted that the ground spare satellite may, in many cases, be used to replace satellites for which coordination agreements with adjacent satellite operators already exist. In such cases, any existing coordination arrangements will continue to be applied to operation of the ground spare satellite.

In summary, the potential operation of the ground spare satellite will not create any exceptional or unusual interference problems with neighboring satellites. Hughes remains prepared to engage in coordination discussions with the operators of any neighboring satellites in order to develop a mutually satisfactory operating environment.

TABLE B - 1

SATELLITES USED IN INTERFERENCE ANALYSIS

FREQUENCY BAND	SATELLITE	DESIGNATION
C-BAND	TELSTAR	TEL4
	SATCOM	SCOM
	SPACENET	SC3
	CONTELSAT	CONT
	ASC	ASC
KU-BAND	TELSTAR	TEL4
	CONTELSAT	CONT
	SPACENET	SPC3
	GSTAR	GSTR
	ASC	ASC

INPUT PARAMETERS 12:00:00 13-Dec-89

CARRIER	COMPANY	TYPE	RF BANDWIDTH (MHZ)	NO. OF CHAN	CODE RATE/ MOD. INDEX	BOT MOD. FREQ. (MHZ)	TOP MOD. FREQ. (MHZ)	AVE. TALKER LEVEL (DBMO)	CPAND PREMP NOISE WEIGH (DB)	PHASE	DATA RATE (MBPS)	CHAN. SPACE (MHZ)	TRANSPONDER FREQUENCY UP (GHZ)	TRANSPONDER FREQUENCY DN (GHZ)	POL UP	POL DN	EARTH STATION TRANSMITTER POWR (DBW)	EARTH STATION TRANSMITTER DIAM (M)	EARTH STATION TRANSMITTER GAIN (DB)	--SATELLITE--- RECEIVER GAIN (DB)	--SATELLITE--- RECEIVER TEMP (K)	--SATELLITE--- XMTR EIRP (DBW)	-EARTH STATION RECEIVER DIAM (M)	-EARTH STATION RECEIVER GAIN (DB)	-EARTH STATION RECEIVER TEMP (K)
1	GALS	1	36.000	1	2.560	.020	4.200	.0	12.8	0	.000	.000	6.145	3.920	0	1	26.3	6.0	49.6	25.0	800.	37.0	3.5	40.8	285
2	GALS	4	.150	13	5.000	.000	.015	.0	29.0	0	.000	.200*	6.145	3.920	0	1	5.5	6.0	49.6	25.0	800.	20.5	3.5	40.8	135
3	TEL4	1	36.000	1	2.571	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	1	0	23.5	10.0	53.5	27.0	800.	38.0	3.0	33.5	130
4	TEL4	1	36.000	1	2.571	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	1	0	23.5	10.0	53.5	27.0	800.	35.0	4.5	44.0	125
5	TEL4	1	36.000	1	2.571	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	1	0	23.5	10.0	53.5	27.0	800.	35.0	7.0	47.5	125
6	TEL4	2	36.000	1	.000	.000	.000	.0	.0	4	60.000	.000	6.145	3.920	1	0	21.7	13.0	56.2	27.0	800.	34.8	13.0	53.2	110
7	TEL4	2	30.000	1	.875	.000	.000	.0	.0	4	45.000	.000	6.145	3.920	1	0	24.3	10.0	53.5	27.0	800.	34.3	7.0	47.5	125
8	TEL4	2	1.060	24	.875	.000	.000	.0	.0	4	1.544	1.300*	6.145	3.920	1	0	2.9	12.0	55.1	27.0	800.	15.7	12.0	52.5	110
9	TEL4	2	1.230	24	.750	.000	.000	.0	.0	4	1.544	1.600*	6.145	3.920	1	0	8.8	6.1	49.3	27.0	800.	18.2	6.1	46.3	125
10	SCOM	5	34.000	5820	.000	1.000	17.000	-21.0	7.8	0	.000	.000	6.145	3.920	0	1	18.0	13.0	56.0	24.0	750.	30.0	13.0	53.0	80
11	SCOM	0	36.000	2892	.323	.012	12.388	-18.0	-11.1	0	.000	.000	6.145	3.920	0	1	25.0	13.0	56.0	24.0	750.	34.0	13.0	52.0	80
12	SCOM	0	36.000	1932	.385	.012	8.120	-15.0	-10.3	0	.000	.000	6.145	3.920	0	1	25.0	13.0	56.0	24.0	750.	34.0	13.0	52.0	80
13	SCOM	0	20.700	432	1.501	.012	1.796	-15.0	.0	0	.000	18.000	6.145	3.920	0	1	13.9	13.0	56.0	24.0	750.	25.5	13.0	52.0	80
14	SCOM	1	36.000	1	2.560	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	0	1	25.0	13.0	56.0	24.0	750.	34.0	13.0	52.0	80
15	SCOM	1	36.000	1	2.560	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	0	1	26.7	11.0	54.3	24.0	750.	34.0	11.0	51.3	80
16	SCOM	1	18.000	1	1.500	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	0	1	22.7	11.0	54.3	24.0	750.	33.0	7.0	47.5	80
17	SCOM	1	36.000	1	2.560	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	0	1	27.5	10.0	53.5	24.0	750.	34.0	4.5	44.0	125
18	SCOM	1	36.000	1	2.560	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	0	1	27.5	10.0	53.5	24.0	750.	34.0	7.0	47.5	125
19	SCOM	1	18.000	2	1.500	.025	4.200	.0	12.8	0	.000	16.000	6.145	3.920	0	1	21.5	10.0	53.5	24.0	750.	30.0	4.5	44.0	125
20	SCOM	1	18.000	2	1.500	.025	4.200	.0	12.8	0	.000	16.000	6.145	3.920	0	1	21.5	10.0	53.5	24.0	750.	30.0	10.0	50.5	112
21	SCOM	2	36.000	1	.000	.000	.000	.0	.0	4	60.000	.000	6.145	3.920	0	1	26.7	11.0	54.3	24.0	750.	34.0	11.0	51.3	107
22	SCOM	2	16.600	1	.000	.000	.000	.0	.0	2	8.800	.000	6.145	3.920	0	1	22.5	13.0	56.0	24.0	750.	34.0	3.1	39.5	130
23	SCOM	2	1.030	32	.875	.000	.000	.0	.0	4	1.544	1.300*	6.145	3.920	0	1	7.9	11.0	54.3	24.0	750.	15.0	11.0	51.3	107
24	SCOM	3	.064	100	.875	.000	.000	.0	.0	2	.056	.280*	6.145	3.920	0	1	7.6	5.0	47.4	24.0	750.	9.0	5.0	44.5	125
25	SCOM	4	.037	620	4.412	.000	.003	.0	25.8	0	.000	.048*	6.145	3.920	0	1	-1.0	10.0	53.5	24.0	750.	.0	10.0	50.5	112
26	SC3	0	36.000	1872	.407	.012	7.868	-15.0	-10.3	0	.000	.000	6.145	3.920	1	0	27.0	10.0	54.0	26.0	750.	34.0	10.0	50.5	112
27	SC3	0	17.500	432	1.019	.564	2.074	-15.0	.0	0	.000	18.000	6.145	3.920	1	0	19.0	10.0	54.0	26.0	750.	30.0	10.0	50.5	112
28	SC3	1	36.000	1	2.690	.025	4.200	.0	13.0	0	.000	.000	6.145	3.920	1	0	27.0	10.0	54.0	26.0	750.	34.0	7.0	47.5	120
29	SC3	1	36.000	1	2.690	.025	4.200	.0	13.0	0	.000	.000	6.145	3.920	1	0	27.0	10.0	54.0	26.0	750.	34.0	5.0	45.0	120
30	SC3W	0	36.000	1872	.407	.012	7.868	-15.0	-10.3	0	.000	40.000	6.145	3.920	1	0	15.2	13.0	56.3	26.0	750.	32.0	13.0	52.0	80
31	SC3W	1	36.000	2	2.690	.025	4.200	.0	13.0	0	.000	40.000	6.145	3.920	1	0	17.5	10.0	54.0	26.0	750.	32.0	7.0	47.5	120
32	SC3W	1	36.000	2	2.690	.025	4.200	.0	13.0	0	.000	40.000	6.145	3.920	1	0	17.5	10.0	54.0	26.0	750.	32.0	5.0	45.0	120
33	SC3W	2	72.000	1	.000	.000	.000	.0	.0	4	125.000	.000	6.145	3.920	1	0	24.0	10.0	54.0	26.0	750.	35.7	10.0	50.5	112
34	CONT	2	36.000	1	1.000	.000	.000	.0	.0	4	60.000	.000	6.145	3.920	1	0	24.0	13.0	56.0	25.0	800.	34.5	13.0	52.0	80
35	CONT	1	36.000	1	2.571	.025	4.200	.0	12.8	0	.000	.000	6.145	3.920	1	0	25.0	10.0	53.5	25.0	800.	34.5	5.0	44.5	80
36	CONT	2	16.000	2	1.000	.000	.000	.0	.0	4	16.000	.000	6.145	3.920	1	0	15.5	9.2	53.5	25.0	800.	31.5	5.0	44.5	80
37	CONT	2	1.100	32	.875	.000	.000	.0	.0	4	1.544	1.300*	6.145	3.920	1	0	3.7	10.0	53.5	25.0	800.	14.8	10.0	50.5	90
38	CONT	3	.040	160	.875	.000	.000	.0	.0	4	.056	.200*	6.145	3.920	1	0	1.1	5.0	47.3	25.0	800.	7.5	5.0	44.5	125
39	CONT	3	.040	620	.875	.000	.000	.0	.0	4	.056	.048*	6.145	3.920	1	0	-9.5	10.0	53.5	25.0	800.	1.0	10.0	50.5	89
40	ASC	0	35.000	1800	.388	.060	7.860	-15.0	-10.3	0	.000	.000	6.145	3.920	1	0	25.0	13.0	56.0	25.0	800.	34.0	13.0	52.0	80
41	ASC	0	12.000	372	.908	.012	1.550	-20.0	.0	0	.000	12.000	6.145	3.920	1	0	10.7	10.0	53.5	25.0	800.	22.0	10.0	50.5	56
42	ASC	1	32.000	1	2.560	.025	4.200	.0	12.8	0	.000	12.000	6.145	3.920	1	0	25.0	13.0	56.0	25.0	800.	34.0	5.0	44.5	125
43	ASC	2	36.000	1	.000	.000	.000	.0	.0	4	64.000	.000	6.145	3.920	1	0	24.5	10.0	53.5	25.0	800.	33.0	11.0	51.5	71
44	ASC	2	9.600	1	.500	.000	.000	.0	.0	4	7.700	.000	6.145	3.920	1	0	24.5	10.0	53.5	25.0	800.	33.0	3.0	39.5	130
45	ASC	2	3.750	8	.667	.000	.000	.0	.0	4	4.000	4.000	6.145	3.920	1	0	11.5	10.0	53.5	25.0	800.	23.0	10.0	50.5	89
46	ASC	2	1.100	32	.875	.000	.000	.0	.0	4	1.544	1.300*	6.145	3.920	1	0	3.7	10.0	53.5	25.0	800.	14.8	10.0	50.5	89
47	ASC	2	1.100	32	.875	.000	.000	.0	.0	4	1.544	1.300*	6.145	3.920	1	0	3.1	10.0	53.5	25.0	800.	14.1	10.0	50.5	56
48	ASC	3	.040	160	.875	.000	.000	.0	.0	4	.056	.200*	6.145	3.920	1	0	1.1	5.0	47.3	25.0	800.	7.5	5.0	44.5	125
49	ASC	3	.040	620	.875	.000	.000	.0	.0	4	.056	.048*	6.145	3.920	1	0	-9.5	10.0	53.5	25.0	800.	1.0	10.0	50.5	89

Table B.1.1 C-band Satellite Input Parameters

T H E R M A L   N O I S E   S U M M A R Y   12:00:00   13-Dec-89

CARRIER	COMPANY	EARTH - TO - SPACE EIRP (DBW)	POINTING LOSS (DB)	SPACE LOSS* (DB)	RCV G/T (DB/K)	SPACE - TO - EARTH EIRP (DBW)	POINTING LOSS (DB)	SPACE LOSS* (DB)	RCV G/T (DB/K)	C/KT - (DB/HZ) UP	C/KT DN	C/KT TOTAL	C/N - (DB) UP	C/N DN	C/N TOTAL	TOTAL THERMAL NOISE (PWOP)	S/N (DB)	EB/KT (DB)	SINGLE ENTRY INTERFERENCE OBJECTIVE (PWOP)	S/I (DB)	C/I (DB)
1	GALS	75.9	.0	199.8	-4.0	37.0	.0	196.2	16.3	100.7	85.7	85.5	25.1	10.1	10.0		47.2			=53.2	22.0
2	GALS	55.5	.0	199.8	-4.0	20.5	.0	196.2	19.5	80.3	72.4	71.7	28.5	20.6	20.0	34.	74.7				17.0
3	TEL4	77.0	.3	199.8	-2.0	38.0	.0	196.2	18.4	103.5	88.8	88.6	27.9	13.2	13.1		50.4			=53.2	22.0
4	TEL4	77.0	.3	199.8	-2.0	35.0	.0	196.2	23.0	103.5	90.4	90.2	27.9	14.9	14.7		52.0			=53.2	22.0
5	TEL4	77.0	.3	199.8	-2.0	35.0	.1	196.2	26.5	103.5	93.8	93.4	27.9	18.3	17.8		55.1			=59.2	28.0
6	TEL4	77.9	.3	199.8	-2.0	34.8	.2	196.2	32.8	104.4	99.8	98.5	28.8	24.2	22.9			20.7			27.2
7	TEL4	77.8	.3	199.8	-2.0	34.8	.1	196.2	26.5	104.3	93.6	93.3	29.5	18.9	18.5			16.2			26.8
8	TEL4	58.0	.3	199.8	-2.0	15.7	.2	196.2	32.1	84.5	80.0	78.7	24.2	19.7	18.4			16.2			21.6
9	TEL4	58.1	.0	199.8	-2.0	18.2	.1	196.2	25.3	84.9	75.8	75.3	24.0	14.9	14.4			12.2			21.0
10	SCOM	74.0	.3	199.8	-4.8	30.0	.2	196.2	34.0	60.1	58.5	56.2	24.1	22.5	20.2	5477.	52.6		1000.	60.0	
11	SCOM	81.0	.3	199.8	-4.8	34.0	.2	196.2	33.0	104.7	99.2	98.1	29.2	23.6	22.5	3659.	54.4		1000.	60.0	
12	SCOM	81.0	.3	199.8	-4.8	34.0	.2	196.2	33.0	104.7	99.2	98.1	29.2	23.6	22.5	4127.	53.8		1000.	60.0	
13	SCOM	69.9	.3	199.8	-4.8	25.5	.2	196.2	33.0	93.6	90.7	88.9	20.5	17.5	15.7	5423.	52.7		1000.	60.0	
14	SCOM	81.0	.3	199.8	-4.8	34.0	.2	196.2	33.0	104.7	99.2	98.1	29.2	23.6	22.5		59.8			=59.2	28.0
15	SCOM	81.0	.3	199.8	-4.8	34.0	.2	196.2	32.3	104.7	98.5	97.6	29.2	22.9	22.0		59.3			=59.2	28.0
16	SCOM	77.0	.3	199.8	-4.8	33.0	.1	196.2	28.5	100.7	93.8	93.0	28.2	21.2	20.4		51.5			=48.5	22.0
17	SCOM	81.0	.3	199.8	-4.8	34.0	.0	196.2	23.0	104.7	89.4	89.3	29.2	13.9	13.7		51.0			=53.2	22.0
18	SCOM	81.0	.3	199.8	-4.8	34.0	.1	196.2	26.5	104.7	92.8	92.6	29.2	17.3	17.0		54.3			=53.2	22.0
19	SCOM	75.0	.3	199.8	-4.8	30.0	.0	196.2	23.0	98.7	85.4	85.2	26.2	12.9	12.7		43.8			=48.5	22.0
20	SCOM	75.0	.3	199.8	-4.8	30.0	.2	196.2	30.0	98.7	92.2	91.3	26.2	19.7	18.8		49.9			=48.5	22.0
21	SCOM	81.0	.3	199.8	-4.8	34.0	.2	196.2	31.0	104.7	97.2	96.5	29.2	21.6	20.9			18.7			27.2
22	SCOM	78.5	.3	199.8	-4.8	34.0	.0	196.2	18.4	102.2	84.8	84.7	30.0	12.6	12.5			15.2			17.2
23	SCOM	62.2	.3	199.8	-4.8	15.0	.2	196.2	31.0	85.9	78.2	77.5	25.8	18.1	17.4			15.1			21.8
24	SCOM	55.0	.0	199.8	-4.8	9.0	.0	196.2	23.5	79.0	64.9	64.8	31.0	16.9	16.7			16.7			19.4
25	SCOM	52.5	.3	199.8	-4.8	.0	.2	196.2	30.0	76.2	62.2	62.0	30.6	16.5	16.4	175.	67.6				24.0
26	SC3	81.0	.3	199.8	-2.8	34.0	.2	196.2	30.0	106.7	96.2	95.8	31.2	20.6	20.3	6032.	52.2		600.	62.2	
27	SC3	73.0	.3	199.8	-2.8	30.0	.2	196.2	30.0	98.7	92.2	91.3	26.3	19.8	18.9	5710.	51.7		600.	62.2	
28	SC3	81.0	.3	199.8	-2.8	34.0	.1	196.2	26.7	106.7	93.0	92.8	31.2	17.4	17.3		55.3			=59.6	28.0
29	SC3	81.0	.3	199.8	-2.8	34.0	.0	196.2	24.2	106.7	90.6	90.5	31.2	15.0	14.9		53.0			=53.6	22.0
30	SC3W	71.5	.3	199.8	-2.8	32.0	.2	196.2	33.0	97.2	97.2	94.2	21.7	21.6	18.6	8802.	50.6		600.	62.2	
31	SC3W	71.5	.3	199.8	-2.8	32.0	.1	196.2	26.7	97.2	91.0	90.1	21.7	15.4	14.5		52.6			=53.6	22.0
32	SC3W	71.5	.3	199.8	-2.8	32.0	.0	196.2	24.2	97.2	88.6	88.1	21.7	13.0	12.5		50.5			=53.6	22.0
33	SC3W	78.0	.3	199.8	-2.8	35.7	.2	196.2	30.0	103.7	97.9	96.9	25.2	19.3	18.3			15.9			27.4
34	CONT	80.0	.3	199.8	-4.0	34.5	.2	196.2	33.0	104.5	99.7	98.4	28.9	24.1	22.9			20.6			15.5
35	CONT	78.5	.3	199.8	-4.0	34.5	.0	196.2	25.5	103.0	92.4	92.0	27.4	16.8	16.4		53.8			=53.2	22.0
36	CONT	69.0	.3	199.8	-4.0	31.5	.0	196.2	25.5	93.5	89.4	87.9	21.4	17.3	15.9			15.9			22.0
37	CONT	57.2	.3	199.8	-4.0	14.8	.2	196.2	31.0	81.7	78.0	76.4	21.3	17.5	16.0			14.0			27.1
38	CONT	48.4	.0	199.8	-4.0	7.5	.0	196.2	23.5	73.2	63.4	63.0	27.1	17.4	17.0			14.9			24.0
39	CONT	44.0	.3	199.8	-4.0	1.0	.2	196.2	31.0	68.5	64.2	62.8	22.4	18.2	16.8			14.8			24.0
40	ASC	81.0	.3	199.8	-4.0	34.0	.2	196.2	33.0	105.5	99.2	98.3	30.0	23.7	22.8	3660.	54.4		1000.	60.0	
41	ASC	64.2	.3	199.8	-4.0	22.0	.2	196.2	33.0	88.7	87.2	84.9	17.9	16.4	14.1	10196.	49.9		1000.	60.0	
42	ASC	81.0	.3	199.8	-4.0	34.0	.0	196.2	23.5	105.5	89.9	89.8	30.4	14.9	14.8		52.0			=53.2	22.0
43	ASC	78.0	.3	199.8	-4.0	33.0	.2	196.2	33.0	102.5	98.2	96.8	26.9	22.6	21.2			18.7			27.5
44	ASC	78.0	.3	199.8	-4.0	33.0	.0	196.2	18.4	102.5	83.8	83.7	32.6	13.9	13.9			11.8			21.0
45	ASC	65.0	.3	199.8	-4.0	23.0	.2	196.2	31.0	89.5	86.2	84.5	23.7	20.5	18.8			16.7			20.3
46	ASC	57.2	.3	199.8	-4.0	14.8	.2	196.2	31.0	81.7	78.0	76.5	21.3	17.6	16.0			14.0			21.5
47	ASC	56.6	.3	199.8	-4.0	14.1	.2	196.2	33.0	81.1	79.3	77.1	20.7	18.9	16.7			14.6			21.5
48	ASC	48.4	.0	199.8	-4.0	7.5	.0	196.2	23.5	73.2	63.4	63.0	27.1	17.4	17.0			14.9			21.5
49	ASC	44.0	.3	199.8	-4.0	1.0	.2	196.2	31.0	68.5	64.2	62.8	22.4	18.2	16.8			14.8			21.5

Table B.1.2 C-band Satellite Thermal Noise Summary

W A N T E D — FAILS TO MEET SINGLE ENTRY INTERFERENCE OBJECTIVE (DB) — 12:00:00 — 13-Dec-89

2.0 DEGREE SPACING — New FCC pattern, 29-25 LOG(A) ; A = GEOCENTRIC ANGLE

INTERFERING

WANTED	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
1	3										1	3		1	1		1	1			1	1																											
2	1																																																
3			4	1	1	1	1																			1		1	1		1	1	1	1	1	1				4		1							
4			3																																					2									
5			5	3	3	2	3																			3	1	3	3		2	2	2	3	3	2				6		3	2	2					
6			1																																					1									
7			4	2	2	1	2																			2		2	2		1	1		1	2	1				4		1	1	1					
8			8	6	6																					2	1	7	7		5	5			6					4		6		1					
9	1		*	9	9	1	2												1	1						4	3	9	9	2	*	*		1	9	2				6		8		3					
10	*	*	*	*	*						7	8		*	*	*	*	*	*	*	4	6	1	*	4			*	*						*							*							
11	1																																																
12	4													1	2	1	2	2			1																												
13												1							2	2	2	1		1																									
14	2											2																																					
15	2											2					1	1																															
16	1											1																																					
17	3											3																																					
18																																																	
19	7										2	5		4	4	3	4	4		2	1	2																											
20	1																																																
21	1											2																																					
22	2											2																																					
23	8	3									1	4		5	6	4	6	6	8	8		1																											
24	6	5										1		3	3	2	3	3	*	*																													
25	*	*	2								3	6		8	8	7	8	8	*	*	1	3		4																									
26			7	5	5	3	3																			1	4	5	5				2	3	5	2				4		4	1	1					
27						3	4		1																	1	5						2	4		2		1		2			3	3	1			1	
28			6	3	3	3	3																			3	1	3	3		3	3	2	3	3	3				6		3	2	2	1				
29			3																																					2									
30			5	4	4	2	3		2																		3	6	6		4	4	4	3	4			1				4	3					1	
31			3	1	1																							2	2						1							1							
32			5	2	2																							3	3						2							2							
33			2																							1		1	1											2									
34																																																	
35			3																																					2									
36			6	4	4	1	2																			4		4	4					1	4					7		4	1	3					
37	6		*	*	*	5	7	1	4			2		4	4	2	5	5	6	6						*	3	*	*	7	*	*	4	6	*	7		2		*	2	*	5	8	4			2	
38	1		*	8	8	1	2												*	*						3	3	8	8	3	*	*		1	8	3		3		6		8		2				3	
39	2	1	*	9	9	2	3		1						1		1	1	*	*						6	4	*	*	3	*	*		2	*	4		5		8		9	1	4	1			5	
40			4	2	2																						1	2	2						1							1							
41			4	2	2	5	7		2																	7	5	3	3				4	6	2	5		1		8		2	5	6	3			1	
42			3	1	1																										1	1								2									
43			3	1	1	1	1																			1		1	1		1	1		1	1					3		1							
44			8	5	5	1	1																			4		4	4					1	5	4				7		4		3					
45			7	5	5																					2		6	6						5					4		5		1					
46	1		*	8	8		1												1	1						4	3	9	9	2	*	*		1	8	2				6		8		3					
47	1		*	9	9	1	2												1	1						5	3	*	*	2	*	*		1	9	2				7		9	1	3					
48			8	6	6														*	*						1	1	6	6	1	*	*			5	1		1		3		5						1	
49			9	7	7		1												*	*						3	2	8	8	1	7	7			7	1		3		5		7		2				3	

Table B.1.3 C-band Satellite Interference Analysis Results (2° Spacing)

INPUT PARAMETERS 12:00:00 06-DEC-89

CARRIER	COMPANY	TYPE	RF BANDWIDTH (MHZ)	NO. OF CHAN	CODE RATE/ MOD. INDEX	BOT MOD. FREQ. (MHZ)	TOP MOD. FREQ. (MHZ)	AVG. TALKER LEVEL (DBMO)	CPAND PREMP NOISE WEIGH (DB)	PHASE	DATA RATE (MBPS)	CHAN. SPACE (MHZ)	TRANSPONDER FREQUENCY UP (GHZ)	TRANSPONDER FREQUENCY DN (GHZ)	POL UP	POL DN	EARTH STATION TRANSMITTER POWR (DBW)	EARTH STATION TRANSMITTER DIAM (M)	EARTH STATION TRANSMITTER GAIN (DB)	--SATELLITE--- RECEIVER GAIN (DB)	--SATELLITE--- RECEIVER TEMP (K)	--SATELLITE--- XMTR EIRP (DBW)	EARTH STATION RECEIVER DIAM (M)	EARTH STATION RECEIVER GAIN (DB)	EARTH STATION RECEIVER TEMP (K)
1	GALS	1	27.000	1	2.333	.025	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	18.5	6.1	57.0	29.9	650.	46.5	1.2	41.3	285
2	GALS	1	27.000	2	2.214	.025	4.200	.0	12.8	0	.000	27.000	14.250	11.950	0	1	16.0	6.1	57.0	29.9	650.	42.0	2.4	47.3	285
3	GALS	2	1.229	16	.500	.000	.000	.0	.0	2	.512	1.600*	14.250	11.950	0	1	-6.2	6.1	57.0	30.0	650.	26.1	1.8	44.8	285
4	GALS	2	.307	67	.500	.000	.000	.0	.0	2	.128	.400*	14.250	11.950	0	1	-5.7	1.8	46.4	30.0	650.	17.0	6.1	55.4	285
5	GALS	2	.067	270	.500	.000	.000	.0	.0	4	.056	.100*	14.250	11.950	0	1	-8.5	2.4	48.9	30.0	650.	14.7	2.4	47.3	285
6	GALS	4	.040	270	4.333	.000	.008	.0	25.0	0	.000	.000	14.250	11.950	0	1	-5.4	2.4	48.9	30.0	650.	17.8	6.0	55.3	235
7	TBL4	1	27.000	1	2.214	.001	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	25.4	6.1	56.6	29.0	800.	46.5	1.2	41.1	300
8	TBL4	1	27.000	1	2.214	.001	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	25.4	6.1	56.6	29.0	800.	44.0	1.8	44.8	300
9	TBL4	1	36.000	1	3.286	.001	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	23.4	7.7	58.6	29.0	800.	44.0	5.5	54.5	290
10	TBL4	2	30.000	1	.875	.000	.000	.0	.0	4	45.000	.000	14.250	11.950	0	1	23.2	5.5	55.7	29.0	800.	43.8	5.5	54.5	290
11	TBL4	2	1.060	27	.750	.000	.000	.0	.0	4	1.544	1.029*	14.250	11.950	0	1	.4	5.5	55.7	29.0	800.	25.4	5.5	54.5	290
12	TBL4	1	27.000	1	2.214	.001	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	25.4	6.1	56.6	29.0	800.	46.5	1.2	41.1	300
13	TBL4	1	27.000	1	2.214	.001	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	25.4	6.1	56.6	29.0	800.	44.0	1.8	44.8	300
14	TBL4	1	36.000	1	3.286	.001	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	23.4	7.7	58.6	29.0	800.	44.0	5.5	54.5	290
15	TBL4	2	30.000	1	.875	.000	.000	.0	.0	4	45.000	.000	14.250	11.950	0	1	23.2	5.5	55.7	29.0	800.	43.8	5.5	54.5	290
16	TBL4	2	1.060	27	.750	.000	.000	.0	.0	4	1.544	1.029*	14.250	11.950	0	1	.4	5.5	55.7	29.0	800.	25.4	5.5	54.5	290
17	TBL4	2	.625	45	.500	.000	.000	.0	.0	2	.250	.500*	14.250	11.950	0	1	-7.1	6.1	56.6	29.0	800.	27.0	1.8	44.8	300
18	TBL4	2	.312	90	.500	.000	.000	.0	.0	2	.125	.250*	14.250	11.950	0	1	.3	1.8	46.4	29.0	800.	21.0	6.1	55.4	290
19	CONT	2	10.000	4	.750	.000	.000	.0	.0	4	16.000	5.000	14.250	11.950	0	1	12.0	7.0	58.0	31.5	900.	37.0	7.0	57.0	251
20	CONT	2	36.000	1	1.000	.000	.000	.0	.0	4	60.000	.000	14.250	11.950	0	1	27.0	7.0	58.0	31.5	900.	46.0	7.0	57.0	251
21	CONT	2	54.000	1	1.000	.000	.000	.0	.0	4	90.000	.000	14.250	11.950	0	1	22.5	8.0	59.5	31.5	900.	46.0	8.0	58.0	251
22	CONT	3	1.250	30	.750	.000	.000	.0	.0	4	2.059	1.500*	14.250	11.950	0	1	2.5	5.5	56.5	31.5	900.	27.0	5.5	55.0	251
23	CONT	3	.135	250	.500	.000	.000	.0	.0	2	.112	.162*	14.250	11.950	0	1	-2.4	1.8	46.4	31.5	900.	18.0	1.8	44.8	316
24	CONT	1	27.000	1	2.214	.025	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	23.5	5.5	56.5	31.5	900.	46.0	1.8	44.8	316
25	CONT	1	27.000	1	2.214	.025	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	23.5	5.5	56.5	31.5	900.	46.0	5.5	55.0	251
26	SPC3	0	36.000	1872	.407	.012	7.868	-15.0	-10.3	0	.000	36.000	14.250	11.950	0	1	25.9	10.0	61.3	27.3	1000.	37.9	10.0	59.3	214
27	SPC3	0	36.000	1872	.407	.012	7.868	-15.0	-10.3	0	.000	36.000	14.268	11.968	0	1	25.9	10.0	61.3	27.3	1000.	37.9	10.0	59.3	214
28	SPC3	0	36.000	1872	.727	.012	7.868	-17.0	-10.3	0	.000	36.000	14.268	11.968	0	1	16.7	10.0	61.3	27.3	1000.	38.2	10.0	59.3	214
29.	SPC3	0	36.000	1872	.727	.012	7.868	-17.0	-10.3	0	.000	36.000	14.250	11.950	0	1	16.7	10.0	61.3	27.3	1000.	38.2	10.0	59.3	214
30	SPC3	0	17.500	432	1.224	.012	1.796	-20.0	.0	0	.000	18.000	14.250	11.950	0	1	14.0	7.0	58.2	27.3	1000.	32.4	7.0	56.0	251
31	SPC3	0	20.700	432	1.690	.012	1.796	-20.0	.0	0	.000	18.000	14.250	11.950	0	1	14.0	7.0	58.2	27.3	1000.	32.4	7.0	56.0	251
32	SPC3	2	72.000	1	.000	.000	.000	-12.7	.0	4	125.000	.000	14.250	11.950	0	1	29.0	7.0	58.2	27.3	1000.	42.4	7.0	56.0	251
33	SPC3	2	72.000	1	.000	.000	.000	-12.7	.0	4	125.000	.000	14.250	11.950	0	1	25.9	10.0	61.3	27.3	1000.	42.4	10.0	59.3	214
34	SPC3	2	7.600	8	.000	.000	.000	.0	.0	2	6.312	9.000	14.250	11.950	0	1	17.8	4.5	54.3	27.3	1000.	30.0	4.5	53.0	316
35	SPC3	2	15.150	4	.500	.000	.000	.0	.0	2	6.312	18.000	14.250	11.950	0	1	17.8	4.5	54.3	27.3	1000.	33.0	4.5	53.0	316
36	SPC3	2	1.030	46	.750	.000	.000	-9.3	.0	4	1.544	1.500*	14.250	11.950	0	1	-3.1	9.2	60.5	27.3	1000.	23.4	9.2	59.0	250

Table B.2.1 Ku-band Satellite (1st Group) Input Parameters

THERMAL NOISE SUMMARY 12:00:00 06-DEC-89

CARRIER	COMPANY	EARTH - TO - SPACE EIRP (DBW)	POINTING LOSS (DB)	SPACE LOSS (DB)	RCV G/T (DB/K)	SPACE - TO - EARTH EIRP (DBW)	POINTING LOSS (DB)	SPACE LOSS (DB)	RCV G/T (DB/K)	C/KT - (DB/HZ) UP	DN	TOTAL	C/N - (DB) UP	DN	TOTAL	TOTAL THERMAL NOISE (PWOP)	S/N (DB)	BB/KT (DB)	SINGLE ENTRY INTERFERENCE OBJECTIVE (PWOP)	S/I (DB)	C/I (DB)
1	GALS	75.5	.3	207.8	1.8	46.5	.0	206.1	16.8	97.8	85.8	85.5	23.5	11.4	11.2		47.4			=46.9	16.5
2	GALS	73.0	.3	207.8	1.8	42.0	.1	206.1	22.8	95.3	87.2	86.5	21.0	12.8	12.2		47.8			=47.9	16.0
3	GALS	50.8	.3	207.8	1.9	26.1	.0	206.1	20.3	73.2	68.9	67.5	12.3	8.0	6.6			7.4			16.0
4	GALS	40.7	.0	207.8	1.9	17.0	.2	206.1	30.9	63.4	70.2	62.5	8.5	15.3	7.7			8.5			13.0
5	GALS	40.4	.0	207.8	1.9	14.7	.1	206.1	22.8	63.1	59.9	58.2	14.8	11.6	9.9			7.7			18.0
6	GALS	43.5	.0	207.8	1.9	17.8	.2	206.1	30.8	66.2	70.9	64.9	20.2	24.8	18.9	291.	65.4				23.3
7	TEL4	82.0	.3	207.8	-.0	46.5	.0	206.1	16.3	102.5	85.3	85.2	28.2	11.0	10.9		46.5			=51.9	22.0
8	TEL4	82.0	.3	207.8	-.0	44.0	.0	206.1	20.0	102.5	86.5	86.4	28.2	12.2	12.1		47.7			=51.9	22.0
9	TEL4	82.0	.3	207.8	-.0	44.0	.2	206.1	29.9	102.5	96.2	95.3	26.9	20.6	19.7		59.9			=61.3	28.0
10	TEL4	78.9	.3	207.8	-.0	43.8	.2	206.1	29.9	99.4	96.0	94.3	24.6	21.2	19.6			17.2			27.4
11	TEL4	56.1	.3	207.8	-.0	25.4	.2	206.1	29.9	76.6	77.6	74.0	16.3	17.3	13.8			10.9			21.8
12	TEL4	82.0	.3	207.8	-.0	46.5	.0	206.1	16.3	102.5	85.3	85.2	28.2	11.0	10.9		46.5			=51.9	22.0
13	TEL4	82.0	.3	207.8	-.0	44.0	.0	206.1	20.0	102.5	86.5	86.4	28.2	12.2	12.1		47.7			=51.9	22.0
14	TEL4	82.0	.3	207.8	-.0	44.0	.2	206.1	29.9	102.5	96.2	95.3	26.9	20.6	19.7		59.9			=61.3	28.0
15	TEL4	78.9	.3	207.8	-.0	43.8	.2	206.1	29.9	99.4	96.0	94.3	24.6	21.2	19.6			17.2			27.4
16	TEL4	56.1	.3	207.8	-.0	25.4	.2	206.1	29.9	76.6	77.6	74.0	16.3	17.3	13.8			10.9			21.8
17	TEL4	49.5	.3	207.8	-.0	27.0	.0	206.1	20.0	70.0	69.5	66.7	12.0	11.6	8.8			9.7			17.0
18	TEL4	46.7	.0	207.8	-.0	21.0	.2	206.1	30.8	67.5	74.1	66.6	12.5	19.1	11.7			12.6			17.0
19	CONT	70.0	.3	207.8	2.0	37.0	.2	206.1	33.0	92.5	92.3	89.4	22.5	22.3	19.4			16.1			18.0
20	CONT	85.0	.3	207.8	2.0	46.0	.2	206.1	33.0	107.5	101.3	100.4	31.9	25.7	24.8			22.6			28.5
21	CONT	82.0	.3	207.8	2.0	46.0	.2	206.1	34.0	104.5	102.3	100.2	27.1	25.0	22.9			20.7			29.0
22	CONT	59.0	.3	207.8	2.0	27.0	.2	206.1	31.0	81.5	80.3	77.8	20.5	19.3	16.9			13.4			19.7
23	CONT	44.0	.0	207.8	2.0	18.0	.0	206.1	19.8	66.8	60.3	59.4	15.5	9.0	8.1			5.9			12.3
24	CONT	80.0	.3	207.8	2.0	46.0	.0	206.1	19.8	102.5	88.3	88.1	28.1	14.0	13.8		49.4			=49.7	19.8
25	CONT	80.0	.3	207.8	2.0	46.0	.2	206.1	31.0	102.5	99.3	97.6	28.1	25.0	23.3		58.8			=57.3	27.4
26	SPC3	87.2	.5	207.8	-2.7	37.9	.2	206.1	36.0	104.8	96.2	95.6	29.2	20.6	20.1	6324.	52.0		1000.	60.0	
27	SPC3	87.2	.5	207.8	-2.7	37.9	.2	206.1	36.0	104.8	96.2	95.6	29.2	20.6	20.1	6324.	52.0		1000.	60.0	
28	SPC3	78.0	.5	207.8	-2.7	38.2	.2	206.1	36.0	95.6	96.5	93.0	20.0	20.9	17.5	2286.	56.4		1000.	60.0	
29	SPC3	78.0	.5	207.8	-2.7	38.2	.2	206.1	36.0	95.6	96.5	93.0	20.0	20.9	17.5	2286.	56.4		1000.	60.0	
30	SPC3	72.2	.3	207.8	-2.7	32.4	.2	206.1	32.0	90.0	86.7	85.0	17.6	14.3	12.6	6276.	52.0		1000.	60.0	
31	SPC3	72.2	.3	207.8	-2.7	32.4	.2	206.1	32.0	90.0	86.7	85.0	16.8	13.5	11.9	3292.	54.8		1000.	60.0	
32	SPC3	87.2	.3	207.8	-2.7	42.4	.2	206.1	32.0	105.0	96.7	96.1	26.4	18.1	17.5			15.1			25.0
33	SPC3	87.2	.5	207.8	-2.7	42.4	.2	206.1	36.0	104.8	100.7	99.3	26.2	22.1	20.7			18.3			25.0
34	SPC3	72.1	.3	207.8	-2.7	30.0	.2	206.1	28.0	89.9	80.3	79.9	21.1	11.5	11.0			11.8			20.0
35	SPC3	72.1	.3	207.8	-2.7	33.0	.2	206.1	28.0	89.9	83.3	82.4	18.1	11.5	10.6			11.4			20.0
36	SPC3	57.4	.5	207.8	-2.7	23.4	.2	206.1	35.0	75.0	80.7	74.0	14.9	20.6	13.8			10.8			20.0

Table B.2.2 Ku-band Satellite (1st Group) Thermal Noise Summary

FAILS TO MEET SINGLE ENTRY INTERFERENCE OBJECTIVE (DB) 12:00:00 06-DEC-89

2.0 DEGREE SPACING New FCC pattern, 29-25 LOG(A) ; A = GEOCENTRIC ANGLE

INTERFERING

WANTED	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1																																				
2																																				
3	8	*				7	*	9	8	1		*	9	8	1					3				9	9	3	2					1				
4	2	*				*	7	7	5			7	7	5						2				6	6	5	3					1				
5	6	*				*	9	7	6			9	7	6						2				7	7	4	2									
6	1						6	6	4			6	6	4						1				5	5		2									
7	2	1					2	1	1			2	1	1						1	1			2	2											
8	1						1					1								1				1	1											
9																																				
10																																				
11	5	7				6	8	7	6			8	7	6						1				7	7	4	2									
12	2	1					2	1	1			2	1	1						1	1			2	2											
13	1						1					1								1				1	1											
14																																				
15																																				
16	5	7				6	8	7	6			8	7	6						1				7	7	4	2									
17	5	*				8	8	7	6			8	7	6						1				7	7	2	2									
18	1	9				9	6	5	4			6	5	4										4	4	1	1									
19																																				
20																																				
21																																				
22	1	3					4	3	2			4	3	2										3	3	1										
23	2	*				1	4	2	1			4	2	1										3	3											
24																																				
25																																				
26																																				
27	1						1					1												1	1											
28																																				
29																																				
30																																				
31																																				
32																																				
33																																				
34	5	1					5	3	3			5	3	3										5	5											
35	2						3	1	1			3	1	1										2	2											
36	1	4				2	4	4	2			4	4	2										3	3	1	1									

Table B.2.3 Ku-band Satellite (1st Group) Interference Analysis Results (2° Spacing)

INPUT PARAMETERS 13:30:00 06-DEC-89

CAR IER	COM-PANY	TYPE	RF BAND-WIDTH (MHZ)	NO. OF CHAN	CODE RATE/ MOD. INDEX	BOT MOD. FREQ. (MHZ)	TOP MOD. FREQ. (MHZ)	CPAND AVE. TALKER LEVEL (DBMO)	PREEMP NOISE WEIGH (DB)	PHASE	DATA RATE (MBPS)	CHAN. SPACE (MHZ)	TRANSPONDER FREQUENCY UP (GHZ)	TRANSPONDER FREQUENCY DN (GHZ)	POL U P	POL D N	EARTH STATION TRANSMITTER POWR (DBW)	EARTH STATION TRANSMITTER DIAM (M)	EARTH STATION TRANSMITTER GAIN (DB)	--SATELLITE--- RECEIVER GAIN (DB)	--SATELLITE--- RECEIVER TEMP (K)	--SATELLITE--- XMTR EIRP (DBW)	-EARTH STATION RECEIVER DIAM (M)	-EARTH STATION RECEIVER GAIN (DB)	-EARTH STATION RECEIVER TEMP (K)
1	GALS	1	27.000	1	2.333	.025	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	18.5	6.1	57.0	29.9	650.	46.5	1.2	41.3	285
2	GALS	1	27.000	2	2.214	.025	4.200	.0	12.8	0	.00027.000		14.250	11.950	0	1	16.0	6.1	57.0	29.9	650.	42.0	2.4	47.3	285
3	GALS	2	1.229	16	.500	.000	.000	.0	.0	2	.512	1.600*14.250		11.950	0	1	-6.2	6.1	57.0	30.0	650.	26.1	1.8	44.8	285
4	GALS	2	.307	67	.500	.000	.000	.0	.0	2	.128	.400*14.250		11.950	0	1	-5.7	1.8	46.4	30.0	650.	17.0	6.1	55.4	285
5	GALS	2	.067	270	.500	.000	.000	.0	.0	4	.056	.100*14.250		11.950	0	1	-8.5	2.4	48.9	30.0	650.	14.7	2.4	47.3	285
6	GALS	4	.040	270	4.333	.000	.008	.0	25.0	0	.000	.000	14.250	11.950	0	1	-5.4	2.4	48.9	30.0	650.	17.8	6.0	55.3	285
7	GSTR	1	36.000	1	3.286	.025	4.200	56.0	12.8	0	.000	.000	14.250	11.950	0	1	20.0	57.0559.0		29.0	3540.	47.0	7.5	57.4	145
8	GSTR	1	36.000	1	3.286	.025	4.200	56.0	12.8	0	.000	.000	14.250	11.950	0	1	23.0	55.0556.0329.0			3540.	47.0	5.5	54.7	145
9	GSTR	1	22.000	1	1.619	.025	4.200	.0	12.8	0	.000	.000	14.250	11.950	0	1	24.0	35.0	55.0229.0		3540.	47.0	1.2	41.3	250
10	GSTR	2	54.000	1	.000	.000	.000	-14.0	.0	4	90.000	.000	14.250	11.950	0	1	24.0	35.0	55.0229.0		3540.	47.0	5.0	53.7	145
11	GSTR	2	36.000	1	.000	.000	.000	-13.9	.0	4	60.000	.000	14.250	11.950	0	1	22.0	57.0559.0		29.0	3540.	47.0	7.5	57.4	145
12	GSTR	2	36.000	1	.000	.000	.000	-13.9	.0	4	60.000	.000	14.250	11.950	0	1	23.0	25.0556.0329.0			3540.	47.0	5.5	54.7	145
13	GSTR	3	.039	562	.875	.000	.000	-12.7	.0	4	.056	.096*14.250		11.950	0	1	-7.0	57.0559.0		29.0	3540.	14.5	7.5	57.4	145
14	GSTR	3	.039	562	.875	.000	.000	-12.7	.0	4	.056	.096*14.250		11.950	0	1	-4.0	85.0556.0329.0			3540.	14.5	5.5	54.7	145
15	GSTR	1	36.000	1	3.286	.025	4.200	56.0	12.8	0	.000	.000	14.250	11.950	0	1	20.0	57.0559.0		28.0	1800.	42.0	7.5	57.4	145
16	GSTR	1	36.000	1	3.286	.025	4.200	56.0	12.8	0	.000	.000	14.250	11.950	0	1	23.0	25.0556.0328.0			1800.	42.0	5.5	54.7	145
17	GSTR	2	54.000	1	.875	.000	.000	.0	.0	4	90.000	.000	14.250	11.950	0	1	24.0	35.0	55.0228.0		1800.	43.0	5.0	53.7	145
18	GSTR	2	36.000	1	.000	.000	.000	-13.9	.0	4	60.000	.000	14.250	11.950	0	1	20.0	57.0559.0		28.0	1800.	42.0	7.5	57.4	145
19	GSTR	2	36.000	1	.000	.000	.000	-13.9	.0	4	60.000	.000	14.250	11.950	0	1	23.0	25.0556.0328.0			1800.	42.0	5.5	54.7	145
20	GSTR	3	.039	562	.875	.000	.000	-12.7	.0	4	.056	.096*14.250		11.950	0	1	-7.0	57.0559.0		28.0	1800.	9.5	7.5	57.4	145
21	GSTR	3	.039	562	.875	.000	.000	-12.7	.0	4	.056	.096*14.250		11.950	0	1	-4.0	85.0556.0328.0			1800.	9.5	5.5	54.7	145
22	GSTR	3	.112	195	.500	.000	.000	.0	.0	2	.056	.157*14.250		11.950	0	1-11.0411.0		61.0829.0			800.	16.0	1.8	45.3	265
23	GSTR	3	.112	400	.500	.000	.000	.0	.0	2	.056	.157*14.250		11.950	0	1	-5.0	61.0	46.0529.0		800.	6.5	11.0	60.5	265
24	GSTR	3	.224	178	.555	.000	.000	.0	.0	2	.112	.314*14.250		11.950	0	1	-3.0	12.0448.0		29.0	800.	16.8	2.4	47.6	265
25	ASC	2	54.000	1	.000	.000	.000	-14.0	.0	4	90.000	.000	14.250	11.950	0	1	24.0	7.0	58.0	27.0	5900.	50.0	7.0	57.0	251
26	ASC	2	36.000	1	.000	.000	.000	-14.0	.0	4	60.000	.000	14.250	11.950	0	1	24.0	7.0	58.0	27.0	5900.	42.0	7.0	57.0	251
27	ASC	2	10.000	4	.750	.000	.000	-12.0	.0	4	12.00012.000		14.250	11.950	0	1	12.0	7.0	58.0	27.0	5900.	33.0	7.0	57.0	251
28	ASC	2	15.000	4	.500	.000	.000	-5.0	.0	2	6.00018.000		14.250	11.950	0	1	13.0	77.0	57.0527.0		*****	33.0	7.0	56.0	316
29	ASC	2	3.900	14	.500	.000	.000	-5.0	.0	2	1.544	4.500	14.250	11.950	0	1	7.0	77.0	57.0527.0		*****	27.0	7.0	56.0	316
30	ASC	3	.140	126	.500	.000	.000	-5.0	.0	2	.056	.571*14.250		11.950	0	1	-1.0	85.0	55.0	27.0	*****	15.0	5.0	53.5	316

Table B.3.1 Ku-band Satellite (2nd) Group) Input Parameters

THERMAL NOISE SUMMARY 13:30:00 06-DEC-89

CARRIER	COMPANY	EARTH-TO-SPACE EIRP (DBW)	POINTING LOSS (DB)	SPACE LOSS (DB)	RCV G/T (DB/K)	SPACE-TO-EARTH EIRP (DBW)	POINTING LOSS (DB)	SPACE LOSS (DB)	RCV G/T (DB/K)	C/KT - (DB/HZ) UP	DN	TOTAL	C/N - (DB) UP	DN	TOTAL	TOTAL THERMAL NOISE (PWOP)	S/N (DB)	EB/KT (DB)	SINGLE ENTRY INTERFERENCE OBJECTIVE (PWOP)	S/I (DB)	C/I (DB)
1	GALS	75.5	.3	207.8	1.8	46.5	.0	206.1	16.8	97.8	85.8	85.5	23.5	11.4	11.2		47.4			=46.9	16.5
2	GALS	73.0	.3	207.8	1.8	42.0	.1	206.1	22.8	95.3	87.2	86.5	21.0	12.8	12.2		47.8			=47.9	18.0
3	GALS	50.8	.3	207.8	1.9	26.1	.0	206.1	20.3	73.2	68.9	67.5	12.3	8.0	6.6			7.4			16.0
4	GALS	40.7	.0	207.8	1.9	17.0	.2	206.1	30.9	63.4	70.2	62.5	8.5	15.3	7.7			8.5			13.0
5	GALS	40.4	.0	207.8	1.9	14.7	.1	206.1	22.8	63.1	59.9	58.2	14.8	11.6	9.9			7.7			18.0
6	GALS	43.5	.0	207.8	1.9	17.8	.2	206.1	30.8	66.2	70.9	64.9	20.2	24.8	18.9	291.	65.4				23.3
7	GSTR	579.0	.5	207.8	-6.5	47.0	.2	206.1	35.8	592.8	105.1	105.1	****	29.5	29.5		69.8			=61.3	28.0
8	GSTR	579.0	.5	207.8	293.5	47.0	.2	206.1	33.1	892.8	102.4	102.4	****	26.8	26.8		67.1			=61.3	28.0
9	GSTR	79.0	.3	207.8	193.5	47.0	.0	206.1	17.3	293.0	86.8	86.8	****	13.4	13.4		45.4			=49.2	22.0
10	GSTR	79.0	.3	207.8	193.5	47.0	.2	206.1	32.1	293.0	101.4	101.4	215.7	24.1	24.1			21.8			27.2
11	GSTR	581.0	.5	207.8	-6.5	47.0	.2	206.1	35.8	594.8	105.1	105.1	519.2	29.5	29.5			27.3			27.2
12	GSTR	579.0	.5	207.8	293.5	47.0	.2	206.1	33.1	892.8	102.4	102.4	817.2	26.8	26.8			24.6			27.2
13	GSTR	552.0	.5	207.8	-6.5	14.5	.2	206.1	35.8	565.8	72.6	72.6	519.9	26.7	26.7			24.5			21.6
14	GSTR	552.0	.5	207.8	293.5	14.5	.2	206.1	33.1	865.8	69.9	69.9	819.9	24.0	24.0			21.8			21.6
15	GSTR	579.0	.5	207.8	-4.6	42.0	.2	206.1	35.8	594.7	100.1	100.1	****	24.5	24.5		64.8			=61.3	28.0
16	GSTR	579.0	.5	207.8	295.4	42.0	.2	206.1	33.1	894.7	97.4	97.4	****	21.8	21.8		62.1			=61.3	28.0
17	GSTR	79.0	.3	207.8	195.4	43.0	.2	206.1	32.1	294.9	97.4	97.4	217.6	20.1	20.1			17.3			27.2
18	GSTR	579.0	.5	207.8	-4.6	42.0	.2	206.1	35.8	594.7	100.1	100.1	519.2	24.5	24.5			22.3			27.2
19	GSTR	579.0	.5	207.8	295.4	42.0	.2	206.1	33.1	894.7	97.4	97.4	819.2	21.8	21.8			19.6			27.2
20	GSTR	552.0	.5	207.8	-4.6	9.5	.2	206.1	35.8	567.7	67.6	67.6	521.8	21.7	21.7			19.5			21.6
21	GSTR	552.0	.5	207.8	295.4	9.5	.2	206.1	33.1	867.7	64.9	64.9	821.8	19.0	19.0			16.8			21.6
22	GSTR	50.0	.5	207.8	800.0	16.0	.1	206.1	21.1	870.3	59.5	59.5	819.8	9.0	9.0			9.0			17.0
23	GSTR	41.0	.0	207.8	500.0	6.5	.2	206.1	36.3	561.8	65.1	65.1	511.3	14.6	14.6			14.6			17.0
24	GSTR	445.0	.5	207.8	-.0	16.8	.1	206.1	23.4	465.3	62.6	62.6	411.8	9.1	9.1			9.5			17.0
25	ASC	82.0	.3	207.8	-10.7	50.0	.2	206.1	33.0	91.8	105.3	91.6	14.5	28.0	14.3			12.1			27.2
26	ASC	82.0	.3	207.8	-10.7	42.0	.2	206.1	33.0	91.8	97.3	90.7	16.2	21.7	15.2			12.9			27.2
27	ASC	70.0	.3	207.8	-10.7	33.0	.2	206.1	33.0	79.8	88.3	79.2	9.8	18.3	9.2			7.2			20.8
28	ASC	70.0	.3	207.8	482.1	33.0	.2	206.1	31.0	572.6	86.3	86.3	500.8	14.5	14.5			15.5			16.0
29	ASC	64.0	.3	207.8	482.1	27.0	.2	206.1	31.0	566.6	80.3	80.3	500.7	14.4	14.4			15.4			16.0
30	ASC	54.0	.3	207.8	-17.9	15.0	.2	206.1	28.5	56.6	65.8	56.1	5.1	14.3	4.6			5.6			16.0

Table B.3.2 Ku-band Satellite (2nd Group) Thermal Noise Summary

W FAILS TO MEET SINGLE ENTRY INTERFERENCE OBJECTIVE (DB) 13:30:00 06-DEC-89

A 2.0 DEGREE SPACING New FCC pattern, 29-25 LOG(A) ; A = GEOCENTRIC ANGLE

N INTERFERING

T

E

D

WANTED	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1																														
2																														
3	8	*				7	9	*	*	1	1	?			5	7									3					
4	2	*				*	3	5	6						2	5														
5	6	*				*	7	8	8		1	1			4	5									1					
6	1						2	4	5						1	4														
7																														
8																														
9	2	1					2	2	2		1	1													3					
10																														
11																														
12																														
13		*																												
14		*				2																								
15																														
16																									2					
17									1	1															3					
18																														
19																									1					
20	2	*				4	2	2	2																					
21	4	*				7	5	5	5																					
22	7	*				6	8	8	8		1	1			3	3									2					
23	4	*				4	5	6	7						2	5														
24	7	*				2	8	8	8		1	1			3	3									2					
25																														
26																														
27							1	1	1																					
28																														
29	1						2	3	3																					
30	1	*					1	1	1																					

Table B.3.3 Ku-band Satellite (2nd Group) Interference Analysis Results (2° Spacing)

CONSOLIDATED FINANCIAL STATEMENTS

GM Hughes Electronics Corporation and Subsidiaries

STATEMENT OF FINANCIAL RESPONSIBILITY

The following consolidated financial statements of GM Hughes Electronics Corporation and subsidiaries were prepared by management which is responsible for their integrity and objectivity. The statements have been prepared in conformity with generally accepted accounting principles and, as such, include amounts based on judgments of management. Financial information elsewhere in this Annual Report is consistent with that in the financial statements.

Management is further responsible for maintaining a system of internal accounting controls, designed to provide reasonable assurance that the books and records reflect the transactions of the companies and that its established policies and procedures are carefully followed. Perhaps the most important feature in the system of control is that it is continually reviewed for its effectiveness and is augmented by written policies and guidelines, the careful selection and training of qualified personnel, and a strong program of internal audit.

Deloitte Haskins & Sells, independent certified public accountants, are engaged to audit the financial statements of GM Hughes Electronics Corporation and its subsidiaries and express opinions thereon. Their audit is conducted in accordance with generally accepted auditing standards which comprehend a review of internal accounting controls and a test of transactions. The Independent Auditors' Report appears below.

The Board of Directors, through its Audit Committee, is responsible for (1) assuring that management fulfills its responsibilities in the preparation of the financial statements, and (2) engaging the independent public accountants. The Committee reviews the scope of the audits and the accounting principles being applied in financial reporting. The independent public accountants, representatives of management, and the internal auditors meet regularly (separately and jointly) with the Committee to review the activities of each and to ensure that each is properly discharging its responsibilities. To ensure complete independence, Deloitte Haskins & Sells have full and free access to meet with the Committee, without management representatives present, to discuss the results of their audit, the adequacy of internal accounting controls, and the quality of the financial reporting.

President

Bruce W. Alexander
Treasurer

INDEPENDENT AUDITORS' REPORT

1114 Avenue of the Americas
New York, New York 10036

February 13, 1989

Deloitte Haskins+Sells

The Stockholder and Board of Directors of GM Hughes Electronics Corporation:

We have audited the Consolidated Balance Sheet of GM Hughes Electronics Corporation and subsidiaries as of December 31, 1988 and 1987 and the related Statements of Consolidated Income and Available Separate Consolidated Net Income and Consolidated Cash Flows for each of the three years in the period ended December 31, 1988. These financial statements are the responsibility of the Corporation's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, these financial statements present fairly, in all material respects, the financial position of GM Hughes Electronics Corporation and subsidiaries at December 31, 1988 and 1987 and the results of their operations and their cash flows for each of the three years in the period ended December 31, 1988 in conformity with generally accepted accounting principles.

As discussed in Note 1 to the Financial Statements, effective January 1, 1988 the Corporation changed its method of accounting for certain manufacturing overhead costs.

Deloitte Haskins + Sells

STATEMENT OF CONSOLIDATED INCOME AND AVAILABLE SEPARATE CONSOLIDATED NET INCOME

For the Years Ended December 31, 1988, 1987 and 1986

(Dollars in Millions Except Per Share Amounts)

	1988	1987	1986
Revenues			
Net sales:			
Outside customers	$ 7,518.2	$ 7,273.2	$ 7,212.8
General Motors and affiliates (Note 2)	3,482.8	3,134.4	3,158.7
Other income—net	242.6	73.4	68.5
Total Revenues	11,243.6	10,481.0	10,440.0
Costs and Expenses			
Cost of sales and other operating charges, exclusive of items listed below	8,446.1	8,035.5	8,154.8
Selling, general and administrative expenses	1,094.4	882.9	851.5
Depreciation and amortization of property	496.8	460.0	423.4
Amortization of intangible assets (Note 1)	155.2	148.8	148.8
Interest expense	67.2	54.6	50.3
Total Costs and Expenses	10,259.7	9,581.8	9,628.8
Income before Income Taxes	983.9	899.2	811.2
United States, foreign and other income taxes (Note 5)	349.3	378.1	366.1
Income before cumulative effect of accounting change	634.6	521.1	445.1
Cumulative effect of accounting change (Note 1)	18.7	—	—
Net Income	653.3	521.1	445.1
Available Separate Consolidated Net Income (Note 9):			
Adjustments to exclude the effect of purchase accounting	148.8	148.8	148.8
Earnings Excluding Purchase Accounting Adjustments	$ 802.1	$ 669.9	$ 593.9
Available Separate Consolidated Net Income	$ 256.9	$ 219.2	$ 190.0
Average number of shares of General Motors Class H Common Stock outstanding (in millions)	127.9	130.8	127.8
Earnings Attributable to General Motors Class H Common Stock on a Per Share Basis (Note 10):			
Before cumulative effect of accounting change	$1.96	$1.67	$1.48
Cumulative effect of accounting change	0.05	—	—
Net earnings attributable to GM Class H Common Stock	$2.01	$1.67	$1.48

Reference should be made to notes on pages 36 through 42.

STATEMENT OF CONSOLIDATED CASH FLOWS

For the Years Ended
December 31, 1988, 1987 and 1986
(Dollars in Millions)

	1988	1987	1986
Cash Flows from Operating Activities			
Income before cumulative effect of accounting change	$ 634.6	$ 521.1	$ 445.1
Adjustments to reconcile income before cumulative effect of accounting change to net cash provided by operating activities:			
Depreciation and amortization of property	496.8	460.0	423.4
Amortization of intangible assets	155.2	148.8	148.8
Net pension income	(79.3)	(37.1)	(57.5)
Deferred income taxes and other—net	100.7	101.8	54.6
Change in operating assets and liabilities:			
Accounts receivable	60.5	(112.6)	.3
Contracts in process	(48.1)	(110.3)	(136.8)
Inventories excluding effect of accounting change	(89.4)	(22.2)	(17.2)
Prepaid expenses	(129.1)	(61.1)	15.8
Accounts payable	(50.5)	8.5	65.9
Income taxes excluding effect of accounting change	(48.4)	101.3	48.2
Accrued and other liabilities	(296.5)	(10.2)	(167.7)
Other operating accounts	44.2	72.7	(43.5)
Net Cash Provided by Operating Activities	750.7	1,060.7	779.4
Cash Flows from Investing Activities			
Acquisition of companies, net of cash acquired	(373.7)	(110.0)	–
Expenditures for property and special tools	(533.0)	(469.4)	(700.6)
Proceeds from disposals of property	26.7	25.9	39.2
Notes receivable	15.9	(31.6)	–
Net Cash Used in Investing Activities	(864.1)	(585.1)	(661.4)
Cash Flows from Financing Activities			
Net increase in notes payable	145.0	313.6	67.1
Increase in long-term debt	140.4	67.8	121.2
Decrease in long-term debt	(22.5)	(280.9)	(29.9)
Cash dividends paid to General Motors	(175.0)	(144.0)	(120.0)
Net Cash Provided by (Used in) Financing Activities	87.9	(43.5)	38.4
Net increase (decrease) in cash and cash equivalents	(25.5)	432.1	156.4
Cash and cash equivalents at beginning of the year	731.3	299.2	142.8
Cash and cash equivalents at end of the year	$ 705.8	$ 731.3	$ 299.2

Reference should be made to notes on pages 36 through 42.

CONSOLIDATED BALANCE SHEET

December 31, 1988 and 1987

(Dollars in Millions Except Per Share Amount)

ASSETS	1988	1987
Current Assets		
Cash and cash equivalents (Note 1)	$ 705.8	$ 731.3
Accounts and notes receivable:		
Trade receivables (less allowances)	595.0	628.1
General Motors and affiliates (Note 2)	308.6	280.1
Contracts in process, less advances and progress payments of $2,174.4 and $1,981.2	2,035.4	1,756.0
Inventories (less allowances) (Note 1)	783.9	664.0
Prepaid expenses	97.7	66.8
Total Current Assets	4,526.4	4,126.3
Property—Net (Note 3)	2,805.0	2,750.6
Intangible Assets (Note 1)	4,080.6	3,947.0
Investments and Other Assets—principally at cost (less allowances)	395.8	302.7
Total Assets	$11,807.8	$11,126.6

LIABILITIES AND STOCKHOLDER'S EQUITY		
Current Liabilities		
Accounts payable:		
Outside	$ 448.1	$ 429.2
General Motors and affiliates (Note 2)	57.4	49.4
Advances on contracts	529.3	630.3
Notes payable (Note 4)	733.9	588.9
United States, foreign and other income taxes, including deferred amounts of $430.5 and $637.9 (Note 5)	545.0	789.6
Accrued liabilities (Note 8)	1,110.6	939.9
Total Current Liabilities	3,424.3	3,427.3
Long-Term Debt and Capitalized Leases (Note 4)	285.1	168.4
Other Liabilities and Deferred Credits	548.4	459.5
Stockholder's Equity (Note 11):		
Capital stock (outstanding, 1,000 shares, $0.10 par value) and additional paid-in capital	6,365.9	6,365.9
Net income retained for use in the business	1,180.5	702.2
Subtotal	7,546.4	7,068.1
Accumulated foreign currency translation adjustments	3.6	3.3
Total Stockholder's Equity	7,550.0	7,071.4
Total Liabilities and Stockholder's Equity	$11,807.8	$11,126.6

Reference should be made to notes on pages 36 through 42

NOTES TO CONSOLIDATED FINANCIAL STATEMENTS

NOTE 1: SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

Organization and Consolidation

The consolidated financial statements include the accounts of GM Hughes Electronics Corporation (GMHE) and domestic and foreign subsidiaries which are more than 50% owned, principally Hughes Aircraft Company (Hughes) and Delco Electronics Corporation (Delco Electronics). Investments in associated companies in which at least 20% of the voting securities is owned are accounted for under the equity method of accounting. As used herein, the term "the Corporation" refers to GMHE and its subsidiaries.

GMHE became a wholly-owned subsidiary of General Motors Corporation (General Motors or GM) effective December 31, 1985, coincident with the acquisition of Hughes by GM for $2.7 billion in cash and cash equivalents and 100 million shares of GM Class H common stock having an estimated total value of $2,561.9 million. In addition, GM had guaranteed to pay the Howard Hughes Medical Institute (Institute) on December 31, 1989, for each share of GM Class H common stock issued in connection with the acquisition and held by the Institute on that date, the amount, if any, by which the market value per share of GM Class H common stock might be below $30; provided that such payment would not be greater than $20 per share.

On February 28, 1989, GM and the Institute announced that they had reached agreement to terminate GM's existing guarantee obligations. Under other terms of the new agreement: (i) GM purchased 35 million shares of GM Class H common stock from the Institute on February 28, 1989; (ii) the Institute received put options exercisable under most circumstances at $30 per share on March 1, 1991, 1992, 1993 and 1995 for 20 million, 10 million, 10 million and 15 million shares, respectively; (iii) GM will have the option to call the Institute's shares from March 1, 1989 until February 28, 1991, 1992, 1993 and 1995 for 20 million, 10 million, 10 million and 15 million shares, respectively, at a call price of $35 per share for all shares except for the 15 million shares callable until February 28, 1995, for which the call price is $37.50 per share; and (iv) GM paid to the Institute $675 million in cash and approximately $300 million in notes.

The acquisition of Hughes was accounted for as a purchase. The purchase price in excess of the net book value of Hughes, $4,244.7 million, was assigned to patents and related technology, $500.0 million; the future economic benefits to GM of the Hughes Long-Term Incentive Plan (LTIP), $125.0 million; and other intangible assets, $3,619.7 million. These intangible assets are being amortized on a straight-line basis: patents and related technology over 15 years, the future economic benefits of the LTIP over five years and other intangible assets over 40 years. Amortization is applied directly to the asset accounts.

For the purpose of determining earnings per share and

(continued)

NOTE 1: (continued)

amounts available for dividends on the common stocks of General Motors, the amortization of these intangible assets is charged against earnings attributable to GM $1-2/3 par value common stock.

The earnings of GMHE and its subsidiaries since the acquisition of Hughes form the base from which any dividends on the GM Class H common stock are declared. These earnings include income earned from sales to GM and its affiliates, but exclude purchase accounting adjustments (see Notes 2 and 9).

On September 14, 1987, GM issued a new class of preference stock which is convertible, on a one-for-two fixed basis on varying future dates beginning in 1990, into GM Class H common stock. Such preference stock is a common stock equivalent for purposes of computing Earnings Attributable to GM Class H Common Stock on a Per Share Basis. However, the issuance of such preference stock has no dilutive effect, because to the extent that shares of GM Class H common stock deemed to be outstanding would increase, such increased shares would also increase the numerator of the fraction used to determine Available Separate Consolidated Net Income.

Revenue Recognition

Outside sales are attributable principally to long-term contracts. Long-term contract sales are recorded primarily using the percentage-of-completion (cost-to-cost) method of accounting. Under this method, sales are recorded equivalent to costs incurred plus a portion of the profit expected to be realized on the contract, determined based on the ratio of costs incurred to estimated total costs at completion.

Profits expected to be realized on contracts are based on the Corporation's estimates of total sales value and cost at completion. These estimates are reviewed and revised periodically throughout the lives of the contracts, and adjustments to profits resulting from such revisions are recorded in the accounting period in which the revisions are made. Estimated losses on contracts are recorded in the period in which they are identified.

Certain of the Corporation's contracts contain cost or performance incentives which provide for increases in profits for surpassing stated objectives and decreases in profits for failure to achieve such objectives. Amounts associated with incentives are included in estimates of total sales values when there is sufficient information to relate actual performance to the objectives.

Sales under United States Government contracts accounted for 53.2%, 57.3% and 60.1% of total sales in 1988, 1987 and 1986, respectively.

Cash Flows

In the fourth quarter of 1988, the Corporation adopted Statement of Financial Accounting Standards (SFAS) No. 95, Statement of Cash Flows, as required by the Financial Accounting Standards Board (FASB). Accordingly, the Statement of Changes in Consolidated Financial Position for the years ended December 31, 1987 and 1986 has been restated to conform with SFAS No. 95. For purposes of the Statement of Consolidated Cash Flows, cash equivalents are defined as short-term, highly liquid investments with original maturities of 90 days or less.

Supplemental disclosure of cash flow information required by SFAS No. 95 is as follows:

(Dollars in Millions)	1988	1987	1986
Cash paid during the years for:			
Interest	$ 88.1	$ 61.3	$ 50.7
Income taxes	$522.8	$238.3	$215.4
Acquisition of companies:			
Fair value of assets acquired	$649.6	$161.6	$ —
Cash paid	379.0	110.7	—
Liabilities assumed	$270.6	$ 50.9	$ —

Accounts Receivable and Contracts in Process

Trade receivables consist principally of amounts related to long-term contracts and programs. Amounts billed under retainage provisions of contracts are not significant, and substantially all amounts are collectible within one year.

Contracts in process are stated at costs incurred plus estimated profit less amounts billed to customers and advances and progress payments received. Engineering, tooling, manufacturing and applicable overhead costs, including administrative, research and development and selling expenses, are charged to costs and expenses when they are incurred. In accordance with defense industry practice, 1988 amounts include approximately $261.8 million which are not expected to be realized within one year. Under certain contracts with the United States Government, progress payments are received based on costs incurred on the respective contracts. Title to the inventories relating to such contracts (included in contracts in process) vests with the United States Government.

Inventories

Inventories are stated at the lower of cost or market principally using the first-in, first-out (FIFO) or average cost methods.

Major Classes of Inventories

(Dollars in Millions)	1988	1987
Productive material, work in process and supplies	$744.1	$632.9
Finished product	39.8	31.1
Inventories	$783.9	$664.0

Property and Depreciation

Property is carried at cost. Depreciation of property is provided based on estimated useful lives generally using accelerated methods.

Income Taxes

The tax effects of timing differences between pretax accounting income and taxable income, principally related to profits on long-term contracts, provisions for losses on contracts,

(continued)

NOTES TO CONSOLIDATED FINANCIAL STATEMENTS

NOTE 1: (concluded)

employe benefit plans and depreciation, are deferred. Provisions are made for estimated United States and foreign income taxes, less available tax credits and deductions, which may be incurred on remittance of the subsidiaries' undistributed earnings less those deemed to be indefinitely reinvested. At December 31, 1988 and 1987, undistributed earnings of foreign subsidiaries amounted to approximately $253.4 million and $592.3 million, respectively.

GMHE and its domestic subsidiaries join with General Motors in filing a consolidated United States Federal income tax return. The portion of the consolidated tax liability recorded by GMHE and its subsidiaries included in the consolidated return generally is equivalent to the liability they would have incurred on a separate return basis.

In December 1987, the FASB issued SFAS No. 96, Accounting for Income Taxes, to be effective in 1989 with earlier adoption encouraged. During 1988, the FASB delayed implementation of the Statement until 1990. GMHE has not yet adopted the Statement. The effect of the adoption of the Statement will be favorable, but in an amount that the Corporation is unable to quantify at this time.

Research and Development

Expenditures for research and development are charged to costs and expenses as incurred and amounted to $550.9 million in 1988, $416.0 million in 1987 and $408.1 million in 1986.

Foreign Currency Translation

Exchange and translation gains (losses) included in consolidated earnings amounted to $8.7 million in 1988, ($6.1) million in 1987 and ($5.7) million in 1986.

Accounting Change

Effective January 1, 1988, accounting procedures at Delco Electronics were changed to include in inventory certain manufacturing overhead costs previously charged directly to expense. The Corporation believes this change is preferable because it provides a better matching of costs with related revenues. The effect of this change on 1988 earnings was a favorable adjustment of $0.05 per share of GM Class H common stock.

NOTE 2: RELATED PARTY TRANSACTIONS

Sales, Purchases and Administrative Expenses

The amounts due from and to GM and affiliates result from sales of products to and purchases of materials and services from units controlled by GM. Purchases from GM and affiliates, including computer systems services provided by Electronic Data Systems Corporation, amounted to approximately $210.2 million, $171.4 million and $102.5 million in 1988, 1987 and 1986, respectively.

Common administrative expenses are allocated to the Corporation by GM which amounted to $17.5 million, $13.6 million and $26.5 million in 1988, 1987 and 1986, respectively.

Incentive Plans

GMHE and Delco Electronics participate in various incentive plans of GM and its subsidiaries, which cover certain eligible employes.

Other

GMHE and Delco Electronics participate in GM's pension and other postemployment benefit programs (see Note 6).

NOTE 3: PROPERTY—NET

(Dollars in Millions)	1988	1987
Land and improvements	$ 191.8	$ 175.1
Buildings and unamortized leasehold improvements	995.2	908.9
Machinery and equipment	2,423.1	2,138.5
Satellites and related facilities	336.0	297.3
Furniture, fixtures and office machines	104.3	87.9
Construction in progress	186.5	181.3
Total	4,236.9	3,789.0
Less accumulated depreciation	1,437.6	1,060.1
Net real estate, plants and equipment	2,799.3	2,728.9
Special tools—less amortization	5.7	21.7
Property—net	$2,805.0	$2,750.6

NOTE 4: NOTES PAYABLE, LONG-TERM DEBT AND CAPITALIZED LEASES

At December 31, 1988 and 1987, notes payable include amounts due to banks under short-term lines of credit of $70.0 million and $120.0 million, respectively. At December 31, 1988, the Corporation had unused short-term lines of credit of $405.0 million.

(Dollars in Millions)	1988	1987
Foreign bank debt	$116.7	$ 74.5
Term loan	100.0	—
Revolving credit loan	200.0	10.0
Other debt, with interest at 8% to 13%	55.3	57.1
Total	472.0	141.6
Less current portion	214.4	1.8
Long-term debt	257.6	139.8
Capitalized leases	27.5	28.6
Total long-term debt and capitalized leases	$285.1	$168.4

The unsecured revolving credit loan agreement provides for an aggregate commitment of $300.0 million through December, 1989. Interest generally approximates the London Interbank Offered Rate (LIBOR) and is 9.4% at December 31, 1988. The agreement also requires that the Corporation pay a fee of .1875% per annum of the total commitment. The foreign bank debt is denominated in Japanese yen and bears interest at rates ranging from 5.3% to 7.0% at December 31, 1988, with maturity dates from 1991 to 1998. The term loan represents a note payable to an insurance company bearing interest at 9.2% and maturing in 1992.

(continued)

NOTE 4: (concluded)

Annual maturities of long-term debt and capitalized leases are $215.0 million in 1989, $22.6 million in 1990, $6.5 million in 1991, $127.4 million in 1992, $28.0 million in 1993 and $100.0 million thereafter. Property, plant, and equipment with a net book value of $57.8 million at December 31, 1988 is pledged as collateral under such debt.

NOTE 5: UNITED STATES, FOREIGN AND OTHER INCOME TAXES

(Dollars in Millions)	1988	1987	1986
Taxes estimated to be payable currently:			
United States Federal	$413.9	$262.2	$229.5
Foreign	7.3	.3	11.1
State and local	78.4	91.8	36.8
Total	499.6	354.3	277.4
Taxes deferred—net:			
United States Federal	(155.9)	57.1	84.8
Foreign	5.6	(3.8)	(4.6)
State and local	—	(29.5)	8.5
Total	(150.3)	23.8	88.7
Total taxes*	$349.3	$378.1	$366.1

*Excluding effect of accounting change.

Deferred income taxes result from timing differences in the recognition of revenue and expense for financial reporting and for income tax purposes. The principal timing difference has resulted from profits on long-term contracts recognized using the percentage-of-completion method for financial reporting purposes and the completed-contract method for income tax purposes.

The tax effects of timing differences are summarized as follows:

(Dollars in Millions)	1988	1987	1986
Profits on long-term contracts accounted for under the completed-contract method for tax purposes	($231.3)	($246.4)	($184.5)
Utilization of net operating loss carryforwards for tax purposes	—	—	52.0
Tax credit carryforwards	—	47.0	190.0
Provisions for losses on contracts not currently reported for income tax purposes	43.1	100.1	(65.7)
Employe benefit plans	(15.9)	63.0	42.6
Excess of tax over book depreciation	70.8	75.4	59.5
Other	(17.0)	(15.3)	(5.2)
Deferred income taxes—net	($150.3)	$ 23.8	$ 88.7

Under the Tax Reform Act of 1986, the Revenue Act of 1987, and the Technical and Miscellaneous Revenue Act of 1988, the Federal tax deferral benefits related to the completed-contract method have been substantially reduced.

Income before income taxes included the following components:

(Dollars in Millions)	1988	1987	1986
Domestic income	$823.2	$762.8	$694.0
Foreign income	160.7	136.4	117.2
Total	$983.9	$899.2	$811.2

The consolidated effective income tax rate on income before income taxes differs from the United States statutory income tax rate for the reasons set forth in the following table:

	1988	1987	1986
U.S. statutory income tax rate	34.0%	40.0%	46.0%
Investment tax credits	(.3)	(.9)	(2.3)
Foreign tax rate differential	(4.8)	(2.5)	(6.9)
State and local income taxes	5.7	4.2	3.0
Purchase accounting adjustments	5.1	6.6	8.4
Effect of tax rate decrease on reversing timing differences	(6.8)	(4.2)	—
Other	2.6	(1.2)	(3.1)
Effective income tax rate*	35.5%	42.0%	45.1%

*Excluding effect of accounting change.

NOTE 6: PENSION PROGRAM AND POSTEMPLOYMENT BENEFITS

Total pension credit of the Corporation amounted to $79.3 million in 1988, $37.1 million in 1987 and $57.5 million in 1986.

GMHE and Delco Electronics participate in the defined benefit pension plans of General Motors, which cover substantially all of its employes. Plans covering represented employes generally provide benefits of negotiated stated amounts for each year of service as well as significant supplemental benefits for employes who retire with 30 years of service before normal retirement age. The benefits provided by the plans covering salaried employes are generally based on years of service and the employe's salary history. Certain nonqualified pension plans covering executives are based on targeted wage replacement percentages and are generally unfunded. The accumulated plan benefit obligation and plan net assets for the employes of GMHE and Delco Electronics are not determinable separately.

Hughes maintains contributory defined benefit retirement plans covering substantially all of its employes. Benefits are based on years of service and compensation earned during

(continued)

NOTES TO CONSOLIDATED FINANCIAL STATEMENTS

NOTE 6: (concluded)

a specified period of time before retirement. The net pension credit of Hughes included the components shown below.

(Dollars in Millions)	1988	1987	1986
Benefits earned during the year	$ 83.3	$100.6	$ 91.3
Interest accrued on benefits earned in prior years	228.4	220.3	187.7
Actual return on assets	(436.8)	(260.0)	(531.1)
Net amortization and deferral	48.6	(112.3)	175.8
Net periodic pension credit	($ 76.5)	($ 51.4)	($ 76.3)

Costs are actuarially determined using the projected unit credit method and are funded in accordance with United States Government cost accounting standards to the extent such costs are tax-deductible.

The following table sets forth the funded status of the Hughes plans and the amounts recognized in the Consolidated Balance Sheet as of December 31, 1988 and 1987.

	December 31,	
(Dollars in Millions)	1988	1987
Actuarial present value of benefits based on service to date and present pay levels:		
Vested	$1,856.6	$1,784.9
Nonvested	225.0	206.7
Accumulated benefit obligation	2,081.6	1,991.6
Additional amounts related to projected pay increases	466.0	431.6
Total projected benefit obligation based on service to date	2,547.6	2,423.2
Plan assets at fair value	3,792.3	3,444.6
Plan assets in excess of projected benefit obligation	1,244.7	1,021.4
Unamortized net amount resulting from changes in plan experience and actuarial assumptions	(379.8)	(165.8)
Unamortized net asset at date of adoption	(613.5)	(680.7)
Prepaid pension cost recognized in the Consolidated Balance Sheet	$ 251.4	$ 174.9

Plan assets are invested primarily in listed common stock, cash and short-term investment funds, United States government securities and other investments.

The weighted average discount rate used in determining the actuarial present values of the projected benefit obligation shown above was 9.5% at December 31, 1988 and 1987. The rate of increase in future compensation levels was 6.0% at December 31, 1988 and 1987. The expected long-term rate of return on assets used in determining pension cost was 10.0% for both 1988 and 1987.

In addition to providing pension benefits, the Corporation provides certain health care and life insurance benefits for retired employes. Substantially all of the Corporation's employes may become eligible for those benefits if they reach normal retirement age while working for the Corporation. The estimated cost of such benefits, which is expensed as incurred, totaled $35.9 million in 1988, $30.8 million in 1987 and $27.1 million in 1986.

NOTE 7: INCENTIVE PLANS

In 1985, GM stockholder approval was obtained in connection with GM's acquisition of Hughes for a GMHE Incentive Plan. Under this Plan, shares, rights or options to acquire up to 20 million shares of GM Class H common stock may be granted during the ten-year life of the Plan.

The GM Incentive and Compensation Committee may grant options and other rights to acquire shares of GM Class H common stock under the provisions of the Plan. The option price is equal to 100% of the fair market value of GM Class H common stock on the date the options were granted. These nonqualified options generally expire ten years from the dates of grant and are subject to earlier termination under certain conditions.

Changes in the status of outstanding options were as follows:

GM Class H common stock	Option Prices	Shares Under Option
Granted in 1986	$19.75	78,910
Outstanding at December 31, 1986	19.75	78,910
Granted	24.34-24.69	764,100
Terminated	24.34	(4,400)
Outstanding at December 31, 1987	19.75-24.69	838,610
Granted	30.00-30.25	818,375
Exercised	19.75-24.60	(44,530)
Terminated	24.34-30.25	(72,510)
Outstanding at December 31, 1988	$19.75-$30.25	1,539,945

Options for 71,175 shares of GM Class H common stock were exercisable at December 31, 1988; the maximum number of shares for which additional options and other rights may be granted under the Plan was 18,156,080 at December 31, 1988.

(continued)

NOTE 7: (concluded)

Hughes also maintains a bonus plan under which awards are granted to officers and other key executives. The aggregate amount and the individual awards are determined by the Hughes Board of Directors, subject to certain limitations based on earnings. The cost of the Hughes Aircraft Bonus Plan was $33.6 million in 1988, $27.7 million in 1987, and $24.8 million in 1986.

Key officers and employes of GMHE and Delco Electronics participate in various incentive plans of GM.

NOTE 8: ACCRUED LIABILITIES

(Dollars in Millions)	1988	1987
Payrolls and other compensation	$ 350.5	$329.6
Provision for losses on contracts	117.4	57.4
Other	642.7	552.9
Total	$1,110.6	$939.9

NOTE 9: AVAILABLE SEPARATE CONSOLIDATED NET INCOME

Dividends on GM Class H common stock are declared out of the Available Separate Consolidated Net Income of GMHE earned since the acquisition of Hughes by GM. The Available Separate Consolidated Net Income of GMHE is determined quarterly and is equal to the separate consolidated net income of GMHE, excluding the effects of purchase accounting adjustments arising from the acquisition of Hughes, multiplied by a fraction, the numerator of which is the weighted average number of shares of GM Class H common stock outstanding during the period and the denominator of which is currently 400 million shares.

The denominator used in determining the Available Separate Consolidated Net Income of GMHE will be adjusted as deemed appropriate by the GM Board of Directors to reflect subdivisions or combinations of GM Class H common stock and to reflect certain transfers of capital to or from GMHE.

Dividends may be paid on GM Class H common stock only when, as and if declared by the GM Board of Directors in its sole discretion. The current policy of the GM Board of Directors with respect to GM Class H common stock is to pay cash dividends commencing in 1989 approximately equal to 35% of the Available Separate Consolidated Net Income of GMHE for the prior year.

NOTE 10: EARNINGS ATTRIBUTABLE TO GENERAL MOTORS CLASS H COMMON STOCK ON A PER SHARE BASIS

Earnings attributable to General Motors Class H common stock on a per share basis have been determined based on the relative rights of the GM Class H common stock to participate with other GM common stocks in dividends from the earnings of General Motors. The operation of the GMHE Incentive Plan and the assumed conversion of the preference shares discussed in Note 1 do not have a material dilutive effect on earnings per share of GM Class H common stock at this time.

NOTE 11: STOCKHOLDER'S EQUITY

The authorized capital stock of GMHE consists of 1,000 shares of $0.10 par value common stock. At December 31, 1988 and 1987, 1,000 shares having an aggregate par value of $100 were issued and outstanding. All of the outstanding capital stock of GMHE is held by General Motors.

(Dollars in Millions)	1988	1987	1986
Net income retained for use in the business:			
Balance at beginning of the year	$ 702.2	$325.1	$ —
Net income	653.3	521.1	445.1
Cash dividends paid to General Motors	(175.0)	(144.0)	(120.0)
Balance at end of the year	$1,180.5	$702.2	$325.1
Accumulated foreign currency translation adjustments:			
Balance at beginning of the year	$ 3.3	($ 1.3)	$ —
Change during the year	.3	4.6	(1.3)
Balance at end of the year	$ 3.6	$ 3.3	($ 1.3)

As the sole stockholder of GMHE, GM is able to cause GMHE to pay dividends and make advances to or otherwise enter into transactions with GM as GM deems desirable and appropriate. GM reserves the right to cause GMHE to pay dividends to GM in such amounts as GM determines are desirable under the then prevailing facts and circumstances. Such amounts may be the same as, greater than or less than the dividends paid by GM on its Class H common stock. There is no fixed relationship, on a per share or aggregate basis, between the dividends that may be paid by GM to holders of its Class H common stock and the dividends or other amounts that may be paid by GMHE to GM.

NOTE 12: ACQUISITIONS

On December 31, 1988, Hughes acquired substantially all of the net assets of Honeywell Inc.'s Training and Control Systems Division, a designer, developer, and producer of military trainers and simulators. On May 23, 1988, Hughes acquired Rediffusion Simulation Limited and its principal affiliated companies (RSL). RSL is a supplier of commercial and military flight simulator systems and computer-based training systems. The aggregate purchase price of these acquisitions of approximately $379 million was paid in cash. Effective September 30, 1987, Hughes acquired substantially all of the net assets and business of M/A-COM Telecommunications Division, a manufacturer of digital communications products, from M/A-COM Telecommunications, Inc., for cash of approximately $110 million. The acquisitions were accounted for by the purchase method and,

(continued)

NOTES TO CONSOLIDATED FINANCIAL STATEMENTS

NOTE 12: (concluded)

accordingly, the operating results of the entities acquired, which were not material, have been consolidated with those of GMHE since their respective acquisition dates. The respective purchase prices were allocated to the net assets acquired, including intangible assets, based on preliminary estimates of their fair values at the dates of acquisition.

Intangible assets represent principally the excess of cost over the fair value of net assets of purchased businesses which is being amortized using the straight-line method over periods not exceeding 40 years.

NOTE 13: COMMITMENTS AND CONTINGENT LIABILITIES

Minimum future commitments under operating leases having noncancellable lease terms in excess of one year, primarily for real property, aggregating $2,320.6 million, are payable $202.8 million in 1989, $186.2 million in 1990, $162.2 million in 1991, $151.2 million in 1992, $142.1 million in 1993 and $1,476.1 million thereafter. Certain of the leases contain escalation clauses and renewal or purchase options. Rental expenses under operating leases were $207.9 million in 1988, $202.2 million in 1987 and $182.1 million in 1986.

Hughes and Delco Electronics, incident to their business activities, are parties to a number of legal proceedings which are in various stages of development. While litigation not covered by insurance involves aggregate claims for damages against the Corporation which are substantial, it is the opinion of management, based in part upon consultation with outside counsel, that Hughes and Delco Electronics have substantial defenses to such claims which they intend to vigorously pursue and the aggregate ultimate liability of Hughes and Delco Electronics under such claims should not have a material adverse effect on the consolidated financial position of the Corporation.

NOTE 14: SEGMENT REPORTING

The Corporation operates principally within the field of modern high-technology electronics for use in defense, automotive and other products. The defense products segment includes radar and weapon control systems, guided missile systems, and defense satellites. Automobile radios, dashboard instrumentation and other automotive electronic products are included in the automotive products segment. The other products segment includes commercial electronics products and services such as communication satellites, specialized automated production and test equipment, microwave and millimeter-wave components and equipment and solar cells. Intercompany transfers between segments are not material. Information concerning operations by segment is as follows:

(Dollars in Millions)	Defense Products	Automotive Products	Other Products	Corporate	Total
Revenues:					
1988	$6,857.8	$3,456.9	$ 928.9	$ —	$11,243.6
1987	6,617.7	3,215.7	647.6	—	10,481.0
1986	6,491.4	3,179.5	769.1	—	10,440.0
Operating Profit*:					
1988	$ 160.2	$ 618.7	$ 50.3	($20.7)	$ 808.5
1987	289.1	520.5	86.4	(15.6)	880.4
1986	261.8	488.3	72.1	(29.2)	793.0
Identifiable Assets at Year End**:					
1988	$8,300.0	$1,792.4	$1,653.3	$62.1	$11,807.8
1987	7,930.4	1,873.2	1,267.3	55.7	11,126.6
1986	7,578.5	1,654.4	1,146.7	30.5	10,410.1
Depreciation and Amortization*:					
1988	$ 463.2	$ 108.6	$ 80.2	$ —	$ 652.0
1987	442.9	96.1	69.8	—	608.8
1986	406.6	96.9	68.7	—	572.2
Capital Expenditures***:					
1988	$ 412.7	$ 77.9	$ 42.4	$ —	$ 533.0
1987	374.4	44.4	50.6	—	469.4
1986	378.5	265.2	56.9	—	700.6

*Includes $148.8 million ($123.5 million and $25.3 million related to defense and other products segments, respectively) of purchase price accounting adjustments associated with GM's purchase of Hughes Aircraft Company in 1985.

**Identifiable assets include the unamortized goodwill associated with the purchase of Hughes Aircraft Company as detailed below:

	Defense	Other	Total
1988	$3,152.5	$645.7	$3,798.2
1987	3,276.0	671.0	3,947.0
1986	3,399.5	696.3	4,095.8

***Reflects automotive tool rebills of $21.3 million, $84.9 million and $36.3 million in 1988, 1987 and 1986 respectively.

A reconciliation of operating profit shown above to Income before Income Taxes shown in the Statement of Consolidated Income and Available Separate Consolidated Net Income follows:

(Dollars in Millions)	1988	1987	1986
Operating Profit	$808.5	$880.4	$793.0
Other Income—net	242.6	73.4	68.5
Interest Expense	(67.2)	(54.6)	(50.3)
Income before Income Taxes	$983.9	$899.2	$811.2

Export sales from the U.S. were as follows:

(Dollars in Millions)	1988	1987	1986
Asia	$ 265.9	$ 318.9	$ 357.7
Europe	598.8	412.1	311.4
Africa	82.2	82.7	42.6
Canada	402.1	288.5	296.4
Middle East	20.5	53.5	93.6
Latin America	18.7	62.0	11.1
Total	$1,388.2	$1,217.7	$1,112.8

SUPPLEMENTARY INFORMATION

Selected Quarterly Data

(Dollars in Millions Except Per Share Amounts)

	1988 Quarters				1987 Quarters			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Revenues	$2,670.0	$2,874.5	$2,633.8	$3,065.3	$2,684.6	$2,622.8	$2,517.2	$2,656.4
Income before income taxes	283.0	254.5	229.2	217.2	247.7	250.8	245.2	155.5
United States, foreign and other income taxes	87.0	90.6	86.8	84.9	109.7	110.0	111.2	47.2*
Income before cumulative effect of accounting change	196.0	163.9	142.4	132.3	138.0	140.8	134.0	108.3
Cumulative effect of accounting change	18.7	–	–	–	–	–	–	–
Net income	214.7**	163.9	142.4	132.3	138.0	140.8	134.0	108.3
Earnings excluding purchase accounting adjustments	251.9	201.1	179.6	169.5	175.2	178.0	171.2	145.5
Available separate consolidated net income	$ 81.6	$ 64.2	$ 57.2	$ 53.9	$ 57.8	$ 58.3	$ 55.8	$ 47.3
Average number of shares of General Motors Class H Common Stock outstanding (in millions)	129.5	127.7	127.4	127.2	132.0	130.9	130.4	129.9
Earnings attributable to General Motors Class H Common Stock on a per share basis:								
Before cumulative effect of accounting change	$0.58	$0.50	$0.45	$0.43	$0.44	$0.44	$0.43	$0.36
Cumulative effect of accounting change	0.05	–	–	–	–	–	–	–
Net earnings attributable to GM Class H Common Stock	$0.63	$0.50	$0.45	$0.43	$0.44	$0.44	$0.43	$0.36
Stock price range of General Motors Class H common:								
High	$40.63	$35.25	$30.88	$30.63	$22.13	$24.69	$24.94	$25.25
Low	$24.13	$26.63	$28.00	$25.13	$19.44	$21.38	$23.63	$20.13

*The effective income tax rate for the 1987 fourth quarter includes recognition of taxes on reversing timing differences previously deferred at rates in excess of the current statutory rate.

**Includes gain on the sale of a portion of Hughes stock holdings in Nippon Avionics Co. Ltd. of $114.7 million.

Selected Financial Data

(Dollars in Millions Except Per Share Amounts)

	Historical			Pro Forma	
	1988	1987	1986	1985	1984
Revenues	$11,243.6	$10,481.0	$10,440.0	$9,503.8	$8,549.0
Available separate consolidated net income	$ 256.9	$ 219.2	$ 190.0	$ 160.0	$ 169.6
Average number of shares of General Motors Class H Common Stock outstanding (in millions)	127.9	130.8	127.8	131.0	131.0
Earnings attributable to General Motors Class H Common Stock on a per share basis	$2.01	$1.67	$1.48	$1.22	$1.29
Expenditures for property and special tools	$ 533.0	$ 469.4	$ 700.6	$ 744.0	$ 712.9
Cash and cash equivalents	$ 705.8	$ 731.3	$ 299.2	$ 142.8	$ 108.2
Working capital	$ 1,102.1	$ 699.0	$ 382.2	$ 101.4	$ 91.2
Total assets	$11,807.8	$11,126.6	$10,410.1	$9,885.2	$9,491.4
Long-term debt and capitalized leases	$ 285.1	$ 168.4	$ 383.2	$ 293.1	$ 295.5