

DOMESTIC LONG-DISTANCE COMMUNICATIONS NETWORK STUDY  
Communications Systems Engineering

COMPUTER PROGRAM FOR DETERMINING SATELLITE COSTS

by

J.H. Thomas

Systems Modelling & Analysis Group

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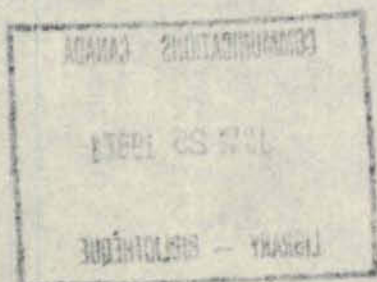
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## 1. INTRODUCTION

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This report describes a computer program which models a communications satellite to meet predetermined system parameters.

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This report describes a computer program to model a communications satellite to meet predetermined system parameters. The modelling technique used is based on "A Technique for Modelling Communications Satellites" presented in the Comsat Technical Review, Spring 1972.

The technique is based on relationships derived from existing satellite designs. Future satellites may be planned based on the parametric relationships established by these designs and reasonable extrapolations thereof. The technique is not intended to provide exact designs but is useful for planning design alternatives and testing the sensitivity of the results to parameter changes.

The program is particularly useful when spot beam technology is being studied and the transponders in the satellite are not all identical. The program will determine the required characteristics of the individual transponders and estimate the weight and cost of the satellite.

The program has been verified by modelling both the ANIK and the proposed Fairchild/TRW domestic satellite systems. The results compare favourably with the known characteristics of these satellites.

The space segment costs derived from the use of the program may be used as input in network modelling as described in "The Network Optimization Technique Used in the Domestic Long Distance Communications Network Study" by R.R. Bowen, Serial Document No. 8.

## 2. GENERAL DESCRIPTION

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The computer program may be broken into seven separate blocks.

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The program may be broken into seven segments as follows:

- Section 1. - Accepts input data defining the parameters of the system for which the satellite is to be designed.
- Section 2. - Determines the antenna gain for each subsystem based on the required beam coverage. Designs the antenna reflector based on the maximum gain required by any of the subsystems in the satellite.
- Section 3. - Determines the communications weight common to all the subsystems in the satellite.
- Section 4. - Specifies the required satellite transmitter power and determines the weight of the transmitter. Determines the weight of any associated batteries required to meet the specified eclipse performance.
- Section 5. - Determines the weight of the solar array and sums the individual subsystem weights to determine the communications payload weight.
- Section 6. - Determines the utilization factor to convert the communications payload to satellite mass at beginning of life computes the cost of producing and launching the satellites.
- Section 7. - Prints out the satellite subsystem parameters and the complete satellite parameters. Prints out separately the total cost breakdown and the total annual charges.

### 3. INPUT DATA

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The overall satellite parameters and the communications parameters which the individual subsystems in the satellite are required to meet must be given.

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The basic satellite parameters such as downlink frequency, the number of receiver boxes\* and the number of satellites required are inputted as common parameters to the program. System parameters such as satellite antenna beamwidths, downlink carrier-to-noise densities, earth station parameters and eclipse protection requirements are inputted separately for each subsystem.

Input data specifications are given in FIGS. 1 and 2. In all cases data is accepted in G.O. format as used on XDS-Sigma 7/9 computers.

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\*A receiver box contains dual receivers and driver amplifiers consisting of two mixer assemblies, dual frequency generator, dual driver amplifier and receiver power converters in an EMI shield.



#### 4. SIMPLIFIED PROGRAM

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The computer program is described below.

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1. Input:           The North-South antenna beamwidth (BW1)  
                  The East-West antenna beamwidth (BW2)  
  
Calculates:        $GS = 40.8 - 10 \log (BW1 * BW2)$   
  
Determines:       The antenna gain (GS) required by each subsystem.
2. Input:           The transmit frequency (F) in GHz  
  
Calculates:        $ARW = 0.28 * 10^{(GS/10)} * RMD / F * F$   
  
Determines:       The reflector weight (ARW) based on the maximum reflector size required by any of the subsystems sharing that reflector. The efficiency is 27%.
3. Input:           The number of receiver boxes (DAT(7))  
                  The number of reflectors (DAT(8))  
                  The number of feedhorns (DAT(9))  
  
Calculates:        $WCE = DAT(7) * WR + DAT(8) * ARW + DAT(9) * WF$   
  
Determines:       The communications payload weight exclusive of transmitters (WCE)
4. Input:           The diameter in feet of the earth station antennas associated with each subsystem D(I)  
  
                  The noise temperature in dB of the receiver associated with the earth stations T(I)  
  
                  The specified down link carrier-to-noise density which the individual subsystems must meet CNOD(I)  
  
Calculates:        $G = 5.6 * (D(I)^2) * F * F$   
                   $GES = 10 * \log(G)$   
                   $TXS = CNOD(I) - GS + 20 \log F - GES + T(I) - 42.9$   
  
Determines:       The antenna gain in dB (G) of the earth station associated with each subsystem. The transmitter

power (TXS) required by each subsystem in the satellite. (The equation allows 1 dB for satellite output losses.)

5. Input: Any additional power required by any subsystem AP(I)  
 Calculates:  $TXSW = (10^{**} TXS/10) * 3.4 + AP(I)$   
 Determines: The total DC power requirements for each subsystem (TXSW)
6. Input: The eclipse factor AK(I) for each subsystem.  
 The number of channels per beam M(I)  
 The number of beams N(I)  
 Calculates:  $PAR = 1.1 * (AK(I) * TXSW / 13.1 + TXSW) * M(I) * N(I)$   
 $PE = AK(I) * TXSW * M(I) * N(I) / 0.81$   
 Determines: The solar array output power (PAR) required by each subsystem and the total solar array power (PRR) required by all the subsystems. The total DC power required by each individual subsystem (PE).
7. Input: The spares ratio for the transmitters in each subsystem SS(I)  
 Calculates:  $WTWT = 3.5 + (10^{**} (TXS/10)) / 10$   
 $WEM = M(I) * N(I) * ((2 * WM) + WTWT * (SS(I) + 1))$   
 Determines: The weight of one transmitter (WTWT) and the total weight of all the transmitters in the same subsystem (WEM)
8. Input: None required  
 Calculates:  $WES = 1.2 * PE / ESS$   
 $NO = NO + N(I) * M(I)$   
 Determines: The weight of the batteries associated with the transmitters in each subsystem (WES).  
 The number of transponders in the spacecraft (NO)
9. Input: None required  
 Calculates:  $GA = \frac{PRR}{(0.045 PRR + 90)}$

FIGURE 1

BASIC SATELLITE PARAMETERS

DAT(1)	DAT(2)	DAT(3)	DAT(4)	DAT(5)	DAT(6)	DAT(7)	DAT(8)	DAT(9)	DAT(10)
<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>

KEY:

DAT(1)	Downlink Frequency (GHz)
DAT(2)	Nos. of satellites made (NS1)
DAT(3)	Nos. of satellites launched (NS2)
DAT(4)	Nos. of satellites over which development is amortized (NS3)
DAT(5)	Any R&D costs in millions of dollars (R)
DAT(6)	Any incentive charges in millions of dollars (AIC)
DAT(7)	Nos. of receiver boxes in satellite
DAT(8)	Nos. of antennas in satellite
DAT(9)	Nos. of feedhorns in satellite
DAT(10)	Nos. of subsystems in satellite

FIGURE 2

SUBSYSTEM SYSTEM REQUIREMENTS

Subsystem No. ISS ☐

N1	BW1	BW2	CNOD	D	T	
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
N2	AP	AW	AK	M	N	SS
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
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KEY:

ISS Subsystem reference number  
 N1 Line number  
 BW1 E-W beamwidth (deg)  
 BW2 N-S beamwidth (deg)  
 CNOD Downlink CNO (dB)  
 D Dia. E.S. antenna (ft)  
 T Temp of E.S. Rx. (db)

N2 Line number  
 AP Any additional power (watts)  
 AW Any additional weight (lbs)  
 AK Eclipse capability (i.e. 0.50  $\equiv$   $\frac{1}{2}$  protection)  
 M Nos. of R.F. channels/beam  
 N Nos. of beams  
 SS Transmitter spares ratio (i.e. 0.33  $\equiv$  1 spare/3 Tx's).

If (GA.LT. 3.5)      GA = 3.5  
 If (GA.GT. 18.0)    GA = 18.0  
 WAR = PAR/GA

- Determines: The weight of the solar array (WAR) required by each subsystem.
10. Input: The weight of any additional equipment associated with the subsystem AW(I)
- Calculates:  $ATW = (WCE/NO) * N(I) * M(I) + AW(I)$
- Determines: The weight of the common equipment associated with each subsystem (ATW)
11. Input: None required
- Determines: The weight of the communications equipment associated with each subsystem (WHS). The total weight of all the communications equipment (WSC)
12. Input: None required
- Calculates: If (WSC.LT.400.) GO TO 6T  
 $WS = WSC / ((0.31/2400 * WSC) + 0.3)$   
 6T WS = WSC/0.38
- Determines: The total weight of the spacecraft at start of life.
13. Input: None required
- Calculates:  $RAS = WHS/WSC$   
 $WSS = WS * RAS$
- Determines: The ratio (RAS) of the total communications payload for each subsystem to the total communications payload. The total satellite weight apportioned to each subsystem (WSS)
14. Input: The number of satellites built DAT(2)  
 The number of satellites launched DAT(3)  
 The number of satellites over which development is amortized DAT(4)
- Calculates:  $COS = (R + ((0.9/DAT(4) + 0.22) * DAT(2) + 0.3 * DAT(3)) * WS ** 0.5)$
- Determines: The total capital cost inclusive of launch costs of the complete space system (COST)



15. Input: The total incentive costs in millions of dollars (AIC)
- Calculates: 
$$\text{SATAN} = ((0.19 * 0.9 / \text{DAT}(4) + 0.61 * 0.22) * \text{DAT}(2) + 0.22 * 0.3 * \text{DAT}(3)) * (\text{WS} ** 0.5) + 0.22 * \text{AIC} * \text{DAT}(3)$$
- Determines: The total space system annual charges (SATAN) in millions of dollars.

## 5. RESULTS OF ANIK SATELLITE SIMULATION

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The results of a simulation of the ANIK satellite based on the input data given is presented below.

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Comparative figures for the ANIK satellites are given in brackets. It should be noted that the total capital cost is influenced by the number of satellites over which development is amortized.

	<u>INPUT</u>									
	4.0	3.0	2.0	3.0	.0	.0	1.0	1.0	1.0	1.0
1	1.0	3.0	8.0	102.2	97.0	22.0				
	2.0	.0	20.0	1.0	12.0	1.0	.0			

	<u>OUTPUT</u>	
	1	TOTAL
SAT G	27.00	27.00 (27)
OUT (W)	5.11	( 5)
DC REQ	246.88	246.88 (240)
TX WT	67.33	
BAT WT	51.49	
AR WT	70.54	
REM WT	36.38	
COM WT	225.74	225.74
TOT WT	594.05	594.05 (600)
TOTAL DEV. COST		21.94
TOTAL PROD. COST		16.09
CAPITAL PER LAUNCH		7.31 (7.5)
TOTAL CAPITAL COST		52.65 ( 48)
TOTAL ANNUAL CHARGE		17.20
*STOP* 0		

## 6. RESULTS OF FAIRCHILD/TRW DOMESTIC SATELLITE SIMULATION

The results of a simulation of the Fairchild/TRW satellite based on the input data given is presented below.

Comparative figures for the actual Fairchild/TRW satellites are given in brackets. It should be noted that the total capital cost is influenced by the number of satellites over which development is amortized.

<u>INPUT</u>									
4.0	3.0	2.0	6.0	.0	.0	2.0	2.0	7.0	2.0
1									
1.0	3.0	8.0	102.2	97.0	22.0				
2.0	.0	15.0	1.0	6.0	2.0	.0			
2									
1.0	3.0	3.0	106.2*	97.0	22.0				
2.0	.0	15.0	1.0	4.0	3.0	.0			

<u>OUTPUT</u>					
	1		2		TOTAL
SAT G	27.00	(28)	31.26	(30.5)	31.26
OUT (W)	5.11	( 5)	4.81	( 5)	
DC REQ	246.88		232.55		479.43 (460)
TX WT	67.33		66.98		
BAT WT	51.49		48.50		
AR WT	57.45		54.12		
REM WT	43.69		43.69		
COM WT	219.96		213.28		433.24 (400)
TOT WT	578.85		561.27		1140.12 (1030)

TOTAL DEV. COST	15.19	
TOTAL PROD. COST	22.29	
CAPITAL PER LAUNCH	10.13	(10.6)
TOTAL CAPITAL COST	57.74	
TOTAL ANNUAL CHARGE	10.31	
*STOP* 0		

\*The carrier-to-noise density given includes 4 dB allowance to compensate for losses in the output circuits in the satellite associated with the spot beams.



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