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Aerospace Report No.
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Part 4
Revision 1
26 February 1975

SHUTTLE USER ANALYSIS (STUDY 2.2)
FINAL REPORT

Volume III: Business Risk and Value of Operations In Space (BRAVO)

Part 4: Computer Programs and Data Look-Up

Prepared by

Advanced Mission Analysis Directorate
Advanced Orbital Systems Division

30 September 1974

Systems Engineering Operations
THE AEROSPACE CORPORATION
El Segundo, California

Prepared for

OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Volume III: Business Risk and Value of Operations In Space (BRAVO)

Part 4: Computer Programs and Data Look-Up

Approved by

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FOREWORD

The Shuttle User Analysis (Study 2.2) Final Report is comprised of four volumes, which are titled as follows:

Volume I - Executive Summary

Volume II - User Charge Analysis

Volume III - Business Risk and Value of Operations In Space (BRAVO)

- Part 1 - Summary
- Part 2 - User's Manual
- Part 3 - Workbook
- Part 4 - Computer Programs and Data Look-Up

Volume IV - Standardized Subsystem Modules Analysis

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REVISION SUMMARY

REV. CODE	REV. DATE	REVISION DETAILS	REVISION ACTION	REV. CCN	REVISION APPROVAL(S)
Revision 1	26 February 1975	Title page	Revised		Robert H. Herndon, Group Director Advanced Mission Analysis Directorate Advanced Orbital Systems Division 1 April '75 Date Ernest I. Pritchard, Director Study 2.2 Office Advanced Mission Analysis Directorate
		Revision Summary Page	New		
		Page 5-1	Revised		
		Page 5-3	Revised		
		Page 5-6	Revised		
		Page 5-7	Revised		
		Page 5-8	Revised		
		Page 13-2	Revised		
		Page 13-3	Revised		

AEROSPACE FORM 3024

TABLES

FIGURES

1. INTRODUCTION

This part (Part 4) of the BRAVO report contains computer program listings as well as graphical and tabulated data needed by the analyst to perform a BRAVO analysis. This document contains some information previously documented in Reference 1-1 but reproduced here for easy availability. Sections 5, 12, and 13 are new material. Sections 3 and 4 have been revised. Only minor changes have been made to Sections 6, 7, 8, 9, and 10.

Section 2 describes the graphical aid which can be used to determine the earth coverage of satellites in synchronous equatorial orbits. Section 3 contains the listing for the Satellite Synthesis Computer Program as well as a sample printout for the DSCS-II satellite program and a listing of the symbols used in the program. This program is coded in FORTRAN language. The APL language listing for the Payload Program Cost Estimating Computer Program is given in Section 4. This language is compatible with many of the time-sharing remote terminal computers used in the United States. Section 5 contains the APL listings for the Satellite System Optimization Risk, Logistics, and System Computer Program, which is also referred to as RISK. Information on the NASA Space Tracking and Data Network (STDN) is given in Section 6. Data on the Intelsat Communications network are contained in Section 7. Costs for telecommunications systems leasing, line-of-sight microwave relay communications systems, U. S. Postal Service, submarine telephone cables, and terrestrial power generation systems are described in Sections 8 through 12, respectively. The APL language listing for the Cost Effectiveness Computer Program is given in Section 13.

References used in Sections 6 through 12 are listed in Section 14.

2. GRAPHICAL AID FOR DETERMINING COVERAGE BY SATELLITES IN SYNCHRONOUS EQUATORIAL ORBITS

This section describes the use of a graphical aid developed by The Aerospace Corporation for use in determining earth coverage by satellites in geosynchronous orbit. The aid allows the user to:

1. establish the footprint around an aiming point corresponding to a given antenna bandwidth when he is given the prescribed boresight aiming point on the earth's surface, and

2. define the required orientation of the antenna beam axis and the antenna beamwidth when he knows the area on the earth's surface to be covered by a beam emanating from the satellite.

The aid itself, which consists of:

1. an azimuthal equidistance mapping of longitude meridians and latitude parallels (Fig. 2-1);

2. a set of ten transparent coverage overlays displaying earth footprints (i.e., beam intersections) corresponding to six antenna beamwidths from 0.5 to 16 deg and a series of ten off-nadir aiming points from 0 to 8.5 deg (Fig. 2-1a through Fig. 2-1j); and

3. a transparent overlay of visibility circles for six series of elevation angles which conform to the above mapping (Fig. 2-1k);

is contained in an envelope at the back of last years report, ATR-74(7334)-1, Vol. IV, Part 4 (15 February 1974)*.

The aid is currently used to answer two specific questions, although other applications may be developed in the future as the user becomes more knowledgeable in its usage. The use of the aid in answering these questions is illustrated by the following two examples.

---

* This report (see Reference 1-1, Section 14 for full title) is available upon request from The Aerospace Corporation. Contact E. I. Pritchard, telephone (213) 648-5737.

1. What is the beam's footprint on the earth when the off-nadir angle and azimuth for the boresight aiming point on the earth's surface is given?

Example:	Satellite longitude	=	100 deg E
	Off-nadir angle	=	5 deg
	Azimuth angle	=	40 deg

Place the cross (+) on Figure 2-1f at the center of Figure 2-1 and rotate Figure 2-1f until the index line intersects the azimuth scale on Figure 2-1 at 40 deg. The resulting aiming point is approximately 121 deg E longitude (21 deg from the graphical aid plus the original satellite longitude of 100 deg) and 23 deg N latitude. The coordinates for the footprints corresponding to a beamwidth of 0.5, 1, 2, 4, 8, 16 deg can be read directly from the appropriate footprint traced on Figure 1-1, i.e., for a bandwidth of 1 deg, the footprint runs from approximately 117 to 124 deg E and 20 to 26 deg N.

2. What is the required orientation of the antenna beam axis and the antenna bandwidth if it is desired to cover a specific area of the earth's surface by a beam emanating from a satellite in synchronous equatorial orbit?

Example: On Figure 2-1, plot the specific area to be covered relative to the satellite's longitude (0 deg on the figure). Select the transparent coverage overlay (Figure 2-1X)[1] which best covers the specified area. Place the cross (+) on this overlay at the center of Figure 2-1. Rotate Figure 2-1X until the area on Figure 2-1 is covered by a beam footprint. The index line on Figure 2-1X intersects the azimuth scale of Figure 2-1 at the required azimuth. The required beamwidth is that corresponding to the smallest footprint which encloses the specified area.

The graphical aid can also be used to determine the antenna elevation angle to any ground location by placing the cross (+) in Figure 2-1k at the center of Figure 2-1. Thus, for the first example, the elevation angle would be approximately 66 deg.

---

[1] $a \leq X \leq j$

3. SATELLITE SYNTHESIS COMPUTER PROGRAM

3.1 PROGRAM LISTING

The listing for the Satellite Synthesis Computer Program is shown on the following pages of this section in FORTRAN language.

```
      PROGRAM SSPRO (INPUT,OUTPUT,TAPE60=INPUT)
      REAL  MPRL, MPFM, MPFR, MP1, MPIR, MPGR, MP2R
    4 CONTINUE
C     THIS ROUTINE READS THE VALUES FROM THE DATA CARD DECK
    2 FORMAT (
     1 A10, 4F10.4,   A10         /
     2      4F10.4,  2A10         /
     3  A10, F10.4,  2A10, F10.4, A10   /
     4      4F10.4,   A10, F10.4 /
     5      5F10.4,   A10          /
     6      6F10.4                 /
     7      6F10.4                 /
     8      6F10.4                 )
    5 READ (60, 2     )
     1    CODE,      ORBAPO,    ORBPER,    ORBINC,     PBATF ,   STABTYP,
     2    XMISPWR,   PNTACC,    DEN1,      XIOC,       STRTYP,   PROPTYP,
     3    PWRTYP,        S    ,  ORINT,    ACSPROP,    XME1,        TYPE,
     4    SORTIE,        B,          C,    CFI,        PADTYP,   DV1,
     5    XMMDMIN,   XMMDINC,   XMMDMAX,       R    ,  REDUN,    PROGRAM,
     6    XMODMIN,   XMODINC,   XMODMAX,   PACKFTR,    D,            T ,
     7    XNDNLNK,   XNTAPRC,   DATAPRO,   ENCODR,     XNXPOND,  PWRXPON,
     8    ANTDIAM,   COMFREQ,    XNANT,        F,           G,          H
      IF ( ORBAPO .LT. 20. ) STOP
      G = 32.2
      IF (SORTIE .EQ.  1. ) GO TO  110
      PF = PACKFTR
      RETGR = 500. $ RET1R = 500. $ RET2R = 750. $ RETSOR = 100.
      EXCGR =     0. $ EXC1R =1265. $ EXC2R =1900. $ EXCSOR =     0.
      XMAGGR =    0. $XMAG1R =1575. $XMAG2R =2300. $XMAGSOR =     0.
      DDKGR = 400. $ DDK1R = 400. $ DDK2R = 600. $ DDKSOR =     0.
      RAILGR = 320. $RAIL1R =     0. $RAIL2R =     0. $RAILSOR =     0.
      DISGR = 270. $ DIS1R = 270. $ DIS2R = 270. $ DISSOR = 150.
       IF (DV1 .LT. 2. ) DV1 = 0.000
      IF (STABTYP .EQ. 10HSPIN       ) ORINT =0.OR.10HUNORI
      IF (STABTYP .EQ. 10H2-SPIN     ) ORINT =0.OR.10HUNORI
      IF (STABTYP .EQ. 10HSPIN       ) PADTYP =0.OR.10HRIGID
      IF ( ORINT  .EQ. 10HUNORI      ) STRTYP =0.OR.10HENDO
      XNDL = XNDNLNK
      XNTR = XNTAPRC
      DP   = DATAPRO
      ENC  = ENCODR
      XME2 = 0.
      XNAME =   6HSATWTS
      CALL DATE (TODAY ).
      POM = 896.
       IF ( PROPTYP .EQ. 10HSOLID      ) PD = 111.
       IF ( PROPTYP .EQ. 10HLIQUID     ) PD = 63.
       IF ( PROPTYP .EQ. 10HNONE       )  PD = 1.
       IF ( PD .LT. 1. ) PD = 1.
      IF (TYPE .EQ. 10HCOM       ) GO TO 11
      IF (TYPE .EQ. 10HOBS       ) GO TO 12
      IF (TYPE .EQ. 10HNAV       )GO TO  13
   11  CONTINUE
C       USE THESE FACTORS FOR COM ( COM )
        ECFM = 1.33
        GNFM = 1.79
        ACINFM = 1.28
```

```
300        IF (ACSPROP .EQ. 10HCOLD GAS   ) ACINFM = 2.8                       000063
304          TTCFM   = 0.75                                                      000064
305          ELFM    = 1.45                                                      000065
307        XMEFM = 1.50                                                          000066
310        XMMDLC = 5.                                                           66-1
312          SATLIFC = ( 1.223 * XMMDLC ) + 0.067                                66-2
315        GO TO 14                                                              000067
315    12  CONTINUE                                                              000068
       C       USE THESE FACTORS FOR OBS ( EOS )                                 000069
315         ECFM = 1.35                                                          000070
316         GNFM = 1.08                                                          000071
320         ACINFM  = 2.30                                                       000072
321         IF (ACSPROP .EQ. 10HHOT GAS    ) ACINFM = 1.28                       000073
325         TTCFM    = 0.54                                                      000074
326         ELFM     = 2.40                                                      000075
330         XMEFM    = 1.00                                                      000076
331        XMMDLC = 1.                                                           76-1
333        GO TO 14                                                              000077
       C       USE THESE FACTORS FOR NAV ( SEO )                                 000078
333    13   ECFM = 1.35                                                          000079
334         GNFM = 1.07                                                          000080
336         ACINFM = 1.28                                                        000081
337        IF (ACSPROP .EQ. 10HCOLD GAS   ) ACINFM = 2.8                         000082
343         TTCFM  = 1.16                                                        000083
344         ELFM = 1.81                                                          000084
346         XMEFM = 1.47                                                         000085
347        XMMDLC = 2.                                                           85-1
351    14  CONTINUE                                                              000086
351        STRRL = 1.0 $ ECRL = 1.0 $ GNRL = 1.0 $ AMRL = 1.0 $ ACINRL = 1.0     000087
356        TTCRL = 1.0 $ ELRL = 1.0 $ XMERL = 1.0                                000088
361          ADPRL = 1.0 $ PALLRL = 1.0                                          000089
363         AMFM = 1.0                                                           89-1
365    20     CONTINUE                                                           000090
365         XMOD = XMODMIN                                                       000091
367    22   CONTINUE                                                             000092
367         XMMD = XMMDMIN                                                       000093
371    23   CONTINUE                                                             000094
373        ACINRLF = (.1018 * XMMD) + 0.5209                                     000095
375        TTCRLF  = (.1814 * XMMD) + 0.5465                                     000096
377        GNRLF   = (.1334 * XMMD) + 0.6565                                     000097
402        ELRLF   = (.0594 * XMMD) + 0.8515                                     000098
405        DISTRLF = 1.0                                                         000099
       C        DSCS-II (777) HAS AN MMD OF 4 YEARS FOR COM MISSION EQUIPMENT    99-1
406         XMERCOM = ( .1814 * XMMD ) + 0.2744                                  100
410         XMERLF = 1.                                                          100-1
411          IF ( CODE .EQ. 10HDSCS-II    ) XMERLF = XMERCOM                     100-2
415        SATLIF = ( 1.223 * XMMD  ) + 0.067                                    000101
                                                                                 000102
       C   THIS ROUTINE CALCULATES THE CURRENT EXPENDABLE WEIGHT (COL 1 )        000103
       C   --------------------------------------------------------------        000104
420        XMMD1 = 2.5                                                           000100
421        SATLIF1= ( 1.223 * XMMD1 ) + 0.067                                    000105
423        GW1 = 1000.                                                           000107
424         DW1 = 800.                                                           000108
426     8  CONTINUE                                                              000109
426    17  CONTINUE                                                              000110
426        XLTOD1 = 1.0                                                          000111
```

```
427          IF (DEN1 .GT. 0. )GO TO 28
432          IF (GW1 .GE. 2000. ) GO TO 26
434          IF (GW1 .LT. 2000. ) GO TO 27
436     26   CONTINUE
436          DEN = 144.335 / ((GW1 - MP1 - AMIN1 ) ** 0.374153 )
444          IF (GW1 .GT. 10000. ) DEN = 4.5
451          GO TO 28
452     27   CONTINUE
452          DEN =   36.8468 /((GW1 - MP1 - AMIN1 ) ** 0.194521 )
460          IF (GW1 .LT. 500.    ) DEN = 11.
465     28   CONTINUE
465          IF (DEN1 .GT. 0.) DEN = DEN1
470          VOL1 = DW1 / DEN
472          DIAM1 = (VOL1 / (.785 * XLTOD1)) ** .333333
477           XLG1 = XLTOD1 * DIAM1
500          IF (DIAM1.LT. 14.7 ) GO TO 15
503     24   CONTINUE
503          DIAM1 = 14.67
504           IF (STABTYP .EQ. 10H2-SPIN      .AND. ACSPROP .EQ. 10HHOT GAS    )
            1  WPF = 0.348
515          XLG1 = VOL1 / (.785 * (DIAM1 ** 2.))
523     15   CONTINUE
523          DIAM1E = 3. * ANTDIAM
525          XLG1E  = XLG1  + ANTDIAM
526          GWT = GW1
530          EC1  = 0.025  * GW1
531          AVEALT  = (ORBAPO + ORBPER) / 2.
534          WGN3A = 1.11 * (( GW1 ** .537) * (PNTACC ** (-0.243)))
544          WGNSPIN =  1.79 * ((GW1 ** .35 ) * (PNTACC ** (-0.39 )))
554          WG2SPIN =  3.54 * ((GW1 ** .417) * (PNTACC ** (-0.107)))
564          IF (STABTYP .EQ. 10HSPIN       ) GN1 = WGNSPIN
570          IF (STABTYP .EQ. 10H2-SPIN     ) GN1 = WG2SPIN
574           IF (STABTYP .EQ. 10H3-AXIS    ) GN1 = WGN3A
600          CDPI = 50. +(5. *(ORBAPO **  .1)*(XNOL-1.))+(15. *XNTR) + DP+ ENC
615          TTC1 = CDPI
616          TOTPWR = XMISPWR + 200.
620           IF (ACSPROP .EQ. 10HHOT GAS   ) WPF = 0.348
624          IF ( ACSPROP .EQ.10HCOLD GAS  ) WPF = 1.040
631          ACWP1 = WPF * (SATLIF1 ** 0.200) * (GW1 ** 0.769)
640          ACINHG =(0.128 * ACWP1 )+ (0.063 *(GW1 **  0.725))
646          ACINCG =(1.15 * (ACWP1 ** 0.846))+ (1.37 * (GW1 ** 0.269))
657          IF (ACSPROP  .EQ. 10HHOT GAS   ) ACSIN1 = ACINHG
663          IF (ACSPROP  .EQ. 10HCOLD GAS  ) ACSIN1 = ACINCG
667          IF (ORINT .EQ. 10HORI          .AND. PADTYP  .EQ. 10HRIGID      )
            1 GO TO 18
677          IF (ORINT .EQ. 10HORI          .AND. PADTYP  .EQ. 10HFLEX       )
            1 GO TO 19
706          IF (ORINT .NE. 10HORI          ) GO TO 21
707     18   CONTINUE
707          WSAORL=((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT) ))) / ( 9.0 -
            1 (ALOG10(SATLIF1))))* ((1.0 /PF) + 0.35) * (0.99 ** (XIOC -1960.))
733           WSAORM = ((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT)))) / (9.0 -
            1 (ALOG10 (SATLIF1))))* ((1.0 / PF) + (2. * 0.35))* (0.99 **
            1 (XIOC - 1960.))
757           WSAORH = ((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT)))) / (8.6 -
            1 1.4 * ( ALOG10 (SATLIF1)))) * ((1.0 /PF) + 0.35) * (0.99 **
            1  (XIOC - 1960.))
```

```
1004        IF (AVEALT .LT. 501. ) WSA = WSAORL
1010        IF (AVEALT .GT. 501. .AND. AVEALT .LT. 19000.) WSA = WSAORM
1021        IF (AVEALT .GE. 19000. )WSA = WSAORH
1025        GO TO 25
1026     19 CONTINUE
1026        WSAORL=((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT) ))) / ( 9.0 -
          1 (ALOG10(SATLIF1)))* ((0.2 /PF) + 0.35) * (0.99 ** (XIOC -1970.))
1052        WSAORM = ((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT)))) / (9.0 -
          1 (ALOG10 (SATLIF1)))) * ((0.2 / PF) + (2. * 0.35))* (0.99 **
          1 (XIOC - 1970.))
1076        WSAORH = ((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT)))) / (8.6 -
          1 1.4 * ( ALOG10 (SATLIF1)))) * ((0.2 /PF) + 0.35) * (0.99 **
          1   (XIOC - 1970.))
1123        IF (AVEALT .LT. 501. ) WSA = WSAORL
1127        IF (AVEALT .GT. 501. .AND. AVEALT .LT. 19000.) WSA = WSAORM
1140        IF (AVEALT .GE. 19000. )WSA = WSAORH
1144        GO TO 25
1145     21    CONTINUE
1145        WSAORL=((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT) ))) / (3.38-.3 *
          1 (ALOG10(SATLIF1))))* ((.38 /PF) + 0.35) * (0.99 ** (XIOC -1960.))
1172        WSAORM = ((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT)))) / (3.38-.3*
          1 (ALOG10 (SATLIF1)))) * ((.38 / PF) + (2. * 0.35))* (0.99 **
          1 (XIOC - 1960.))
1217        WSAORH = ((TOTPWR * (2.67 - 0.39 * (ALOG10 (AVEALT)))) / (3.19-
          1 0.47* ( ALOG10 (SATLIF1)))) * ((.38 /PF) + 0.35) * (0.99 **
          1   (XIOC - 1960.))
1244        IF (AVEALT .LT. 501. ) WSA = WSAORL
1250        IF (AVEALT .GT. 501. .AND. AVEALT .LT. 19000.) WSA = WSAORM
1261        IF (AVEALT .GE. 19000. )WSA = WSAORH
1265      25 CONTINUE
1265        PBAT = ( PBATF * XMISPWR ) + 200.
      C     BAT. WT = FACTOR X WATTS X ECLIPSE TIME/CYCLE X  REDUNDANCY X IOC
1270        R = REDUN
1271        FB1  = 0.454333 +(0.037333  * SATLIF1)
1274        FB2  = 1.01814  - (0.00003628 * AVEALT )
1277        FB  = FB1 * FB2
1301        TE  =  0.03694 * (AVEALT ** 0.349087 )
1304        IF (AVEALT .LT. 2800.) TE = 0.59
1311        BATT = FB * TE * PBAT * (1. + R) * (0.99 ** (XIOC - 1970.))
1324     16 CONTINUE
1324        WELE  = XME3         + TTC1 + GN1
1327        DIST = 0.013 * (( WELE ** 1.31) * (VOL1 ** 0.16))
1337         ELINV = 3.11 * (TOTPWR ** .333 )
1343        EL1  = WSA + BATT + DIST + ELINV
1347        IF (STRTYP .EQ. 10HENDO       ) SFR1 = 0.218
1353        IF (STRTYP .EQ. 10HEXO        ) SFR1 = 0.129
1363        EQWT = EC1 + GN1 + AMIN1 + MP1 + ACSIN1 + ACMP1 + TTC1 + EL1
          1 + XME3 + RESID1
1373        XLTOD = XLG1 / DIAM1
1375        STR1 = SFR1 * (((EQWT ** .9) * (XLTOD ** .24)) ** 1.096 )
1406        CF11= CF1
1410        CON1 = CF11* (STR1 + EC1 + GN1 + ACSIN1 + AMIN1 + TTC1 + EL1 )
1416        PALLET =    0.0

1416         IF ( DV1 .LT. 2. ) GO TO 6
      C      N204 / .50 UDMH + .50 HYDRAZINE VAC. IMPULSE  = 310. SEC
      C                    N2H4 VAC ISP = 200.
```

```
1421          IF ( PROPTYP .EQ. 10HLIQUID    ) XMPISP = 300.
1425          IF ( PROPTYP .EQ. 10HLIQUID    ) XMPISP = 200.
1430          IF ( PROPTYP .EQ. 10HSOLID     ) XMPISP = 250.
1434            MP1 = ( EXP ( DV1 / ( XMPISP * G )) - 1.) * ( DW1 + ACWP1 )
1445          AMIN1 = .25 * MP1
1446            TOTIMP = MP1 * XMPISP
1450      6     CONTINUE
1450            IF (DV1 .EQ. 0. ) MP1    = 0.0
1452            IF (DV1 .EQ. 0. ) AMIN1 = 0.0
1454          XPONDWT = XNXPOND *((0.09 * PWRXPON) -(3.13 * XNXPOND) +  64.)
1461            IF ( CODE .EQ.10HDSCS-II    ) XPONDWT = 180.
        C         NOTE -- COMFREQ IS EXPRESSED IN GIGAHERTZ
1465          ANTWT    = 0.512 * ((ANTDIAM ** 1.661) * (COMFREQ ** .332) )*XNANT
1476            IF ( CODE .EQ.10HDSCS-II    ) ANTWT = 57.
1502          XME3 = XME1 + XPONDWT + ANTWT
1505          DW1 = STR1 + EC1 + GN1 + ACSIN1 + AMIN1 + TTC1 +
             1 EL1 + XME3 + RESID + CON1
1517            GW1 = DW1 + ACWP1 + MP1
1521          WTDIF = ABS (GWT - GW1 )
1524          IF (WTDIF .GT.  1.) GO TO 17
1527          AMWP1 = MP1
1527          SFCWT = STR1 / (GW1 - STR1 -AMIN1 -AMWP1 -SEPDRY -SEPWP- XLAND1)
1536          AREA1 =(3.141590 * DIAM1 * XLG1) + (2. * .785 *(DIAM1 ** 2.))
        C
        C     THIS ROUTINE CALCULATES ADAPTER WT. FOR THE CURRENT WT. ON A 10
        C      FT. DIAM. MOUNT  (EXPENDABLE BOOSTER )
        C     ------------------------------------------------------------
1545          TH1 = .10
1547      3   CONTINUE
1547          DIA1AV = (10.0 + DIAM1)  / 2.
1552          DBBL = 10.00
1552          DBSH  = 13.5
1554          PALL1 = 0.
1554          IF (PALLET .EQ. 1.) GO TO 1
1557          HBL = ABS (( 10.0 - DIAM1 )   / 2. )
1562          IF (HBL .LT. .5) HBL = .50
1565          FBL = (3. * GW1)  + ((((HBL/2.) + (XLG1/2.)) * GW1 ) /(DIA1AV /4.))
1574          R1AV = DIA1AV / 2.
1575          TH1 =(FBL /(2. * 3.14159*10.*144.*1000000.*((9.*((TH1/ R1AV)
             1**.6)) +(.16*((R1AV /HBL) ** 1.3) *((TH1/R1AV)**.3))))))**.5
1621          TH1T = ABS (TH1- TBL )
1623          TH1TT = .0001 * TH1
1625          TBL = TH1
1626              IF (TH1T .GT.TH1TT ) GO TO 3
1632          IF (TH1 .LT. .00333 ) TH1 = .00333
1634          THBL = 12. * TH1
1635          ADP1 = 3.14159 * (5.0 + (DIAM1 /2.)) * (1.414 * HBL) * TH1 *
             1 172.8 * 1.5
1644          ADP1T =(0.02 * GW1      )      +  12.
1647          IF (ADP1 .LT. ADP1T ) ADP1 = ADP1T
1653          GO TO 7
1654      1   CONTINUE
1654            ADP1 = 0.
1655          PALUN = 78.59
1656          PALL1 =  PALUN * XLG1
1660      7   CONTINUE
```

```
1660        XLWC = GW1 + ADP1         + PALL1
1663        XLW1V = XLW1
1664        PALL1V = PALL1
1665        ADP1V = ADP1
1666          ADP1VL = H3L
1670        TH3LV = TH3L
1671        SF8LV = SFCWT

      C      THIS ROUTINE CALCULATES THE GROUND REFURB. WT. (COL. R )
      C      -------------------------------------------------------------

1673     31  CONTINUE
1673        STRFR = 1.    $ ECFR = 1.   $ GNFR = 1.   $ AMFR = 1.   $ ACINFR = 1.
1700        TTCFR = 1.   $ ELFR = 1.   $ XMEFR = 1.
1704         TOTPWRR = TOTPWR
1705        GWGR = GW1
1706        GWMR = GWGR
1707        XLTODGR = 0.7
1711     33 CONTINUE
1711        GWGRT = GWGR
1712        PKDENMR= DEN
1714          AMWPMR = MPGR
1715        VOLMR = (GWGR - AMWPMR - AMINMR - SPWPMR - SPINMR) / PKDENMR
          1 + (AMWPMR /PD) + ((AMINMR + SPINMR) / 490.) + (SPWPMR / POM )
1733         DIAMMR = ( VOLMR / ( .785 * XLTODGR)) ** .333333
1740        IF (DIAMMR .GT. 15.00)GO TO 127
1743        GO TO 128
1743    127 CONTINUE
1744        DIAMMR = 15.00
1745        XLGMR = VOLMR / (.785 * (DIAMMR ** 2.))
1751        AREAMR =(3.14159 * DIAMMR * XLGMR) + (2. * .785 *(DIAMMR ** 2.))
1760        ECFA = AREAMR / AREA1
1762        GO TO 129
1762    128 CONTINUE
1762        XLGMR = XLTODGR* DIAMMR
1764        AREAMR =(3.14159 * DIAMMR * XLGMR) + (2. * .785 * (DIAMMR ** 2.))
1772        ECFA = AREAMR / AREA1
1774    129 CONTINUE
1774        DIAMRE = 3. * ANTDIAM
1776        XLGMRE = XLGMR + ANTDIAM
2000     38 CONTINUE
2000        ECGR   = EC1   * ECFR            * ECFA
2002        GNGR =   ((GN1 * GNFR) + 10.)  * GNRLF
2006         IF (ACSPROP .EQ. 10HHOT GAS    ) WPF = 0.348
2012        IF ( ACSPROP .EQ.10HCOLD GAS    ) WPF = 1.040
2017        ACWPGR= WPF * (SATLIF   ** 0.200) * (GWGR** 0.769)
      C       EQUATION IS FOR EXPENDABLE SATELLITES WHICH EXPEND 2/3 OF THEIR
      C          PROPELLANT FOR INITIAL POSITIONING - SINCE SHUTTLE LAUNCHED
      C          SATELLITES WILL BE POSITIONED BY THE SHUTTLE OR THE OOS, ONLY
      C          1/3 OF THE ACS PROPELLANT IS REQUIRED.
2026          ACWPGR = ACWPGR / 3.0
2027        ACINHG =(0.128 * ACWPGR)+ (0.063 *(GWGR**   0.725))
2035        ACINCG =(1.15 * (ACWPGR** 0.846))+ (1.37 *  (GWGR** 0.269))
2046        IF (ACSPROP  .EQ. 10HHOT GAS    ) ACSINGR= ACINHG
2052        IF (ACSPROP  .EQ. 10HCOLD GAS   ) ACSINGR= ACINCG
2056         ACINGR = ACSINGR* ACINRLF
```

```
2060        DGNMMR =    (GNGR - (GNGR / GNRLF)) + (ACINGR - ACINGRB)        000331
2064        MPGR = MP1 * (DWGR / DW1 )                                          000332
2067        TOTINGR = XMPISR * MPGR                                             000333
2070         AMINGR = 0.25 * MPGR * AMRL                                        332
2073    35  CONTINUE                                                            000336
2101        TTCGR = TTC1 * TTCFR * TTCRLF                                       000337
2103        DTCMMR =    TTCGR - (TTCGR / TTCRLF)                                000338
2104         WSAGR = WSA * ELRLF                                                000339
2106         BATTGR = BATT * ELRLF                                              000340
2110         DISTGR = DIST * ELRLF                                              000341
2111         ELINVGR = ELINV * ELRLF                                            000342
2113         ELGR = WSAGR + BATTGR + DISTGR + ELINVGR                           000343
2116        DELMMR =   ELGR  - (ELGR / ELRLF)                                   000344
2120        ANTWGR = ANTWT * XMEFR * XMERLF                                     344-1
2122        XPONWGR = XPONDWT * XMEFR * XMERLF                                  344-2
2123        XME1GR  = XME1  * XMEFR * XMERLF                                    344-3
2125        XMEGR   =  ANTWGR + XPONWGR + XME1GR                                345
2130         DM2 = XMEGR - ( XMEGR / XMERLF )                                   345-1
2132        EQWTGR = ECGR + GNGR + ACINGR + ACWPGR + AMINGR + MPGR + TTCGR     000346
           1 + ELGR + XMEGR  + RESIDGR                                          000347
2142        XLTODGR = XLGMR / DIAMMR                                            000348
2144        STRGR  = SFR1  * (((EQWTGR ** .9) * (XLTODGR ** .24)) ** 1.036 )   000349
      C      ADD 10 PERCENT TO STRUCTURE FOR IMPROVED GROUND ACCESSIBILITY      000350
2155        STRGR  = STRGR * 1.10                                               000351
2157        CFGR = CF1                                                          000352
2160        CONGR = CFGR *(STRGR +ECGR +GNGR +ACINGR +AMINGR +TTCGR +ELGR )     000353
2165        DWGR = STRGR + EQWTGR - ACWPGR - MPGR                               000354
           1  + CONGR                                                           000355
2172        GWGR = DWGR + ACWPGR + MPGR                                         000356
2173        WGW  = ABS (GWGRT - GWGR )                                          000357
2176        WGWT =   1.                                                         000358
2177        IF (WGW .GT. WGWT ) GO TO 33                                        000359
                                                                                000360
      C     THIS ROUTINE CALCULATES ADAPTER LENGTH AND WEIGHT                   000361
                                                                                000362
2203        AM2R = MPGR + AMINGR                                                000363
2204        PALL2R = 0.                                                         000364
2205        PALLMR = 0.                                                         000365
2205        IF (PALLET .EQ. 1. ) GO TO 47                                       000366
2210        TMR = .10                                                           000367
2211    39  CONTINUE                                                            000368
2211        DIMRAV = (DBSH + DIAMMR )   /2.                                     000369
2214        HBLMR  = ABS ((DBSH - DIAMMR )   / 2. )                             000370
2216        IF(HBLMR .LT. .50 ) HBLMR = .50                                     000371
2221        FMR = (3. * GWMR) + (((( HBLMR /2.) + (XLGMR /2.)) * GWMR) /        000372
           1  (DIMRAV / 4.))                                                    000373
2230        RMRAV  = DIMRAV / 2.                                                000374
2232        THMR =(FMR /(2. * 3.14159*10.*144.*1000000. *((9. *((TMR /RMRAV)   000375
           1**.6))+ (.16*((RMRAV/HBLMR)**1.3) * ((TMR/RMRAV)** .3 ))))))** .5   000376
                                                                                000377
2256        THMRT = ABS (THMR - TMR)                                            000378
2260        THMRTT = .0001 * THMR                                               000379
2262        TMR = THMR                                                          000380
2263        IF (THMRT .GT. THMRTT ) GO TO 39                                    000381
2267        IF (THMR .LT. .00333 ) THMR = .00333                                000382
2271        THBLMR = 12. * THMR                                                 000383
2273    34  CONTINUE                                                            000384
2273         ADPMR = 3.14159 * (   DIMRAV            ) * (1.414 * HBLMR)  *
```

```
                1   THMR * 172.8 * 1.5
2300                 ADPMRT =(0.02 * GWMP )   + 12.
2303            .   IF ( ADPMR .LT. ADPMRT ) ADPMR = ADPMRT
2306                 REPMR = REUSE
2310                GO TO 48
2310         47     CONTINUE
2310                ADPMR = 0.
2311                PALLMR = 73.59 * XLGMR
2313         48     CONTINUE
2314                  ADPGR = ADPMR
          C          ADD 100 POUNDS FOR DOCKING RING + RENDEZVOUS EQUIP.
2315                 ADPGR = ADPMR + 100.
2316                 PALLGR = PALL1R
2317                 GWMR = GWGR
2320                XLWGR = GWGR + ADPGR          + PALLGR

2323         35     CONTINUE
2323                 IF (STABTYP .EQ. 10H2-SPIN     ) GO TO 98
2325                 IF (STABTYP .EQ. 10HSPIN       ) GO TO 98

          C         THIS ROUTINE COMPUTES CURRENT DESIGN ON-ORB MAINT WTS

2327                  TOTPW1R = TOTPWR
2330                STRF1R= (0.114286 * XMOD) + 0.885714
2333                IF (XMOD .GT. 8.) STRF1R= (0.0875 * XMOD) + 1.1
2340                ECF1R = 1.
2341                GNF1R = 1.0 $ TTCF1R = 1.0 $ ACINF1R = 1.1$ ELF1R = 1.
2346                 AMF1R = 1.0
2346                XMEF1R = 1.0
2347                GW1R = 1.1 * GW1
2351                DW1R = 1.1 * DW1
2353         51     CONTINUE
2353                GW1TR = GW1R
2354                 IF ( DEN1 .GT. 0. ) GO TO 65
2357                IF (GW1R .GT. 2000. ) GO TO 62
2362                IF (GW1R .LT. 2000. ) GO TO 63
2363         62     CONTINUE
2363                PKDEN1R = 528.6 / ((GW1R - MP1R  - AMIN1R)**0.605528)
2371                IF (GW1R .GT. 10000. ) PKDEN1R = 2.0
2376                GO TO 65
2377         63     CONTINUE
2377                PKDEN1R = 15.23 / ((GW1R - MP1R - AMIN1R) ** .147222)
2405                IF (GW1R .LT. 300.    ) PKDEN1R = 7.0
2412         65     CONTINUE
2412                IF (DEN1 .GT. 0. ) PKDEN1R = DEN1
2415                VOL1R = ((GW1R -  MP1R  - AMIN1R)/ PKDEN1R)+(  MP1R /PD) +
                  1(AMIN1R / 492. )
2424                XLTOD1R = 0.7
2426                DIAM1R = (VOL1R  / (.785 * XLTOD1R)) ** .333333
2433                IF (DIAM1R .GT. 15.00 ) GO TO  68
2436                GO TO 69
2436         68     CONTINUE
2437                DIAM1R = 15.00
2440                XL1R = VOL1R / (.785 * (DIAM1R ** 2.))
2444                AREA1R = (3.14159 * DIAM1R * XL1R) + (2.* .785 *(DIAM1R ** 2.))
2453                ECF1A = AREA1R / AREA1
2454                IF(ECF1A .LT. 1. ) ECF1A = 1.
```

```
2460          GO TO 71                                                              000435
2461     69   CONTINUE                                                              000436
2461          XL1R = XLTOD1R * DIAM1R                                               000437
2463          AREA1R = (3.14159 * DIAM1R * XL1R) + (2.* .785 *(DIAM1R ** 2.))       000438
2471          ECF1A = AREA1R / AREA1                                                000439
2473     71   CONTINUE                                                              000440
2475          DIA1RE = 3. * ANTDIAM                                                 440-1
2477          XL1RE  = XL1R  + ANTDIAM                                              440-2
2500          EC1R = ECF1R * EC1 * ECF1A                                            000441
2503          GN1R  =  (( GN1 * GNF1R) + 10.) * GNPLF                               000442
2506          TTC1R = TTC1  * TTCF1R * TTCRLF                                       000443
2511          DTCMM1R =  TTC1R - (TTC1R /TTCRLF)                                    000444
2513           WSA1R = WSA * ELRLF                                                  000445
2515           BATT1R  = BATT * ELRLF                                               000446
2516           DIST1R  =(DIST  * ELRLF) + (19.7 * (XMOD -1.))                       000447
2523           DISTF1R = DIST1R  / DIST                                             000448
2523           ELINV1R = ELINV * ELRLF                                              000449
2525           EL1R = WSA1R + BATT1R + DIST1R + ELINV1R                             000450
2531          DELMM1R =  EL1R  - (EL1R /ELRLF )                                     000451
2532          ANTW1R = ANTWT * XMERLF* XMEF1R                                       451-1
2535          XPONW1R = XPONDWT * XMEF1R * XMERLF                                   451-2
2537          XME11R  = XME1 * XMEF1R * XMERLF                                      451-3
2540          XME1R  = ANTW1R + XPONW1R + XME11R                                    452
2543            DM3A = XME1R - ( XME1R / XMERLF )
2545           IF (ACSPROP .EQ. 10HHOT GAS   ) WPF = 0.348                          454
2551          IF ( ACSPROP .EQ.10HCOLD GAS  ) WPF = 1.040                           000457
2556          ACWP1R= WPF * (SATLIF   ** 0.200) * (GW1R** 0.769)                    000458
         C       EQUATION IS FOR EXPENDABLE SATELLITES WHICH EXPEND 2/3 OF THEIR    000459
         C           PROPELLANT FOR INITIAL POSITIONING - SINCE SHUTTLE LAUNCHED    000460
         C           SATELLITES WILL BE POSITIONED BY THE SHUTTLE OR THE OOS, ONLY  000461
         C           1/3 OF THE ACS PROPELLANT IS REQUIRED.                         000462
2565            ACWP1R = ACWP1R / 3.0                                               000463
2566          ACINHG =(0.128 * ACWP1R)+ (0.063 *(GW1R**  0.725))                    000464
2574          ACINCG =(1.16 * (ACWP1R** 0.846))+ (1.37 * (GW1R** 0.269))            000465
2605          IF (ACSPROP  .EQ. 10HHOT GAS    ) ACSIN1R= ACINHG                     000466
2611          IF (ACSPROP  .EQ. 10HCOLD GAS  ) ACSIN1R= ACINCG                      000467
2616           ACIN1R = ACSIN1R * ACINF1R * ACINRLF                                 000468
2620          DGNMM1R = (GN1R - (GN1R / GNRLF)) + (ACIN1R - (ACIN1R / ACINRLF))     000469
2624          MP1R   =(DW1R / DW1 ) * MP1                                           000470
2626          TOTIM1R = XMPISP * MP1R                                               000471
2630           AMIN1R = 0.25 * MP1R * AMRL * AMF1R                                  473
2634     66   CONTINUE                                                              000474
2641          EQWT1R = EC1R + GN1R + TTC1R + EL1R + XME1R + ACIN1R + ACWP1R  +      000475
             1 AMIN1R + MP1R + RESID1R                                              000476
2650          XLTOD1R = XL1R / DIAM1R                                               000477
2652          STR1R = SFR1 * ((( EQWT1R ** .9) + (XLTOD1R ** .24)) ** 1.096 )       000478
2664          STR1R = STR1R * STRF1R                                                000479
2666          CON1R = CF1 * (STR1R + EC1R + GN1R + ACIN1R + AMIN1R + TTC1R  +       000480
             1 EL1R )                                                               000481
2673          GW1R = STR1R + EQWT1R + CON1R                                         000482
2676          DW1R = GW1R - ACWP1R - MP1R                                           000483
2700          W6 = ABS (GW1R - GW1TR )                                              000484
2703          IF (W6 .GT. 1. ) GO TO 61                                             000485
2707          DI1RAV = (DBSH + DIAM1R) / 2.                                         000486
2711          T1R= 0.10                                                             000487
2713     67   CONTINUE                                                              000488
2713          H1R= ABS ((DBSH - DIAM1R) / 2. )                                      000489
```

```
2716          IF (H1R.LT. .5 ) H1R = .50
2722          F1R = (3. * GW1R) + (((H1R/2.) + (XLG1R/2.)) * GW1R) / (DI1RAV
             1 /4.))
2731          RRAV = DI1RAV / 2.
2732          TH1R =(F1R / (2. * 3.1+159*10.*144.*1000000. *((9. *((T1R /RRAV)
             1** .6)) + (.16 *((RRAV /H1R)** 1.3) *((T1R /RRAV) **.3)))))** .5
2756          THT1R = ABS ( TH1R - T1R )
2760          THTT1R = .0001 * TH1R
2762          T1R = TH1R
2763          IF (THT1R .GT. THTT1R ) GO TO 67
2767          IF (TH1R .LT. .00333 ) TH1R = .00333
2771          ADP1R = 3.1+159 *((DIAM1R / 2.) +(DRSH/2.)) * (1.414 * H1R) * TH1R
             1 * 172.8 * 1.5
3001          ADP1RT =(0.02 * GW1R )  + 12.
3004          IF(ADP1R .LT. ADP1RT) ADP1R = ADP1RT
        C     ADD 100 POUNDS FOR DOCKING RING + RENDEZVOUS EQUIP.
3010          ADP1R = ADP1R  + 100.
3011          XLW1R = GW1R + ADP1R

3013    37    CONTINUE


        C     THIS ROUTINE COMPUTES LOW COST DESIGN ON-ORB MAINT WTS
        C     ----------------------------------------------------------------
3013          XMODLC = 15.
3014          STRFM = 1.0
3016          TOTPWRM = TOTPWR
3017          XLTOD2R= 0.7
3021          GW2R = 1.1 * GW1
3023          DW2R = 1.1 * DW1
3025    40    CONTINUE
3025          GW2TR = GW2R
3026          AMWP2R = MP2R
3030          IF ( DEN1 .GT. 0. ) GO TO 55
3033          IF (GW2R .GE. 2750.) GO TO 45
3035          IF (GW2R .LT. 2750.) GO TO 50
3036    45    CONTINUE
3036          PKDENR = +67.251 / ((GW2R - AMWP2R - AMIN2R) ** .549932 )
3044          IF(GW2R .GT. 10000.) PKDENR = 3.0
3051          GO TO 55
3052    50    CONTINUE
3052          PKDENR =  23.901 / ((GW2R - AMWP2R - AMIN2R) ** .174528 )
3060          IF(GW2R .LT. 500. )  PKDENR = 8.0
3065    55    CONTINUE
3065          IF(DEN1 .GT. 0.    )  PKDENR = DEN1
3070          AMWP2R = MP2R
3071          AM2R = AMWP2R + AMIN2R
3073          VOL2R = (( GW2R - AM2R ) /PKDENR )+(MP2R /PD) +(AMIN2R /490.)
3101          DIAM2R =  ( VOL2R / (.785 * XLTOD2R))** .333333
3106          IF (DIAM2R .GT. 15.00)GO TO 56
3111          GO TO 57
3111    56    CONTINUE
3112          DIAM2R = 15.00
3113          XLGR = VOL2R / (.785 * (DIAM2R ** 2.))
3117          AREA2R = (3.1+159 * DIAM2R * XLGR) + (2. * .785 * (DIAM2P ** 2.))
3126          ECFA = AREA2R / AREA1
3130          GO TO 58
```

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3130   57   CONTINUE                                                                000544
3130        XLGR =  XLTOD2R* DIAM2R                                                000545
3132        AREA2R = (3.14159 * DIAM2R * XLGR) + (2. * .785 * (DIAM2R ** 2.))      000546
3140        ECFA = AREA2R / AREA1                                                  000547
3142   58   CONTINUE                                                                000548
3142        DIA2RE = 3. * ANTDIAM                                                  548-1
3144        XLGRE  = XLGR  + ANTDIAM                                               548-2
3145        IF(ECFA .LT. 1. ) ECFA = 1.0                                           000549
3151          EC2R = ECFM * EC1                                                    000550
3153        GN2R = ((GN1 * GNFM) + 10.)                                            000551
3156        TTC2R = TTC1 * TTCFM                                                   000552
3160         WSA2R = WSA * ELFM                                                    000553
3162         PBAT = ( PBATF * XMISPWR ) + 200.                                     554
       C    BAT. WT = FACTOR X WATTS X ECLIPSE TIME/CYCLE X  REDUNDANCY X IOC      000555
3165        R = REDUN                                                              000556
3166        FB1  = 0.454333 +(0.037333  * SATLIF1)                                 000557
3171        FB2  = 1.01814  - (0.00003628 * AVEALT )                               000558
3174        FB   = FB1 * FB2                                                       000559
3176        TE   =  0.03694 * (AVEALT ** 0.349087 )                                000560
3201        IF (AVEALT .LT. 2800.) TE = 0.59                                       000561
3206        BATT2= FB * TE * PBAT  * (1. + R) * (0.99 ** (XIOC - 1970. ))          000562
3220         BATT2R = BATT2* ELFM                                                  000563
3222         DIST2R = DIST * ELFM                                                  000564
3223         ELINV2R = ELINV * ELFM                                                000565
3225         EL2R = WSA2R + BATT2R + DIST2R + ELINV2R                              000566
3231          RLFMELC = ( .1814 * XMMDLC ) + 0.2744                                567-1
3234        ANTW2R = ANTWT * XMEFM * RLFMELC                                       565-1
3236         XPONW2R = XPONDWT * XMEFM   * RLFMELC                                 566-2
3240         XME12R = XME1 * XMEFM  * RLFMELC                                      566-3
3241         XME2R = ANTW2R + XPONW2R + XME12R                                     567
3244          DM3 = XME2R - ( XME2R / RLFMELC )                                    567-3
3246         IF (ACSPROP .EQ. 10HHOT GAS   ) WPF = 0.348                           569
3252        IF ( ACSPROP .EQ.10HCOLD GAS  ) WPF = 1.040                            000572
3257        ACWP2R= WPF * (SATLIFC ** 0.200) * (GW2R** 0.769)                      000573
       C       EQUATION IS FOR EXPENDABLE SATELLITES WHICH EXPEND 2/3 OF THEIR     000574
       C          PROPELLANT FOR INITIAL POSITIONING - SINCE SHUTTLE LAUNCHED      000575
       C          SATELLITES WILL BE POSITIONED BY THE SHUTTLE OR THE OOS, ONLY    000576
       C          1/3 OF THE ACS PROPELLANT IS REQUIRED.                           000577
3266          ACWP2R = ACWP2R / 3.0                                                000578
3267        ACINHG =(0.128 * ACWP2R)+ (0.063 *(GW2R**  0.725))                     000579
3275        ACINCG =(1.16 * (ACWP2R** 0.846))+ (1.37 * (GW2R** 0.269))             000580
3306        IF (ACSPROP  .EQ. 10HHOT GAS   ) ACSIN2R= ACINHG                       000581
3312        IF (ACSPROP  .EQ. 10HCOLD GAS  ) ACSIN2R= ACINCG                       000582
3316         ACIN2R = ACSIN2R * ACINFM                                             000583
3320         MP2R = ( DW2R / DW1 ) * MP1                                           584-1
3322        TOTIM2R = XMPISP * MP2R                                                000584
3324         AMIN2R = 0.25 * MP2R * AMRL * AMFM                                    586
3330   60   CONTINUE                                                                000587
3335        EQWT2R = EC2R + GN2R + TTC2R + EL2R + XME2R + ACIN2R + ACWP2R          000588
           1 + AMIN2R + MP2R + RESID2R                                             000589
3344        XLTOD2R = XLGR / DIAM2R                                                000590
3346         STR2R = 2.29 * (((EQWT2R ** .9)*(XLTOD2R** .24)) ** .90)              000592
3360        STR2R = STR2R * STRFM                                                  000593
3362         CFFM = CF1 * CONFM                                                    000594
3364         CF2R = CFFM                                                           000595
3364        CON2R = CFFM *(STR2R +EC2R +GN2R +ACIN2R +AMIN2R +TTC2R + EL2R)        000596
3372        GW2R = STR2R + EQWT2R + CON2R                                          000597
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3375          DW2R  =  GW2R - ACWP2R - MP2R
3377          W3 = ABS ( GW2TR - GW2R)
3402            W4 =  1.
3404          IF ( W3 .GT. W4 ) GO TO  40
3410          TR= .10
3411     70    CONTINUE
        C     THIS ROUTINE CALCULATES ADAPTER LENGTH AND WEIGHT

3411          PALL2R = 0.
3412          IF (PALLET .EQ. 1. ) GO TO 72
3414          DIARAV = (DBSH + DIAM2R) / 2.
3417          HR       = ABS ((DBSH - DIAM2R ) / 2.)
3421          IF (HR    .LT.  .50 ) HR      = .50
3424          FR= (3. * GW2R) + ((((HR/2.)+(XLGR/2.))* GW2R) / ( DIARAV /4.))
3433          RAVE = DIARAV / 2.
3435          THR  =(FR /     (2. * 3.1415*10.*144.*1000000. *((9. *((TR /RAVE)
             1 ** .6)) + (   0.16*((RAVE /HR) ** 1.3) *((TR / RAVE) **.3)))))**.5
3461            THTR = ABS (THR - TR )
3463            THTTR = .0001 * THR
3465          TR  = THR
3466            IF ( THTR  .GT. THTTR ) GO TO  70
3472          IF ( THR .LT. .00333 ) THR = .00333
3474            THRI = 12. * THR
3475            ADP2R = 3.14159 * (   DIARAV        )          * (1.414 * HR ) *  THR
             1  * 172.8 * 1.5
3502            ADP2RT =(0.02 * GW2R )     + 12.
3505          IF ( ADP2R .LT. ADP2RT ) ADP2R = ADP2RT
        C       ADD 100 POUNDS FOR DOCKING RING + RENDEZVOUS EQUIP.
3510            ADP2R = ADP2R + 100.
3512          GO TO 73
3512     72   CONTINUE
3512          ADP2R = 0.
3513          PALL2R = 78.59 * XLGR
3515     73   CONTINUE
3515          XLW2R = GW2R + ADP2R           + PALL2R
3520          GO TO 99
3521     98   CONTINUE
3521            STR1R=0.$ EC1R=0.$GN1R=0. $ AMIN1R=0.$ ACIN1R =0. $ TTC1R =0.
3525            EL1R =0. $ BATT1R = 0. $ DIST1R = 0. $ WSA1R = 0. $ ELINV1R = 0.
3527            XME1R  = 0. $ CON1R = 0. $ DW1R = 0. $ ACWP1R = 0. $ MP1R = 0.
3532            GW1R = 0. $ ADP1R = 0. $ PALL1R = 0. $ XLW1R = 0. $  DIAM1R = 0.
3534            XL1R = 0. $ H1R    = 0. $ PKDEN1R= 0. $ TOTPW1R=0.
3536            STR2R = 0.$ EC2R = 0. $ GN2R = 0. $ AMIN2R = 0. $ ACIN2R = 0.
3541            TTC2R = 0.$ EL2R = 0. $ BATT2R = 0. $ DIST2R = 0. $ ELINV2R = 0.
3543            XME2R = 0.$ CON2R = 0. $ DW2R = 0. $ ACWP2R = 0. $ MP2R = 0.
3546            DTCMM1R = 0. $ DELMM1R = 0. $ DGNMM1R = 0.
3547            GW2R = 0.$ ADP2R = 0. $ PALL2R = 0. $ XLW2R = 0. $ DIAM2R = 0.
3552            XLGR = 0. $ HR = 0. $ PKDENR = 0. $ TOTPWRM = 0. $ XMMDLC = 0.
3554            ANTW1R = 0. $ XPONW1R = 0.   $ XME12R = 0.
3556            ANTW2R = 0. $ XPONW2R = 0.   $ XME11R = 0. $ WSA2R  = 0.
3560     99   CONTINUE
        C       THIS ROUTINE COMPUTES SORTIE WTS.
3570          DIA2SE = 3. * ANTDIAM
3571          XLGSE  = XLGS  + ANTDIAM

        C       THESE CARDS LIST COST NAMES FOR GROUND REFURBISHABLE SAT. WTS.(R)
3573          WS2 =((STRGR + ECGR)*( CFGR + 1. )) + ADPGR
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3577       WE2 = ELGR *(CFGR + 1. )
3600      WC2 = TTCGR *(CFGR    + 1. )
3602      WA2 = (GNGR + ACINGR) *(CFGR   + 1. )
3604      WAP2 = ACWPGR
3606      WP2 = AMINGR *(CFGR  + 1. )
3610       WPP2 = MPGR
3611      WM2  = XMEGR
3613      DA2     =   DGNMMR
3614      DC2   = DTCMMR
3616      DE2   = DELMMR
      C   THESE CARDS LIST COST NAMES FOR ON-ORBIT MAINT. SAT. WTS.  (M)
3617      WS3=((STR2R + EC2R ) *    ( CF2R + 1. )) + ADP2R
3623      WE3  = EL2R *(CF2R   + 1. )
3625       WC3 = TTC2R *(CF2R   + 1. )
3626       WP3 = AMIN2R *(CF2R  + 1. )
3630      WAP3 = ACWP2R
3631         WA3 = ( GN2R + ACIN2R ) *(CF2R     + 1. )
3634      WPP3 = AMWP2R
3635      WM3  = XME2R
3637      DA3 = DGNMM2R
3640      DC3   = DTCMM2R
3642      DE3   = DELMM2R
      C    THESE CARDS LIST COST NAMES FOR CURRENT DESIGN ON-ORB SAT. WTS.
3643      DA3A = DGNMM1R
3645      DC3A = DTCMM1R
3646      DE3A = DELMM1R
3650      WS3A = (( STR1R + EC1R) * ( CF1   + 1.)) + ADP1R
3654      WE3A = EL1R *   (CF1 + 1.)
3655      WC3A = TTC1R *  (CF1 + 1.)
3657      WP3A = AMIN1R *  (CF1 + 1.)
3660      WAP3A = ACWP1R
3662      WA3A  =  (GN1R + ACIN1R) * (CF1 + 1.0)
3664      WPP3A = AMWP1R
3666      WM3A   = XME1R
      C    THESE CARDS LIST COST NAMES FOR CURRENT WEIGHT COSTS
3667      WSC =((STR1 + EC1) *( CF11+ 1.0 )) + ADP1
3673      WEC = EL1 *(CF11 + 1. )
3675      WCC = TTC1 *(CF11   + 1. )
3676      WAC = (GN1 + ACSIN1) *(CF11  + 1. )
3701      WPC = AMIN1 *(CF11  + 1. )
3702      WAPC = ACWP1
3704       WPPC = MP1
3705      WMC   = XME3
3707      XLW2 = XLWGR
3710      XLW3 = XLW2R
      100 FORMAT (1H1)
3712      PRINT 100
      106  FORMAT ( 5X,*PROGRAM*, A14, 5X, *CASE NUMBER*, A12, A40 )
3716        PRINT 106, PROGRAM, CODE, TODAY
      115 FORMAT( 10X, *TYPE ATTID. CONT.*,  A15, A12  )
3730      PRINT 115, STABTYP, ACSPROP
      130 FORMAT (
         1 10X, *MEAN MISS. DUR.*, F17.3,
         1 22X, *DESIGN    LIFE (YR.)*, F15.3  /
         1 10X, *TYPE SATELLITE*,   A21,
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              1 19X, *MODULARITY (UNITS)*, F17.0 /
              1 10X, *MISS. POWER (W)*, F20.0, 19X, *BATT. REDUN. / PERCENT *,
              1 F16.1, F5.1 /
              1 10X, *POINT. ACCUR. (DEG)*, F15.6, 10X,
              1 10X, *TYPE ELECT. POWER*, A13,A10, A10,       )
3740            PRINT 130, XMAD, SATLIF, TYPE, XMOD, XMISPWP, REDUN, PBATF,
              1 PNTACC,        PWRTYP, ORINT, PADTYP
            140 FORMAT (10X,*I. O. C.*, F27.0, 19X, *VELOCITY*, F27.0 /
              1 10X, *ARRAY PACK. FACT.*, F19.1, 19X, *EXT. ON. LINKS*, F21.0 /
              1 10X, *NUMB. TAPE RECORD.*, F18.1, 19X,*DATA PROCESS. WT.*,F18.0/
              1 10X, *ENCRYPTION WT.*, F23.0, 18X,*CONTINGENCY*, F24.0 )
3772            PRINT 140, XIOC, DV1, PF, XNDL, XNTR, DP, ENC, CF1
            142 FORMAT (10X,*NUMB. TRANSPONDERS*, F18.0, 19X,*TRANS. PWR.(WATTS)*,
              1 F17.0 / 10X,*ANTENNA DIAM. (FT)* F18.2, 19X,*COMM. FREQ. (GHZ)*,
              1 F18.0 )
4016            PRINT 142, XNXPOND, PWRXPON, ANTDIAM, COMFREQ
            141 FORMAT(10X, *NUMBER OF MODULES*, 39X,*1*, 9X,*1*,2F10.0)
4032            PRINT 141, XMOD    , XMODLC
            145 FORMAT (44X,*CDR*,7X,*LC*, 18X, *CDR*, 7X, *CDR*, 6X, *LCR* )
4042            PRINT 145
            102 FORMAT (5X,*ITEM*,25X,* MMD *, 3X,*OM MOD*,4X,*OM MOD*,3X,
              1*REFERENCE*,4X,*GROUND*, 3X, *ON-ORB*, 3X,
              1*ON-ORB*,4X,*SORTIE*)
4046            PRINT 102
            103  FORMAT (32X,*FACTOR*, 4X, *FACTOR*, 4X, *FACTOR*,4X,*WEIGHT*,
              1   5X, *REFURB.*,
              1 3X, *MAINT.*, 3X, *MAINT.*,5X, *MODE* / )
4052            PRINT 103
            104 FORMAT (  5X,  *STRUCTURE*,           14X, 3F10.3, 5F10.0   /
              1           5X,  *ENVIRON. CONT.*,       9X, 3F10.3, 5F10.0   /
              1           5X,  *GUID. NAV. + STAB.*,   5X, 3F10.3, 5F10.0   /
              1           5X,  *DRY PROPULSION*,       9X, 3F10.3, 5F10.0   /
              1           5X,  *REACT. CONT.*,        11X, 3F10.3, 5F10.0   /
              1           5X,  *C. D. P. I.*,         12X, 3F10.3, 5F10.0   /
              1           5X,  *ELECTRICAL*,          13X, 3F10.3, 5F10.0  /
              1 6X,*SOLAR ARRAY*, F47.0, 3F10.0 / 6X, *BATTERY*, F51.0, 3F10.0 /
              1 6X,*DISTRIBUTION*, F30.3, F10.3, F6.0, 3F10.0 /
              1 6X,*PWR. CONDITION.* F43.0, 3F10.0  )
            107  FORMAT (5X, *MISS. EQUIPMENT*, 8X, 3F10.3, 5F10.0 /
              1 6X,*EQUIPMENT*, F49.0, 3F10.0 / 6X,*ANTENNA*, F51.0, 3F10.0 /
              1 6X,*TRANSPONDER*, F47.0, 3F10.0 /
              1           5X,  *CONTINGENCY*,         12X, 3F10.3, 5F10.0 /
              1           3X,  *DRY WEIGHT*,          45X,         5F10.0 /
              1           5X,  *REACT. CONT. PROPEL.*, 33X,        5F10.0 /
              1           5X,  *MAIN PROPELLANT*,     33X,         5F10.0 /
              1           3X,  *WET WEIGHT*,          45X,         5F10.0  /
              1           5X,  *ADAPTER WEIGHT*,       9X, 3F10.3, 5F10.0 )
4056            PRINT 104,
              1STRRL,     STRF1R,  STRFM,    STR1,    STRGR,   STR1R,   STR2R,STRSOR,
              1ECRL,      ECF1R,   ECFM,     EC1,     ECGR,    EC1R,    EC2R, ECSOR,
              1GNRLF,     GNF1R,   GNFM,     GN1,     GNGR,    GN1R,    GN2R, GNSOR,
              1AMRL,      AMF1R,   AMFM,     AMIN1,   AMINGR,  AMIN1R,  AMIN2R, AMINSOR,
              1ACINRLF,   ACINF1R,ACINFM,    ACSIN1,  ACINGR,  ACIN1R,  ACIN2R, ACINSOR,
              1TTCRLF,    TTCF1R,  TTCFM,    TTC1,    TTCGR,   TTC1R,   TTC2R,  TTCSOR,
              1ELRLF,     ELF1R,   ELFM,     EL1,     ELGR,    EL1R,    EL2R,   ELSOR,
              1 WSA, WSAGR, WSA1R, WSA2R, BATT, BATTGR, BATT1R, BATT2R,
              1 DISTF1R, DISTFM, DIST, DISTGR, DIST1R, DIST2R,
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           1 ELINV, ELINVGR, ELINV1R, ELINV2R                                      000747
4306         PRINT 107, XMERLF,XMEF1R, XMEFM, XME3, XMEGR, XME1R, XME2R,          748
           1                                                  XMESOR,              748-1
           1  XME1, XME1GR, XME11R, XME12R,                                        748-1
           1  ANTWT, ANTWGR, ANTW1R, ANTW2R,                                       748-2
           1  XPONDWT, XPONWGR, XPONW1R, XPONW2R,                                 748-3
           1CONRL,  CONFR,   CONFM,  CON1,   CONGR,  CON1R, CON2R, CONSOR,         000749
           1                         DW1,    DWGR,   DW1R,   DW2R,    DWSOR,       000750
           1                         ACWP1,  ACWPGR, ACWP1R, ACWP2R, ACWPSOR,      000751
           1                         MP1,    MPGR,   MP1R,   MP2R,    MPSOR,       000752
           1                         GW1,    GWGR,   GW1R,   GW2R,   GWSOR,        000753
           1ADPRL,   ADPFR,  ADPFM,  ADP1,   ADPGR,  ADP1R,  ADP2R,ADPSOR          000754
       105 FORMAT (3X,*AUTO. PAYLOAD SUBWT*, 36X, 5F10.0  )                        756
4472         PRINT 105,   XLWC, XLWGR, XLW1R, XLW2R ,XLWSOR                        000757
4510         PRINT 100                                                             757-1
4514         PRINT 145                                                             757-2
4520         PRINT 102                                                             757-3
       111 FORMAT(/5X,*SPACELAB MOD.*, F90.0 / 5X,*SPACELAB PALLET*, F88.0 /       729-3
           1      5X, *EQUIPMENT*  / 7X, *EXPERIMENTS + MISSION EQUIP.*, F73.0/    729-4
           17X,*DATA PROCESS + DISP.*,   F81.0 / 7X,*ELECT. POWER*,    F89.0 /     729-5
           1         7X, *ENVIRON. CONT*, F88.0/  7X,*SUPPORTS*,         F93.0 /   729-6
           1         5X, *DOCKING ADAPT*, F90.0/  5X,*FWD TUNNEL*,       F93.0/    729-7
           1 5X,*AFT TUNNEL*, F93.0 / 3X,*SPACELAB SUBTOTAL*, F88.0  / )           758-8
       112 FORMAT (5X,*RETENTION MECHANISM*, 45X, 4F10.0  /                        758-9
           1 5X, *MODULE EXCHANGE MECH.*, 43X, 4F10.0  /                           758-10
           1 5X, *MODULE MAGAZINE*,       49X, 4F10.0  /                           758-11
           1 5X, *DEPLOY/DOCKING MECH.*,  44X, 4F10.0  /                           758-12
           1 5X, *SIDE RAILS*,            54X, 4F10.0  /                           758-13
           1 5X, *ATMOS. CONT.(EXT. CREW)*, 41X, 4F10.0  /                         758-14
           1 5X, *DISPLAYS + DATA MANAG.*,  42X, 4F10.0  /                         758-15
           1 5X,*EXTRA CREW *, 53X, 4F10.0 /5X,*CREW FURNISH*, 51X, 4F10.0 /       758-16
           1 5X,*ELECT. POWER*, 51X, 4F10.0/5X,*EVA / IVA*,       49X,4F10.0 //    758-17
           1 5X,*RCS PROPEL*,54X, 4F10.0/5X,*ORB. SUPPT. TOTAL*,46X,4F10.0 //      758-18
           1 5X,*OMS HARDWARE*, 51X, 4F10.0/5X, *OMS PROPELLANT*,49X, 4F10.0//729-16A
           1 5X,*ORB. SUPPT. TOTAL*, 40X, 4F10.0 //                              729-16B
           15X,*LONGITUDINAL CG*, 48X, 4F10.0                 )                    729-17
4524         PRINT 111, PRESMOD, PALLSOR, EXPSOR, DPSOR, ELPSOR, ECSOR,            748
           1 SUPTSOR, DKSOR, FWDTUN, AFTUN, SUBTOT                                 758-21
4556         PRINT 112,                                                            758-22
           1 RETGR,  RET1R,  RET2R, RETSOR, EXCGR,  EXC1R,  EXC2R,  EXCSOR,        758-23
           1 XMAGGR, XMAG1R, XMAG2R, XMAGSOR, DDKGR, DDK1R, DDK2R, DDKSOR,         758-24
           1 RAILGR, RAIL1R, RAIL2R, RAILSOR, ATMGR, ATM1R, ATM2R, ATMSOR,         758-25
           1 DISGR,  DIS1R,  DIS2R,  DISSOR, CREWGR, CREW1R, CREW2R, CREWSOR,      758-26
           1 FURNGR, FURN1R, FURN2R, FURNSOR, ELPGR, ELP1R,  ELP2R, ELPSOR,        758-27
           1 EVAGR,  EVA1R,  EVA2R,  EVASOR, RCSPGR, RCSP1R, RCSP2R, RCSPSOR,      758-28
           1 TOTGR,  TOT1R,  TOT2R,  TOTSOR, OMSGR,  OMS1R,  OMS2R,  OMSSOR,       758-29
           1 OMSPGR, OMSP1R, OMSP2R, OMSPSOR, GTOGR, GTO1R;  GTO2R;  GTOSOR;       758-30
           1 XCGGR,  XCG1R,  XCG2R,  XCGSOR                                        758-31
4772    90   CONTINUE                                                              000759
4772         PRINT 100                                                             759-1
       108 FORMAT ( 3X, *PAYLOAD GEOMETRY* /                                       000760
           1  10X, *DIAMETER (FT.)*,   F44.1, 4F10.1 /                             000761
           1  10X, *LENGTH (FT.)*, F46.1, 4F10.1 /                                 000762
           1 10X, *ENVELOPE DIAM.  (FT.)*, F37.1, 4F10.1  /                        762-1
           1 10X, *ENVELOPE LENGTH (FT.)*, F37.1, 4F10.1  /                        762-2
           1 3X, *ADAPT. LENGTH (FT.)*, F46.1, 4F10.1 /                            000763
           1 3X, *ADAPT. THICK. (FT.)*,F46.5, 4F10.5 /                             763-1
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              1 3X, *DENSITY (LB/CU FT)*, F47.1,  4F10.1 /                          000764
              1 3X, *TOTAL ELECT. POWER (W)*, F43.1    , 4F10.1 )                   000765
   4776         PRINT 108,                                                        765-1
              1                DIAM1, DIAMMR, DIAM1R , DIAM2R,  DIAM2S,
              1                XLG1,  XLGMR,  XL1R,    XLGR ,  XLGS,                000767
              1                DIAM1E, DIAMRE, DIA1RE,  DIA2RE,  DIA2SE,            767-1
              1                XLG1E,  XLGMRE, XL1RE,   XLGRE,   XLGSE,             767-2
              1                HBL,    HBLMR,   H1R,     HR,   HS,                  000768
              1                 TH1, THMR, TH1R, THR,  THRSOR,                    768-1
              1                DEN ,   PKDENMR,PKDEN1R, PKDENR,  PKDENS,            000769
              1 TOTPWR, TOTPWRR, TOTPWR1R, TOTPWRM     , TOTPWRS                    000770
            109 FORMAT ( 3X, *BOOSTER DIAM. (FT)*, F47.1,  4F10.1    )              000771
   5122         PRINT 109,  DB3L,  DBSH,  DBSH,  DBSH,  DBSH                        000772
            135 FORMAT (3X, *MEAN MISS. DUR.*, F52.3, 4F10.3 )                      000773
   5140         PRINT 135, XMMD1, XMMD, XMMD, XMMDLC    , XMMD                      000774
            136  FORMAT ( 3X, *DES. LIFE*, F58.3, 4F10.3/)                          000775
   5156          PRINT 136, SATLIF1, SATLIF,SATLIF, SATLIF   , SATLIF               000776
            195 FORMAT (3X,*COST WEIGHT SUMMARY*, /    )                            000777
   5174         PRINT  195                                                          000778
            200 FORMAT(59X, *CDR*, 12X,     *CDR*,    13X,    *LCR*            /    000779
              1     57X,     *GROUND*,   9X, *ON-ORBIT*, 8X, *ON-ORBIT*,6X,*SORTIE*/ 000780
              143X,*REFERENCE*,4X,*REFURBISH*,6X,*MAINTENANCE*,5X,*MAINTENANCE*     000781
              15X,*MODE*    / +5X,*WEIGHT*, 4X,  *MMD*, +X,*WT.*,  6X,  *MMD*, +X,  000782
              1 *WT.*, 6X, *MMD*, 4X, *WT.* ,  5X,  *WT.*   )                       000783
   5200         PRINT 200                                                           000784
            205 FORMAT (5X, *STR + TPS + ADP              WS*, 10X,  7F8.0 ,F10.0  /   000785
              1          5X, *GN + ACS                    WA*, 10X,  7F8.0, F10.0  /   000786
              1          5X, *DRY PROPULSION              WP*, 10X,  7F8.0, F10.0  /   000787
              1          5X, *C. D. P. I.                 WC*, 10X,  7F8.0, F10.0 /    000788
              1          5X, *ELECTRICAL                  WE*, 10X,  7F8.0, F10.0 /    000789
              1          5X, *MISSION EQUIP.              WM*, 10X,  7F8.0, F10.0 /    000790
              1          5X, *ATT. CONT. PROP.           WAP*, 10X,  7F8.0, F10.0 /    000791
              1          5X, *MAIN PROPELL.              WPP*, 10X,  7F8.0, F10.0 /    000792
              1          3X, *LAUNCH WEIGHT*,         26X, F8.0, 3F16.0, F10.0 //  )   000793
   5204         PRINT 205, WSC,   DS2,   WS2,   DS3A,   WS3A,   DS3,    WS3,  WS4,    000794
              1                WAC,   DA2,   WA2,   DA3A,   WA3A,   DA3,    WA3,  WA4,    000795
              1                WPC,   DP2,   WP2,   DP3A,   WP3A,   DP3,    WP3,  WPC,    000796
              1                WCC,   DC2,   WC2,   DC3A,   WC3A,   DC3,    WC3,  WC4,    000797
              1                WEC,   DE2,   WE2,   DE3A,   WE3A,   DE3,    WE3,  WE4,    000798
              1                WMC,   DM2,   WM2,   DM3A,   WM3A,   DM3,    WM3,  WM4,    000799
              1               WAPC, DAP2, WAP2, DAP3A, WAP3A, DAP3, WAP3, WAP4,         000800
              1               WPPC, DPP2, WPP2, DPP3A, WPP3A, DPP3, WPP3, WPP4,         000801
              1                   XLWC,      XLWGR,      XLW1R,      XLW2R ,XLW4        000802
   5422         IF  (PROPTYP .EQ.10HLIQUID        ) P2 =  4                           000803
   5426         IF  (PROPTYP .EQ.10HSOLID         ) P2 =  1                           000804
   5432         IF  (STABTYP .EQ.10H3- AXIS       ) A1 =  3.                          000805
   5436         IF  (STABTYP .EQ.10HSPIN          ) A1 =  1.                          000806
   5442         IF  (STRTYP  .EQ.  10HEXO         ) S1 =   2.                         000807
   5446         IF  (STRTYP  .EQ.  10HENDO        ) S1 =   1.                         000808
   5452         IF ( XLV  .EQ. 1. ) XLVT = 10HSHUTTLETUG                              000809
            210 FORMAT(5X, *TYPE STRUCTURE                S1 =*, F10.0 , A12 /        000810
              1        5X, *ELECT. POWER (WATTS)          E1 =*, F15.0, 3F16.0     /  000811
              1        5X, *ORBIT ALTITUDE                C1 =*, F10.0 /              000812
              1     5X,*TYPE STABILITY            A1=*, F10.0, A12, A12 /             000813
              1        5X, *TOTAL IMPULSE                 P1 =*,  2X, +F16.0      /   000814
              1        5X, *TYPE PROPELLANT               P2 =*, F10.0    , A12 )     000815
   5456          PRINT 210, S1,STRTYP, TOTPWR, TOTPWRR, TOTPW1R, TOTPWRM,             000816
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                1 ORBAPO, A1, STABTYP, ACSPROP, TOTIMP,                             000817
                1 TOTIM2E, TOTIMGR, TOTIM2R,          P2, PROPTYP                   000818
5522      304   XMMD = XMMD + XMMDINC                                               000819
5524            IF ( XMMD .LE. XMMDMAX ) 23, 306                                    000820
5531      306   CONTINUE                                                            000821
5531            XMOD = XMOD + XMODINC                                               000823
5533            IF ( XMOD .LE. XMODMAX ) 22,4                                       000824
5540      199   CONTINUE                                                            000825
5540      110  CONTINUE                                                             826
        C       THESE CARDS REPRESENT THE SORTIE MODE                               900
5540           PRINT 100
5544             PRINT 136, PROGRAM, CODE, TODAY
         213    FORMAT ( 16X, *SORTIE MODE*)                                     903
5556             PRINT 213                                                       904
5562            PRINT 130, XMMD, SATLIF, TYPE, XMOD, XMISPWR, REDUN, PBATF,         700
              1 PNTACC,       PWRTYP, ORINT, PADTYR                                 000701
5614           PRINT 140, XIOC, DV1, PF, XNDL, XNTR, DP, ENC, CF1                   706
5640            PRINT 142, XNXPOND, PWRXPON, ANTDIAM, COMFREQ                       705-4
          214  FORMAT(/,8X,*ITEM*,18X, *WEIGHT*, 7X, *XCG*,7X, *YCG*, 7X, *ZCG*,    907
              1 7X,*VOL.*   )                                                       908
5654           PRINT 214                                                            909
          215  FORMAT (5X, *STRUCTURE*,      14X, F10.0, F10.3, 3F10.0     /        910
              1         5X, *ENVIRON. CONT.*,9X, F10.0, F10.3, 3F10.0     /         911
              1         5X, *DATA PROCESS.*,10X, F10.0, F10.3, 3F10.0    /          912
              1         5X, *ELECTRICAL*,    13X, F10.0, F10.3, 3F10.0    /         913
              1         5X, *DISPLAYS*,      15X, F10.0, F10.3, 3F10.0     /        914
              1         5X, *PERSONNEL*,     14X, F10.0, F10.3, 3F10.0     /        915
              1         5X, *FURNISHINGS*,   12X, F10.0, F10.3, 3F10.0     /        916
              1         5X, *EVA EQUIP.*  ,  13X, F10.0, F10.3, 3F10.0    /         917
              1         5X, *DOCKING MOD.*,  11X, F10.0, F10.3, 3F10.0     /        918
              1         5X, *FWD TUNNEL*,    13X, F10.0, F10.3, 3F10.0     /        919
              1         5X, *AFT TUNNEL*,    13X, F10.0, F10.3, 3F10.0     /        920
              1         5X, *ATTACH FITT.*,  11X, F10.0, F10.3, 3F10.0     /        921
              1         5X, *CONTINGENCY*,   12X, F10.0, F10.3, 3F10.0    //  )     922
          216  FORMAT (3X, *DRY WEIGHT*,     15X, F10.0, F10.3, 3F10.0     //       923
              1         5X, *CONSUMABLES*,   14X, F10.0, F10.3, 3F10.0     //       924
              1         3X, *WET WEIGHT*,    15X, F10.0, F10.3, 3F10.0     //       925
              1         5X, *ADAPTER*,       18X, F10.0, F10.3, 3F10.0     /        926
              1         5X, *PALLET*,        19X, F10.0, F10.3, 3F10.0     //       927
              1         3X, *LAUNCH WT.*,    15X, F10.0, F10.3, 3F10.0         )    928
5660           PRINT 215,     STRSOR,    STRXCG,    STRYCG,    STRZCG,    STRVOL,   930
              1               ECSOR,     ECXCG,     ECYCG,     ECZCG,     ECVOL,    931
              1               TTCSOR,    TTCXCG,    TTCYCG,    TTCZCG,    TTCVOL,   932
              1               ELSOR,     ELXCG,     ELYCG,     ELZCG,     ELVOL,    933
              1               DISPSOR,   DISPXCG,   DISPYCG,   DISPZCG,   DISPVOL,  934
              1               PERSSOR,   PERSXCG,   PERSYCG,   PERSZCG,   PERSVOL,  935
              1               FURNSOR,   FURNXCG,   FURNYCG,   FURNZCG,   FURNVOL,  936
              1               EVASOR,    EVAXCG,    EVAYCG,    EVAZCG,    EVAVOL,   937
              1               DKMOD,     DKMDXCG,   DKMDYCG,   DKMDZCG,   DKMDVOL,  938
              1               FWDTUNN,   FWTNXCG,   FWTNYCG,   FWTNZCG,   FWTNVOL,  939
              1               AFTTUNN,   AFTNXCG,   AFTNYCG,   AFTNZCG,   AFTNVOL,  940
              1               ATTFIT,    ATTXCG,    ATTYCG,    ATTZCG,    ATTVOL,   940-1
              1               CONSOR,    CONTXCG,   CONTYCG,   CONTZCG,   CONTVOL   941
6066           PRINT 216,     DWSOR,     DWXCG,     DWYCG,     DWZCG,     DWVOL,    942
              1               FLUIDS,    FLUDXCG,   FLUDYCG,   FLUDZCG,   FLUDVOL,  943
              1               GWSOR,     GWXCG,     GWYCG,     GWZCG,     GWVOL,    944
              1               ADPSOR,    ADPXCG,    ADPYCG,    ADPZCG,    ADPVOL,   945
```

ADP2RT -	011171	AFTNVOL-	011510	AFTNXCG-	011505	AFTNYCG-	011506
AFTNZCG-	011507	AFTTUNN-	011504	AFTUN -	011312	AMFM -	010534
AMFR -	010700	AMF1R -	011016	AMINGR -	010737	AMINMR -	010715
AMINSOR-	011261	AMIN1 -	010555	AMIN1F -	011024	AMIN2R -	011114
AMRL -	010525	AMWPMR -	010713	AMWP1 -	010640	AMWP1R -	011242
AMWP2R -	011112	AM2R -	010764	ANTDIAM-	010442	ANTWGR -	010750
ANTWT -	010635	ANTW1R -	011050	ANTW2R -	011135	AREAMR -	010722
AREA1 -	010645	AREA1R -	011031	AREA2R -	011120	ATMGR -	011315
ATMSOR -	011320	ATM1R -	011316	ATM2R -	011317	ATTFIT -	011511
ATTVOL -	011515	ATTXCG -	011512	ATTYCG -	011513	ATTZCG -	011514
AVEALT -	010566	A1 -	011422	B -	010413	BATT -	010613
BATTGR -	010743	BATT1R -	011042	BATT2 -	011127	BATT2R -	011130
C -	010414	CDPI -	010573	CFFM -	011151	CFGR -	010760
CFI -	010415	CF1 -	010627	CF11 -	010626	CF2R -	011153
CODE -	010370	COMFREQ-	010443	CONFM -	011152	CONFR -	011270
CONGR -	010761	CONRL -	011267	CONSOR -	011271	CONTVOL-	011521
CONTXCG-	011516	CONTYCG-	011517	CONTZCG-	011520	CON1 -	010630
CON1R -	011065	CON2R -	011154	CREWGR -	011321	CREWSOR-	011324
CREW1R -	011322	CREW2R -	011323	D -	010432	DAR2 -	011410
DAP3 -	011412	DAP3A -	011411	DATAPRO-	010436	DA2 -	011207
DA3 -	011222	DA3A -	011230	DBBL -	010650	DBSH -	010651
DC2 -	011210	DC3 -	011224	DC3A -	011231	DDKGR -	010465
DDKSOR -	010470	DDK1R -	010466	DDK2R -	010467	DELMMR -	010747
DELMM1R-	011047	DELMM2R-	011227	DEN -	010554	DEN1 -	010400
DE2 -	011211	DE3 -	011226	DE3A -	011232	DGNMMR -	010733
DGNMM1R-	011060	DGNMM2R-	011223	DIAMMR -	010720	DIAMRE -	010724
DIAM1 -	010557	DIAM1E -	010562	DIAM1R -	011027	DIAM2R -	011116
DIAM2S -	011370	DIARAV -	011160	DIA1AV -	010647	DIA1RE -	011033
DIA2RE -	011121	DIA2SE -	011174	DIMRAV -	010770	DISGR -	010475
DISPSOR-	011450	DISPVOL-	011454	DISPXCG-	011451	DISPYCG-	011452
DISPZCG-	011453	DISSOR -	010500	DIST -	010615	DISTFM -	011265
DISTF1R-	011044	DISTGR -	010744	DISTRLF-	010543	DIST1R -	011043
DIST2R -	011131	DIS1R -	010476	DIS2R -	010477	DI1RAV -	011057
DKMDVOL-	011476	DKMDXCG-	011473	DKMDYCG-	011474	DKMDZCG-	011475
DKMOD -	011472	DKSOR -	011310	DM2 -	010754	DM3 -	011141
DM3A -	011054	DP -	010503	DPP2 -	011414	DPP3 -	011416
DPP3A -	011415	DPSOR -	011305	DP2 -	011402	DP3 -	011404
DP3A -	011403	DS2 -	011375	DS3 -	011377	DS3A -	011376
DTCMMR -	010741	DTCMM1R-	011040	DTCMM2R-	011225	DV1 -	010417
DWGR -	010735	DWSOR -	011272	DWVOL -	011525	DWXCG -	011522
DWYCG -	011523	DWZCG -	011524	DW1 -	010552	DW1R -	011021
DW2R -	011110	ECFA -	010723	ECFM -	010512	ECFR -	010676
ECF1A -	011032	ECF1R -	011011	ECGR -	010726	ECRL -	010523
ECSOR -	011257	ECVOL -	011437	ECXCG -	011434	ECYCG -	011435
ECZCG -	011436	EC1 -	010565	EC1R -	011035	EC2R -	011123
ELFM -	010516	ELFR -	010703	ELF1R -	011015	ELGR -	010746
ELINV -	010617	ELINVGR-	010745	ELINV1R-	011045	ELINV2R-	011132
ELPGR -	011331	ELPSOR -	011306	ELP1R -	011332	ELP2R -	011333
ELRL -	010530	ELRLF -	010542	ELSOR -	011264	ELVOL -	011447
ELXCG -	011444	ELYCG -	011445	ELZCG -	011446	EL1 -	010620
EL1R -	011046	EL2R -	011133	ENC -	010504	ENCOOR -	010437
EQWT -	010622	EQWTGR -	010755	EQWT1R -	011062	EQWT2R -	011145
EVAGR -	011334	EVASOR -	011337	EVAVOL -	011471	EVAXCG -	011466
EVAYCG -	011467	EVAZCG -	011470	EVA1R -	011335	EVA2R -	011336
EXCGR -	010455	EXCSOR -	010460	EXC1R -	010456	EXC2R -	010457
EXPSOR -	011304	F -	010445	FB -	010611	FBL -	010654
FB1 -	010607	FB2 -	010610	FLUDVOL-	011532	FLUDXCG-	011527

```
              1                    PALLSOR,   PALLXCG,   PALLYCG,   PALLZCG,   PALLVOL,        946
              1                    XLWSOR,    XLWXCG,    XLWYCG,    XLWZCG,    XLWVOL          947
   6166    308   XMMD = XMMD + XMMDINC                                                      000819
   6170          IF ( XMMD .LE. XMMDMAX ) 23, 310                                           000820
   6175    310   CONTINUE                                                                   000821
   6175          XMOD = XMOD + XMODINC                                                      000823
   6177          IF ( XMOD .LE. XMODMAX ) 22,4                                              000824
   6204          END                                                                        000827
```

PROGRAM LENGTH INCLUDING I/O BUFFERS
011617

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

1	-	001655	2	-	006216	3	-	001550	4	-	000003
5	-	000003	6	-	001451	7	-	001661	9	-	000427
11	-	000275	12	-	000316	13	-	000334	14	-	000352
15	-	000524	16	-	001325	17	-	000427	18	-	000710
19	-	001027	20	-	000366	21	-	001146	22	-	000370
23	-	000372	24	-	000504	25	-	001266	26	-	000437
27	-	000453	28	-	000466	31	-	001674	33	-	001712
34	-	002274	35	-	002324	36	-	002074	37	-	003014
38	-	002001	39	-	002212	40	-	003026	45	-	003037
47	-	002311	48	-	002314	50	-	003053	55	-	003066
56	-	003112	57	-	003131	58	-	003143	60	-	003331
61	-	002354	62	-	002364	63	-	002400	65	-	002413
66	-	002635	67	-	002714	68	-	002437	69	-	002462
70	-	003412	71	-	002474	72	-	003513	73	-	003516
90	-	004773	98	-	003522	99	-	003561	100	-	006635
102	-	007036	103	-	007056	104	-	007100	105	-	007273
106	-	006640	107	-	007200	108	-	007476	109	-	007571
110	-	005541	111	-	007301	112	-	007351	115	-	006647
127	-	001744	128	-	001763	129	-	001775	130	-	006655
135	-	007577	136	-	007565	140	-	006747	141	-	007020
142	-	007001	145	-	007027	195	-	007612	199	-	005541
200	-	007517	205	-	007657	210	-	007774	213	-	010044
214	-	010050	215	-	010061	216	-	010207	304	-	005523
306	-	005532	308	-	006167	310	-	005176			

BLOCK NAMES AND LENGTHS
SSPRO - 011617

VARIABLE ASSIGNMENTS

ACINCG	-	010600	ACINFM	-	010514	ACINFR	-	010701	ACINF1R	-	011014
ACINGR	-	010732	ACINGR3	-	010734	ACINHG	-	010577	ACINRL	-	010526
ACINRLF	-	010537	ACINSOR	-	011262	ACIN1R	-	011057	ACIN2R	-	011144
ACSINGR	-	010731	ACSIN1	-	010601	ACSIN1R	-	011056	ACSIN2R	-	011143
ACSPROP	-	010407	ACWPGR	-	010730	ACWPSOR	-	011273	ACWP1	-	010576
ACWP1R	-	011055	ACWP2R	-	011142	ADPFM	-	011277	ADPFR	-	011276
ADPGR	-	011004	ADPMR	-	011000	ADPMRT	-	011001	ADPRL	-	010532
ADPSOR	-	011300	ADPVOL	-	011542	ADPXCG	-	011537	ADPYCG	-	011540
ADPZCG	-	011541	ADP1	-	010662	ADP1R	-	011100	ADP1RT	-	011101
ADP1T	-	010663	ADP1V	-	010671	ADP1VL	-	010672	ADP2R	-	011170

FLUDYCG -	011530	FLUDZCG -	011531	FLUIDS -	011526	FMR -	010772
FR -	011162	FURNGR -	011325	FURNSOR -	011330	FURNVOL -	011465
FURNXCG -	011462	FURNYCG -	011463	FURNZCG -	011464	FURN1R -	011326
FURN2R -	011327	FWDTUN -	011311	FWDTUNN -	011477	FWTNVOL -	011503
FWTNXCG -	011500	FWTNYCG -	011501	FWTNZCG -	011502	F1R -	011072
G -	010446	GNFM -	010313	GNFR -	010677	GNF1R -	011012
GNGR -	010727	GNRL -	01052[illegible]	GNRLF -	010541	GNSOR -	011260
GN1 -	010572	GN1R -	011036	GN2R -	011124	GTOGR -	011360
GTOSOR -	011363	GTO1R -	011361	GTO2R -	011362	GWGP -	010706
GWGRT -	010711	GWMR -	010707	GWSOR -	011275	GWT -	010564
GWVOL -	011536	GWXCG -	011533	GWYCG -	011534	GWZCG -	011535
GW1 -	010551	GW1R -	011020	GW1TR -	011022	GW2R -	011107
GW2TR -	011111	H -	010447	HBL -	010653	HBLMR -	010771
HR -	011161	HS -	011371	H1R -	011071	MPFM -	010362
MPFR -	010363	MPGR -	010366	MPRL -	010361	MPSOR -	011274
MP1 -	010364	MP1R -	010365	MP2R -	010367	OMSGR -	011350
OMSPGR -	011354	OMSPSOR -	011357	OMSP1R -	011355	OMSP2R -	011356
OMSSOR -	011353	OMS1R -	011351	OMS2R -	011352	ORBAPO -	010371
ORBINC -	010373	ORBPER -	010372	ORINT -	010406	PACKFTR -	010431
PADTYP -	010416	PALLET -	010631	PALLGP -	011605	PALLMR -	010766
PALLRL -	010533	PALLSOR -	011303	PALLVOL -	0115[illegible]6	PALLXCG -	011543
PALLYCG -	011544	PALLZCG -	011545	PALL1 -	010652	PALL1R -	011173
PALL1V -	010670	PALL2R -	010765	PALUN -	010664	PBAT -	010606
PBATF -	010374	PD -	010511	PDM -	010510	PERSSOR -	011455
PERSVOL -	011461	PERSXCG -	011456	PERSYCG -	011457	PERSZCG -	011460
PF -	010450	PKDENMR -	010712	PKDENR -	011113	PKDENS -	011373
PKDEN1R -	011023	PNTACC -	010377	PRESMOD -	011302	PROGRAM -	010425
PROPTYP -	010403	PWRTYP -	010404	PWRXPON -	010441	P2 -	011421
R -	010423	RAILGR -	010471	RAILSOR -	010474	RAIL1R -	010472
RAIL2R -	010473	RAVE -	011163	RA1LSOR -	011314	RCSPGR -	011340
RCSPSOR -	011343	RCSP1R -	011341	RCSP2R -	011342	REDUN -	010424
REPMR -	011002	RESID -	010636	RESIDGR -	010756	RESID1 -	010623
RESID1R -	011063	RESID2R -	011147	RETGR -	010451	RETSOR -	010454
RET1R -	010452	RET2R -	010453	REUSE -	011003	RLFMELC -	011134
RMRAV -	010773	RRAV -	011074	R1AV -	010655	S -	010405
SATLIF -	010546	SATLIF? -	010521	SATLIF1 -	010550	SEPDRY -	010642
SEPWP -	010643	SFBLV -	010674	SFCWT -	010641	SFR1 -	010621
SORTIE -	010412	SPINMR -	010717	SPWPMR -	010716	STARTYP -	010375
STRFM -	011104	STRFR -	010675	STRF1R -	011010	STRGR -	010757
STRRL -	010522	STRSOR -	011256	STRTYP -	010402	STRVOL -	011433
STRXCG -	011430	STRYCG -	011431	STRZCG -	011432	STR1 -	010625
STR1R -	011064	STR2R -	011150	SUBTOT -	011313	SUPTSOR -	011307
S1 -	011423	T -	010433	TBL -	010657	TE -	010612
THBL -	010661	THBLMR -	010777	THBLV -	010673	THMR -	010774
THMRT -	010775	THMRTT -	010776	THR -	011164	THRI -	011167
THRSOR -	011372	THTR -	011165	THTTR -	011166	THTT1R -	011077
THT1R -	011076	TH1 -	010645	TH1R -	011075	TH1T -	010656
TH1TT -	010650	TMR -	010767	TODAY -	010507	TOTGR -	011344
TOTIMGR -	011427	TOTIMP -	010633	TOTIM1R -	011051	TOTIM2E -	011426
TOTIM2R -	011145	TOTINGR -	010736	TOTPWR -	010575	TOTPWRM -	011105
TOTPWRR -	010705	TOTPWRS -	011374	TOTPW1R -	011037	TOTSOR -	011347
TOT1R -	011345	TOT2R -	011346	TR -	011157	TTCFM -	010515
TTCFR -	010702	TTCF1R -	011013	TTCGR -	010740	TTCRL -	010527
TTCRLF -	010540	TTCSOR -	011263	TTCVOL -	011443	TTCXCG -	011440
TTCYCG -	011441	TTCZCG -	011442	TTC1 -	010574	TTC1R -	011037
TTC2R -	011125	TYPE -	010411	T1R -	011070	VOLMR -	010714
VOL1 -	010556	VOL1R -	011025	VOL2R -	011115	WAC -	011247

```
WAPC     -  011251   WAP2     -  011203   WAP3     -  011216   WAP3A    -  011237
WAP4     -  011413   WA2      -  011202   WA3      -  011217   WA3A     -  011240
WA4      -  011401   WCC      -  011246   WC2      -  011201   WC3      -  011214
WC3A     -  011235   WC4      -  011405   WEC      -  011245   WELE     -  010614
WE2      -  011200   WE3      -  011213   WE3A     -  011234   WE4      -  011406
WGNSPIN-    010570   WGN3A    -  010567   WGW      -  010762   WGWT     -  010763
WG2SPIN-    010571   WMC      -  011253   WM2      -  011206   WM3      -  011221
WM3A     -  011243   WM4      -  011407   WPC      -  011250   WPF      -  010561
WPPC     -  011252   WPP2     -  011205   WPP3     -  011220   WPP3A    -  011241
WPP4     -  011417   WP2      -  011204   WP3      -  011215   WP3A     -  011236
WSA      -  010605   WSAGR    -  010742   WSAORH   -  010604   WSAORL   -  010602
WSAORM   -  010603   WSA1R    -  011041   WSA2R    -  011126   WSC      -  011244
WS2      -  011177   WS3      -  011212   WS3A     -  011233   WS4      -  011400
WTDIF    -  010537   W3       -  011155   W4       -  011156   W6       -  011066
XCGGR    -  011364   XCGSOR   -  011367   XCG1R    -  011365   XCG2R    -  011366
XIOC     -  010401   XLAND1   -  010644   XLGMR    -  010721   XLGMRE   -  010725
XLGR     -  011117   XLGRE    -  011122   XLGS     -  011176   XLGSE    -  011175
XLG1     -  010560   XLG1E    -  010563   XLG1R    -  011073   XLTOD    -  010624
XLTODGR-    010710   XLTOD1   -  010553   XLTOD1R-    011026   XLTOD2R-    011106
XLV      -  011424   XLVT     -  011425   XLWC     -  010665   XLWGR    -  011006
XLWSOR   -  011301   XLWVOL   -  011552   XLWXCG   -  011547   XLWYCG   -  011550
XLWZCG   -  011551   XLW1     -  010667   XLW1R    -  011102   XLW1V    -  010666
XLW2     -  011254   XLW2R    -  011172   XLW3     -  011255   XLW4     -  011420
XL1R     -  011030   XL1RE    -  011034   XMAGGR   -  010461   XMAGSOR-    010464
XMAG1R   -  010462   XMAG2R   -  010463   XMEFM    -  010517   XMEFR    -  010704
XMEF1R   -  011017   XMEGR    -  010753   XMERCOM-    010544   XMERL    -  010531
XMERLF   -  010545   XMESOR   -  011266   XME1     -  010410   XME1GR   -  010752
XME1R    -  011053   XME11R   -  011052   XME12R   -  011137   XME2     -  010505
XME2R    -  011140   XME3     -  010615   XMISPWR-    010376   XMMD     -  010536
XMMDINC-    010421   XMMDLC   -  010520   XMMDMAX-    010422   XMMDMIN-    010420
XMMD1    -  010547   XMOD     -  010535   XMODINC-    010427   XMODLC   -  011103
XMODMAX-    010430   XMODMIN-    010426   XMPISP   -  010632   XNAME    -  010506
XNANT    -  010444   XNDL     -  010501   XNDNLNK-    010434   XNTAPRC-    010435
XNTR     -  010502   XNXPOND-    010440   XPONDWT-    010634   XPONWGR-    010751
XPONW1R-    011051   XPONW2R-    011136

START OF CONSTANTS
006207

START OF TEMPORARIES
010257

START OF INDIRECTS
010357

UNUSED COMPILER SPACE
000200
```

3.2 EXAMPLE PRINTOUT

This section shows an example printout produced by the Satellite Synthesis Computer Program for the DSCS-II satellite program.

PROGRAM BRAVO | CASE NUMBER OSCS-II | 07/22/74

TYPE ATTID. CONT.	3-AXIS HOT GAS		
MEAN MISS. DUR.	3.000	DESIGN LIFE (YR.)	3.736
TYPE SATELLITE	COM	MODULARITY (UNITS)	25.
MISS. POWER (W)	218.	BATT. REDUN. / PERCENT	0.0 1.0
POINT. ACCUR. (DEG)	.150000	TYPE ELECT. POWER SOLAR	ORI RIGID
I. O. C.	1975.	VELOCITY	300.
ARRAY PACK. FACT.	.9	EXT. DN. LINKS	1.
NUMB. TAPE RECORD.	0.0	DATA PROCESS. WT.	0.
ENCRYPTION WT.	25.	CONTINGENCY	0.
NUMB. TRANSPONDERS	0.	TRANS. PWR. (WATTS)	0.
ANTENNA DIAM. (FT)	3.65	COMM. FREQ. (GHZ)	8.
NUMBER OF MODULES			

ITEM	HMD FACTOR	CDR OM MOD FACTOR	LC OM MOD FACTOR	1 REFERENCE WEIGHT	1 CDR GROUND REFURB.	25. CDR ON-ORB MAINT.	15. LCR ON-ORB MAINT.	SORTIE MODE
STRUCTURE	1.000	3.287	1.000	92.	84.	458.	573.	0.
ENVIRON. CONT.	1.000	1.000	1.330	22.	22.	56.	29.	0.
GUID. NAV. + STAB.	1.067	1.000	1.790	67.	82.	82.	130.	0.
DRY PROPULSION	1.000	1.000	1.000	10.	10.	22.	19.	0.
REACT. CONT.	1.096	1.100	1.280	19.	12.	24.	25.	0.
C. D. P. I.	1.091	1.000	.750	75.	82.	82.	56.	0.
ELECTRICAL	1.030	1.000	1.450	235.	242.	715.	341.	0.
SOLAR ARRAY				66.	68.	68.	96.	
BATTERY				83.	86.	86.	121.	
DISTRIBUTION		8.648	0.000	62.	64.	537.	90.	
PWR. CONDITION.				23.	24.	24.	34.	
MISS. EQUIPMENT	.819	1.000	1.000	237.	194.	194.	280.	0.
EQUIPMENT				0.	0.	0.	0.	
ANTENNA				57.	47.	47.	67.	
TRANSPONDER				180.	147.	147.	213.	
CONTINGENCY	0.000	0.000	0.000	0.	0.	0.	0.	0.
DRY WEIGHT				757.	728.	1633.	1453.	0.
REACT. CONT. PROPEL.				80.	26.	47.	48.	0.
MAIN PROPELLANT				40.	38.	86.	77.	0.
WET WEIGHT				877.	792.	1767.	1577.	0.
ADAPTER WEIGHT	1.000	0.000	0.000	76.	249.	210.	222.	0.
AUTO. PAYLOAD SUBWT				953.	1041.	1977.	1799.	0.

ITEM	MMD	CDR OM MOD	LC OM MOD	REFERENCE	CDR GROUND	CDR ON-ORB	LCR ON-ORB	SORTIE
SPACELAB MOD.								0.
SPACELAB PALLET								0.
EQUIPMENT								
EXPERIMENTS + MISSION EQUIP.								0.
DATA PROCESS + DISP.								0.
ELECT. POWER								0.
ENVIRON. CONT								0.
SUPPORTS								0.
DOCKING ADAPT								0.
FWD TUNNEL								0.
AFT TUNNEL								0.
SPACELAB SUBTOTAL								0.
RETENTION MECHANISM					500.	500.	750.	100.
MODULE EXCHANGE MECH.					0.	1265.	1900.	0.
MODULE MAGAZINE					0.	1575.	2300.	0.
DEPLOY/DOCKING MECH.					400.	400.	600.	0.
SIDE RAILS					320.	0.	0.	0.
ATMOS. CONT.(EXT. CREW)					0.	0.	0.	0.
DISPLAYS + DATA MANAG.					270.	270.	270.	150.
EXTRA CREW					0.	0.	0.	0.
CREW FURNISH					0.	0.	0.	0.
ELECT. POWER					0.	0.	0.	0.
EVA / IVA					0.	0.	0.	0.
RCS PROPEL					0.	0.	0.	0.
ORB. SUPPT. TOTAL					0.	0.	0.	0.
OMS HARDWARE					0.	0.	0.	0.
OMS PROPELLANT					0.	0.	0.	0.
ORB. SUPPT. TOTAL					0.	0.	0.	0.
LONGITUDINAL CG					0.	0.	0.	0.

PAYLOAD GEOMETRY

DIAMETER (FT.)	4.6	5.2	8.2	7.4	0.0
LENGTH (FT.)	4.6	3.6	5.8	5.2	0.0
ENVELOPE DIAM. (FT.)	10.9	10.9	10.9	10.9	10.9
ENVELOPE LENGTH (FT.)	8.2	7.3	9.4	8.8	3.7
ADAPT. LENGTH (FT.)	2.7	4.2	2.6	3.0	0.0
ADAPT. THICK. (FT.)	.00333	.00333	.00333	.00333	0.0000[illegible]
DENSITY (LB/CU FT)	10.0	10.0	5.4	6.7	[illegible]
TOTAL ELECT. POWER (W)	418.0	418.0	418.0	418.0	[illegible]
BOOSTER DIAM. (FT)	10.0	13.5	13.5	13.5	13.5
MEAN MISS. DUR.	2.500	3.000	3.000	5.000	3.000
DES. LIFE	3.124	3.736	3.736	3.736	3.736

COST WEIGHT SUMMARY

		REFERENCE WEIGHT	CDR GROUND REFURBISH MMD	CDR GROUND REFURBISH WT.	CDR ON-ORBIT MAINTENANCE MMD	CDR ON-ORBIT MAINTENANCE WT.	LCR ON-ORBIT MAINTENANCE MMD	LCR ON-ORBIT MAINTENANCE WT.	SORTIE MODE WT.
STR + TPS + ADP	WS	190.	0.	355.	0.	724.	0.	824.	0.
GN + ACS	WA	86.	17.	94.	7.	107.	0.	155.	0.
DRY PROPULSION	WP	10.	0.	10.	0.	22.	0.	19.	10.
C. D. P. I.	WC	75.	7.	82.	7.	82.	0.	56.	[illegible]
ELECTRICAL	WE	235.	7.	242.	21.	715.	0.	341.	[illegible]
MISSION EQUIP.	WM	237.	-43.	194.	-43.	194.	43.	280.	[illegible]
ATT. CONT. PROP.	WAP	80.	0.	26.	0.	47.	0.	48.	0.
MAIN PROPELL.	WPP	40.	0.	38.	0.	0.	0.	76.	0.
LAUNCH WEIGHT		953.		1041.		1977.		1799.	0.

TYPE STRUCTURE	S1 =	2.	EXO			
ELECT. POWER (WATTS)	E1 =		418.	418.	418.	418.
ORBIT ALTITUDE	C1 =	19323.				
TYPE STABILITY	A1=	0.	3-AXIS	HOT GAS		
TOTAL IMPULSE	P1 =		7987.	0.	0.	15318.
TYPE PROPELLANT	P2 =	4.	LIQUID			

3.3 PROGRAM SYMBOL LIST

The following pages of this section list the symbols used in the Satellite Synthesis Computer Program.

ACINCG	This list represents the attitude control inert weight for various items (lb).
ACINFM	
ACINFR	
ACINF1R	
ACINGR	
ACINGRB	
ACINHG	
ACINRL	
ACINRLF	
ACIN1R	
ACIN2R	
ACSINGR	
ACSIN1	
ACSIN1R	
ACSIN2R	
ACSPROP	Attitude Control Propellant Weight (lb)
ACWPGR	
ACWP1	
ACWP1R	
ACWP2R	
ADPFM	Adapter Weight (lb)
ADPFR	
ADPGR	
ADPMR	
ADPMRT	

ADPRL	Adapter Weight (lb) - (Cont'd)
ADP1	↓
ADP1R	
ADP1RT	
ADP1T	
ADP1V	
ADP1VL	
ADP2R	
ADP2RT	
AMFM	Apogee Motor Inert Weight (lb)
AMFR	↓
AMF1R	
AMINGR	
AMINGMR	
AMIN1	
AMIN1R	
AMIN2R	
AMRL	
AMWPMR	Apogee Motor Propellant Weight (lb)
AMWP1	↓
AMPW1R	
AMWP2R	
AM2R	
ANTDIAM	Communication Antenna Diameter (ft)
ANTWT	Communication Antenna Weight (lb)

AREAMR	Structural Area (ft^2)
AREA1	↓
AREA1R	↓
AREA2R	↓
AVEALT	Average Altitude (nmi)
BATT	Battery Weight (lb)
CDP1	Communications and Data Processing Weight (lb)
CFFM	Contingency Factor
CFGR	↓
CF1	↓
CF11	↓
CF2R	↓
CODE	Satellite Name (SEO-1)
COMFREQ	Communication Frequency (GHz)
CONFM	Contingency Weight (lb)
CONFR	↓
CONGR	↓
CONRL	↓
CON1	↓
CON1R	↓
CON2R	↓

DAP2 DAP3 DAP3A	Attitude Control Propellant Incremental Weights due to MMD Variation (lb) ↓
DATAPRO	Data Processing Weight (lb)
DA2 DA3 DA3A	Cost Name for Guidance and Navigation ↓
DBBL	Satellite Diameter (ft)
DBSH	Shuttle Adapter Diameter (ft)
DC2 DC3 DC3A	Cost Name CDPI Incremental Weights due to MMD Variation ↓
DELMMR DELMM1R DELMM2R	Electrical Weight Change due to MMD Variation (lb) ↓
DEN DEN1	Satellite Density (lb/ft^3) ↓
DE2 DE3 DE3A	Cost Names for Electrical Weight Variation with MMD ↓
DGNMMR DGNMM1R DGNMM2R	Guidance and Navigation Incremental Weight due to MMD Variation (lb) ↓

DIAMMR	Satellite Diameter (ft)
DIAM1	↓
DIAM1R	
DIARAV	
DIAM2R	
DIARV	
DIA1AV	
DIMRAV	
DI1RAV	
DISTFM	Electrical Distribution Weight (lb)
DISTF1R	↓
DIST1R	
DIST2R	
DM2	Mission Equipment Weight Variation with MMD, Cost Name (lb)
DM3	↓
DM3A	
DP	Apogee Motor Dry Weight Variation with MMD, Cost Name (lb)
DP2	↓
DP3	
DP3A	
DPP2	Launch Weight Variation with MMD, Cost Name (lb)
DPP3	↓
DPP3A	
DS2	Cost Name of Structural Weight Variation with MMD (lb)
DS3	↓
DS3A	

DTCMMR	CDPI Weight Variation with MMD (lb)
DTCMM1R	↓
DTCMM2R	
DV1	Velocity (ft/sec)
DWGR	Satellite Dry Weight (lb)
DW1	↓
DW1R	
DW2R	
ECFA	Environmental Control Factors
ECFM	↓
ECFR	
ECF1A	
ECF1R	
ECGR	
ECRL	
EC1	Environmental Control Weight (lb)
EC1R	↓
EC2R	
ELFM	Electrical Factors and Weight (lb)
ELFR	↓
ELF1R	
ELGR	
ELINV	
ELRL	
ELRLF	
EL1	
EL1R	
EL2R	

ENC	Encoder Weight (lb)
ENCODR	↓
EQWT	Equipment Weight (lb)
EQWTGR	↓
EQWT1R	
EQWT2R	
FB	3g Longitudinal Load on Satellite Adapter (lb)
FBL	↓
FB1	
FB2	
FMR	
FR	
R1R	
G	Gravity 32.2 ft/sec^2
GNFM	Guidance and Navigation Factors and Weight (lb)
GNFR	↓
GNF1R	
GNGR	
GNRL	
GNRLF	
GN1	
GN1R	
GN2R	

GWGR	Gross Weight (lb)
GWGRT	↓
GWMR	↓
GWT	↓
GW1	↓
GW1R	↓
GW1TR	↓
GW2R	↓
GW2TR	↓
HBL	Adapter Height (ft)
HBLMR	↓
HE	↓
HR	↓
H1R	↓
MPFM	Main Propellant Weight (lb)
MPFR	↓
MRGR	↓
MPRL	↓
MP1	↓
MP1R	↓
MP2R	↓
ORBAPO	Orbit Apogee (nmi)
ORBINC	Orbit Inclination (deg)
ORBPER	Orbit Perigee Altitude (nmi)
ORINT	Solar Array Paddles Orientation

PACKFTR (PF)	Solar Array Cells Packing Factor (0.9)
PADTYP	Type of Solar Array Paddle (FLEX, RIGID)
PALLET	Shuttle Pallet Weight (lb)
PALLFM	
PALLFR	
PALLGR	
PALLMR	
PALLRL	
PALL1	
PALL1R	
PALL1V	
PALL2R	
PALUN	Pallet Unit Weight (lb/ft)
PBAT	Battery Power (watts)
PD	Propellant Density (lb/ft^3)
PDM	
PF	Solar Cell Packing Factor
PKDENMR	Satellite Packing Density (lb/ft^3)
PKDENR	
PKDEN1R	
PNTACC	Pointing Accuracy (deg)
PROGRAM	Program Name (BRAVO)
PROPTYP	Propellant Type (Liquid or Solid)

PWRTYP	Power Type (Solar)
PWRXPON	Transponder Power (watts)
RAVE	Adapter Average Radius (ft)
DMRAV	↓
RRAF	
RIAV	
REDUN	Redundancy Factor for Batteries
REPMR	Residual Propellant Weight (lb)
RESID	↓
RESIDGR	
RESID1	
RESID1R	
RESID2R	
REUSE	Factor for Reuse
SATLIF	Satellite Design Life (years)
SATLIF1	↓
SEPDRY	Solar Electric Propulsion Dry Weight (lb)
SEPWP	Solar Electric Propulsion Propellant Weight (lb)
SFBLV	Structure Factor
SFCWT	↓
SFR1	
SPINMR	Solar Propulsion Inert Weight (lb)
SPIN2R	↓

SPWPMR	Solar Propulsion Propellant Weight (lb)
SPWP2R	↓
STABTYP	Attitude Control Type (3-axis)
STRFM	Structure Weight
STRFR	↓
STRF1R	↓
STRGR	↓
STRRL	↓
STRTYP	Structure Type (EXO or ENDO)
STR1	Structure Weight (lb)
STR1R	↓
STR2R	
TBL	Adapter Sidewall Thickness (ft)
TE	↓
TH	↓
THBL	↓
THBLMR	↓
THBLV	↓
THMR	↓
THMRT	↓
THMRTT	↓
THR	↓
THR1	↓
THTR	↓
THTTR	↓
THTT1R	↓
THT1R	↓

TH1	Adapter Sidewall Thickness (ft) - (Cont'd)
TH1R	↓
TH1T	↓
TH1TT	↓
TMR	↓
TODAY	Today's Date
TOTIMGR	Launch Weight (lb)
TOTIM1R	↓
TOTIM2R	↓
TOTINGR	↓
TOTIMP	Total Impulse (lb/sec)
TOTPWR	Total Power (watts)
TOTPWRE	↓
TOTPWRM	↓
TOTPWRR	↓
TOTPW1R	↓
TTCFM	CDPI Weight and Factors
TTCFR	↓
TTCF1R	↓
TTCGR	↓
TTCRL	↓
TTCRLF	↓
TTC1	↓
TTC1R	↓
TTC2R	↓
TYPE	Satellite Type (COM, NAV, OBS)

VOLMR	Satellite Volume (ft^3)
VOL1	↓
VOL1R	
VOL2R	
WAC	Cost Names for Cost/Weight Printout - Have No Effect on Program
WAPC	↓
WAP2	
WAP3	
WAP3A	
WA2	
WA3	
WA3A	
WC	
WCC	
WC2	
WC3	
WC3A	
WEC	
WELE	
WE2	
WE3	
WE3A	
WGNSPIN	Guidance and Navigation Weight Spinner (lb)
WGN3A	Guidance and Navigation Weight 3-Axis (lb)
WGN2SPIN	Guidance and Navigation Weight 2-Spin (lb)

WGW	Cost Names for Cost/Weight Printout - Have No Effect on Program
WGWT	↓
WMC	↓
WM2	↓
WM3	↓
WM3A	↓
WPC	↓
WPF	↓
WPPC	↓
WPP2	↓
WPP3	↓
WPP3A	↓
WP2	↓
WP3	↓
WP3A	
WSA	Solar Array Weight (lb)
WSAORH	Solar Array Weight Oriented, High Orbit Weight
WSAORL	Solar Array Weight Oriented, Low Orbit Weight
WSAORM	Solar Array Weight Oriented, Medium Orbit Weight
WSC	Cost Names
WS2	↓
WS3	↓
WS3A	
WTDIF	Difference in Weight (lb)
W3	Cost Names
W4	↓
W6	

XIOC	Year, Initial Operational Capability
XLANDI	Adapter Length (ft)
XLGMR	
XLGR	
XLG1	
XLG1R	
XLTDBL	Length-to-Diameter Ratio
XLTOD	
XLTODGR	
XLTOD1	
XLTOD1R	
XLTOD2R	
XLV	Launch Weight (lb)
XLVT	
XLWC	
XLWGR	
XLW1	
XLW1R	
XLW1V	
XLW2	
XLW2R	
XLW3	
XLW3A	
XLW4	
XL1R	
XMEF1R	Mission Equipment Factors and Weight
XMEFM	
XMEFR	
XMEGR	

XMERL	Mission Equipment Factors and Weight (Cont'd)
XME1	
XME1R	
XME2	
XME2R	
XME3	
XMISPWR	Mission Equipment Power (watts)
XMMD	Mean Mission Duration (years)
XMMDINC	Mean Mission Duration (years) Increment
XMMDMAX	Mean Mission Duration (years) Maximum
XMMDMIN	Mean Mission Duration (years) Minimum
XMMD1	Mean Mission Duration (years)
XMOD	Number of Modules
XMODINC	Number of Modules Increment
XMODMAX	Number of Modules Maximum
XMODMIN	Number of Modules Minimum
XMPISP	Main Propellant Specific Impulse (sec)
XNAME	Program Name (SATWTS)
XNDL	Number of Down Links
XNDNLNK	
XNTAPRC	Number of Tape Recorders
XNTR	
XNXPOND	Number of Transponders
XPONDWT	Transponder Weight (lb)

4. SPACE SYSTEMS PAYLOAD PROGRAM COST ESTIMATING COMPUTER PROGRAM LISTING

The listing for the Space Systems Payload Program Cost Estimating Computer Program is shown in this section.

```
      ∇PAYPROG[⎕]∇
    ∇ PAYPROG
[1]     INITIALIZE
[2]     CONSTANTS
[3]     'ENTER SATELLITE'
[4]     ⎕
[5]     WHFAC
[6]     DORCA
[7]     FACTOR
[8]     CER
[9]     →(TYPE≠2)/CRNOT
[10]    CURRDUS2
[11]  CRNOT:TOTALING
[12]    SPREAD
[13]    LV
[14]    OUTCOST
[15]    OUTSPD
[16]    OUTLV
[17]    MESPD
    ∇

      ∇INITIALIZE[⎕]∇
    ∇ INITIALIZE
[1]     PD←PU←0
[2]     MD←MU←0
[3]     CU←0
[4]     LD←0
[5]     FAL←FDEV←FUNI←1
[6]     FSSD←FSLD←FSCD←FSAD←FSPD←FSMD←FSGD←1
[7]     FSSU←FSLU←FSCU←FSAU←FSPU←FSMU←FSLU←1
[8]     SSRS←SSRNE←SSNEW←SSREF←SSMTN←,0
[9]     ALV1←ALV2←ALV3←0
[10]    LVS1←LVS2←LVS3←COLV1←COLV2←COLV3←,0
[11]    LVC1←LVC2←LVC3←1
[12]    FLSD←FLLD←FLCD←FLAD←FLPD←FLMD←FLGD←1
[13]    FLSU←FLLU←FLCU←FLAU←FLPU←FLMU←FLLU←1
[14]    WS←WL←WC←WA←WAP←WP←WPP←WM←0
[15]    WLR←WCR←WAR←WAPR←WMR←0
[16]    LS←LL←LC←LA←LP←LM←1
    ∇
```

```
      ∇CONSTANTS[⎕]∇
    ∇ CONSTANTS
[1]   BL←1
[2]   CFS←2
[3]   OAO←3
[4]   LOS←4
[5]   JHQ←5
[6]   CM2←6
[7]   COM←7
[8]   RMB←31
[9]   RMW←25
[10]  OVHD←2.06
[11]  FEE←1.13
[12]  PLD←1.5
[13]  PLU←1.3
[14]  ECP←1.15
[15]  PI←1,1.065,1.114,1.17,1.225
[16]  YP←73
[17]  FLYP←79
[18]  G1←0.13
[19]  E1←P1←M1←YRD←RR←MR←0
[20]  C1←P2←M2←LES←LVTYPE←1
[21]  TYPE←S1←2
[22]  A1←RMOD←3
[23]  TMOD←10
    ∇

      ∇WHFAC[⎕]∇
    ∇ WHFAC
[1]   →2×TYPE
[2]   FTYPE1
[3]   →0
[4]   FTYPE2
[5]   →0
[6]   FTYPE3
[7]   →0
    ∇
```

```
      ∇FTYPE1[⎕]∇
    ∇ FTYPE1
[1]   FTYPE2
[2]   RR←MR←0
    ∇

      ∇FTYPE2[⎕]∇
    ∇ FTYPE2
[1]   WRATIO
[2]   FLED←0.536+0.464×WER÷WE
[3]   FLEU←0.307+0.693×WER÷WE
[4]   FLCD←0.715+0.285×WCR÷WC
[5]   FLCU←0.475+0.525×WCR÷WC
[6]   TEMP←(WAR+WAPR)÷WA+WAP
[7]   FLAU←0.466+0.534×TEMP
[8]   →(TEMP≥1.6)/D1
[9]   FLAD←0.938+0.062×TEMP
[10]  →D2
[11] D1:FLAD←0.813+0.187×TEMP
[12] D2:FLMD←0.812+0.188×WMR÷WM
[13]  FLMU←0.39+0.61×WMR÷WM
[14]  →(QMTN=0)/F21
[15]  FLAU←FLAU×1.0074-0.0074×TMOD
[16] F21:→(MR≠0)/F22
[17]  MR←0.25
[18] F22:MR←MR×RMOD÷TMOD
[19]  →(RR≠0)/0
[20]  RR←0.39
    ∇

      ∇WRATIO[⎕]∇
    ∇ WRATIO
[1]   →(WER≠0)/WR1
[2]   WER←WE
[3]  WR1:→(WCR≠0)/WR2
[4]   WCR←WC
[5]  WR2:→(WAR≠0)/WR3
[6]   WAR←WA
[7]  WR3:→(WAPR≠0)/WR4
[8]   WAPR←WAP
[9]  WR4:→(WMR≠0)/0
[10]  WMR←WM
    ∇
```

```
      ∇FTYPE3[⎕]∇
    ∇ FTYPE3
[1]    LSD← 1 0.81 0.56 0.62 0.53 0.59 0.59
[2]    LED← 1 0.54 0.65 0.65 0.73 0.75 0.76
[3]    LCD← 1 0.57 1 0.72 0.7 0.79 0.79
[4]    LAD← 1 0.58 1 0.68 0.61 0.52 0.71
[5]    LPD← 1 0.88 ,5ρ0.85
[6]    LMD← 0.75 0.75 0.63 0.75 0.75 0.75 0.75
[7]    LSU← 1 0.89 0.59 0.81 0.42 0.81 0.81
[8]    LEU← 1 0.59 0.79 0.95 0.85 0.54 0.8
[9]    LCU← 1 0.78 1 0.66 ,3ρ0.85
[10]   LAU← 1 0.63 1 0.82 0.83 0.59 0.87
[11]   LPU← 1 1.14 ,5ρ0.75
[12]   LMU← 1 1 0.83 1 0.65 1 1
[13]   LLU← 1 1 ,(3ρ0.74), 1 1
[14]   FLSD←LSD[LS]
[15]   FLED←LED[LE]
[16]   FLCD←LCD[LC]
[17]   FLAD←LAD[LA]
[18]   FLPD←LPD[LP]
[19]   FLMD←LMD[LM]
[20]   FLSU←LSU[LS]
[21]   FLEU←LEU[LE]
[22]   FLCU←LCU[LC]
[23]   FLAU←LAU[LA]
[24]   FLPU←LPU[LP]
[25]   FLMU←LMU[LM]
[26]   FLLU←LLU[LM]
[27]   FLGD←0.71
[28]   LSD←LED←LCD←LAD←LPD←LMD←LSU←LEU←LCU←LAU←LPU←LMU←LLU←⍳0
[29]   →(MR≠0)/F31
[30]   MR←0.25
[31] F31:→(RR≠0)/0
[32]   RR←0.3
    ∇
```

```
      ∇DORCA[⎕]∇
    ∇ DORCA
[1]   YRN←YR-68
[2]   PI←PI[YRN]
[3]   WG←WS+WER+WCR+WAR+WAPR+WP+WPP+WMR
[4]   →(YRD≠0)/D6
[5]   YRD←3+(WG>3000)
[6]  D6:→(LVTYPE=3)/D5
[7]   ALV1←(8.376×PI)+0.76×PI×(LVTYPE=2)
[8]  D5:→(M1≠0)/D4
[9]   →((M2=1)∨(M2=2)∨(M2=9)∨((M2=7)∧(WMR≥500)))/D1
[10]  →((M2=6)∨(M2=10)∨((M2=3)∧(WMR≥500))∨((M2=4)∧(WMR≥500))∨((M2=7)∧(WMR<500))∨((M2=8)∧(WMR≥200)))/D2
[11]  →((M2=5)∨((M2=3)∧(WMR<500))∨((M2=4)∧(WMR<500))∨((M2=8)∧(WMR<200)))/D3
[12] D1:M1←1
[13]  →D4
[14] D2:M1←2
[15]  →D4
[16] D3:M1←3
[17] D4:→(~((M2=1)∨(M2=2)∨(M2=6)))/0
[18]  G1←0.025
    ∇
```

```
      ∇FACTOR[⎕]∇
    ∇ FACTOR
[1]   FALL←OVHD×FEE×ECP×PI×FAL
[2]   FD←FALL×PLD×FDEV
[3]   FU←FALL×PLU×FUNI
[4]   FSD←FD×FSSD×FLSD÷1000
[5]   FED←FD×FSED×FLED÷1000
[6]   FCD←FD×FSCD×FLCD÷1000
[7]   FAD←FD×FSAD×FLAD÷1000
[8]   FPD←FD×FSPD×FLPD÷1000
[9]   FMD←FD×FSMD×FLMD÷1000
[10]  FGD←FAL×FDEV×FSGD×FLGD
[11]  FSU←FU×FSSU×FLSU÷1000
[12]  FEU←FU×FSEU×FLEU÷1000
[13]  FCU←FU×FSCU×FLCU÷1000
[14]  FAU←FU×FSAU×FLAU÷1000
[15]  FPU←FU×FSPU×FLPU÷1000
[16]  FMU←FU×FSMU×FLMU÷1000
[17]  FLU←FAL×FUNI×FSLU×FLLU
    ∇
```

```
      ∇CER[⎕]∇
    ∇ CER
      OV←~UN←WS<10.25
      HI←~LO←WS<9.95
      →(S1=1)/ENDOS
      SD←FSD×(OV×700+550.33×WS*0.26)+UN×1650
      SU←FSU×(HI×450+11.39×WS*0.57)+LO×490
      →ELEC
    ENDOS:SD←FSD×(OV×¯657.92+550.33×WS*0.26)+UN×350
      SU←FSU×(HI×¯22.2+11.39×WS*0.57)+LO×20
    ELEC:ED←FED×453.83+66.63×E1*0.48
      EU←FEU×111.59+4.9075×E1*0.62
      CD←FCD×(15.1×WC)+((C1=1)×765.4)+(C1=2)×3965.4
      CU←FCU×((WC<13)×90)+(WC≥13)×¯83.05+8.4×WC
      AD←FAD×((A1=1)×263.42+125.68×(WA+WAP)*0.36)+((A1≠1)×11.92×(WA+WAP))+((A1=2)×5700)+(A1=3)×2187
      AU←FAU×((A1=1)×27.51+16.003×(WA+WAP)*0.5)+(A1≠1)×28.87+4.28×(WA+WAP)
      →(P1=0)/MISS
      →(P2=4)/LIQ
      PD←FPD×((P1<50000)×30)+(P1≥50000)×¯187.97+0.01×P1
      PU←FPU×35+(P1>200000)×95
      →MISS
    LIQ:PD←FPD×8.9675×P1*0.5
      PU←FPU×0.08315599999999999×P1*0.7
    MISS:→(WM=0)/GSE
      MD←FMD×(1.575*(M1=2))×(3.15*(M1=3))×397.49+242.58×WM*0.4
      MU←FMU×(1.375*(M1=2))×(2.75*(M1=3))×(30*(WM<17))×(¯309.47+82.45×WM*0.5)*(WM≥17)
    GSE:GD←FGD×G1×ED+CD+AD+4×EU+CU+AU
      SPU←SU+EU+CU+AU+PU
      SAU←SPU+MU
      LU←FLU×0.12×((SAU+FAL×FUNI)*0.848)×3*(M1≠1)
      SPD←SD+ED+CD+AD+PD
      SAD←SPD+MD
      AVGU←LES*(¯0.074)
      AS←SU×AVGU
      AE←EU×AVGU
      AC←CU×AVGU
      AA←AU×AVGU
      AP←PU×AVGU
      AM←MU×AVGU
      ASPU←AS+AE+AC+AA+AP
      ASAU←ASPU+AM
    ∇
```

```
      ∇CURREUS2[⎕]∇
    ∇ CURREUS2
[1]   SD←SD-SU
[2]   ED←ED-EU
[3]   CD←CD-CU
[4]   AD←AD-AU
[5]   PD←PD-PU
[6]   MD←0.75×MD
[7]   SPD←SD+ED+CD+AD+PD
[8]   SAD←SPD+MD
    ∇
```

```
      ∇TOTALING[⎕]∇
    ∇ TOTALING
[1]   QRD←+/SSRS
[2]   QME←+/SSRME
[3]   QINV←+/SSNEW
[4]   QREF←+/SSREF
[5]   QMTN←+/SSMTN
[6]   SIN←AS×QINV
[7]   EIN←AE×QINV
[8]   CIN←AC×QINV
[9]   AIN←AA×QINV
[10]  PIN←AP×QINV
[11]  MIN←AM×QINV
[12]  MEEXC←(SSRME>0)∧(SSNEW=0)∧(SSREF>0)
[13]  MEQ←+/MEEXC
[14]  MEDELT←LES×MEQ×(1-RR)×AM
[15]  MIN←MIN+MEDELT
[16]  SPIN←SIN+EIN+CIN+AIN+PIN
[17]  SAIN←SPIN+MIN
[18]  MISCD←0.5+0.0025×SAIN
[19]  MISCIN←0.0154×SAIN
[20]  RDME←QME×MD
[21]  RDSUB←(QRD×SPD+GD)+RDME
[22]  SETDD←0.06×RDSUB+MISCD
[23]  SETDIN←0.06×1.0154×SAU×LES*0.926
[24]  SETDO←0.06×LU×LES
[25]  TOTRD←RDSUB+MISCD+SETDD
[26]  TOTINV←SAIN+MISCIN+SETDIN
[27]  REFOPS←QREF×RR×ASAU
[28]  MTNOPS←QMTN×MR×ASAU
[29]  LOPS←LU×QINV+QREF+0.6666667×QMTN×(M1≠1)
[30]  TOTOPS←REFOPS+MTNOPS+LOPS+SETDO
    ∇
```

```
      ∇SPREAD[⎕]∇
    ∇ SPREAD
[1]   AVGC←(TOTRD-RDME)÷QRL
[2]   VECT←SSRS
[3]   WHSPD
[4]   CORD←SUM
[5]   AVGC←RDME÷QME
[6]   VECT←SSRME
[7]   WHSPD
[8]   CORM←SUM
[9]   CORDTE←⌊0.5+CORD+CORM
[10]  AVGC←(TOTINV-MEDELT)÷QINV
[11]  VECT←SSNEW
[12]  SP3
[13]  COIN←SUM
[14]  AVGC←MEDELT÷MEQ
[15]  VECT←MEEXC
[16]  SP3
[17]  COIM←SUM
[18]  COINVES←⌊0.5+COIN+COIM
[19]  CORO←0
[20]  →(QREF=0)/NOREF
[21]  AVGC←LU+REFOPS÷QREF
[22]  VECT←SSREF
[23]  SP2
[24]  CORO←SUM
[25] NOREF:COMO←0
[26]  →(QMTN=0)/NOMTN
[27]  AVGC←(LU×0.6666667×(M1≠1))+MTNOPS÷QMTN
[28]  VECT←SSMTN
[29]  SP2
[30]  COMO←SUM
[31] NOMTN:AVGC←LU+SETDO÷QINV
[32]  VECT←SSNEW
[33]  SP2
[34]  COLO←SUM
[35]  COOPERAT←⌊0.5+CORO+COMO+COLO
[36]  COTOTAL←CORDTE+COINVES+COOPERAT
    ∇
```

```
      ∇WHSPD[⎕]∇
    ∇ WHSPD
[1]   →2×YRD-1
[2]   SP2
[3]   →0
[4]   SP3
[5]   →0
[6]   SP4
[7]   →0
[8]   SP5
    ∇


      ∇SP2[⎕]∇
    ∇ SP2
[1]   TEMP1←0,0,0,0,0.5×AVGC×VECT
[2]   TEMP2←0,0,0,0.5×AVGC×VECT,0
[3]   SUM←TEMP1+TEMP2
    ∇


      ∇SP3[⎕]∇
    ∇ SP3
[1]   TEMP1←0,0,0,0,0.2×AVGC×VECT
[2]   TEMP2←0,0,0,0.55×AVGC×VECT,0
[3]   TEMP3←0,0,0.25×AVGC×VECT,0,0
[4]   SUM←TEMP1+TEMP2+TEMP3
    ∇


      ∇SP4[⎕]∇
    ∇ SP4
[1]   TEMP1←0,0,0,0,0.1×AVGC×VECT
[2]   TEMP2←0,0,0,0.35×AVGC×VECT,0
[3]   TEMP3←0,0,0.43×AVGC×VECT,0,0
[4]   TEMP4←0,0.12×AVGC×VECT,0,0,0
[5]   SUM←TEMP1+TEMP2+TEMP3+TEMP4
    ∇
```

```
      ∇SP5[⎕]∇
    ∇ SP5
[1]   TEMP1←0,0,0,0,0.070000000000000001×AVGC×VECT
[2]   TEMP2←0,0,0,0.18×AVGC×VECT,0
[3]   TEMP3←0,0,0.35×AVGC×VECT,0,0
[4]   TEMP4←0,0.3×AVGC×VECT,0,0,0
[5]   TEMP5←0.1×AVGC×VECT,0,0,0,0
[6]   SUM←TEMP1+TEMP2+TEMP3+TEMP4+TEMP5
    ∇


      ∇LV[⎕]∇
    ∇ LV
[1]   →((+/LVS1)=0)/0
[2]   CODE←LVC1
[3]   AVGC←ALV1
[4]   VECT←LVS1
[5]   WHSPD2
[6]   COLV1←⌊0.5+SUM
[7]   →((+/LVS2)=0)/END1
[8]   CODE←LVC2
[9]   AVGC←ALV2
[10]  VECT←LVS2
[11]  WHSPD2
[12]  COLV2←⌊0.5+SUM
[13]  →((+/LVS3)=0)/END1
[14]  CODE←LVC3
[15]  AVGC←ALV3
[16]  VECT←LVS3
[17]  WHSPD2
[18]  COLV3←⌊0.5+SUM
[19] END1:COLV←COLV1+COLV2+COLV3
[20]  TOTPLLV←COTOTAL+COLV
    ∇

      ∇WHSPD2[⎕]∇
    ∇ WHSPD2
[1]   →(CODE=1)/4
[2]   SP3
[3]   →0
[4]   SUM←0,0,0,0,AVGC×VECT
[5]   →0
    ∇
```

```
      ∇OUTCOST[⎕]∇
    ∇ OUTCOST
[1]   RM←RMB↑' '
[2]   ST←RM,RMW↑'STRUCTURE'
[3]   EL←RM,RMW↑'ELECTRICAL POWER'
[4]   CO←RM,RMW↑'COMMUNICATIONS AND DATA'
[5]   SB←RM,RMW↑'STABILITY AND CONTROL'
[6]   PR←RM,RMW↑'PROPULSION'
[7]   SP←RM,RMW↑'   SPACECRAFT'
[8]   MI←RM,RMW↑'MISSION EQUIPMENT'
[9]   SA←RM,RMW↑'   SATELLITE'
[10]  GS←RM,RMW↑'GSE'
[11]  LN←RM,RMW↑'LAUNCH SUPPORT'
[12]  DEV←SD,ED,CD,AD,PD,SPD
[13]  UNIT←AS,AE,AC,AA,AP,ASPU
[14]  HEADER
[15]  SUBCOST
[16]  WORDS←(TEMP,(RMB+RMW))ρST,EL,CO,SB,PR,SP
[17]  WORDS,CM
[18]  DEV←MD,SAD
[19]  UNIT←AM,ASAU
[20]  SUBCOST
[21]  WORDS←(TEMP,(RMB+RMW))ρMI,SA
[22]  WORDS,CM
[23]  DEV←GD,LD
[24]  UNIT←GU,LU
[25]  SUBCOST
[26]  WORDS←(TEMP,(RMB+RMW))ρGS,LN
[27]  WORDS,CM
    ∇

      ∇SUBCOST[⎕]∇
    ∇ SUBCOST
[1]   NUMB←⍉(2,ρDEV)ρDEV,UNIT
[2]   CM← 10 0 13 2 DFT NUMB
[3]   TEMP←ρDEV
    ∇
```

```
      ∇HEADER[⎕]∇
    ∇ HEADER
[1]   RTOT←RMW+10+13+RMB×2
[2]   R1←(⌊((RTOT-⍴NAME)÷2))⍴' '
[3]   R1,NAME
[4]   ⍳0
[5]   RH←(⌊((RTOT-20)÷2))⍴' '
[6]   RH,'SATELLITE BASIC COST'
[7]   Y1←'6970717273'
[8]   YEAR←Y1[(Y2-1),(Y2←2×YRN)]
[9]   RH←(⌊((RTOT-26)÷2))⍴' '
[10]  DO←RH,'(MILLIONS OF 19'
[11]  LLAR←' DOLLARS)'
[12]  DO,YEAR,LLAR
[13]  ⍳0
[14]  ⍳0
[15]  RH←(RMB+RMW+10-4)⍴' '
[16]  RH,'RDTE          UNIT'
[17]  ⍳0
    ∇
```

```
    ∇OUTSPD[⎕]∇
  ∇ OUTSPD
    FYV←(FLYP-5)+⍳23
    FY1←'     FY  '
    FY2← 4 0 DFT FYV
    FY3←'  TOT'
    ⍳0
    ⍳0
    FY1,FY2,FY3
    ⍳0
    '          SCHEDULES'
   →(QRD=0)/NRD
    WORDS←'     SPACECRAFT DESIGNS      '
    NUMB←SSRS,QRD
    SUBLNCH
    WORDS,CM
   NRD:→(QME=0)/NME
    WORDS←'     MISS EQUIP DESIGNS      '
    NUMB←SSRME,QME
    SUBLNCH
    WORDS,CM
   NME:→(QINV=0)/NINV
    WORDS←'     NEW SAT LAUNCHES        '
    NUMB←SSNEW,QINV
    SUBLNCH
    WORDS,CM
   NINV:→(QREF=0)/NREF
    WORDS←'     REFURB LAUNCHES         '
    NUMB←SSREF,QREF
    SUBLNCH
    WORDS,CM
   NREF:→(QMTN=0)/NMTN
    WORDS←'     MAINTENANCE FLTS        '
    NUMB←SSMTN,QMTN
    SUBLNCH
    WORDS,CM
   NMTN:→((+/LVS1)=0)/NLV
    WORDS←'     LAUNCH VEHICLE 1        '
    NUMB←LVS1,(+/LVS1)
```

```
[38]  SUBLNCH
[39]  WORDS,CM
[40]  →((+/LVS2)=0)/NLV
[41]  WORDS←'     LAUNCH VEHICLE 2
[42]  NUMB←LVS2,(+/LVS2)
[43]  SUBLNCH
[44]  WORDS,CM
[45]  →((+/LVS3)=0)/NLV
[46]  WORDS←'     LAUNCH VEHICLE 3
[47]  NUMB←LVS3,(+/LVS3)
[48]  SUBLNCH
[49]  WORDS,CM
[50] NLV:⍳0
[51]  ⍳0
[52]  '       FISCAL FUNDING'
[53]  W1←'    RDTE'
[54]  NUMB←CORDTE,+/CORDTE
[55]  SUBOTSP
[56]  W1,CM
[57]  W2←'    INV '
[58]  NUMB←COINVES,+/COINVES
[59]  SUBOTSP
[60]  W2,CM
[61]  W3←'    OPER'
[62]  NUMB←COOPERAT,+/COOPERAT
[63]  SUBOTSP
[64]  W3,CM
[65]  WORDS←'    PTOT'
[66]  NUMB←COTOTAL,+/COTOTAL
[67]  SUBOTSP
[68]  W4←WORDS,CM
[69]  W4
    ∇

      ∇SUBLNCH[⎕]∇
    ∇ SUBLNCH
[1]   CM← 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 5 0 DFT NUMB
    ∇
```

```
      ∇SUBOTSP[⎕]∇
    ∇ SUBOTSP
[1]   CN← 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0 5 0
    ∇                                                                                    DFT NUMB

      ∇DFT[⎕]∇
    ∇ Z←W DFT X;D;E;F;G;H;I;J;K;L;Y
[1]   D←' 0123456789.¯'
[2]   →(∨/W≠⌊W←,W+(H←0)×L←1<⍴⍴X)/DFTERR+0×F←2
[3]   →(3 2 1 <⍴⍴X)/(DFTERR+F←0), 2 3 +⌶26
[4]   →(2+⌶26),⍴X←((∨/ 1 2 =⍴W)⌽ 1 2)⍉(1,⍴,X)⍴X
[5]   X←(0 1 1 /⍴X)⍴X
[6]   →((∧/(⍴W)≠ 1 2 ,2×E←1⍴⌽⍴X),1≠⍴W)/(DFTERR×F←1),3+⌶26
[7]   I←1+⌈/0,,⌊10⍟|X+1>|X
[8]   W←(2+I+W+(W≠0)+∨/,X<0),W
[9]   →(∨/2>-/[1] W←⍉(E,2)⍴W)/DFTERR+0×F←2
[10]  Z←((K←1⍴⍴X),+/W[1;])⍴' '
[11]  X←⌊0.5+X×10*(⍴X)⍴W[2;]
[12] DFTLP:→(E<H←H+1)/DFTEND
[13]  J←1+⌊10|(|Y←X[;H])∘.÷10*¯1+⌽⍳I←W[1;H]
[14]  J←(,J)×G←,⍉(⌽⍴J)⍴(,⍉(J≠1)∨.∧(⍳I)∘.≤⍳I-F+1),(K×1+F←W[2;H])⍴1
[15]  →(∧/0≤Y)/2+⌶26
[16]  J[1+(⍴J)|¯1+(I-+/(K,I)⍴G)+I×¯1+⍳K]←12×Y<0
[17]  J←(K,I)⍴J
[18]  →(0=F)/3+⌶26
[19]  J←J[;(1⌽⍳G),(G←-/W[;H])+⍳F]
[20]  J[;G]←11
[21]  →DFTLP,⍴Z[;(+/W[1;⍳H-1])+⍳I]←D[1+J]
[22] DFTEND:→L/0
[23]  →0×⍴Z←,Z
[24] DFTERR:'DFT ',(3 6 ⍴' RANK LENGTHDOMAIN')[F+1;],' PROBLEM.'
    ∇
```

```
      ∇OUTLV[⎕]∇
     ∇ OUTLV
[1]    ⍳0
[2]    →((+/COLV1)=0)/0
[3]    WORDS←'     LV1 '
[4]    NUMB←COLV1,+/COLV1
[5]    SUBOTSP
[6]    W5←WORDS,CM
[7]    W5
[8]    →((+/COLV2)=0)/END3
[9]    WORDS←'     LV2 '
[10]   NUMB←COLV2,+/COLV2
[11]   SUBOTSP
[12]   WORDS,CM
[13]   →((+/COLV3)=0)/END2
[14]   WORDS←'     LV3 '
[15]   NUMB←COLV3,+/COLV3
[16]   SUBOTSP
[17]   WORDS,CM
[18]  END2:WORDS←'     LTOT'
[19]   NUMB←COLV,+/COLV
[20]   SUBOTSP
[21]   W6←WORDS,CM
[22]   W6
[23]  END3:⍳0
[24]   WORDS←'     TOT '
[25]   NUMB←TOTPLLV,+/TOTPLLV
[26]   SUBOTSP
[27]   W7←WORDS,CM
[28]   W7
     ∇
```

```
      ∇MESPD[⎕]∇
    ∇ MESPD
[1]   CO1←⌊0.5+1.06×CORM
[2]   CO5←CORDTE-CO1
[3]   MEIN←(1.0154×MIN)+(0.06×1.0154×MU×LES*0.926)-MEDELT
[4]   AVGC←MEIN÷QINV
[5]   VECT←SSNEW
[6]   SP3
[7]   COIME←SUM
[8]   CO2←⌊0.5+COIM+COIME
[9]   CO6←COINVES-CO2
[10]  MEROP←23ρ0
[11]  →(QREF=0)/ME1
[12]  AVGC←AM×RR
[13]  VECT←SSREF
[14]  SP2
[15]  MEROP←SUM
[16] ME1:MEMOP←23ρ0
[17]  →(QMTN=0)/ME2
[18]  AVGC←AM×MR
[19]  VECT←SSMTN
[20]  SP2
[21]  MEMOP←SUM
[22] ME2:CO3←⌊0.5+MEROP+MEMOP
[23]  CO7←COOPERAT-CO3
[24]  CO4←CO1+CO2+CO3
[25]  CO8←CO5+CO6+CO7
[26]  OUTME
    ∇
```

```
      ∇OUTME[⎕]∇
    ∇ OUTME
[1]   R1,NAME
[2]   DO,YEAR,LLAR
[3]   ⍳0
[4]   ⍳0
[5]   FY1,FY2,FY3
[6]   ⍳0
[7]   '       FISCAL FUNDING'
[8]   ⍳0
[9]   '       MISSION EQUIPMENT'
[10]  NUMB←CO1,+/CO1
[11]  SUBOTSP
[12]  W1,CM
[13]  NUMB←CO2,+/CO2
[14]  SUBOTSP
[15]  W2,CM
[16]  NUMB←CO3,+/CO3
[17]  SUBOTSP
[18]  W3,CM
[19]  NUMB←CO4,+/CO4
[20]  SUBOTSP
[21]  WORDS←'    MTOT'
[22]  WORDS,CM
[23]  ⍳0
[24]  '       SPACECRAFT'
[25]  NUMB←CO5,+/CO5
[26]  SUBOTSP
[27]  W1,CM
[28]  NUMB←CO6,+/CO6
[29]  SUBOTSP
[30]  W2,CM
[31]  NUMB←CO7,+/CO7
[32]  SUBOTSP
[33]  W3,CM
[34]  NUMB←CO8,+/CO8
[35]  SUBOTSP
[36]  WORDS←'    STOT'
[37]  WORDS,CM
[38]  ⍳0
[39]  W4
[40]  ⍳0
```

```
[41]  →((+/COLV1)=0)/0
[42]  →((+/COLV2)=0)/OM1
[43]  W6
[44]  →OM2
[45] OM1:W5
[46] OM2:⍳0
[47]  ⍳0
[48]  W7
    ∇
```

5. SATELLITE SYSTEM OPTIMIZATION RISK, LOGISTICS, AND SYSTEM COMPUTER PROGRAM LISTING

The listing for the Satellite System Optimization and Risk Assessment Computer Program is shown in this section in APL language.

In order to correct an inconsistency in computing availability and expected numbers between the orbital service and ground-based service algorithms, extensive changes in the GNDSERV (page 5-6) and ORBSERV (page 5-8) programs were required. Namely, in one case, "total time" was defined as "program time;" in the other as "program time plus outage time." Both algorithms now use the "program time" definition.

The executive program (COMBINE) (page 5-3) has been changed to permit more computation than the original version permitted.

Minor revisions in two initialization programs - NOM (page 5-7) and GO (page 5-6) - were required to accommodate added input data (e.g., unit cost multiplier).

```
      ∇CIN[⎕]∇
    ∇ CIN
[1]   'NOTE: ALL COSTS IN MILLIONS OF ';BASEYEAR;' DOLLARS.'
[2]   SP 4;'LIFT COST=';2 RND CLIFT+CEOS+COOS×NEEDTUG
[3]   SP 4;'LAUNCH SUPPORT COST=';2 RND OP;' PER LAUNCH.'
[4]   SP 4;'SAT. UNIT COST=';2 RND UNIT
[5]   SP 4;'RDTE=';2 RND CRD
[6]   SP 4;'UNIT COST OF AVERAGE MODULE=';2 RND CSRU
[7]   SP 4;'UNIT COST OF EQUIPMENT REQUIRING SATELLITE RETURN TO GROUND=';
      2 RND CNRU
[8]   SP 4;'REPAIR COST OF SINGLE TRUNCATION=';2 RND UNIT×CRTRUNC
[9]   SP 4;'REPAIR COST OF SINGLE MODULE=';2 RND CSRU×CRSRU
[10]  SP 4;'COST OF SATELLITE REPAIR/REFURB ON GROUND=';2 RND CNRU×CRNRU
[11]  SP 4;'REPAIR/REFURB MULTIPLIER=';2 RND CRM
    ∇
```

```
    ∇COMBINE[⎕]∇
  ∇ COMBINE;ALPHA;BETA;Z;A;K;N;PHOLD;Q;I;L
    Q←1-P
    AB2←WEIBFIT T,[1.5] RNRU←(*-LNRU×T)×(RSRU←1-(1-*-T×LW)*G+1)*NNRU
    ALPHA←AB2[1]
    BETA←AB2[2]
    I←¯1+⍳SRUMAX
    →L2×⍳FLAG=0
    GNDSERV SREQ
    ENRU←EN-(SREQ+ETR)÷RB
    RNRU←X1×THETA←ALPHA×!÷BETA
    ORBSERV SREQ
    CT←CPROG1 SREQ
    'SERVICABLE SATELLITE, NO ORBITAL SPARE.'
    AV←A0
    OUTPRT
    Z←(ALPHA←AB[1]),(BETA←AB[2]),AB←WEIBFIT T,[1.5] R←RNRU×(1-(1-*-LW×T)*G+1
    )*M
    →L1×⍳OSP=0
    →L4×⍳SHORT=1
    INPRT
    CIN
  L4:LI 1
    ENRU←ENRU+ENRU×(SREQ+1)÷SREQ
    ORBSERV SREQ+1
    AV←A1
    'SERVICABLE SATELLITE, 1 ORBITAL SPARE.'
    CT←CPROG1 SREQ+1
    OUTPRT
  L1:LI 1
  L2:'EXPENDABLE SATELLITE, NO ORBITAL SPARE.'
    Z←(ALPHA←AB[1]),(BETA←AB[2]),AB←WEIBFIT T,[1.5] R←RNRU×(1-(1-*-LW×T)*G+1
    )*M
    TR←0
    DUM←⍳0×+/(UNIT←UNITGR),(OP←OPGR),(CRD←CRDGR),(CLIFT←GCLIFT),CLIFT1←
    GCLIFT1
    GNDSERV SREQ
    'AVAILABILITY IS ';6 RND AV0
    CT←EXP SREQ
    TEST1
    →L3×⍳OSP=0
    GNDSERV SREQ+1
    'EXPENDABLE SATELLITE, 1 ORBITAL SPARE.'
    'AVAILABILITY IS ';6 RND AV1
    CT←EXP SREQ+1
    TEST1
  L3:TR←TRHOLD
    GNDSERV SREQ
    CT←CPROG2 SREQ
    'RETRIEVABLE AND REFURBISHABLE SATELLITE, NO ORBITAL SPARE.
    'AVAILABILITY IS ';6 RND AV0
    TEST1
    →0×⍳OSP=0
    GNDSERV SREQ+1
    'RETRIEVABLE AND REFURBISHABLE SATELLITE, 1 ORBITAL SPARE.'
    'AVAILABILITY IS ';6 RND AV1
    CT←CPROG2 SREQ+1
    TEST1
  ∇
```

```
      ∇COUT1[⎕]∇
    ∇ COUT1;Z;ZZ
[1]   SP 4;'CRDT=';2 RND CRD;Z←', WHICH IS ';2 RND 100×CRD÷CT;ZZ←' PCT. OF TOTAL.
      '
[2]   →4×ι+/INV=0
[3]   SP 4;'INVEST.=';2 RND INV;Z;2 RND 100×INV÷CT;ZZ
[4]   SP 4;'TRANS.=';2 RND TRANS;Z;2 RND 100×TRANS÷CT;ZZ
[5]   SP 4;'MAINT.=';2 RND MAINT;Z;2 RND 100×MAINT÷CT;ZZ
[6]   SP 4;'OPNS=';2 RND OPNS;Z;2 RND 100×OPNS÷CT;ZZ
[7]   →0×ιP=1
[8]   SP 4;'CAT. SAT. LOSSES=';2 RND CLOSS;Z;2 RND 100×CLOSS÷CT;ZZ
    ∇
```

```
      ∇CPROC1[⎕]∇
    ∇ CT←CPROC1 S
[1]   →L1×ιSHARE=1
[2]   TRANS←(÷RB)×CLIFT×ESRU+ENRU+⌈S÷2
[3]   →L2
[4]  L1:TRANS←(÷RB)×(S×CLIFT1)+(CLIFT×ENRU)+CLIFT×ESPU
[5]  L2:INV←(UNIT×S+CSP)+CSRU×NSRU×SPAREMOD=1
[6]   REPAIRSPU←ESPU×SRUPAR×CSRU×CRSRU
[7]   REPAIRNRU←ENRU×CRNRU×CNRU
[8]   CLOSS←UNIT×Q×ENRU
[9]   MAINT←REPAIRNRU+REPAIRSRU
[10]  OPNS←OP×E1
[11]  CT←TRANS+MAINT+OPNS+CRD+CLOSS+INV
    ∇
```

```
      ∇CPROC2[⎕]∇
    ∇ CT←CPROC2 S;Z
[1]   →L1×ιSHARE=1
[2]   TRANS←(÷RB)×CLIFT×(EN×RB)-S-⌈S÷2
[3]   →L2
[4]  L1:TRANS←(Z×CLIFT1)+CLIFT×EN-Z←S÷RB
[5]  L2:OPNS←EN×OP
[6]   MAINT←(CRM×UNIT)×EN-S÷RB
[7]   INV←UNIT×S+CSP
[8]   CT←CRD+INV+MAINT+OPNS+TRANS+CLOSS
    ∇
```

```
      ∇ENSTAT2[⎕]∇
    ∇ ETR←R ENSTAT2 M;N;SLOPES;STEPS;Z;F
[1]   Z←(N←⌈Z),F←1|Z←TM÷TC+1E¯10
[2]   SLOPES←(TC÷M)×(F×1-R*N)+N-STEPS←(1-R*N)÷1-R
[3]   ETR←S×(STEPS-1)+SLOPES-RANDOM←TM×(1-R)÷M
[4]   →0
    ∇
```

```
      ∇ETRUNC[⎕]∇
    ∇ ETR←ETRUNC TC;R;K;L
[1]   L←(-⍟R←*-LNRU×TC)÷TC
[2]   K←⌊TM÷TC+EPSILON
[3]   ETR←((S×R)÷1+(EPSILON×R=1)-R)×((1+L×TM)×1-R*K)-L×TC×(1+(K×R*K+1)-(K+1)×R*K)
      ÷1-R
[4]   →0
    ∇
```

```
      ∇EN[⎕]∇
    ∇ Z←T EN S
[1]   Z←*-S×T÷TP
    ∇
```

```
      ∇EXP[⎕]∇
    ∇ CT←EXP S;Z
[1]   CT←CRD+(INV←0)+(MAINT←EN×UNIT)+(OPNS←EN×OP)+TRANS←(EN+Z×(÷RB)×(⌈S÷
      2)-S)×CLIFT1×1+Z←SHARE=0
    ∇
```

```
     ∇GNDSERV[⎕]∇
   ∇ GNDSERV S;Z;V;SI;Y;Q;R1;G1;ZZ;R2;G2;YI;T;M;A;B;APQ;L;M
      ZZ←⍳+/0×(Q←1-P),SI←÷S
      ZZ←⍳+/0×(Z←H÷RB×TH),(W←1-D×TH←ALPHA×ZZ),D←Z÷TM×(BETA×ZZ←!÷BETA)*BETA÷Z←
      BETA-1
      A←P∘.×(L←TR÷TH)-SI×1-TSR←TR FN S
      B←Q∘.×(M←TB÷TH)-SI×1-TSB←TB FN S
      X1←Z+APQ←A+B
      AV0←1-S×W×X1÷1+X1
      ETR←TRUNCS
      RBA←RB
      EN←(÷RB)×ETR+S+EF←S×TM×W÷TH×1+X1
      RB←1
      ERFG←EN-(÷RB)×ETR+S+EF1←S×TM×W÷TH×1+X1←(H÷RB×TH)+APQ
      RB←RBA
      →0÷⍳S=1
      YI←÷Y←(V←S-1)÷S
      R1←P×1+(V×TVR←TR FN S)-S×TR FN V
      R2←Q×1+(V×TVB←TB FN S)-S×TB FN V
      G1←P×L+(Y×1-TVR)-YI×1-TR FN V
      G2←Q×M+(Y×1-TVB)-YI×1-TB FN V
      X3←(TAU÷TH)+G1+G2+(Z×1+R1+R2)-(÷V)×1-*-V×Z
      ETR←TRUNCS
      AV1←1-S×W×X3÷1+X3
      EN1←(÷RB)×ETR+S+EF2←S×TM×W÷TH×1+X3
      RB←1
      X3←(TAU÷TH)+G1+G2+(Z×1+R1+R2)-(÷V)×1-*-V×Z←H÷RB×TH
      ERFG1←EN1-(÷RB)×ETR+S+EF3←S×TM×W÷TH×1+X3
      RB←RBA
    ∇
```

```
     ∇GO[⎕]∇
   ∇ GO V
      HW←HNW←HNRU←H
      T←(DTINT←TM÷NINT)×⍳NINT
      M←NSRU
      G←V[13]
      LNW←LAMFAC×0
      LW←LAMFAC×LSRU
      LNRU←LAMFAC×LNRU
      K←SRUMAX
      DETAIL←0
      CRD←V[1]
      OP←V[2]
      UNIT←UNITVEC×V[3]
      CRDGR←V[4]
      OPGR←V[5]
      UNITGR←UNITVEC×V[6]
      CLIFT←V[7]
      CLIFT1←V[8]
      GCLIFT←V[9]
      GCLIFT1←V[10]
      →L1×⍳SHARE=1
      CLIFT1←GCLIFT1←0.5×CLIFT←GCLIFT←12.78
    L1:FLAG←V[11]
      BASE←V[12]
      CRSPU←CRTRUNC←CRNRU←CRM
      CNRU←UNIT
      COMBINE
      NOM
    ∇
```

```
      ∇ILOOP[⎕]∇
    ∇ Z←ILOOP K;ISTOP;I;J
[1]   ISTOP←K[ρK]
[2]   Z←ι1+I←¯1
[3]  L1:Z←Z,+/(J!N-I)×(2*J)÷(I+I+J)!KN+I+J←¯1+ιN-I←I+1
[4]   →L1×ιISTOP≠I
    ∇
```

```
      ∇INT[⎕]∇
    ∇ II←INT;A;J;K;N;KN;Z
[1]   KN←(Y←LNW÷LU)+N+N←M×S
[2]   →(G= 1 2)/L1,L2
[3]   →0,II←÷N×LNU+LV
[4]  L1:→0,II←(÷LU)×(2*I)×(I!N)÷(KN-I)×I!KN
[5]  L2:II←(3*I)×(I!N)×(÷LW×YN-I)×ILOOP I
    ∇
```



```
      ∇LI[⎕]∇
    ∇ LI S
[1]   →4×ι(S≤30)
[2]   30 1 ρ' '
[3]   →0
[4]   (S,1)ρ' '
    ∇
```

```
      ∇NOM[⎕]∇
    ∇ NOM
[1]   UNITVEC←LAMFAC←1
[2]   LNRU←LHOLD
[3]   LNW←LNWHOLD
[4]   LW←LWHOLD
[5]   CRM←CRMHOLD
[6]   TAU←0
[7]   H←2
[8]   RB←REOS×RINF
[9]   →0×ιNEEDTUG=0
[10]  RB←RB×ROOS
[11]  S←SREQ
[12]  TR←TRHOLD
    ∇
```

```
      ∇ORBSERV[⎕]∇
    ∇ ORBSERV S;ALPHA;BETA;RS;AB;T0;RSA0;Z;PNWI;PWI;PNW;PW;M1;M2;M3
[1]   THOLD←T
[2]   →L1×⍳G≠0
[3]   AB←(÷LW),1+1E¯10
[4]   →L2
[5]  L1:AB←WEIBFIT T,[1.5] RSACALC T
[6]  L2:ALPHA←AB[1]
[7]   BETA←AB[2]
[8]   ADJ←÷1+H÷THETA←ALPHA×!÷BETA
[9]   AB1←WEIBFIT T,[1.5] RSRU←1-(1-*-T×LW)*G+1
[10]  ADJ1←÷1+H÷AB1[1]×!÷AB1[2]
[11]  →L3×⍳G≠0
[12]  ET←S÷ENRU←ESRU←(M×S)×ADJ1×LW×T[⍴T]
[13]  →L4
[14] L3:RSA0←RSACALC,T0←ALPHA×(÷BETA×!÷BETA)*÷BETA-1
[15]  ET←S÷ENRU÷ESRU←ADJ1×(-⍟RSA0)+(TM-T0)÷THETA←ALPHA×!÷BETA
[16] L4:E1←ET÷ERP←ET×¯1+÷RB
[17]  ENW←ESRU×PNW←1⌊+/PNWI←LNW×Z←INT
[18]  EW←ESRU×PW←1⌊+/PWI←I×LW×Z
[19]  EK1W←ESRU×1-PNW+PW
[20]  →L5×⍳G≠0
[21]  SRUBAR←1+(÷ET-S)×TRBAR←SRUTRUNC
[22]  →L6
[23] L5:SRUBAR←((1-÷M×S)×(+/I×PNWI)+(+/I×PWI)+PNW+(⍴I)×1-PW+PNW)+(÷ET-S)×TRBAR
      ←SRUTRUNC
[24] L6:A0←1-OUT1←(÷TM)×(HK1W×EK1W)+(ENRU×HNRU)+(÷RB)×(HW×EW)+HNW×ENW
[25]  →L9×⍳OSP=0
[26]  M1←(TAU×S-1)÷S
[27]  →L9×⍳S=1
[28]  Z←⍳+/0×(A←T FN S),(B←(T÷TR,TB) FN S1),(VI←÷V←S÷S1←S-1),TH←÷LNRU
[29]  RT←1+(S1×A)-S×B
[30]  GT←T+(VI×TH×1-A)-V×TH×1-B
[31]  M2←(P×GT[1])+(Q×GT[2])+((1+(P×RT[1])+((Q←1-P)×RT[2]))×HRB)-(TH÷S1)×1-(
      HRB←H÷RB) FN S1
[32]  →L7×⍳G≠0
[33]  M3←(0.5×HW)×1-*-HW×S×LNRU+LW×M
[34]  →L8
[35] L7:M3←(0.5×HW)×1-(*-LNRU×HW)×RSACALC,HW
[36] L8:A1←1-OUT2←(÷TM)×(ENRU×M1+M2)+(EW+ENW)×M1+M3
[37] L9:T←THOLD
    ∇
```

```
      ∇RND[⎕]∇
    ∇ X2←N RND X1
[1]   X2←(⌊0.5+X1×10*N)÷10*N
[2]   ⍝ N IS THE NUMBER OF DECIMAL PLACES TO BE KEPT.∇
    ∇
```

```
      ∇RSACALC[⎕]∇
    ∇ RSA←RSACALC T;R1;Q1;R0;RI
[1]  L1:R0←1-(Q1*G+1)÷RW←(G+1)×R1×(Q1←1-R1←*-LW×T)*G
[2]   RSA←(*-M×S×LNW×T)×+/(((⍴T),⍴I)⍴(I!M×S))×(R0∘.*(M×S)-I)×RW∘.*I
[3]   →0
    ∇
```

```
      ∇SP[⎕]∇
    ∇ DUM←SP S
[1]   →4×ι(S≤65)
[2]   DUM←65ρ' '
[3]   →0
[4]   DUM←Sρ' '
    ∇
```

```
      ∇SRUTRUNC[⎕]∇
    ∇ ETR←SRUTRUNC;MSRU;I;Y;R;Z
[1]   MSRU←(÷LSRU)×(+/((Y*I)÷I←ιG+1))-(Y←1-*-LSRU×TC)*G+1
[2]   →(G= 0 1 2)/L0,L1,L2
[3]  L0:Z←(R←1-Y),MSRU←Y÷LSRU
[4]   →L3
[5]  L1:R←1-Y×Y
[6]   →L3
[7]  L2:R←(3×(1-Y)*2)-2×(1-Y)*3
[8]  L3:ETR←NTRUNCS×R ENSTAT2 MSRU
    ∇
```

```
      ∇TEST1[⎕]∇
    ∇ TEST1;I
[1]   →L1×ι(0=ρρCT)∨0=ρρH
[2]   CT←CT[I←(H=RNOM)/ιρH]
[3]   EN←EN[I]
[4]   TRANS←TRANS[I]
[5]   MAINT←MAINT[I]
[6]   OPNS←OPNS[I]
[7]  L1:'NR. OF LAUNCHES=';2 RND EN
[8]   'PROGRAM COST=';2 RND CT
[9]   COUT1
[10]  LI 1
    ∇
```



```
      ∇TRUNCS[⎕]∇
    ∇ ETR←TRUNCS;T;M;RS
[1]   T←(TC÷NINT)×ιNINT
[2]   M←(0,TC) NEWTINT RS←1,*-(T÷ALPHA)*BETA
[3]   ETR←RS[ρRS] ENSTAT2 M
```

```
      ∇WEIBFIT[⎕]∇
    ∇ AB←WEIBFIT TP;TUNIT;R;XY;PLP;P
[1]   TUNIT←1
[2]   AB←((*(1↑XY)÷¯1↑XY)÷TUNIT),¯1↑XY←,XY←(PLP×⍟-⍟(R,¯1)↑TP)⌹(PLP,PLP←P×⍟P←(R,
      ¯1)↑TP)×(Rρ¯1),⍟TUNIT×((R←1↑ρTP),1)↑TP
[3]   ⍝  TP = MATRIX:  TP←(T[1],T[2],...),[1.5] P[1],P[2],...
    ∇
```

6. NASA SPACE TRACKING AND DATA NETWORK (STDN)

NASA facilities for tracking, command, and data acquisition for satellites were developed for three general classes of missions: deep space, manned space flight, and unmanned satellites. The earth station facilities for these missions have been termed the Deep Space Network (DSN), the Manned Space Flight Network (MSFN), and the Space Tracking and Data Acquisition Network (STADAN). An integrated NASA communication system (NASCOM) links these earth stations to each other and to control centers.

The STDN is a combination of MSFN and STADAN intended to consolidate the two systems and to provide spacecraft support using fewer earth stations than the parent networks.

STDN facilities and characteristics are summarized herein. These facilities and characteristics have been selected on the basis of more than a decade of operating experience and a thorough study (Ref. 6-1) of the support requirements for missions in the latter 1970's and the alternative configurations of earth stations to satisfy these requirements. The configuration described in this section is the preferred alternative of those studied and represents the most probable form of the consolidated earth station network for manned and unmanned satellites in the late 1970's.

The introduction of a Tracking and Data Relay Satellite (TDRS) in the 1979 time frame should result in fewer earth stations being required to support missions similar to those projected by NASA from 1973 to 1978. While requirements will change somewhat for the 1980's, the capabilities of the STDN as outlined here are assumed to carry through into the 1980's for purposes of BRAVO analysis for future missions.

Current STDN system capabilities and equipment are summarized in Table 6-1 for easy reference. The table lists the characteristics of the 15 primary STDN sites shown in Figure 6-1 as well as five special purpose

Table 6-1. System Capabilities and Equipment Chart

Site	Links: Rec	Links: Cmd	Telemetry: Antenna Type	Telemetry: Frequency Band (12)	Telemetry: MFR	Telemetry: Data System	Command: Antenna Type	Command: Frequency Band	Command: Xmitr	Command: SCE	Tracking: Antenna Type	Tracking: Frequency Band
ULA	4	3	85' 40' SATAN SATAN	MULTIBAND MULTIBAND VHF VHF	4 4 2 2	STADAC	30' SATAN SATAN SCAMP	S VHF VHF VHF	1-S 4-VHF	3	30' Dipole Array Mini-track	S VHF VHF
ACN	2	2	30' SATAN	S VHF	4 2	Augm. 642B	30' SATAN	S VHF	1-S 2-VHF	2	30'	S
BDA(1)	2	2	30' SATAN/ (10) YAGI ARRAY	S VHF	4 2	Augm. 642B	30' SCAMP	S VHF	1-S 2-VHF	2	30'	S
CYI	2	2	30' SATAN/(10) YAGI ARRAY	S VHF	4 2	Augm. 642B	30' SCAMP	S VHF	1-S 2-VHF	2	30'	S
GDS(5)	3	2	85' 30' SATAN	S S VHF	4 4 2	Augm. 642B	85' 30' SATAN	S S VHF	1-S 1-S 2-VHF	2	85' 30' Mini-track	S S VHF
GWM	2	2	30' SATAN	S VHF	4 2	Augm. 642B	30' SATAN	S VHF	1-S 2-VHF	2	30'	S
HAW	2	2	30' SATAN/ (10) YAGI ARRAY	S VHF	4 2	Augm. 642B	30' SCAMP	S VHF	1-S 2-VHF	2	30	S
BUR	3	2	40' 30' SATAN SATAN	MULTIBAND S } VHF } VHF	4 2 2	STADAC	30' SATAN SATAN	S VHF VHF	1-S 3-VHF	2	30' Mini-track	S VHF
MAD	2	2	85' SATAN	S VHF	4 2	Augm. 642B	85' SATAN	S VHF	1-S 2-VHF	2	85' Mini-track	S VHF
MIL	3	3	30' 30' SATAN	S S VHF	4 4 2	Augm. 642B	30' 30' SCAMP	S S VHF	1-S 1-S 2-VHF	3	30 30'	S S
ORR	4	3	85' 30' SATAN SATAN	MULTIBAND S VHF VHF	4 4 2 2	STADAC	30' SATAN SATAN	S VHF VHF	1-S 3-VHF	3	30' Dipole Array Mini-track	S VHF VHF
QUI	2	2	40 SATAN/ SATAN(2, 9)	MULTIBAND VHF	4 3	STADAC	Dual 14' SATAN SCAMP	S VHF VHF	1-S 3-VHF	2	Dual 14' Mini-track	S VHF
ROS(9)	4	3	85' 85' SATAN SATAN	MULTIBAND MULTIBAND VHF VHF	4 4 2 2	STADAC	Daul 14' SATAN SATAN SCAMP	S VHF VHF VHF	1-S 4-VHF	3	Dual 14' Dipole Array	S VHF
ACO	3	2	40' 30' SATAN(11) SATAN	MULTIBAND S } VHF } VHF	4 2 2	Augm. 642B	30' SATAN SCAMP	S VHF VHF	1-S 3-VHF	2	30' Dipole Array Mini-track	S VHF VHF

Footnotes on next page.

Table 6-1. System Capabilities and Equipment Chart (Cont'd)

	Links		Telemetry				Command				Tracking	
TAN(1)	1	1	40'	MULTIBAND	4	Augm. 642B	Dual 14' SATAN	S VHF	1-S 2-VHF	1	Dual 14' Dipole Array Mini- track	S VHF VHF
ETC(3)	2 2	1 1	40' SATAN 30' 30'	MULTIBAND VHF S S	4 4 3	STADAC Augm. 642B	SATAN 30' 30' SCAMP	VHF S S VHF	2-VHF 1-S 1-S 2-VHF	1 1	Mini- track 30' 30'	VHF S S
VAN	1	1	30'	S	4	Augm. 642B	30	S	1-S	1	30	S
ATS, ROS(4, 6)	4	3	85'(5) SATAN 15' 15'MMW	C VHF S&L	2 3 1 1	1-D^3F	85'(5) SCAMP 15'	C VHF S&L	1-C 2-VHF 1-S&L	ATS 1-5 ATS F&G ATS F EXP	85'(5)	C
ATS, AVE(4, 6)	3	3	40' SATAN 15'	C VHF S&L	2 3 1	1-D^3F	40' SCAMP 15'	C VHF S&L	1-C 2-VHF 1-S&L	ATS 1-5 ATS F&G ATS F EXP	40'	C
ATS, TRANS-PORT-ABLE GND, STATION (1, 6)			40' SATAN 15'	C VHF S&L	2 2 1	1-D^3F	40' SCAMP 15'	C VHF S&L	1-C 2-VHF 1-S&L	ATS 1-5 ATS F&G ATS F EXP	40'	C
ATS, MIT(4, 6)	2	2	21' 15'	C&UHF S&L	1 1		21' 15'	C S&L	1-C 1-S&L			

Notes:

(1) Launch Support Sites
(2) Space Diversity SATAN Antennas
(3) Special Purpose Sites
(4) ATS Dedicated Sites
(5) ROS 85-2 Dish Shared with ATS
(6) ATS Frequency Bands:

Bands	Receive	Command
VHF	136-138 MHz	147-157 MHz
UHF	835-855 MHz	-
L	1500-1580 MHz	1620-1700 MHz
S	2050- 2100 MHz	2200-2300 MHz
C	3700-4200 MHz	5952-6425 MHz

(7) Not fully implemented
(8) ATS antennas not included.
(9) Two SATANs are required for a space-diversity capability.
(10) These SATAN/YAGI Arrays satisfy the requirement for a SATAN telemetry system at these locations.

(12) Multiband Receive:
136-138 MHz
400-410 MHz
1700-1710 MHz
2200-2300 MHz
2550-2619 MHz(7)
2600-2700 MHz(7)

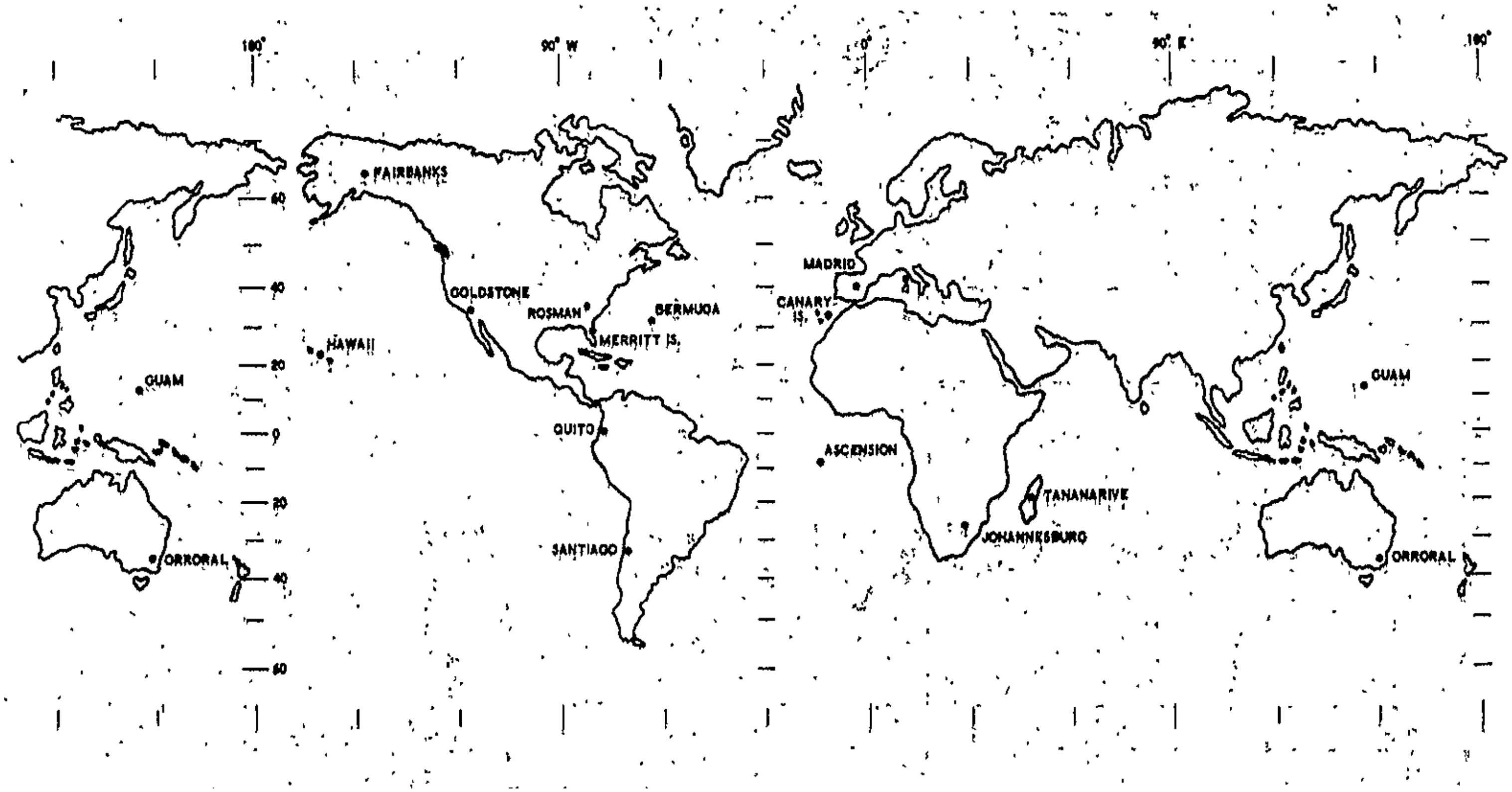


Figure 6-1. NASA Space Tracking and Data Network (STDN)

sites: the Engineering Training Center (ETC), Greenbelt, Maryland, and four dedicated stations for the Application Technology Satellites (ATS), three of them collocated with other stations.

Table 6-1 lists for each site the number of receive and command links; the telemetry antennas, frequency, number of multifunction receivers (MFR), and data systems; the command antennas, frequency, number and frequency of transmitters, and number of spacecraft command encoders (SCE); and the tracking antennas and frequency. Abbreviations for earth stations and equipments listed in Table 6-1 are shown in Table 6-2.

Table 6-3 summarizes the requirements for NASCOM channels for each of the 15 primary STDN sites. The first ten sites listed should have wideband facilities while the remaining five stations can use narrow band facilities. However, narrow band facilities are listed as alternative solutions to wideband facilities for five stations where requirements might be satisfied by additional equipment for data stripping or data compression to reduce high rate real-time spacecraft data to fit onto 7.2 kbps lines. Regardless of the specific solution chosen in each case, the communications requirements listed for each site provide a good measure of the capabilities of the late 1970's.

Table 6-2. Abbreviations Used in Table 6-1

SITES

AGO	Santiago, Chile
ATS	Applications Technology Satellite(s) - dedicated earth stations or equipment
ACN	Ascension Island
BDA	Bermuda
BUR	Johannesburg, S. Africa
CYI	Grand Canary Island
ETC	Engineering Training Center, Greenbelt, Maryland
GDS	Goldstone, California
GWM	Guam
HAW	Hawaii
MAD	Madrid, Spain
MIL	Merritt Island, Florida
ORR	Orroral Valley, Australia
QUI	Quito, Ecuador
ROS	Rosman, N. Carolina
TAN	Tananarive, Malagasy Republic
ULA	Fairbanks, Alaska

EQUIPMENT

SATAN	136 Mhz receive; 148 Mhz transmit command.
SCAMP	148 Mhz transmit command
SATAN/YAGI	136 Mhz receive-only array with capabilities of SATAN receive system
MINITRACK	136 Mhz angle tracking system
STADAC	Station Data Acquisition Control System (multiplexing formatting and real-time data transmission to Goddard Space Flight Center)
Augm. 624B	Real-time data transmission system using 624B computer, augmented to provide STADAC-compatible data transmission formats and functions plus storage to increase data buffering
MFR	Multifunction receiver
SCE	Spacecraft command encoder

Table 6-3. STDN Requirements for NASCOM Channels

Site	Wideband Solution: WB Data Channel	Wideband Solution: Quantity[a] Narrowband Channels: 7.2 kbps	Wideband Solution: Quantity[a] Narrowband Channels: V	Wideband Solution: Quantity[a] Narrowband Channels: TTY	Narrowband Solution: Quantity: 7.2 kbps	Narrowband Solution: Quantity: V	Narrowband Solution: Quantity: TTY
MIL	2-50.0 kbps or higher	- (3)	- (3)	- (2)	-	-	-
ROS	Present systems: 1-800 kHz analog 1-128 kHz analog 1-240 kbps digital	- (4)	- (3)	- (2)	-	-	-
CYI	1-28.5 kbps or higher	2 (1)	2 (1)	- (2)	4	3	2
ACN	1-28.5 kbps or higher	2 (1)	2 (1)	- (2)	4	3	2
HAW	1-28.5 kbps or higher	2 (1)	2 (1)	- (2)	5	3	2
GDS	1-28.5 kbps or higher	2 -	2 -	- (2)	4	4	2
ORR	1-28.5 kbps or higher	2 (1)	2 (2)	- (2)	-	-	-
MAD	1-28.5 kbps or higher	2 -	2 (1)	- (2)		-	-
AGO	-	-	-	-	2	2	2
ULA	1-38.0 kbps or higher 1-28.5 kbps or higher	1 - 1 -	- (1) 3 (1)	2 - - -	- -	- -	- -
BUR	-	-	-	-	2	2	2
BDA	-	-	-	-	4	2	2
TAN	-	-	-	-	2	2	2
QUI	-	-	-	-	2	2	2
QWM	1-28.5 kbps or higher	1 (1)	3 -	- (2)	3	2	2

WB = Wideband

7.2 kbps = Voice bandwidth data channel

V = Voice channel

TTY = Teletype channel

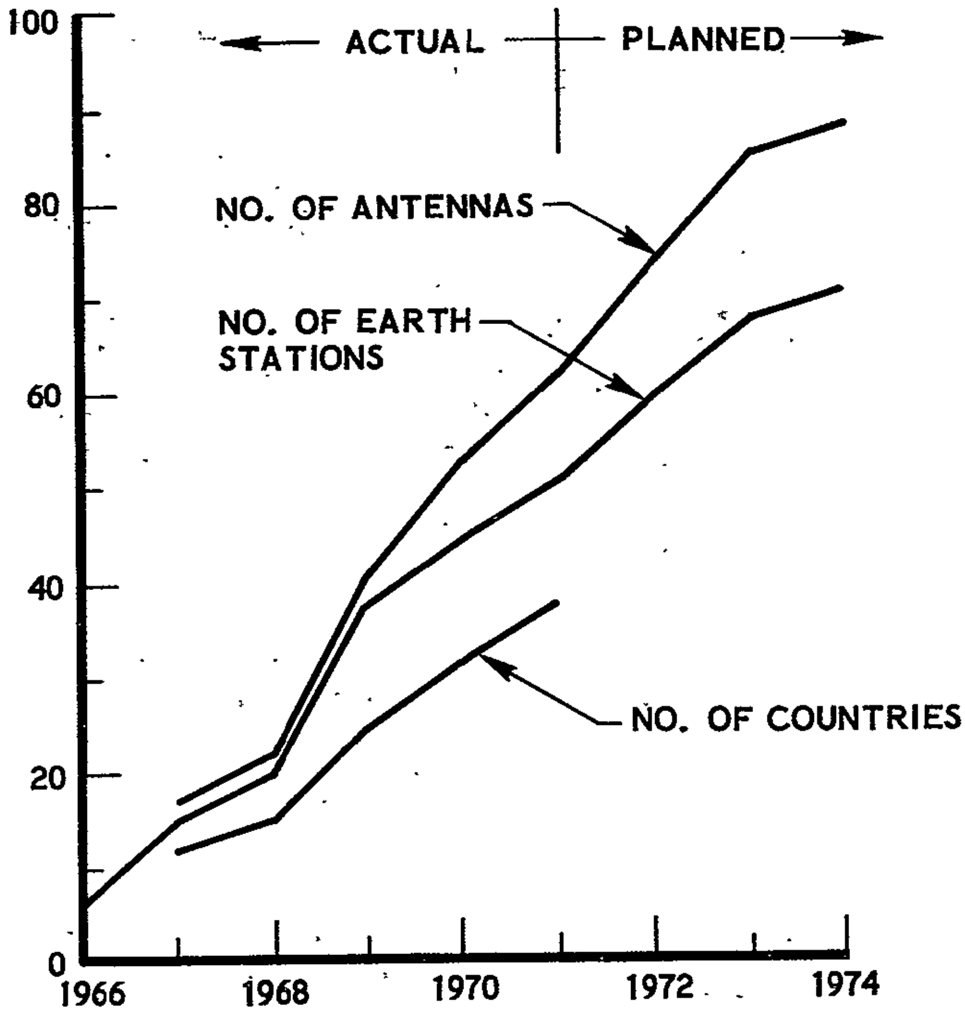
[a]Quantities shown in parentheses are provided separately from the wideband or group (48 kHz) channel system; other quantities shown are provided as a sub-channelization of the wideband group (48 kHz) channel.

7. THE INTELSAT COMMUNICATIONS NETWORK

The Intelsat (International Telecommunications Satellite Consortium) Network provides high quality communications by satellite throughout most of the world, primarily among nations outside the Communist bloc. The system has grown rapidly since the first commercial operations in 1965. In 1974, 71 earth stations using 88 antennas will be operating, based on 1971 planning as shown in Figure 7-1. A further growth in the number of earth stations is anticipated, but at a much lower rate. The bulk of the increase in traffic, which is expected to grow at 15 to 20 percent per year, will be accommodated by augmenting the capacity of existing earth stations which are located to serve the principal traffic demands. The current Intelsat IV satellites have a capacity of about 5000 voice circuits or 12 television channels in each of the five primary satellites. Two additional satellites are in orbit to provide backup capacity in the event of degraded service or failure of primary satellites. It is planned that future generations of Intelsat satellites will have higher capacity to match the traffic growth.

The Intelsat system provides service primarily to telecommunications common carriers rather than directly to users since the Intelsat system usually interfaces the terrestrial network at the satellite earth stations. Rates charged to users by common carriers reflect the composite of costs to provide service, including switching and other distribution costs, and costs of alternative terrestrial transmission systems.

Table 7-1 lists the Intelsat system earth stations in existence or planned as of 1971 with their projected 1982 demand in terms of voice channels. The list provides system planners with approximate locations where the Intelsat system would be available to provide high quality, reliable, voice and wideband data communications service.



SOURCES: COMSAT ANNUAL REPORT, 1971, AND COMSAT ANNUAL REPORT TO THE PRESIDENT AND THE CONGRESS, MAY 31, 1971

Figure 7-1. Planned Growth of Intelsat System

Table 7-1. Intelsat Earth Stations and Projected 1982 Traffic Demand[1]

	Station Locations	No. of Voice Channels	Station Locations	No. of Voice Channels
Atlantic Basin	**North America**		**Africa**	
	U. S., Maine, Andover[2] }	8000	Ethiopia	<100
	U.S., W. Va, Etam[2] }		Sudan, Khartoum	100
	Canada, N.S., Mill Village	1300	Algeria	<100
	Europe		Morocco	125
	U.K., Goonhilly Downs[3]	2800	Ivory Coast	150
	Germany, Raisting[3]	1050	Nigera	125
	France, Pleumeur Bodou	1300	Senegal	<100
	Belgium, Brussels	375	Congo	<100
	Netherlands	300	Camaroon	<100
	Nordic[4]	275	Gabon	<100
	Switzerland	450	Malagasy Rep.	<100
	Italy, Fucino[3]	1150	**Caribbean, Central and South America**	
	Spain, Buitrago[3]	675	Ascension	<100
	Spain, Grand Canary	<100	Barbados	250
	Greece	275	Trinidad/Tobago	250
	Yugoslavia	<100	Martinique	125
	Near East		Jamaica	500
	Turkey, Ankara	<100	Puerto Rico, Cayey	1000
	Iran	150	Mexico	425
	Israel	1150	Panama	275
	Kuwait[3]	<100	Venezuela	275
	Saudi Arabia	<100	Colombia	250
			Peru	375
			Brazil	550
			Argentina	575
			Chile	325
Pacific Basin	**North America**		**Asia and Australia**	
	U.S., Calif., Jamesburg[5] }	5800	Japan[3]	1730
	U.S., Wash., Brewster[5] }		Korea	320
	Canada, B.C., Lake Cowichan	200	China, Rep. of[3]	575
	U.S., Alaska, Talkeetna	500	Phillipines[3]	700
	Oceania		Viet Nam	400
	U.S., Hawaii, Paumalu	3400	Thailand[3]	460
	U.S., Guam, Pulantat	450	Singapore[3]	<100
			Australia, Moree	1050
			Australia, Carnarvon	100
Indian Ocean Basin	**S.E. Asia and Australia**		**Near East**	
	Australia, Geduna	1300	Kuwait[3]	200
	China, Rep. of[3]	<100	Bahrain	200
	Japan[3]	325	Saudi Arabia[3]	<100
	Philippines[3]	<100	Iran[3]	<100
	Hong Kong	325	Lebanon	125
	Singapore[3]	325	**Africa**	
	Malasia	150	Kenya	375
	Thailand[3]	<100	Zambia	<100
	Indonesia	225	Nigeria[3]	<100
	India Area		**Europe**	
	Ceylon	<100	UK, Goonhilly Downs[3]	1800
	India, Dehradun }	425	Germany, Raisting[3]	125
	India, Arvi }		Spain, Buitrago[3]	150
	Pakistan	1100	Italy, Fucino[3]	150

[1]Traffic demand estimated in equivalent number of 4 kHz one-way voice channels.

[2]Either Etam or Andover capable of handling the total U.S.-Atlantic Basin traffic.

[3]Communicates with satellites in more than one ocean basin.

[4]Serves Norway, Sweden, Finland, Denmark.

[5]Either Jamesburg or Brewster capable of handling all U.S.-West Coast traffic to other parts of the Pacific Basin.

The 1982 (selected to show demand a decade into the future) traffic demand for these earth stations, in terms of equivalent voice channels, has been estimated based primarily on traffic estimates and growth rates from Comsat Corporation (the operating agency for Intelsat), AT&T, and the Federal Communications Commission, assuming a 15 percent annual growth rate. Demand for other years can be calculated by using the 15 percent growth rate, i.e., traffic doubles in five years. Where a prospective system requires voice or low speed data channels adding up to a small fraction of a particular earth station's normal load, service can be expected to be available. However, requirements for a large fraction of capacity, particularly high speed data links, may require special arrangements and additional equipment, particularly in the less industrialized countries. Stations with fewer than 100 voice channels should be assumed to provide only a few voice channels to any proposed system use.

8. TELECOMMUNICATION SYSTEMS LEASE COSTS

This section presents data on lease costs to provide a basis for comparing the cost of communications using prospective satellite systems with the cost to provide the same communication services using leased lines in the terrestrial communication network for voice and data transmission. These costs are representative of communications costs for the areas of the world with developed communication systems and were taken from Reference 8-1. All costs have been adjusted to 1973 dollars from 1969 dollars in the data source using the Bureau of Labor Statistics wholesale price index for all commodities to adjust for inflation and using a four percent per year declining trend (constant dollars) in communications costs. Commodity indices for 1969 and 1973 were 106.5 and 130.7, respectively.

Annual costs in 1973 dollars are shown in Table 8-1 for U.S. domestic leased voice circuits at several distances which are the break points in the rate charged per mile. Figure 8-1 shows the 1973 annual costs per circuit from Table 8-1 as a function of distances in kilometers. For convenience in calculations, the actual cost variation has been approximated in the range up to 804 kilometers (500 miles) by two straight lines.

Transoceanic leased voice circuit costs in 1973 dollars are shown in Table 8-2 together with the corresponding distances. The basic data, in cost per channel per month, have been restated in terms of costs per circuit (two channels per circuit) per year in addition to being adjusted to 1973 dollar costs. These costs are composite costs of the communications media used, essentially satellite and submarine telephone cables, established by international agreements. The user has no control over the medium used by the carrier to provide service and no distinction in rates is made relating to the medium actually used. Thus, comparisons using these data would be between the costs of prospective space systems and the costs of

Table 8-1. Lease Costs, U.S. Domestic Voice Circuits

DISTANCE (mi)	DISTANCE (km)	COST/MONTH[1] (1969 Dollars)	COST/YEAR (1973 Dollars)
25	40	82.5	1,032
100	161	255.75	3,198
250	402	503.25	6,293
500	804	792.00	9,903
1500	2414	1617.00	20,219

[1] Duplex (two-way circuits) costs shown here are 10 percent greater than costs per channel (one way or "simplex"), per FCC tariffs.

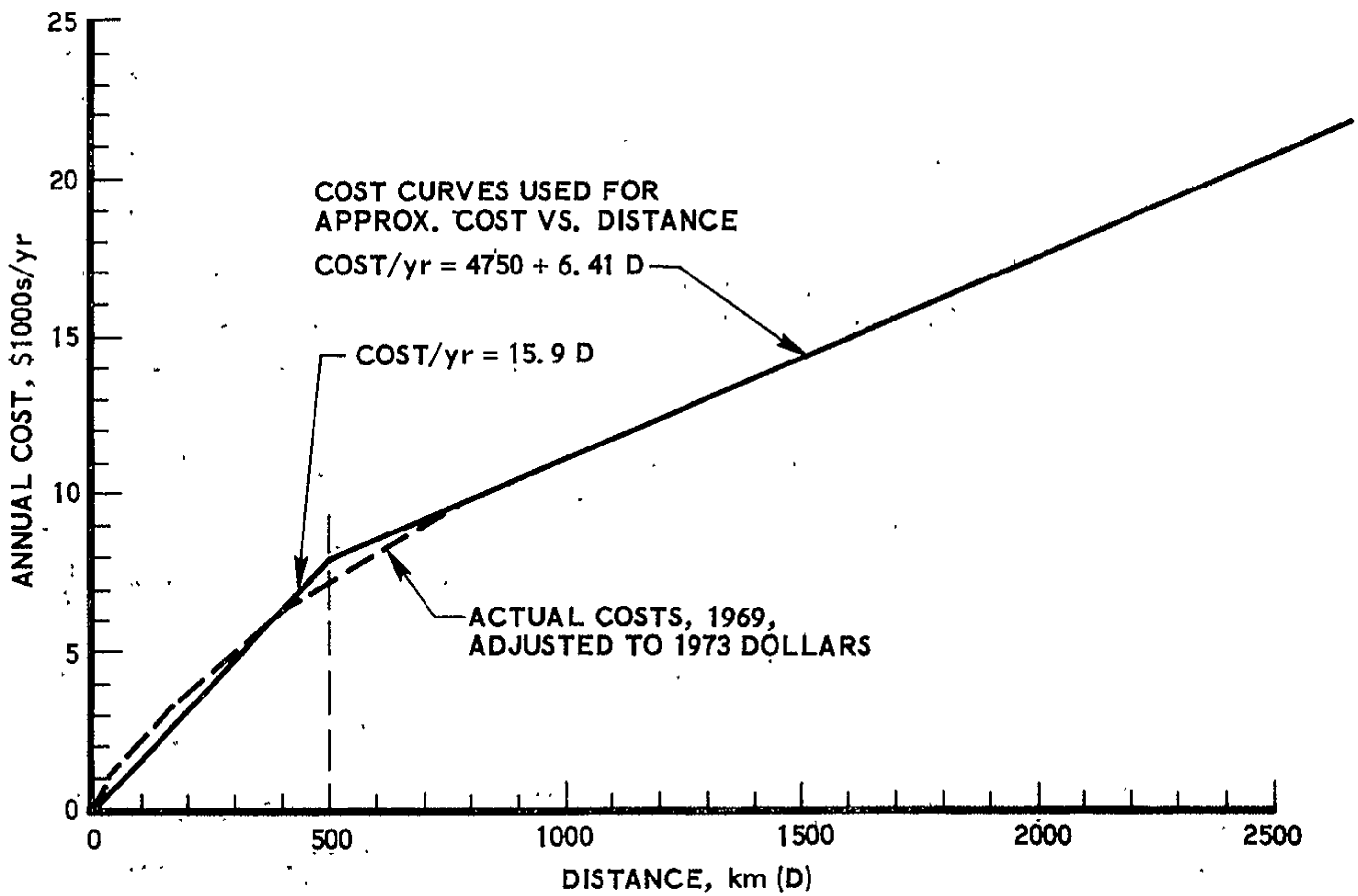


Figure 8-1. U.S. Leased Duplex Voice Circuit Costs, 1973 Dollars

Table 8-2. Lease Costs, Transoceanic Voice Circuits

From	To	Cost/channel per Month ($1969)	Approx. distance (km)[1] Actual	Shortest	Cost/circuit per Year $1000, 1973
Japan	Philippines	16,582	3140		380
Japan	Guam	10,987	2670		264
Hawaii	Japan	16,506	6270		396
Hawaii	Philippines	15,120	8620		363
Hawaii	California	8,064	4020		194
Hawaii	Colorado	8,064	5460		194
Hawaii	Pennsylvania	8,064	7820		194
California	Guam	16,128	9650	9170	387
Nebraska	Okinawa	21,571	11400	9170	518
Nebraska	Puerto Rico	5,040	3940		121
Nebraska	Spain	11,945	7400	5550	287
N. Dakota	Bermuda	6,048	3540		145
Georgia	Puerto Rico	5,040	2570		121
Virginia	Panama	7,812	3280	1930	187
Virginia	Bermuda	6,048	1380		145
Virginia	Paris	12,933	6300	5550	310
Virginia	Stuttgart	12,627	6780	5950	303
Maryland	United Kingdom	13,392	5950	5310	321
N. Jersey	Spain	11,945	5870		287
Florida	Bahamas	2,520	322		60
Florida	Puerto Rico	5,040	1800		121
Florida	Cuba	1,008	481		24
Florida	Jamaica	5,976	1010		143
Panama	Uruguay	11,592	5620		278

[1] Shortest foreign-U.S. distance. Great circle distance from foreign point to nearest major U.S. city.

leasing from the established common carrier network, rather than costs of leasing service from terrestrial systems exclusively. The cost data have been plotted in Figure 8-2 as a function of distance, using two straight-line curves fitted by inspection to represent the cost/distance relationship. Substantial variation about the curves is evident, reflecting the variability of factors which bear on the international agreements. For purposes of projecting costs into the future, the cost/distance curves are preferable to a matrix of costs for each pair of countries, or areas within countries. The curves can be projected with more certainty than the individual link costs.

Costs for transoceanic links to and from the contiguous United States are related to the great circle distance between the foreign end of the link and the nearest major city in the U.S. rather than to the nominal point within the U.S. Thus, the actual transoceanic rate is the same regardless of the location within the U.S. and the curves of Figure 8-2 will provide the correct costs when distances are measured in the proper manner.

Table 8-3 shows interexchange lease costs for 500 kilometers for voice circuits in foreign countries. The sample includes primarily European countries but rates for other foreign countries in the non-Communist part of the world generally fall within the range of variation of costs shown in the table. These costs tend to vary directly with distance. For some of the countries shown, rates are a constant amount per kilometer while, for others, the cost per kilometer declines somewhat with increasing distance. Use of the average value of $29.00 per year per kilometer per circuit for estimating costs appears to offer the best compromise between simplicity of calculations and accuracy of results.

Table 8-4 lists international voice circuit lease costs among European voice circuits. The same value may be assumed for projections of costs for other foreign areas on the basis that the technology used is similar throughout the world and most countries have an interest in promoting good communications.

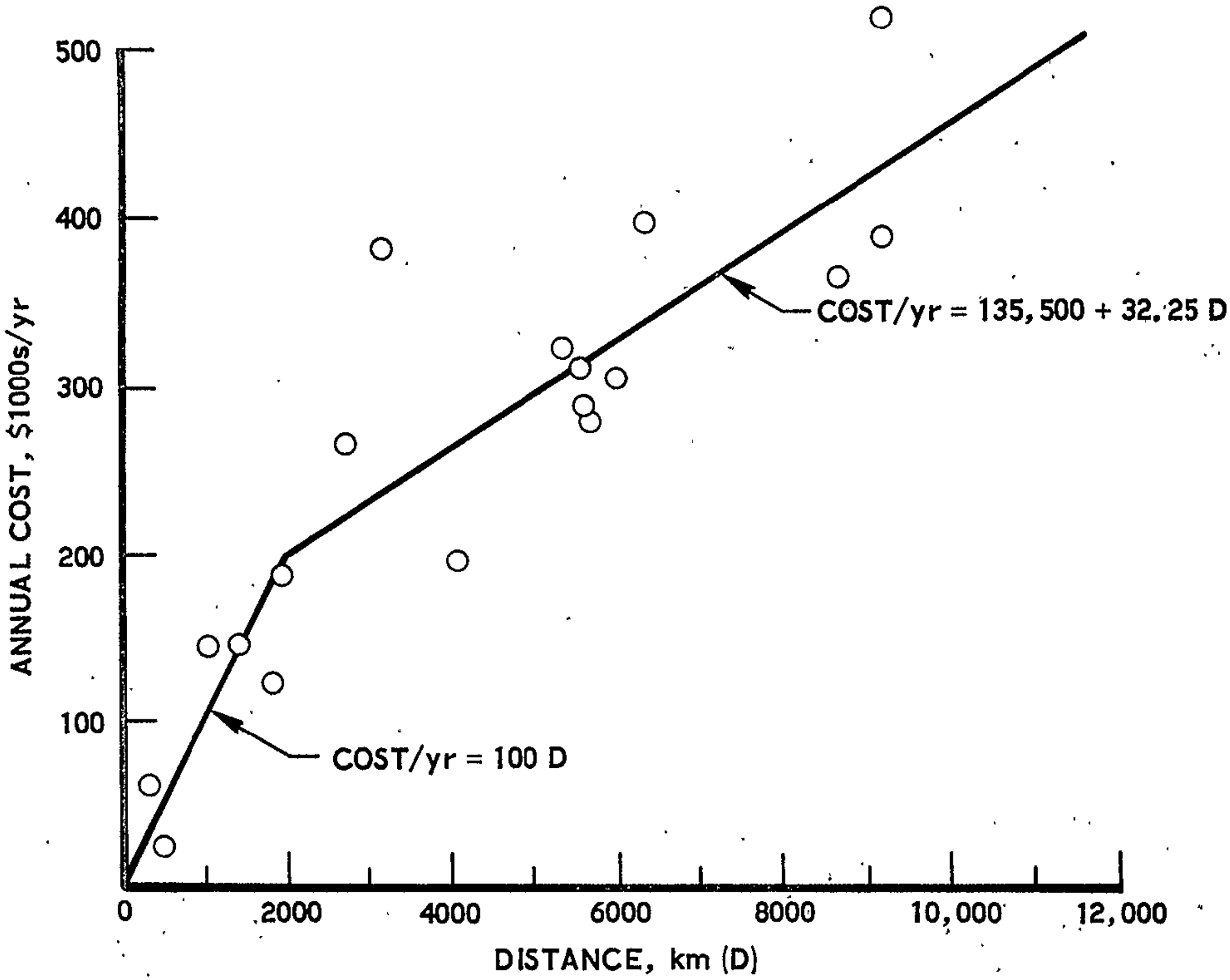


Figure 8-2. Leased Duplex Voice Costs, Transoceanic, 1973 Dollars

Table 8-3. Lease Costs, Interexchange Voice Circuits, Foreign

Country	Cost Per Month @ 500 km (311 mi) ($1969)
Belgium	$ 1400
Denmark	550
France	1350
W. Germany	2250
Greece	1600
Italy	1410
Norway	775
Portugal	1100
Turkey	1280
United Kingdom	600
Australia	1317
Japan	840
Philippines	600
Average	$ 1159

Average cost per kilometer (1969 dollars) = $27.82 per year, per km

Average cost per kilometer (1973 dollars) = **$29.00 per year, per km**

or = $ 2.42 per month, per km

or = $ 3.89 per month, per mile

Table 8-4. Lease Costs, International Voice Circuit, Europe

From	To	Cost Per Month	Distance (km)	Annual Cost/km (1969 $)
London	Oslo	3026	1205	30.1
London	Copenhagen	3035	977	37.3
London	Belgium	1820	367	59.5
London	Frankfurt	2637	660	47.9
London	Greece	8886	2389	44.6
London	Paris	1851	367	60.5
London	N. Italy	3271	1046	37.5
London	Lisbon	6795	1564	52.1
Oslo	Belgium	4639	1255	44.4
Oslo	Copenhagen	1209	595	24.4
Oslo	Paris	5685	1385	49.3
Oslo	Frankfurt	3267	1368	28.7
Copenhagen	Frankfurt	2385	692	41.4
Copenhagen	Belgium	3528	772	54.8
Paris	Lisbon	5489	1403	46.9
Paris	Ankara	8073	2735	35.4
Paris	N. Italy	2874	692	49.8
Paris	S. Italy	4181	1384	36.3
Italy	Ankara	8429	1850	54.7
Italy	Greece	4704	965	58.5
Average				44.70

Average cost per circuit (1969 dollars) = $44.70 per year, per km

Average cost per circuit (1973 dollars) = **$46.58 per year, per km**

or $3.88 per month, per km

or $6.25 per month, per mile

The cost trend of a three-minute public telephone call of 500, 1000, and 2000 miles in the United States is shown in Figure 8-3. Data for the period from 1919 to 1972 are shown in current (current at the time, or actual) dollars. The costs for the latter part of this period, 1959 to 1972, have been stated in constant 1972 dollars, using the Bureau of Labor Statistics wholesale price index for all commodities, and have been extrapolated to 1995.

The average rate of decrease of four percent per year for a 1000-mile call, as shown in the figure, has been selected as an indicator of long-haul communications cost trends for projecting costs of communications, both U.S. and foreign, from the currently prevailing costs. The decline in costs reflects the interaction between growth in the demand for communications and decreasing cost per call due to advances in communications technology and the economies of scale and heavier traffic. This interaction and the effect on cost can be expected to be similar throughout the world.

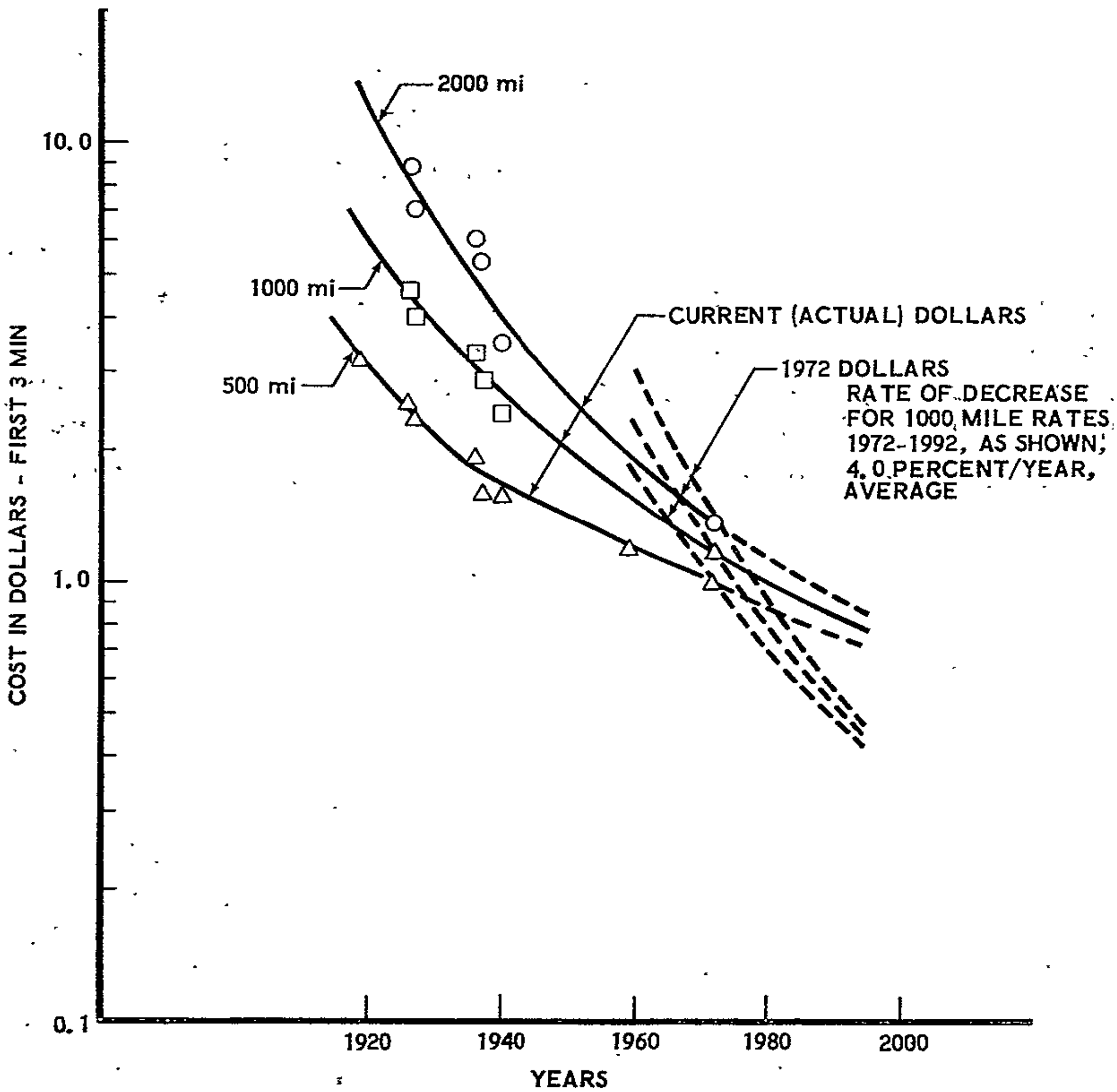


Figure 8-3. Cost Trend, Public Telephone Cost of Station-Station Day Call, First Three Minutes, U.S.

9. LINE-OF-SIGHT MICROWAVE RELAY COMMUNICATIONS SYSTEM COSTS

Line-of-sight microwave relay trunk lines are the least expensive longer-haul terrestrial communications medium under most circumstances. These trunks make up the bulk of the AT&T Long Lines Department network in the contiguous United States (along with aerial or buried telephone cables). Special purpose carriers also have assumed the use of microwave relay systems for inter-city and national voice/data transmission in proposals for systems to service special segments of the communications market, e.g., airline operations data, or business voice and digital data communications.

Where terrestrial transmission costs are required for dedicated communications facilities of systems in the planning stages, microwave relay costs can be used as representative of costs for communications systems which might actually include other media such as aerial or buried cable or high-frequency radio. Even where a detailed system design might show other media to be preferable, costs for such media are not so different, and the likelihood of their being selected is not so great as to disturb overall communications costs significantly.

In order to provide some insight into the cost relationships for microwave relay systems, the characteristics and costs of a domestic U. S. system proposed by the Data Transmission Company (Datran) subsidiary of University Computing Company are given below and analyzed using data from additional sources. From the data and analysis, costs and cost relationships are developed which are useful in estimating costs of microwave relay systems with different configurations.

9.1 THE DATRAN SYSTEM

The system proposed to the Federal Communications Commission by Datran would connect 35 cities using a single trunk microwave relay line and spur lines, as shown in Figure 9-1. Trunk lines and spur line relays would transmit digital data at carrier frequencies in the 4-6 GHz band. Relays would be spaced at approximately 30-mile (48 km) intervals. Distribution at traffic centers, shown in Figure 9-2, would use 11 GHz microwave relays spaced at five miles (8 km); and subscribers would be connected to the distribution microwave relays by cable. Message switching would be accomplished at ten District Offices located in ten of the 35 traffic centers; a single Regional Office would switch messages among the ten District Offices. Message switching would require no more than three seconds to establish a connection. Availability was estimated to be 99.98 percent. P.01 (probability of less than one percent of not getting a circuit) service would be provided during the busy hours. The system is designed to ensure an error probability of less than 10^{-7}.

Time division multiplexing (TDM) would be used with phase shift keying (PSK) to allow simultaneous broadcast by up to six compatible subscribers. Channel sampling at 20 kilobits per second (kbps) would be used for order wire voice. Initially, data rates up to 2 kbps would be available in the asynchronous mode and up to 14.4 kbps in synchronous mode. Higher rates, 19.2-48.0 kbps, would be offered later as the market required. Changes in capacity would be accomplished by changing channel equipment modules.

Maintenance would be simplified by the modular design of equipment, designed for field replacement of malfunctioning modules. Transportable spare stations and modules would be used to patch around catastrophic failures. One maintenance crew, consisting of seven persons, would be responsible for 10 microwave stations.

Investment costs for the system over the six years of system installation are shown in Table 9-1. Of the $349M total costs shown, transmission and switching account for $179M, and local distribution $161M. Not shown is $69M in facilities, which would probably be customer-owned.

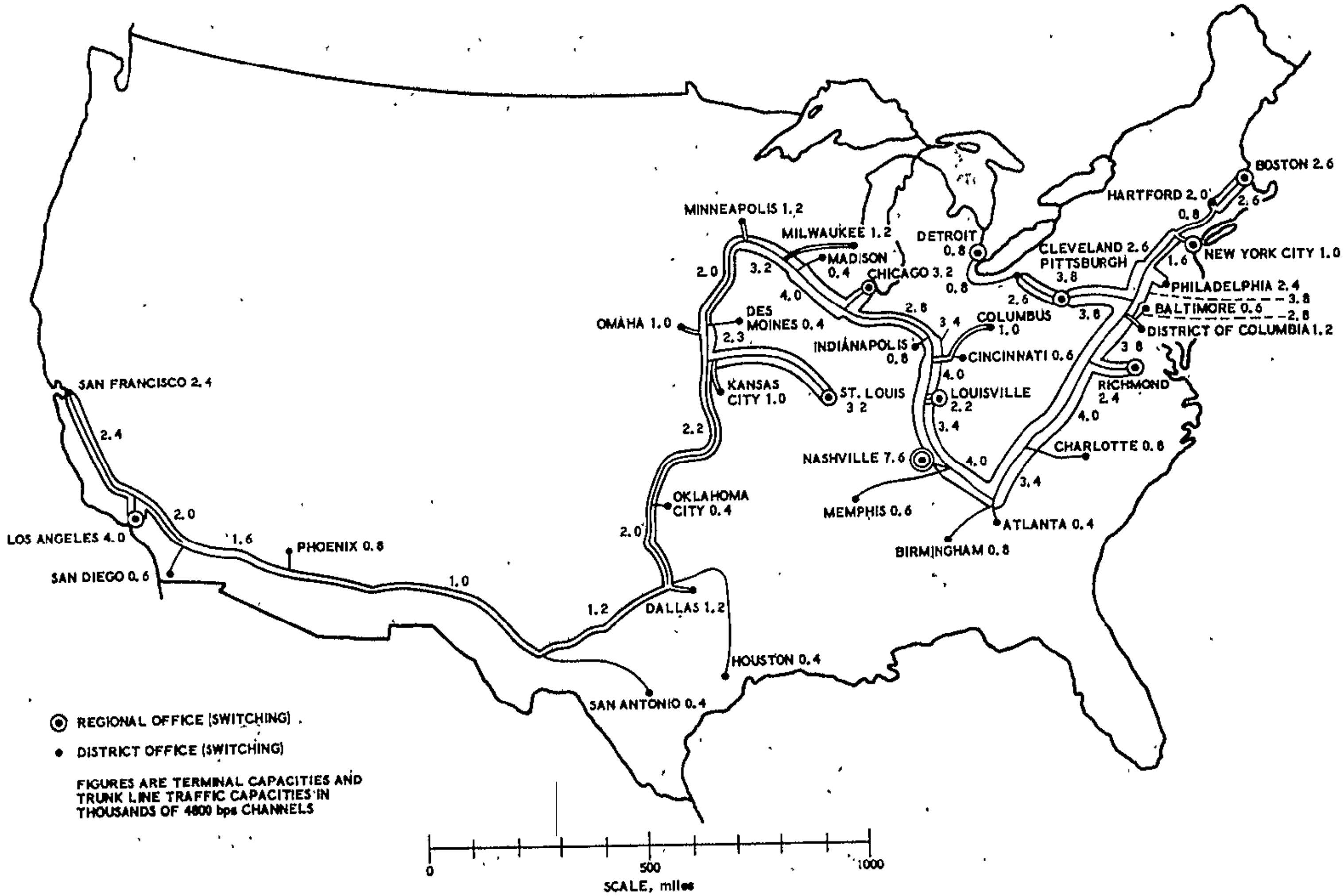


Figure 9-1. Datran Microwave Relay System

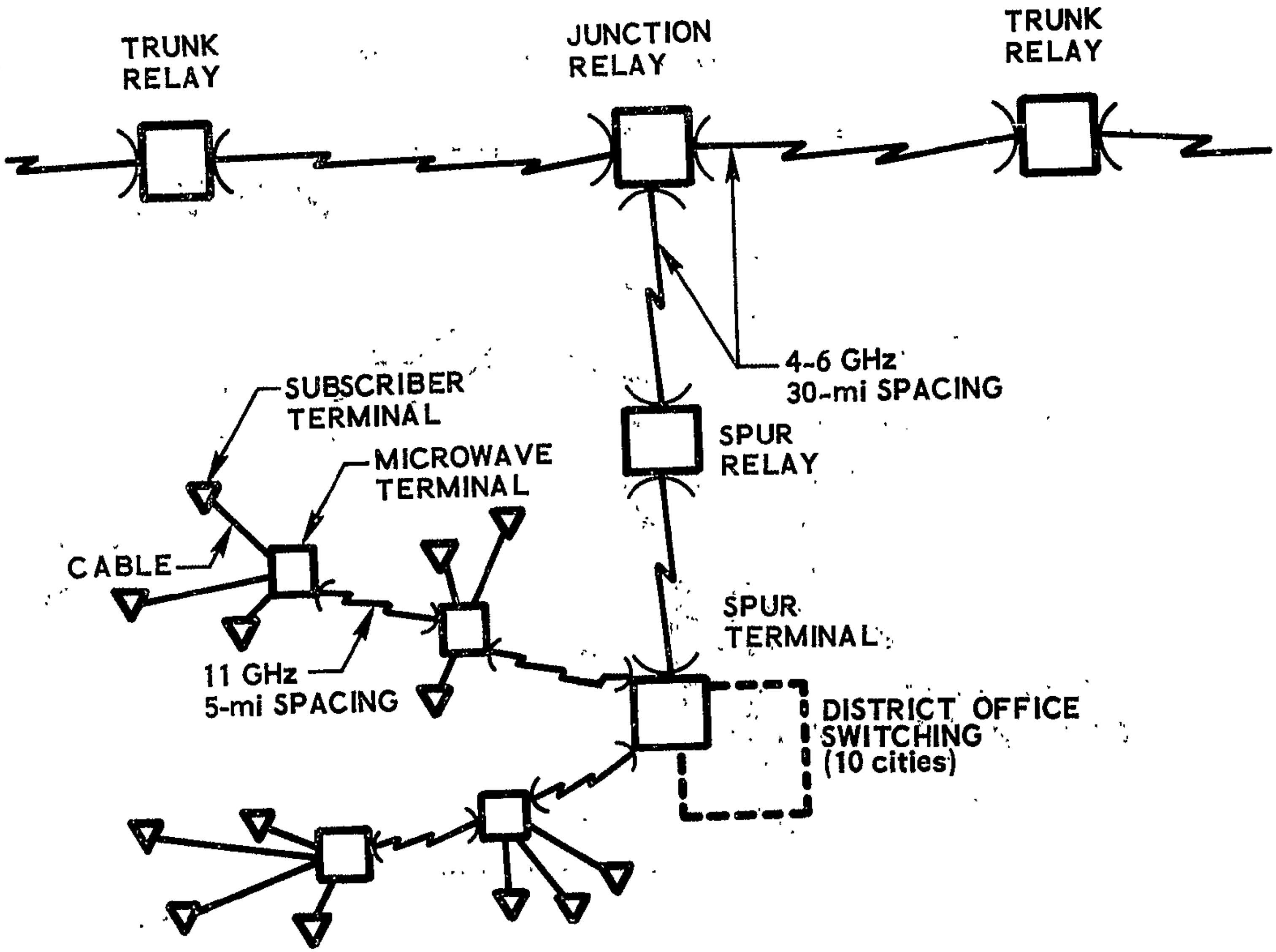


Figure 9-2. Datran Microwave Relay System Configuration

Table 9-1. Datran Microwave Relay System Investment Cost ($M)

	Year						Total
	1	2	3	4	5	6	
Trunks, Spurs	1.5	86.1	26.7	0	0	0	114.3
Dist. Office Switching	1.5	9.5	17.2	21.0	10.8	0	60.0
Regional Office Switching	0	0	0	1.4	3.7	0	5.1
Local Distrib.	0	0	21.5	62.8	56.2	20.5	161.0[1]
Vehicles	0	0.4	0.5	0.5	0.4	0.5	2.3
Other	0	4.2	2.1	0	0	0	6.3
Total	3.0	100.2	68.0	85.7	71.1	21.0	349.0

[1] Approximately 70 percent of total local distribution costs.

The following charge rates for switched message service were proposed:

Data Rate (kbps)	Cost, ¢/min	Cost, ¢/kilobit
0.15	8.0	0.890
4.80	19.5	0.068
9.60	35.0	0.061
14.40	47.0	0.054

Customers would be billed for actual message time, based on a six-second initial period and six-second increments for additional time. The combination of three-second switching time and six-second billing interval would offer distinct cost advantages for customers with substantial amounts of traffic in messages of only a few seconds duration. The current common carrier network, by comparison, requires approximately 20 seconds for switching and bills for an initial three-minute period at the minimum.

9.2 UNIT INVESTMENT COSTS, MICROWAVE TERMINALS AND RELAYS

Investment costs of microwave terminals and relays are broken down to the level of major components and functional elements in Table 9-2, using data from Cosgrove and Chipp (Ref. 9-1). The $161,600 cost per relay station is divided approximately one-third each to building, site, and power; electronics and antenna system; and installation and engineering. Costs are essentially independent of the number of channels carried.

Terminal costs show a similar apportionment of costs for small capacity terminals. However, the multiplexing equipment required is directly related to the terminal capacity, and costs for this equipment increase as the 0.85 power of channel capacity. Costs for large terminals with hundreds of channels are dominated by multiplex equipment costs and the attendant costs for documentation, spares, and support equipment.

The unit costs of terminals and relays as a function of the number of channels of capacity are shown in Figure 9-3. These costs are 14 percent greater than those based directly on the Cosgrove and Chipp data in order to match the Datran estimates.

Table 9-2. Microwave Relay Investment Costs

30-mile hops
7-8 GHz frequency

150-ft guyed tower
4-ft antennas

Typical Terminal	Costs ($1000s)			
No. of 4 kHz Telephone Channels	12	24	60	120
Electronics ($19.5), 160 ft Waveguide($1.0) Antenna & Tower ($6.0), Hardware ($1.0)	27.5	27.5	27.5	27.5
Multiplex with Signalling	27.2	42.2	90.0	162.0
Total Electronics Cost	54.7	69.7	117.5	189.5
Documentation (6.3%) Transportation (2%), Spares (7%), Ground Support Equip. (6.3%) Total 21.6% of Electronics Hardware Cost	11.8	15.1	25.4	40.9
Installation, Engineering	67.0	68.0	71.0	76.0
Bldg. (200 ft^2, $5.0); Power (15kw $20.0); Commercial Power ($10.0); Land, Grading, Roads, Tower Foundation ($14.0); Fuel Storage (1000 gal, $1.0); Fencing (800 ft, $8.0)	58.0	58.0	58.0	58.0
Total	191.5	210.8	271.9	364.4

Typical Relay (costs essentially independent of channel capacity)	Cost ($1000s)
Electronics ($38.0), Waveguide ($2.0) Tower and Antenna ($6.5), Hardware and Miscellaneous ($2.5)	49.0
Documentation, Transportation, Spares, Support Equipment, Total 21.6% of electronic equipment	10.6
Installation, Engineering	44.0
Building, Power, Site Preparation, Roads, Fences, (same as for terminal)	58.0
Total	161.6

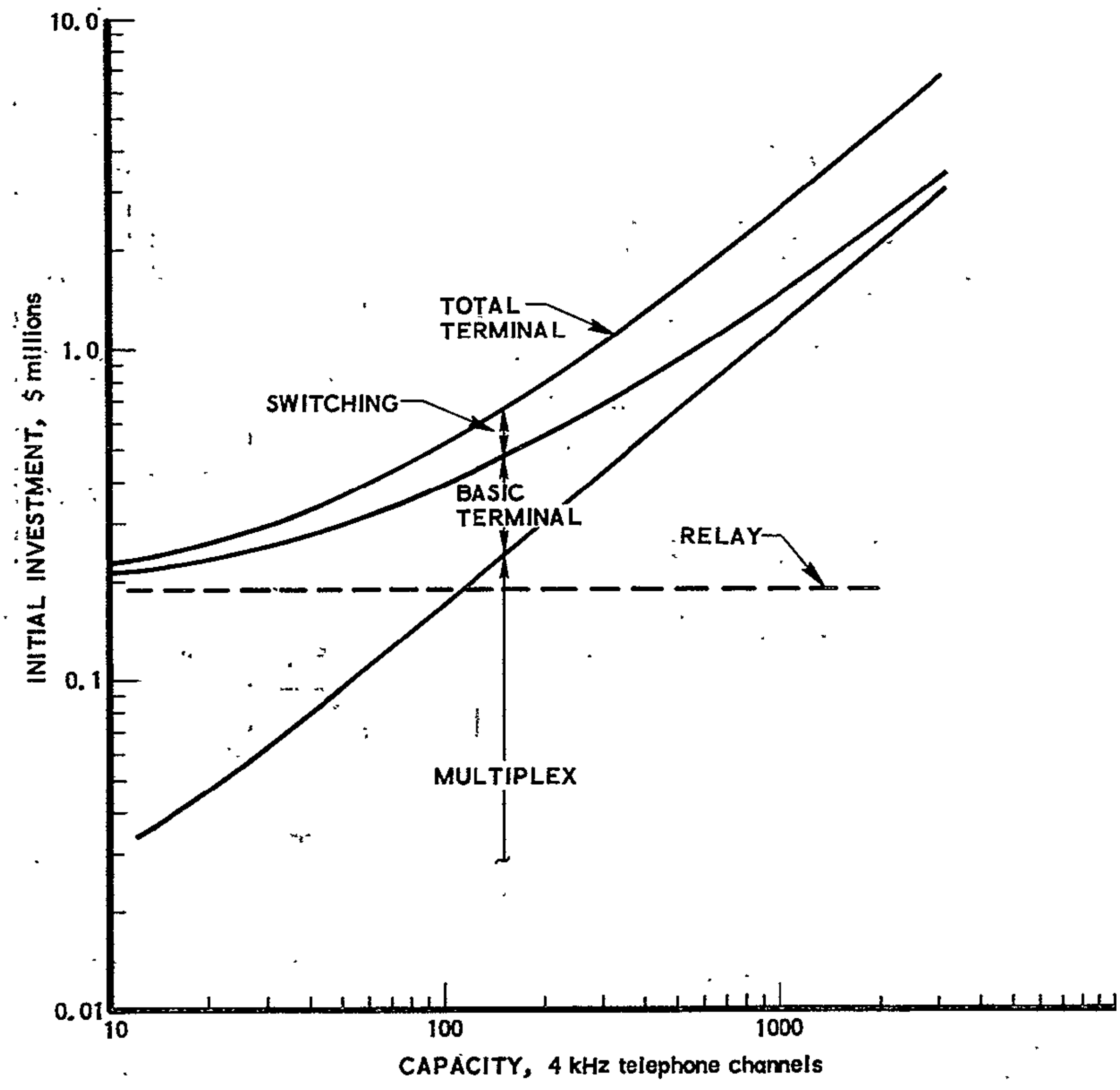


Figure 9-3. Line-of-Sight Microwave Terminal and Relay Station Investment Costs vs Capacity

The top curve of the figure includes the additional costs of message switching at $1160 per channel.

9.3 ANNUAL OPERATIONS AND ...

Annual costs of operating and maintaining microwave relay systems are sensitive to system configuration. Low capacity, simple systems consisting of two terminals and a very few relays tend to have higher personnel costs and lower spares costs per dollar of initial investment than networks with many terminals and high capacity. The differences are the result of scale effects (doubling a terminal's cost may increase personnel costs by only a small fraction) and equipment mix (high capacity networks have a higher proportion of multiplexing and switching equipment cost, and thus a higher proportion of spares costs).

Differences due to configuration are apparent in the estimates of annual costs in Table 9-3 for two systems. One system, used by Cosgrove and Chipp for an example, is a single trunk system, 3000 miles long, with two terminals of 60 channel capacity. Switching equipment is not included. The other, the Datran system, has somewhat more than twice the length (and number of relays) and 36 terminals, most of which have channel capacities of 1000 to 2000. Switching equipment is included. Annual costs for the former were 15.7 percent, for the latter, 11.2 percent of investment. A value of 14 percent of initial investment should be used for annual operations and maintenance costs (capital recovery costs not included) for relatively short systems with two or three terminals and relatively few channels. For systems approximating either of the example systems in the table, the corresponding percentages may be used.

Table 9-3. Annual Operations and Maintenance Cost – Microwave Relay Systems

Cosgrove & Chipp (Two Terminals, 99 Relays) (no switching costs)			Datran (36 Terminals, 241 Relays) (switching costs included)		
Cost Element and Cost Relationship	Annual Cost ($1000s)	% of $16.6 M Invest.	Cost Relationship	Annual Cost ($1000s)	% of $179 M Invest.
Personnel (104 @ $16,000)[1]	1810	10.9	Personnel (374 @ $18,200)[2]	6820	3.8
Replacement parts (10% of electronics cost)	511	3.1	Replacement parts (10% of electronics cost)	12,000	6.7
Utilities (101 stations @ $2000)	202	1.2	Utilities (277 stations @ $2280)[2]	632	0.4
Fuel Oil (101 stations @ $300)	30	0.2	Fuel Oil (277 stations @ $340)[2]	95	0.1
Misc. (1/4% of investment)	42	0.3	Misc. (1/4% of investment)	448	0.2
Total	2595[3]	15.7	Total	19,995[3]	11.2

[1] Includes 9% overhead and administration.

[2] Datran costs are about three years later than Cosgrove & Chipp data and appear to be about 14% higher. Cosgrove & Chipp unit costs have been increased 14% as appropriate for application to Datran system.

[3] Does not include capital recovery costs.

10. U. S. POSTAL SERVICE RATES

As an alternative to the transfer of data by communications satellite, the Postal Service may be used for transport and delivery of data or information in printed copy, photographs, or rolls of tape. The Postal Service rates below can serve as a basis for estimating cost for cost-effectiveness comparisons with space systems.

Rates charged by the Postal Service cover much more than the transportation of mail from one place to another. The rates also cover the costs of mail collection, sorting according to destination, local and long-haul transportation, further sorting, and local transport and delivery. Costs other than transportation comprise the bulk of the costs, as seen below.

	Percent of Total Costs
Collection	9
Processing	32
Transporting	11
Delivery	42
Administration	6
	100

Processing and delivery costs are responsible for three-fourths of total costs. Comparisons of costs for postal services with costs of information transfer by satellite must include the corresponding processing and sorting function costs for the system which uses satellites for "transportation" if the comparisons are to be valid.

Postal Service mail categories and charges are summarized below in sufficient detail to permit calculation of mailing costs according to the class of mail, the kind of sender, and the nature of the material.

Rates for most mail classes vary with distance, with rate steps related to eight postal zones. Zone 1 surrounds the originating office direct service area, and Zones 2 through 8 are circular bands at increasing distance. Zone charts which tabulate destination postal zip codes by zone are used by post offices to determine zones and postal rates. These zone charts vary with the location of the origination post office. They are cumbersome to use in generalized studies inasmuch as zone charts for all originating post offices of concern in a study must be at hand in order to determine postal rates. Postal rates are tabulated on the following pages of this section in the form used by the Postal Service, i.e., with respect to zones.

Table 10-1 relates these zones to their approximate distances from the originating office, allowing the zone distance between two points to be determined without resort to zone charts of either point.

Table 10-2 outlines the characteristics, limitations, and costs of postal service by the major mail classifications, first through fourth class. Tables 10-3 through 10-6 provide rates detail that is too extensive for the format of Table 10-2.

The detail in Table 10-2 and the supporting tables will be adequate in most cases to determine postal rates for specific prospective mail usage. In case of doubt, the main post office of any large city can provide additional clarification.

Table 10-1. Approximate Distances from Los Angeles to Postal Zones 1 through 8

Zone	Distance, miles[1]
1	Less than 50 [2]
2	50 to 125
3	125 to 250
4	250 to 600
5	600 to 1000
6	1000 to 1400
7	1400 to 1850
8	More than 1850

[1] Distances are approximate, based on scaling distances from Los Angeles to Zone boundaries as identified from the Postal Service Official Zone Chart for Los Angeles.

[2] Less than 50 miles but greater than radius served directly by the originating post office.

Table 10-2. Principal Mail Categories and Rates, U.S. Postal Service

	First Class	Airmail	Priority
Users, Uses	Letters, cards, business reply mail, sealed parcels	Same as first class	Sealed parcels
Characteristics, Limitations	Written, typed material must go first class Privacy assured, letters and sealed packages 12 oz or less	Same as first class, except: 8 oz or less	Same as first class, except: >8 oz up to 70 lb
Handling Outgoing Transportation	 Top priority-first dispatch Fastest surface or space-available air over 200 miles[1]	 Same as first class Fastest available	 Same as first class Fastest available
Cost	6¢/card 8¢/oz Bus. reply: 8¢/card <2 oz, 8¢/oz + 2¢ each piece >2 oz, 8¢/oz + 5¢ each piece	9¢/card 11¢/oz Bus. reply: 11¢/card <2 oz, 11¢/oz + 2¢ each >2 oz, 11¢/oz + 5¢ each	See Table 10-3

[1] First Class mail is, essentially, "unguaranteed airmail". Currently a large portion, roughly three-fourths, of first class mail from post offices in major metropolitan centers goes by air to destinations more than a few hundred miles away.

Table 10-2. Principal Mail Categories and Rates, U.S. Postal Service (cont'd)

	Second Class[1]			
	Zone Rate Publ.	Classroom Publ.	Non-Profit Publ.	Transient Rate
Users, Uses	Mass circulation magazines and business publications	Publishers of weekly scholastic magazines and Sunday School journals	Churches, schools, labor unions, fraternal orders, scientific societies, veterans' org., Scouts	General public
Characteristics, Limitations				
Handling Outgoing	Within 24 hours[2]	Same as column to left	Same as column to left	Same as column to left
Transportation	Fastest surface	Same	Same	Same
Incoming	No later than 2nd day	Same	Same	Same
Cost	See Table 10-4	See Table 10-4	See Table 10-4	6¢ first 2 oz 1¢ per additional oz

[1]Rates and characteristics of second class mail delivered in the same county have been excluded from the table because they would be of no value to the purposes of this document.

[2]Major publishers pre-sort and deliver to the post office on schedules designed to minimize post office costs. These arrangements typically result in faster service.

Table 10-2. Principal Mail Categories and Rates, U.S. Postal Service (cont'd)

	Third Class			Controlled Circulation
	Single Piece Rate	Bulk Rate, Reg.	Bulk Rate, Non-Profit	
Users, Uses	Greeting cards, small parcels, printed matter, booklets, mail order catalogs, general public	Quantity advertising newsletters, booklets, catalogs, samples, seeds	Quantity mailings for fund raising newsletters, reports, booklets, non-profit corporations	Magazines & periodicals not 2nd class because circulated to readers without charge, trade publications
Characteristics, Limitations	Less than one pound per piece	Less than one pound per piece	Less than one pound per piece	25% non-advertising min. 24 pages, minimum
Handling Outgoing	Within 24 hours	Same	Same	Same
Transportation	Earliest surface	Same	Same	Same
Incoming	No later than 2nd day	Same	Same	Same
Cost	8¢, 1st 2 oz 2¢ per add'l oz	Circulars: 23¢/lb, 4.0-4.2 ¢ each [1] minimum Books: 17¢/lb 4.0-4.2¢ each minimum	Circulars: 11¢/lb 1.7¢ each, minimum Books: 8¢/lb 1.7¢ each minimum	15¢/lb 4¢ each, minimum

[1] The higher minimum rate applies when more than 250,000 pieces are mailed per year.

Table 10-2. Principal Mail Categories and Rates, U.S. Postal Service (cont'd)

	Fourth Class			
	Educational Materials	Library Materials	Parcel Post	Catalogs
Users, Uses	Books, films, catalogs, recordings, printed music, other educational materials, book and record publishing clubs, book dealers	Similar to "educational materials" category but mailed by libraries or other educational institutions	All mailable matter not in any other class	Catalogs and similar printed and bound material
Characteristics, Limitations			70 pounds, max.	8 oz to 10 pounds, 24 pp or more individually addressed
Handling				
Outgoing	Within 24 hours	Same	Same	Same
Transportation	Earliest surface	Same	Same	Same
Incoming	Within 24 hours	Same	Same	Same
Cost	14¢, first pound 7¢ each add'l pound	6¢, first pound 2¢ each addl' pound	See Table 10-5	See Table 10-5

Table 10-3. Priority Mail Rates

Weight over 8 ounces and not exceeding: (Lbs.)	RATE					
	Local Zones 1, 2 and 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
1	1.00	1.00	1.00	1.00	1.00	1.00
1-½	1.20	1.22	1.25	1.30	1.40	1.50
2	1.40	1.43	1.51	1.60	1.68	1.77
2-½	1.60	1.65	1.76	1.90	2.02	2.16
3	1.80	1.86	2.01	2.20	2.36	2.54
3-½	2.00	2.08	2.26	2.49	2.69	2.93
4	2.20	2.30	2.52	2.79	3.03	3.31
4-½	2.40	2.51	2.77	3.09	3.37	3.70
5	2.60	2.73	3.02	3.39	3.71	4.08
6	3.08	3.23	3.58	4.03	4.43	4.88
7	3.56	3.73	4.14	4.67	5.15	5.68
8	4.04	4.23	4.70	5.31	5.87	6.48
9	4.52	4.73	5.26	5.95	6.59	7.28
10	5.00	5.23	5.82	6.59	7.31	8.08
11	5.48	5.73	6.38	7.23	8.03	8.88
12	5.96	6.23	6.94	7.87	8.75	9.68
13	6.44	6.73	7.50	8.51	9.47	10.48
14	6.92	7.23	8.06	9.15	10.19	11.28
15	7.40	7.73	8.62	9.79	10.91	12.08
16	7.88	8.23	9.18	10.43	11.63	12.88
17	8.36	8.73	9.74	11.07	12.35	13.68
18	8.84	9.23	10.30	11.71	13.07	14.48
19	9.32	9.73	10.86	12.35	13.79	15.28
20	9.80	10.23	11.42	12.99	14.51	16.08
21	10.28	10.73	11.98	13.63	15.23	16.88
22	10.76	11.23	12.54	14.27	15.95	17.68
23	11.24	11.73	13.10	14.91	16.67	18.48
24	11.72	12.23	13.66	15.55	17.39	19.28
25	12.20	12.73	14.22	16.19	18.11	20.08
26	12.68	13.23	14.78	16.83	18.83	20.88
27	13.16	13.73	15.34	17.47	19.55	21.68
28	13.64	14.23	15.90	18.11	20.27	22.48
29	14.12	14.73	16.46	18.75	20.99	23.28
30	14.60	15.23	17.02	19.39	21.71	24.08
31	15.08	15.73	17.58	20.03	22.43	24.88
32	15.56	16.23	18.14	20.67	23.15	25.68
33	16.04	16.73	18.70	21.31	23.87	26.48
34	16.52	17.23	19.26	21.95	24.59	27.28
35	17.00	17.73	19.82	22.59	25.31	28.08
36	17.48	18.23	20.38	23.23	26.03	28.88
37	17.96	18.73	20.94	23.87	26.75	29.68
38	18.44	19.23	21.50	24.51	27.47	30.48
39	18.92	19.73	22.06	25.15	28.19	31.28
40	19.40	20.23	22.62	25.79	28.91	32.08
41	19.88	20.73	23.18	26.43	29.63	32.88
42	20.36	21.23	23.74	27.07	30.35	33.68
43	20.84	21.73	24.30	27.71	31.07	34.48
44	21.32	22.23	24.86	28.35	31.79	35.28
45	21.80	22.73	25.42	28.99	32.51	36.08
46	22.28	23.23	25.98	29.63	33.23	36.88
47	22.76	23.73	26.54	30.27	33.95	37.68
48	23.24	24.23	27.10	30.91	34.67	38.48
49	23.72	24.73	27.66	31.55	35.39	39.28
50	24.20	25.23	28.22	32.19	36.11	40.08
51	24.68	25.73	28.78	32.83	36.83	40.88
52	25.16	26.23	29.34	33.47	37.55	41.68
53	25.64	26.73	29.90	34.11	38.27	42.48
54	26.12	27.23	30.46	34.75	38.99	43.28
55	26.60	27.73	31.02	35.39	39.71	44.08
56	27.08	28.23	31.58	36.03	40.43	44.88
57	27.56	28.73	32.14	36.67	41.15	45.68
58	28.04	29.23	32.70	37.31	41.87	46.48
59	28.52	29.73	33.26	37.95	42.59	47.28
60	29.00	30.23	33.82	38.59	43.31	48.08
61	29.48	30.73	34.38	39.23	44.03	48.88
62	29.96	31.23	34.94	39.87	44.75	49.68
63	30.44	31.73	35.50	40.51	45.47	50.48
64	30.92	32.23	36.06	41.15	46.19	51.28
65	31.40	32.73	36.62	41.79	46.91	52.08
66	31.88	33.23	37.18	42.43	47.63	52.88
67	32.36	33.73	37.74	43.07	48.35	53.68
68	32.84	34.23	38.30	43.71	49.07	54.48
69	33.32	34.73	38.86	44.35	49.79	55.28
70	33.80	35.23	39.42	44.99	50.51	56.08

Table 10-4. Second Class Postal Rates

Second Class Category	Zone-Rate Publications	Classroom Publications	Non-Profit[2] Publications
Cost[1]			
1. Reading Matter, ¢/lb	4.0	2.3	2.4
2. Advertising matter, ¢/lb			
Zones 1 and 2	6.0[3]	3.6	4.4
Zone 3	7.2	4.4	5.2
Zone 4	9.6	5.9	6.9
Zone 5	11.9	7.4	8.6
Zone 6	14.4	9.0	9.4
Zone 7	15.3	9.5	9.5
Zone 8	17.8	11.1	9.7
3. Charge per piece	0.2	0.1	0.04
4. (Minimum total charge per piece)	(1.3)	(0.8)	(0.2)

[1]Total cost per piece is the sum of Items 1, 2, and 3, but not less than item 4.

[2]4.6¢/lb for authorized agricultural publications (Zones 1 and 2).

[3]Non-profit publications with less than 10 percent advertising are charged at the reading matter rate.

Table 10-5. Parcel Post Rates - Fourth Class

Weight—1 pound and not exceeding (pounds)	Zones: Local	1 and 2	3	4	5	6	7	8
2	$0.60	$0.65	$0.70	$0.75	$0.80	$0.90	$1.00	$1.05
3	.60	.75	.80	.85	.95	1.10	1.20	1.35
4	.65	.80	.85	.95	1.10	1.30	1.40	1.60
5	.70	.85	.90	1.05	1.20	1.45	1.65	1.90
6	.70	.95	1.00	1.15	1.35	1.60	1.85	2.10
7	.75	1.05	1.10	1.25	1.50	1.75	2.10	2.35
8	.75	1.10	1.15	1.35	1.60	1.90	2.30	2.60
9	.80	1.15	1.20	1.45	1.75	2.05	2.45	2.85
10	.80	1.20	1.30	1.55	1.90	2.20	2.65	3.10
11	.80	1.25	1.35	1.60	2.00	2.30	2.85	3.35
12	.85	1.30	1.45	1.70	2.10	2.45	3.05	3.55
13	.85	1.35	1.55	1.80	2.20	2.60	3.25	3.80
14	.90	1.40	1.60	1.90	2.35	2.75	3.45	4.00
15	.90	1.45	1.65	2.00	2.45	2.85	3.60	4.20
16	.95	1.55	1.75	2.05	2.55	2.95	3.80	4.40
17	1.00	1.60	1.80	2.15	2.65	3.10	3.95	4.60
18	1.00	1.65	1.90	2.20	2.75	3.20	4.15	4.80
19	1.05	1.70	2.00	2.30	2.85	3.35	4.30	5.00
20	1.05	1.75	2.05	2.40	2.95	3.50	4.50	5.20
21	1.10	1.85	2.10	2.45	3.05	3.65	4.65	5.40
22	1.15	1.90	2.15	2.55	3.15	3.75	4.85	5.60
23	1.15	1.95	2.20	2.60	3.25	3.90	5.00	5.80
24	1.20	2.00	2.25	2.65	3.35	4.05	5.15	6.00
25	1.20	2.05	2.30	2.75	3.45	4.15	5.35	6.20
26	1.20	2.10	2.35	2.85	3.55	4.30	5.50	6.40
27	1.25	2.15	2.40	2.90	3.70	4.45	5.65	6.60
28	1.25	2.20	2.45	2.95	3.80	4.60	5.80	6.80
29	1.30	2.25	2.50	3.05	3.90	4.70	5.95	7.00
30	1.30	2.30	2.55	3.10	4.00	4.85	6.10	7.20
31	1.35	2.35	2.65	3.20	4.10	5.00	6.25	7.40
32	1.40	2.40	2.70	3.30	4.20	5.15	6.45	7.60
33	1.40	2.45	2.75	3.35	4.30	5.25	6.60	7.80
34	1.45	2.50	2.80	3.40	4.40	5.40	6.75	8.00
35	1.45	2.55	2.85	3.45	4.50	5.55	6.90	8.20
36	$1.45	$2.60	$2.90	$3.55	$4.60	$5.65	$ 7.10	$8.40
37	1.50	2.65	3.00	3.65	4.70	5.75	7.25	8.60
38	1.50	2.70	3.05	3.70	4.80	5.90	7.45	8.80
39	1.55	2.75	3.10	3.80	4.90	6.05	7.60	9.00
40	1.55	2.80	3.15	3.85	5.00	6.15	7.75	9.20
CONSULT POSTMASTER FOR WEIGHT AND SIZE LIMITS								
41	1.60	2.85	3.20	3.95	5.15	6.25	7.95	9.40
42	1.65	2.90	3.25	4.00	5.25	6.40	8.10	9.60
43	1.65	2.95	3.30	4.10	5.35	6.55	8.25	9.80
44	1.70	3.00	3.35	4.15	5.45	6.65	8.40	10.00
45	1.70	3.05	3.40	4.20	5.55	6.80	8.55	10.20
46	1.70	3.10	3.50	4.30	5.65	6.90	8.70	10.40
47	1.75	3.10	3.55	4.40	5.75	7.00	8.90	10.60
48	1.75	3.15	3.60	4.45	5.85	7.15	9.05	10.80
49	1.80	3.20	3.65	4.50	5.95	7.30	9.20	11.00
50	1.80	3.25	3.70	4.60	6.05	7.40	9.35	11.15
51	1.85	3.30	3.80	4.70	6.15	7.50	9.50	11.35
52	1.90	3.35	3.85	4.75	6.25	7.65	9.65	11.55
53	1.90	3.40	3.90	4.80	6.35	7.80	9.80	11.75
54	1.95	3.40	3.95	4.90	6.45	7.90	9.95	11.90
55	1.95	3.45	4.00	4.95	6.55	8.00	10.10	12.10
56	1.95	3.50	4.10	5.05	6.60	8.10	10.25	12.25
57	2.00	3.55	4.15	5.15	6.70	8.25	10.40	12.45
58	2.00	3.60	4.20	5.20	6.80	8.40	10.55	12.60
59	2.05	3.65	4.25	5.25	6.90	8.50	10.70	12.80
60	2.05	3.65	4.30	5.35	7.00	8.60	10.85	12.95
61	2.10	3.70	4.35	5.45	7.05	8.70	11.00	13.10
62	2.15	3.70	4.40	5.50	7.15	8.85	11.15	13.30
63	2.15	3.75	4.45	5.55	7.25	9.00	11.30	13.45
64	2.20	3.80	4.50	5.60	7.35	9.10	11.45	13.65
65	2.20	3.85	4.60	5.70	7.45	9.20	11.60	13.80
66	2.20	3.90	4.65	5.80	7.50	9.30	11.75	13.95
67	2.25	3.95	4.70	5.85	7.60	9.40	11.85	14.15
68	2.25	3.95	4.75	5.90	7.70	9.55	12.00	14.30
69	2.30	4.00	4.80	5.95	7.75	9.65	12.15	14.50
70	2.30	4.05	4.85	6.05	7.85	9.75	12.25	14.65

Table 10-6. Fourth Class Mail, Catalog Rates

Individual Mailings								
Weight, lb	Zones, Costs in cents							
	Local	1 & 2	3	4	5	6	7	8
1.5	28	34	34	36	38	40	42	46
2.0	29	35	36	38	41	43	47	51
2.5	30	37	38	41	43	47	51	56
3.0	31	39	40	43	47	51	56	62
3.5	32	40	42	46	50	55	60	67
4.0	33	42	44	48	53	58	65	73
4.5	34	44	46	51	56	62	69	78
5.0	35	45	48	53	59	66	74	83
6.0	37	49	52	58	65	73	83	94
7.0	39	52	56	63	71	81	92	105
8.0	41	56	60	68	77	88	101	116
9.0	43	59	64	73	83	96	110	127
10.0	45	62	68	78	89	103	119	137

Bulk Mailings[1]		
Zones	Piece Rate, cents	Bulk Pound Rate, cents
Local	21	2.1
1 and 2	25	3.4
3	25	4.0
4	25	5.0
5	25	6.1
6	25	7.5
7	25	9.1
8	26	10.8

[1]300 pieces, minimum, mailed at one time. Total cost is sum of piece rate times number of pieces and pound rate times number of pounds.

11. SUBMARINE TELEPHONE CABLE COSTS

The first of the transoceanic submarine telephone cables was AT&T's TAT-1 ("Trans-Atlantic Telephone"), which went into service in 1956, providing 51 telephone circuits of 3 kHz bandwidth between the U.S. and England. Since that time, cables of increasingly larger capacity have been installed. AT&T's most recent transatlantic cable, TAT-5, carries 825 telephone circuits of 3 kHz bandwidth; and the current generation of British cables has a capacity of 1840 circuits of 3 kHz bandwidth or 1380 circuits of 4 kHz bandwidth. Currently, submarine cables connect North America with Europe, the Bahamas, the Caribbean Islands, South America, Hawaii, Guam, Japan, New Zealand, Australia, the Philippines, and several points in the East Indies and Southeast Asia. Cables also interconnect Europe with the Near East and with South Africa.

11.1 INVESTMENT COSTS

Improvements in technology and economies of scale have reduced the investment cost per submarine telephone cable circuit by an order of magnitude, as shown in Figure 11-1. The figure shows the investment cost per half-circuit[1] per kilometer versus capacity in half-circuits for the three groups of cables: the first cables of the late 1950's with 70 to 80 half-circuits, the cables of the 1960's with 100 to 1250 half-circuits, and the cables planned for installation in the 1970's with capacities to about 6000 half-circuits. Cables with over 20,000 half-circuits, which are under development by AT&T for installation about 1976, are not shown because no estimated costs are available. Telephone half-circuit bandwidths of 3 kHz are usually provided in submarine cables. However, in Figure 11-1 the capacities are plotted in terms of 4 kHz bandwidth rather than the

[1] Two half-circuits, or channels, are required for a two-way telephone circuit.

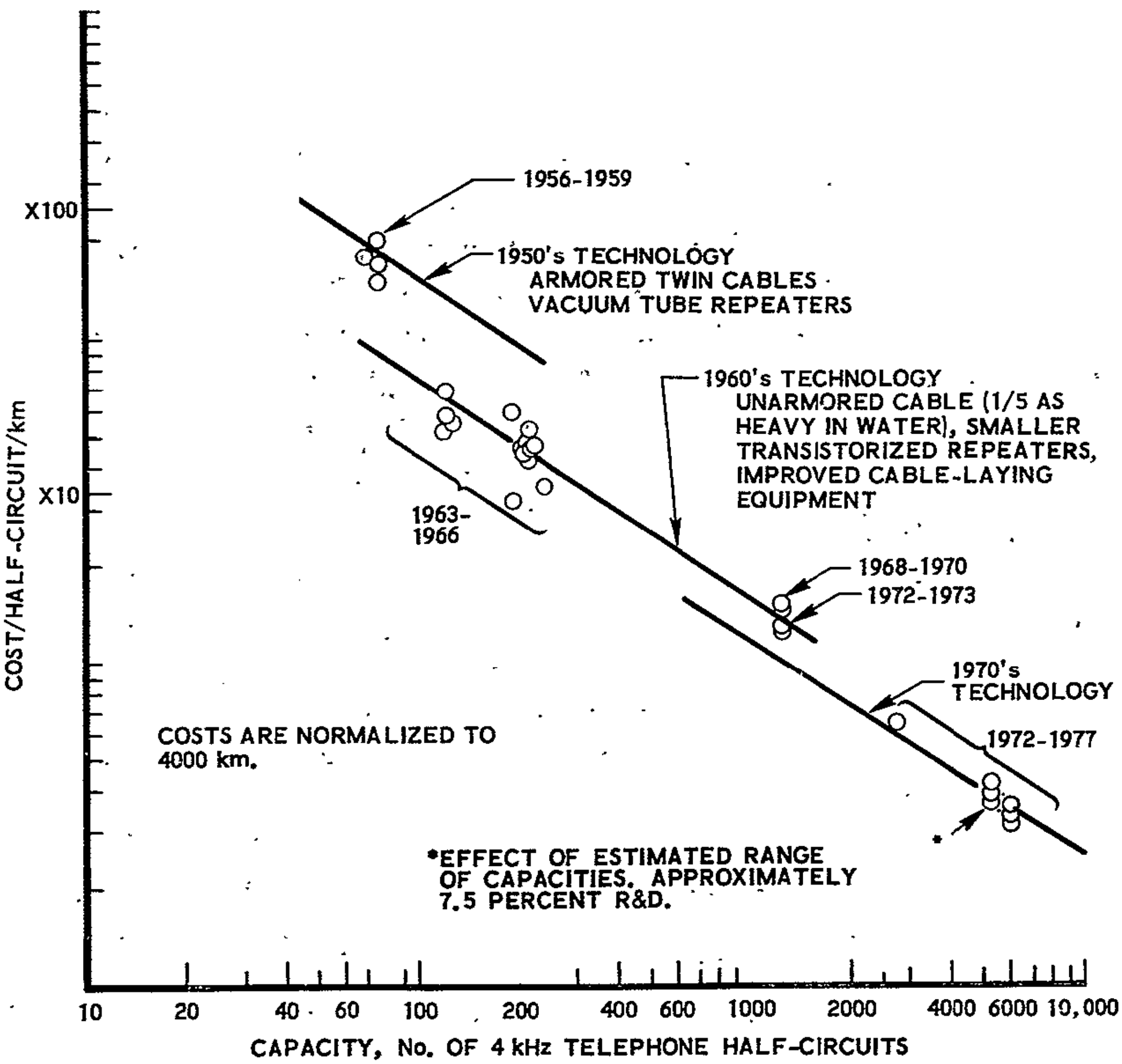


Figure 11-1. Investment Cost of Submarine Telephone Cables (1973 Dollars) per Half-Circuit per Kilometer

nominal 3 kHz bandwidth in the interest of comparability with overland and satellite communication systems, which usually provide 4 kHz bandwidth.

The reduction of investment cost per half-circuit per kilometer over the past 15 years has resulted from two factors: improvements in technology and increases in capacity per cable. The first cables were cumbersome and expensive to construct and lay. They employed vacuum-tube repeaters in bulky cannisters, and the armored twin cables were heavy and tended to kink during laying operations. Cables of the 1960's were unarmored single cables, about one-fifth the weight in water, using transistorized repeaters in much smaller cannisters, and were easier and less expensive to lay using equipment that had been brought into service after the first cables had been laid. Inasmuch as cable construction and laying costs are relatively insensitive to capacity up to the largest capacity available, costs per half-circuit dropped almost inversely as the available cable capacity increased to about 200 to 250 half-circuits in the mid-1960's and about 1250 half-circuits by 1968.

Costs based on AT&T estimates of investment costs for cables of 2500 to 6000 half-circuits, in the lower right corner of the figure, reflect a further decrease in unit cost due both to economy of scale and further advances in technology. The effect of advancing technology is indicated by the use of separate lines in the figure to represent unit costs of the cables of the 1950's, 1960's, and 1970's. A line representing the technology of the 1980's would be lower than the line for the 1970's by a factor of 0.73 if, as appears to be reasonable, the 3.1 percent per year trend of unit cost reduction for a particular capacity from the 1960's to the 1970's continues.

Costs in Figure 11-1 have been normalized to 4000 kilometers (2486 miles) using the relative cost factors of Figure 11-2 to adjust for the effect of distance on cost per kilometer. These factors are based on estimated costs for AT&T's TAT-3 cable system which is approximately 6436 kilometers (4000 miles) long. Eleven percent of the TAT-3 costs are cable terminal costs (Ref. 11-1) which are constant regardless of cable length.

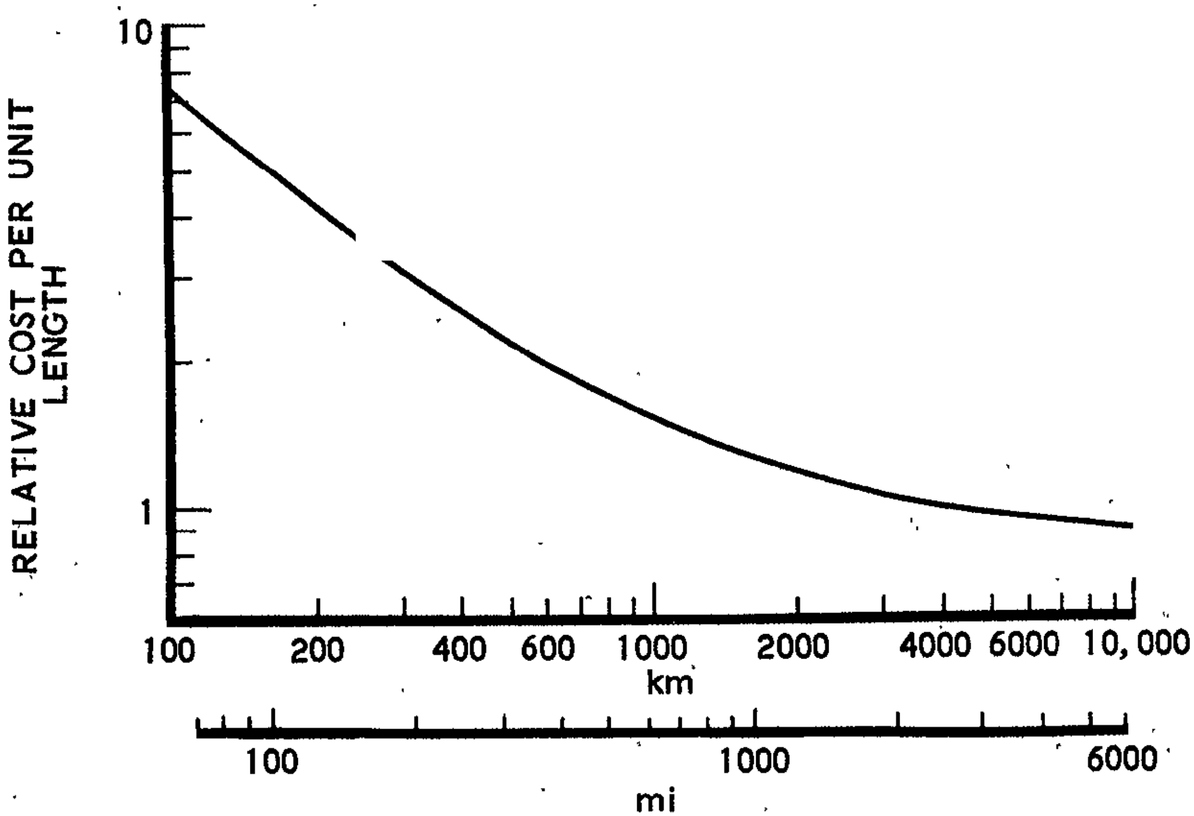


Figure 11-2. Relative Cost per Unit Length vs Length for Submarine Telephone Cable Systems

The effect of these relative cost factors is small for most cable systems since most cable systems exceed 2500 kilometers, and the distance-related costs of cable construction and laying are dominant. For cable systems shorter than 2500 kilometers, however, costs per mile should be adjusted. For these shorter systems the cable terminal costs and the fixed costs associated with planning and initiating the system become an increasingly important part of total costs, and costs per kilometer are more than ten percent greater than the normalized values.

The service life of a submarine cable is estimated by AT&T to be 24 years.

11.2 ANNUAL OPERATING COSTS

Annual operating costs, excluding administrative costs, for a sample of seven submarine cable systems are derived from AT&T estimates[1] of revenue required for maintenance, depreciation, taxes, and return on investment. Administrative expenses, excluded from the preceding estimates, are derived from expenses reported to the Federal Communications Commission (Ref. 11-2). Total annual operating costs as a percentage of gross investment are calculated from these two sources.

		Percent of Gross Investment
Depreciation (24-year life)		4.2
Maintenance		2.8
Taxes and return on investment		15.3
Administrative expenses[2]		
Traffic	0.6	
Commercial	0.9	
General Office	1.7	
Other	1.5	
Services from AT&T General Dept.	0.9	
Total Administrative		5.6
Total Annual Operating and Maintenance		27.9

[1] Comments of AT&T on FCC Docket 18875, "Inquiry into Policy to be Followed in Future Licensing of Facilities for Overseas Communications," August 19, 1970.

[2] Data are the 1969 values of AT&T Long Lines department expenses as a percentage of gross Long Lines plant cost.

The estimated revenue required for taxes and return on investment, 15.3 percent, for the seven submarine cable systems can be compared to a 1969 return of 17.3 percent on Long Lines Department net plant investment, of which 2.4 percent went to taxes other than Federal Income Tax, 7.1 percent was required for Federal Income Tax, and 7.8 percent remained as return on investment.

For purposes of estimating annual costs, excluding depreciation, taxes, and return, for submarine cable systems, the following may be used:

Maintenance	2.8% of initial investment
Administrative expense	5.6% of initial investment
TOTAL	8.4% of initial investment.

12. TERRESTRIAL POWER GENERATION SYSTEM COSTS

Costs of nuclear electric power generation were estimated to provide baseline costs for comparing the estimated costs of a solar cell power satellite (SCPS) system in the time period 1990 - 2020.

Nuclear power costs were selected for the comparison inasmuch as the bulk of new capacity added in this time period will be nuclear according to Federal Power Commission estimates. According to FPC estimates in the 1970 National Power Survey, approximately 45 percent of U. S. generating capacity will be nuclear by 1990. Projecting the trends to 2020, about 68 percent of capacity will be nuclear or new technology. In addition, both the nuclear and SCPS systems are best suited to supply base load power. Both systems have higher capital costs per kW of capacity and lower operating costs (including fuel) per kW hr produced than fossil fueled plants; hence, the costs per kW hr for these systems are the most competitive relative to fossil-fueled system costs at high utilization rates.

The SCPS system was assumed for the analysis to provide for a fraction, either ten percent or 25 percent, of the incremental growth of U. S. generating capacity beyond 1990 out to 2020. Growth of U. S. generating capacity was projected at six percent per year. Nuclear systems to provide the same capacities were assumed for comparison.

Nuclear capacity installed in the 1990s was assumed to be of the boiling water reactor (BWR) or pressurized water reactor (PWR) types. Fast breeder reactors were assumed to be selected for all capacity added after 2000. These assumptions were intended to approximate a transition to fast breeder reactors from their initial commercial installations in the 1980s to their dominance of newly installed capacity in the first decade of the next century.

Nuclear generation costs only were included. Transmission and distribution costs were excluded. Costs per unit output were calculated in terms of mills per kW hr generated, rather than per kW hr solid. Sales are about ten percent less than the amount generated owing to losses in transmission and distribution. Costs from the data sources were adjusted to April 1973 dollar levels using the Bureau of Labor Statistics index of wholesale prices, and further calculations and results were in constant April 1973 dollars.

The primary source of data for nuclear power facilities was the Federal Power Commission's 1970 National Power Survey, December 1971, which provides estimates of costs and characteristics of the electric power industry based on extensive data and analyses from the industry. The actual data are complete through 1968.

Additional sources were referred to for information on fossil and nuclear fuel resources and price projections, projections of nuclear technology, and projections of nuclear costs. Most of the additional information was not used directly in arriving at cost estimates inasmuch as the FPC projections take into account anticipated changes in costs during the 1970s and 1980s.

12.1 NUCLEAR INVESTMENT COSTS

The following estimates of nuclear plant investment costs for BWR or PWR plants were the basis for the estimates used in this study. The FPC estimate applies to the 1970s and 1980s; the AEC model applies to the early 1980s. Both estimates include interest costs during construction; they do not include allowances for escalation of construction costs with time.

	Unit Capacity In MWe*	1968$	1972$	1973$
FPC:				
Plant	1200-2800	222/kW		282/kW
Nuclear Inventory		30/kW		32/kW
Total		252/kW		320/kW
AEC Model**				
Plant	1000 2000		336/kW 275/kW	369/kW 302/kW
Nuclear Inventory			(not stated)	(not stated)

* MWe is megawatt electrical output capacity.

** Estimates based on AEC cost model used by F. C. Olds, Capital Cost Calculation for Future Power Plants, Power Engineering, January 1973. Includes costs for near-zero radiation waste control and cooling towers.

Based on the data above, the plant investment cost for a large nuclear unit, 2000 MWE capacity, would cost about $300/kW (the simple average of $282 and $302, rounded up to $300). Thus the following investment costs were used for nuclear plants with 2000 MWE units[(1)].

	Time Period	Cost/kW of Installed Capacity, 1973$
BWR and PWR		
Plant	1990s	300
Nuclear Inventory		38
Total Investment		338
Fast Breeder Reactors		
Plant @ (1.23 x BWR or PWR)*	2000 to 2020	369
Nuclear Inventory**		38
Total Investment		407

* Page IV-1-58 of 1970 National Power Suevey.

** Not estimated for FBRs in the source. Assumed, herein, that nuclear inventory cost will be the same for BWRs and PWRs.

---

(1) Two or three units per plant site will be common.

12.2 NUCLEAR PLANT ANNUAL COSTS

The FPC data for annual plant operating costs were estimated in terms of O&M, G&A, fuel burnup, and annual fixed charges as follows:

	Annual Cost Per kW. of Installed Capacity Per Year	
	1968$	1973$
O&M (Payroll, Engineering Exp., Supplies, Equipt.)	3.00	3.80
G&A (17 % of O&M)*	0.52	0.66
Fuel Burnup @ 0.5 mills/ kW hr, 54% cap. factor		2.37

* Page I-19-19; ratio of G&A to O&M for power production, 1968.

Annual fixed charges, per FPC estimates, page I-19-6 of the 1970 National Power Survey, figured in percent of gross investment are:

Insurance	0.2%
Income Taxes	2.2%
Other Taxes	2.4%
Total	4.8%

The estimated O&M cost per kilowatt per year is an average derived from detailed estimates for individual plants of various capacities and plants with one or more generating units. The fuel burnup cost of 0.5 mills/kW hr is an estimated composite cost. Fuel costs are estimated to decline rapidly with the introduction of FBRs from 1.2 mills/kW hr (1968$) for BWRs and PWRs in 1990 to 0.4 mills/kW hr (1968$) for FBRs in 1995. This latter cost, adjusted to 0.5 mills/kW hr (1973$) was used to estimate fuel costs for the entire period from 1990 to 2020. Higher costs in the first decade of the period would tend to be offset by lower costs in the second two decades, if it is assumed that fuel costs will be reduced further in the period 2000 to 2020.

A capacity factor[(1)] of 54 percent was assumed for the economic analysis to determine costs per kW·hr generated. This is the FPC's estimated average factor for all types of electrical generation in 1990.

Documents used to derive the above information are listed as References 12-1 through 12-9 in Section 14 of this volume of the final report.

(1) Ratio of kW hr per year generated and sold to kW hr capacity (kW capacity times 8766 hours per year).

13. COST EFFECTIVENESS COMPUTER PROGRAM

The listing for the Cost Effectiveness Computer Program is listed in APL language on Figures 13-1 through 13-16.

```
SATELLITE R AND D
   MISSION EQUIPMENT
   SPACECRAFT
SATELLITE INVESTMENT
   MISSION EQUIPMENT
   SPACECRAFT
SATELLITE OPERATIONS
L/V DIRECT OPERATING COSTS
GROUND SYSTEM INVESTMENT
   ELECTRONICS
   SUPPORT FACILITIES
GROUND SYSTEM OPERATIONS
TOTAL SYSTEM COSTS
YEARS AFTER START
NPV FACTOR
UNIT DEMAND PER YEAR
NPV UNIT DEMAND
SATELLITE R AND D REVENUE
   NPV MISSION EQUIPMENT R AND D
   MISSION EQUIPMENT UNIT CHARGE
   MISSION EQUIPMENT REVENUE
   NPV SPACECRAFT R AND D
   SPACECRAFT UNIT CHARGE
   SPACECRAFT REVENUE
SATELLITE INVESTMENT REVENUE
   NPV MISSION EQUIPMENT INVESTMENT
   MISSION EQUIPMENT UNIT CHARGE
   MISSION EQUIPMENT REVENUE
   NPV SPACECRAFT INVESTMENT
   SPACECRAFT UNIT CHARGE
   SPACECRAFT REVENUE
SATELLITE OPERATING REVENUE
   NPV OPERATIONS
   OPERATIONS UNIT CHARGE
   OPERATIONS REVENUE
L/V DOC REVENUE
   NPV L/V DOC
   L/V DOC UNIT CHARGE
   L/V DOC REVENUE
GROUND SYSTEM INVESTMENT REVENUE
   NPV ELECTRONICS
   ELECTRONICS UNIT CHARGE
   ELECTRONICS REVENUE
   NPV SUPPORT FACILITIES
   SUPPORT FACILITIES UNIT CHARGE
   SUPPORT FACILITIES REVENUE
GROUND SYSTEMS OPERATIONS REVENUE
   NPV OPERATIONS
   OPERATIONS UNIT CHARGE
   OPERATIONS REVENUE
TOTAL SYSTEM CHARGE RATE
TOTAL SYSTEM REVENUE
TOTAL NPV OF SYSTEM COSTS
```

Figure 13-1. Output, Cost/Revenue Analysis for Constant Dollars (CORAN)

```
SATELLITE R AND D
    MISSION EQUIPMENT
    SPACECRAFT
SATELLITE INVESTMENT
    MISSION EQUIPMENT
    SPACECRAFT
SATELLITE OPERATIONS
L/V DIRECT OPERATING COSTS
GROUND SYSTEM INVESTMENT
    ELECTRONICS
    SUPPORT FACILITIES
GROUND SYSTEM OPERATIONS
TOTAL SYSTEM COSTS
YEARS AFTER START
INFLATION
TOTAL SYSTEM COST IN CURRENT DOLLARS
CONSTANT DOLLAR NPV FACTOR
CURRENT DOLLAR NPV FACTOR
UNIT DEMAND PER YEAR
NPV UNIT DEMAND
SATELLITE R AND D REVENUE
    NPV MISSION EQUIPMENT R AND D
    MISSION EQUIPMENT UNIT CHARG
    MISSION EQUIPMENT REVENUE
NPV SPACECRAFT R AND D
    SPACECRAFT UNIT CHARGE
    SPACECRAFT REVENUE
SATELLITE INVESTMENT REVENUE
    NPV MISSION EQUIPMENT INVESTMENT
    MISSION EQUIPMENT UNIT CHARGE
    MISSION EQUIPMENT REVENUE
    NPV SPACECRAFT INVESTMENT
    SPACECRAFT UNIT CHARGE
    SPACECRAFT REVENUE
SATELLITE OPERATING REVENUE
    NPV OPERATIONS
    OPERATIONS UNIT CHARGE
    OPERATIONS REVENUE
L/V DOC REVENUE
    NPV L/V DOC
    L/V DOC UNIT CHARGE
    L/V DOC REVENUE
GROUND SYSTEM INVESTMENT REVENUE
    NPV ELECTRONICS
    ELECTRONICS UNIT CHARGE
    ELECTRONICS REVENUE
    NPV SUPPORT FACILITIES
    SUPPORT FACILITIES UNIT CHARGE
    SUPPORT FACILITIES REVENUE
GROUND SYSTEMS OPERATIONS REVENUE
    NPV OPERATIONS
    OPERATIONS UNIT CHARGE
    OPERATIONS REVENUE
TOTAL SYSTEM CHARGE RATE
TOTAL SYSTEM REVENUE
TOTAL NPV OF SYSTEM COSTS
```

Figure 13-2. Output, Cost/Revenue Analysis for Current Dollars (CORANR)

```
      ∇CONSTANTD[⎕]∇
    ∇ CONSTANTD
[1]     ARR[1;]←ARR[2;]+ARR[3;]
[2]     ARR[4;]←ARR[5;]+ARR[6;]
[3]     ARR[9;]←ARR[10;]+ARR[11;]
[4]     ARR[13;]←ARR[1;]+ARR[4;]+ARR[7;]+ARR[8;]+ARR[9;]+ARR[
        12;]
[5]     →(FF=0)/T1
[6]     →(FF=1)/T2
[7]   T2:F=F
[8]     →T3
[9]   T1:DISFAC
[10]  T3:ARR[15;]←(1+F)*(-ARR[14;])
[11]    ARR[17;]←ARR[15;]×ARR[16;]
[12]    ARR[19;]←ARR[2;]×ARR[15;]
[13]    ZARR[17]←+/ARR[17;]
[14]    ZARR[20]←(+/ARR[19;])÷ZARR[17]
[15]    ARR[21;]←ARR[16;]×ZARR[20]
[16]    ARR[22;]←ARR[3;]×ARR[15;]
[17]    ZARR[23]←(+/ARR[22;])÷ZARR[17]
[18]    ARR[24;]←ARR[16;]×ZARR[23]
[19]    ARR[18;]←ARR[21;]+ARR[24;]
[20]    ARR[26;]←ARR[5;]×ARR[15;]
[21]    ZARR[27]←(+/ARR[26;])÷ZARR[17]
[22]    ARR[28;]←ARR[16;]×ZARR[27]
[23]    ARR[29;]←ARR[6;]×ARR[15;]
[24]    ZARR[30]←(+/ARR[29;])÷ZARR[17]
[25]    ARR[31;]←ARR[16;]×ZARR[30]
[26]    ARR[25;]←ARR[28;]+ARR[31;]
[27]    ARR[33;]←ARR[7;]×ARR[15;]
[28]    ZARR[34]←(+/ARR[33;])÷ZARR[17]
[29]    ARR[35;]←ARR[16;]×ZARR[34]
[30]    ARR[32;]←ARR[35;]
[31]    ARR[37;]←ARR[8;]×ARR[15;]
[32]    ZARR[38]←(+/ARR[37;])÷ZARR[17]
[33]    ARR[39;]←ARR[16;]×ZARR[38]
[34]    ARR[36;]←ARR[39;]
[35]    ARR[41;]←ARR[10;]×ARR[15;]
[36]    ZARR[42]←(+/ARR[41;])÷ZARR[17]
[37]    ARR[43;]←ARR[16;]×ZARR[42]
[38]    ARR[44;]←ARR[11;]×ARR[15;]
[39]    ZARR[45]←(+/ARR[44;])÷ZARR[17]
[40]    ARR[46;]←ARR[16;]×ZARR[45]
[41]    ARR[40;]←ARR[43;]+ARR[46;]
[42]    ARR[48;]←ARR[12;]×ARR[15;]
[43]    ZARR[49]←(+/ARR[48;])÷ZARR[17]
[44]    ARR[50;]←ARR[16;]×ZARR[49]
[45]    ARR[47;]←ARR[50;]
[46]    ZARR[51]←ZARR[20]+ZARR[23]+ZARR[27]+ZARR[30]+ZARR[
        34]+ZARR[38]+ZARR[42]+ZARR[45]+ZARR[49]
[47]    ARR[52;]←ARR[18;]+ARR[25;]+ARR[32;]+ARR[36;]+ARR[
        40;]+ARR[47;]
[48]    ARR[53;]←ARR[19;]+ARR[22;]+ARR[26;]+ARR[29;]+ARR[
        33;]+ARR[37;]+ARR[41;]+ARR[44;]+ARR[48;]
[49]    NPV←+/ARR[53;]
[50]    PEAK←⌈/ARR[13;]
[51]    REVENUE←+/ARR[52;]
    ∇
```

Figure 13-3. The APL Function CONSTANTD

```
      ∇DISFAC[⎕]∇
    ∇ DISFAC
[1]   RISK← 4 2 ρ0
[2]   RISK[;1]← 25 27 38 66
[3]   RISK[;2]← 30 36 40 72
[4]   RECES← 4 1 ρ0
[5]   RECES[;1]← 0 25 25 25
[6]   GRWTH← 4 4 ρ0
[7]   GRWTH[;1]← 25 25 25 25
[8]   GRWTH[;2]← 40 35 30 25
[9]   GRWTH[;3]← 80 65 50 35
[10]  GRWTH[;4]← 125 100 75 50
[11]  SMF←SMF
[12]  SMN←SMN
[13]  RSMN←SMN+1
[14]  XRSMN←SMN+1
[15]  FPROJ←FPROJ
[16]  →(FPROJ=0)/T1
[17]  →(FPROJ=1)/T34
[18] T34:SHARE←SHARE
[19]  →(SHARE>0.15)/T35
[20]  SMB←1
[21]  →T36
[22] T35:SMB←1÷(1-SHARE)
[23] T36:RECON←RECON
[24]  →(RECON=0)/T2
[25]  →(RSMN≤1)/T3
[26]  →((RSMN≤5)∧(RSMN>1))/T5
[27]  →((RSMN≤15)∧(RSMN>5))/T6
[28]  UF←RECES[4;1]×0.001
[29]  →T4
[30] T3:UF←RECES[1;1]×0.001
[31]  →T4
[32] T5:UF←RECES[2;1]×0.001
[33]  →T4
[34] T6:UF←RECES[3;1]×0.001
[35] T4:F←SMB×UF
[36] T34:SMR←((1+F)×(1+SMF))-1
[37]  →0
[38] T2:→((RSMN≤1)∧(SMF≤0.02))/T7
[39]  →((RSMN≤5)∧(RSMN>1)∧(SMF≤0.02))/T8
[40]  →((RSMN≤15)∧(RSMN>5)∧(SMF≤0.02))/T9
[41]  →((RSMN>15)∧(SMF≤0.02))/T10
[42]  →((RSMN≤1)∧(SMF>0.02)∧(SMF≤0.05))/T11
[43]  →((RSMN≤5)∧(RSMN>1)∧(SMF>0.02)∧(SMF≤
      0.05))/T12
[44]  →((RSMN≤15)∧(RSMN>5)∧(SMF>0.02)∧(SMF≤
      0.05))/T13
[45]  →((RSMN>15)∧(SMF>0.02)∧(SMF≤0.05))/T14
```

Figure 13-4. The APL Function DISFAC for Constant Dollars

```
[46]  ←[[RSMN41]0[SMF70.05]0[SMF40.08]]/T15
[47]  ←[[RSMN45]0[RSMN71]0[SMF70.05]0[SMF4
       0.08]]/T16
[48]  ←[[RSMN415]0[RSMN75]0[SMF70.05]0[SMF4
       0.08]]/T17
[49]  →((RSMN>15)∧(SMF>0.05)∧(SMF≤0.08))/T18
[50]  →((RSMN≤1)∧(SMF>0.08))/T19
[51]  →((RSMN≤5)∧(RSMN>1)∧(SMF>0.08))/T20
[52]  →((RSMN≤15)∧(RSMN>5)∧(SMF>0.08))/T21
[53]  →((RSMN>15)∧(SMF>0.08))/T22
[54] T7:UF←GRWTH[1;1]×0.001
[55]  →T4
[56] T8:UF←GRWTH[2;1]×0.001
[57]  →T4
[58] T9:UF←GRWTH[3;1]×0.001
[59]  →T4
[60] T10:UF←GRWTH[4;1]×0.001
[61]  →T4
[62] T11:UF←GRWTH[1;2]×0.001
[63]  →T4
[64] T12:UF←GRWTH[2;2]×0.001
[65]  →T4
[66] T13:UF←GRWTH[3;2]×0.001
[67]  →T4
[68] T14:UF←GRWTH[4;2]×0.001
[69]  →T4
[70] T15:UF←GRWTH[1;3]×0.001
[71]  →T4
[72] T16:UF←GRWTH[2;3]×0.001
[73]  →T4
[74] T17:UF←GRWTH[3;3]×0.001
[75]  →T4
[76] T18:UF←GRWTH[4;3]×0.001
[77]  →T4
[78] T19:UF←GRWTH[1;4]×0.001
[79]  →T4
[80] T20:UF←GRWTH[2;4]×0.001
[81]  →T4
[82] T21:UF←GRWTH[3;4]×0.001
[83]  →T4
[84] T22:UF←GRWTH[4;4]×0.001
[85]  →T4
[86] T1:→(TTYPE=0)/T23
[87]  →(FRISK=3)/T24
[88]  →(FRISK=2)/T25
[89]  →(FRISK=1)/T26
[90]  →(FRISK=0)/T27
```

Figure 13-4. The APL Function DISFAC for Constant Dollars (Cont'd)

```
[91] T23:→(FRISK=3)/T28
[92]  →(FRISK=2)/T29
[93]  →(FRISK=1)/T30
[94]  →(FRISK=0)/T31
[95] T24:UF←RISK[4;1]×0.001
[96]  →T32
[97] T25:UF←RISK[3;1]×0.001
[98]  →T32
[99] T26:UF←RISK[2;1]×0.001
[100] →T32
[101]T27:UF←RISK[1;1]×0.001
[102] →T32
[103]T28:UF←RISK[4;2]×0.001
[104] →T32
[105]T29:UF←RISK[3;2]×0.001
[106] →T32
[107]T30:UF←RISK[2;2]×0.001
[108] →T32
[109]T31:UF←RISK[1;2]×0.001
[110]T32:→(SMB≠0)/T4
[111] IN←0
[112]T33:IN←IN+1
[113] F←ASSF
[114] CONSTANTD
[115] VG←ARR[13;]-ARR[52;]
[116] G←⌈/VG
[117] SMB←1÷(1-(G÷CAF))
[118] F←SMB×UF
[119] →(((|F)-(|ASSF))<0.0001)/T34
[120] ASSF←F
[121] →T33
```

Figure 13-4. The APL Function DISFAC for Constant Dollars (Cont'd)

```
      ∇DATAIN[⎕]∇
    ∇ DATAIN
[1]   SMN←SMN
[2]   RSMN←SMN+1
[3]   XRSMN←SMN+1
[4]   ARR←(53,XRSMN)⍴0
[5]   N←0,⍳SMN
[6]   ZARR←53⍴0
[7]   ARR[14;]←N
[8]   MERD←MERD
[9]   MERD←MERD
[10]  SCRD←SCRD
[11]  SCRD←SCRD
[12]  MEIV←MEIV
[13]  MEIV←MEIV
[14]  SCIV←SCIV
[15]  SCIV←SCIV
[16]  STOP←STOP
[17]  STOP←STOP
[18]  L∆VOP←L∆VOP
[19]  L∆VOP←L∆VOP
[20]  GSIVEL←GSIVEL
[21]  GSIVEL←GSIVEL
[22]  GSIVSF←GSIVSF
[23]  GSIVSF←GSIVSF
[24]  GSOP←GSOP
[25]  GSOP←GSOP
[26]  DN←DN
[27]  DN←DN
[28]  ARR[2;]←MERD
[29]  ARR[3;]←SCRD
[30]  ARR[5;]←MEIV
[31]  ARR[6;]←SCIV
[32]  ARR[7;]←STOP
[33]  ARR[8;]←L∆VOP
[34]  ARR[10;]←GSIVEL
[35]  ARR[11;]←GSIVSF
[36]  ARR[12;]←GSOP
[37]  ARR[16;]←DN
    ∇
```

Figure 13-5. The APL Function DATAIN for Constant Dollars

```
      ∇DFT[⎕]∇
    ∇ Z←W DFT X;D;E;F;G;H;I;J;K;L;Y
[1]   D←' 0123456789.¯'
[2]   →(∨/W≠⌊W←,W+(H←0)×L←1<ρρX)/DFTERR+0×F←2
[3]   →(3 2 1 <ρρX)/(DFTERR+F←0), 2 3 +⌶26
[4]   →(2+⌶26),ρX←((∨/ 1 2 =ρW)⌽ 1 2)⍉(1,ρ,X)ρX
[5]   X←(0 1 1 /ρX)ρX
[6]   →((∧/(ρW)≠ 1 2 ,2×E←1ρ⌽ρX),1≠ρW)/(DFTERR×F←1),3+⌶
      26
[7]   I←1+⌈/0,,⌊10⍟|X+1>|X
[8]   W←(2+I+W+(W≠0)+∨/,X<0),W
[9]   →(∨/2>-/[1] W←⍉(E,2)ρW)/DFTERR+0×F←2
[10]  Z←((K←1ρρX),+/W[1;])ρ' '
[11]  X←⌊0.5+X×10*(ρX)ρW[2;]
[12] DFTLP:→(E<H←H+1)/DFTEND
[13]  J←1+⌊10|(|Y←X[;H])∘.÷10*¯1+⌽⍳I←W[1;H]
[14]  J←(,J)×G←,⍉(⌽ρJ)ρ(,⍉(J≠1)∨.∧(⍳I)∘.≤⍳I-F+1),(K×1+F←W[
      2;H])ρ1
[15]  →(∧/0≤Y)/2+⌶26
[16]  J[1+(ρJ)|¯1+(I-+/(K,I)ρG)+I×¯1+⍳K]←12×Y<0
[17]  J←(K,I)ρJ
[18]  →(0=F)/3+⌶26
[19]  J←J[;(1⌽⍳G),(G←-/W[;H])+⍳F]
[20]  J[;G]←11
[21]  →DFTLP,ρZ[;(+/W[1;⍳H-1])+⍳I]←D[1+J]
[22] DFTEND:→L/0
[23]  →0×ρZ←,Z
[24] DFTERR:'DFT ',(3 6 ρ' RANK LENGTHDOMAIN')[F+1;],' PROBLEM.'
    ∇
```

Figure 13-6. The APL Function DFT

```
      ∇EFT[⎕]
    ∇ Z←W EFT X;D;E;H;J;K;L;Q;S;T;U;Y
[1]   D←'0123456789.E¯ '
[2]   →(∨/W≠⌊W←,W+(H←0)×L←1<ρρX)/EFTERR+0×K←2
[3]   →(3 2 1 <ρρX)/(EFTERR+K←0),2 3 +⍳26
[4]   X←((∨/ 1 2 =ρW)⌽ 1 2)⍉(1,ρ,X)ρX
[5]   X←(⌽2ρ⌽ρX)ρX
[6]   →((∧/(ρW)≠ 1 2 ,2×E←1ρ⌽ρX),1≠ρW)/(EFTERR×K←1),2+⍳
      26
[7]   W←(W+6+(∨/,X<0)+∨/,1>|X),W
[8]   →(∨/6>-/[1] W←⍉(E,2)ρW)/EFTERR+0×K←2
[9]   Z←((K←1ρρX),+/W[1;])ρ' '
[10] EFTLP:→(E<H←H+1)/EFTEND
[11]  S←1+⌊10⍟|Y+0=Y←X[;H]
[12]  U←1+⌊10⍟|Y+0=Y←⌊0.5+(10*Q-15)+Y×10*(Q←W[2;H])-S
[13]  J←(((T-4)ρ1),4ρ0)\1+⌊10|(|Y÷10*U>Q)∘.÷10*¯1+⌽⍳¯4+T←W[1;H]
[14]  J[;T- 2 1]←1+⌊10|(|S-U≤Q)∘.÷ 10 1
[15]  J[;(⍳U←T-4+Q),T]←13
[16]  J[;1,U,T,T-3]←⍉(4,K)ρ(Kρ11),(13+0>Y,S-1),Kρ12
[17]  J[;⍳T-3]←J[;(1⌽⍳U+1),(U+1+⍳Q)]
[18]  J[;T- 2 1 0]←(-S≤0)⌽J[;T- 2 1 0]
[19]  →EFTLP,ρZ[;(+/W[1;⍳H-1])+⍳T]←D[J]
[20] EFTEND:→L/0
[21]  →0×ρZ←,Z
[22] EFTERR:'EFT ',(3 6 ρ'RANK LENGTHDOMAIN')[K+1;],' PROBLEM.'
    ∇
```

Figure 13-7. The APL Function EFT

```
        ∇LOAD[⎕]∇
      ∇ Z←LOAD A;B
[1]     Z←(0,A)⍴' '
[2]   T1:B←,⍞
[3]     →('//'∧.=2↑B)/0
[4]     Z←Z,[1](1,A)⍴A↑B
[5]     →T1
      ∇
```

Figure 13-8. The APL Function LOAD

```
      ∇EXECUTE[⎕]∇
    ∇ EXECUTE
[1]   DATAIN
[2]   CONSTANTD
[3]   SHOW
    ∇
```

Figure 13-9. The APL Function EXECUTE for Constant Dollars

```
      ∇SHOW[⎕]∇
    ∇ SHOW
[1]    'FF=';FF
[2]    'FPROJ=';FPROJ
[3]    'FECON=';FECON
[4]    ' '
[5]    'SMN=';SMN
[6]    'SMF=';SMF
[7]    ' '
[8]    'SHARE=';SHARE
[9]    'SMB=';SMB
[10]   'UF=';UF
[11]   ' '
[12]   'F=';F
[13]   'SMR=';SMR
[14]   ' '
[15]   'NPV=';NPV
[16]   'PEAK=';PEAK
[17]   'REVENUE=';REVENUE
    ∇
```

Figure 13-10. The APL Function SHOW for Constant Dollars

```
      ∇CURRENTD[⎕]∇
    ∇ CURRENTD
[1]    ARR[1;]←ARR[2;]+ARR[3;]
[2]    ARR[4;]←ARR[5;]+ARR[6;]
[3]    ARR[9;]←ARR[10;]+ARR[11;]
[4]    ARR[13;]←ARR[1;]+ARR[4;]+ARR[7;]+ARR[8;]+ARR[9;]+ARR[12;]
[5]    ARR[15;]←(1+SMF)*(ARR[14;])
[6]    ARR[16;]←ARR[13;]×ARR[15;]
[7]    →(FF=0)/T1
[8]    →(FF=1)/T2
[9]   T2:F=F
[10]   →T3
[11]  T1:DISFAC
[12]  T3:ARR[17;]←(1+F)*(-ARR[14;])
[13]   ARR[18;]←(1+SMR)*(-ARR[14;])
[14]   ARR[20;]←ARR[18;]×ARR[19;]
[15]   ARR[21;]←ARR[24;]+ARR[27;]
[16]   ZARR20←+/ARR[20;]
[17]   ARR[22;]←ARR[2;]×ARR[17;]
[18]   ARR[23;RSMN]←(+/ARR[22;])÷ZARR20
[19]   ARR[24;]←ARR[19;]×ARR[23;]
[20]   ARR[25;]←ARR[3;]×ARR[17;]
[21]   ARR[26;RSMN]←(+/ARR[25;])÷ZARR20
[22]   ARR[27;]←ARR[19;]×ARR[26;]
[23]   ARR[28;]←ARR[31;]+ARR[34;]
[24]   ARR[29;]←ARR[5;]×ARR[17;]
[25]   ARR[30;RSMN]←(+/ARR[29;])÷ZARR20
[26]   ARR[31;]←ARR[19;]×ARR[30;]
[27]   ARR[32;]←ARR[6;]×ARR[17;]
[28]   ARR[33;RSMN]←(+/ARR[32;])÷ZARR20
[29]   ARR[34;]←ARR[19;]×ARR[33;]
[30]   ARR[36;]←ARR[7;]×ARR[17;]
[31]   ARR[37;RSMN]←(+/ARR[36;])÷ZARR20
[32]   ARR[38;]←ARR[19;]×ARR[37;]
[33]   ARR[35;]←ARR[38;]
[34]   ARR[40;]←ARR[8;]×ARR[17;]
[35]   ARR[41;RSMN]←(+/ARR[40;])÷ZARR20
[36]   ARR[42;]←ARR[19;]×ARR[41;]
[37]   ARR[39;]←ARR[42;]
[38]   ARR[43;]←ARR[46;]+ARR[49;]
[39]   ARR[44;]←ARR[10;]×ARR[17;]
[40]   ARR[45;RSMN]←(+/ARR[44;])÷ZARR20
[41]   ARR[46;]←ARR[19;]×ARR[45;]
[42]   ARR[47;]←ARR[11;]×ARR[17;]
[43]   ARR[48;RSMN]←(+/ARR[47;])÷ZARR20
[44]   ARR[49;]←ARR[19;]×ARR[48;]
[45]   ARR[51;]←ARR[12;]×ARR[17;]
[46]   ARR[52;]←(+/ARR[51;])÷ZARR20
[47]   ARR[53;]←ARR[19;]×ARR[52;]
[48]   ARR[50;]←ARR[53;]
[49]   ARR[54;]←ARR[23;]+ARR[26;]+ARR[30;]+ARR[33;]+ARR[37;]+ARR[
       41;]+ARR[45;]+ARR[48;]+ARR[52;]
[50]   ARR[55;]←ARR[21;]+ARR[28;]+ARR[35;]+ARR[39;]+ARR[43;]+ARR[
       50;]
[51]   ARR[56;]←ARR[22;]+ARR[25;]+ARR[29;]+ARR[32;]+ARR[36;]+ARR[
       40;]+ARR[44;]+ARR[47;]+ARR[51;]
[52]   NPV←+/ARR[22;]++/ARR[25;]++/ARR[29;]++/ARR[32;]++/ARR[
       36;]++/ARR[40;]++/ARR[44;]++/ARR[47;]++/ARR[51;]
[53]   PEAK←⌈/ARR[13;]
[54]   REVENUE←+/ARR[55;]
    ∇
```

Figure 13-11. The APL Function CURRENTD

```
      ∇DISFAC[⎕]
    ∇ DISFAC
[1]   RISK← 4 2 ρ0
[2]   RISK[;1]← 25 27 38 66
[3]   RISK[;2]← 30 36 40 72
[4]   RECES← 4 1 ρ0
[5]   RECES[;1]← 0 25 25 25
[6]   GRWTH← 4 4 ρ0
[7]   GRWTH[;1]← 25 25 25 25
[8]   GRWTH[;2]← 40 35 30 25
[9]   GRWTH[;3]← 80 65 50 35
[10]  GRWTH[;4]← 125 100 75 50
[11]  SMF←SMF
[12]  SMN←SMN
[13]  RSMN←SMN+1
[14]  XRSMN←SMF+1
[15]  FPROJ←FPROJ
[16]  →(FPROJ=0)/T1
[17]  →(FPROJ=1)/T34
[18] T34:SHARE←SHARE
[19]  →(SHARE>0.15)/T35
[20]  SMB←1
[21]  →T36
[22] T35:SMB←1÷(1-SHARE)
[23] T36:FECON←FECON
[24]  →(FECON=0)/T2
[25]  →(RSMN≤1)/T3
[26]  →((RSMN≤5)∧(RSMN>1))/T5
[27]  →((RSMN≤15)∧(RSMN>5))/T6
[28]  UF←RECES[4;1]×0.001
[29]  →T4
[30] T3:UF←RECES[1;1]×0.001
[31]  →T4
[32] T5:UF←RECES[2;1]×0.001
[33]  →T4
[34] T6:UF←RECES[3;1]×0.001
[35] T4:F←SMB×UF
[36] T34:SMR←((1+F)×(1+SMF))-1
[37]  →0
[38] T2:→((RSMN≤1)∧(SMF≤0.02))/T7
[39]  →((RSMN≤5)∧(RSMN>1)∧(SMF≤0.02))/T8
[40]  →((RSMN≤15)∧(RSMN>5)∧(SMF≤0.02))/T9
[41]  →((RSMN>15)∧(SMF≤0.02))/T10
[42]  →((RSMN≤1)∧(SMF>0.02)∧(SMF≤0.05))/T11
[43]  →((RSMN≤5)∧(RSMN>1)∧(SMF>0.02)∧(SMF≤0.05))/T12
[44]  →((RSMN≤15)∧(RSMN>5)∧(SMF>0.02)∧(SMF≤0.05))/T13
[45]  →((RSMN>15)∧(SMF>0.02)∧(SMF≤0.05))/T14
```

Figure 13-12. The APL Function DISFAC for Current Dollars

```
      [⎕46]
[46]  →((RSMN≤1)∧(SMF>0.05)∧(SMF≤0.08))/T15
[47]  →((RSMN≤5)∧(RSMN>1)∧(SMF>0.05)∧(SMF≤0.08))/T16
[48]  →((RSMN≤15)∧(RSMN>5)∧(SMF>0.05)∧(SMF≤0.08))/T17
[49]  →((RSMN>15)∧(SMF>0.05)∧(SMF≤0.08))/T18
[50]  →((RSMN≤1)∧(SMF>0.08))/T19
[51]  →((RSMN≤5)∧(RSMN>1)∧(SMF>0.08))/T20
[52]  →((RSMN≤15)∧(RSMN>5)∧(SMF>0.08))/T21
[53]  →((RSMN>15)∧(SMF>0.08))/T22
[54] T7:UF←GRWTH[1;1]×0.001
[55]  →T4
[56] T8:UF←GRWTH[2;1]×0.001
[57]  →T4
[58] T9:UF←GRWTH[3;1]×0.001
[59]  →T4
[60] T10:UF←GRWTH[4;1]×0.001
[61]  →T4
[62] T11:UF←GRWTH[1;2]×0.001
[63]  →T4
[64] T12:UF←GRWTH[2;2]×0.001
[65]  →T4
[66] T13:UF←GRWTH[3;2]×0.001
[67]  →T4
[68] T14:UF←GRWTH[4;2]×0.001
[69]  →T4
[70] T15:UF←GRWTH[1;3]×0.001
[71]  →T4
[72] T16:UF←GRWTH[2;3]×0.001
[73]  →T4
[74] T17:UF←GRWTH[3;3]×0.001
[75]  →T4
[76] T18:UF←GRWTH[4;3]×0.001
[77]  →T4
[78] T19:UF←GRWTH[1;4]×0.001
[79]  →T4
[80] T20:UF←GRWTH[2;4]×0.001
[81]  →T4
[82] T21:UF←GRWTH[3;4]×0.001
[83]  →T4
[84] T22:UF←GRWTH[4;4]×0.001
[85]  →T4
[86] T1:→(FTYPE=0)/T23
[87]  →(FRISK=3)/T24
[88]  →(FRISK=2)/T25
[89]  →(FRISK=1)/T26
[90]  →(FRISK=0)/T27
[91] T23:→(FRISK=3)/T28
```

Figure 13-12. The APL Function DISFAC for Current Dollars (Cont'd)

```
      [⎕92]
[92]   →(FRISK=2)/T29
[93]   →(FRISK=1)/T30
[94]   →(FRISK=0)/T31
[95]  T24:UF←RISK[4;1]×0.001
[96]   →T32
[97]  T25:UF←RISK[3;1]×0.001
[98]   →T32
[99]  T26:UF←RISK[2;1]×0.001
[100]  →T32
[101]T27:UF←RISK[1;1]×0.001
[102]  →T32
[103]T28:UF←RISK[4;2]×0.001
[104]  →T32
[105]T29:UF←RISK[3;2]×0.001
[106]  →T32
[107]T30:UF←RISK[2;2]×0.001
[108]  →T32
[109]T31:UF←RISK[1;2]×0.001
[110]T32:→(SMB≠0)/T4
[111]  IN←0
[112]T33:IN←IN+1
[113]  F←ASSF
[114]  CURRENTD
[115]  VG←ARR[13;]-ARR[52;]
[116]  G←⌈/VG
[117]  SMB←1÷(1-(G÷CAF))
[118]  F←SMB×UF
[119]  →(((|F)-(|ASSF))<0.0001)/T34
[120]  ASSF←F
[121]  →T33
      ∇
```

Figure 13-12. The APL Function DISFAC for Current Dollars (Cont'd)

```
    ∇DATAIN[⎕]∇
  ∇ DATAIN
    SMN←SMN
    RSMN←SMN+1
    XRSMN←SMN+1
    ARR←(56,XRSMN)ρ0
    N←0+ιSMN
    ZARR←56ρ0
    ARR[14;]←N
    MERD←MERD
    MERD←MERD
    SCRD←SCRD
    SCRD←SCRD
    MEIV←MEIV
    MEIV←MEIV
    SCIV←SCIV
    SCIV←SCIV
    STOP←STOP
    STOP←STOP
    LΔVOP←LΔVOP
    LΔVOP←LΔVOP
    GSIVEL←GSIVEL
    GSIVEL←GSIVEL
    GSIVSF←GSIVSF
    GSIVSF←GSIVSF
    GSOP←GSOP
    GSOP←GSOP
    DN←DN
    DN←DN
    ARR[2;]←MERD
    ARR[3;]←SCRD
    ARR[5;]←MEIV
    ARR[6;]←SCIV
    ARR[7;]←STOP
    ARR[8;]←LΔVOP
    ARR[10;]←GSIVEL
    ARR[11;]←GSIVSF
    ARR[12;]←GSOP
    ARR[19;]←DN
  ∇
```

Figure 13-13. The APL Function DATAIN for Current Dollars

```
      ∇EXECUTE[⎕]∇
    ∇ EXECUTE
[1]   DATAIN
[2]   CURRENTD
[3]   SHOW
    ∇
```

Figure 13-14. The APL Function EXECUTE for Current Dollars

```
      ∇SHOW[⎕]∇
    ∇ SHOW
[1]   'FF=';FF
[2]   'FPROJ=';FPROJ
[3]   'FECON=';FECON
[4]   ' '
[5]   'SMN=';SMN
[6]   'SMF=';SMF
[7]   ' '
[8]   'SHARE=';SHARE
[9]   'SMB=';SMB
[10]  'UF=';UF
[11]  ' '
[12]  'F=';F
[13]  'SMR=';SMR
[14]  ' '
[15]  'NPV=';NPV
[16]  'PEAK=';PEAK
[17]  'REVENUE=';REVENUE
    ∇
```

Figure 13-15. The APL Function SHOW for Current Dollars

```
        ∇PRT[⎕]∇
      ∇ PRT
[1]     ZARR[1]←+/ARR[1;]
[2]     ZARR[2]←+/ARR[2;]
[3]     ZARR[3]←+/ARR[3;]
[4]     ZARR[4]←+/ARR[4;]
[5]     ZARR[5]←+/ARR[5;]
[6]     ZARR[6]←+/ARR[6;]
[7]     ZARR[7]←+/ARR[7;]
[8]     ZARR[8]←+/ARR[8;]
[9]     ZARR[9]←+/ARR[9;]
[10]    ZARR[10]←+/ARR[10;]
[11]    ZARR[11]←+/ARR[11;]
[12]    ZARR[12]←+/ARR[12;]
[13]    ZARR[13]←+/ARR[13;]
[14]    ZARR[52]←+/ARR[52;]
[15]    ZARR[53]←+/ARR[53;]
      ∇
```

Figure 13-16. The APL Function PRT

14. REFERENCES

1-1. Space Shuttle/Payload Interface Analysis (Study 2.4) Final Report, Volume IV, BRAVO, Part 4, Computer Programs and Data Look-Up, The Aerospace Corporation, ATR-74(7334)-1, Vol. IV, Part 4 (15 February 1974).

6-1. Network Integration Study, STDN No. 809, Networks Directorate, Goddard Space Flight Center, Greenbelt, Maryland (June 1972).

8-1. Defense Communication Agency Cost Manual, DCA Circular 600-60-1 (17 November 1970).

9-1. Thomas Cosgrove and Rodney D. Chipp, "Economic Considerations for Communications Systems," IEEE Transactions on Communications Technology, Vol. COM-16, No. 4 (August 1968).

10-1. "Toward Postal Excellence," Report of the President's Commission on Postal Organization (June 1968).

10-2. Postal Rate Data, U. S. Postal Service, Washington, D. C., via Post Office, El Segundo, California (28 February 1973).

11-1. R. T. Nichols, Submarine Telephone Cables and International Telecommunications, RM 3472-RC, The Rand Corporation (February 1963).

11-2. Statistics of Communications Common Carriers, 1969, Federal Communnications Commission, U. S. Government Printing Office (1971).

12-1. The 1970 National Power Survey, Federal Power Commission, Volumes I through IV, U. S. Government Printing Office, Washington, D. C. (December 1971).

12-2. United States Energy Through the Year 2000, Walter G. Dupree, Jr. and James A. West, U. S. Department of the Interior, U. S. Government Printing Office (December 1972).

12-3. Harold E. Vann, Cost Trends for Nuclear Power Plants, Nuclear News, Vol. 14, No. 10X (October 15, 1974).

12-4. I. S. Zheluder, Energy Sources and Requirements, Nuclear News, Vol. 14, No. 10X (October 15, 1974).

12-5. Ray Schuster, PMC Digs into Build the Breeder, Power Engineering, (January 1973).

12-6. Energy "Demand" Studies, An Analysis and Appraisal, Committee on Interior and Insular Affairs of the U. S. House of Representatives, 92nd Congress, 2nd Session, U. S. Government Printing Office, Washington, D. C. (1972).

12-7. W. E. Mooz and C. C. Mow, California's Electricity Quandary: 1. Estimating Future Demand, R-1084-NSF/CSRA, The Rand Corporation (September 1972).

12-8. Task 4 Report, Economic Analysis - Competitive Power System, Report No. ATR-73(7283-04)-1, The Aerospace Corporation, El Segundo, California (December 31, 1972).

12-9. F. C. Olds, Capital Cost Calculation for Future Power Plants, Power Engineering (January 1973).