1 INTRODUCTION

NORAD maintains general perturbation element sets on all resident space objects. These element sets are periodically refined so as to maintain a reasonable prediction capability on all space objects. In turn, these element sets are provided to users. The purpose of this report is to provide the user with a means of propagating these element sets in time to obtain a position and velocity of the space object.

The m imortant point to be noted is that not just any prediction model will su ! ce. The

The main program DRIVER reads the input NORAD 2-line element set in either G-card

```
*       SGP                                                     31 OCT 80
        SUBROUTINE SGP(IFLAG,TSINCE)
        COMMON/E1/XMO,XNODEO,OMEGAO,EO,XINCL,XNO,XNDT2O,XNDD6O,BSTAR,
       1          X,Y,Z,XDOT,YDOT,ZDOT,EPOCH,DS50
        COMMON/C1/CK2,CK4,E6A,QOMS2T,S,TOTHRD,
       1         XJ3,XKE,XKMPER,XMNPDA,AE
```

```
      AXNSL=E*COS(OMGAS)
      AYNSL=E*SIN(OMGAS)-C6/P
      XL=FMOD2P(XLS-C5/P*AXNSL)

*      SOLVE KEPLERS EQUATION

      U=FMOD2P(XL-XNODES)
      ITEM3=0
      EO1=U
      TEM5=1.
   20 SINEO1=SIN(EO1)
      COSEO1=COS(EO1)
      IF5714-=1.
      IF5714-=1.
```

$$\% = \frac{1}{a_o \; ! \; s}$$

```
      TEMP2=CAPU
      DO 130 I=1,10
      SINEPW=SIN(TEMP2)
      COSEPW=COS(TEMP2)
      TEMP3=AXN*SINEPW
      TEMP4=AYN*COSEPW
      TEMP5=AXN*COSEPW
      TEMP6=AYN*SINEPW
      EPW=(CAPU-TEMP4+TEMP3-TEMP2)/(1.-TEMP5-TEMP6)+TEMP2
      IF(ABS(EPW-TEMP2) .LE. E6A) GO TO 140
  130 TEMP2=EPW

*      SHORT PERIOD PRELIMINARY QUANTITIES

  140 ECOSE=TEMP5+TEMP6
      ESINE=TEMP3-TEMP4
      ELSQ=AXN*AXN+AYN*AYN
      TEMP=1.-ELSQ
      PL=A*TEMP
      R=A*(1.-ECOSE)
      TEMP1=1./R
      RDOT=XKE*SQRT(A)*ESINE*TEMP1
      RFDOT=XKE*SQRT(PL)*TEMP1
      TEMP2=A*TEMP1
      BETAL=SQRT(TEMP)
      TEMP3=1./(1.+BETAL)
      COSU=TEMP2*(-3142.8(0)11(SE)(QRT2.8(0)4=EU.EDO)SS)11((-L.+BE)11(1T7U)11(=TE)1TEMP=1.-ELS
      BETAL=P
```

10 (o !6

```
*       SDP4                                                    3 NOV 80
        SUBROUTINE SDP4(IFLAG,TSINCE)
        COMMON/E1/XMO,XNODEO,OMEGAO,EO,XINCL,XNO,XNDT2O,
       1           XNDD6O,BSTAR,X,Y,Z,XDOT,YDOT,ZDOT,EPOCH,DS50
        COMMON/C1/CK2,CK4,E6A,QOMS2T,S,TOTHRD,
       1           XJ3,XKE,XKMPER,XMNPDA,AE
        DOUBLE PRECISION EPOCH, DS50

        IF  (IFLAG .EQ. 0) GO TO 100

*       RECOVER ORIGINAL MEAN MOTION (XNODP) AND SEMIMAJOR AXIS (AODP)
*       FROM INPUT ELEMENTS

        A1=(XKE/XNO)**TOTHRD
        COSIO=COS(XINCL)
        THETA2=COSIO*COSIO
        X3THM1=3.*THETA2-1.
        EOSQ=EO*EO
        BETAO2=1.-EOSQ
        BETAO=SQRT(BETAO2)
        DEL1=1.5*CK2*X3THM1/(A1*A1*BETAO*BETAO2)
        AO=A1*(1.-DEL1*(.5*TOTHRD+DEL1*(1.+134./81.*DEL1)))
        DELO=1.5*CK2*X3THM1/(AO*AO*BETAO*BETAO2)
        XNODP=XNO/(1.+DELO)
        AODP=AO/(1.-DELO)
```

```
XMAM=XMDF+XNODP*TEMPL
CALL DPPER(E,XINC,OMGADF,XNODE,XMAM)
XL=XMAM+OMGADF+XNODE
BETA=SQRT(1.-E*E)
XN=XKE/A**=S5
```

```
      COS2U=2.*COSU*COSU-1.
      TEMP=1./PL
      TEMP1=CK2*TEMP
      TEMP2=TEMP1*TEMP

*      UPDATE FOR SHORT PERIODICS

      RK=R*(1.-1.5*TEMP2*BETAL*X3THM1)+.5*TEMP1*X1MTH2*COS2U
      UK=U-.25*TEMP2*X7THM1*SIN2U
      XNODEK=XNODE+1.5*TEMP2*COSIO*SIN2U
      XINCK=XINC+1.5*TEMP2*COSIO*SINIO*COS2U
      RDOTK=RDOT-XN*TEMP1*X1MTH2*SIN2U
      RFDOTK=RFDOT+XN*TEMP1*(X1MTH2*COS2U+1.5*X3THM1)

*      ORIENTATION VECTORS

      .U*
```

8 THE SGP8 MODEL

The NORAD mean element sets can be used for prediction with SGP8. All symbols not defined

D_1 = %) "

D

$$\ddot{n}_o = \dot{n}\left[\frac{4}{3}D_{17} + 3\dot{e}^2 *^{"2} + 3e\ddot{e} *^{"2} - 6(*/*)^2 + 4D_{18} - 7D_{19}\right]$$
$$+\dot{n}_1/C_1 + C_1\left[D_{16}\dot{C}_1/C\right]C$$

$$\# = \#_o + \dot{\#}_1 \overset{!}{(t ! t_o)} + \frac{7}{3}\frac{1}{\dot{n}_o} Z_1 \overset{\cdot}{,} + \dot{\#}_2(t ! t_o)$$

$$M = M_o + \dot{n}_o(t ! t_o) + Z_1 + \dot{M}_1 \overset{!}{(t ! t_o)} + \frac{7}{3}\frac{1}{\dot{n}_o} Z$$

" , =

+ "r

ṙ = r̈ + "ṙ

r

Position and velocity are given by

$$r = rU$$

$$\dot{r} = \dot{r}U + r\dot{f}V.$$

```
 XGDT1=-.5*PARDT1*UNM5TH
 XHDT1=-PARDT1*COSI
 XLLDOT=XNODP+XMDT1+
2           .0625*PARDT2*BETAO*(13.-78.*THETA2+137.*THETA4)
 OMGDT=XGDT1+
1      .0625*PARDT2*(7.-114.*THETA2+395.*THETA4)+PARDT4*(3.-36.*
2         THETA2+49.*THETA4)
 XNODOT=XHDT1+
1       (.5*PARDT2*(4.-19.*THETA2)+2.*PARDT4*(3.-7.*THETA2))*COSI
 TSI=1./(PO-S)
 ETA=EO*S*TSI
 ETA2=ETA**2
 PSIM2=ABS(1./(1.-ETA2))
 ALPHA2=1.+EOSQ
 EETA=EO*ETA
 4OS2G=2.*COSG**2-1.
 D5=TSI*PSIM2
 D1=D5/PO
 D2=12.+ETA2*(36.+4.5*ETA2)
 D3=ETA2*(15.+2.5*ETA2)
 D4=ETA*(5.+3.75*ETA2)
 B1=CK2*TTHMUN
 B2=-CK2*UNMTH2
 B3=A3COF*SINI
 C0=.5*B*RHO*QOMS2T*XNODP*AODP*TSI**4*PSIM2**3.5/SQRT(ALPHA2)
 C1=1.5*XNODP*ALPHA2**2*C0
 C4=D1*D3*B2
 C5=D5*D4*B3
 XNDT=C1*(
1  (2.+ETA2*(3.+34.*EOSQ)+5.*EETA*(4.+ETA2)+8.5*EOSQ)+
1   D1*D2*B1+   C4*4OS2G+C5*-B2=-PHA4N1.2418/D
```

```
      SINE=SIN(ZC2)
      COSE=COS(ZC2)
      ZC5=1./(1.-EM*COSE)
      CAPE=(XMAM+EM*SINE-ZC2)*
     1   ZC5+ZC2
      IF(A9S(CAPE-ZC2) .LE. E6A) GO TO 140
  130 ZC2=CAPE

*      SHORT PERIOD PRELIMINARY QUANTITIES

  140 AM=(XKE/XN)**TOTHRD.0442.0989-1.2418TD[BETA)11(2M=)11(1.-E)11(M*EM)]JT*[SINO)11(S=S)11(I

  )
```

C

" , =

+ "r

ṙ = ṙ + "ṙ

r ḟ = (r ḟ)

Position and velocity are given by

$$r = rU$$

$$\dot{r} = \dot{r}U + r\dot{f}V.$$

```
*       SDP8                                                    14 NOV 80
      SUBROUTINE SDP8(IFLAG,TSINCE)
      COMMON/E1/XMO,XNODEO,OMEGAO,EO,XINCL,XNO,XNDT2O,
```

```
 XHDT1=-PARDT1*COSI
 XLLDOT=XNODP+XMDT1+
2           .0625*PARDT2*BETAO*(13.-78.*THETA2+137.*THETA4)
 OMGDT=XG.*THETA4)




 XARS*(SHET**42.*)11(P.*)1M2*EO*.*TAO
 .*DT*TAO



 HPARARNAO*(7.11(EO1())1J0-1.23065-1IFLAS2)11(0*2)1J0-1.2418TDCALL(2)16.5(D5*P)1INIT4*EO*

 OA=XOMGDS*TS



 T2*
 55
```

```
*      UPDATE FOR SHORT PERIOD PERIODICS

       SNI2DU=SINIO2*(
      1   G3*(.5*(1.-7.*THETA2)*SN2F2G-3.*UNM5TH*G10)-G5*SINI*CSFG*(2.+
      2         ECOSF))-.5*G5*THETA2*AXNM/COSIO2
       XLAMB=FM+OMGASM+XNODES+G3*(.5*(1.+6.*COSI-7.*THETA2)*SN2F2G-3.*
      1      (UNM5TH+2.*COSI)*G10)+G5*SINI*(COSI*AXNM/(1.+COSI)-(2.
      2      +ECOSF)*CSFG)
       Y4=SINI2*SNFG+CSFG*SNI2DU+.5*SNFG*COSIO2*DI
       Y5=SINI2*CSFG-SNFG*SNI2DU+.5*CSFG*COSIO2*DI
       R=RM+DR
       RDOT=XN*AM*EM*SNF/BETA+G14*(2.*G2*UNMTH2*SN2F2G+G4*CSFG)
       RVDOT=XN*AM**2*BETA/-A/
      1      G14*DR+AM*G13*SINI*DIWC

*      ORIENTATION VECTORS

       SNLAMB=SIN(XLAMB)
       CSLAMB=COS(XLAMB)
       TEMP=2.*(Y5*SNLAMB-Y4*CSLAMB)
       UX=Y4*TEMP+CSLAMB
       VX=Y5*TEMP-SNLAMB
       TEMP=2.*(Y5*CSLAMB+Y4*SNLAMB)
       UY=-Y4*TEMP+SNLAMB
       VY=-Y5*TEMP+CSLAMB
       TEMP=2.*SQRT(1.-Y4*Y4-Y5*Y5)
       UZ=Y4*TEMP
       VZ=Y5*TEMP

VUXCSLAMBVUYSNLAMB
```

```
X4=-A3*SINOMO+A4*COSOMO
X5=A5*SINOMO
X6=A6*SINOMO
X7=A5*COSOMO
X8=A6*COSOMO
```

```
      IF(EQ.GT.(.65)) GO TO 45
      G211=3.616-13.247*EQ+16.290*EQSQ
      G310=-19.302+117.390*EQ-228.419*EQSQ+156.591*EOC
      G322=-18.9068+109.7927*EQ-214.6334*EQSQ+146.5816*EOC
      G410=-41.122+242.694*EQ-471.094*EQSQ+313.953*EOC
      G422=-146.407+841.880*EQ-1629.014*EQSQ+1083.435*EOC
      G520=-532.114+3017.977*EQ-5740*EQSQ+3708.276*EOC
      GO TO 55
   45 G211=-72.099+331.819*EQ-508.738*EQSQ+266.724*EOC
      G310=-346.844+1582.851*EQ-2415.925*EQSQ+1246.113*EOC
      G3-146342.585+1554.908-Q6EQ+12.095*EQSQ+017*EOC1A*SIOQNVCO4IT27-53(5(GO)401)11CO4*EXNOG-5
```

```
      RETURN

*     ENTRANCE FOR DEEP SPACE SECULAR EFFECTS

      ENTRY DPSEC(XLL,OMGASM,XNODES,EM,XINC,XN,T)
      XLL=XLL+SSL*T
      OMGASM=OMGASM+SSG*T
      XNODES=XNODES+SSH*T
      EM=EO+SSE*T
      XINC=XINCL+SSI*T
      IF(XINC .GE. 0.) GO TO 90
      XINC = -XINC
      XNODES = XNODES + PI
      OMGASM = OMGASM - PI
   90 IF(IRESFL .EQ. 0) RETURN
  100 IF (ATIME.EQ.0.D0)    GO TO 170
      IF(T.GE.(0.D0).AND.ATIME.LT.(0.D0)) GO TO 170
      IF(T.LT.(0.D0).AND.ATIME.GE.(0.D0)) GO TO 170
  105 IF(DABS(T).GE.DABS(ATIME)) GO TO 120
      DELT=STEPP
      IF (T.GE.0.D0)    DELT = STEPN
  110 ASSIGN 100 TO IRET
      GO TO 160
  120 DELT=STEPN
      IF (T.GT.0.D0)    DELT = STEPP
  125 IF (DABS(T-ATIME).LT.STEPP)    GO TO 130
      ASSIGN 125 TO IRET
      GO TO 160
  130 FT = T-ATIME
      ASSIGN 140 TO IRETN
      GO TO 150
  140 XN = XNI+XNDOT*FT+XNDDT*FT*FT*0.5
      XL = XLI+XLDOT*FT+XNDOT*FT*FT*0.5
      TEMP = -XNODES+THGR+T*THDT
      XLL = XL-OMGASM+TEMP
      IF (ISYNFL.EQ.0)    XLL = XL+TEMP+TEMP
      RETURN
C
C     DOT TERMS CALCULATED
C
  150 IF (ISYNFL.EQ.0)    GO TO 152
      XNDOT=DEL1*SIN (XLI-FASX2)+DEL2*SIN (2.*(XLI-FASX4))
     1     +DEL3*SIN (3.*(XLI-FASX6))
      XNDDT = DEL1*COS(XLI-FASX2)
     *       +2.*DEL2*COS(2.*(XLI-FASX4))
     *       +3.*DEL3*COS(3.*(XLI-FASX6))
      GO TO 154
  152 XOMI = OMEGAQ+OMGDT*ATIME
```

```
C
      ENTRY DPPER(EM,XINC,OMGASM,XNODES,XLL)
      SINIS = SIN(XINC)
      COSIS = COS(XINC)
```

11 DRIVER AND FUNCTION SUBROUTINES

The DRIVER controls the input and output function and the selection of the model. The input consists of a program card which specifies the model to be used and the output times and either a G-card or T-card element set.

```
   1       F7.7,2(1X,F8.4),1X,F11.8)
703 FORMAT(79X,A1)
704 FORMAT(1H1,A80,/,1X,A80,//,1X,A4,7H TSINCE,
   1 14X,1HX,16X,1HY,16X,1HZ,14X,
   1 4HXDOT,13X,4HYDOT,13X,4HZDOT,//)
705 FORMAT(7F17.8)
706 FORMAT(A80)
707 FORMAT(79X,A1)
930 FORMAT("SHOULD USE DEEP SPACE EPHEMERIS")
940 FORMAT("SHOULD USE NEAR EARTH EPHEMERIS")
950 FORMAT("EPHEMERIS NUMBER",I2," NOT LEGAL, WILL SKIP THIS CASE")
800 WRITE(6,930)
    GO TO 9
850 WRITE(6,940)
```

```
      FUNCTION  ACTAN(SINX,COSX)
      COMMON/C2/DE2RA,PI,PIO2,TWOPI,X3PIO2
      ACTAN=0.
      IF (COSX.EQ.0.  ) GO TO 5
      IF (COSX.GT.0.  ) GO TO 1
      ACTAN=PI
      GO TO 7
    1 IF (SINX.EQ.0.  ) GO TO 8
      IF (SINX.GT.0.  ) GO TO 7
      ACTAN=TWOPI
      GO TO 7
    5 IF (SINX.EQ.0.  ) GO TO 8
       IF (SINX.GT.0.  ) GO TO 6
      ACTAN=X3PIO2
      GO TO 8
    6 ACTAN=PIO2
      GO TO 8
    7 TEMP=SINX/COSX
      ACTAN=ACTAN+ATAN(TEMP)
    8 RETURN
      END
```

```
 FUNCTION THETAG(EP)
 COMMON /E1/XMO,XNODEO,OMEGAO,EO,XINCL,XNO,XNDT2O,XNDD6O,BSTAR,
1 X,Y,Z,XDOT,YDOT,ZDOT,EPOCH,DS50
```

AE	distance units/Earth radii	1.0
DE2RA	radians/degree	.174532925E-1
PI	!	

$k_2 = \frac{1}{2} J_2 a_E^2$

$k_4 = -\frac{3}{8} J_4 a_E^4$

$A_{3,0} = -J_3 a_E^3$

q_o = parameter for the SGP4/SGP8 density function

s

```
1 88888U          80275.98708465  .00073094  13844-3  66816-4 0    8
2 88888  72.8435 115.9689 0086731  52.6988 110.5714 16.05824518  105

SGP  TSINCE              X                Y                Z

      0.            2328.96594238   -5995.21600342    1719.97894287
    360.00000000    2456.00610352   -6071.94232177    1222.95977784
```

```
1 11801U          80230.29629788  .01431103  00000-0  14311-1
2 11801  46.7916 230.4354 7318036  47.4722  10.4117  2.28537848

SDP8 TSINCE              X                Y                Z

      0.            7469.47631836     415.99390792    5829.64318848
    360.00000000   -3337.38992310   32351.39086914  -24658.63037109
```

ACKNOWLEDGEMENTS