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TITLE- A Computer Program for Simulating Uprated Saturn I Trajectories

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ABSTRACT

A computer program has been developed which extends the capability of the BCMASP simulator to cover Uprated Saturn I trajectories. The basic BCMASP format and structure is utilized throughout with the targeting and event sequencing subroutines modified as necessary.

The trajectory model includes both manned and unmanned launch configurations, and has a provision for the incorporation of a wind velocity profile during the critical early stages of the trajectory if desired.

Preliminary Reference Trajectories, as produced by Chrysler Corporation Space Division for MSFC, can be duplicated with differences on the order of 0.1% in final payload and other critical parameters. The more sophisticated Operational Trajectories can be duplicated to an accuracy of about .6%.

Among the potential areas suitable for analysis with the Uprated Saturn I simulator are launch vehicle payload capability studies, engine failure and abort problems, and the initial phases of rendezvous missions.

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SUBJECT: A Computer Program for Simulating Uprated Saturn I Trajectories

DATE: September 29, 1967

FROM: V. J. Esposito

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TECHNICAL MEMORANDUM

I. INTRODUCTION

The increasing variety of experimental objectives and missions being studied for the Apollo Applications Program demands a thorough understanding of the characteristics and performance capabilities of the launch vehicles used to support these missions.

In order to provide an engineering tool for studying the capabilities and limitations of the Uprated Saturn I in its role as an AAP launch vehicle, a computer simulation program has been developed. This program is essentially a modification and extension of the basic BCMASP programs used for studying Saturn V performance; and it parallels the Saturn V model as closely as possible in structure, format, and nomenclature.

Among the potential areas suitable for analysis with the program are:

1. Uprated Saturn I payload-to-orbit capability studies.

2. Study of detailed profiles for specific launch trajectories to determine the relative influence of selected parameters.

3. Orbital access studies for a variety of orbits.

4. Engine failure and abort studies.

5. Initial phases of dual-launch rendezvous studies.

Paragraphs II through IV that follow describe the Uprated Saturn I trajectory simulator at progressively increasing levels of detail, beginning with a general description of model, and concluding with the actual subroutine program and data deck listings.

II. GENERAL DESCRIPTION OF UPRATED SATURN I SIMULATOR

The program targets from launch to orbital insertion in two steps, using a total of three variables to match three selected trajectory constraints. For the initial step of the targeting procedure the first stage kick angle (DLTH1), which represents an artificially instantaneous rotation of the velocity vector after a nominal 10 second vertical rise from lift-off, is targeted to match a selected constraint at the time of launch escape system (LES) jettison about 170 seconds later. The BCMASP criterion for this targeting is normally the altitude at the time of LES jettison; however, other alternative and potentially more useful criteria can also be utilized. After satisfying the first criterion by varying DLTH1, the program then targets a similar variable DLTH2 (the second stage kick angle) and also the second stage pitch rate (DTH2) to satisfy two burnout conditions at orbital insertion. These two conditions or constraints are the altitude (actually geocentric radius) and the flight path angle.

The final payload in orbit obtained as a result of this targeting will not necessarily be the maximum that can be achieved. A second targeting technique that can be used in order to optimize the final payload is to relax the constraint on the first stage kick angle (DLTH1). The program then re-targets the entire trajectory from launch to orbital injection, using the flexibility obtained by the more liberal constraint on DLTH1 to optimize the payload placed in orbit.

Both techniques for targeting can be useful in Uprated Saturn I studies. The first method will show the maximum payload obtainable without exceeding some predetermined first stage constraint, such as maximum permissable dynamic pressure (QMAX); whereas, using the second method will show the payload improvement that can be obtained by relaxing the first stage constraint to optimize the weight into orbit. With some relatively simple program modifications, the constraining criterion for the first stage kick angle can be changed to fit various study objectives. Other parameters such as the product of dynamic pressure and angle-of-attack (QALPHA), or aerodynamic heating indicator (AHI) might be used.

The basic program is designed to inject the space-vehicle payload into an elliptical parking orbit at perigee. The eccentricity of the orbit is established by specifying the desired perigee and apogee altitudes (in the form of geocentric distances) in the data deck. The correct insertion velocity to be used for the 2nd stage engine cutoff criterion is calculated internally.

III. DETAILED TRAJECTORY MODEL STRUCTURE

A. Trajectory Sequencing: The Events List

The basic outline or "flight plan" for the launch trajectory is spelled out in the subroutine SIMTGT, known as the Events List in BCMASP terminology. Table I shows a portion of a typical Events List for the Uprated Saturn I program.

TABLE I

```
C
C       SHUT DOWN THE CENTER ENGINES.
C
  EVENT IBOFF(KICK)
  CRITERION (T=TENG5)
       CALL SITB(2)
       IDRAG=0
  AUXEQ
C
C       SHUT DOWN THE STAGE ONE ENGINES.
C
 EVENT S1OFF (KICK)
 CRITERION (WGT=WS1OFF)
      TSAV=T+TC2
      ITHR=0
C
C      START THE STAGE TWO ENGINES.
C
 EVENT S4ON(S1OFF)
 CRITERION(T=TSAV)
      WGT=WGT2A
```

Each event represents a point on the trajectory at which a discontinuity occurs in the differential equations being used, or where some modification in the trajectory parameters is made. For example, at EVENT IBOFF, the cutoff in the four inboard engines of the first stage is simulated by dividing the first stage thrust magnitude by two. This is denoted in the Events List by CALL SITB(2) under EVENT IBOFF. In general, the Events List parallels a typical Saturn V launch trajectory Events List except, of course, that it depicts a two stage rather than three stage trajectory. Included are: (1) first stage kick after a short vertical rise, (2) gravity turn phase during low altitude flight, (3) sequential first stage engine shutdown, (4) brief coast period, (5) second stage ignition, (6) mixture ratio shifts during second stage flight, (7) interstage and LES jettison events and (8) second stage shutdown.

Several additional events have been included in order to provide a more realistic simulation of the actual first stage thrust variation. For the first 32 seconds of flight, a gradual buildup of the thrust is simulated by the inclusion of a simple second order thrust buildup function. After 32 seconds the buildup function is removed by EVENT BELAY, and the thrust magnitude follows the normal variation with atmospheric pressure.

A second event, EVENT THRDK, has been inserted to simulate the gradual decay of thrust during the final seconds of first stage flight.

Further modifications to the Events List can be made quite simply to simulate specific trajectory problems. For example, the effect of a premature engine shutdown might be simulated by inserting an event EVENT ENGOUT similar to EVENT IBOFF mentioned previously. A complete listing of the Events List for this program is contained in Appendix A.

B. Trajectory Targeting and Optimization: ETHORB

The BCMASP subroutine ETHORB has been utilized as the basic program for targeting the Uprated Saturn I trajectory from launch to orbital insertion and also for optimizing the payload injected into orbit, if this mode of operation is desired. Two forms of the routine are available: (1) the standard BCMASP ETHORB, which uses the altitude at the time of LES jetison as the criterion for the first phase of the targeting procedure and (2) a modified version of ETHORB, which uses the maximum permitted value of a selected parameter, such as dynamic pressure during first stage flight, as the criterion or constraint for the first targeting phase. Test runs have shown that, when the first phase constraints are sufficiently relaxed and the program optimizes payload into orbit, both routines produce the same trajectory.

Listing for the modified ETHORB is included in Appendix A.

C. Other Important Subroutines

In order to simplify the structure of the Events List, a subroutine of tables and other data needed at various events has been incorporated into the program. This routine, called SITB, is similar to the SVTB used for Saturn V trajectories. A unique feature of the SITB routine, however, is the incorporation of a dual-drag function by means of two separate drag coefficient tables. The distinctly different drag profiles of the unmanned vs. the manned Uprated Saturn I configurations (a consequence primarily of the LES vs. nosecap configuration

differences) requires that these two separate tables be made available. The SITB routine is keyed to select internally the proper table to suit the type of vehicle configuration used, the keying parameter being the weight of the LES shown in the input data deck. If the LES weight is set to zero, the unmanned drag coefficient table is selected. A non-zero weight for the LES indicates a manned launch vehicle configuration, and the corresponding table is selected.

Another unique feature of the SITB is the incorporation of a wind velocity profile table. In this table can be stored the nominal wind velocity vs. altitude profile for the time of year and launch site being used. Alternatively, the table may be left empty for no wind or "still air" studies. In order to integrate the effects of the wind velocity variations into the BCMASP programs a minor modification to the basic differential equation program, DIFEQ, was also required. At present, the wind profile data is stored in an unused thrust table in SITB; and is entered by calls to LOOKUP from DIFEQ.

A second BCMASP subroutine not normally used for launch vehicle trajectories has been incorporated into the program in order to calculate and store the value of a selected parameter such as maximum dynamic pressure (QMAX) during first stage flight. This routine, INTMAX, provides the maximum parameter value necessary for targeting during the first phase of the trajectory when the modified ETHORB targeting routine is used.

IV. MODEL ACCURACY AND PROGRAM LIMITATIONS

The development of an Uprated Saturn I mission passes through three phases representing increasing levels of specific-mission detail in depicting the launch trajectory and overall mission profile to be flown. The launch vehicle trajectories for two of these three phases, as produced by Chrysler Corporation for MSFC, have been used in this study as a reference or guideline for judging the accuracy of the simulated trajectory model developed. The first of these baseline trajectories is the Preliminary Reference Trajectory in which as many as possible of the vehicle and mission constraints and requirements are incorporated, but which is generally characterized by the use of "nominal" vehicle and engine performance data, such as nominal or contract specification values for sea level thrust, specific impulse, and propellant flow rates. At succeeding levels of sophistication, represented by the Reference Trajectory and finally by the Operational Trajectory, the specific mission and vehicle characteristics are refined to produce a tailor-made profile which reflects (1) the actual test stand engine data for thrust and weight-rate variations of the exact engines to be used on

the launch vehicle (2) thrust buildup and decay profiles at engine ignition, cutoff and mixture ratio shifts (3) the inclusion of more sophisticated navigation and guidance equations, (4) the inclusion of a wind profile in the atmospheric model, and (5) six degrees of freedom simulation.

In its present form, the Uprated Saturn I program discussed in this memorandum (when used without the wind profile option) parallels quite closely the Preliminary Reference Trajectory. Sample runs compared with an actual MSFC Preliminary Reference Trajectory (Reference 1), show a payload in orbit difference of only 28 pounds, less than 0.1%. Other trajectory variables show good agreement also.

In attempting to simulate the more sophisticated Operational Trajectory for a typical Uprated Saturn I mission (Reference 2) the simplifications in thrust and weight-rate profile plus other factors cause the trajectory differences to increase. The incorporation of the wind profile table improves the trajectory shaping somewhat over the no-wind Preliminary Reference Trajectory type model, but errors in drag profiles, dynamic pressure, altitude and velocity at first stage burnout, and consequently in final payload obtained are on the order of 1/2 to 1%. For a typical run, the program can simulate an Operational Trajectory with a final payload difference of about 400 pounds or about 0.6% for a 70,000 lb. in-orbit weight.

Figures 1 through 3 show the trajectory profiles for a selected Preliminary Reference Trajectory (Reference 1). Figure 4 shows the deviation of a typical trajectory flown with this model from the Preliminary Reference Trajectory for certain critical variables. One interesting effect that will be noted in the drag error curve is the error of about +7000 lbs. that appears at launch. This represents a phenomenon that has been "wired" in to the differential equations for Saturn V launches. Rather than remove it for the Uprated Saturn I program, a simple compensating effect has been introduced into the thrust profile in the early seconds of flight, thus maintaining the effective thrust-drag force at the proper value.

It can be noted from Figure 4 that in the particular example used here the model trajectory tends to fly somewhat higher than the reference trajectory at maximum altitude, although the final insertion altitude is correct.

The deviation in weight (see Figure 4) that accumulates to about 3000 pounds during first stage flight is caused by the slightly higher than nominal constant weight rate used in the simulator model. At first stage burnout, the BCMASP model stops the fuel flow and hence the weight decrease instantaneously at

140.32 seconds. The Preliminary Reference Trajectory (Reference 1) allows for a 1.3 second "tail-off" in which the weight continues to decrease. This "tail-off" is compensated for by a higher than nominal weight-rate used in the BCMASP simulator, so that the vehicle weights are in correct agreement at stage separation.

As mentioned earlier, precision trajectory simulation, such as that obtained for the Operational Trajectories developed for MSFC by Chrysler Corporation, requires a more sophisticated model than that used in this program. For specific studies, the flexibility of this program and the flexibility of the BCMASP do provide for more precise trajectory simulation than that actually shown here. In order to match more exactly the true thrust and drag profiles of the operational trajectory, tabular rather than function-generated values can be introduced. In this way an exact thrust and drag profile can be obtained. In addition, the fuel weight-rates, now depicted as constant values, can be replaced by a time-varying function or by a set of tabular data. Improvements in the simplified wind profile model might also be incorporated.

In its present form, however, the program should provide a self-consistent set of trajectories for studying and evaluating Uprated Saturn I performance under various trajectory situations. Such potential modifications as strap-on solid rocket thrust assistance and 2-1/2 stage (CSM SPS "third stage") trajectories can be examined.

Appendix A contains a listing of the more important computer routines used in the program as well as a typical input data deck. Only those routines that differ from the standard BCMASP routines are listed.

Appendix B contains a partial listing of a typical trajectory run for a Preliminary Reference Trajectory type model.

V. ACKNOWLEDGEMENTS

Much of the preliminary work on the Uprated Saturn I Trajectory described in this memorandum was based on a similar program developed by Mr. V. S. Mummert and Miss P. A. Cavedo. Their assistance in making available the basic program outline, including the initial format for the Events List, and the format for the SITB is gratefully acknowledged. Additionally, their assistance in helping solve the inevitable programming problems that arose was essential to the completion of the task.

V. J. Esposito

1021-VJE-cfb

Attachments
References
Appendices A and B

REFERENCES

1. CCSD, TN-AP-67-186, "Launch Vehicle Preliminary Reference Trajectory, AAP-1 Mission," dated 14 March 1967.

2. CCSD, TN-AP-67-184, "AS 207 Launch Vehicle Operational Flight Trajectory," dated 27 February 1967.

3. CCSD, TN-AP-67-185, "AS-208 Launch Vehicle Operational Flight Trajectory," dated 3 March 1967.

4. SE 015-001-1, "Natural Environment and Physical Standards for the Apollo Program," dated April 1965.

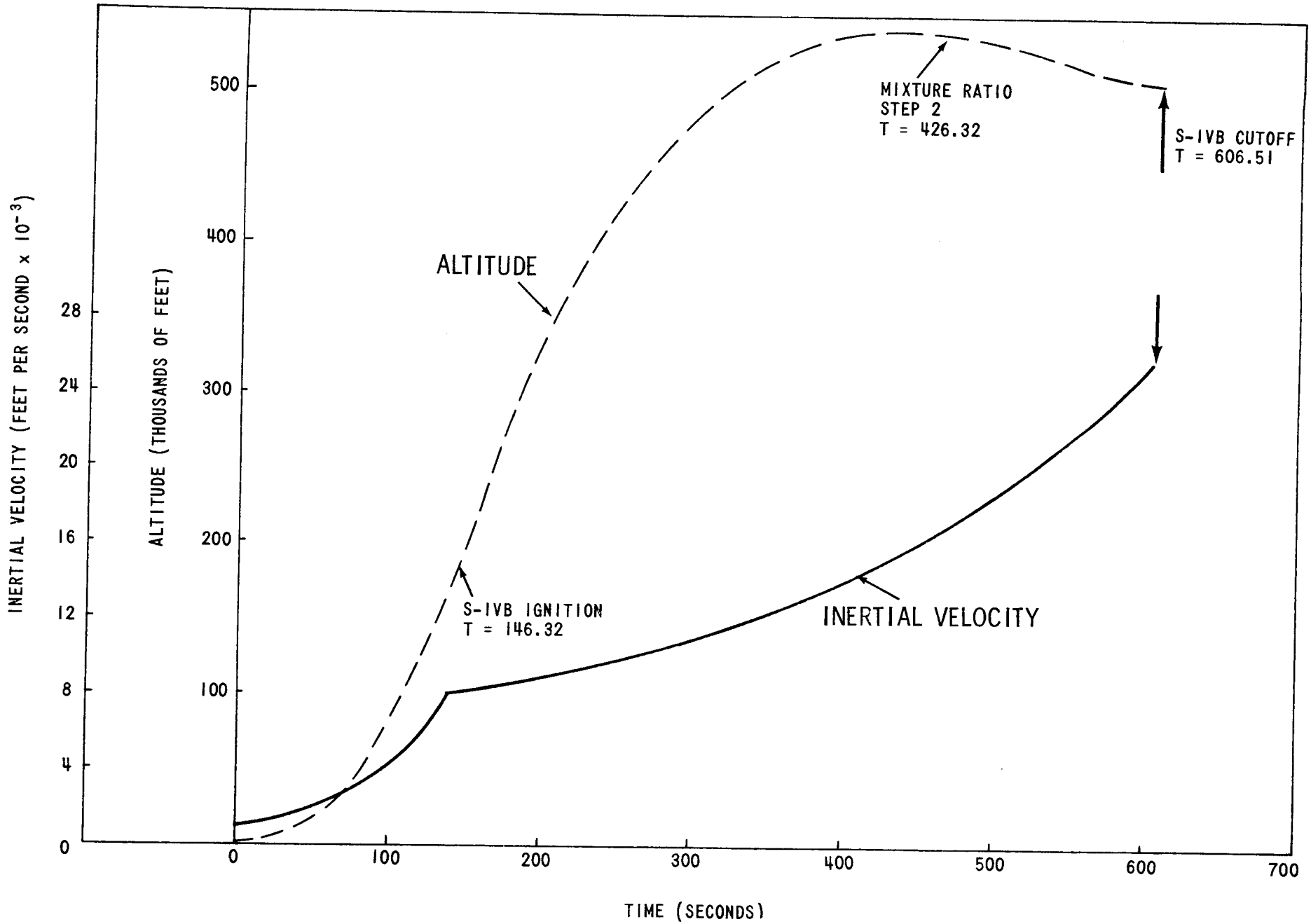

FIGURE 1 - ALTITUDE & INERTIAL VELOCITY vs. TIME FROM LAUNCH
PRELIMINARY REFERENCE TRAJECTORY - (REFERENCE 1)

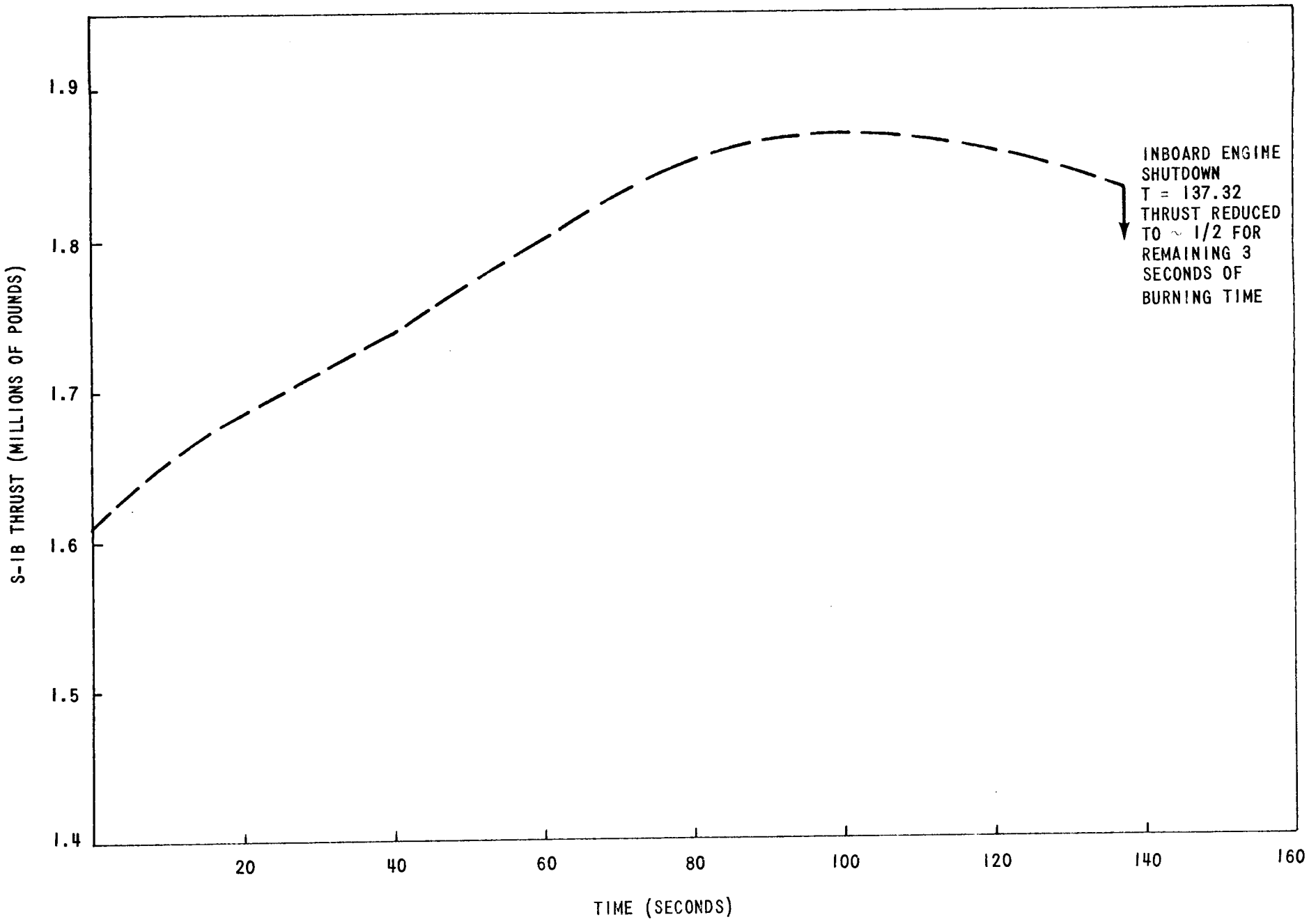

FIGURE 2 - FIRST STAGE THRUST vs. TIME FROM LAUNCH
PRELIMINARY REFERENCE TRAJECTORY - (REFERENCE 1)

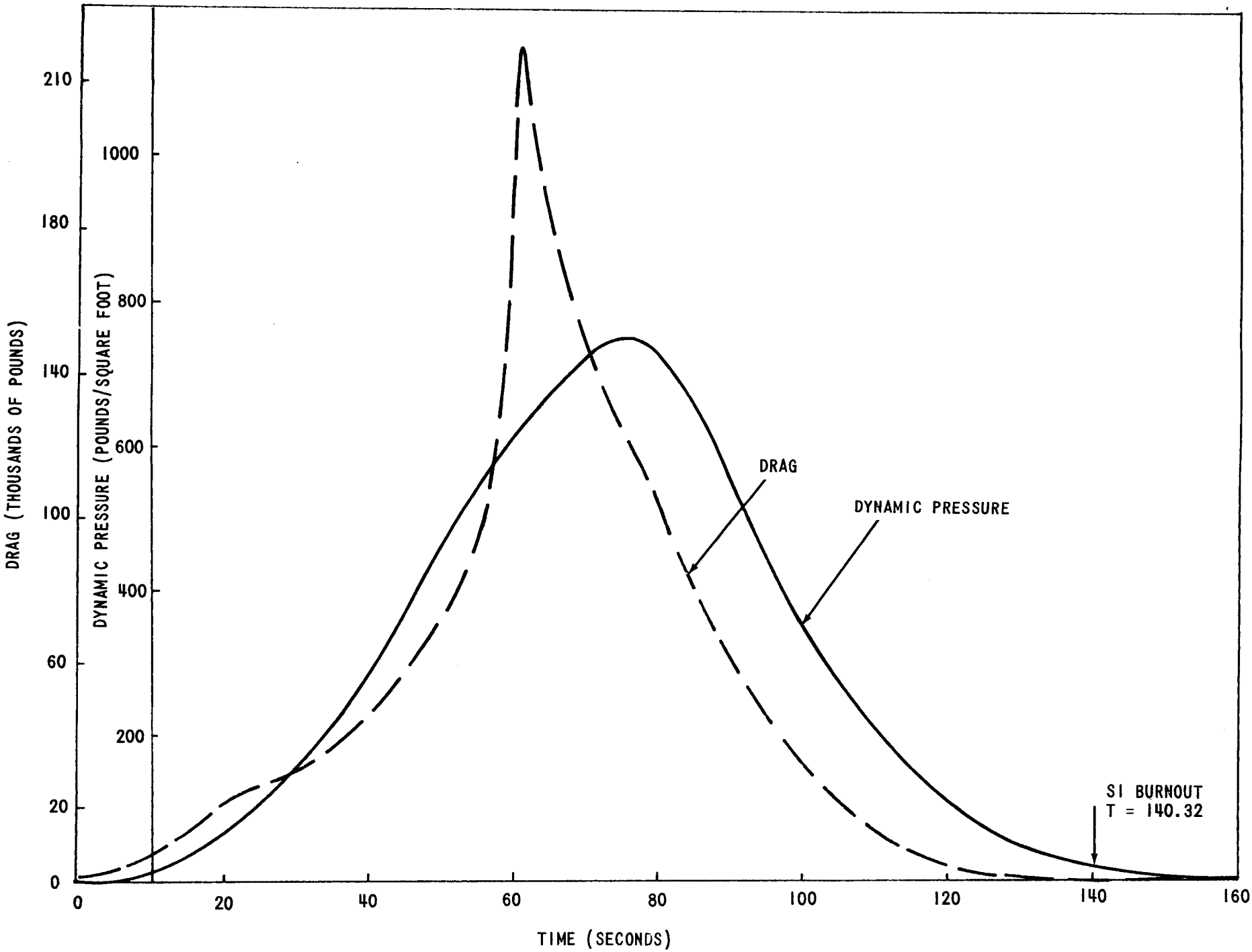

FIGURE 3 - DYNAMIC PRESSURE & DRAG vs. TIME FROM LAUNCH
PRELIMINARY REFERENCE TRAJECTORY - (REFERENCE 1)

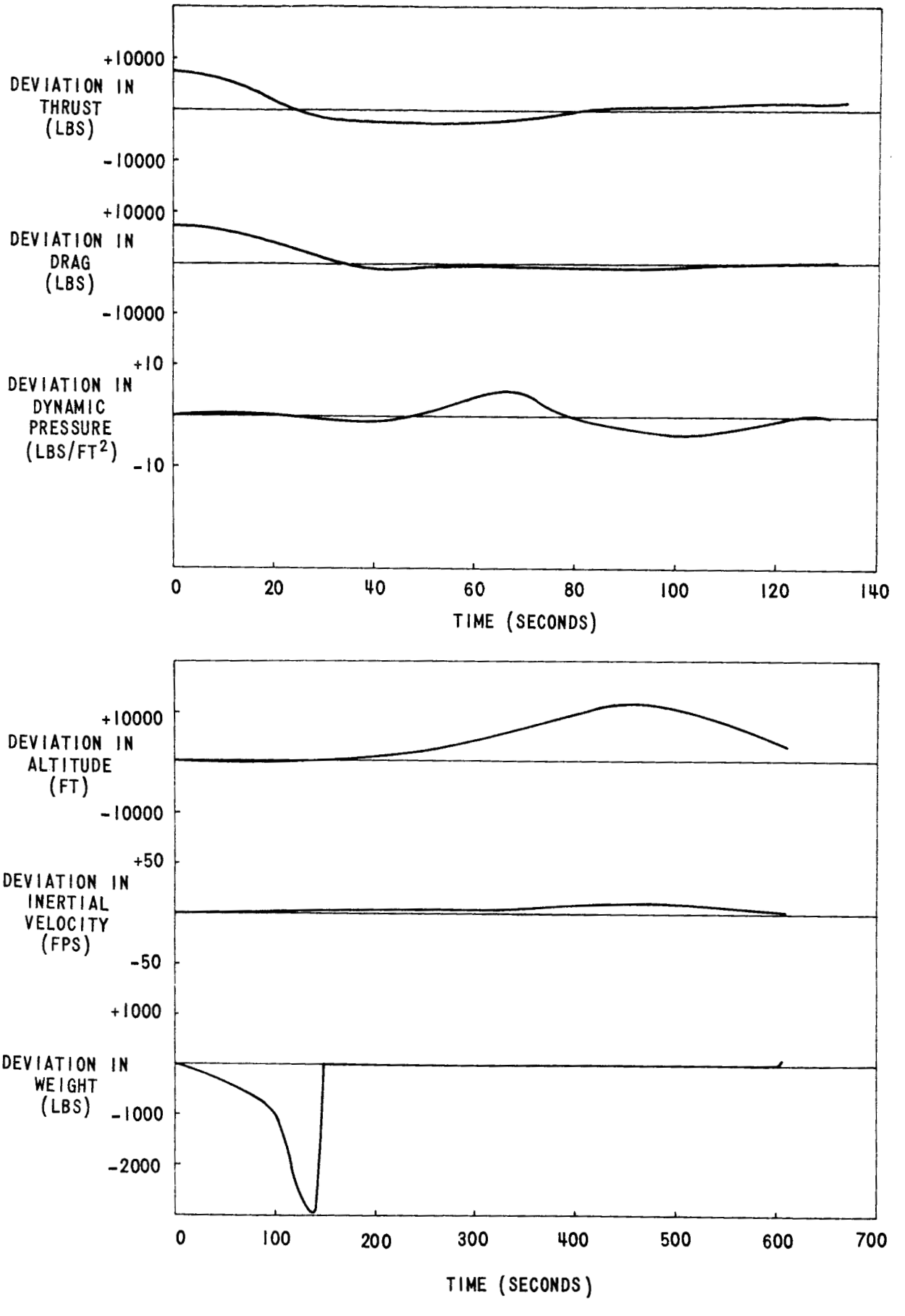

FIGURE 4 - TYPICAL TRAJECTORY DEVIATIONS
(DEVIATIONS FROM PRELIMINARY REFERENCE TRAJECTORY - REFERENCE 1)

APPENDIX A

SPECIAL OR MODIFIED COMPUTER ROUTINES USED FOR THE UPRATED SATURN I SIMULATOR

1. Events List, SIMTGT
2. Optimization Program, ETHORB
3. Tables and other Data, SITB
4. Input Data for typical run, DATA2

SIMTGT

```
JOB     VJE2


OPTION SIMTGT  LIST,REF,ERFILE
       SUBROUTINE SIMTGT
       EQUIVALENCE          (VEH(1),TSL1),          (VEH(2),WGT1),
      .(VEH(3),DWGT1),      (VEH(4),FUEL1),         (VEH(5),TENG5),
      .(VEH(6),THR2A),      (VEH(7),WGT2A),         (VEH(8),DWGT2A),
      .(VEH(9),FUEL2),      (VEH(10),TC3),          (VEH(11),THR3),
      .(VEH(12),WGT3),      (VEH(13),DWGT3),        (VEH(14),TKICK)
       EQUIVALENCE          (VEH(51),XAREA1),       (VEH(52),AT1),
      .(VEH(53),WGTLES),    (VEH(54),WGTISG),       (VEH(56),TC2),
      .(VEH(57),TMIX1),     (VEH(58),DWGT2B),       (VEH(59),THR2B),
      .(VEH(60),TJTISG),    (VEH(61),TJTLES),       (VEH(62),TMIX2),
      .(VEH(63),DWGT2C),    (VEH(64),THR2C),        (VEH(68),TEGT),
      .(VEH(69),TDK),       (VEH(50),ACC01),        (VEH(48),DFDA1),
      .(VAR(368),QMAX),     (VAR(369),TMAX),        (VAR(370),QSUM)
C
C                EQUIVALENCES FOR UPRATED SATURN I VEHICLE
C
       EQUIVALENCE        (FLT(C22),RAPOGR),    (VAR(375),RAPOG)
       DIMENSION          TQ(4),                Q(4)
C
C      LAUNCH VERTICALLY FROM THE SURFACE OF THE EARTH.
C
 EVENT LAUNCH(START)
 CRITERION(T=0.)
       WS1OFF=WGT1-FUEL1
       WGT=WGT1
       CALL ELINIT
       CALL SITB(1)
 AUXEQ
       F(T) = -75.705*T**2 + 4385.3*T - 63725.
       THRN=TSL1 + F(T)
C
C      INITIATE THE GRAVITY TURN.
C
 EVENT KICK(LAUNCH)
 CRITERION(T=TKICK)
       CALL IKICK
C
C      DELAY THRUST BUILDUP FUNCTION
C
 EVENT DELAY(KICK)
 CRITERION(T=32.)
       THRN=TSL1
       DO 100 I=1,3
       TQ(I)=0.
 100   Q(I)=0.
       QMAX=0.
 AUXEQ
       IF(QMAX.NE.0.)  GO TO 9910
       Q(4)= (RHOA*VA**2)/288.
       TQ(4)=T
       DO 200 I=2,4
       TQ(I-1)=TQ(I)
 200   Q(I-1)=Q(I)
       IF(Q(1).EQ.0.)  GO TO 9910
```

```
JOB     VJE2

      CALL INTMAX (1,TQ,Q,TMAX,QMAX,QSUM)
      IF(QMAX.EQ.0.) GO TO 9910
      WRITE(6,101) TQ(3),Q(3),TMAX,QMAX
 101  FORMAT(5H TQ =E15.8,3X,4H Q =E15.8,3X,7H TMAX =E15.8,3X,
     .7H QMAX =E15.8)
C
C       BEGIN THRUST DECAY
C
 EVENT THRDK(KICK)
 CRITERION(T=TDK)
      ACC0=ACC01
      DFDA=DFDA1
 AUXEQ
C
C     END GRAVITY TURN.
C
 EVENT ENDGT(LAUNCH)
 CRITERION(T=TEGT)
      IGT=0
      OMEGAP=0.
      OMEGAY=0.
 AUXEQ
C
C     SHUT DOWN THE CENTER ENGINES.
C
 EVENT IBOFF(KICK)
 CRITERION(T=TENG5)
      CALL SITB(2)
      IDRAG=0
 AUXEQ
C
C     SHUT DOWN THE STAGE ONE ENGINES.
C
 EVENT S1OFF(KICK)
 CRITERION(WGT=WS1OFF)
      TSAV=T+TC2
      ITHR=0
C
C     START THE STAGE TWO ENGINES.
C
 EVENT S4ON(S1OFF)
 CRITERION(T=TSAV)
      WGT=WGT2A
      ITHR=1
      CALL SITB(3)
      TSAV1=T+TMIX1
      TSAV2=T+TJTISG
      TSAV3=T+TJTLES
      TSAV4=T+TMIX2
      WS4OFF=WGT2A-FUEL2-WGTLES-WGTISG
C
C     FIRST S-IVB MIXTURE RATIO SHIFT.
C
 EVENT MIX1(S4ON,S4OFF1)
 CRITERION(T=TSAV1)
      CALL SITB(4)
```

SIMTGT

```
JOB     VJE2


C
C       JETTISON THE INTERSTAGE.
C
 EVENT JETISG(S4ON,S4OFF1)
 CRITERION(T=TSAV2)
        WGT=WGT-WGTISG
C
C       JETTISON THE LAUNCH ESCAPE SYSTEM.
C
 EVENTJETLES(S4ON,S4OFF1)
 CRITERION(T=TSAV3)
        WGT=WGT-WGTLES
        OMEGAP=DTH2
        CALL IPITCH(DLTH2)
        OMEGAY=DPSI2
        CALL IYAW(DLPSI2)
 AUXEQ
        V=VALUE(VX)
        VCIR=SQRT(GME/R)
        VOFF=VCIR*SQRT(2./(1.+R/RAPOGR))
C
C       SECOND S-IVB MIXTURE RATIO SHIFT.
C
 EVENT MIX2(S4ON,S4OFF1)
 CRITERION(T=TSAV4)
        CALL SITB(5)
C
C                WLIGHT IS EQUAL TO WEIGHT WS4OFF
C
 EVENT EMPTY(S4ON,S4OFF1)
 CRITERION(WGT=WS4OFF)
C
C       SHUT DOWN THE STAGE TWO ENGINES.
C
 EVENT S4OFF1(S4ON)
 CRITERION(V=VOFF)
        V=VALUE(VX)
        ITHR=0
        OMEGAY=0.
        OMEGAP=0.
        TSAV=T+TC3
        BETAI=BETA(RX,VX)
 AUXEQ
 EVENT STOP(S4OFF1)
 CRITERION(T=TSAV)
 LAST
DECK SIMTGT TO BE COMPILED
 END
```

```
      OPTION ETHORB  LIST,REF,ERFILE
 1          SUBROUTINE ETHORB
      C
 2          COMMON /C1/VAR(375)/C3/SHP(100)/C4/TWV(400)/C5/FLT(130)
      C
 3          EQUIVALENCE              (VAR(108),      R),     (VAR(190),    ALT),
           1(VAR(195),    WGT),      (VAR(203), BETAI),     (SHP(004), DLTH1),
           2(SHP(005), DLTH2),       (SHP(006),  DTH2),     (TWV(109), QALT3),
           3(TWV(010),IPRTRJ),       (TWV(011),  QRE4),     (TWV(012), QBTA4),
           4(FLT(067), ALT3R),       (FLT(023),   REO),     (FLT(068), BTA4R),
           5(TWV(267), SENS1),       (TWV(269), SENS2),     (TWV(274),IOPTEO),
           6(TWV(275), QWGT4),       (TWV(  1),     K1),    (TWV(  2),     K2),
           7(BKP( 23),ISKPSW),       (FLT(072), QMAXR),     (VAR(368),   QMAX)
      C
 4          DIMENSION X(3), Y(3), XP(2), YP(2)
      C
      C       INTEGRATE TO EVENT KICK
 5          IF(IPRTRJ.EQ.1) CALL PRTCOM
10          K=0
11          CALL FLTINT(6HLAUNCH,4HKICK)
      C       IF OPTIMIZATION RUN, INCREASE ALT TOLERANCE
12          IF((IOPTEO.EQ.1).AND.(K1.EQ.1).AND.(K2.EQ.1)) GO TO 1
15          TEMP=QALT3
16          WRITE(6,101)
17          GO TO 2
20    1     TEMP=0.5
21          WRITE(6,102)
      C
      C       TARGET TRAJECTORY
      C
      C       TARGET TO EVENT JETLES
22    2     WRITE(6,103)
23          CALL ROLLBK(4HKICK)
24          CALL HUNT1(DLTH1,QMAX,QMAXR,TEMP,4HKICK,6HJETLES,SENS1)
25          ALT3=QMAX
      C       TARGET TO EVENT S4OFF1
26          WRITE(6,104)
27          CALL ROLLBK(6HJETLES)
30          CALL HUNT2(DLTH2,DTH2,R,BETAI,REO,BTA4R,QRE4,QBTA4,
           .            6HJETLES,6HS4OFF1,SENS2)
31          IF((IOPTEO.NE.1).OR .(K1.NE.1).OR .(K2.NE.1)) RETURN
      C
      C       COMPUTE NEW VALUE FOR DLTH1
      C
      C       SET UP TABLE OF POINTS
34          K=K+1
35          WRITE(6,105) K,DLTH1,WGT
36          DO 3 I=1,2
37          X(I)=X(I+1)
40    3     Y(I)=Y(I+1)
42          X(3)=DLTH1
43          Y(3)=WGT
44          IF(K.GT.10) RETURN
47          IF(K.GE.3) GO TO 4
52          DLTH1=DLTH1+.003
53          TEMP=5.
```

ETHORB


```
54          GO TO 2
C             FIT PARABOLA TO POINTS AND FIND MIN
55    4     DO 5 I=1,2
56          XP(I)=X(I)-X(3)
57    5     YP(I)=Y(I)-Y(3)
61          DET=XP(1)*XP(2)*(XP(1)-XP(2))
62          A=(YP(1)*XP(2)-YP(2)*XP(1))/DET
63          B=(XP(1)**2*YP(2)-XP(2)**2*YP(1))/DET
64          XPMIN=-B/(2.*A)
65          YPMIN=XPMIN*(A*XPMIN+B)
C             IF EXPECTED SAVING LT QWGT4, STOP ITERATING
66          IF(ABS(YPMIN).LT.QWGT4) GO TO 6
71          DLTH1=DLTH1+XPMIN
72          GO TO 2
C
73    6     QMAXR=ALT3
74          RETURN
C
75    101   FORMAT(/14X,29H(SELECT DLTH1 TO MATCH QMAXR))
76    102   FORMAT(/14X,49H(SELECT DLTH1 TO OPTIMIZE WGT INTO PARKING ORBIT))
77    103   FORMAT(/9X,23HTARGET   KICK TO JETLES//9X,21HAT JETLES   X  =DLTH1
            1,14X,8HU  =QMAX)
100   104   FORMAT(/9X,25HTARGET   JETLES TO S4OFF1//9X,21HAT S4OFF1   X  =DLTS
            1H2,14X,5HU  =R/21X,8HY  =DTH2,15X,9HV  =BETAI)
101   105   FORMAT(/14X,12HPOINT NUMBER,I3,5X,6HDLTH1=,F14.9,5X,4HWGT=,F12.2)
C
102         END
```

SITB

VJE2

SOURCE PROGRAM SITB

```
      OPTION SITB    LIST,REF,ERFILE
 1          SUBROUTINE SITB(I)
      C
 2          COMMON /C1/VAR(375)/C6/VEH(100)
 3          COMMON /TABLE1/DRAGTB( 52)/TABLE2/CLIFTB( 52)/TABLE3/THRSTB( 52),
           1TABLE4/DWISPT( 52)/TABLE5/CGRVTB( 52)/TABLE6/CPRSTB( 52)
      C
 4          EQUIVALENCE              (VAR( 96),      T),     (VAR(191),     AT),
           1(VAR(192), ITHEN),       (VAR(195),    WGT),     (VAR(199), XAREA),
           2(VAR(273),  ITHR),       (VAR(351),   TREF),     (VAR(352),WGTREF),
           3(VAR(356),  THRN),       (VAR(357), DWGTN),      (VAR(365),   DFDA),
           4(VAR(366), DDWDA),       (VAR(367),   ACCO)
 5         EQUIVALENCE              (VEH(  1),   TSL1),     (VEH(  3), DWGT1),
           1(VEH(  6), THR2A),       (VEH(  8),DWGT2A),      (VEH( 11),   THR3),
           2(VEH( 13), DWGT3),       (VEH( 48), DFDA1),      (VEH( 49),DDWDA1),
           3(VEH( 50), ACCO1),       (VEH( 51),XAREA1),      (VEH( 52),    AT1),
           4(VEH( 58),DWGT2B),       (VEH( 59), THR2B),      (VEH( 63),DWGT2C),
           5(VEH( 64), THR2C),       (VAR(274), IDRAG),      (VAR(275), ILIFT),
           6(VEH( 53),WGTLES)
      C
 6          DIMENSION   TAB11(52),   TAB21(52),   TAB31(52)
      C
 7         DATA TAB11/25.,0.,0.,.2,.25,.3,.4,.5,.6,.7,.8,.9,.95,
           11.,1.05,1.1,1.2,1.3,1.5,2.0,2.5,3.,3.5,4.,5.,6.,
           299.,1.,1.,.65,.6,.53,.48,.45,.43,.42,.45,.5,.67,.78,.77,.68,
           3.61,.52,.39,.31,.25,.19,.15,.07,.01,0./
      C
      C
10         DATA TAB21/25.,0.,0.,.2,.25,.3,.4,.5,.6,.65,.75,.85,.95,1.,
           11.05,1.1,1.2,1.5,2.0,2.5,3.0,3.5,4.,4.5,5.,6.,99.,1.2,1.2,
           2.9,.6,.47,.38,.31,.29,.32,.4,.54,.66,.78,.79,.76,.63,.49,.42,
           3.4,.38,.36,.31,.25,.05,0.0/
      C
      C
11          DATA TAB31/25.,0.,0.,3281.,32808.,42651.,65617.,72178.,
           1 78740.,88583.,91864.,98425.,111549.,114829.,124672.,134514.,
           2 141076.,154199.,157480.,160761.,164042.,173885.,177165.,
           3 183727.,190289.,193560.,262467.,0.,0.,98.43,113.19,26.25,
           4 21.33,26.25,45.93,32.81,55.77,26.25,37.73,-9.84,37.73,
           5 13.12,42.65,32.81,44.29,16.40,37.73,32.81,37.73,65.62,29.53,
           6 164.04/
      C
      C
12         GO TO (100,200,300,400,500),I
      C
      C                ENTER S1 VEHICLE DATA
      C
13   100    DO 5 J = 1,52 0
14     5    THRSTB(J) = TAB31(J)
16          IF(WGTLES.EQ.0.) GO TO 2
21          DO 1 J = 1,52
22   1     DRAGTB(J)=TAB11(J)
24         GO TO 3
25   2     DO 4 J=1,52
26   4     DRAGTB(J)=TAB21(J)
30   3     XAREA=XAREA1
```

SITB


```
      THRN=TSL1
      ITHR=1
      ITHFN=1
      DFDA=0.
      DDWDA=DDWDA1
      ACCC=0.
      AT=AT1
      DWGTN=DWGT1
      GO TO 600
C
C                 CHANGE S1 DATA TO REFLECT IECO
C
 200  DWGTN=.5*DWGTN
      THRN=.5*THRN
      AT=.5*AT
      GO TO 600
C
C                 ENTER S2 VEHICLE DATA
C
 300  DWGTN=DWGT2A
      THRN=THR2A
      ITHFN=0
      GO TO 600
C
C                 CHANGE S2 VEHICLE DATA TO REFLECT MIX1
C
 400  DWGTN=DWGT2B
      THRN=THR2B
      GO TO 600
C
C                 CHANGE S2 VEHICLE DATA TO REFLECT MIX2
C
 500  DWGTN=DWGT2C
      THRN=THR2C
 600  RETURN
      END
```

DATA 2

```
JOB     VJE2


 START OF APOLLO SIMULATION PROGRAM
 TARGET AREA 5,6
 PRINT LATER
 PGHEAD=*SATURN IB LAUNCH TRAJECTORY*
C
C LAUNCH VEHICLE PARAMETERS
      WGT1=1295725.
      FUEL1=888218.
      FUEL2=228082.
      WGT2A=306141.
      WGTLES=6450.
      WGTISG=220.
      AT1=13132.8
      XAREA1=360.
C ENGINE PERFORMANCE PARAMETERS
      TSL1=1670608.8
      DWGT1=6398.34
      THR2A=205000.
       THR2B=231400.
      THR2C=196100.
      DWGT2A=481.22
      DWGT2B=543.40
      DWGT2C=456.07
C MISSION SPECIFIC PARAMETERS
      DATEL=2439504.5
      AL=83.875
      PADLAT=28.5219583
      PADLON=-80.5611417
      PADRAD=20909891.73
      DLTH1=-.26378
      DLTH2=7.0335
      DTH2=-.10981
      DPSI2=0.
      DLPSI2=0.
      ALT3R=311351.
      FLT(072)=5.1
      FLT(022)=21654872.04
      REO=21417903.54
      BTA4R=0.
C EVENT TIMING PARAMETERS
      TIMEL=0.
      TKICK=10.
      VEH(69)=100.
      VEH(68)=130.32
      TENGS=137.32
      TC2=6.0
      TMIX1=1.3
      TJTISG=10.
      TJTLES=29.55
      TMIX2=164.20
      TC3=100.
C TOLERANCES AND OTHER PARAMETERS
      ACCO1=2.9065
      DFDA1=-25280.
      DDWDA1=0.
```

DATA 2

```
JOB     VJE2

      QRE4=250.
      QALT3=0.01
      QBTA4=0.001
      QWGT4=1.
      K1=1
      K2=1
C OPTION SELECTION FOR TARGETING
      IOPTEQ=1
 LAST
```

APPENDIX B

TRAJECTORY PRINTOUT FOR TYPICAL UPRATED SATURN I TRAJECTORY

```
 CD        1.00000000  CL        0.          QALPHA 1.0055992E-09  QAERO  6.9609208E-09  PRX       0.          VPX       1334.10771
 FISP      251.046298  AXIALA    39.6959152  ALPHA  1.4446354E-01  APHIT  1.5258789E-05  RPY       0.          VPY       0.
 DAHI   1.3121278E-13  AHI    1.2828412E-13  DELTAV 1.5574466E-01                         RPZ       0.          VPZ       0.

14  JAN.  1967     0 HR   0 MIN   3.000 SEC          -0 DAY   0 HR   0 MIN   3.000 SEC                                  2.99999997
GEOCENTRIC POWERED FLIGHT
 DATE      2439504.50  TIME      2.99999997  ICOUNT            30  HNORM     1.00000000  ALT       75.0603924  WGT       1276529.97
 RX        15619347.7  VX      -693.301926   DVIX      6.17092228  VAX      17.8532333   RHOA   2.2918086E-03  DWGT      6398.33997
 RY        9752677.25  VY        1149.92616  DVIY      3.84384906  VAY      11.1285095   PRESSA    14.7124299  THRUST    1615252.19
 RZ        9906879.25  VZ        12.5260550  DVIZ      3.99096656  VAZ      11.3948861   THETA     89.8384800  OMEGAP    0.
 R         20909925.7  V         1341.95967  DVI       8.29356802  VA       23.9254067   GINCL     28.3608162  OMEGAY    0.
 XLATC     28.5219574  XLON    -80.5637741   ALFAI     89.9422722  BETAI    1.02155972   DNODE     90.0185966  OMEGAR    0.
 FLIFT     0.          DRAG      8172.58740  FMACH  2.1031054E-02  BETAA    89.8340435
 CD        1.00000000  CL        0.          QALPHA 1.2494203E-04  QAERO  4.5551691E-03  PRX       0.          VPX       1334.10643
 FISP      252.370390  AXIALA    40.5053167  ALPHA  2.7428627E-02  APHIT  1.1030197E-02  RPY       0.          VPY       0.
 DAHI   6.9402697E-02  AHI    5.0438219E-02  DELTAV    121.187247                       RPZ       0.          VPZ       0.

14  JAN.  1967     0 HR   0 MIN  10.000 SEC          -0 DAY   0 HR   0 MIN  10.000 SEC                                 10.0000000
GEOCENTRIC POWERED FLIGHT
 DATE      2439504.50  TIME     10.0000000  ICOUNT            38  HNORM     1.00000000  ALT      465.823799  WGT       1231741.69
 RX        15614659.5  VX      -644.370827   DVIX      7.81665039  VAX      67.3782654   RHOA   2.2675954E-03  DWGT      6398.33997
 RY        9760822.25  VY        1179.35239  DVIY      4.85388923  VAY      41.8966064   PRESSA    14.5139714  THRUST    1645673.23
 RZ        9907073.37  VZ        44.1070023  DVIZ      5.03679478  VAZ      42.9748521   THETA     89.8347244  OMEGAP    0.
 R         20910316.5  V         1344.63051  DVI       10.4894978  VA       90.2329988   GINCL     28.3608198  OMEGAY    0.
 XLATC     28.5219569  XLON    -80.5637779   ALFAI     89.9342461  BETAI    3.84776783   DNODE     90.0646362  OMEGAR    0.
 FLIFT     0.          DRAG     10957.3501   FMACH  7.9434612E-02  BETAA    89.7992296
 CD        1.00000000  CL        0.          QALPHA 5.2988026E-03  QAERO  6.4106763E-02  PRX       0.          VPX       1334.04771
 FISP      256.717567  AXIALA    42.7000451  ALPHA  8.2655907E-02  APHIT  3.6765099E-02  RPY       0.          VPY       0.
 DAHI      3.68594131  AHI       8.37484694  DELTAV    418.278954                       RPZ       0.          VPZ       0.

**** EVENT KICK   AT TIME      10.000 AFTER  1 STEPS

14  JAN.  1967     0 HR   0 MIN  10.000 SEC          -0 DAY   0 HR   0 MIN  10.000 SEC                                 10.0000000
GEOCENTRIC POWERED FLIGHT
 DATE      2439504.50  TIME     10.0000000  ICOUNT            38  HNORM     1.00000000  ALT      465.823799  WGT       1231741.69
 RX        15614659.5  VX      -644.646477   DVIX      7.71873379  VAX      67.1026154   RHOA   2.2675954E-03  DWGT      6398.33997
 RY        9760822.25  VY        1179.75819  DVIY      4.99361682  VAY      42.3024139   PRESSA    14.5139714  THRUST    1645673.23
 RZ        9907073.37  VZ        44.1407285  DVIZ      5.05285275  VAZ      43.0085783   THETA     89.7329969  OMEGAP-6.5226202E- 2
 R         20910316.5  V         1345.11964  DVI       10.4902993  VA       90.2329922   GINCL     28.3608210  OMEGAY    0.
 XLATC     28.5219569  XLON    -80.5637779   ALFAI     89.9326258  BETAI    3.84634781   DNODE     90.0680504  OMEGAR    0.
 FLIFT     0.          DRAG     10957.3497   FMACH  7.9434606E-02  BETAA    89.7329998
 CD        1.00000000  CL        0.          QALPHA 2.4454786E-07  QAERO  6.4106754E-02  PRX       0.          VPX       1334.53943
 FISP      256.717567  AXIALA    42.7000442  ALPHA  3.8146973E-06  APHIT  3.6765099E-02  RPY       0.          VPY       0.
 DAHI      3.68255547  AHI       8.37484694  DELTAV    418.278954                       RPZ       0.          VPZ       0.

14  JAN.  1967     0 HR   0 MIN  10.500 SEC          -0 DAY   0 HR   0 MIN  10.500 SEC                                 10.4999999
GEOCENTRIC POWERED FLIGHT
 DATE      2439504.50  TIME     10.4999999  ICOUNT            42  HNORM  1.2500000E-01  ALT      512.192726  WGT       1228542.42
 RX        15614338.1  VX      -640.765228   DVIX      7.80782413  VAX      71.0269241   RHOA   2.2647222E-03  DWGT      6398.33997
 RY        9761412.75  VY        1182.27591  DVIY      5.07877135  VAY      44.8435822   PRESSA    14.4904220  THRUST    1647048.16
 RZ        9907096.12  VZ        46.6839948  DVIZ      5.12142158  VAZ      45.5517735   THETA     89.7065344  OMEGAP-7.2332458E- 2
 R         20910363.0  V         1345.56151  DVI       10.6294399  VA       95.5548782   GINCL     28.3608217  OMEGAY    0.
```

**** EVENT IGOFF AT TIME 137.320 AFTER 1 STEPS

14 JAN. 1967 0 HR 2 MIN 17.320 SEC -0 DAY 0 HR 2 MIN 17.320 SEC 137.320000
GEOCENTRIC POWERED FLIGHT

DATE	2439504.50	TIME	137.320000	ICOUNT	210	HNORM	4.00000000	ALT	172101.662	WGT	417104.953
RX	15538562.6	VX	-1755.70628	DVIX	-32.9154649	VAX	-1016.10889	RHOA	1.5956420E-06	DWGT	3199.16998
RY	10142721.5	VY	7173.23633	DVIY	53.4592357	VAY	6041.34143	PRESSA	9.1239047E-03	THRUST	947839.539
RZ	10006232.0	VZ	1959.93486	DVIZ	8.02164042	VAZ	1958.75700	THETA	30.3653970	OMEGAP	0.
R	21081897.5	V	7640.62616	DVI	63.2903185	VA	6431.71918	GINCL	28.7476580	OMEGAY	0.
XLATC	28.5755232	XLON	-79.9702873	ALFAI	85.3885765	BETAI	23.8326273	DNODE	100.670967	OMEGAR	0.
FLIFT	0.	DRAG	125.629362	FMACH	5.99044615	BETAA	28.6863570				
CD	1.0573232E-02	CL	0.	QALPHA	3.8492624E-01	QAERO	2.2919076E-01	PRX	0.	VPX	7041.335 8
FISP	261.006573	AXIALA	73.1033945	ALPHA	1.67950153	APHIT	1.02828598	RPY	0.	VPY	0.
DAHI	956.280518	AHI	327246.160	DELTAV	9518.61987			RPZ	0.	VPZ	0.

14 JAN. 1967 0 HR 2 MIN 18.109 SEC -0 DAY 0 HR 2 MIN 18.109 SEC 138.109373
GEOCENTRIC POWERED FLIGHT

DATE	2439504.50	TIME	138.109373	ICOUNT	211	HNORM	4.00000000	ALT	174542.291	WGT	414579.613
RX	15537166.5	VX	-1781.70660	DVIX	-32.9604468	VAX	-1041.69510	RHOA	1.4599993E-06	DWGT	3199.16998
RY	10148400.5	VY	7215.59039	DVIY	53.8518162	VAY	6083.79749	PRESSA	8.3001218E-03	THRUST	947513.9 4
RZ	10007781.6	VZ	1966.32054	DVIZ	8.15765190	VAZ	1965.14200	THETA	30.3804393	OMEGAP	0.
R	21084337.0	V	7688.01917	DVI	63.6628337	VA	6477.61554	GINCL	28.7487872	OMEGAY	0.
XLATC	28.5762031	XLON	-79.9565353	ALFAI	85.3888798	BETAI	23.7262878	DNODE	100.686977	OMEGAR	0.
FLIFT	0.	DRAG	110.215351	FMACH	6.05067736	BETAA	28.5257759				
CD	9.9945507E-03	CL	0.	QALPHA	3.9460383E-01	QAERO	2.1271126E-01	PRX	0.	VPX	7091.32855
FISP	261.006573	AXIALA	73.5246229	ALPHA	1.85511494	APHIT	1.04332447	RPY	0.	VPY	0.
DAHI	805.635223	AHI	327977.316	DELTAV	9569.61743			RPZ	0.	VPZ	0.

14 JAN. 1967 0 HR 2 MIN 20.320 SEC -0 DAY 0 HR 2 MIN 20.320 SEC 140.320139
GEOCENTRIC POWERED FLIGHT

DATE	2439504.50	TIME	140.320139	ICOUNT	212	HNORM	4.00000000	ALT	181404.457	WGT	407507.000
RX	15533146.9	VX	-1854.71606	DVIX	-33.0893879	VAX	-1113.53168	RHOA	1.1379631E-06	DWGT	3199.16998
RY	10164485.0	VY	7335.87787	DVIY	54.9739742	VAY	6204.37860	PRESSA	6.3516461E-03	THRUST	946580.719
RZ	10012149.0	VZ	1984.78252	DVIZ	8.54627538	VAZ	1983.60205	THETA	30.4231248	OMEGAP	0.
R	21091195.5	V	7822.68732	DVI	64.7308598	VA	6608.24811	GINCL	28.7519047	OMEGAY	0.
XLATC	28.5735536	XLON	-79.9173813	ALFAI	85.3903637	BETAI	23.4387598	DNODE	100.731133	OMEGAR	0.
FLIFT	0.	DRAG	89.2329693	FMACH	6.22962660	BETAA	28.0907254				
CD	9.9753089E-03	CL	0.	QALPHA	4.0252475E-01	QAERO	1.7254737E-01	PRX	0.	VPX	7232.868 9
FISP	261.006573	AXIALA	74.7286739	ALPHA	2.33283615	APHIT	1.08599663	RPY	0.	VPY	0.
DAHI	745.212914	AHI	329788.176	DELTAV	9714.11499			RPZ	0.	VPZ	0.

**** EVENT SIOFF AT TIME 140.320 AFTER 1 STEPS

14 JAN. 1967 0 HR 2 MIN 20.320 SEC -0 DAY 0 HR 2 MIN 20.320 SEC 140.320139
GEOCENTRIC POWERED FLIGHT

DATE	2439504.50	TIME	140.320139	ICOUNT	212	HNORM	4.00000000	ALT	181404.457	WGT	407507.000
RX	15533146.9	VX	-1854.71606	DVIX	-23.2991893	VAX	-1113.53168	RHOA	1.1379631E-06	DWGT	0.
RY	10164485.0	VY	7335.87787	DVIY	-15.2535540	VAY	6204.37860	PRESSA	6.3516461E-03	THRUST	0.
RZ	10012149.0	VZ	1984.78252	DVIZ	-15.0688651	VAZ	1983.60205	THETA	30.4231248	OMEGAP	0.
R	21091195.5	V	7822.68732	DVI	31.6637619	VA	6608.24811	GINCL	28.7519047	OMEGAY	0.
XLATC	28.5735536	XLON	-79.9173813	ALFAI	85.3903637	BETAI	23.4387598	DNODE	100.731133	OMEGAR	0.
FLIFT	0.	DRAG	89.2329693	FMACH	6.22962660	BETAA	28.0907254				

**** EVENT MIX2 AT TIME 330.520 AFTER 1 STEPS

14 JAN. 1967 0 HR 5 MIN 30.520 SEC -0 DAY 0 HR 5 MIN 30.520 SEC 330.520138
GEOCENTRIC POWERED FLIGHT

DATE	2439524.50	TIME	330.520138	ICOUNT	234	HNORM	16.0000000	ALT	526824.031	WGT	197457.5[illegible]7
RX	14714397.6	VX	-6974.61591	DVIX	-30.3414738	VAX	-1249.90555	RHOA	5.7982248E-07	DWGT	458.070[illegible]0
RY	11725185.6	VY	9549.77136	DVIY	12.7790039	VAY	6113.63409	PRESSA	3.0448157E-03	THRUST	196100.[illegible]
RZ	10272405.5	VZ	851.905891	DVIZ	-6.84277815	VAZ	1893.25244	THETA	25.0546026	OMEGAP	-1.0774365E-[illegible]1
R	21436319.2	V	11856.1858	DVI	33.6263523	VA	6520.98071	GINCL	28.7998238	OMEGAY	0.
XLATC	28.8662076	XLON	-75.3578529	ALFAI	87.5298529	BETAI	4.08313942	DNODE	101.583931	OMEGAR	0.
FLIFT	0.	DRAG	0.	FMACH	6.33774364	BETAA	31.3569746				
CD	9.9636834E-03	CL	0.	QALPHA	5.3955179E-01	QAERO	8.5610766E-02	PRX	0.	VPX	11850.4[illegible]0
FISP	428.1[illegible]506	AXIALA	31.4528399	ALPHA	6.30238247	APHIT	5.79641342	RPY	0.	VPY	0.
DAHI	0.	AHI	329788.176	DELTAV	25367.8870			RPZ	0.	VPZ	0.

14 JAN. 1967 0 HR 6 MIN 50.109 SEC -0 DAY 0 HR 6 MIN 50.109 SEC 410.109371
GEOCENTRIC POWERED FLIGHT

DATE	2439524.50	TIME	410.109371	ICOUNT	239	HNORM	16.0000000	ALT	563028.773	WGT	161000.1[illegible]7
RX	14057352.0	VX	-9617.65430	DVIX	-36.4976110	VAX	-1249.90555	RHOA	5.7982248E-07	DWGT	458.0700[illegible]0
RY	12529382.4	VY	10727.3845	DVIY	17.0086830	VAY	6113.63409	PRESSA	3.0448157E-03	THRUST	196100.0[illegible]
RZ	1[illegible]317675.[illegible]	VZ	280.689072	DVIZ	-7.60137331	VAZ	1893.25244	THETA	19.2549782	OMEGAP	-1.0774365E-[illegible]1
R	21472439.2	V	14410.2338	DVI	40.9774542	VA	6520.98071	GINCL	28.8057106	OMEGAY	0.
XLATC	28.9486108	XLON	-72.5258026	ALFAI	88.9414368	BETAI	3.9075279E-01	DNODE	101.803883	OMEGAR	0.
FLIFT	0.	DRAG	0.	FMACH	6.33774364	BETAA	34.1324525				
CD	9.9636834E-03	CL	0.	QALPHA	1.27367634	QAERO	8.5610766E-02	PRX	0.	VPX	14263.7402
FISP	428.100506	AXIALA	39.1883540	ALPHA	14.8775253	APHIT	8.57194614	RPY	0.	VPY	0.
DAHI	0.	AHI	329788.176	DELTAV	28179.3599			RPZ	0.	VPZ	0.

14 JAN. 1967 0 HR 9 MIN 30.109 SEC -0 DAY 0 HR 9 MIN 30.109 SEC 570.109367
GEOCENTRIC POWERED FLIGHT

DATE	2439524.50	TIME	570.109367	ICOUNT	249	HNORM	16.0000000	ALT	516071.625	WGT	87708.91[illegible]9
RX	11966577.6	VX	-17223.4902	DVIX	-63.9580626	VAX	-1249.90555	RHOA	5.7982248E-07	DWGT	458.0700[illegible]0
RY	14516905.6	VY	14539.4576	DVIY	33.7524862	VAY	6113.63409	PRESSA	3.0448157E-03	THRUST	196100.0[illegible]
RZ	1[illegible]252845.2	VZ	-1203.05862	DVIZ	-11.8514940	VAZ	1893.25244	THETA	9.72755814	OMEGAP	-1.0774365E-[illegible]1
R	21425626.2	V	22571.9248	DVI	73.2824802	VA	6520.98071	GINCL	28.8019590	OMEGAY	0.
XLATC	28.8[illegible]86607	XLON	-84.4004936	ALFAI	93.0034389	BETAI	-8.7371922E-01	DNODE	102.132351	OMEGAR	0.
FLIFT	0.	DRAG	0.	FMACH	6.33774364	BETAA	41.8436127				
CD	9.9636834E-03	CL	0.	QALPHA	2.74951565	QAERO	8.5610766E-02	PRX	0.	VPX	21569.2546
FISP	428.100506	AXIALA	71.9348679	ALPHA	32.1164708	APHIT	16.2832241	RPY	0.	VPY	0.
DAHI	0.	AHI	329788.176	DELTAV	36545.2661			RPZ	0.	VPZ	0.

14 JAN. 1967 0 HR 10 MIN 9.436 SEC -0 DAY 0 HR 10 MIN 9.436 SEC 609.436005
GEOCENTRIC POWERED FLIGHT

DATE	2439524.50	TIME	609.436005	ICOUNT	259	HNORM	8.0000000	ALT	508163.523	WGT	69694.5674
RX	11236242.5	VX	-20019.1855	DVIX	-79.3986549	VAX	-1249.90555	RHOA	5.7982248E-07	DWGT	458.0700[illegible]0
RY	15116822.2	VY	16035.7375	DVIY	43.0603652	VAY	6113.63409	PRESSA	3.0448157E-03	THRUST	196100.0[illegible]
RZ	10195808.7	VZ	-1713.51530	DVIZ	-14.2922657	VAZ	1893.25244	THETA	8.02322769	OMEGAP	-1.0774365E-[illegible]1
R	21417859.0	V	25706.9795	DVI	91.4473076	VA	6520.98071	GINCL	28.7984300	OMEGAY	0.
XLATC	28.6421108	XLON	-61.6870193	ALFAI	94.3467932	BETAI	-1.7833710E-04	DNODE	102.193672	OMEGAR	0.
FLIFT	0.	DRAG	0.	FMACH	6.33774364	BETAA	44.3763413				
CD	9.9636834E-03	CL	0.	QALPHA	3.11226478	QAERO	8.5610766E-02	PRX	0.	VPX	24335.4641
FISP	428.100506	AXIALA	90.5282831	ALPHA	36.3536615	APHIT	18.8159876	RPY	0.	VPY	0.

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 DAHI      0.          AHI       329788.176  DELTAV    39711.8628                        RPZ       0.          VPZ       0.

**** EVENT S4OFF1 AT TIME     609.436 AFTER  6 STEPS

14  JAN.  1967     0 HR  10 MIN   9.436 SEC          -0 DAY   0 HR  10 MIN   9.436 SEC                                609.436005
GEOCENTRIC FREE FLIGHT
 DATE      2439504.50  TIME      609.436005  ICOUNT          259  HNORM     8.00000000  ALT       508163.523  WGT       69694.5674
 RX        11236242.5  VX       -20019.1855  DVIX     -16.0950956  REMX   1.1376754E 09  RTMX  -1.1264391E 09  DWGT      0.
 RY        15116822.2  VY        16035.7375  DVIY     -21.6536438  REMY  -5.4905751E 08  RTMY   5.6417433E 08  THRUST    0.
 RZ        10195808.7  VZ       -1713.51530  DVIZ     -14.6501130  REMZ  -3.5800230E 08  RTMZ   3.6819810E 08  OMEGAP    0.
 R         21417889.0  V         25706.9795  DVI       30.7011106  REM    1.3129871E 09  GINCL     28.7984300  OMEGAY    0.
 XLATC     28.6421108  XLON     -61.6870193  ALFAI     94.3467932  BETAI -1.7833710E-04  ASNODE   -45.5967746  OMEGAR    0.

14  JAN.  1967     0 HR  10 MIN  10.109 SEC          -0 DAY   0 HR  10 MIN  10.109 SEC                                610.109367
GEOCENTRIC FREE FLIGHT
 DATE      2439504.50  TIME      610.109367  ICOUNT          260  HNORM     8.00000000  ALT       508159.738  WGT       69694.5674
 RX        11222758.6  VX       -20030.0171  DVIX     -16.0757878  REMX   1.1376754E 09  RTMX  -1.1264526E 09  DWGT      0.
 RY        15127615.2  VY        16021.1516  DVIY     -21.6691127  REMY  -5.4905751E 08  RTMY   5.6418512E 08  THRUST    0.
 RZ        10194651.6  VZ       -1723.37962  DVIZ     -14.6484563  REMZ  -3.5800230E 08  RTMZ   3.6819694E 08  OMEGAP    0.
 R         21417889.0  V         25706.9817  DVI       30.7011182  REM    1.3129871E 09  GINCL     28.7984371  OMEGAY    0.
 XLATC     28.6385105  XLON     -61.6373062  ALFAI     94.3718462  BETAI  5.3405762E-05  ASNODE   -45.5968971  OMEGAR    0.

14  JAN.  1967     0 HR  11 MIN  49.436 SEC          -0 DAY   0 HR  11 MIN  49.436 SEC                                709.436005
GEOCENTRIC FREE FLIGHT
 DATE      2439504.50  TIME      709.436005  ICOUNT          267  HNORM    16.0000000  ALT       508156.242  WGT       69694.5674
 RX        9158719.87  VX       -21481.6519  DVIX     -13.1189213  REMX   1.1376754E 09  RTMX  -1.1285166E 09  DWGT      0.
 RY        16608430.6  VY        13760.8201  DVIY     -23.7897332  REMY  -5.4905751E 08  RTMY   5.6566594E 08  THRUST    0.
 RZ        9951703.87  VZ       -3162.72882  DVIZ     -14.2990414  REMZ  -3.5800230E 08  RTMZ   3.6795400E 08  OMEGAP    0.
 R         21418649.0  V         25706.5046  DVI       30.7004898  REM    1.3129871E 09  GINCL     28.8001835  OMEGAY    0.
 XLATC     27.8877919  XLON     -54.3537178  ALFAI     98.0045280  BETAI  3.3990860E-02  ASNODE   -45.6146150  OMEGAR    0.

**** EVENT STOP   AT TIME     709.436 AFTER  1 STEPS

14  JAN.  1967     0 HR  11 MIN  49.436 SEC          -0 DAY   0 HR  11 MIN  49.436 SEC                                709.436005
GEOCENTRIC FREE FLIGHT
 DATE      2439504.50  TIME      709.436005  ICOUNT          267  HNORM    16.0000000  ALT       508156.242  WGT       69694.5674
 RX        9158719.87  VX       -21481.6519  DVIX     -13.1189213  REMX   1.1376754E 09  RTMX  -1.1285166E 09  DWGT      0.
 RY        16608430.6  VY        13760.8201  DVIY     -23.7897332  REMY  -5.4905751E 08  RTMY   5.6566594E 08  THRUST    0.
 RZ        9951703.87  VZ       -3162.72882  DVIZ     -14.2990414  REMZ  -3.5800230E 08  RTMZ   3.6795400E 08  OMEGAP    0.
 R         21418649.0  V         25706.5046  DVI       30.7004898  REM    1.3129871E 09  GINCL     28.8001835  OMEGAY    0.
 XLATC     27.8877919  XLON     -54.3537178  ALFAI     98.0045280  BETAI  3.3990860E-02  ASNODE   -45.6146150  OMEGAR    0.
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