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ABORT-ONCE-AROUND ENTRY CORRIDOR ANALYSIS PROGRAM DOCUMENT

MISSION PLANNING, MISSION ANALYSIS AND SOFTWARE FORMULATION

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1.0 **SUMMARY**

This design note documents the Abort-Once-Around Entry Target Corridor Analysis Program (ABECAP). This program determines the allowable range of flight path angles at entry interface for acceptable entry trajectories from a Shuttle abort-once-around (AOA) situation. The solutions thus determined may be shown as corridor plots of entry interface flight path angle versus range from entry interface (EI) to the target.
2.0 INTRODUCTION

The Shuttle abort-once-around concept is based on a maneuver sequence after the abort decision which provides conditions at entry interface (400,000 feet altitude) as near as possible to those for nominal entry. For abort situations which occur early in the flight, use of maximum delta-V available for the AOA results in entry ranges of up to 6,000 miles from entry interface (EI) to the landing site. These extended ranges produce conditions during the entry phase which approach the vehicle structural and trajectory design limits. Among the vehicle constraints which must be considered are thermal protection system (TPS) surface and back-face temperatures. Trajectory considerations include maximum bank angle required to insure convergence to the reference drag-velocity profile, and minimum bank angle during the equilibrium glide phase to assure adequate crossrange capability. Based on these limiting parameters, an entry dispersion corridor can be defined depicting the allowable range-velocity-flight path angle (R-V-\gamma) conditions at entry interface. The manual determination of this type of corridor is described in Reference 1. A digital computer program to automate this corridor definition is described in this report.
3.0 DISCUSSION

The general method used in finding the shallowest allowable flight path angle is as follows: Position coordinates corresponding to entry ranges of interest are input. For a given entry interface position, a first guess flight path angle is used and the trajectory is integrated to TAEM interface. From this trajectory the maximum bank angle and surface control point temperatures are obtained and saved. The flight path angle is then incremented by a constant value and the trajectory again integrated from the same entry interface position. This second set of bank angle and temperature maximums is compared to the first to predict a subsequent flight path angle. A linear Reguli-Falsi scheme is used in the predictor using the previous two trajectory results. The predicted delta-gammas for each constraint are compared, and the constraint which is the most restrictive, i.e., that predicts the most negative flight path angle to produce the individual constraint limit, is used for the subsequent iteration. For example, if the gamma predicted for the limiting bank angle is \(-1.3^\circ\), and that predicted for the limiting temperature is \(-15^\circ\), then \(-15^\circ\) is used as the next guess. This prediction method is continued until either the maximum bank angle or one surface temperature point is at the limit set and all others are less than their respective limits. This defines the shallowest flight path angle allowable for that range. This also provides an initial guess for the steepest allowable flight path angle at the same range.
In determining the steepest allowable gamma, the above method is repeated using limiting values for minimum equilibrium glide bank angle, and backface overtemperature for any two vehicle TPS panels. After both shallow and steep flight path angle solutions are found, the range is incremented by reading in the next position coordinate set.

The program is set up to determine either the shallow or steep gamma solution or both. Also, the corridor as determined by only one pair of constraints, such as minimum and maximum bank angles, may be found by setting the remaining constraint limits to specific values outside the normal range of consideration. The final outputs for each position include shallowest and steepest flight path angles, corresponding initial entry velocity, and resulting trajectory values for each parameter of interest.

The entry interface velocity corresponding to the given flight path angle under consideration is used by ABECAP. This data is input in tabular form giving EI velocity as a function of EI range and flight path angle. To date, this table was derived from data obtained by using the MLTBRN computer program discussed in Reference 2.

Several of the subroutines in this program are standard Space Vehicle Dynamic Simulation (SVDS) subroutines. Also, several are modified from the Entry Targeting Analysis Program (ETAP), which is described in Reference 3. Several subroutines, including SHALST and STEEP,
were written for this program. These are the two routines which are used to predict the shallowest and steepest allowable flight path angles respectively. The program subroutines are described in detail in Section 6.
4.0 INPUT DESCRIPTION

The input data consists of data from the SVDS base data tape (described in Reference 4) for an entry run. Table 4.0-I identifies the required additional input variables, their symbols and units. These are also input using the standard SVDS input format.

Since the SVDS guidance routine (CONGID) is used to compute roll commands in the program, the associated eraseable memory load must be input for the trajectory under consideration. This is described in Reference 5.
### TABLE 4.0-I

**PROGRAM INPUTS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>Initial altitude</td>
<td>feet</td>
</tr>
<tr>
<td>LATD</td>
<td>EL geodetic latitude</td>
<td>degrees</td>
</tr>
<tr>
<td>LONG</td>
<td>EL longitude</td>
<td>degrees</td>
</tr>
<tr>
<td>VI</td>
<td>EL inertial velocity</td>
<td>ft/sec</td>
</tr>
<tr>
<td>GAM</td>
<td>EL inertial flight path angle</td>
<td>degrees</td>
</tr>
<tr>
<td>AZI</td>
<td>EL inertial azimuth</td>
<td>degrees</td>
</tr>
<tr>
<td>TLATD</td>
<td>Target geodetic latitude</td>
<td>degrees</td>
</tr>
<tr>
<td>TLONG</td>
<td>Target longitude</td>
<td>degrees</td>
</tr>
<tr>
<td>ALPHA</td>
<td>Angle of attack at EL</td>
<td>degrees</td>
</tr>
<tr>
<td>IETG</td>
<td>Flag = 1 for SVDS to call ETGX non-dim.</td>
<td></td>
</tr>
<tr>
<td>BNKMAX</td>
<td>Desired maximum bank angle for trajectory</td>
<td>degrees</td>
</tr>
<tr>
<td>BNKLIN</td>
<td>Desired minimum bank angle for equilibrium glide</td>
<td>degrees</td>
</tr>
<tr>
<td>TCP1</td>
<td>Nose surface temperature limit</td>
<td>°F</td>
</tr>
<tr>
<td>TCP2</td>
<td>Body flap surface temperature limit</td>
<td>°F</td>
</tr>
<tr>
<td>TCP3</td>
<td>Wing leading edge surface temperature limit</td>
<td>°F</td>
</tr>
<tr>
<td>TCP4</td>
<td>Elevon surface temperature limit</td>
<td>°F</td>
</tr>
<tr>
<td>BFOTA</td>
<td>Backface overtemperature limit (panel IPANA)</td>
<td>°F</td>
</tr>
<tr>
<td>BFOTB</td>
<td>Backface overtemperature limit (panel IPANB)</td>
<td>°F</td>
</tr>
<tr>
<td>IPANA</td>
<td>Panel number to be checked for backface overtemperature (first panel)</td>
<td>non-dim.</td>
</tr>
<tr>
<td>IPANB</td>
<td>Panel number to be checked for backface overtemperature (second panel)</td>
<td>non-dim.</td>
</tr>
<tr>
<td>MAXCNT</td>
<td>Number of range points input</td>
<td>non-dim</td>
</tr>
</tbody>
</table>
5.0 OUTPUT DESCRIPTION

Output at the completion of each trajectory simulation is given in Table 5.0-I.
TABLE 5.0-I

PROGRAM OUTPUT

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum bank angle during trajectory</td>
<td>degrees</td>
</tr>
<tr>
<td>Minimum bank angle during trajectory</td>
<td>degrees</td>
</tr>
<tr>
<td>Temperatures for Control Points 1-4</td>
<td>°F</td>
</tr>
<tr>
<td>Total heat load</td>
<td>BTU/ft²</td>
</tr>
<tr>
<td>Maximum heat rate</td>
<td>BTU/ft²/sec</td>
</tr>
<tr>
<td>Backface overtemperatures (all panels)</td>
<td>°F</td>
</tr>
<tr>
<td>(After each flight path angle solution)</td>
<td></td>
</tr>
<tr>
<td>Range from EI to target</td>
<td>n.m.</td>
</tr>
<tr>
<td>Steep or shallow solution</td>
<td></td>
</tr>
<tr>
<td>Solution inertial flight path angle</td>
<td>degrees</td>
</tr>
<tr>
<td>Solution inertial velocity</td>
<td>ft/sec</td>
</tr>
</tbody>
</table>
6.0 SUBROUTINE DOCUMENTATION

The following sections describe program subroutines. Several subroutines are currently in SVDS and are not documented in this note. These were modified only as required to match common variables, and include the following subroutines:

- ATMOS
- AR140C
- CONGID
- GIDNAV
- GIDOUT
- GIDRTE
- HTRATE
- TPS

In addition, several subroutines are unchanged in form and serve the same function as in the ETAP program. These are documented in Reference 3, and are not duplicated in this note. These include the following:

- ALTADJ
- CONST
- DELV
- GEOD
- NAVETG
- SPHECI
- TRAJ
- TRANGE
- TRMAT
- UNITX
- VISC
Those subroutines which are unique to ARECAP are described below.

6.1 Subroutine TERMIN

6.1.1 Purpose
Subroutine TERMIN is the SVDS routine which calls ETGX.

6.1.2 Input
IETG flag determining if ETGX is to be called
  = 0 does not call ETGX
  = 1 calls ETGX

6.1.3 Output
None applicable to ADECAP

6.1.4 Calling Sequence
Call TERMIN

6.1.5 Constants Required
None

6.1.6 Subroutine Required
ETGX, other routines not applicable to ADECAP
6.1.7 Flowchart

(Only that portion of TERMIN applicable to ABECAP is documented in this design note.)

START

INPUT: ISTG

SUBS 'TERMIN' ROUTINE

ISTG = 0

YES

NO

CALL ETGX

RETURN

RETURN

Subroutine TERMIN flowchart
6.2 ETGX

6.2.1 Purpose
ETGX is the routine used to initialize required parameters and adjust initial conditions for each range solution.

6.2.2 Input

| STATE (I,1) | EI geodetic latitude for Ith range input (deg) |
| STATE (I,2) | EI longitude (deg) |
| STATE (I,3) | EI inertial azimuth (deg) |
| STATE (I,4) | EI inertial velocity (ft/sec) |
| STATE (I,5) | EI inertial flight path angle (deg) |
| I | Range data set number (non-dim) |
| MAXCNT | Number of ranges input |

6.2.3 Output

| XR | Initial state vector (ft) |
| RK2ROL | Roll direction indicator (non-dim) |
| GAFI | Initial EI flight path angle (deg) |
| ICONFL | Flag to indicate whether shallow or steep flight path angle to be determined (non-dim) |

6.2.4 Calling Sequence
Call ETGX

6.2.5 Constants Required
None
6.2.6 Subroutines Required

GEOD
SPHECI
CROSS
UNITX
ALTADJ
ETGA
6.2.7 Flowchart

A functional flowchart for subroutine ETUX is shown below. This is essentially the same routine as is in the ETAP program. Detailed discussion of this subroutine is presented in Reference 3.
6.2.7 Flowchart: ETGX

**INPUT:**
LATITUDE - LONGITUDE - AZIMUTH SETS TO BE EVALUATED

**COMPUTE INITIAL E1 ECI STATE VECTOR AND DEFINE ORBITAL PLANE REFERENCE SYSTEM UNIT VECTORS**

**COMPUTE RANGE E1 TO TARGET**

**CALL GAMMA ITERATOR (ETGA) TO DETERMINE SLAUN AND STEEP SOLUTIONS**

**ALL RANGES DONE NO**

**INCREMENT RANGE (LATITUDE, LONGITUDE, AZIMUTH SET), ADJUST E1 STATE VECTOR**

**RETURN**

Subroutine ETGX flowchart
6.3 ETGA

6.3.1 Purpose
Subroutine ETGA is the flight path angle iteration driver. It is modeled after the ETG subroutine in the ETAP (Reference 3).

6.3.2 Input

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROLANG</td>
<td>Initial bank angle</td>
<td>(rad)</td>
</tr>
<tr>
<td>T</td>
<td>Time from EI</td>
<td>(sec)</td>
</tr>
<tr>
<td>XR</td>
<td>Initial state vector</td>
<td>(ft)</td>
</tr>
<tr>
<td>RK2ROL</td>
<td>Roll direction indicator (+1)</td>
<td>(non-dim)</td>
</tr>
<tr>
<td>PHIDT</td>
<td>Target latitude</td>
<td>(rad)</td>
</tr>
<tr>
<td>LAMBT</td>
<td>Target longitude</td>
<td>(rad)</td>
</tr>
<tr>
<td>WT</td>
<td>Vehicle weight</td>
<td>(pounds)</td>
</tr>
<tr>
<td>ALP</td>
<td>Initial angle of attack</td>
<td>(deg)</td>
</tr>
<tr>
<td>GAMEI</td>
<td>Initial flight path angle</td>
<td>(deg)</td>
</tr>
<tr>
<td>ICONFL</td>
<td>Flag to indicate whether shallow (=1) or steep (=2) gamma being determined</td>
<td>(non-dim)</td>
</tr>
<tr>
<td>RT</td>
<td>Range to target</td>
<td>(n.mi.)</td>
</tr>
</tbody>
</table>

6.3.3 Output

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAMEI</td>
<td>Flight path angle shallow or steep solution</td>
<td>(deg)</td>
</tr>
</tbody>
</table>

6.3.4 Calling Sequence

CALL ETGA (XR, RK2ROL, PHIDT, LAMBT, WT, ALP, GAMEI)
6.3.5 Constants Required

Obtained from subroutine CONST

6.3.6 Subroutines Required

CONST
FINDV
TRMAT
RTS%MQ
CONGID
SHALST
STEEP
TRANGE
TRAJ
VISC
TPSDR
DELV
NAVETG
TRGGEN
6.3.7 Flowchart

START

INPUT: XR, ROLL, RT, LAMET, RT, ROLANG, T, WT, ALP, GAMEI, ICONFL

CALL CONST

ICNV = 0
K = 0
ROLL = 0
GAMEI = GAMEI

NEWGAM = 1
T = 0
LF = 0
IPASC = 0
ITRIM = 2
IVIR = 0
IGILE = 9
ROLLC = R2RROL + ROLANG
ALP = XALP
TSTREV = 0
TENDREV = 0

CALL FINDV (RT, GAMEI, VI)

Subroutine ETGA flowchart
Subroutine ETGA flowchart

AVI = VI
AGAMI = GAMII * RAD
AARI = ARII * RAD
ARI = RTMPO(S)
ALONS = LONII * RAD
ALATC = LATC * RAD

L = 0

CALL TRMAT( AVI, AGAMI, AAREI, ARI, ALONS, ALATC, S )

SC(I) = S(I) I = 1, 6

KP = 0

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LFS.05

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Subroutine ETGA flowchart
Subroutine ETGA flowchart

ROLL = ROLL
VTN = VE
GAMEN = GAME
PSTEN = AZTE
RIN = RI
CGLOB = LF
PHIC = LATE
REOTN = REOT
XLOB = LOD.
VIN = VI
FLAMB = LONG

CALL CONSID

ROLLMP = ROLL
ROLL = ROLL * PAB
ALP = ALP CM * RAD
PHIOT = (ROLL - ROLL) / 2

ABS (PHIOT) > PHILL

ROLL = ROLL + E * SIGN (PHILL, PHIOT)

Subroutine ETGA flowchart
Subroutine ETGA flowchart
Subroutine ETGA flowchart concluded.
6.4 FINDV

6.4.1 Purpose
Subroutine FINDV is used to determine the velocity at entry interface corresponding to the EI range and flight path angle being used for a given trajectory.

6.4.2 Input

\[ V(I,J) \quad I=1,\ldots,NG \quad J=1,NR \]

\begin{align*}
I &= 1,3,5 \ldots \quad \text{EI inertial velocity corresponding to range and flight path angle} \quad (\text{ft/sec}) \\
I &= 2,4,6 \ldots \quad \text{EI inertial flight path angle} \quad (\text{degrees}) \\
\text{INITRG} &\quad \text{Initial range in table input} \quad (\text{n.mi.}) \\
\text{NG} &\quad \text{Number of gamma-velocity points input times 2} \quad (\text{non-dim}) \\
\text{NR} &\quad \text{Number of range points input in range, gamma-velocity table} \quad (\text{non-dim}) \\
\text{RT} &\quad \text{Current EI range to target} \quad (\text{n.mi.}) \\
\text{GAMEI} &\quad \text{Current EI flight path angle} \quad (\text{degrees}) \\
\text{DELR} &\quad \text{Range increment in table} \quad (\text{n.mi.})
\end{align*}

6.4.3 Output

\[ VI \quad \text{Entry interface inertial velocity} \quad (\text{ft/sec}) \]

6.4.4 Calling Sequence

\text{Call FINDV} (\text{RT, GAMEI, VI})
6.4.5 Constants Required
None

6.4.6 Subroutines Required
TABLE
6.4.7 Flowchart

START

INPUT:
V(I,J) I=1,NG, J=1, NR
NG
NR
INITES
RT

RT/100.

I = IRNS/R - INITES/2

J = 1

V1 = TABLE(V(1,I), GAMEZ,10)
V2 = TABLE(V(1,J), GAMEZ,10)
VI = V1 - ((RT-IRNS*100)/DLR) * (V2-V1)

J = J+1

Subroutine FINDV flowchart
6.5 TABLE

6.5.1 Purpose

The function TABLE is a table lookup routine designed for use in FINDV to determine entry interface velocity. TABLE uses a linear interpolation scheme.

6.5.2 Input

<table>
<thead>
<tr>
<th>GAMEI</th>
<th>Entry interface flight path angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Number of gamma-velocities in input table for each range (non-dim)</td>
</tr>
</tbody>
</table>

6.5.3 Output

| VI    | Entry interface velocity (ft/sec) |

6.5.4 Calling Sequence

CALL TABLE (V, GAMEI, N)

6.5.5 Constants Required

None

6.5.6 Subroutines Required

None

6.5.7 Flowchart

This is a simple table lookup function with linear interpolation and is not flowcharted in this report.
6.6 TPSDR

6.6.1 Purpose
Subroutine TPSDR is the driver routine to determine the vehicle surface temperatures, heat rate, and backface overtemperatures.

6.6.2 Input

<table>
<thead>
<tr>
<th>QC</th>
<th>Total heat load (BTU/ft²)</th>
</tr>
</thead>
</table>

| TARY(26-29) | Surface temperatures, control points 1-4 |

6.6.3 Output

<table>
<thead>
<tr>
<th>TMAX(1)</th>
<th>Maximum temperature, control point 1 (nose) (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMAX(2)</td>
<td>Maximum temperature, control point 2 (body flap) (°F)</td>
</tr>
<tr>
<td>TMAX(3)</td>
<td>Maximum temperature, control point 3 (wing leading edge) (°F)</td>
</tr>
<tr>
<td>TMAX(4)</td>
<td>Maximum temperature, control point 4 (elevon) (°F)</td>
</tr>
<tr>
<td>QCMAX</td>
<td>Maximum heat load (BTU/ft²)</td>
</tr>
<tr>
<td>QDTMAX</td>
<td>Maximum heat rate (BTU/ft²/sec)</td>
</tr>
<tr>
<td>TMABF</td>
<td>Individual panel backface over-temperatures (°F)</td>
</tr>
</tbody>
</table>

6.6.4 Calling Sequence

CALL TPSDR
6.6.5 Constants Required
Reference heat rates and time in TPS (in SVDS).

6.6.6 Subroutine Required
TPS
HTRATE
TI
6.6.7 Flowchart

START

INITIALIZE
TMAX1 = 0
TMAX2 = 0
TMAX3 = 0
TMAX4 = 0
QCMAX = 0
QUTMAX = 0

I = 1

TAPV(I) = TMAX(I)

YES

TMAX(I) = TAPV(I)
I = I + 1

NO

QCMAX = QC

YES

QCMAX = QCMAX

NO

QCMAX = QC

YES

QUTMAX = QLOC

NO

QUTMAX = QUTMAX

END (I)

Subroutine TPSDR flowchart
6.7 SHALST

6.7.1 Purpose
Subroutine SHALST is used to predict the shallowest gamma allowable at a given range, based on maximum bank angle and surface temperature constraints.

6.7.2 Input

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGAMI</td>
<td>Entry interface flight path angle</td>
<td>(deg)</td>
</tr>
<tr>
<td>VE</td>
<td>Relative velocity</td>
<td>(ft/sec)</td>
</tr>
<tr>
<td>K</td>
<td>Flag set (=1) to show that a workable flight path angle has been found for a given range. (=0 initial value set in ETG)</td>
<td>(non-dim)</td>
</tr>
<tr>
<td>T</td>
<td>Time from entry interface</td>
<td>(sec)</td>
</tr>
<tr>
<td>BNKLIM</td>
<td>Maximum bank angle desired during entry pullup</td>
<td>(deg)</td>
</tr>
<tr>
<td>TLIM(I), I=1,4</td>
<td>Maximum surface temperatures desired on control points 1-4</td>
<td>(°F)</td>
</tr>
<tr>
<td>LF</td>
<td>Current vehicle load factor</td>
<td>(g)</td>
</tr>
<tr>
<td>EPS</td>
<td>Flight path angle solution tolerance</td>
<td>(deg)</td>
</tr>
<tr>
<td>NEWGAM</td>
<td>Flag set (=1) to indicate that new flight path angle predicted</td>
<td>(non-dim)</td>
</tr>
<tr>
<td>BANK</td>
<td>Current bank angle</td>
<td>(deg)</td>
</tr>
<tr>
<td>TM(I), I=1,4</td>
<td>Maximum surface temperature in current trajectory CP (1-4)</td>
<td>(°F)</td>
</tr>
</tbody>
</table>
6.7.3 Output

SGAMI  Predicted flight path angle for subsequent trajectory iteration.

NEWGAM  Flag set =1 to show that new flight path angle has been determined and reset trajectory time to zero. = 0 otherwise.

ICONV  Flag set =1 if shallow gamma solution has been determined, otherwise = 0.

6.7.4 Calling Sequence

CALL SHALST (SGAMI, VE, K, NEWGAM, ICONV)

6.7.5 Constants Required

None

6.7.6 Subroutines Required

PROUT - print format subroutine
6.7.7 Flowchart

START

INPUT:  *NEWGAM*, *SGAMI*, *VE*, *K*, *T*, *BLKLLIM*, *EPS*, *LF*, *TLIM(I) I=1,4*, *BANK*, *TM(I=1-4)*

BANK=ABC(BANK)  
GAM=SGAMI

IF T<2500
NO

IF NEWGAM=0  
YES

IF VGK<1500
NO

IF VE<1500
YES

K=1  
NO

IF (VE > 1500 AND VE > 20000)  
BANKMX = BANK

DELGAM = F(BANKMX, TM(I=1-4))

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30

Subroutine SHALST flowchart
Subroutine SHALST flowchart

\[
\begin{align*}
EWRTG &= \frac{BAKMX - BUKMPG}{GAM - GAMP} \\
DGAM &= \frac{BUKMPG - BAKMX}{EWRTG} \\
TWRTG(i) &= \frac{TM(i) - TMPG(i)}{GAM - GAMP} \quad i = 1, 4 \\
DGAMT(i) &= \frac{TM(i) - TM(i)}{TWRTG(i)} \quad i = 1, 4 \\
\end{align*}
\]

DELGAM = DGAMB

\[
\begin{align*}
DGAMT(i) < DELGAM &\quad \text{YES} \quad \text{DELGAM} = DGAMT(i) \\
\end{align*}
\]

\[
\begin{align*}
DELGAM < -3 &\quad \text{YES} \quad \text{DELGAM} = -3 \\
\end{align*}
\]

\[
\begin{align*}
DELGAM > 3 &\quad \text{YES} \quad \text{DELGAM} = 3 \\
\end{align*}
\]

A

B
Subroutine SHALST flowchart concluded.
6.8 STEEP

6.8.1 Purpose

Subroutine STEEP is used to predict the steepest gamma allowable at a given range based on constraints of maximum TPS panel backface overtemperature, and minimum bank angle during the equilibrium glide phase.

6.8.2 Input

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGAMI</td>
<td>Entry interface flight path angle</td>
<td>deg</td>
</tr>
<tr>
<td>VE</td>
<td>Relative velocity</td>
<td>ft/sec</td>
</tr>
<tr>
<td>K</td>
<td>Flag set =1 if a usable flight path angle has been found for subsequent iteration, = 0 initial value set in ETG</td>
<td>non-dim</td>
</tr>
<tr>
<td>T</td>
<td>Time from entry interface</td>
<td>sec</td>
</tr>
<tr>
<td>EPS</td>
<td>Flight path angle solution convergence tolerance</td>
<td>deg</td>
</tr>
<tr>
<td>LF</td>
<td>Load factor</td>
<td>g's</td>
</tr>
<tr>
<td>BANK</td>
<td>Current bank angle</td>
<td>deg</td>
</tr>
<tr>
<td>BNKLIN</td>
<td>Minimum bank angle desired during equilibrium glide</td>
<td>deg</td>
</tr>
<tr>
<td>IPANA</td>
<td>First panel number for which backface overtemperature is limited</td>
<td>non-dim</td>
</tr>
<tr>
<td>IPANB</td>
<td>Second panel number for which backface overtemperature is limited</td>
<td>non-dim</td>
</tr>
<tr>
<td>TMABF(I)</td>
<td>Backface overtemperature for each TPS panel</td>
<td>°F</td>
</tr>
<tr>
<td>BFLIMA</td>
<td>Backface overtemperature limit for panel (IPANA)</td>
<td>°F</td>
</tr>
<tr>
<td>BFLIMB</td>
<td>Backface overtemperature limit for panel (IPANB)</td>
<td>°F</td>
</tr>
</tbody>
</table>
6.8.3 Output

<table>
<thead>
<tr>
<th>SGAMI</th>
<th>Predicted flight path angle for subsequent trajectory iteration (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEWGAM</td>
<td>Flag set = 1 to show that new flight path angle has been determined, and reset trajectory time to zero. = 0 if new FPA not determined (non-dim)</td>
</tr>
<tr>
<td>ICONV</td>
<td>Flag set = 1 if steep gamma solution is determined; else = 0 (non-dim)</td>
</tr>
</tbody>
</table>

6.8.4 Calling Sequence

CALL STEEP (SGAMI, VE, K, NEWGAM, ICONV)

6.8.5 Constants Required

None

6.8.6 Subroutines Required

PROUT - print format subroutine
6.8.7 Flowchart

START

INPUT:
SGAMI, VE, K, T
EPS, LF, BNK,
BNKLIN, TMAEF,
IRANA, IPANE,
BFLIMA, BFLIMC

GAM = SGAMI
V = VE
BANK = ANI(BANK)

IF BANK = 142 OR T > 2000

YES

DELGAM = -0.5
SGAMI = GAM + DELGAM
NEWGAM = 1
ICONV = 0

NO

IF NEWGAM = 0

NO

BNKMIN = 0
ICONV = 0

YES

IF (1000 < VE < 10000
AND BANK < BNKMIN)
BNKMIN = BANK

NO

BFOF A = TMAEF(IPANA)
BFOF B = TMAEF(IPANE)

A

Subroutine STEEP flowchart
Subroutine STEEP flowchart

\[ BWRTS = \frac{E_{KMIN} - ENKMIN}{GAM - GAMP} \]
\[ DGAM = \frac{E_{KMIN} - ENKMIN}{E_{KRTS}} \]
\[ BFAR = \frac{(E_{RFA} - E_{RFA})}{GAM - GAMP} \]
\[ BFAR = \frac{(E_{FRA} - E_{FRA})}{GAM - GAMP} \]
\[ DSFA = \frac{E_{LIMA} - E_{LIMA}}{BFAR} \]
\[ DGBFB = \frac{E_{LIMA} - E_{LIMA}}{BFAR} \]
\[ DELGAM = DGAM \]

\[ DGEFA > DELGAM \]
\[ DGEFA > DELGAM \]

\[ DELGAM = DGBFB \]

A

K = 1

P

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Subroutine STEEP flowchart
Subroutine STEEP flowchart concluded.
7.0 REFERENCES


