(NASA-CR-165882) AN EXTENDED BET FORMAT FOR LaRC SHUTTLE EXPERIMENTS: DEFINITION AND DEVELOPMENT (Analytical Mechanics Associates, Inc.) 24 p HC A02/MF A01 CSCL 22A G3/12
N82-20206
Unclas
17723

AN EXTENDED BET FORMAT FOR LARC SHUTTLE EXPERIMENTERS: DEFINITION AND DEVELOPMENT

J. T. Findlay
G. M. Kelly
M. W. Henry

AMA Report No. 81-11

June, 1981

NAS1-16087

ANALYTICAL MECHANICS ASSOCIATES, INC.
17 RESEARCH ROAD
HAMPTON, VIRGINIA 23666

ABSTRACT

An extended BET has been developed by AMA, Inc. for LaRC investigators. The extended format results in some subtle changes to the header record as described in AMA Report No. 81-1 (Ref. 1)[1] but the major change is the addition of twenty-six (26) words to each data record. These words include atmospheric related parameters, body axis rate and acceleration data, computed aerodynamic coefficients, and angular accelerations. These parameters were added to facilitate post-flight aerodynamic coefficient determinations (ACME) as well as SEADS (SEADX) analyses. Software (NEWBET) was developed to generate the extended BET file utilizing the previously defined ENTREE BET (Ref. 1), a dynamic data file which may be either derived IMU data or ACIP data, and some atmospheric information. The latter data is expected to be obtained from a LAIRS file but the option exists to utilize the 1962 Standard Atmosphere available on the LaRC library. This report describes the extended BET format completely and briefly discusses the NEWBET utility.

[1] It must be noted that the existing 40 word record BET as described in Ref. 1 remains the fundamental output of ENTREE. It is the product used to generate a LAIRS file and these two files, together with a dynamic data file, will be utilized to generate the extended format.

I. Introduction

The ultimate product from the AMA, Inc. Shuttle post-flight data reduction is the Best Estimate Trajectory (BET) which is disseminated as a modified TIFT file for users at LaRC. A complete definition of the BET format, as generated by ENTREE (Ref. 2), is given in Ref. 1. To review, apart from a subtle header change, the format as described therein contained forty (40) words per data record. Missing from this list were various parameters of interest to investigators; e.g., Mach No., dynamic pressure, atmospheric density, pressure and temperature, and a reasonable first-order estimate of the Shuttle aerodynamic coefficients. To include these parameters on the ENTREE list would have required a major, and needless, modification to that software. Incorporation of an available atmosphere model in the software, e.g., the 1962 Standard, would have resulted in a trivial impact. However, to incorporate a combined measured and/or modelled profile such as LAIRS would have been major. Further, the potential for iteration through subtle atmosphere improvements would be extremely inefficient using the ENTREE program. Keeping in mind that ENTREE requires no atmospheric information whatsoever (though winds can be input) to obtain a BET, the need for an additional software utility was suggested. Thus, the extended BET could readily be generated and, if necessary, the list could easily be modified to include other parameters of interest.

II. Extended BET Format Description

A complete description of the extended BET format is presented in this section. Readers will observe that apart from some header record changes the first forty(40) words of each data record are exactly as described in Ref. 1.[2] An additional twenty-six (26) words have been identified as desirable. Users can read this file using standard TIFT read utilities though certain information on the header record which may be desired can potentially be lost. Access to these data, which are embedded in the extended header record, is described herein.

Header Record

Words	Definition
1	Serial number (unused, 1 written)
2	Number words per record, i.e., number of data channels plus one (for time), i.e., 66
3 - 134	Alphanumeric defining labels and units for each of the 66 words on the ensuing data records, written specifically as:

HEADER WORD	Alphanumberic label	HEADER WORD	UNITS
3	TIME	69	SEC
4	VEL A	70	M/SEC(FT/SEC)
5	GAM A	71	DEG
6	HDG A	72	DEG
7	ALTDE	73	METERS(FEET)
8	LATD	74	DEG

[2] Though the definitions remain the same, six of the first forty words most probably will be changed (numerically) on the extended BET. These are V_A, γ_A, ψ_A, σ_A, β_A and α_A. As well, words 23-25 (geographic wind components) most probably will. It is expected that the ENTREE BET will be generated without incorporating any winds whatsoever. Thus the atmospheric relative and wind relative parameters written on the ENTREE BET will be identical. Further, u_w, v_w and w_w will be written as zeros. These data will be changed in the reformatted version to reflect the atmospheric winds as dictated by the LAIRS file.

HEADER WORD	Alphanumeric label	HEADER WORD	UNITS
9	LONG	75	DEG
10	SIGMAA	76	DEG
11	BETAA	77	DEG
12	ALPHAA	78	DEG
13	YAW E	79	DEG
14	PTCH E	80	DEG
15	ROLL E	81	DEG
16	U	82	M/SEC(FT/SEC)
17	V	83	M/SEC(FT/SEC)
18	W	84	M/SEC(FT/SEC)
19	VEL R	85	M/SEC(FT/SEC)
20	GAM R	86	DEG
21	HDG R	87	DEG
22	SIGMA R	88	DEG
23	BETA R	89	DEG
24	ALPHA R	90	DEG
25	U-WIND	91	M/SEC(FT/SEC)
26	V-WIND	92	M/SEC(FT/SEC)
27	W-WIND	93	M/SEC(FT/SEC)
28	SIG-VA	94	M/SEC(FT/SEC)
29	SIG-GA	95	DEG
30	SIG-HA	96	DEG
31	SIG-H	97	METERS (FEET)
32	SIG-LA	98	DEG
33	SIG-LO	99	DEG
34	SIG-SA	100	DEG
35	SIG-BA	101	DEG
36	SIG-AA	102	DEG
37	SIG-YE	103	DEG
38	SIG-PE	104	DEG

HEADER WORD	Alphanumeric label	HEADER WORD	UNITS
39	SIG-RE	105	DEG
40	SIG-U	106	M/SEC(FT/SEC)
41	SIG-V	107	M/SEC(FT/SEC)
42	SIG-W	108	M/SEC(FT/SEC)
43	MACH A	109	NONE
44	MACH R	110	NONE
45	PINF	111	NEWTON/M2(PSF)
46	TEMP	112	DEG KELVIN(DEG RANKIN)
47	RHO	113	KG/M3(SLUGS/FT3)
48	Q A	114	NEWTON/M2(PSF)
49	Q R	115	NEWTON/M2(PSF)
50	PSTAG	116	NEWTON/M2(PSF)
51	P	117	DEG/SEC
52	Q	118	DEG/SEC
53	R	119	DEG/SEC
54	X ACCEL	120	M/SEC/SEC(FT/SEC/SEC)
55	Y ACCEL	121	M/SEC/SEC(FT/SEC/SEC)
56	Z ACCEL	122	M/SEC/SEC(FT/SEC/SEC)
57	CXB	123	NONE
58	CYB	124	NONE
59	CZB	125	NONE
60	CL	126	NONE
61	CD	127	NONE
62	L/D	128	NONE
63	CL-ROLL	129	NONE
64	CM-PITCH	130	NONE
65	CN-YAW	131	NONE
66	PDOT	132	DEG/SEC2
67	QDOT	133	DEG/SEC2
68	RDOT	134	DEG/SEC2

Beyond these words only eight(8) words are usually provided for in the standard TIFT read. The extended BET file uses a forty-eight(48) word narrative header followed by five(5) words which define planet parameters and the units utilized throughout. Specifically, this extended header is written as:

HEADER WORDS	Description
135 - 182	Narrative uniquely defining the BET
183	Units designator: 1, metric 2, English
184	Epoch, time of day of entry in GMT seconds
185	Earth equatorial radius in units defined by word (183)
186	Earth polar radius in units defined by word (183)
187	Earth spin rate in rad/sec

As necessary, the year-month-day of entry and number of records[(3)] on the file can be extracted by encoding the first two of the narrative words (i.e., header words 135 and 136). Also, the first 40 words of the 48 word narrative are as written on the ENTREE BET. The additional 8 words are provided for to define the source for the atmospheric data used in generation of the extended BET.

---

(3) The number of records on this extended file may differ from the number on the baseline ENTREE BET. The software, NEWBET, is structured to output an extended format BET within a pre-selected altitude range as described in Section IV of this report. Obviously, the most probable use is to extend the entire ENTREE BET to include the additional words. However, there may be regions of interest (altitude spans) where one might want to investigate various atmospheric profiles. Also it should be pointed out that sample LAIRS files used to date lacked the final data record which causes the header word to be off by one (1).

<u>Data Records</u>

Word	Item	Definition	Units
1	T	elapsed integration time from Epoch	seconds
2	V_A	spacecraft velocity with respect to the atmosphere	mps, fps
3	γ_A	flight path angle of V_A, positive oriented above the horizon	degrees
4	Ψ_A	heading angle of V_A, positive clockwise from North	degrees
5	h	altitude above the oblate Earth	m, ft
6	Φ_D	geodetic latitude	degrees
7	λ	longitude with respect to Greenwich prime meridian, positive East	degrees
8	σ_A	spacecraft attitude with respect to the V_A, ordered as: σ_A, roll about V_A (+right wing down)	degrees
9	β_A	β_A, side-slip angle (+ nose left)	degrees
10	α_A	α_A, angle-of-attack (+ nose up)	degrees
11	ψ	Euler angles orienting body axes to local vertical, ordered as: ψ, yaw (+CW from North)	degrees
12	θ	θ, pitch (+ above horizontal)	degrees
13	φ	φ, roll (+ about X-body axis for right wing down)	degrees
14	u	North component of spacecraft's inertial velocity (+ Northward)	mps, fps
15	v	East component of spacecraft's inertial velocity (+ Eastward)	mps, fps
16	w	vertical component of spacecraft's inertial velocity (+ downward)	mps, fps

Word	Item	Definition	Units
17	V_R	spacecraft velocity with respect to Earth	mps, fps
18	γ_R	flight path angle of V_R, + above the horizon	degrees
19	Ψ_R	heading angle of V_R, + CW from North	degrees
20	σ_R	spacecraft attitude with respect to Earth relative velocity ordered as:	degrees
21	β_R	σ_R, relative roll angle (+ right wing down) β_R, relative side-slip angle (+nose left)	degrees
22	α_R	α_R, relative angle-of-attack (+nose up)	degrees
23	u_W	North component of atmospheric wind (+ Southward)	mps, fps
24	v_W	East component of atmospheric wind (+ Westward)	mps, fps
25	w_W	vertical component of atmospheric wind (+ upward)	mps, fps
26	σ_{V_A}*	formal (1σ) standard deviation of V_A estimate (or V_R)	mps, fps
27	σ_{γ_A}*	formal (1σ) standard deviation of γ_A estimate (or γ_R)	degrees
28	σ_{Ψ_A}*	formal (1σ) standard deviation of Ψ_A estimate (or Ψ_R)	degrees
29	σ_h	formal (1σ) standard deviation of altitude estimate	m, ft
30	σ_{Φ_D}	formal (1σ) standard deviation of geodetic latitude estimate	degrees
31	σ_λ	formal (1σ) standard deviation of longitude estimate	degrees
32	σ_{σ_A}*	formal (1σ) standard deviation of σ_A (or σ_R) estimate	degrees
33	σ_{β_A}*	formal (1σ) standard deviation of β_A (or β_R) estimate	degrees
34	σ_{α_A}*	formal (1σ) standard deviation of α_A (or α_R) estimate	degrees

Word	Item	Definition	Units
35	σ_ψ	formal (1σ) standard deviation of Euler ψ (yaw) estimate	degrees
36	σ_θ	formal (1σ) standard deviation of Euler θ (pitch) estimate	degrees
37	σ_φ	formal (1σ) standard deviation of Euler φ (roll) estimate	degrees
38	σ_u	formal (1σ) standard deviation of estimate of North component of inertial velocity	mps, fps
39	σ_v	formal (1σ) standard deviation of East component of inertial velocity	mps, fps
40	σ_w	formal (1σ) standard deviation of estimate of vertical component of inertial velocity	mps, fps
41	M_A	Mach No. (with winds)	N/A
42	M_R	Mach No. (no winds)	N/A
43	P_∞	atmospheric pressure	newtons/m^2, psf
44	T	atmospheric temperature	^oK, ^oR
45	ρ	atmospheric density	kg/m^3, slugs/ft^3
46	q_A	dynamic pressure (with winds)	newtons/m^2, psf
47	q_R	dynamic pressure (no winds)	newtons/m^2, psf
48	P_S	stagnation pressure	newtons/m^2, psf
49	P_B	roll rate	deg/sec
50	Q_B	pitch rate	deg/sec
51	R_B	yaw rate	deg/sec

Word	Item	Definition	Units
52	A_{X_B}	acceleration along x-body axis	m/sec^2, ft/sec^2
53	A_{Y_B}	acceleration along y-body axis	m/sec^2, ft/sec^2
54	A_{Z_B}	acceleration along z-body axis	m/sec^2, ft/sec^2
55	C_{X_B}	x-body force coefficient	N/A
56	C_{Y_B}	y-body force coefficient	N/A
57	C_{Z_B}	z-body force coefficient	N/A
58	C_L	lift coefficient	N/A
59	C_D	drag coefficient	N/A
60	L/D	lift-drag ratio	N/A
61	C_ℓ	total rolling moment coefficient	N/A
62	C_m	total pitching moment coefficient	N/A
63	C_n	total yawing moment coefficient	N/A
64	$\dot{P}_B$	angular acceleration about the x-body axis	deg/sec^2
65	$\dot{Q}_B$	angular acceleration about the y-body axis	deg/sec^2
66	$\dot{R}_B$	angular acceleration about the z-body axis	deg/sec^2

*NOTE: Formal uncertainties are written for these parameters. Any uncertainties associated with the assumed winds, even if given, are not utilized.

III. Auxiliary Equations

A brief summary of some of the relevant equations incorporated in developing the extended BET is presented. A more comprehensive treatment can be found in Ref. 2. Fig. 1 is attached to show some of the coordinate system definitions.

On option, e.g., when an ENTREE BET is generated with a zero wind assumption (which appears to be the most probable situation), wind information from a LAIRS file may be employed. As suggested previously, not only does the inclusion of winds influence many of the additional 26 parameters but it also causes 6 of the first 40 words to be regenerated. This is done as follows:

$$\begin{aligned} u_A &= u + u_W \\ v_A &= v + v_W - |r|\Omega \cos \Phi_c \\ w_A &= w + w_W \end{aligned} \tag{1}$$

Here, u_W, v_W and w_W are the <u>negatives</u> of the values selected from the LAIRS file. These terms, also re-written as data words 23-25, are defined as positive Southward (from the North), positive Westward (from the East), and positive upward (from the direction of the planet surface).

The geocentric latitude, Φ_c, is computed from the geodetic latitude (data word 6) and the two planet radii on the header (header words 185 and 186), viz:

$$\Phi_c = \tan^{-1} \left(\left(\frac{R_P}{R_E}\right)^2 \tan \Phi_D \right) \tag{2}$$

Also, $|r|$, which is the magnitude of the radius vector from the center of the planet to the spacecraft is:

$$|r| = R_L + h \tag{3a}$$

where R_L is the local planet radius at the sub-vehicle point, i.e.:

$$R_L = \frac{R_E}{\sqrt{1 + \left\{ \left(\frac{R_E}{R_P}\right)^2 - 1 \right\} \sin^2 \Phi_c}} \tag{3b}$$

Given the North, East and vertical components of the atmospheric relative velocity from Eqns. (1) it is easy to compute the velocity magnitude and orientation angles to replace data words 2, 3 and 4, respectively.

Thus:

$$V_A = \sqrt{u_A^2 + v_A^2 + w_A^2}$$

$$\gamma_A = \sin^{-1}\left(\frac{-w_A}{V_A}\right) \tag{4}$$

$$\Psi_A = \tan^{-1}\left(\frac{v_A}{u_A}\right)$$

The other three(3) words re-written on option are data words 8, 9, and 10 which are σ_A, β_A and α_A, respectively. Use is made of the Euler angles (data words 11, 12, and 13) to define the G-matrix relating the body axis to local vertical. The atmospheric relative angle-of-attack and sideslip are computed from the body axis components of the atmospheric relative velocity which are readily obtained as:

$$\begin{bmatrix} u_B \\ v_B \\ w_B \end{bmatrix} = G \begin{bmatrix} u_A \\ v_A \\ w_A \end{bmatrix} \tag{5}$$

Thus:

$$\alpha_A = \tan^{-1}\left(\frac{w_B}{u_B}\right)$$

$$\beta_A = \tan^{-1}\left(\frac{v_B}{\sqrt{u_B^2 + w_B^2}}\right) \tag{6}$$

The bank angle, σ_A, with respect to the atmospheric relative velocity vector is computed using elements of the G-matrix and the velocity angles recomputed as Eqns. 4 and 6, viz:

$$\sigma_A = \tan^{-1} \frac{G_{2,3} + \sin\beta_A \sin\gamma_A}{(G_{2,2}\cos\psi_A - G_{2,1}\sin\Psi_A)\cos\gamma_A} \tag{7}$$

For completeness, the G-matrix is given as:

$$G = \begin{bmatrix} c\psi\, c\theta & s\psi\, c\theta & -s\theta \\ -c\varphi s\psi + s\varphi s\theta\, c\psi & c\varphi\, c\psi + s\varphi\, s\theta\, s\psi & c\theta\, s\varphi \\ s\varphi s\psi + c\varphi\, s\theta\, c\psi & -s\varphi\, c\psi + c\varphi\, s\theta\, s\psi & c\theta\, c\varphi \end{bmatrix} \tag{8}$$

where s and c represent sine and cosine, respectively.

This completes the discussion re those parameters which may be overwritten on the extended BET when the LAIRS wind option is incorporated. Beyond this, the remainder of the first 40 words are described sufficiently in Section II and both Refs. 1 and 2 as well. The extended parameters require some additional discussion.

The speed-of-sound is computed from the atmospheric temperature as:

$$c_s = \sqrt{\gamma R T} \tag{9}$$

where γ, $\left(\frac{c_p}{c_v}\right)$, is assumed to be 1.4,

$R = 1716.0\ \mathrm{ft}^2/\mathrm{sec}^2\ {}^\circ R$

and T is in degrees Rankine.

Both Mach numbers can be computed from (9) as:

$$M_A = V_A / c_s$$
$$M_R = V_R / c_s \tag{10}$$

Atmospheric pressure and density are both obtained from the defined atmosphere. Two dynamic pressures are computed, one with and one without the winds, viz:

$$q_A = \tfrac{1}{2} \rho V_A^2$$
$$q_R = \tfrac{1}{2} \rho V_R^2 \tag{11}$$

Stagnation pressure is derived from the following computed pressure ratio, again assuming $\gamma = 1.4$. (See Ref. 3)

$$\underline{M_A \leq 1.0}$$
$$\frac{P_\infty}{P_{STAG}} = (1.0 + M^2/5)^{-3.5}$$
$$\underline{M_A > 1.0} \tag{12}$$
$$\frac{P_\infty}{P_{STAG}} = \left(\frac{5}{6 M^2}\right)^{3.5} \left(\frac{7 M^2 - 1}{6}\right)^{2.5}$$

Body axis rates and accelerations are read from the input dynamic data file. The source for these data can be either the tri-redundant IMU measurements or the ACIP data. For the former, derived body axis rates and accelerations from the IMU measurements of $\Sigma \Delta V_{M50}$ and quaternions (platform to outer roll gimbal) are used as discussed in Ref. 4. The ACIP data are strapped-down instruments and require no special pre-processing apart from the usual instrument calibrations, e.g., bias determination, scale-factor refinements, etc.

Two points worthy of mention are:

(1) The same dynamic data file (calibrated or rectified as determined in the post-flight data processing) used to generate the ENTREE BET must be incorporated in the generation of the extended format,

and (2) Given a reasonable time spacing on the BET (typically $1\overset{s}{.}0$), linear interpolation of these data at smaller intervals should be avoided.

First-order estimates of the in situ aerodynamic coefficients for the Shuttle are next determined. Body axis force coefficients (C_{X_B}, C_{Y_B}, C_{Z_B}) can be obtained directly from the accelerometry.

$$
\begin{aligned}
C_{X_B} &= \frac{m\, A_{X_B}}{q_A\, S} \\
C_{Y_B} &= \frac{m\, A_{Y_B}}{q_A\, S} \qquad (13) \\
C_{Z_B} &= \frac{m\, A_{Z_B}}{q_A\, S}
\end{aligned}
$$

S is the aerodynamic reference area and the mass, m , is computed from:

$$
m = \frac{Wgt}{\dfrac{\mu_{\oplus}}{|r|^2}} \qquad (14)
$$

The coefficients, C_{X_B} and C_{Z_B}, are rotated through α_A to compute the lift and drag coefficients as well as the lift to drag ratio.

$$
\begin{aligned}
C_L &= C_{X_B} \sin\alpha_A - C_{Z_B} \cos\alpha_A \\
C_D &= -C_{X_B} \cos\alpha_A - C_{Z_B} \sin\alpha_A \qquad (15)
\end{aligned}
$$

and $L/D \equiv C_L/C_D$

The moment coefficients computed are the total moment coefficients. Assumed herein are:

(1) The x-z plane is a plane of symmetry

and (2) the mass (and inertias) are constant.

The rolling moment coefficient, C_ℓ , is given by the following expression (Ref. 5):

$$C_\ell = \frac{(\dot{P} I_{xx} - \dot{R} I_{xz} + QR (I_{zz} - I_{yy}) - PQ I_{xz})}{q_A S b} \tag{16a}$$

Similarly, the total pitching and yawing moment coefficients are computed as:

$$C_m = \frac{(\dot{Q} I_{yy} + PR (I_{xx} - I_{zz}) - R^2 I_{xz} + P^2 I_{xz})}{q_A S c} \tag{16b}$$

and

$$C_n = \frac{(\dot{R} I_{zz} - \dot{P} I_{xz} + PQ (I_{yy} - I_{xx}) + QR I_{xz})}{q_A S b}$$

Here, the span, b, is used to normalize the roll and yaw moment coefficients and the chord, c, is used for pitch. For information, mass properties and reference dimensions used for STS-1 are:

Wgt	=	198262.7 lbs
S	=	2690.0 ft^2
b	=	78.057 ft
c	=	39.567 ft
I_{xx}	=	895699.5 slug-ft^2
I_{yy}	=	6920417.1 slug-ft^2
I_{zz}	=	7201452.7 slug-ft^2
I_{xz}	=	168393.3 slug-ft^2
I_{xy}	=	4527.7 slug-ft^2
I_{yz}	=	2193.3 slug-ft^2

Certainly the assumption that the x-z plane is a plane of symmetry is justifiable from the magnitude of the cross-product moments of inertia, I_{xy} and I_{yz}. However, I_{xz} is not negligible and suggests that the principal axes differ from the body axes by ~ 1.5 deg.

A major limitation of the derived aerodynamic coefficients is that the computed values reflect total quantities (which also include reaction jet contributions which are not extracted at this point) and thus, the contributions, i.e., from speed-brakes, elevons, etc., are not separable. Further, noise on the acceleration and gyro data, when significant relative to the signal, will induce spurious (noisy) computations of the coefficients. Some of this is eliminated by negating any aerodynamic coefficient computations above a selected altitude threshold (typically 350,000 ft.). Finally, computation of the moment coefficients requires numerical differentiation of the body rates which can produce further spurious signal on the outputs. Nevertheless, these additional parameters should be helpful as a starting basis for post-flight aerodynamic determinations (ACME).

IV. Software Description

This section discusses the NEWBET utility which enables the generation of the extended parameter BET.

(a) File description

File inputs are as follows:

	TAPE 1	-	40 Word ENTREE BET as described in Ref. 1,
	TAPE 2	-	Dynamic Data File either derived body axis from the IMU's[4] or strapped-down ACIP data,
and, on option,	TAPE 3	-	LAIRS file.

Though the LAIRS file format is documented in Ref. 6 it is perhaps worthwhile to review here: This file is not a TIFT format. The first record is an eight(8) word alphanumeric header. The next record consists of four words which are:

(1) an identification number

(2) year-month-date of entry

(3) hours-min-sec

(4) number of time points

Each ensuing data record contains twenty-six(26) words. These are (1) geodetic altitude, (2) latitude, (3) longitude, (4) time (GMT), (5) local solar time, (6) temperature, (7) pressure, (8) density, (9) East-West wind velocity, (10) North-South wind velocity, (11) total horizontal wind speed, (12) direction the wind is coming from, positive clockwise from North, (13) estimated altitude uncertainty, (14) estimated latitude uncertainty, (15) estimated longitude uncertainty, (16) estimated time uncertainty (GMT), (17) estimated uncertainty in local solar time, (18) estimated temperature uncertainty, (19) estimated pressure uncertainty, (20) estimated density uncertainty, (21) estimated East-West wind uncertainty, (22) estimated North-South wind

[4] If IMU data are used, platform data, properly calibrated for any determined error coefficients (e.g. from ENTREE processing) and center-of-gravity location are rotated externally to create the required body-axis data.

uncertainty, (23) estimated uncertainty in wind speed, (24) estimated uncertainty in wind direction, (25) mean molecular weight, and (26) pressure scale height. Units are metric with altitude, altitude uncertainty and scale-height given as kilometers, all angular quantities in degrees, wind velocities in meters/sec, temperature and associated uncertainty in deg K, pressure in newtons/m^2 and density in kg/m^3. Only the wind components, temperature pressure and density are utilized from the file.

The output file, TAPE 4, is the extended BET file as described in Section II of this report.

(b) User inputs

A namelist input (NAMELIST/SWITCH/) is provided for. Parameters in the input list are defined as follows:

Variable	Size	Type	Description	Default values
LAIR	1	integer	flag controlling atmosphere selection 0, LAIRS file (Tape 3) 1, AT62 (from FTNML1B on LaRC system)	0
IDIAG	1	integer	diagnostic print flag: 1, print 0, do not print	0
IWIND	1	integer	wind selection flag: 1, use LAIRS winds 0, do not use LAIRS winds	1
SREF	1	real	aerodynamic reference area	2690.0 ft^2
SMASS	1	real	Shuttle weight	198262.7 lbs
SPAN	1	real	reference span for roll and yaw moment coefficients	78.057 ft
CHORD	1	real	reference chord for pitching moment coefficient	39.567 ft
EMUP	1	real	Earth's central mass	1.407646853E16 ft^3/sec^2
IXX	1	real	moment of inertia about the X-body axis	895699.5 slug-ft^2
IYY	1	real	moment of inertia about the Y-body axis	6920417.1 slug-ft^2

Variable	Size	Type	Description	Default Value
IZZ	1	real	moment of inertia about the Z-body axis	7201452.7 slug-ft^2
IXY	1	real	X-Y cross product of inertia	4527.7 slug-ft^2
IXZ	1	real	X-Z cross product of inertia	168393.3 slug-ft^2
IYZ	1	real	Y-Z cross product of inertia	2193.3 slug-ft^2
TALT	1	real	threshold altitude above which no aerodynamic coefficients are determined	350000. ft
ALTMIN	1	real	minimum altitude below which the extended BET formatting is terminated	0. ft
ALTMAX	1	real	maximum altitude above which no extended BET formatting is done	600,000. ft
TFINAL	1	real	final time to compute aerodynamic coefficients and incorporate LAIRS winds	2300. sec

Formatted Inputs

The additional eight(8) words of the narrative on the header record can be input via formatted card type. The entire eighty(80) column card image is encoded internally as 8A10. This card input is provided for to enable insertion of the date the BET file (from ENTREE) was reformatted, the atmosphere utilized (e.g., the vintage LAIRS file), and any other relevant qualifiers which can be included in the available space. As indicated previously, most readers will not see these data unless their software is specifically set up to accommodate the larger header record. Though it is not necessary to do so, it is recommended.

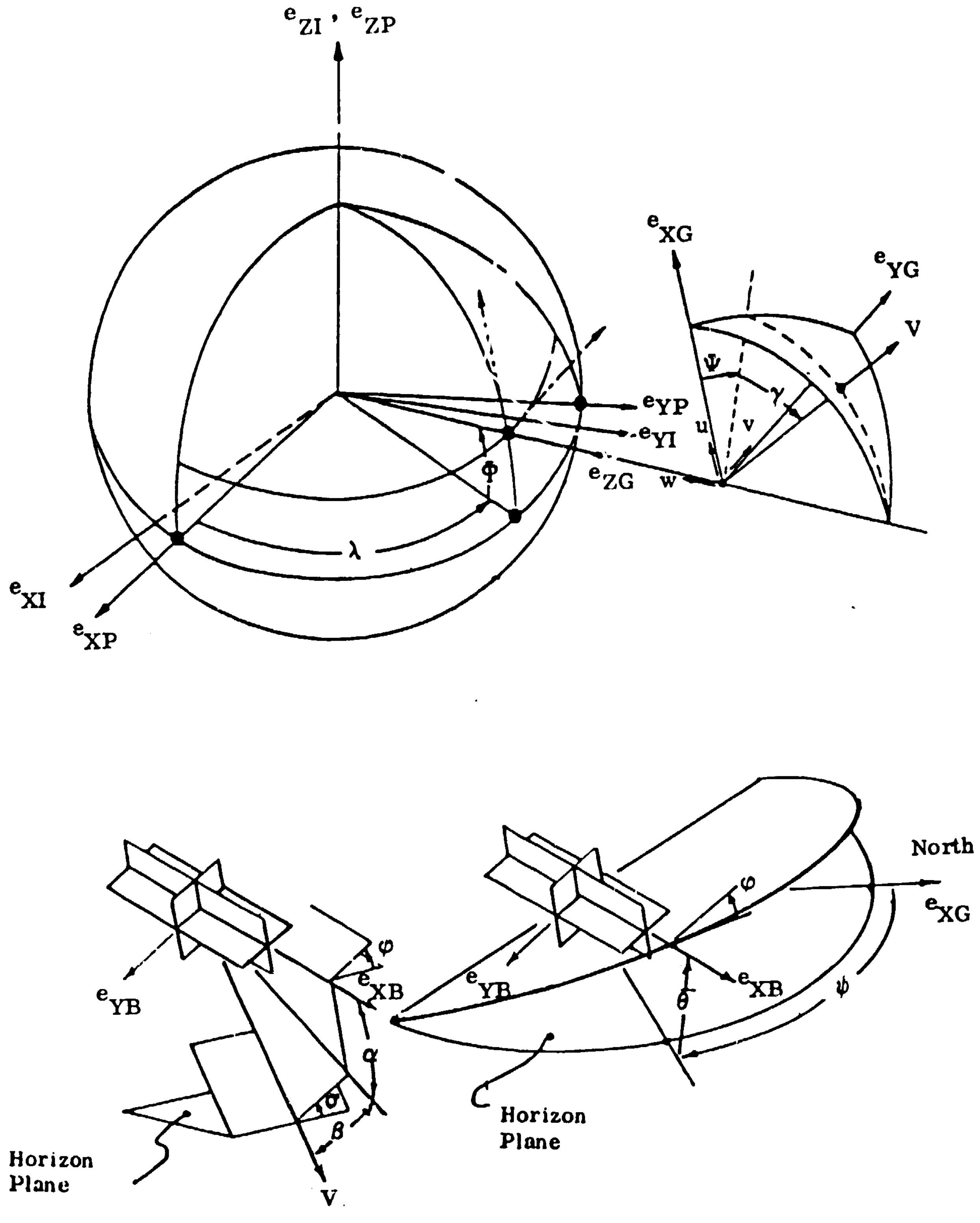
This concludes the input description. In review, to generate the extended format BET the software is structured to:

(1) utilize a LAIRS (or AT62) atmosphere within a specified altitude span,

(2) incorporate LAIRS winds on option,

(3) compute aerodynamic coefficients below a threshold altitude down to a pre-selected time,

(4) incorporate a calibrated dynamic data file to assure the proper body axis rates and accelerations are appended to the file.



(a) σ , β , α System

(b) ψ , θ , φ System

Figure 1 Schematic of Earth, velocity, and spacecraft attitude parameters on BET

REFERENCES

1. Findlay, J. T., "Best Estimate Trajectory (BET) File for Shuttle Experimenters," AMA Report No. 81-1 (under NASA Contract NAS1-16087), Hampton, Virginia: Analytical Mechanics Associates, Inc., January 1981.

2. Waligora, S. R. and Mittleman, J. P., "Entry Trajectory Estimation (ENTREE) Program Description and User's Guide", CSC/SD-79/6145, prepared for NASA LaRC under Contract No. NAS1-15663, November 1979.

3. Equation, Tables, and Charts for Compressible Flow, NACA Report 1135, by Ames Research Staff, 1953.

4. Heck, Dr. M. L., "The Processing of IMU Data in ENTREE-Implementation and Preliminary Results", AMA Report No. 80-23, prepared for NASA LaRC under Contract No. NAS1-16087, October 1980.

5. Dynamics of the Airframe, Bu Aer Report AE-61-4 II, prepared by Servomechanisms Section and Aerodynamics Section of Northrop Aircraft, Inc., September 1952.

6. Brender, K. D., STS-1 Postflight Output Files (Change No. 1 dated April 13, 1981) prepared by OEX Data Manager, Space Systems Division of NASA LaRC, March 1981.