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NASA Contractor Report **189569**

Final STS-35 "Columbia" Descent BET Products and Results for LaRC OEX Investigations

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CONTRACT NAS1-18937
November 1991

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PREFACE

This is the first Orbiter Experiments (OEX) flight since the Challenger accident for which FM&C has been enjoined under Task Agreement Contract NAS1-18937 to provide NASA Langley Research Center (LaRC) with research quality descent Best Estimate Trajectory products. FM&C's prior efforts, as subcontractor to the Bionetics Corporation on their LaRC Contract NAS1-18267, involved archival and development of the trajectory reconstruction software, ENTREE, and the associated pre- and post-processing tools to enable this continued activity. The ENTREE System of Software, Reference 1 herein, was published as a comprehensive user's manual and the various output files were rigorously redefined to facilitate researchers in their post-flight data reduction activities. It is noted that the report was intended to be published as a four part manual but the tracking data pre-processors, planned as Part II, were never published since the ground tracking data interface had never been re-established after the stand-down. However, the file structure enabling use of the C-band tracking data via Johnson Space Center (JSC) has since been defined. In fact, sample data were obtained from the previous OEX flight (STS-32) as part of the software development and check-out. Consequently, FM&C was able to generate BET products for this earlier flight. This additional information has been made available to LaRC. We will publish these results, resources permitting, after completion of the next planned OEX flight, STS-40.

It should also be noted that our efforts on these two flights involved the first use of coherent Doppler data from the Tracking and Data Relay Satellite System (TDRSS) during descent to enable BET generation. This capability was developed for the Aeroassist Flight Experiment (AFE) project, more specifically, in support of the Aerodynamic Performance Experiment (APEX). These data provide an excellent alternative since ground-based S-band tracking data are no longer expected to be available via the Ground Spaceflight Tracking and Data Network (GSTDN) during descent. The support of the past (Mr. Chris Cerimele, EG3) and current (Mr. Matt Ondler, EG3) APEX Principal Investigator (PI) at JSC in the development of this capability is acknowledged. In addition, Mr. Paul Siemers of NASA LaRC must be acknowledged for his interest and support of this effort, both as Principal Investigator for the OEX Shuttle Entry Air Data System (SEADS), as well as his more recent dual role as AFE Project Scientist and co-PI on the Pressure Data/Air Data System (PD/ADS) experiment for that project. Also, the support of the LaRC OEX Data Manager (Ms. Joanne Hudgins) and her supporting Unisys contractors (Messrs. Glenn Bittner and Jim Rowe) is acknowledged. The efforts of these latter persons assured the prompt delivery and conversion of the necessary input data products received from JSC.

Finally, pursuant to the tracking data, one must acknowledge the support provided by JSC as well as the continued support by Goddard Space Flight Center (GSFC) personnel in the delivery of the TDRSS data. The C-band data were made available via the JSC BET contractor, RSOC. This activity is headed by Don Cooper, whose team provides operational BETs in support of the Navigation Section of the Orbit Analysis Branch. Consultation provided by Jon Weaver of that Section in resolving the appropriate identification and location for the high-rate Kwajalein station is acknowledged. To that end, the consultation provided by J. J. Blackburn (Bendix contractor at JSC), and both Jerry Wolfe and Pieter Hoffman-Heyden (network operations personnel at Kennedy Space Center) was greatly appreciated. GSFC personnel who have provided both data and invaluable consultations for this and past activities include: Osvaldo Cuevas of the Mission and Network Support Section (Code 553) and his Section Head, Kate Hartman, for the TDRSS ephemeris; J. A. Jackson, Head of the Trajectory and Tracking Analysis Section (Code 554) for the data delivery; Verna Reamy of Bendix for her invaluable insights; and, both J. B. Joyce (who has since moved on from his previous position as Head, Mission and Network Support Section) and J. Teles (Head, Flight Dynamics Branch) for their past and continued consultations.

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LIST OF SYMBOLS, ACRONYMS AND SUBSCRIPTS

A	acceleration
ADDB	Aerodynamic Design Data Book
ADS	Air Data System (Orbiter side-probes)
AEROBET	Aerodynamic Best Estimate Trajectory
AFE	Aeroassist Flight Experiment
AF'78	1978 Air Force Reference Atmospheres
ALTAIR	ARPA Long-range Tracking, Acquisition and Instrumentation Radar
APEX	AFE Aerodynamic Performance Experiment
ARL	aerodynamic reference line
ARPA	Advanced Research Projects Agency
BET	Best Estimate Trajectory
C	computed tracking observables
C_A	axial force coefficient
C_D	drag coefficient
C_L	lift coefficient
C_m	pitching moment coefficient
C_N	normal force coefficient
CDC	Control Data Corporation
CG	center-of-gravity (also c.g.)
DFRF	NASA Dryden Flight Research Facility
EAFB	Edwards Air Force Base
EFFC	FPS-16 C-band radar at EAFB (see Table 2, p. 14)
EI	entry interface
ENTREE	Entry Trajectory Estimation Program
F	flight computed aerodynamic parameter
FAD	Flight Assessment Deltas
FM&C	Flight Mechanics and Control, Inc.
FPS	C-band radar type
fps	feet per second
FRCC	FPS-16 C-band radar at NASA DFRF (see Table 2, p. 14)
FRFC	FPS-16 C-band radar at NASA DFRF (see Table 2, p. 14)
g	gravitational acceleration
GMT	Greenwich Mean Time
GRAM	MSFC Global Reference Atmospheric Model
GSFC	NASA Goddard Space Flight Center
GSTDN	Ground Spaceflight Tracking and Data Network
h	altitude above Fischer ellipsoid (ALTDE in Appendix B)
HAIR	High Accuracy Instrumentation Radar
HiRAP	High Resolution Accelerometry Package

LIST OF SYMBOLS, ACRONYMS AND SUBSCRIPTS (continued)

Hz	Hertz (Doppler units, cycles per second)
I	moment (or product) of inertia
IMU	Inertial Measurement Unit
JSC	NASA Johnson Space Center
kft	kilofeet
KMACH	Kwajalein P-Band ALTAIR radar (high-rate, see Table 2 herein)
KMACL	Kwajalein P-Band ALTAIR radar (low-rate, see Table 2 herein)
KPTC	FPQ-14 C-Band radar at Kaena Point, Hawaii
KSC	NASA Kennedy Space Center
LAIRS	Langley Atmospheric Information Retrieval System
LaRC	NASA Langley Research Center
LHDF	down-firing RCS jets, left side
LHUF	up-firing RCS jets, left side
L/D	lift-to-drag ratio
L7	body-axis version of final pre-operational ADDB
M	Mach number (MACH in Appendix B)
MSFC	NASA Marshall Space Flight Center
M50	Mean Equator and Equinox of 1950 inertial coordinate system
NASA	National Aeronautics and Space Administration
N/A	not applicable
NOAA	National Oceanic and Atmospheric Administration
O	tracking measurements
OEX	Orbiter Experiments
OI	Operational Instrumentation
P	roll rate
P	predicted aerodynamic parameter
PI	Principal Investigator
PMFC	FPS-16 C-band radar at Point Mugu, California (see Table 2, p. 14)
ppm	parts per million
PTPC	FPQ-6 C-band radar at Point Pillar, California
Q	pitch rate
q	dynamic pressure (QBAR in Appendix B)
R	yaw rate
RCS	Reaction Control System
REFSMMAT	Reference matrix, stable member to Mean 1950 (Table 1, pp. 4, 5)
RHDF	down-firing RCS jets, right side
RHUF	up-firing RCS jets, right side
RMS	root-mean-square

LIST OF SYMBOLS, ACRONYMS AND SUBSCRIPTS (continued)

R_N	Reynolds number (RNUM in Appendix B)
RSOC	Rockwell Space Operations Company
SEADS	Shuttle Entry Air Data System
SILTS	Shuttle Infrared Leeside Temperature Sensing
SNFC	FPS-16 C-band radar on San Nicolas Island (see Table 2, p. 14)
STS	Space Transportation System
SUMS	Shuttle Upper Atmosphere Mass Spectrometer
S/C	spacecraft
T	atmospheric temperature
t	time from epoch
TDRSS	Tracking and Data Relay Satellite System
TDRS1	supporting satellite during STS-35 mission
TDSR	TDRSS south ground station at White Sands, New Mexico
TPQ	C-band radar type
u	southward wind component
v	westward wind component
VAFB	Vandenberg Air Force Base
VDBC	TPQ-18 C-band radar at VAFB (see Table 2, p. 14)
VDFC	FPS-16 C-band radar at VAFB (see Table 2, p. 14)
VDHC	C-band HAIR radar at VAFB (see Table 2, p. 14)
VDSC	FPS-16 C-band radar at VAFB (see Table 2, p. 14)
V_A	air relative velocity (VEL A, Appendix B)
V_{bar}	hypersonic viscous interaction parameter (VBAR in Appendix B)
V_R	Earth relative velocity
WONG	vehicle weight on nose gear
WOW	vehicle weight on wheels (main gear touchdown)
YAWN	RCS yaw jets firing to produce negative yaw
YAWP	RCS yaw jets firing to produce positive yaw

GREEK SYMBOLS

α	angle-of-attack (ALPHA in Appendix B)
β	sideslip angle (BETA in Appendix B)
γ	flight-path angle (GAM A in Appendix B)
δ	control surface deflection
Δ	denotes difference

GREEK SYMBOLS (continued)

θ	Euler pitch angle
λ	longitude
μ	mean
ρ	atmospheric density
ρ_{C_N}	C_N Shuttle-derived density
ρ_{76}	U.S. 1976 Standard Atmosphere density
σ	roll angle about velocity vector (SIGMA, Appendix B)
σ	standard deviation
ϕ	Euler roll angle
Φ	latitude
ψ	Euler yaw angle
Ψ	heading angle (HDG A in Appendix B)

SUBSCRIPTS

A	aileron
A	air-relative parameter
B	body-axis parameter
b	bias
BF	bodyflap
D	geodetically referenced
E	elevator
R	planet-relative parameter
R_A	rudder, with respect to ARL
SB_A	speedbrake, with respect to ARL
W	weighted parameter
X	x-body axis
Y	y-body axis
Z	z-body axis

SUMMARY

Presented herein are the final post-flight results from the Shuttle Columbia entry segment of the STS-35 mission, the fourth such mission to carry the full complement of the following Orbiter Experiments (OEX); the Shuttle Entry Air-Data System (SEADS), an upper-altitude mass spectrometer (SUMS), an infrared thermal-mapping experiment (SILTS), and the micro-g accelerometer package (HiRAP).

The inertial Best Estimate Trajectory (BET), IBETF35, was obtained based on the considerable C-band tracking data available during the flight, enhanced by the use of coherent 1 Hz TDRSS Doppler measurements available from Entry Interface (EI) to approximately 79 kft. Since no cinetheodolite data were available due to the lighting conditions at landing, processing of pseudo altimeter and Doppler data during roll-out on Runway 22 were also included. Tracking data considerations and problems peculiar to this mission are further discussed in Section I of this report. In summary, resolving the appropriate tracker locations for both the high- and low-rate Kwajalein data, as well as quantifying the apparent bad measurements from the Hawaii and Point Pillar passes are discussed. Other editing considerations, to include inconsistencies between the upper altitude data and the coastal radars, and the rather large C-band angular bias determinations, are discussed as part of the actual trajectory reconstruction (refer to Section I. C). Inertial Measurement Unit (IMU) data processing and the resultant selection of IMU1 as the dynamic data source for the reconstruction are also discussed as part of Section I herein. Though the derived, equivalent body-axis dynamics suggested by each of the IMUs compared well as expected, it is noted that instrument parameters were necessarily included in the final trajectory determination to obtain the best, contiguous, top-down reconstruction.

The Inertial BET solution was anchored at an epoch of 19,200 ^{s} GMT on December 11, 1990. At this epoch, the corresponding altitude was approximately 513 kft. As previously stated, the final estimate required the use of an expanded solution set to obtain a maximum-likelihood estimate that best fit the measurements throughout the entire descent time frame. In addition to solving for the usual Shuttle position, velocity, and attitude at epoch, three accelerometer scale-factors and three gyro biases were incorporated. The expanded state was necessary, even after inclusion of the aforementioned C-band biases, because the more simple, state-only estimate did not yield a reasonable fit to the entire complement of tracking data. Section I. C herein presents further details as to the nature of and goodness-of-fit obtained for the final estimate.

The only available STS-35 atmospheric data source was the National Oceanic and Atmospheric Administration (NOAA) "totem-pole" profile data usurped from the Johnson Space Center (JSC) BET generated by RSOC. Upper altitude density comparisons between Shuttle-derived results and model data were made to substantiate the NOAA profile. This atmosphere was utilized for the generation of both the Extended BET (EBETF35) and the Aerodynamic BET (ABETF35). Extended BET discussions are included in Section II of this report.

In Section III, AEROBET considerations and development of same are discussed. Summary results are presented in Section IV. Shown are Shuttle configuration data and longitudinal aerodynamic performance comparisons. For the latter, percentage differences between the flight-derived and predicted coefficients are shown, where the predicted results are based on the final pre-operational data book values. In some instances, configuration data and aerodynamic comparisons are correlated versus past ensemble results from previous Shuttle entry flights, up to and including STS 61-C, the first OEX mission. Where aerodynamic performance comparisons are presented versus the equivalent flight-derived parameters, the predicted coefficients based on the final pre-operational databook are updated based on the final published Flight Assessment Deltas (FAD26).

The Inertial BET, Extended BET, and AEROBET are all available to LaRC researchers as semi-private files under User Catalog 274885C on the NASA LaRC Control Data Corporation (CDC) computers. Due to size considerations, the AEROBET is a direct access file whereas the other two files are indirect access files. Two Appendices are included which present the final tracking data residual plots (Appendix A) and a listing of relevant AEROBET state vector and air-data parameters (Appendix B).

I. INERTIAL TRAJECTORY RECONSTRUCTION

I. A. DYNAMIC DATA PROCESSING

The OI-1 data containing the tri-redundant IMU data for this flight were received from LaRC (converted by Unisys for CDC use) as nine-track physical reel NX0513. These data were reformatted using PREOI1 and edited using the PRETMS utility prior to deriving the equivalent "strapped-down" data using the PREIMUS cubic-spline algorithms. Readers can refer to the software discussions presented in Part I of the ENTREE System of Software user's manual (Reference 1) for further insights as to the need for, and extent of, IMU pre-processing.

It is noted herein that the data for this flight were essentially devoid of any significant time gaps, apart from the occasional 1.12 and 1.92 second skips that are expected due to the incompatability between the downlist rate and the fundamental 6.25 Hz operating frequency of the IMUs. Though each IMU compared favorably, IMU1 was selected as the source for STS-35 reconstruction. This choice was substantiated by comparing the equivalent body-axes data derived from the accumulated sensed velocity changes and attitude quaternions separately measured by each IMU during entry. Differences between the equivalent (derived) body-axes data from the three sources are presented in Figures I-1 through I-3. Figure I-1 shows the differences (derived at the IMU downlist rate for this analysis) between IMU1 and IMU2. Annotated thereon are the computed mean (μ) and standard deviation (σ) in the differences for each component. Similarly, Figure I-2 shows comparisons between the derived IMU1 and IMU3 results, and Figure I-3 depicts similar results between IMU2 and IMU3. Time zero on these plots corresponds to the selected processing epoch for this mission (19,200 GMT seconds). It can be seen that there are only subtle discrepancies between the various IMUs. For the most part, though certainly not critical, the isolated "spikes" can be identified as more germaine to the data from IMU2 and IMU3, indicating that the data from IMU1 were better.

As information, Figure I-4 is included to show the actual body-axes rates and accelerations derived from the IMU1 measurements. Presented are the spacecraft roll rate (P_B), pitch rate (Q_B), yaw rate (R_B), and accelerations along the X, Y, and Z body axes. These data are plotted from epoch throughout the entire entry phase, subdivided into three 700 second intervals to show the ongoing dynamics. It is noted that the acceleration data shown thereon are below the IMU measurement threshold ($\approx$ 1 milli-g) for the first 300 seconds.

For completeness, as well as satisfy archival requirements, the following table (Table 1) is included which defines the various IMU matrices for STS-35. These are the Columbia orbiter-unique transformation between the navigation base and the body axes, and the IMU specific matrices which define transformations between the navigation base and the outer roll gimbal (the stable member) and the so-called REFSMMATs which orient the stable platform to the inertial M50 system. Inspection of these matrices indicates that both IMU 1 and 3 were changed-out since the last Columbia mission (STS-32). Again, readers are referred to Part I of Reference 1 for more information concerning the rigorous IMU treatment utilizing these matrices.

Navigation base to body matrix

0.982956500000	0.000436332300	- 0.183837900000
- 0.000452950800	0.999999900000	- 0.000048404800
0.183837900000	0.000130849300	0.982956600000

Navigation base to outer roll gimbal matrices

IMU1

0.999999615063	0.000834364233	- 0.000271495562
- 0.000834364202	0.999999651918	0.000000226526
0.000271495657	0.000000000000	0.999999963145

IMU2

0.999995413970	0.002305187539	0.001961801379
- 0.002305210043	0.999997338223	0.000009252310
- 0.001961774830	- 0.000013774632	0.999998075741

IMU3

0.999991103679	0.004149357326	- 0.000754459966
- 0.004149344094	0.999991388317	0.000019031280
0.000754532435	- 0.000015900597	0.999999715378

Table 1. IMU matrices for STS-35.

Reference matrices: stable member to Mean of 1950

IMU1

0.051770310849	- 0.757755279541	0.650481879711
- 0.259236693382	0.618830084801	0.741515696049
- 0.964425265789	- 0.207017302513	- 0.164400935173

IMU2

- 0.772230446339	0.147799253464	0.617912113667
0.564199090004	- 0.287655889988	0.773907840252
0.292129099369	0.946260750294	0.138748407364

IMU3

0.408958375454	0.401200652122	0.819628596306
- 0.616607129574	- 0.540627181530	0.572291731834
0.672717332840	- 0.739432334900	0.026289150119

Table 1. IMU matrices for STS-35 (concluded).

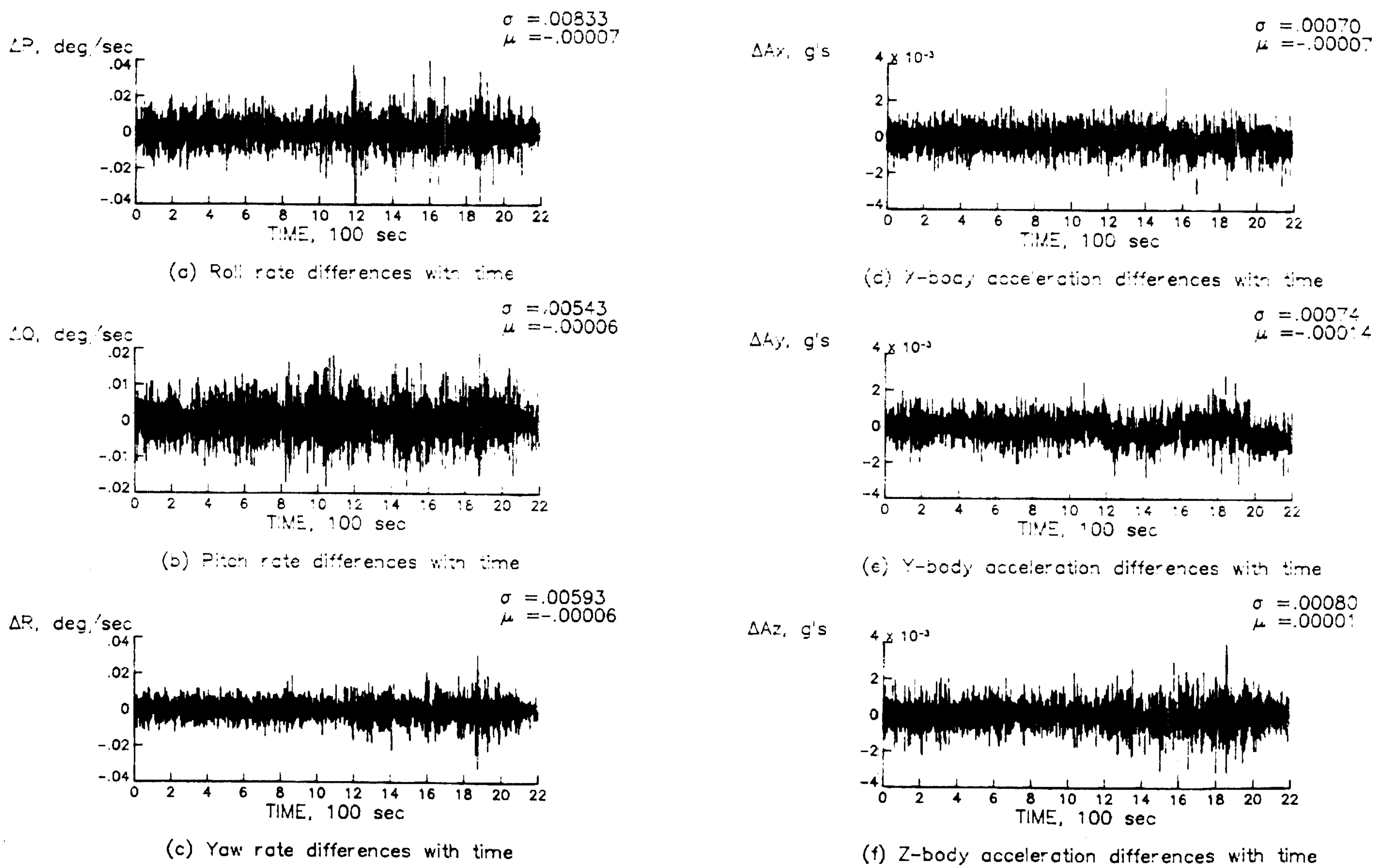

Figure I-1. Differences in derived body-axis dynamics, IMU1 - IMU2.

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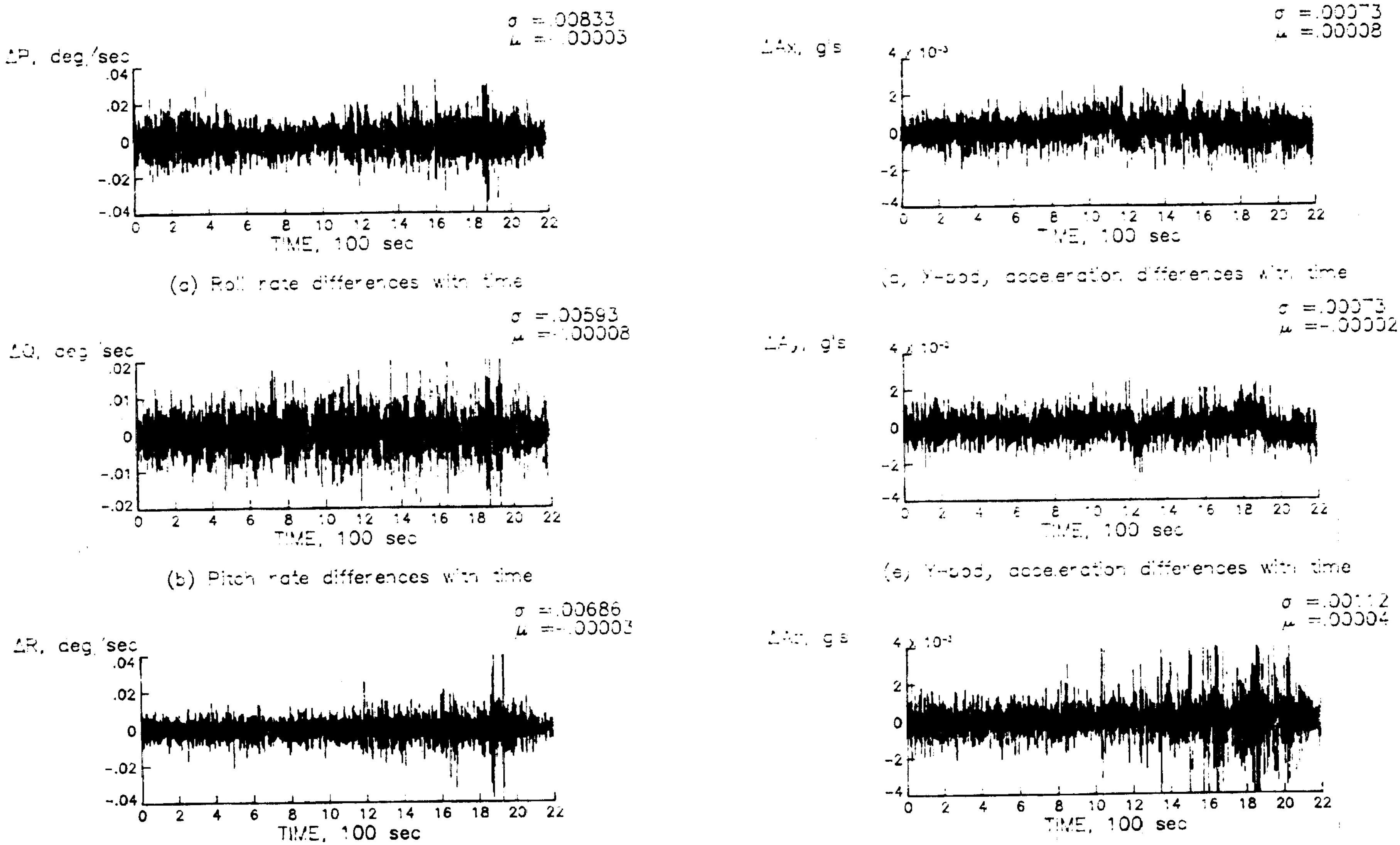

(a) Roll rate differences with time

(b) Pitch rate differences with time

(c) Yaw rate differences with time

(d) X-body acceleration differences with time

(e) Y-body acceleration differences with time

(f) Z-body acceleration differences with time

Figure I-2. Differences in derived body-axis dynamics, IMU1 - IMU3.

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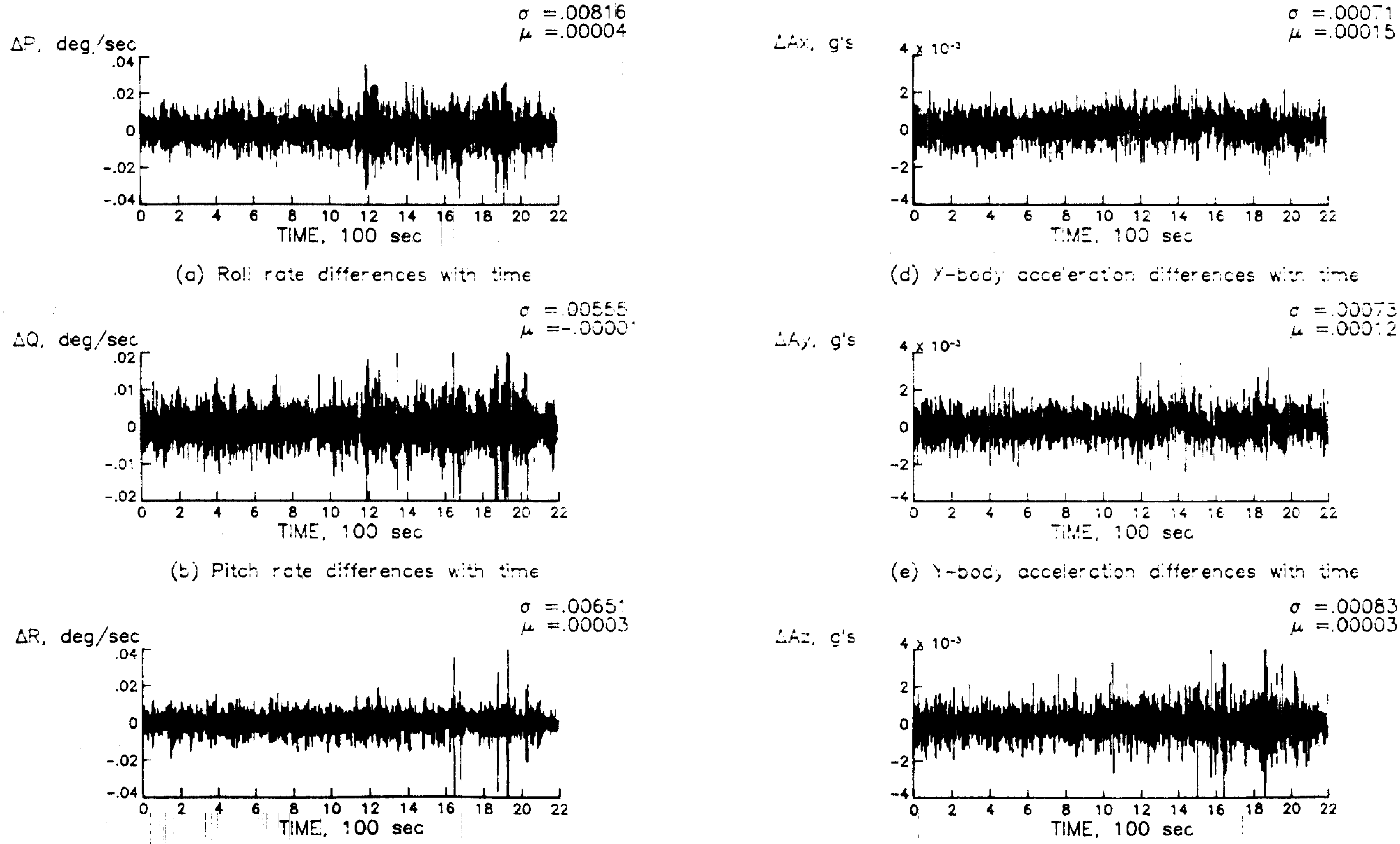

(a) Roll rate differences with time

(b) Pitch rate differences with time

(c) Yaw rate differences with time

(d) X-body acceleration differences with time

(e) Y-body acceleration differences with time

(f) Z-body acceleration differences with time

Figure I-3. Differences in derived body-axis dynamics, IMU2 - IMU3.

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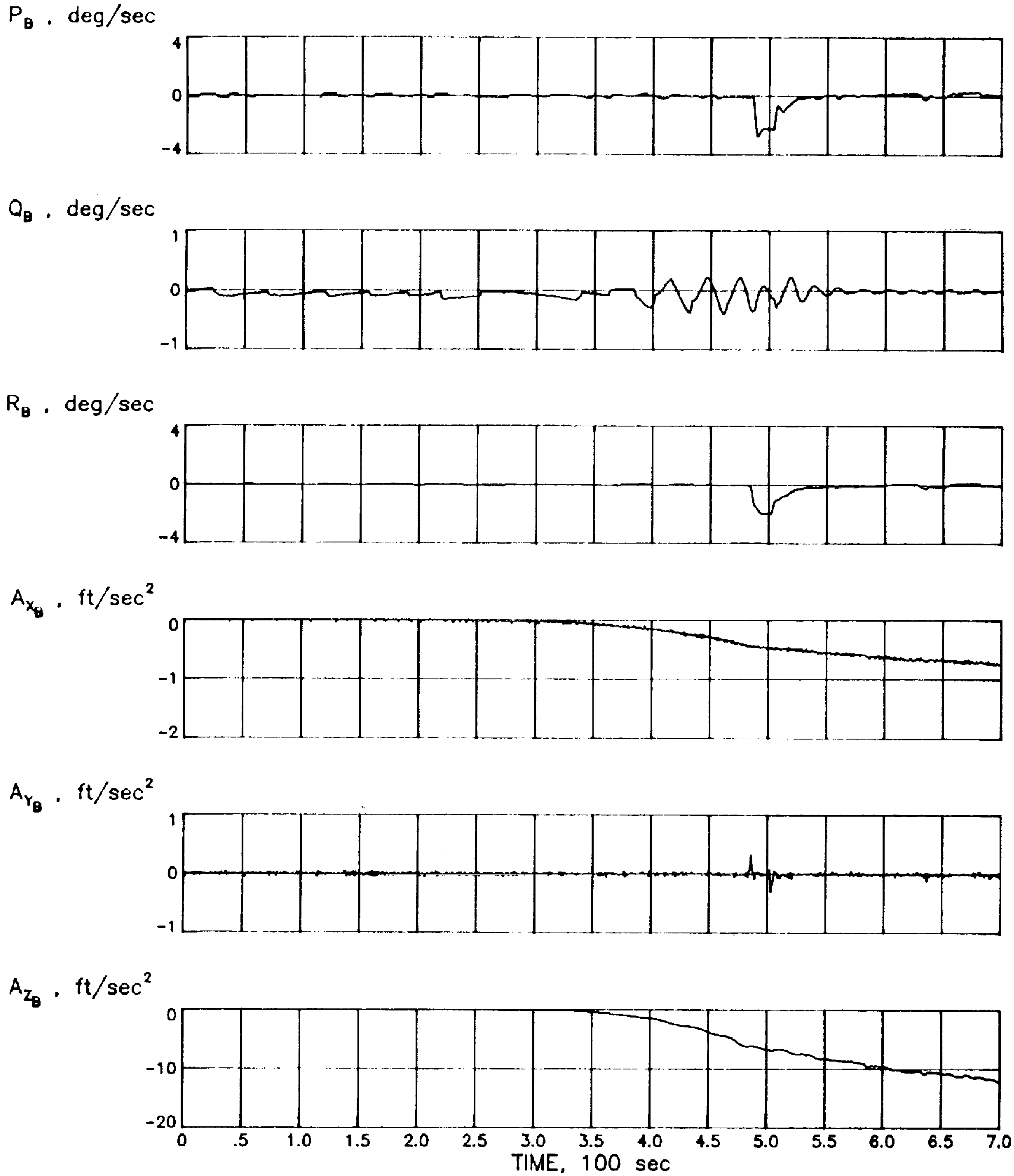


Figure I-4. STS-35 derived body-axis dynamics from IMU1.

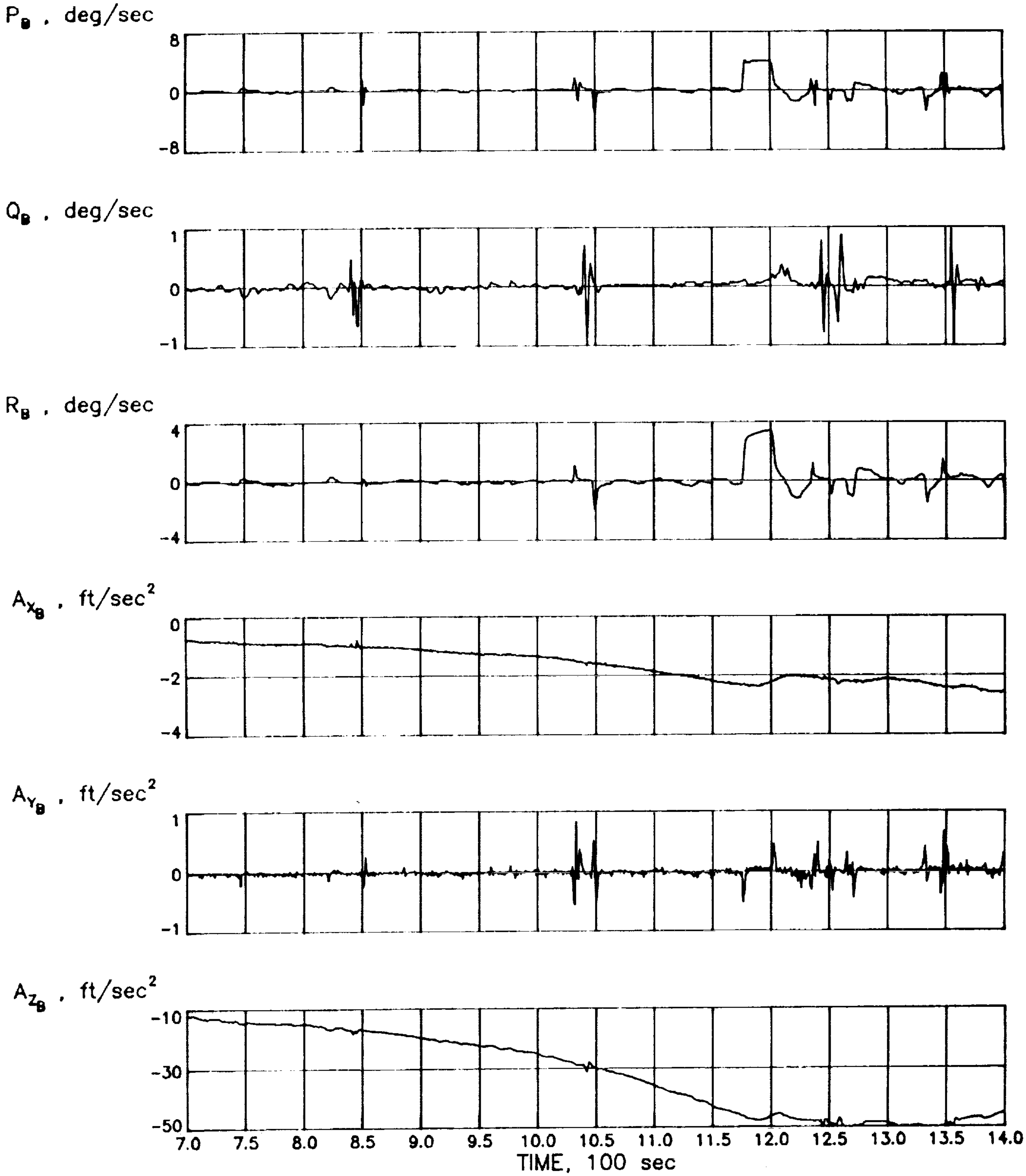


Figure I-4. (continued)

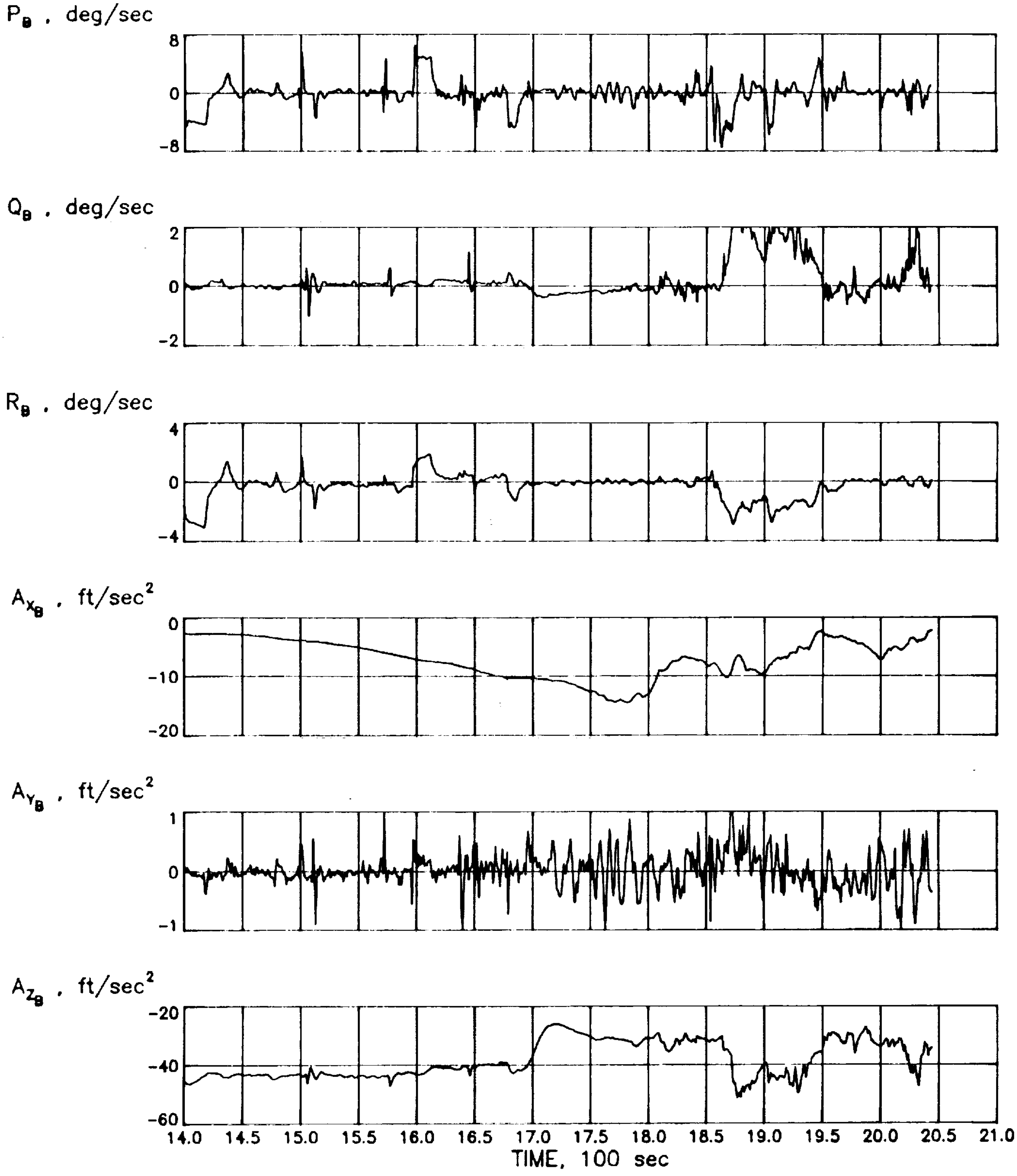


Figure I-4. (concluded)

I. B. TRACKING DATA PROCESSING

Historically, C-band tracking information via JSC, high-speed play-back S-band data from GSFC, and cinetheodolite tracking from EAFB have been employed for trajectory reconstruction at LaRC. Since the TDRSS has become operational, coherent S-band tracking from the GSTDN are no longer expected during Shuttle entries. Recognizing this as a potential limitation, particularly for entry reconstruction on future missions such as the AFE, FM&C has developed the necessary software to utilize the TDRSS data in lieu of the more conventional ground-based tracking (Reference 2). Moreover, C-band tracking data have not routinely been obtained from JSC since the Shuttle stand-down. Consequently, this interface was recently reestablished in anticipation of the OEX post-flight data processing requirements.

The revised C-band interface has been satisfied via the so-called ADDLOG tape provided by JSC's current BET contractor, RSOC. They also provided (informally) accompanying documentation usurped from an official JSC publication which completely described the contents of this deliverable. Three ADDLOG tapes were received for this flight, namely JP359 (entry playback), JP3510 (real time ADDLOG), and JP3511 (real time KMACL). These data were also converted by Unisys for use at LaRC. The output of that activity resulted in four separate CDC compatible files (35HSR1, 35HSR2, 35HSR3, and 35LSR1). These files were accessed, archived under user catalog UN=U446631, analyzed, edited for "blunder" points, and combined and reformatted for use in ENTREE. The combined C-band data file is a semi-private indirect access file (CBNDF35) under the above mentioned user catalog. This file contains the high- and low-rate C-band measurements available throughout entry for this mission. These data were combined using PREOBS (unpublished) for use in the ENTREE software. In addition, the two-way coherent TDRSS measurements (received from LaRC via GSFC on physical reel JHP353) were included thereon. These data, Doppler only, were taken at a one per second rate pursuant to a request from the APEX PI at JSC. The final combined ENTREE observations file for trajectory reconstruction is T35OBS, a semi-private indirect access file under user catalog U446631.

Figure I-5 shows the Shuttle entry ground-track for STS-35 on which are superimposed the locations of the various tracking stations (complexes). Figure I-6 shows the altitude profile along with annotated bar graphs depicting the available coverage (above an assumed 5^0

elevation mask angle) during the entry time frame. At first glance, it is quite apparent that there was considerable tracking available during this mission. However, as a consequence of some of the early editing, it was determined that the Hawaii data (KPTC) were questionable. Even though this was a low elevation pass (maximum of 5.3 degrees), one is always reluctant to give up on these mid-range data. However, it was quite apparent that the range measurements were disjoint in the middle of the pass, suggesting more than a shift from/to either leading-edge or trailing-edge skin tracking phenomena; the elevation data exhibited a sawtooth, searching pattern over the latter half of the pass; and the azimuth component, excluding the last minute of tracking, was marginal. These residual signatures will again be reviewed as part of the final trajectory estimate discussions in Section I. C.

Other C-band editing involved the exclusion of the range component from San Nicolas Island (SNFC) which was visibly segmented as if to suggest a multiplicity of range ambiguities, and the deletion of the Point Pillar pass (PTPC). Neither of the latter deletions are considered significant since there was ample overlap coverage from the remaining stations throughout this same time frame. In fact, the PTPC data might well have been good data if, contrary to published station characteristics information, it had already been corrected for refraction. A similar discrepancy occurred with one of the Vandenberg stations (VDBC) but, in that instance, there was sufficient data to substantiate that these measurements had in fact been corrected for refraction despite information to the contrary. Again, the Point Pillar coverage was a low elevation pass with a maximum elevation of only 6.1 degrees.

It is noted that both high- and low-rate tracking data were available from the Kwajalein Atoll complex, apparently to satisfy a request by JSC navigation personnel to provide simultaneous data for a planned Kalman filtering exercise, ostensibly as part of the descent validation process. Both sets of data were presumably referenced to the master Tradex site. Early results clearly indicated that this was not the case. A preliminary assessment suggested that the low-rate data had been transformed as reported. The actual location of the sensor for the high-rate data remained in question. FM&C consulted with both JSC and KSC to clarify the actual sensor location for the high-rate data. It was learned that only one sensor was operable during the STS-35 descent mission. Consequently, since the low-rate data (KMACL herein) was apparently data from the KMAC radar (properly transformed to the master site), one should expect that the high-rate data (KMACH herein) were also KMAC measurements, though, in this instance, consistent with the actual sensor location. After iterating with both JSC and KSC, the KSC recommended sensor location was utilized.

Pursuant to the aforestated commentary, the actual C-band trackers utilized for the trajectory reconstruction on this flight are given in Table 2 below.

Radar Type	Acronym	Geod. Lat. (degrees)	Longitude (degrees)	Altitude (feet)	Modulus of Refraction	Scale Hgt (feet)	Max. Elev. (degrees)
ALTAIR	KMACH	9.3954318	167.479288	206.37	382	18650	13
ALTAIR	KMACL	9.3987028	167.481992	86.02	382	18650	13
FPS-16	PMFC	34.123011	240.845125	-197.05	318	22455	29
FPS-16	SNFC	33.247708	240.479350	725.49	311	22924	14
TPQ-18	VDBC	34.665867	239.418650	202.36	317	22573	44
FPS-16	VDFC	34.583053	239.438981	1974.15	299	23613	52
HAIR	VDHC	34.758258	239.372886	10.69	320	22395	37
FPS-16	VDSC	34.582761	239.438525	1974.11	299	23613	52
FPS-16	EFFC	34.970458	242.068583	2540.39	287	24306	56
FPS-16	FRCC	34.960828	242.088561	2481.36	288	24252	59
FPS-16	FRFC	34.957753	242.088153	2462.07	289	24169	60

Table 2. STS-35 tracking station locations, refraction and other information.

Included above are the relevant parameters required for the refraction calculations, i. e., the modulus of refraction and the atmospheric scale height. Refraction corrections are only applied for those stations not otherwise corrected. However, even for those stations whose data are already corrected, the computations are made. The data from all stations are down-weighted at the limbs accordingly (as a percentage, nominally 10%, of the magnitude of the refraction correction) to minimize the dependence on any refraction algorithms employed. The maximum radar elevation angle which occurred over each station is also presented as additional information. Note that the ALTAIR station which provides both the high- and low-rate Kwajalein data is actually specified as P-band. Though not completely understood, perhaps the radar is so designated because this frequency band lies in the mid-range of the ALTAIR dual-frequency radar capability. In any event, these data are properly treated herein as a conventional C-band skin-tracking radar which provides the usual measurements of range, azimuth and elevation. As readers will observe in the next sub-section, additional editing in terms of significant bias determinations and removal of same was also required to enable the BET for STS-35.

It is noted that the TDRSS data were requested by the APEX PI from deorbit throughout entry. Due to computer equipment problems at the TDRSS ground-station (White Sands, New Mexico) data were not enabled until (approximately) entry interface. However, apart from the loss which occurred during the first roll reversal, the TDRSS data were essentially contiguous throughout entry upon reacquisition, at least down to an altitude of approximately 79 kft. The TDRSS data were from one of the westerly located satellites which, consistent with the GSFC notation, corresponds to the first satellite launched (TDRS1). The necessary ephemeris information for this satellite was received separately from GSFC. At the time of this mission, this satellite was nominally located at approximately 4^0 south latitude, 171^0 west longitude and, of course, at geosynchronous altitude. However, since the satellite position is not actually fixed, the TDRS1 radius, declination, and longitude were specified by GSFC at ten (10) minute intervals. The reconstruction software uses this detailed ephemeris information and employs cubic spline interpolation to satisfy the data processing requirements. It should also be stated that the White Sands ground station utilized during this mission was the southerly site, TDSR.

Readers are reminded that TDRSS data represent a relatively new S-band Doppler observable type for orbit determination and its use for endo-atmospheric trajectory reconstruction is most unique. Consequently, at least for these early Shuttle entry reconstruction applications, it is utilized herein to augment the solution without constraining the estimate to actually fit the TDRSS data commensurate with its own measurement accuracy. This down-weighting, as it were, amounts to fitting the data with an equivalent 1 Hz presumed accuracy rather than the virtually zero RMS noise expected. The "looser" tolerance compensates for the fact that it is almost impossible to compute this observable as accurate as the measurements themselves (refraction considerations in the atmosphere, tracking satellite ephemeris uncertainties, etc.); it de-sensitizes the filter to the limited geometry afforded by such a pass (particularly since the Shuttle transponder does not provide ranging via TDRSS); and it accommodates the considerable signal resulting as a consequence of spacecraft angular motion during the rather lengthy, certainly dynamic entry flight. These limitations having been stated, one should still understand that the accuracy of any Shuttle entry trajectory reconstruction can be further substantiated by these TDRSS data. FM&C's use of these data for Shuttle applications is tantamount to providing a quality assessment, i.e., an independent verification of the accuracy of the reconstructed trajectory that might otherwise be obtained by using data from the ground-based radars only.

In addition to the C-band and TDRSS data, pseudo observables were incorporated to enhance the trajectory estimate during the final landing phase. This has commonly been done at LaRC whenever cinetheodolite data are not available, as was the case due to the night-time lighting conditions commensurate with the STS-35 landing. These pseudo observables included theoretical measurements of altitude during rollout (referenced to the vehicle center-of-gravity after nose gear contact) and null Doppler measurements after the known stop-time. Three pseudo Doppler stations collocated around the runway are used to control the post-stop Shuttle north, east, and vertical velocities to essentially zero values.

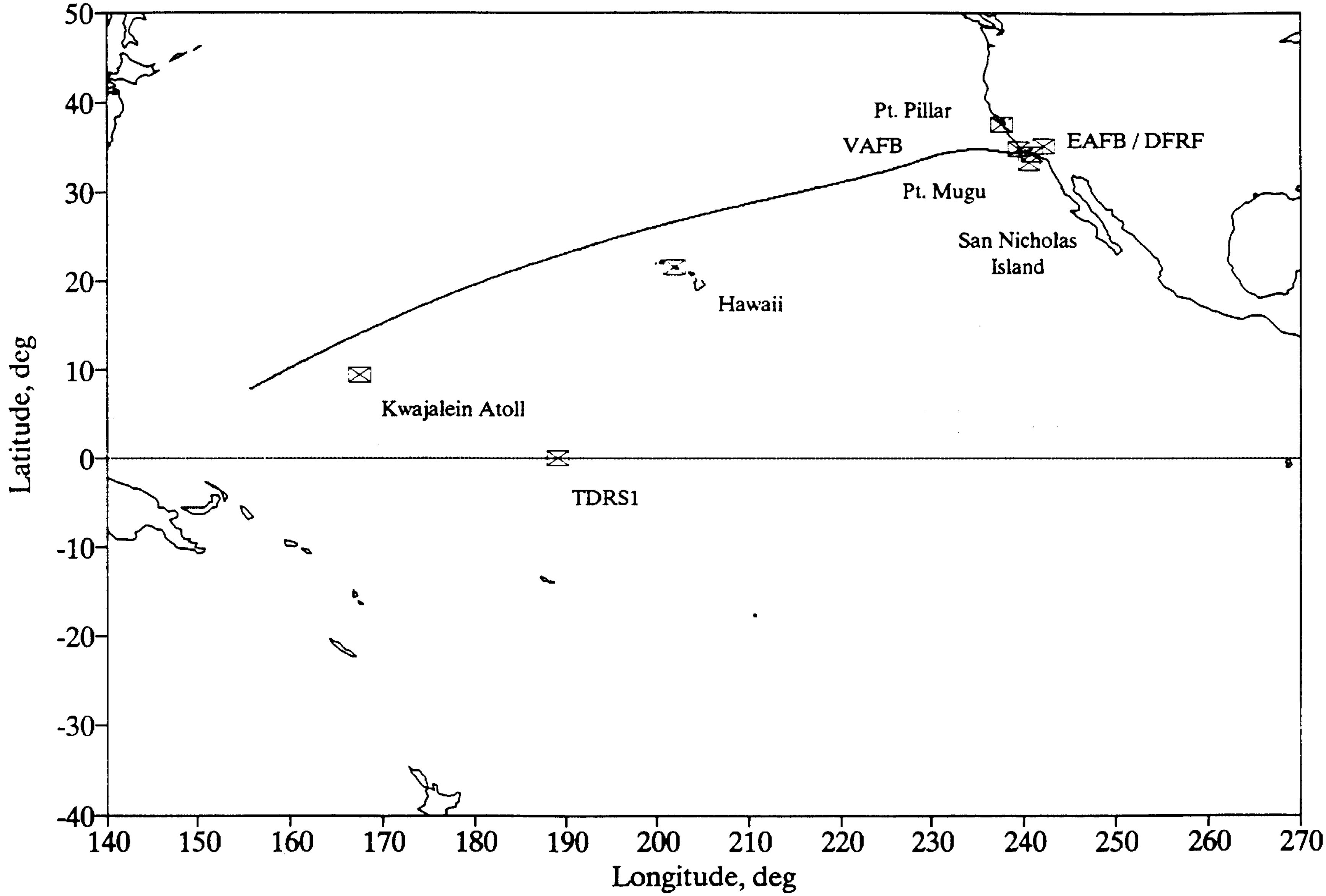


Figure I-5. STS-35 ground track and metric tracking coverage.

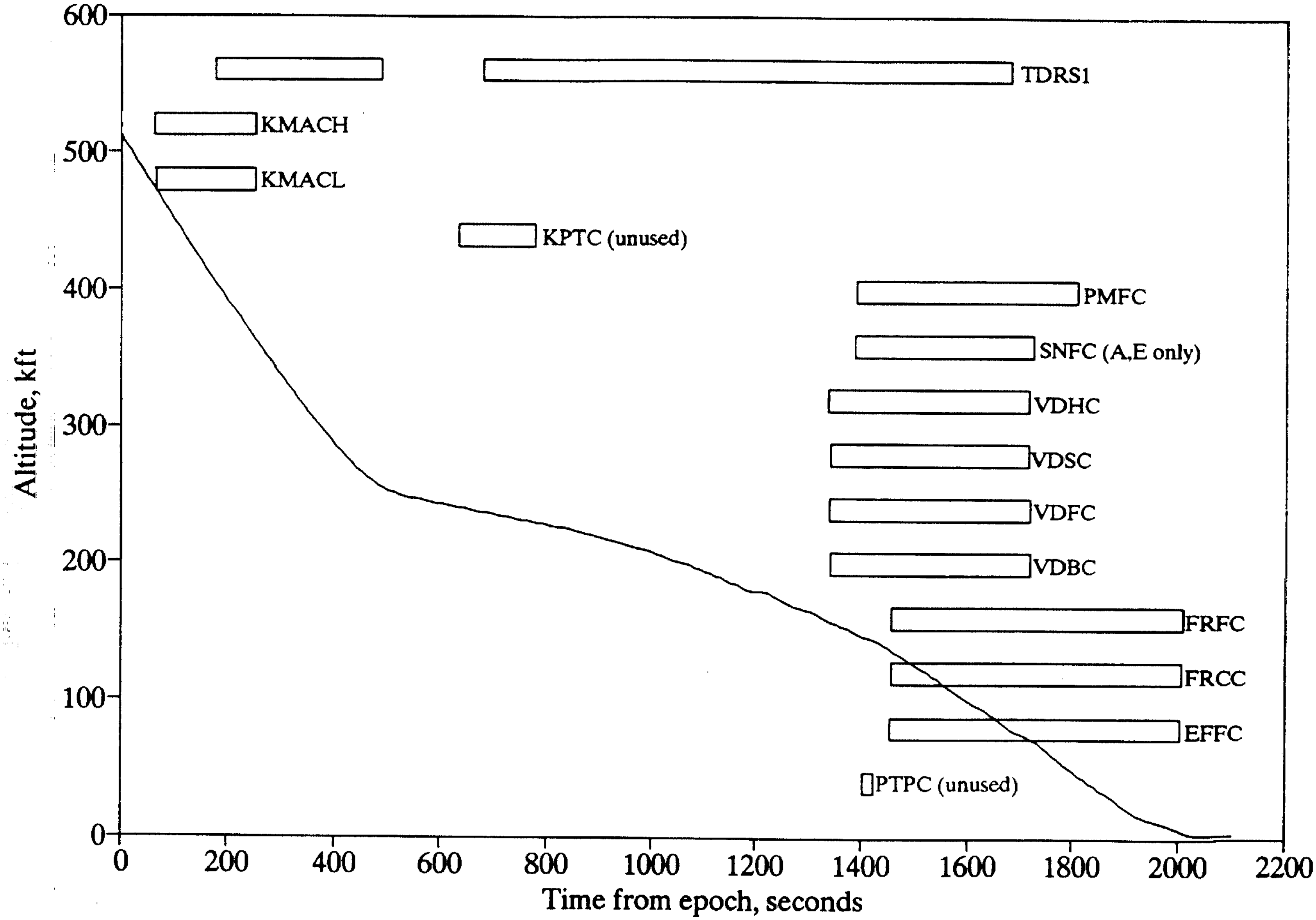


Figure I-6. STS-35 altitude profile and tracking timelines.

I. C. RECONSTRUCTION RESULTS

Early ENTREE reconstruction activities for STS-35 concentrated on state-only estimates, where state-only refers to the nine state variables which completely describe the Shuttle position, velocity and attitude histories during descent. Such methodology has been successfully employed on previous missions, to include the last Columbia mission, STS-32, during January 1990. This is the preferred method since the trajectory estimate is felt to be more unique. Historically, extended parameters have been included into the solution set (IMU parameters mostly) as required to enable a better fit. However, one can never be sure that the resultant parameters determined are actually real calibrations or a "sink" to absorb other discrepancies (perhaps some other IMU errors, observational biases, etc.).

It was anticipated that a state-only solution would be satisfactory for STS-35, particularly since the IMUs compared so favorably and there was ample tracking available for the trajectory determination. Even if the state-only solution was not sufficient, such an estimate would, by inference, provide one with a measure of the enhanced fit to be expected when incorporating instrument parameters or radar biases into an expanded solution set.

The first results obtained clearly indicated that state-only estimation resulted in a miscompare between the uppermost altitude tracking and that from the coastal radars. The ensemble statistics were satisfactory, indicative of an essentially zero mean estimate fit to within a 2 σ weighted root-mean-square. However, there was considerable structure in the associated residual plots from any given station. Also, comparisons versus the TDRSS data were degraded. Moreover, results from ESOLVES (a stand-alone solve utility which evaluates the relative improvement of fit to be gained by inclusion of additional solve-fors) indicated that there was virtually little improvement to be expected. As a point of interest, the indicated altitude correction at epoch was somewhat higher ($\approx$ 4,500 feet) than expected.

Recalling the previous discussions and concerns with some of the tracking data, additional reviews and editing were conducted. The presumed locations for the Kwajalein sensors were substantiated by obtaining a state estimate using these data only. Here, the attitude angle corrections were suppressed since determinations of same are impossible over this uppermost altitude (low density) interval. A reasonable fit was obtained which substantiated both sensor locations. The Hawaii data were reconsidered and again removed as part of the ensemble data set for reasons previously discussed. Once again, the initial altitude estimate seemed to be higher than expected (by some 6,000 feet in this instance) and the TDRSS comparisons degraded. Moreover, this solution, when passed through the remaining data, resulted in first pass residuals in excess of 100 σ.

Clearly, adequate state-only estimation for the STS-35 descent was not to be realized. Given the extent of the miscompare between the up-range and down-range radars, far greater than ever observed on any of the previous flights reduced at LaRC, and, further, assuming that the data from each radar were accurate, the discrepancies must occur as a result of state propagation errors. Since ENTREE uses dynamic data from the selected IMU in a deterministic integration algorithm to propagate the state throughout entry, the IMU data must be questioned. Such a statement can be made even though it has already been shown that the actual measurements from each of the tri-redundant IMUs compared as well as one could expect. Nevertheless, errors well below the IMU measurement threshold can be significant in the deterministic prediction scheme.

As the data processing evolved, it became clear that there were some biases visible in the C-band data. In part, these biases were responsible for the fact that the ESOLVES analysis did not suggest any significant improvement to the overall fit when additional solution parameters were investigated. Consequently, prior to finalizing the BET for this flight, which knowingly would require inclusion of IMU parameters in the final estimate, it was felt that these biases, where significant, should be removed. Separately, bias values were determined for both Kwajalein sensors as well as for the coastal radars. The biases were determined by selectively processing data over the upper and lower altitude intervals, respectively. The residual means were computed from these short arc reductions and adopted as biases since, other than the apparent biases, excellent fits were otherwise obtained. The following table (Table 3) is included to show these determinations. As a point of reference, each bias is compared to the expected RMS measurement accuracy to show the extent of the levels determined. Only radar angle biases are shown in the table since these were the most obvious determinations. Other small (range and angle) biases were not removed since they were not felt to be significant in the final analysis.

STATION	COMPONENT	BIAS (degrees)	WEIGHTED BIAS ($\approx\sigma$ level)
KMACL	AZIMUTH	-0.01353	-1.18
KMACL	ELEVATION	-0.00573	- 0.5
KMACH	AZIMUTH	-0.01382	-1.21
PMFC	ELEVATION	-0.01276	-1.11
SNFC	AZIMUTH	-0.00756	-0.66
SNFC	ELEVATION	0.01139	0.99
VDHC	ELEVATION	0.00826	0.72
VDSC	ELEVATION	-0.01710	-1.49
VDFC	ELEVATION	-0.01578	-1.38

Table 3. C-band biases determined for STS-35.

The above observational biases were incorporated and estimates were generated for which a variety of solution parameters were investigated. As a result of this analysis, the final ENTREE estimate included, in addition to the nine state, some six IMU parameters. These latter parameters were gyro biases (3) and accelerometer scale-factors (3). The software solves for these parameters in the platform axes, i. e., the axes consistent with the actual measurements, to provide for a more rigorous model. However, the software assumes that there are three independent accelerometers per platform rather than the two that actually exist. This approximation is not felt to be significant and is consistent with the modeling done on all previous flights. The final ENTREE estimate is presented in Table 4. It should be noted that the initial estimate of the nine state parameters conform to the RSOC values at epoch. The initial values assumed for the IMU parameters represent perfect instrumentation. As a point of reference, gyro biases of approximately 0.022 deg/hr are commensurate with the 1 σ expected accuracy. This is the fixed-drift component and does not include the potential for an additional g-sensitive drift component of 0.025 deg/hr/g. In addition, the scale-factors shown are expressed as errors from a perfect 1.0 value. An expected level of 100 ppm is consistent with the accelerometer specifications.

PARAMETER	INITIAL	FINAL
Velocity (V_R), fps	24358.99	24357.56
Flight path angle (γ_R), deg	-1.5116	-1.5147
Heading angle (Ψ_R), deg	60.7434	60.7438
Altitude (h), ft	512680	513594
Latitude (Φ_D), deg	7.7759	7.7771
Longitude (λ), deg	155.6030	155.6038
Euler yaw angle (ψ), deg	60.4417	60.4936
Euler pitch angle (θ), deg	38.0809	38.0749
Euler roll angle (ϕ), deg	0.0789	0.0411
IMU roll gyro bias (P_b), deg/hr	0.0	0.034
IMU pitch gyro bias (Q_b), deg/hr	0.0	-0.094
IMU yaw gyro bias (R_b), deg/hr	0.0	0.058
IMU X-accelerometer scale-factor error, ppm	0.0	278
IMU Y-accelerometer scale-factor error, ppm	0.0	200
IMU Z-accelerometer scale-factor error, ppm	0.0	-10

Table 4. Final ENTREE parameter estimates for STS-35.

Clearly, the error coefficients determined for the IMU parameters are quite large, particularly when compared to levels determined on prior flights at LaRC. However, as stated previously, the relative inconsistency between the upper altitude and coastal radar data was more significant than ever observed such that these results are not surprising. Nonetheless, these determinations should not be construed as exact IMU calibrations which, in this particular instance, would imply calibrations for the selected IMU1 measurements. Past experience has shown that such determinations, though indicative, are not unique. It was previously demonstrated that the IMU1 measurements agreed favorably with those from the other IMUs but, it was also stated, differences at levels implied by the above error correction coefficients might well go undetected in the direct IMU comparison analyses.

Moreover, it was pointed out that IMU1 was changed out since the last Columbia mission. Again, readers should not interpret that the replacement is of lesser quality or, perhaps, is not as well aligned within the spacecraft. Suffice it to say that, for the ensemble tracking data available, the above solution set best fits these observables and, though (perhaps) not unique, some IMU correction terms must be incorporated.

Separate discussions with personnel at JSC vindicated the assessment that IMU1 had performed the best overall during the STS-35 descent. Indeed, the feeling was that the overall onboard navigation performance during this mission was essentially nominal. Their post-flight analyses had quantified the performance as an approximate 1 σ (or better) flight. Despite this apparent quandary, FM&C is comfortable with the fact that some instrument determinations must be included if one is going to fit the ensemble of tracking data available for this mission. Though the determinations herein may not be unique, the final trajectory that results agrees quite well with the JSC BET throughout the entire entry time frame and, as next shown, the final fit to the tracking data is excellent.

Final residual plots showing the goodness-of-fit to the C-band tracking data are given in Appendix A. Plotted are the residuals as well as the weighted residuals. Annotated on each plot are the residual mean and standard deviation computed for each component. The TDRSS Doppler residuals are presented as Figure I-7 as part of this sub-section. As previoulsy discussed, these data, though down-weighted heavily, were incorporated to obtain the final estimate.

Table 5 herein summarizes the overall fit quality. Whereas some small biases remain, the most notable being the -0.56 σ weighted mean in the range component from VDBC, it is obvious that an excellent fit has been obtained. In fact, the overall ensemble statistics (computed based on 12,345 observations) reflect a weighted mean of -0.04 and an ensemble weighted standard deviation of 0.756. However, close inspection of the individual residual charts in Appendix A does show some signal remaining. The range and azimuth from the Kwajalein stations still exhibit a modest ramp signature in the respective residuals. The Vandenberg data suggest, at least in the elevation component, that there might be some refraction considerations remaining, though, admittedly, some of this signature could be spacecraft related. The elevation residuals from the Edwards/Dryden stations exhibit a sharp, unexplained ramp increase near the end of each of their respective passes. Finally, the TDRSS residuals still exhibit considerable structure. The long period variation between $\pm$ 2 Hz is either Shuttle trajectory or tracking satellite ephemeris related, i. e., this spread is probably consistent with the accuracy of either since 1 Hz at S-band frequencies corresponds to an extremely accurate (0.22 fps) line-of-sight velocity measurement. The higher frequency, more dominant structure is directly related to Shuttle rotational motion during entry. As can be seen, each of these contributions totally mask any apparent measurement noise.

Composite residuals by component for the C-band trackers are shown in Figure I-8 through I-10 herein. Composite range residuals are presented as Figure I-8. Composite azimuth and elevation residuals are given in Figures I-9 and I-10, respectively. Individual station signatures cannot be gleaned from these figure but such plots best reflect the overall fit to the tracking data throughout the entire entry. Though the weighted residuals are not shown, the weighted mean and weighted standard deviation are annotated on each figure along with the actual dimensional values for each component. Lastly, strictly as information, Figure I-11 is included to show the previously discussed Hawaii pass. Though not included as part of the fitting process, these data have been passed through the final estimate to show the measurement discrepancies. The jump discontinuity in ranging and the considerable signal remaining in the angular data can readily be seen. For the latter, the elevation residuals vary between (approximately) -2 σ and 7 σ.

The final inertial BET for this flight, derived as just described, is available on the LaRC CDC machines as a semi-private indirect access file (IBETF35) under User Catalog UN=274885C. Approximate event times of interest are listed below in terms of seconds from epoch. The remaining sections of this report discuss the Extended and Aerodynamic BETs derived from this inertial product.

Entry Interface (EI)	185
Main Gear Deployment	2030
Weight on Wheels (WOW)	2046
Weight on Nose Gear (WONG)	2060
Stop time	2106

TYPE	STATION	ACCEPTED	MEAN	WEIGHTED MEAN	STD. DEV.	WEIGHTED STD. DEV.
DOPPLER	TDRS1	1079 of 1247	0.14	0.14	1.16	1.16
RANGE	KMACL	31 of 31	-14.5	-0.37	31.4	0.79
	KMACH	183 of 183	2.1	0.05	32.6	0.82
	PMFC	360 of 379	-6.8	-0.17	34.2	0.86
	VDHC	358 of 358	1.9	0.05	26.8	0.68
	VDSC	336 of 345	6.0	0.15	21.0	0.53
	VDFC	351 of 358	-11.1	-0.28	28.9	0.73
	VDBC	349 of 355	-22.4	-0.56	20.0	0.51
	FRFC	527 of 537	14.4	0.36	23.2	0.59
	FRCC	520 of 527	-1.5	-0.04	24.5	0.62
	EFFC	519 of 531	8.9	0.23	25.3	0.64
AZIMUTH	KMACL	31 of 31	-0.0008	-0.07	0.0061	0.53
	KMACH	184 of 184	-0.0008	-0.07	0.0065	0.57
	PMFC	389 of 389	0.0040	0.35	0.0063	0.55
	SNFC	291 of 294	-0.0002	-0.02	0.0045	0.4
	VDHC	376 of 376	-0.0005	-0.04	0.0038	0.33
	VDSC	348 of 363	-0.0042	-0.36	0.0061	0.53
	VDFC	348 of 371	-0.0016	-0.14	0.0071	0.62
	VDBC	371 of 372	0.0009	0.08	0.0050	0.44
	FRFC	461 of 540	-0.0005	-0.04	0.0088	0.76
	FRCC	447 of 534	0.0043	0.38	0.0096	0.84
	EFFC	486 of 545	-0.0023	-0.20	0.0086	0.75
ELEVATION	KMACL	30 of 30	-0.0031	-0.18	0.0074	0.45
	KMACH	184 of 184	-0.0016	-0.07	0.0082	0.47
	PMFC	387 of 387	-0.0020	-0.16	0.0050	0.35
	SNFC	238 of 241	-0.0055	-0.38	0.0071	0.46
	VDHC	374 of 374	-0.0022	-0.13	0.0067	0.49
	VDSC	359 of 363	-0.0021	-0.10	0.0101	0.74
	VDFC	331 of 369	-0.0031	-0.16	0.0131	0.98
	VDBC	370 of 371	0.0001	0.01	0.0059	0.44
	FRFC	467 of 541	-0.0047	-0.32	0.0123	0.97
	FRCC	521 of 536	-0.0009	-0.10	0.0094	0.75
	EFFC	522 of 542	-0.0052	-0.37	0.0110	0.84

Units are Hz, ft, and degrees

Table 5. Summary of fit statistics for STS-35.

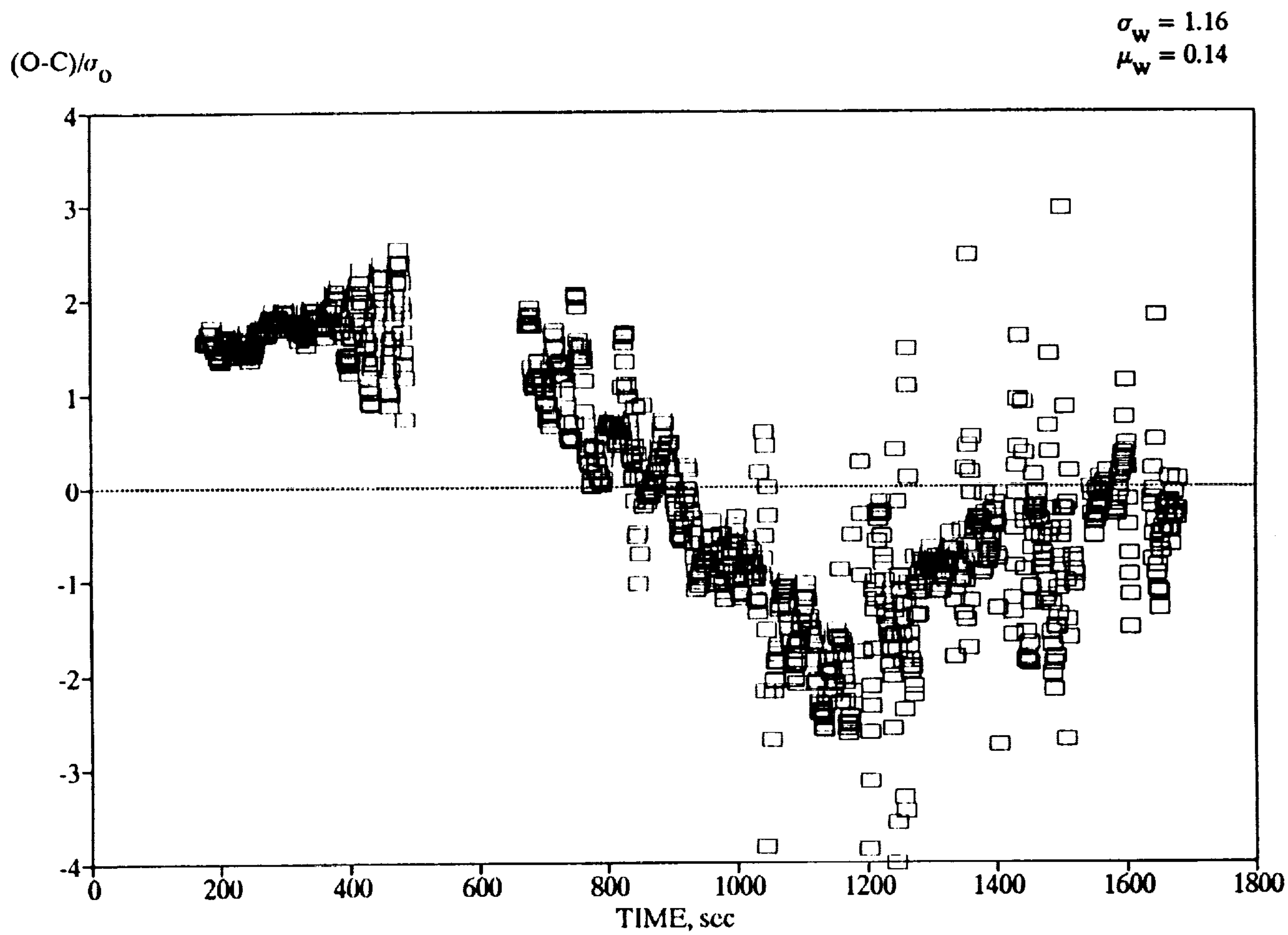
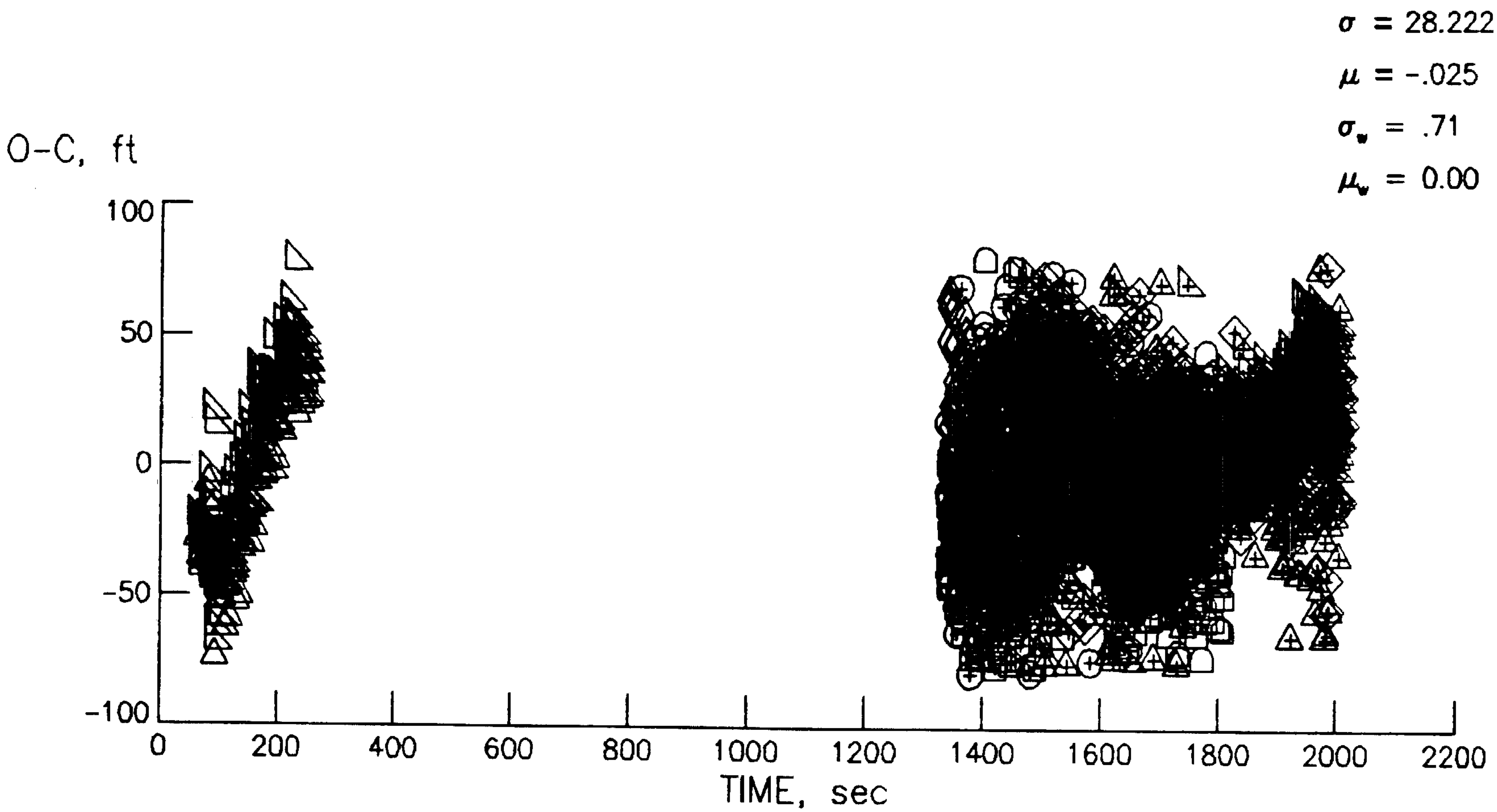
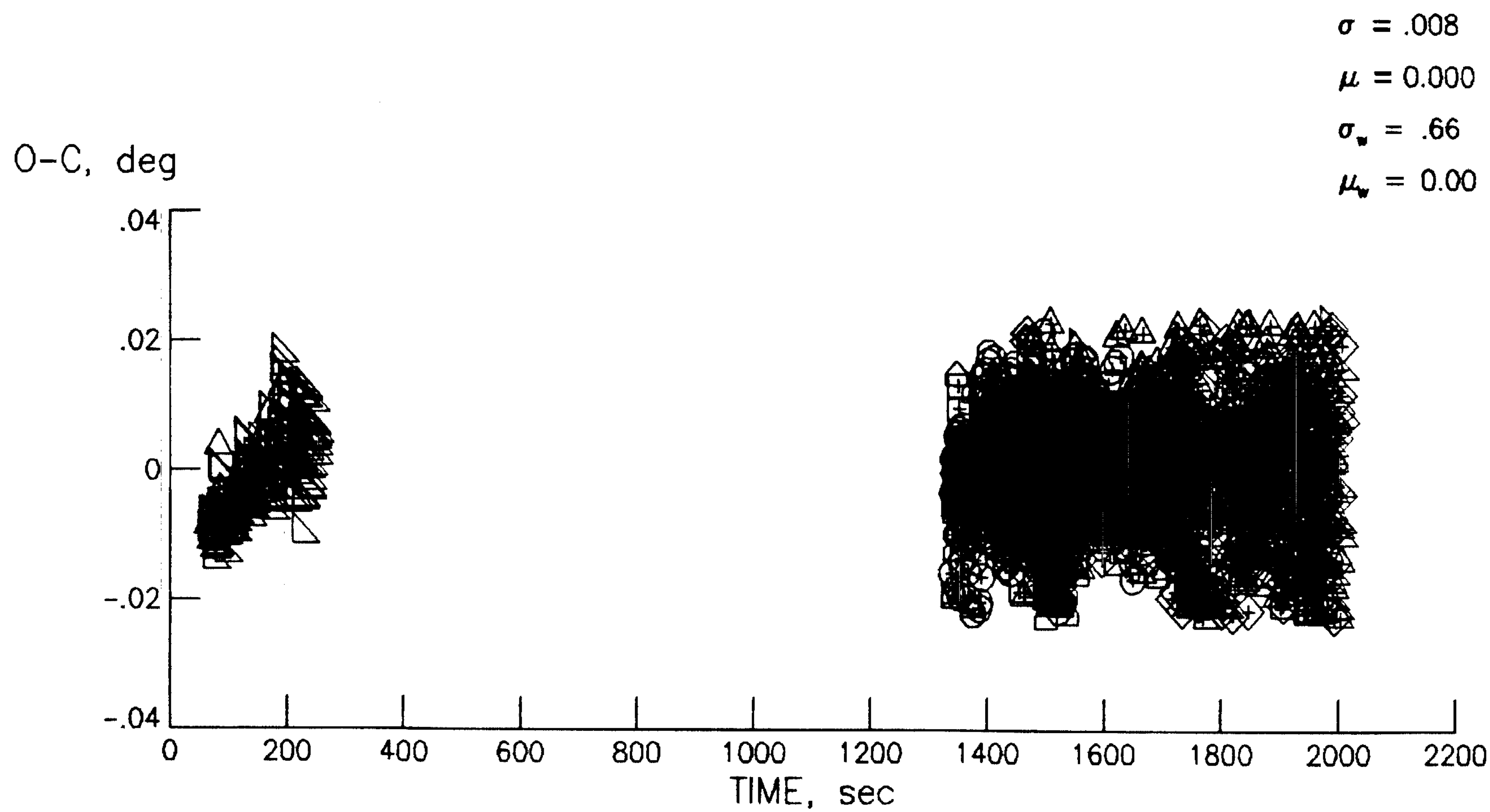


Figure I-7. Final TDRS1 Doppler residuals for STS-35.



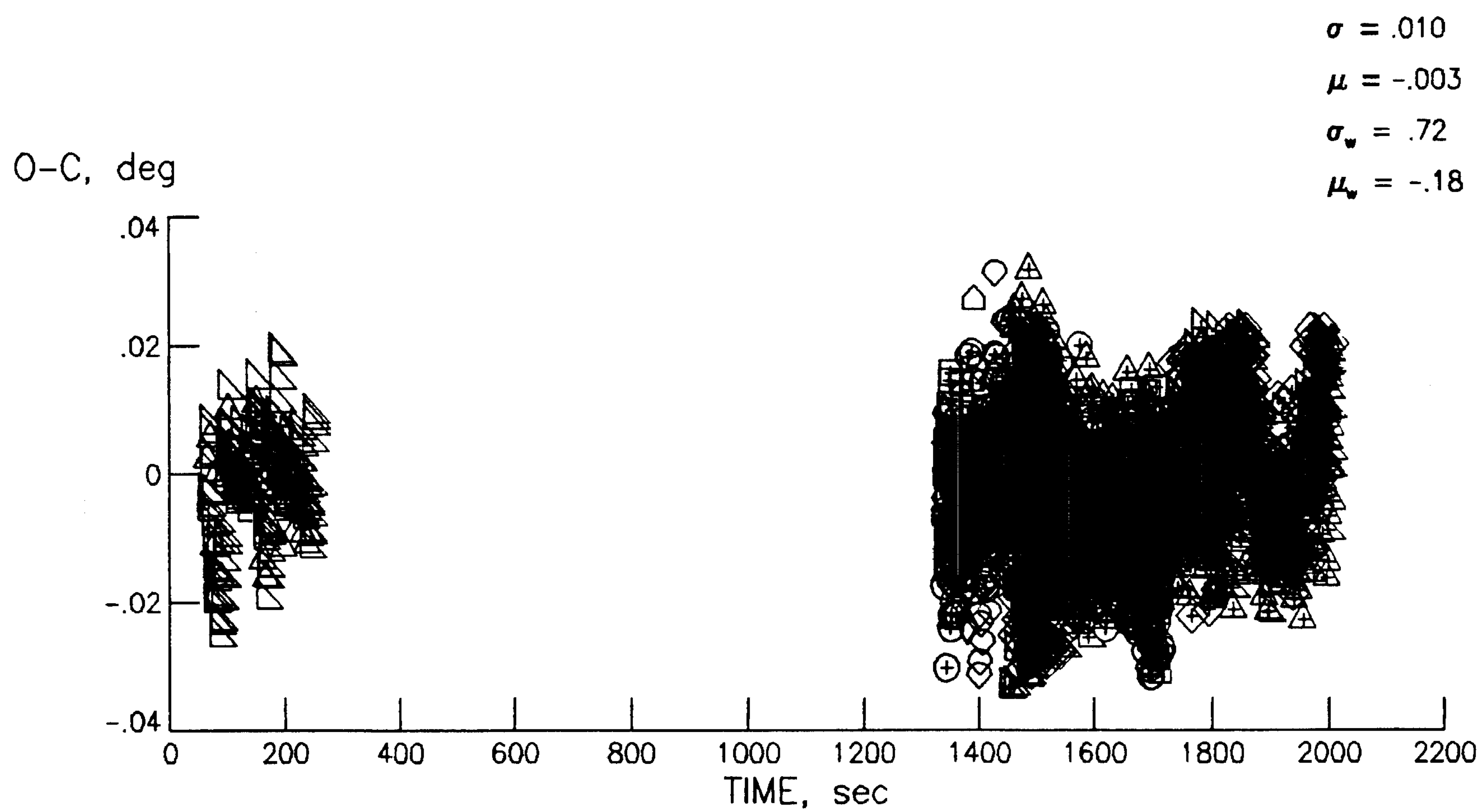
(a) Residuals

Figure I-8. Composite range residuals for STS-35 entry reconstruction.



(a) Residuals

Figure I-9. Composite azimuth residuals for STS-35 entry reconstruction.



(a) Residuals

Figure I-10. Composite elevation residuals for STS-35 entry reconstruction.

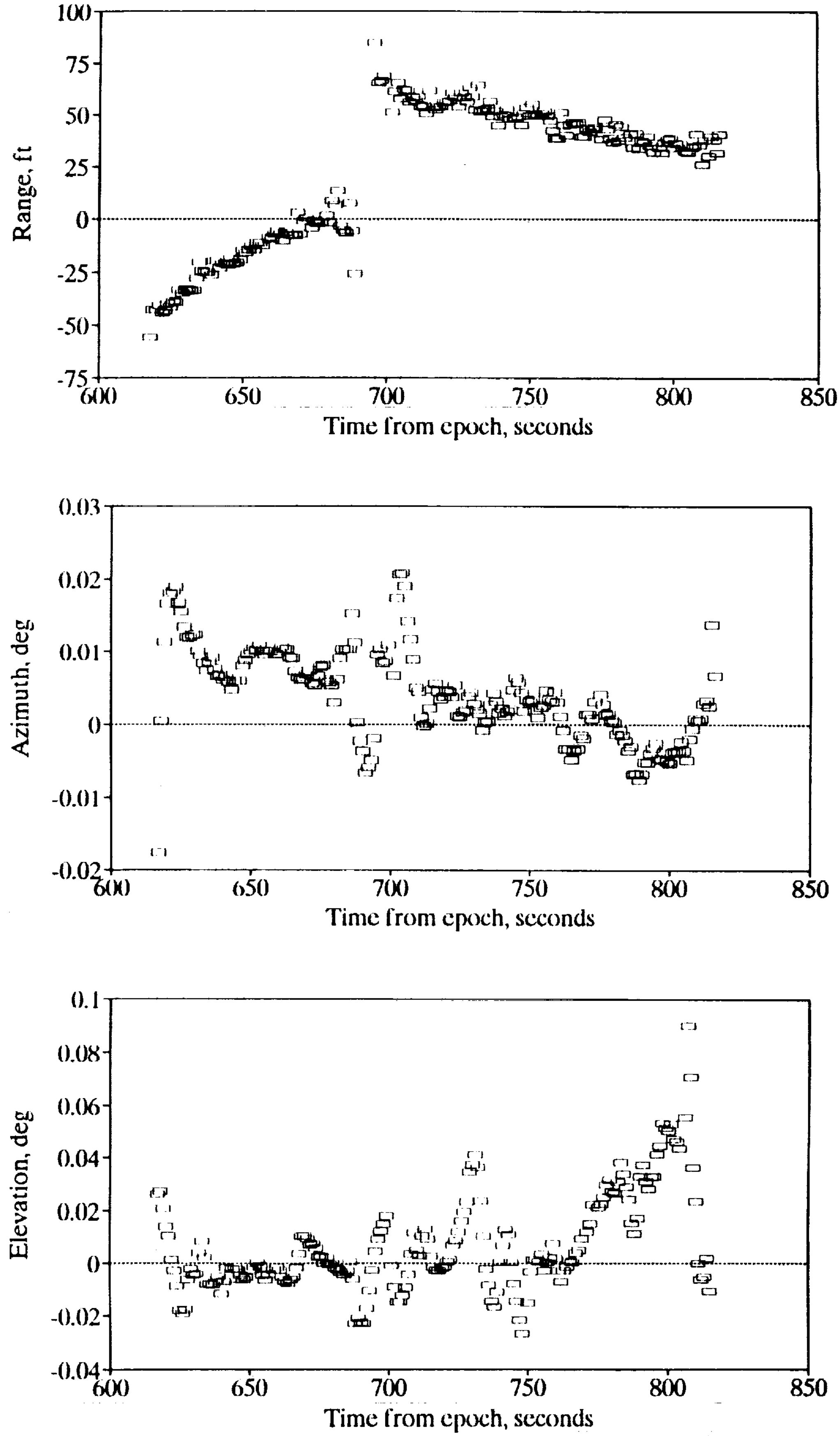


Figure I-11. KPTC residuals based on final BET for STS-35.

II. EXTENDED BET DEVELOPMENT

Development of the 66-word Extended BET for STS-35 was rather straightforward in view of the limited options available. Past activities at LaRC involved the development of LAIRS files based on the available NOAA remote sounding information taken in support of a specific entry flight. These data, along with the equivalent "totem-pole" atmospheres extracted from the JSC BET files, permitted optional analyses to select that atmosphere deemed most appropriate for the mission. In view of the fact that the LAIRS activity has ceased, the only option remaining is the JSC data. For readers unfamiliar with the "totem-pole" atmospheres, it is relevant to state that these data are derived by Mr. Mel Gelman of the Climatology Branch of the National Weather Service. They are based on the same remote sensing data which were the source for the LAIRS file generation. Gelman spatially locates vertical profiles in the vicinity of a representative ground-track for the Shuttle. These data are cross interpolated versus altitude, latitude and longitude, resulting in a single Shuttle specific atmosphere. Extraction of these data using RELAIRS is a rather simple process. The extracted results are rewritten to conform to the usual LAIRS file format and combined with the inertial trajectory data to generate the Extended BET.

Atmospheric parameters obtained from the JSC STS-35 data are presented as Figures II-1 through II-4, respectively. As seen thereon, temperature, density, pressure, and horizontal wind components are plotted versus altitude. These data are plotted over the lowermost 400 kft since results above this altitude are not particularly meaningful.

As a measure of confidence in the JSC data, the upper altitude atmospheric density and temperature were compared versus that which would be expected based on Shuttle-derived results as well as elaborate model considerations. These comparisons are presented in Figure II-5 where, it can readily be seen, metric units are employed. This is commensurate with the available software which has been utilized on past missions to develop an atmospheric database for JSC (Reference 3). It is noted that the density for each of the atmospheric sources has been normalized to the 1976 Standard Atmosphere. The Shuttle-derived density profile is computed using the predicted (L7 pre-operational databook), flight-substantiated (FAD26, Reference 4), normal force coefficient and the in situ normal acceleration profile sensed by IMU1. Temperature is computed from the perfect gas law after integration of the hydrostatic equation to obtain the pressure profile. Model data included are the Marshall Space Flight Center (MSFC) Global Reference Atmospheric Model (GRAM, Reference 5) and the 1978 Air Force Reference

Atmospheres (AF'78, Reference 6). Whereas there are some differences noted, particularly near 70 km, the Shuttle-derived density profile compares quite favorably with the JSC data. Moreover, based on past experience, the Shuttle-derived profile is representative of a reasonably smooth density, devoid of any major density shears or other abrupt structure. Data from both models tend to be more dense below approximately 85 km but such comparisons are not atypical.

On the basis of the limited analysis just presented, the JSC data appear to be adequate for this flight. The final Extended BET for this flight is available on the LaRC CDC machines as EBETF35 under user catalog UN=274885C. Appendix B contains a listing (at a 2 second spacing) of pertinent parameters from the Extended BET. Included are the air-relative velocity, flight path and heading angles, altitude, attitude angles with respect to the air-relative velocity vector, Mach number, dynamic pressure, and both the hypersonic viscous parameter (VBAR) and Reynolds number (RNUM). Readers should note that labels utilized conform to word definitions employed on the Aerodynamic BET file later presented. Actually, Reynolds number and the hypersonic viscous parameter were extracted from the AEROBET since these data are not written to the Extended BET. As a final note, QBAR, VBAR and RNUM are only computed below entry interface where meaningful atmospheric information is available. In the case of VBAR, no computations are included below a value of 0.005, i. e., below the minimum value utilized in the aerodynamic databook formulation as discussed in the next section.

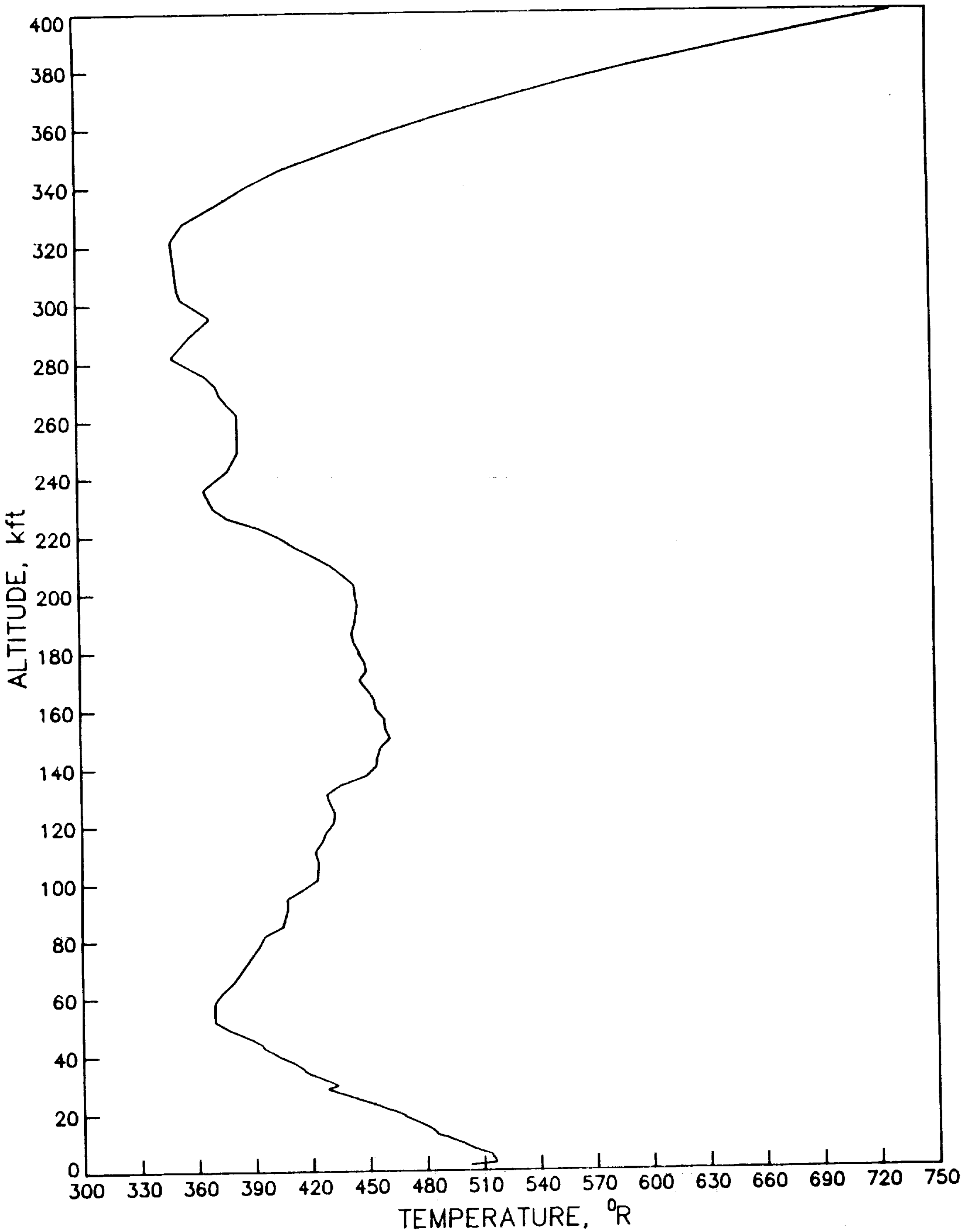


Figure II-1. STS-35 temperature profile.

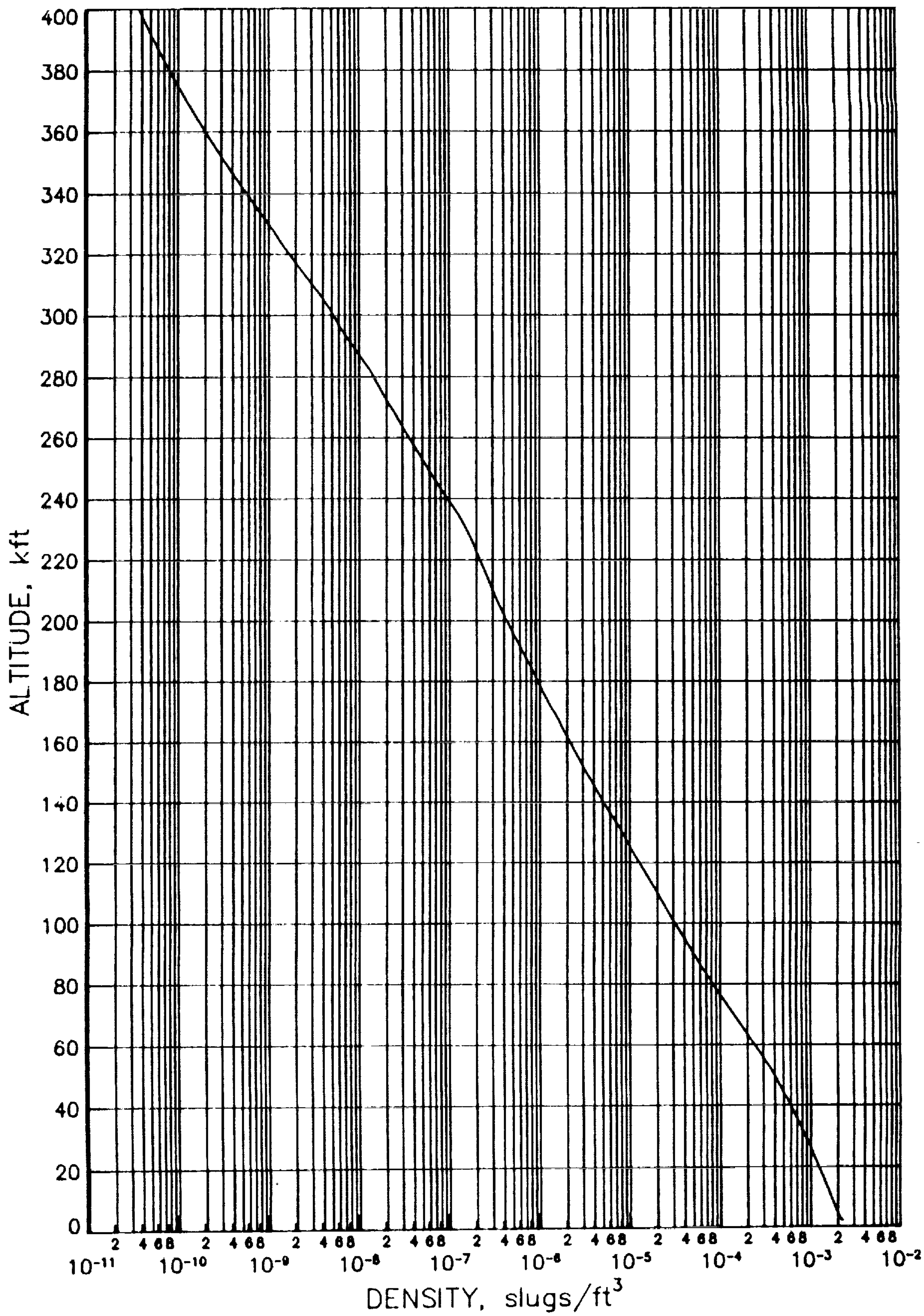


Figure II-2. Density profile for STS-35.

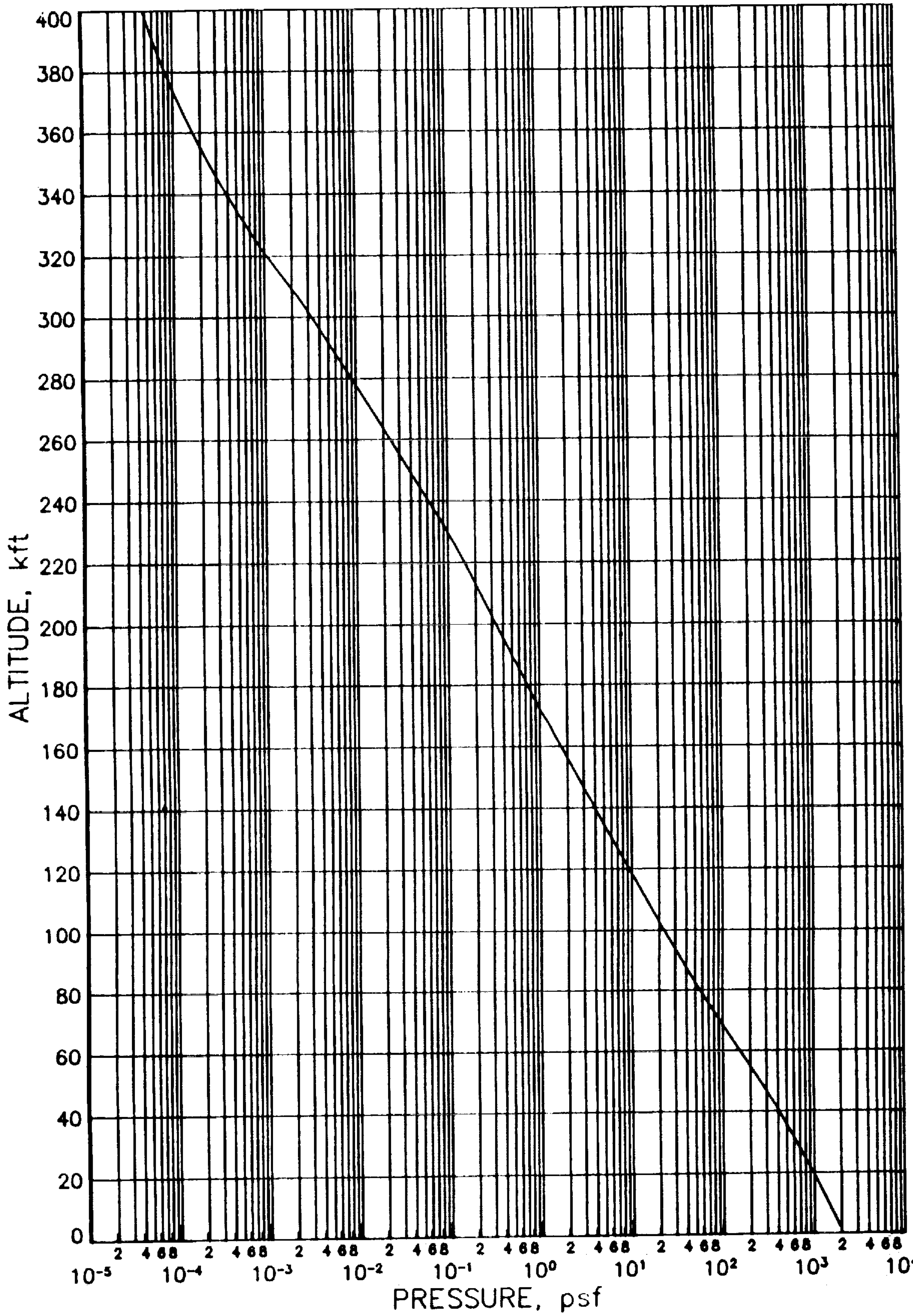


Figure II-3. STS-35 pressure profile.

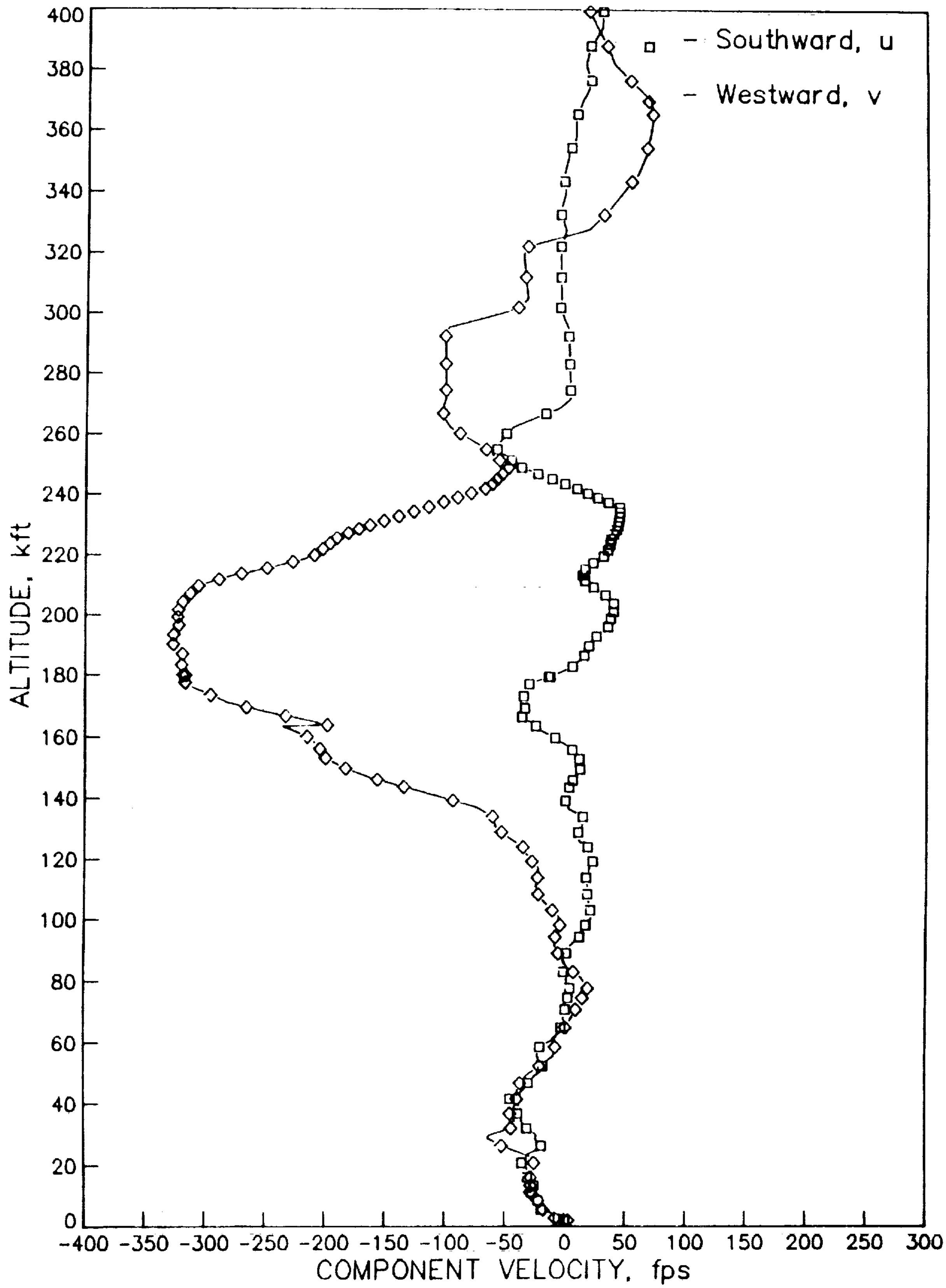


Figure II-4. Horizontal wind components versus altitude for STS-35.

December 11, 1990

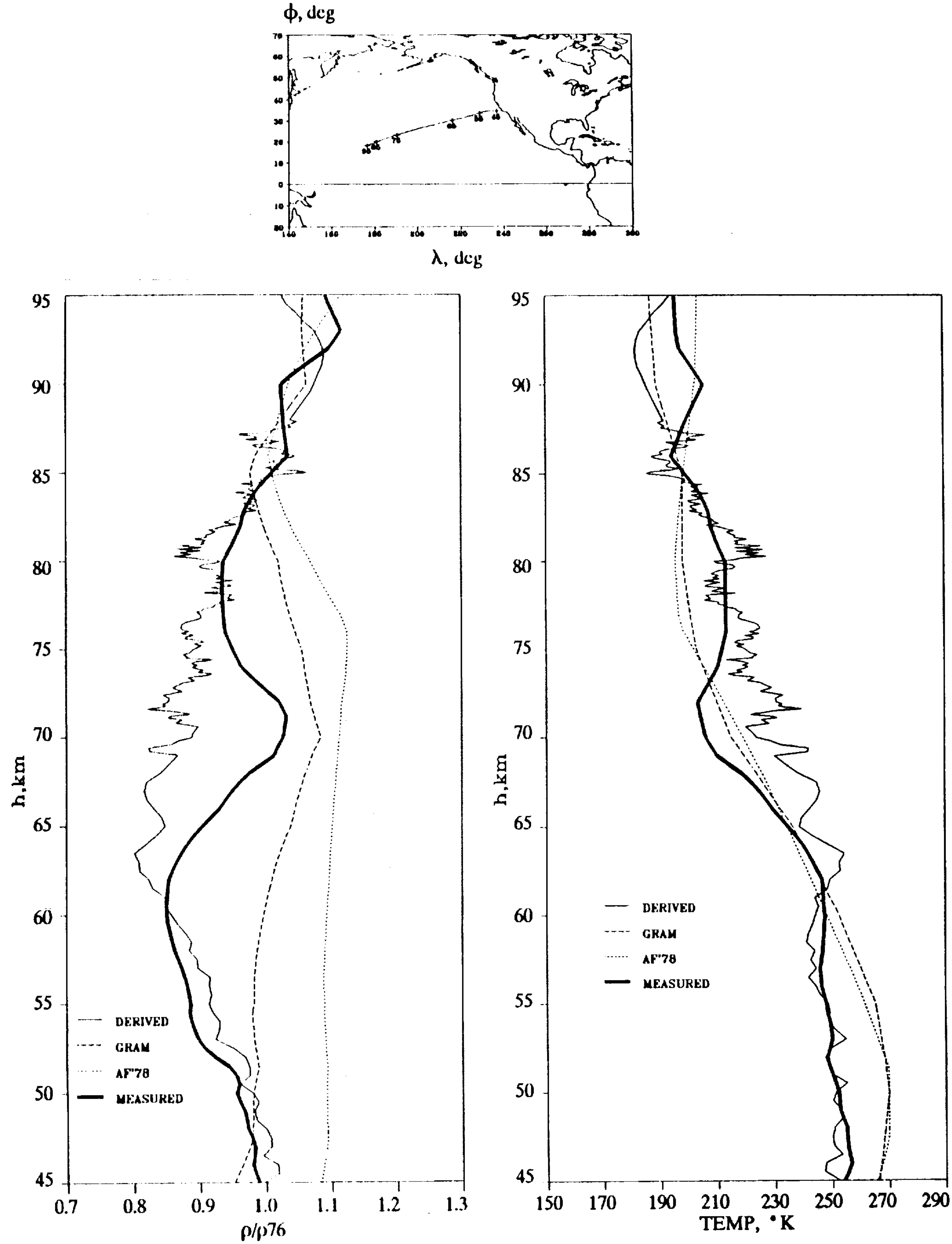


Figure II-5. STS-35 density and temperature comparisons.

III. AERODYNAMIC BET DEVELOPMENT

The 218-word AEROBET for STS-35 was developed using the previously discussed Extended BET which was based on the FM&C reconstructed inertial trajectory and the JSC atmospheric data. As discussed in Part IV of Reference 1, this file is combined with the onboard measurements of the control surface deflections and RCS jet activity to define the in situ orbiter configuration; the final spacecraft mass and inertia properties; and the Shuttle aerodynamic databook (final pre-operational L7 version, Reference 7, rectified using the FAD26) to create the Aerodynamic BET. Given these data, interesting comparisons between flight-derived and predicted aerodynamic coefficients can be made. Readers are urged to peruse the previously noted reference for more details as to the AEROBET file contents, the various computations utilized, the Orbiter aerodynamic databook formulation, and, equally important, a discussion of the Shuttle control surface and RCS jet configuration.

Flight data are derived from the IMU measurements (in the body axes) and the associated air-relative information as discussed in the previous inertial and Extended BET development sections. Though the flight computations are straightforward, readers are reminded that the uppermost altitude for which meaningful performance computations can be made is restricted to approximately 280 kft due to IMU accelerometer (quantization) limitations. The quantization limitation of 1 cm/sec corresponds to approximately 1 mg. However, for appreciable signal, in situ measurements of the spacecraft accelerations, angular rates (and, equivalently, angular accelerations), the spacecraft mass and inertia properties, and the associated QBAR (see Table B-1 of Appendix B) define the flight data as indicated in Reference 1. Mass properties utilized for this flight are presented as Table 6 herein. The center-of-gravity data are given as inches in the structural reference system.

As one might expect, the resultant computations are "total" coefficients, consequently, the effects of the RCS jets must be removed. A measure of the RCS activity is derived from the so-called OI-2 file provided by LaRC. Figure III-1 shows the RCS firings which, at a 1 second spacing, are seen to be minimal.

The OI-2 file is also the source for the Shuttle control surface measurements necessary for the aerodynamic databook formulation. These data were reformatted for use at LaRC by Unisys. The nine-track reel was NX0562. This file was provided at 25 samples per second and thinned using the FM&C software utility, CONFIG, to 1 per second at times commensurate with the other BET data. CONFIG nominally performs editing, to include selection of the best data channels where redundancy is available. However, for this flight, it was evident that the measurements in many of the channels of interest were extremely noisy. Consequently, the separate measurements of inboard and outboard elevon panel deflections on a given side were necessarily considered as one in the same rather than the usual averaging per side. For this purpose, FM&C adopted the cleanest channel available. On any given side, this approximation is of little concern. However, in some instances, left and right side elevon data had to be assumed equal across sides. This assumption negates computations of aileron deflection, an approximation of little consequence for performance investigations. Finally, rudder and speedbrake deflections were properly held stale for the first 1535 and 1285 seconds, respectively, despite the recorded implications. As noted, most if not all of the modifications required were of minimal importance. However, had these data been any noisier, the development of a contiguous AEROBET over the entire entry time frame might well have been prohibited. Final, edited control surface deflections for STS-35 are presented as Figure III-2.

Pursuant to the control surface measurement problems previously noted, FM&C discussed these anomalies with JSC, to include the concern that there seemed to be a more noticeable increase of erratic configuration data over the past few flights. The source for these erratic data has not been identified or isolated. To repeat, the control surface editing required on this particular flight did not present any particular problems for performance comparisons. The concern herein is that further degradations in the recorded data might well preempt (or, at least, degrade) such comparisons in the future.

The AEROBET generated for this flight is available on the CDC machines at LaRC as ABETF35, a semi-private file under UN=274885C. In this instance, due to size considerations, the file is a direct access file. The last section herein presents some summary results generated from the AEROBET.

	Weight Lbs.	Center-of-gravity (inches)		
		X	Y	Z
Post deorbit	227706.2	1078.7	-0.5	371.4
Entry Interface	226613.2	1080.8	-0.5	371.4
EI + 3 minutes	226486.2	1080.2	-0.5	371.2
Mach 3	225531.2	1079.1	-0.5	370.8
Landing	225329.2	1080.5	-0.4	368.4

	Moments and products of inertia slug ft2					
	Ixx	Iyy	Izz	Ixy	Ixz	Iyz
Post deorbit	946415	7352420	7640401	850	182210	868
Entry Interface	949754	7263416	7550845	1109	181057	451
EI + 3 minutes	947949	7245809	7534404	1162	176254	461
Mach 3	944545	7228591	7517573	1523	171229	533
Landing	973441	7249220	7513760	1783	163136	520

Approximate EI time is 19385 GMT seconds

Table 6. STS-35 mass properties.

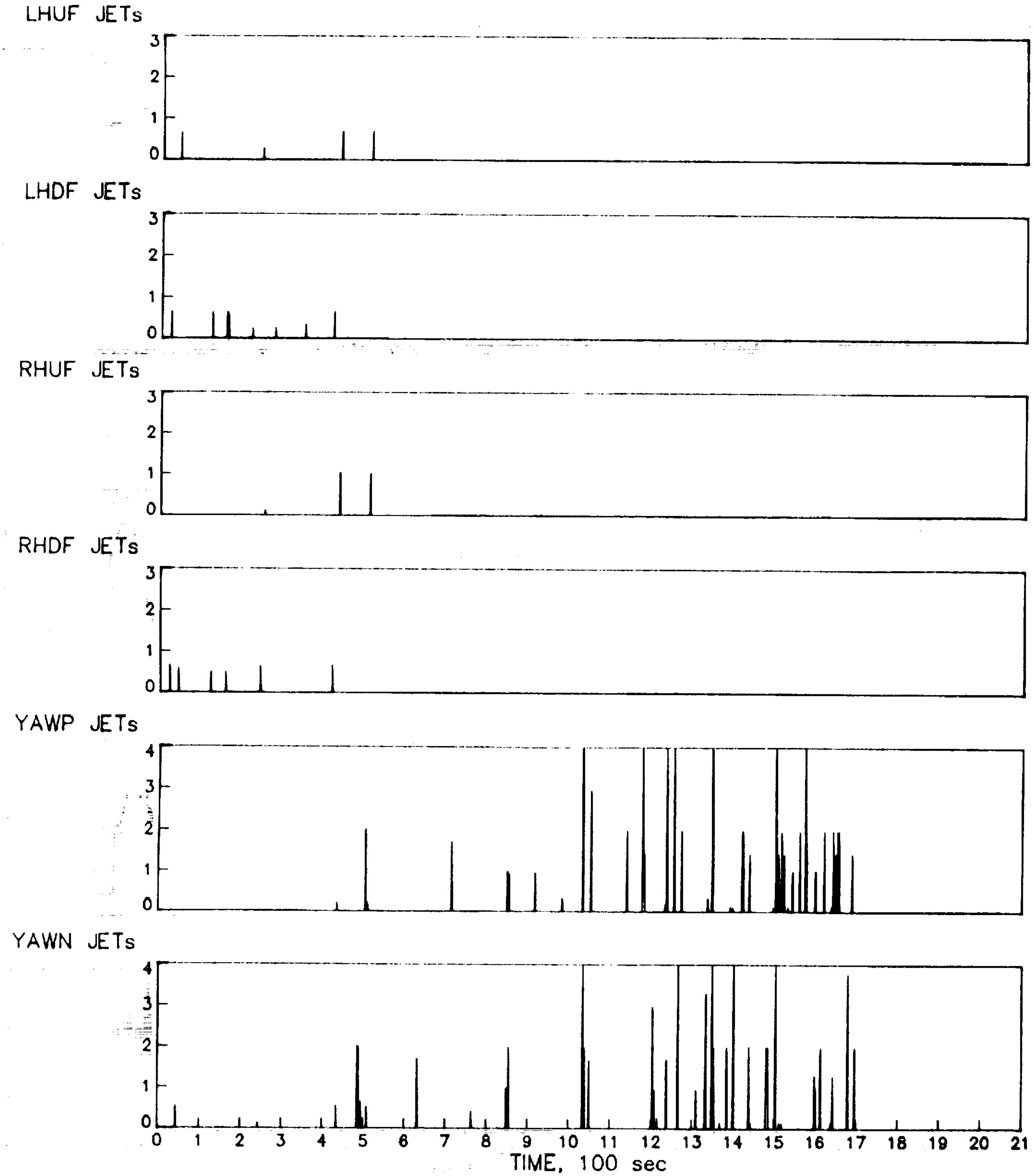


Figure III-1. STS-35 RCS jet activity during entry.

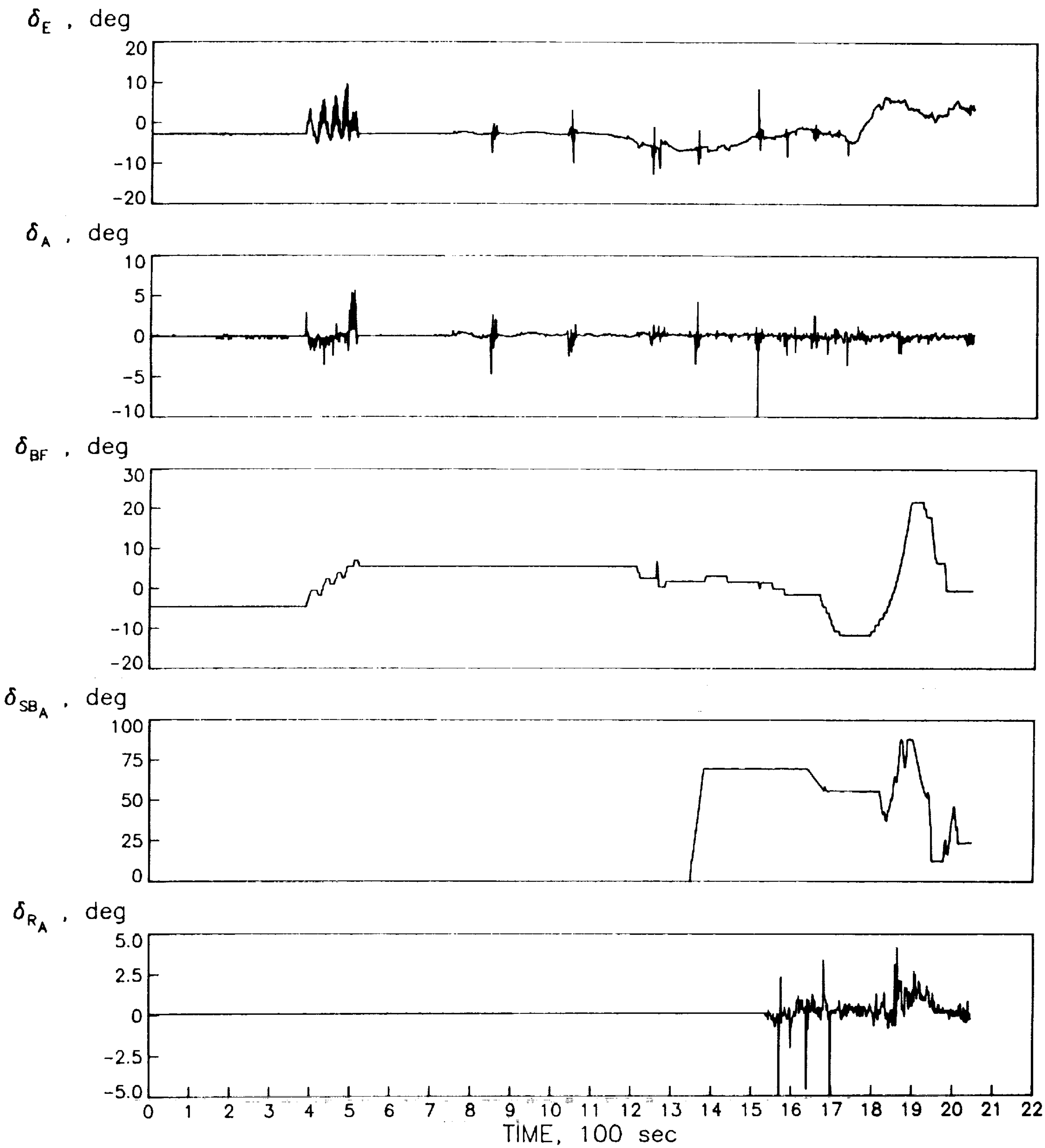


Figure III-2. Time history of STS-35 control surface deflections.

IV. SUMMARY RESULTS

Summary results showing aerodynamic performance comparisons for STS-35 are presented herein. Time histories of most of the elements necessary to determine flight coefficients and generate the necessary databook predictions have already been presented, either as figures within the report or included as part of the listing in Appendix B. In this section, some of this information will be re-plotted versus Mach number as a matter of interest prior to presenting the actual flight/databook differences. Though Mach number is utilized as the independent variable here, readers should note that the databook formulation incorporates table look-ups versus altitude, VBAR, and Mach number dependent upon the particular flight regime. Since altitude is used above 300 kft, and since this altitude is well above the threshold of the IMU accelerometer measurements, plots versus altitude, though interesting, will not be presented. VBAR is utilized for values of that variable between 0.08 ($h \approx 300$ kft) and 0.005. The lowermost value translates to an approximate Mach number of 14.4 ($h \approx 181$ kft). However, even though VBAR is utilized throughout much of the entry, plots versus Mach number are still considered the most relevant. To that extent, it should also be stated that these plots were initiated 410 seconds from epoch to assure that Mach number would be a monotonically decreasing variable thereafter. This time corresponds to an altitude of 282 kft.

Figures IV-1 and IV-2 show the spacecraft angular rates and linear accelerations versus Mach number. Control surface deflections are presented as Figure IV-3. The shaded band shown thereon provides for a measure of comparison versus the total range flown over an ensemble of 22 of the first 24 Shuttle entry flights, i. e., through and including STS 61-C. Obviously, the shaded region shown on this and other plots herein may no longer reflect a total spread since many later missions are not included in the compiled statistics.

Figure IV-4 presents the flight center-of-gravity plotted against Mach number. Again, the range associated with the earlier 22 flights is noted by the shaded region. As can be seen, the flight c.g. is somewhat forward of the previous subset of flights. This flight might well represent the extreme since it was one of the heaviest, if not the heaviest, Shuttle entry flights of record with its associated Astro payload.

The air-relative attitude angles included as part of the listing in Appendix B are re-plotted herein versus Mach number in Figure IV-5. Again, angle-of-attack excursions based on the

22-flight subset are indicated thereon. No comparable ranges were ever computed for the side-slip and roll angles. It can be observed that the excursions in the side-slip angle are quite small as one should expect, i. e., there are no steady-state departures from the inherent weather-vane stability of the Orbiter. This is an observation that supports the adequacy of the NOAA wind profile adopted from the JSC BET, at least over the subsonic environs where winds are more significant. On many past flights, large departures in side-slip and erroneous angle-of-attack computations were evident and had to be rectified by wind estimation methods and other supporting analyses. In any event, comparisons of both α and β with the equivalent SEADS-derived quantities should be of interest.

The final summary results presented are the longitudinal aerodynamic performance comparisons. Aerodynamic differences are presented as a percentage of the flight-derived coefficient. The differences are defined as flight-extracted minus predicted values. Lift, drag, and L/D comparisons are shown in Figure IV-6. Similarly, axial, normal, and pitching moment coefficient comparisons are presented in Figure IV-7, the latter at the 65 percent moment reference center consistent with the databook. The statistical bands superimposed on these figures indicate the expected aerodynamic comparison accuracy, again based on the 22-flight subset. It should be understood that the predicted values herein were rectified using the FAD26 incrementals. These prediction corrections were derived based on consensus opinion of the various project aerodynamicists from analyses of flights through STS-26 (an August 1985 flight). Also, it can be observed that the major departure in the force coefficients (above Mach 20), which suggests a 20 percent over-prediction, coincides with the density bulge indicated in the measured density profile (refer back to Figure II-5 herein). The SEADS determined QBAR should substantiate that this discrepancy is in fact a limitation of the measured density.

The pitching moment comparisons do show considerable differences when compared with the expected results indicated by the statistical band. Though this is not completely understood, it was previously noted that the flight c. g. was further forward than on previous missions and, as can be seen in Figure IV-3, the elevon displacement is toward the lowermost boundary. Obviously, some of the pitching moment discrepancy may be related to density accuracy.

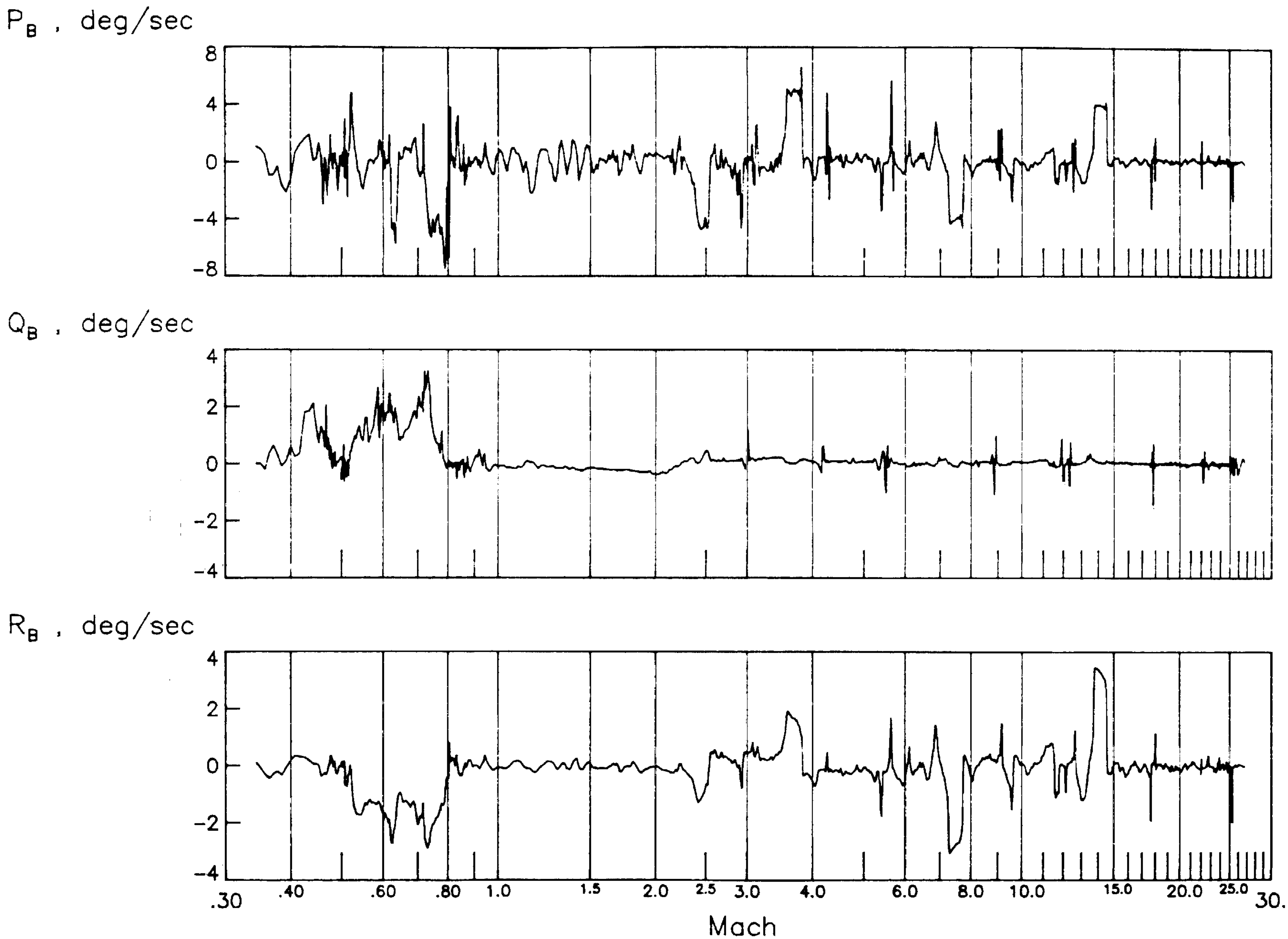


Figure IV-1. Spacecraft angular rates versus Mach number during STS-35 entry.

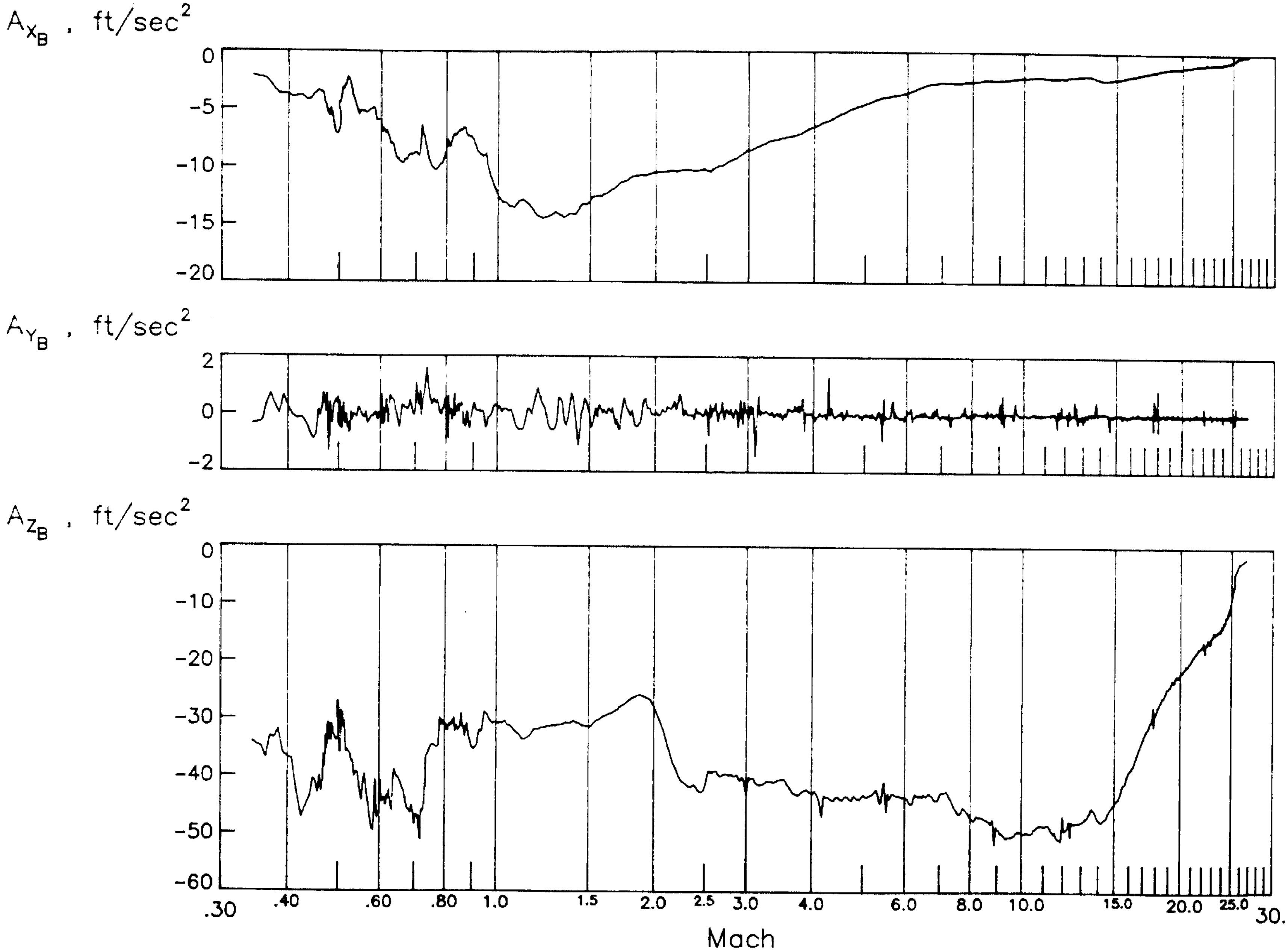


Figure IV-2. STS-35 body-axis accelerations versus Mach number.

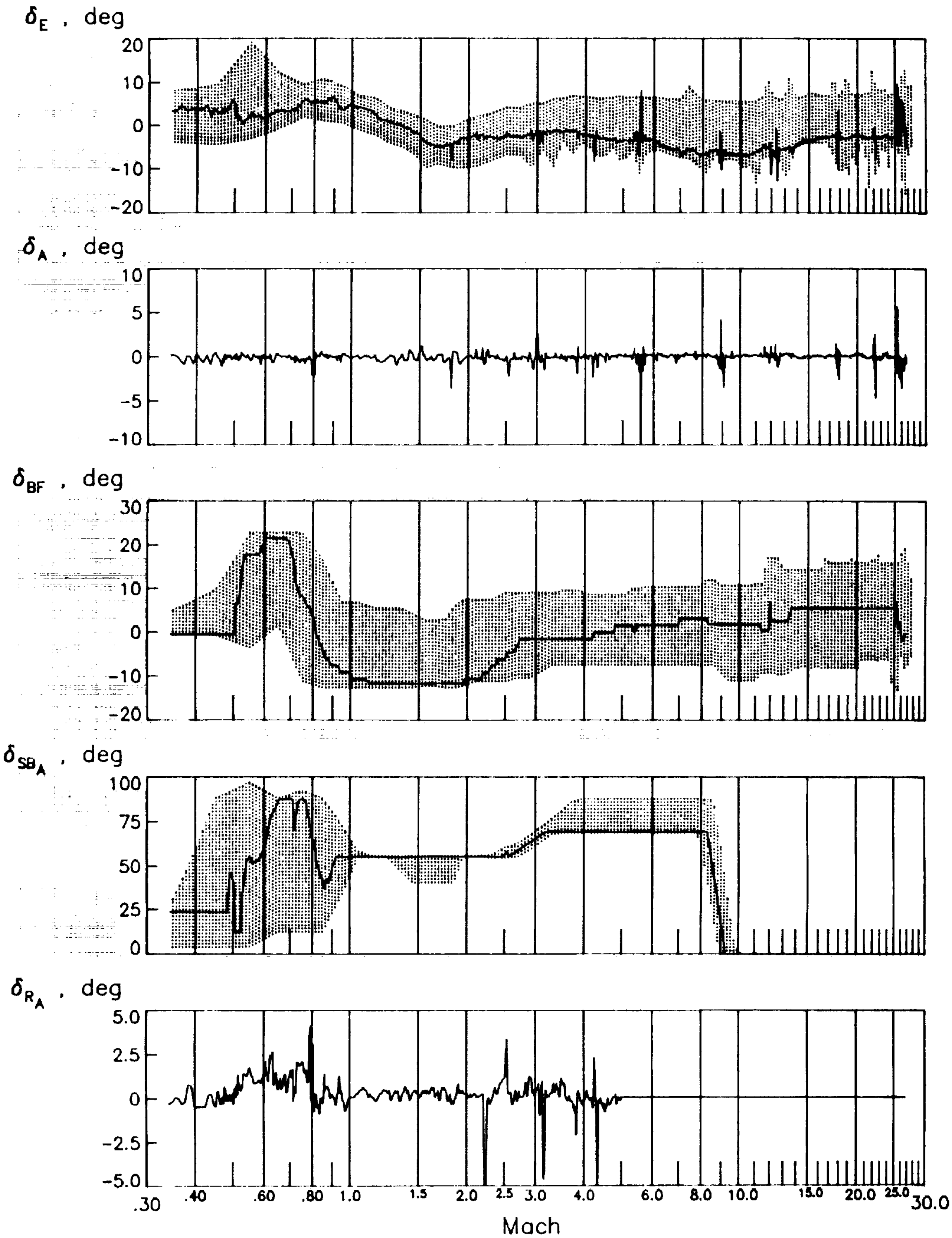


Figure IV-3. STS-35 control surface deflections versus Mach number.

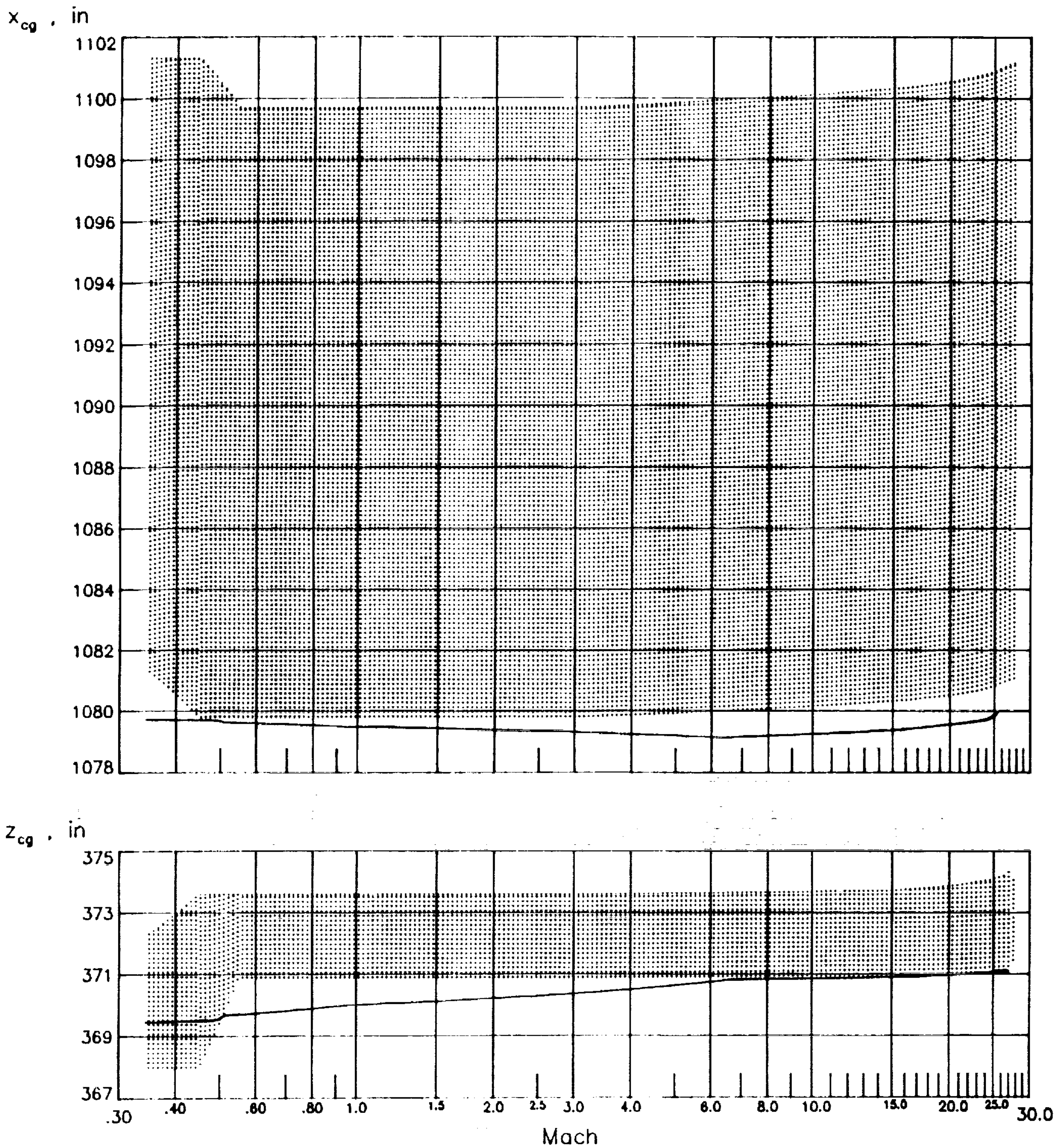


Figure IV-4. STS-35 center-of-gravity versus Mach number.

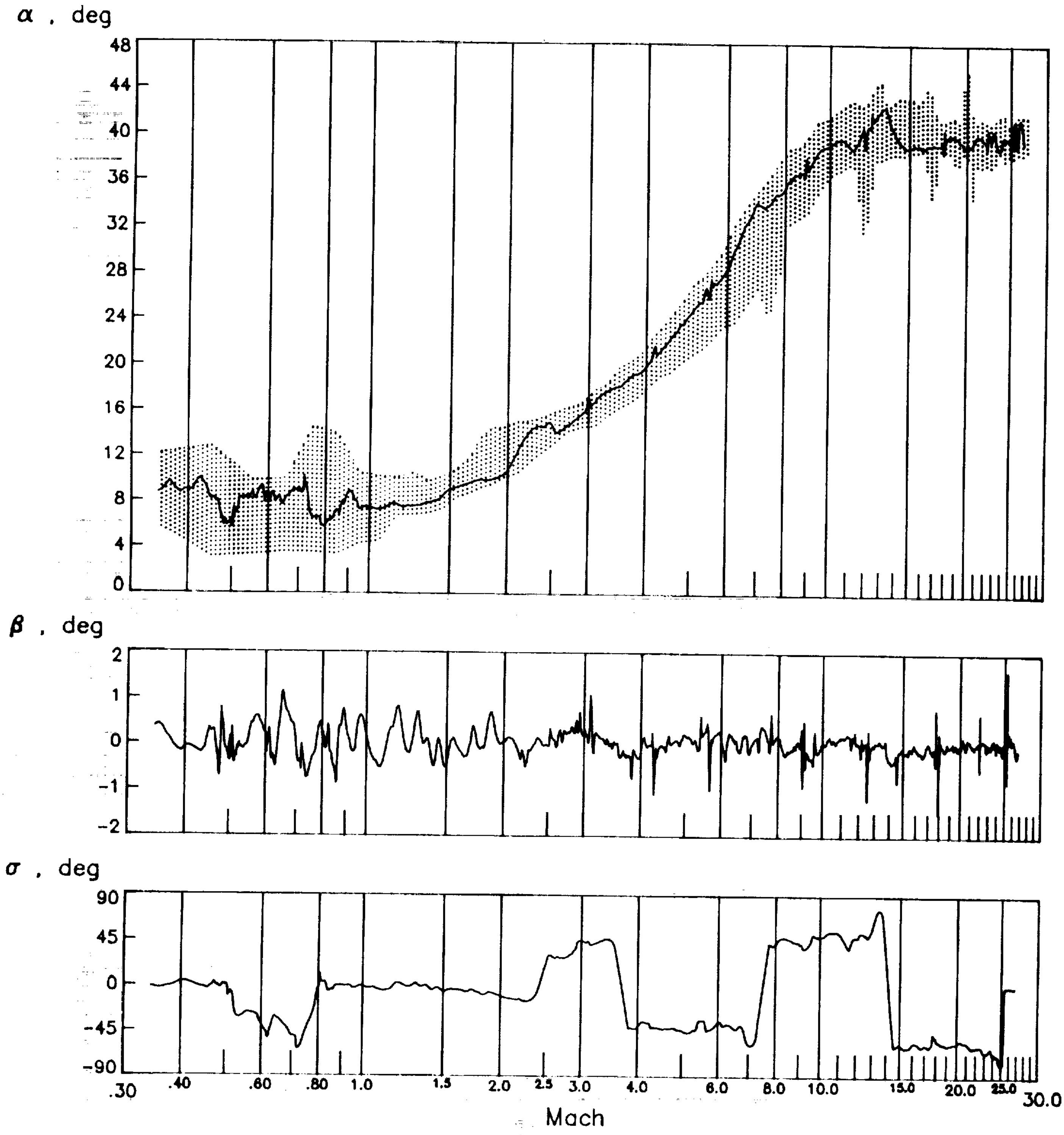


Figure IV-5. STS-35 air-relative attitude angles versus Mach number.

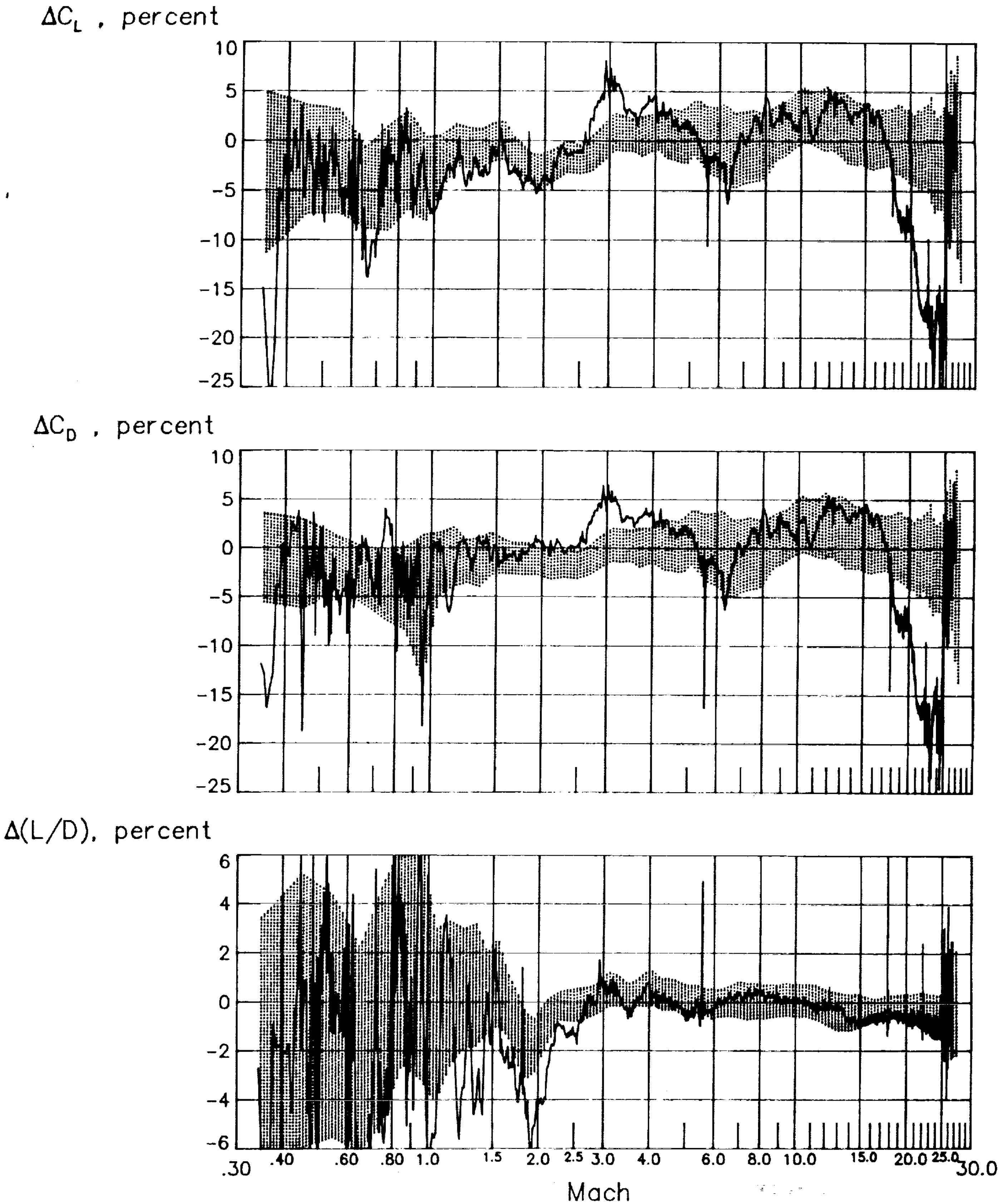


Figure IV-6. **STS-35 flight/databook lift, drag and L/D comparisons for which the predicted values are rectified by the FAD26 incrementals.**

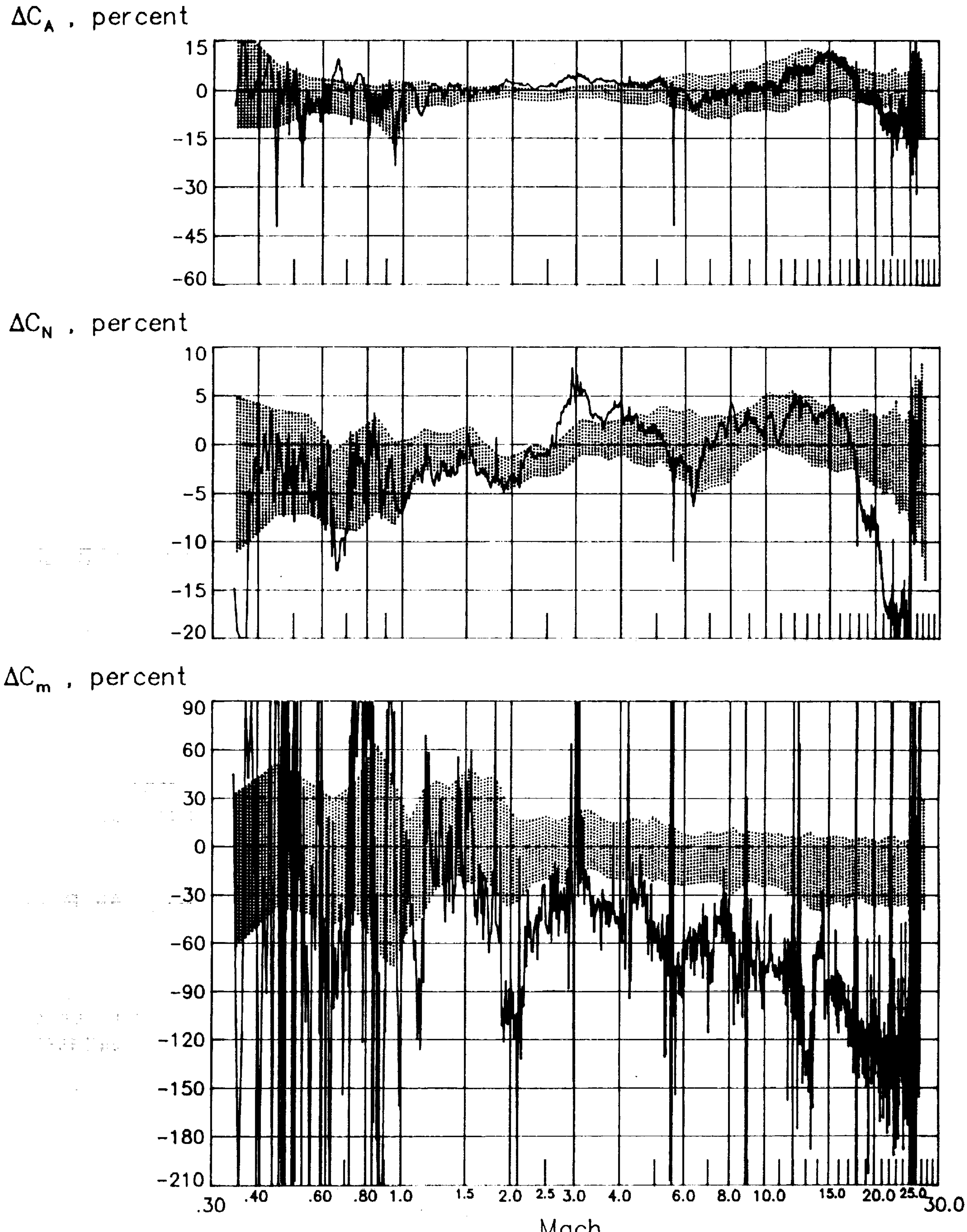


Figure IV-7. STS-35 axial force, normal force and pitching moment comparisons. (databook rectified by FAD26, C_m referenced to 65% X/L)

REFERENCES

(1) *Findlay, J. T., Oakes, K. F., Jasinski, R. A., and Wood, J. S.;*
"The ENTREE System of Software; Parts I, III and IV," FM&C Report No. 89-R-3, May-June 1990.

(2) *Oakes, K. F., and Findlay, J. T.;*
"TDRSS Range and Doppler Observation Processing and Modeling for Inclusion in the ENTREE Program," FM&C Report No. 90-R-1, January 1990.

(3) *Findlay, J. T., and Jasinski, R. A.;*
"Final Shuttle-derived Atmospheric Database: Development and Results from Thirty-two Flights," NASA CR-185636, July 1990.

(4) *Romere, P. O. (prepared by);*
"Flight Assessment Package, Orbiter Aerodynamics, FAD26," JSC-22078, April 1986.

(5) *Justus, C. G., et al;*
"The NASA/MSFC Global Reference Atmospheres - Mod 3 (With Spherical Harmonic Wind Model)," NASA CR-3256, March 1980.

(6) *Cole, A. E., and Kantor, A. J.;*
"Air Force Reference Atmospheres," AFGL-TR-78-0051, Air Force Surveys in Geophysics, No. 382, February 1978.

(7) *Schlosser, D. C. and Bornemann, W. E. (approved by);*
"Pre-Operational Aerodynamic Design Data Book, Volume I, Orbiter Vehicle," Rockwell International Report SD72-SH-0060-1L-7, April 1982.

APPENDIX A

FINAL C-BAND RESIDUALS FOR STS-35 TRAJECTORY RECONSTRUCTION

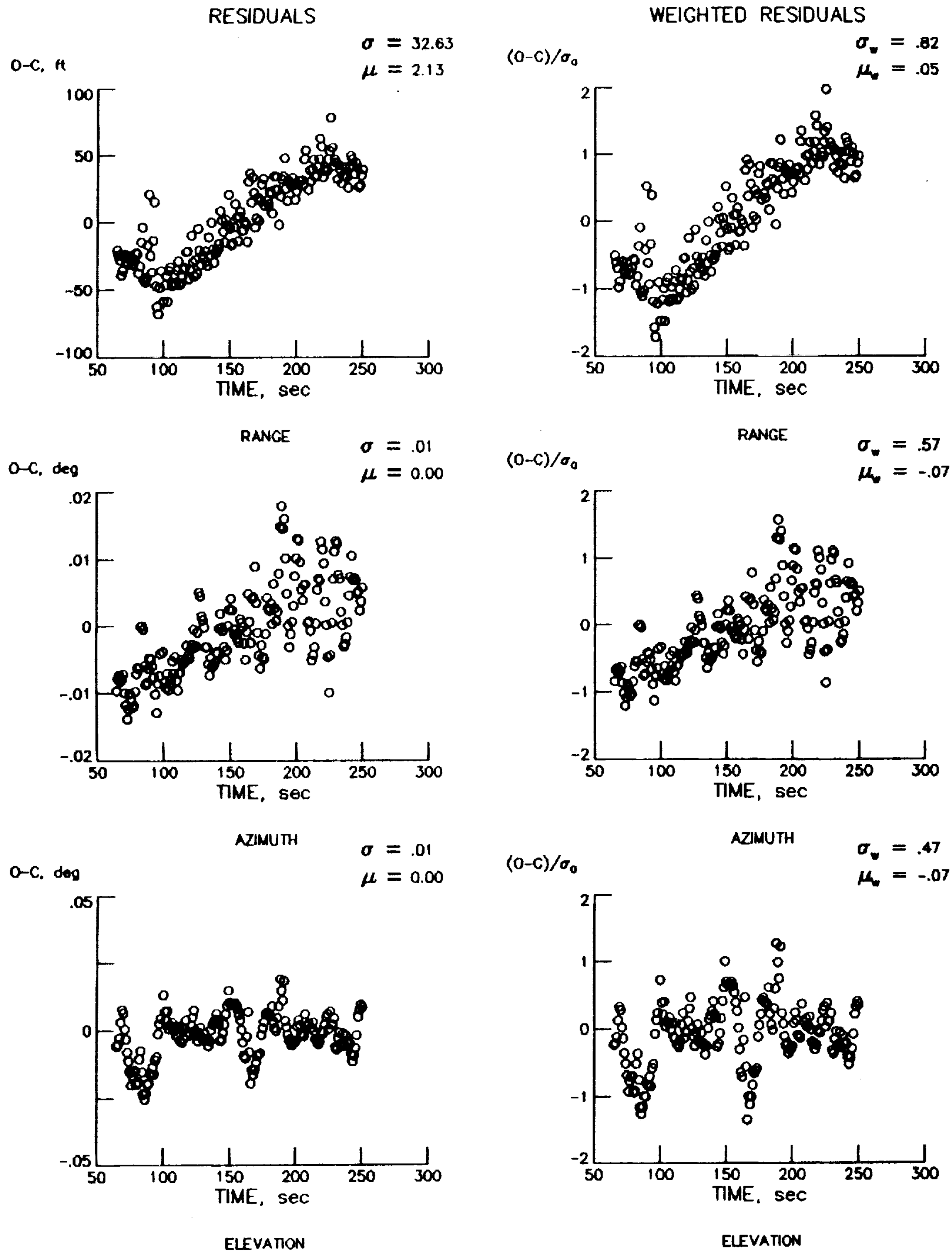


Figure A-1. Final residuals for high-rate Kwajalein station, KMACH.

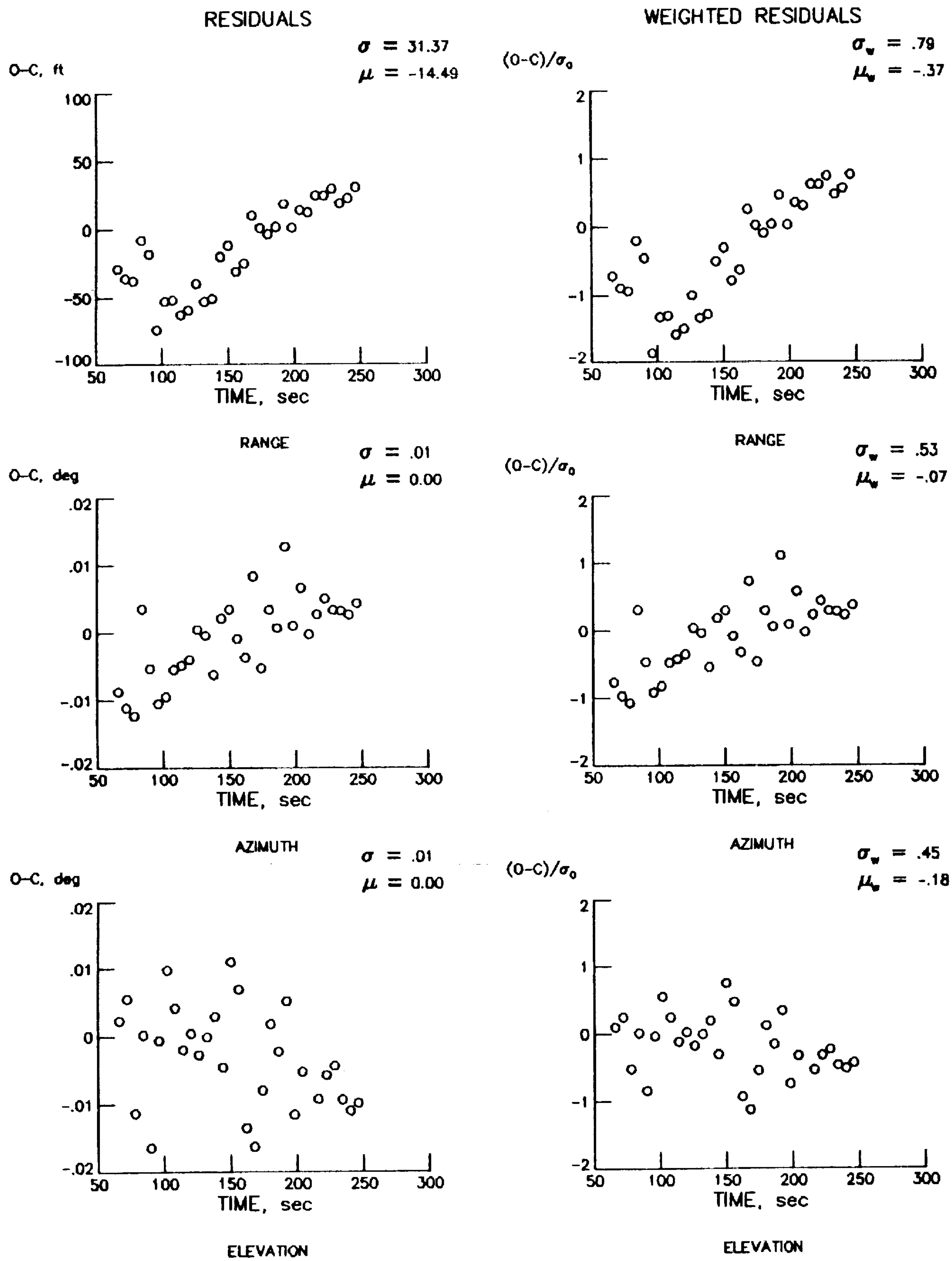


Figure A-2. Final residuals for low-rate Kwajalein station, KMACL.

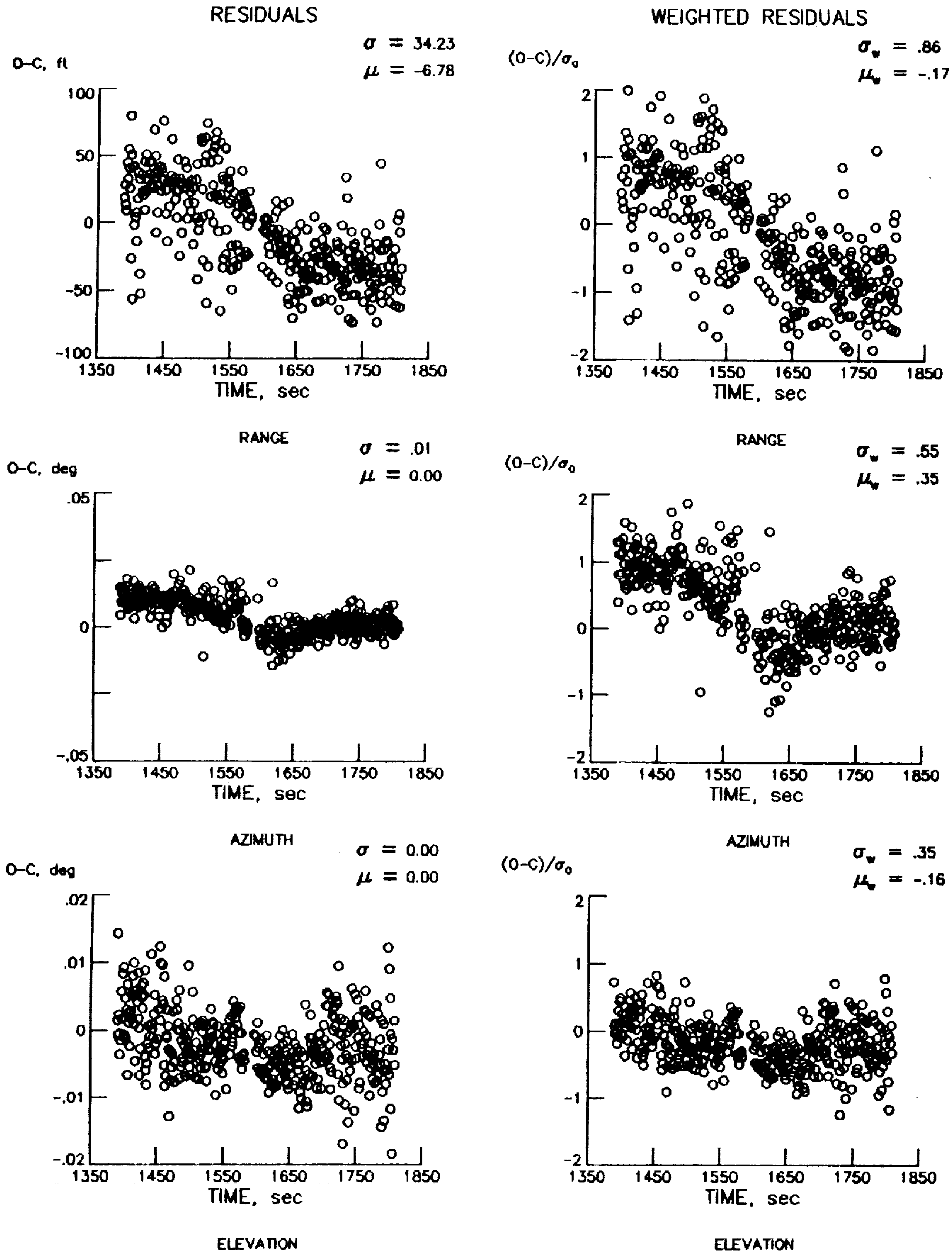


Figure A-3. Final residuals for Pt. Mugu, PMFC.

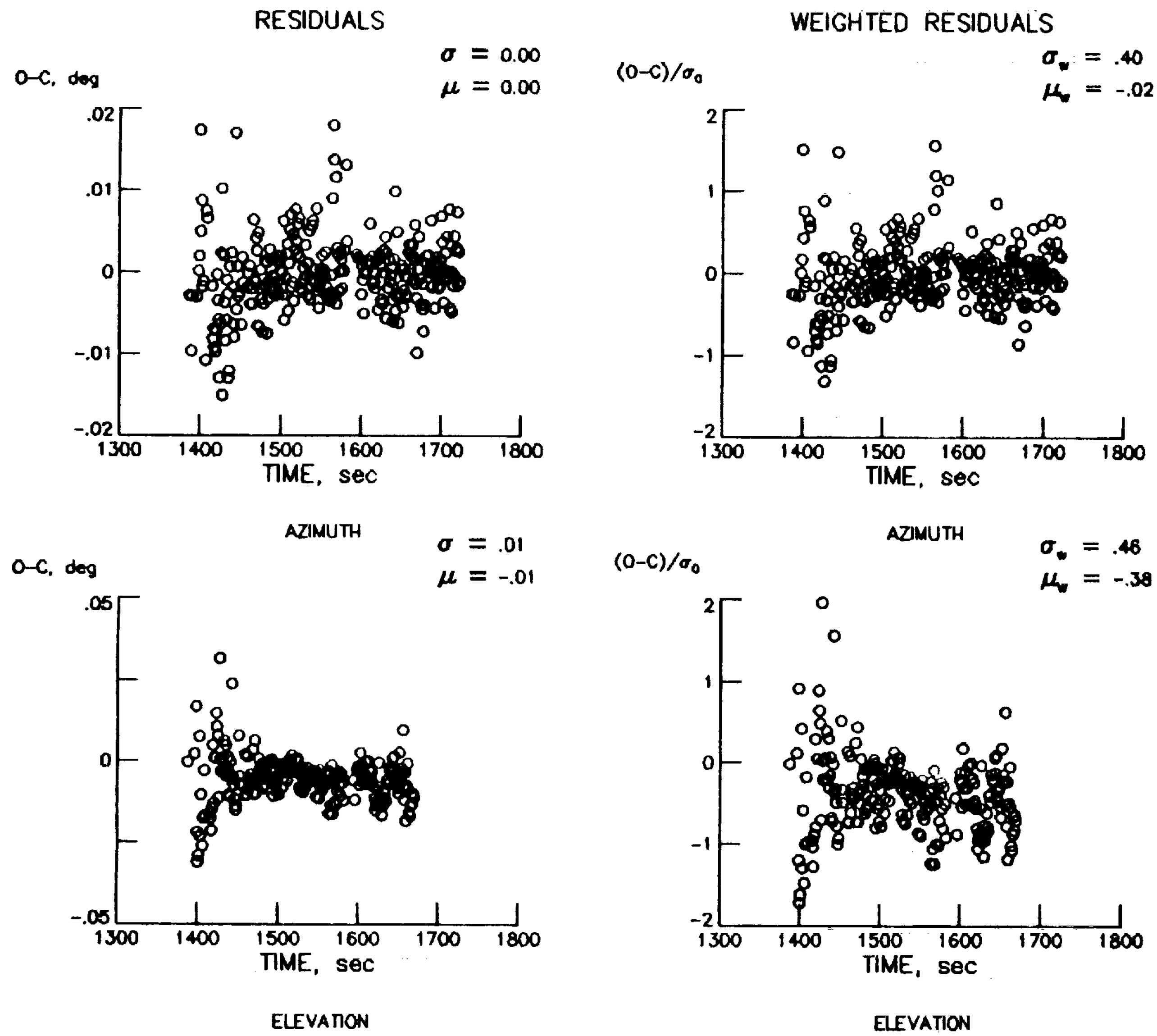


Figure A-4. Final azimuth and elevation residuals for SNFC.

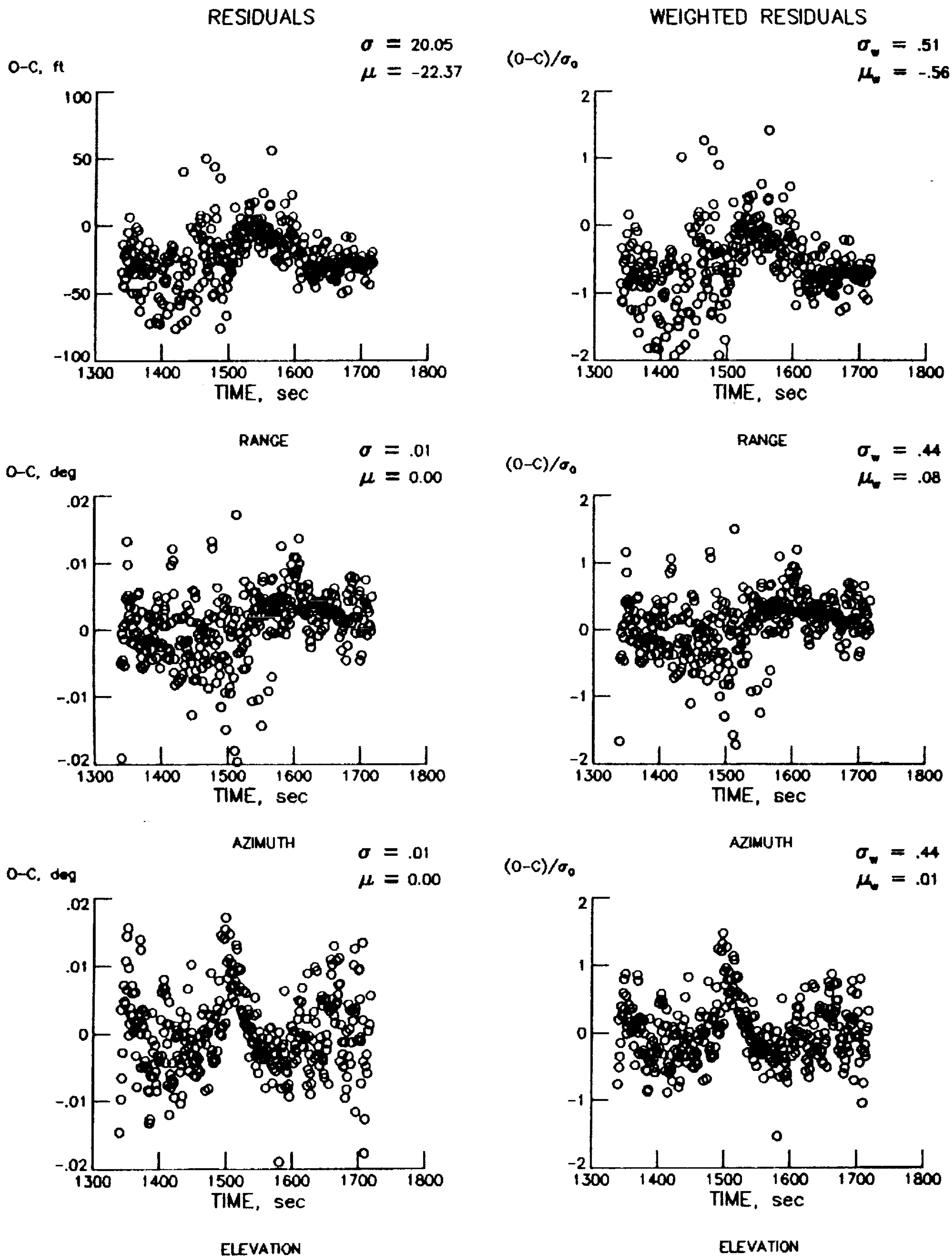


Figure A-5. Final Vandenberg residuals, VDBC.

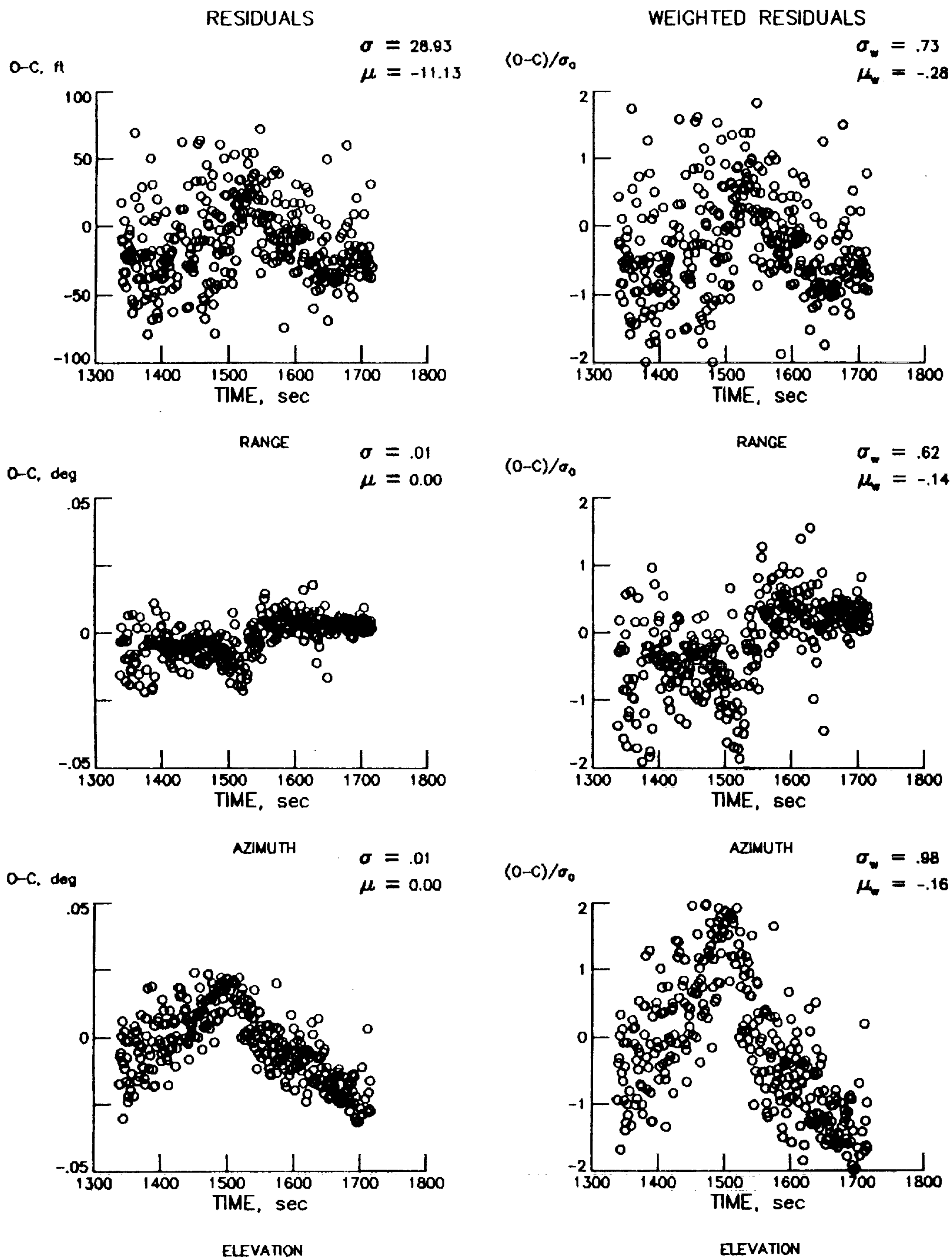


Figure A-6. Final Vandenberg residuals, VDFC.

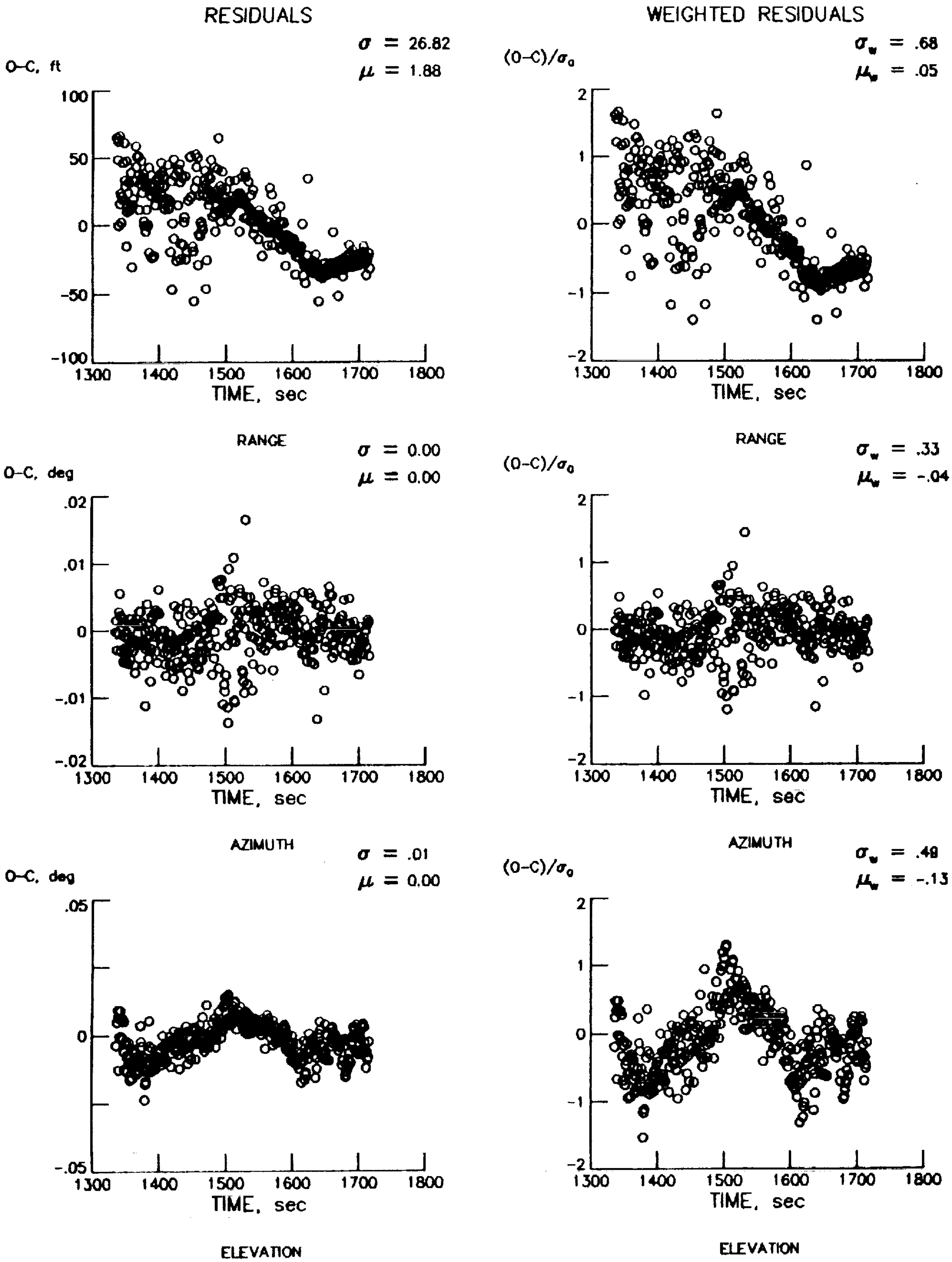


Figure A-7. Final Vandenberg residuals, VDHC.

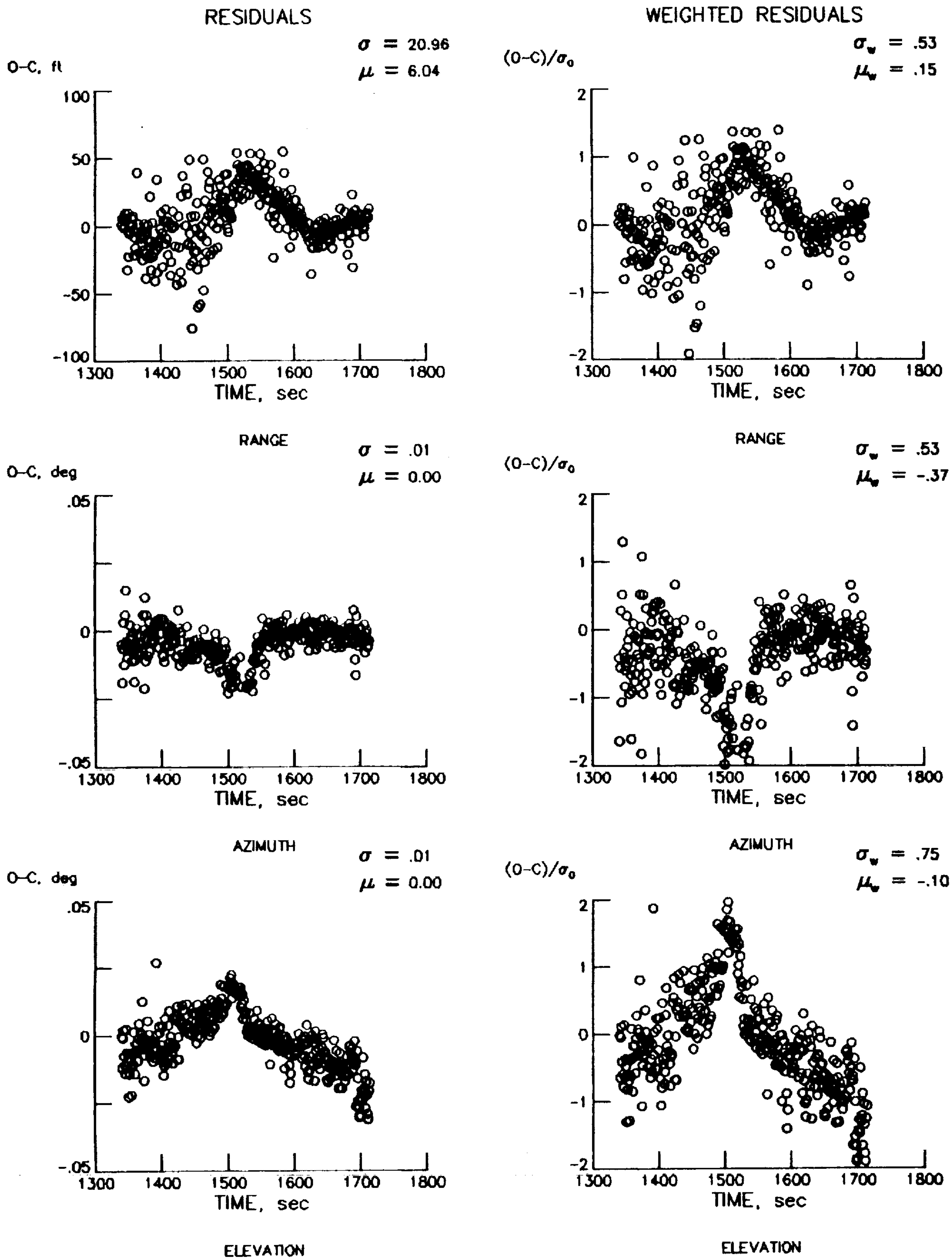


Figure A-8. Final Vandenberg residuals, VDSC.

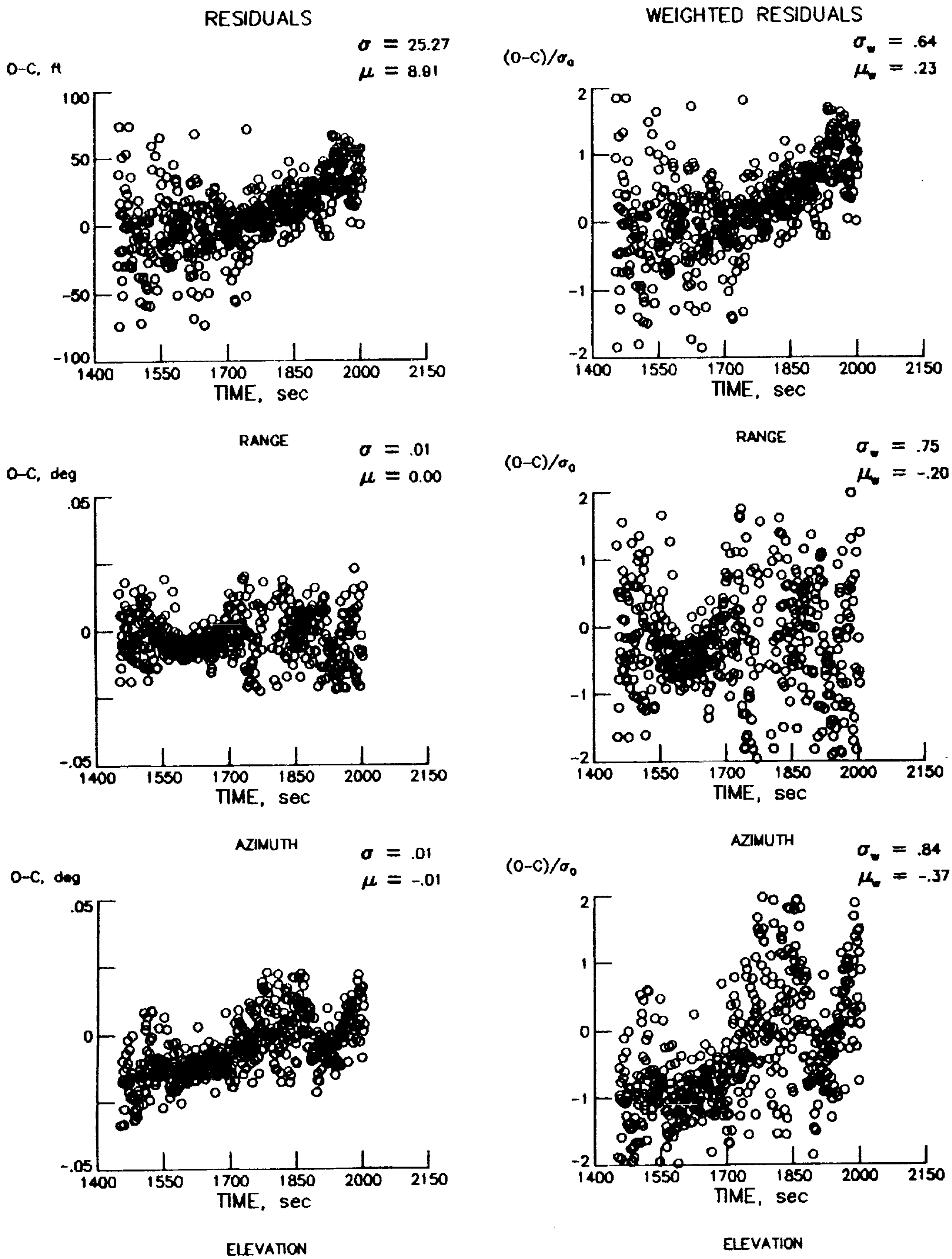


Figure A-9. Final Edwards residuals, EFFC.

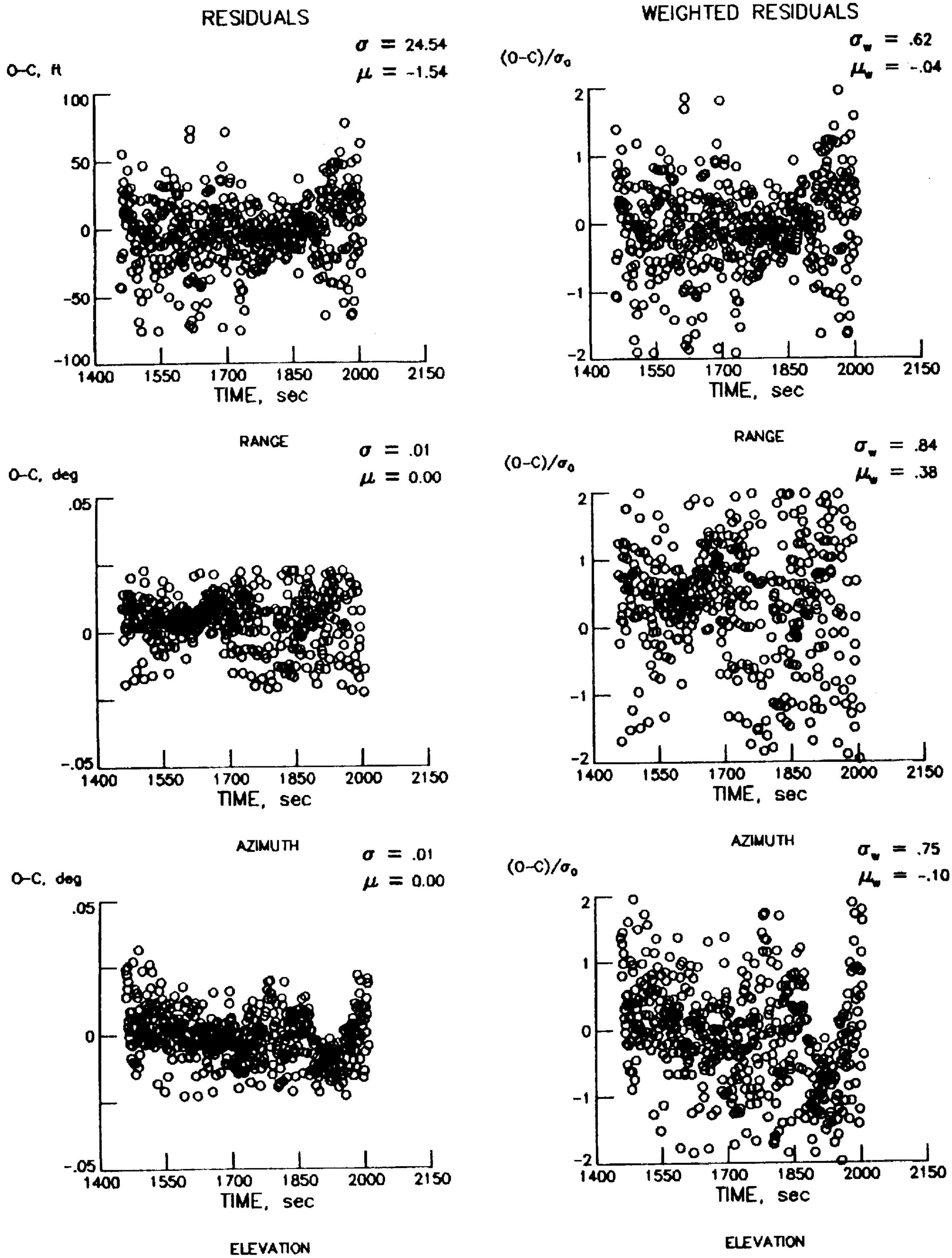


Figure A-10. Final Dryden residuals, FRCC.

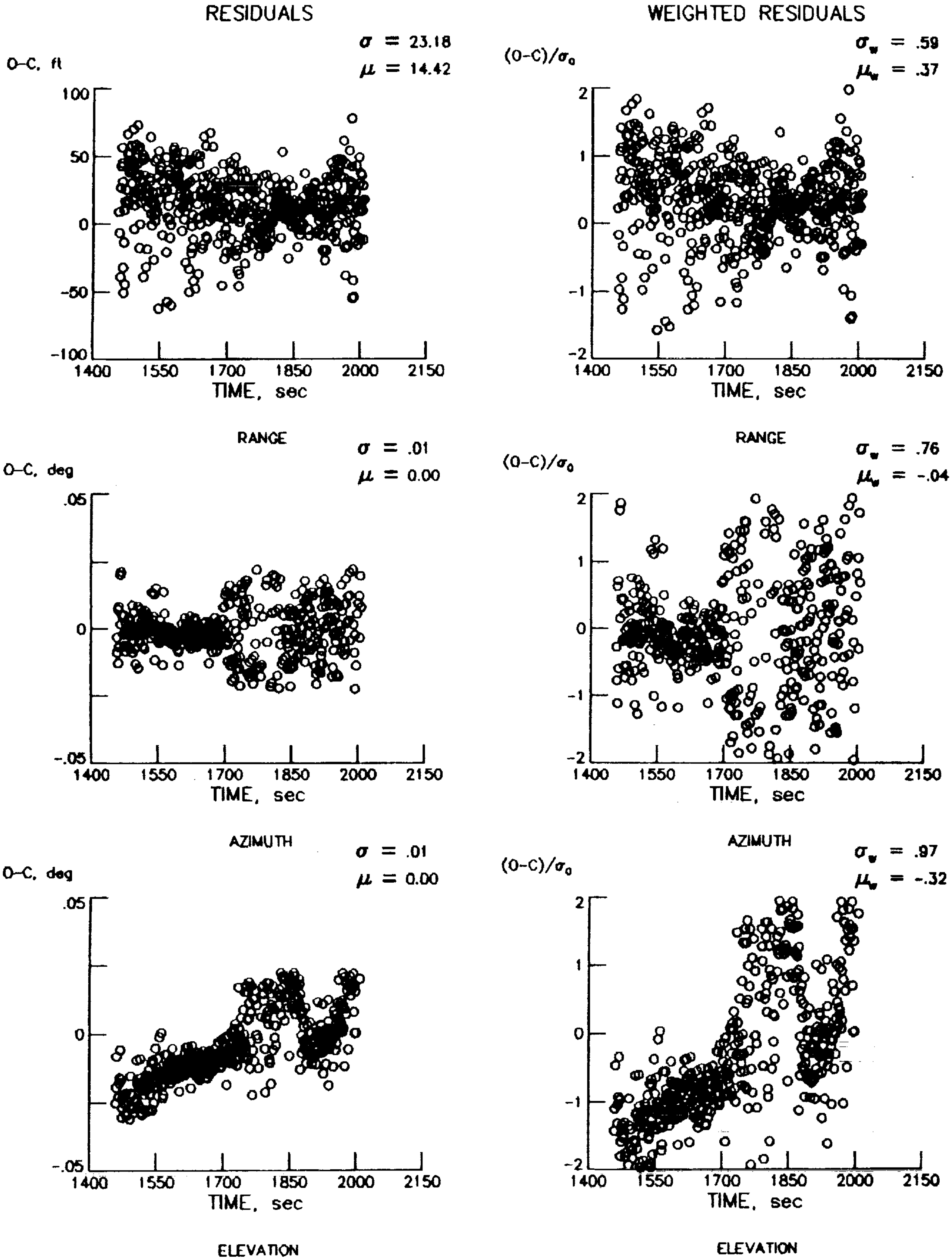


Figure A-11. Final Dryden residuals, FRFC.

APPENDIX B

LISTING OF TRAJECTORY AND AIR-DATA PARAMETERS

FOR THE STS-35 COLUMBIA OEX ENTRY MISSION

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
0	513594	24357.7	-1.515	60.74	0.03	0.28	39.59				
2	512327	24359.3	-1.514	60.76	-0.11	0.16	39.67				
4	511062	24360.9	-1.513	60.78	-0.27	-0.01	39.77				
6	509797	24362.5	-1.512	60.80	-0.43	-0.18	39.86				
8	508533	24364.1	-1.511	60.82	-0.57	-0.35	39.96				
10	507270	24365.7	-1.510	60.84	-0.72	-0.50	40.08				
12	506008	24367.3	-1.509	60.86	-0.59	-0.41	40.23				
14	504746	24368.9	-1.508	60.87	-0.44	-0.29	40.39				
16	503486	24370.4	-1.508	60.89	-0.30	-0.18	40.56				
18	502226	24372.0	-1.507	60.91	-0.16	-0.06	40.74				
20	500967	24373.6	-1.506	60.93	-0.02	0.05	40.93				
22	499709	24375.2	-1.505	60.95	0.11	0.17	41.13				
24	498452	24376.7	-1.504	60.97	0.24	0.29	41.26				
26	497196	24378.3	-1.503	60.99	0.29	0.33	41.29				
28	495941	24379.9	-1.502	61.01	0.11	0.15	41.28				
30	494686	24381.4	-1.501	61.03	-0.08	-0.02	41.24				
32	493433	24383.0	-1.500	61.05	-0.26	-0.20	41.17				
34	492181	24384.6	-1.499	61.07	-0.44	-0.37	41.09				
36	490929	24386.2	-1.498	61.09	-0.57	-0.49	41.02				
38	489679	24387.8	-1.497	61.11	-0.36	-0.27	40.96				
40	488429	24389.3	-1.496	61.13	-0.14	-0.06	40.88				
42	487180	24390.9	-1.494	61.16	0.08	0.16	40.82				
44	485933	24392.5	-1.493	61.18	0.19	0.29	40.77				
46	484686	24394.0	-1.492	61.20	0.20	0.31	40.75				
48	483440	24395.6	-1.491	61.22	0.19	0.32	40.74				
50	482195	24397.1	-1.490	61.24	0.20	0.35	40.73				
52	480952	24398.7	-1.489	61.26	0.20	0.36	40.73				
54	479709	24400.3	-1.488	61.29	0.15	0.14	40.74				
56	478467	24401.8	-1.487	61.31	0.09	-0.08	40.75				
58	477226	24403.4	-1.486	61.33	0.03	-0.30	40.77				
60	475986	24404.9	-1.485	61.35	0.01	-0.31	40.81				
62	474748	24406.5	-1.484	61.38	-0.00	-0.29	40.84				
64	473510	24408.0	-1.482	61.40	-0.03	-0.28	40.87				
66	472273	24409.6	-1.481	61.42	-0.05	-0.26	40.93				
68	471038	24411.1	-1.480	61.44	-0.07	-0.24	40.98				
70	469803	24412.7	-1.479	61.47	-0.09	-0.23	41.05				
72	468569	24414.2	-1.478	61.49	-0.12	-0.22	41.03				
74	467337	24415.8	-1.477	61.51	-0.15	-0.20	40.99				
76	466106	24417.3	-1.475	61.54	-0.20	-0.19	40.97				
78	464875	24418.9	-1.474	61.56	-0.23	-0.18	40.92				
80	463646	24420.4	-1.473	61.59	-0.27	-0.17	40.85				
82	462418	24421.9	-1.472	61.61	-0.32	-0.17	40.79				
84	461191	24423.5	-1.471	61.63	-0.37	-0.16	40.74				
86	459965	24425.0	-1.469	61.66	-0.40	-0.15	40.69				
88	458740	24426.6	-1.468	61.68	-0.48	-0.15	40.65				
90	457516	24428.1	-1.467	61.71	-0.53	-0.15	40.62				
92	456294	24429.6	-1.466	61.73	-0.60	-0.15	40.59				
94	455072	24431.2	-1.464	61.76	-0.67	-0.15	40.58				
96	453852	24432.7	-1.463	61.78	-0.73	-0.14	40.57				
98	452633	24434.2	-1.462	61.81	-0.81	-0.15	40.58				
100	451415	24435.8	-1.461	61.83	-0.88	-0.15	40.58				
102	450198	24437.3	-1.459	61.86	-0.97	-0.16	40.60				
104	448982	24438.8	-1.458	61.89	-1.04	-0.16	40.62				
106	447768	24440.3	-1.457	61.91	-1.13	-0.17	40.66				
108	446554	24441.9	-1.455	61.94	-1.21	-0.17	40.70				
110	445342	24443.4	-1.454	61.97	-1.30	-0.17	40.75				

Table B-1. STS-35 trajectory and air-data parameters.

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
112	444131	24444.9	-1.453	61.99	-1.40	-0.19	40.80				
114	442921	24446.4	-1.451	62.02	-1.50	-0.27	40.86				
116	441712	24448.0	-1.450	62.05	-1.57	-0.44	40.94				
118	440505	24449.5	-1.449	62.07	-1.31	-0.32	41.02				
120	439299	24451.0	-1.447	62.10	-1.06	-0.18	41.06				
122	438094	24452.5	-1.446	62.13	-0.80	-0.05	41.04				
124	436890	24454.0	-1.444	62.15	-0.56	0.09	40.95				
126	435688	24455.5	-1.443	62.18	-0.32	0.21	40.87				
128	434487	24457.0	-1.441	62.21	-0.08	0.34	40.81				
130	433287	24458.5	-1.440	62.24	-0.10	0.22	40.78				
132	432088	24460.0	-1.439	62.27	-0.17	0.06	40.75				
134	430891	24461.5	-1.437	62.29	-0.23	-0.10	40.74				
136	429695	24463.0	-1.436	62.32	-0.31	-0.27	40.73				
138	428500	24464.5	-1.434	62.35	-0.38	-0.41	40.72				
140	427306	24466.0	-1.433	62.38	-0.41	-0.34	40.73				
142	426114	24467.5	-1.431	62.41	-0.44	-0.25	40.74				
144	424923	24469.0	-1.430	62.44	-0.47	-0.17	40.76				
146	423734	24470.5	-1.428	62.47	-0.51	-0.09	40.78				
148	422545	24472.0	-1.427	62.50	-0.54	-0.01	40.82				
150	421358	24473.5	-1.425	62.53	-0.60	0.06	40.86				
152	420173	24475.0	-1.424	62.56	-0.64	0.13	40.91				
154	418988	24476.4	-1.423	62.58	-0.70	0.15	40.96				
156	417805	24477.9	-1.421	62.61	-0.81	-0.03	41.03				
158	416623	24479.4	-1.419	62.64	-0.92	-0.21	41.04				
160	415443	24480.9	-1.418	62.68	-1.03	-0.39	40.99				
162	414264	24482.4	-1.416	62.71	-0.96	-0.37	40.95				
164	413087	24483.9	-1.415	62.74	-0.77	-0.26	40.90				
166	411910	24485.3	-1.413	62.77	-0.58	-0.14	40.85				
168	410736	24486.8	-1.412	62.80	-0.40	-0.03	40.82				
170	409562	24488.3	-1.410	62.83	-0.21	0.08	40.79				
172	408390	24489.7	-1.408	62.86	-0.04	0.20	40.76				
174	407220	24491.2	-1.407	62.89	0.13	0.30	40.75				
176	406050	24492.7	-1.405	62.92	0.24	0.35	40.75				
178	404883	24494.2	-1.404	62.95	0.19	0.26	40.77				
180	403716	24495.6	-1.402	62.99	0.15	0.18	40.80				
182	402551	24497.1	-1.400	63.02	0.11	0.09	40.83				
184	401388	24498.5	-1.399	63.05	0.06	-0.00	40.88				
186	400226	24500.0	-1.397	63.08	0.01	-0.09	40.92	18.45	0.01	0.8681	2.08E+02
188	399065	24530.0	-1.394	63.08	-0.05	-0.23	40.98	18.56	0.01	0.8536	2.17E+02
190	397906	24532.6	-1.392	63.11	-0.11	-0.32	41.04	18.68	0.01	0.8359	2.29E+02
192	396748	24535.2	-1.390	63.14	-0.16	-0.42	41.00	18.80	0.01	0.8186	2.41E+02
194	395592	24537.8	-1.388	63.18	-0.22	-0.50	40.96	18.93	0.01	0.8016	2.54E+02
196	394437	24540.3	-1.387	63.21	-0.25	-0.39	40.92	19.05	0.01	0.7850	2.67E+02
198	393284	24542.5	-1.385	63.25	-0.26	-0.23	40.89	19.18	0.02	0.7683	2.82E+02
200	392132	24544.6	-1.383	63.29	-0.29	-0.09	40.86	19.30	0.02	0.7515	2.97E+02
202	390982	24546.7	-1.382	63.33	-0.33	0.06	40.84	19.43	0.02	0.7352	3.14E+02
204	389833	24548.7	-1.380	63.37	-0.36	0.21	40.83	19.56	0.02	0.7192	3.31E+02
206	388686	24550.8	-1.378	63.41	-0.43	0.23	40.82	19.69	0.02	0.7035	3.50E+02
208	387540	24552.9	-1.376	63.45	-0.56	-0.01	40.82	19.82	0.02	0.6879	3.70E+02
210	386396	24554.9	-1.374	63.48	-0.68	-0.25	40.81	19.96	0.02	0.6721	3.91E+02
212	385253	24557.0	-1.373	63.52	-0.76	-0.45	40.83	20.09	0.02	0.6567	4.14E+02
214	384112	24559.1	-1.371	63.56	-0.49	-0.31	40.89	20.23	0.02	0.6417	4.38E+02
216	382972	24561.2	-1.369	63.59	-0.23	-0.17	40.95	20.36	0.02	0.6271	4.64E+02
218	381834	24563.6	-1.367	63.63	0.04	-0.01	41.02	20.50	0.02	0.6126	4.91E+02
220	380697	24568.1	-1.365	63.67	0.31	0.13	40.91	20.64	0.03	0.5981	5.21E+02

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
222	379562	24572.6	-1.363	63.70	0.56	0.27	40.75	20.77	0.03	0.5839	5.52E+02
224	378429	24577.1	-1.361	63.74	0.78	0.36	40.59	20.91	0.03	0.5700	5.85E+02
226	377297	24581.6	-1.359	63.78	0.82	0.29	40.46	21.05	0.03	0.5565	6.20E+02
228	376167	24586.1	-1.357	63.81	0.86	0.24	40.34	21.20	0.03	0.5433	6.58E+02
230	375038	24589.6	-1.355	63.85	0.90	0.18	40.22	21.33	0.03	0.5301	6.97E+02
232	373911	24593.0	-1.353	63.90	0.92	0.12	40.11	21.45	0.03	0.5172	7.40E+02
234	372786	24596.4	-1.351	63.94	0.96	0.06	40.00	21.59	0.04	0.5046	7.85E+02
236	371662	24599.7	-1.349	63.98	0.98	-0.00	39.89	21.72	0.04	0.4923	8.32E+02
238	370540	24603.1	-1.347	64.02	1.02	0.01	39.79	21.85	0.04	0.4803	8.83E+02
240	369419	24605.3	-1.345	64.06	1.08	0.19	39.69	21.99	0.04	0.4682	9.38E+02
242	368300	24606.4	-1.344	64.10	1.14	0.35	39.59	22.13	0.04	0.4562	9.98E+02
244	367183	24607.6	-1.342	64.14	1.01	0.35	39.52	22.26	0.05	0.4445	1.06E+03
246	366068	24608.8	-1.340	64.18	0.86	0.33	39.45	22.40	0.05	0.4331	1.13E+03
248	364954	24609.9	-1.338	64.22	0.70	0.31	39.38	22.55	0.05	0.4220	1.20E+03
250	363841	24611.0	-1.336	64.26	0.54	0.28	39.31	22.69	0.05	0.4111	1.28E+03
252	362731	24611.9	-1.334	64.30	0.37	0.25	39.25	22.82	0.06	0.4002	1.36E+03
254	361622	24612.8	-1.332	64.33	0.20	0.22	39.34	22.95	0.06	0.3896	1.45E+03
256	360514	24613.7	-1.330	64.37	0.03	0.18	39.43	23.09	0.06	0.3792	1.55E+03
258	359409	24614.7	-1.328	64.41	-0.16	0.14	39.52	23.23	0.07	0.3691	1.65E+03
260	358305	24615.7	-1.326	64.45	-0.33	0.10	39.61	23.37	0.07	0.3593	1.76E+03
262	357203	24616.1	-1.324	64.49	-0.52	0.07	39.70	23.50	0.07	0.3496	1.87E+03
264	356103	24616.3	-1.322	64.53	-0.72	0.02	39.78	23.63	0.08	0.3400	2.00E+03
266	355004	24616.6	-1.320	64.57	-0.92	-0.03	39.86	23.75	0.08	0.3307	2.13E+03
268	353907	24616.9	-1.318	64.61	-1.12	-0.09	39.93	23.88	0.09	0.3217	2.27E+03
270	352812	24617.3	-1.316	64.65	-1.31	-0.13	40.01	24.02	0.09	0.3130	2.42E+03
272	351719	24617.6	-1.314	64.69	-1.52	-0.18	40.08	24.15	0.10	0.3044	2.59E+03
274	350627	24617.5	-1.312	64.73	-1.72	-0.26	40.14	24.28	0.10	0.2956	2.77E+03
276	349538	24617.4	-1.310	64.77	-1.81	-0.40	40.21	24.42	0.11	0.2872	2.96E+03
278	348450	24617.3	-1.308	64.81	-1.71	-0.35	40.30	24.55	0.12	0.2790	3.16E+03
280	347364	24617.2	-1.306	64.85	-1.55	-0.26	40.38	24.69	0.12	0.2710	3.39E+03
282	346280	24617.1	-1.304	64.89	-1.38	-0.16	40.46	24.83	0.13	0.2633	3.62E+03
284	345197	24616.6	-1.302	64.92	-1.19	-0.05	40.53	24.95	0.14	0.2558	3.87E+03
286	344117	24615.9	-1.300	64.96	-1.02	0.04	40.58	25.05	0.15	0.2485	4.13E+03
288	343039	24615.1	-1.298	65.00	-0.85	0.13	40.64	25.16	0.16	0.2414	4.40E+03
290	341962	24614.4	-1.296	65.04	-0.68	0.23	40.68	25.27	0.17	0.2346	4.70E+03
292	340887	24613.7	-1.294	65.07	-0.51	0.33	40.71	25.38	0.18	0.2279	5.01E+03
294	339814	24613.0	-1.291	65.11	-0.34	0.42	40.73	25.48	0.19	0.2215	5.34E+03
296	338744	24611.9	-1.289	65.15	-0.37	0.32	40.77	25.57	0.20	0.2151	5.70E+03
298	337675	24610.7	-1.287	65.19	-0.41	0.22	40.79	25.67	0.21	0.2089	6.08E+03
300	336607	24609.6	-1.285	65.24	-0.46	0.12	40.80	25.76	0.22	0.2029	6.48E+03
302	335542	24608.5	-1.283	65.28	-0.49	0.02	40.81	25.85	0.23	0.1971	6.91E+03
304	334479	24607.3	-1.281	65.32	-0.53	-0.08	40.80	25.95	0.25	0.1915	7.37E+03
306	333418	24606.3	-1.278	65.36	-0.58	-0.18	40.78	26.05	0.26	0.1859	7.87E+03
308	332359	24605.4	-1.276	65.39	-0.60	-0.27	40.75	26.15	0.28	0.1803	8.43E+03
310	331302	24604.5	-1.274	65.43	-0.63	-0.37	40.70	26.26	0.30	0.1749	9.02E+03
312	330247	24603.5	-1.272	65.47	-0.62	-0.42	40.65	26.36	0.32	0.1697	9.65E+03
314	329194	24602.6	-1.269	65.51	-0.44	-0.32	40.61	26.47	0.34	0.1646	1.03E+04
316	328143	24601.4	-1.267	65.54	-0.27	-0.24	40.55	26.58	0.36	0.1597	1.10E+04
318	327094	24594.7	-1.265	65.58	-0.09	-0.14	40.47	26.62	0.38	0.1554	1.17E+04
320	326048	24586.7	-1.263	65.62	0.08	-0.06	40.39	26.66	0.40	0.1513	1.24E+04
322	325003	24578.8	-1.261	65.65	0.24	0.01	40.29	26.69	0.42	0.1473	1.31E+04
324	323961	24570.9	-1.259	65.69	0.38	0.08	40.17	26.73	0.44	0.1435	1.38E+04
326	322920	24563.2	-1.257	65.72	0.50	0.13	40.04	26.76	0.46	0.1397	1.46E+04
328	321882	24556.5	-1.255	65.76	0.60	0.17	39.90	26.79	0.49	0.1360	1.55E+04
330	320846	24557.8	-1.252	65.80	0.67	0.20	39.74	26.78	0.52	0.1319	1.64E+04

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
332	319813	24559.0	-1.250	65.85	0.72	0.20	39.56	26.78	0.55	0.1280	1.74E+04
334	318781	24560.3	-1.247	65.89	0.75	0.22	39.38	26.77	0.59	0.1242	1.85E+04
336	317752	24561.6	-1.244	65.94	0.73	0.18	39.22	26.76	0.62	0.1205	1.97E+04
338	316725	24562.8	-1.242	65.98	0.68	0.13	39.14	26.75	0.66	0.1169	2.09E+04
340	315701	24564.0	-1.239	66.03	0.58	0.04	39.19	26.75	0.70	0.1134	2.21E+04
342	314678	24565.2	-1.236	66.07	0.43	-0.06	39.25	26.74	0.75	0.1101	2.35E+04
344	313659	24566.3	-1.233	66.12	0.25	-0.20	39.30	26.73	0.79	0.1068	2.49E+04
346	312642	24567.4	-1.230	66.16	0.02	-0.37	39.34	26.73	0.84	0.1037	2.65E+04
348	311627	24568.4	-1.227	66.21	-0.14	-0.47	39.38	26.72	0.90	0.1007	2.81E+04
350	310615	24569.5	-1.223	66.25	-0.11	-0.38	39.42	26.72	0.95	0.0977	2.98E+04
352	309607	24570.4	-1.220	66.30	-0.13	-0.34	39.45	26.71	1.01	0.0949	3.16E+04
354	308601	24571.3	-1.217	66.34	-0.19	-0.31	39.47	26.70	1.07	0.0921	3.35E+04
356	307598	24572.2	-1.213	66.39	-0.27	-0.31	39.48	26.70	1.13	0.0895	3.55E+04
358	306598	24573.0	-1.210	66.44	-0.42	-0.35	39.48	26.69	1.20	0.0869	3.76E+04
360	305601	24573.9	-1.206	66.48	-0.59	-0.40	39.46	26.69	1.27	0.0844	3.98E+04
362	304607	24573.1	-1.202	66.53	-0.79	-0.48	39.45	26.67	1.34	0.0822	4.20E+04
364	303617	24571.0	-1.198	66.57	-0.99	-0.57	39.52	26.65	1.41	0.0802	4.40E+04
366	302630	24568.8	-1.194	66.62	-0.95	-0.43	39.69	26.62	1.48	0.0782	4.62E+04
368	301647	24566.4	-1.190	66.66	-0.83	-0.24	39.86	26.59	1.55	0.0764	4.83E+04
370	300667	24559.2	-1.186	66.70	-0.73	-0.06	40.04	26.49	1.62	0.0748	5.01E+04
372	299691	24551.9	-1.182	66.74	-0.62	0.11	40.21	26.40	1.69	0.0732	5.20E+04
374	298719	24544.4	-1.178	66.77	-0.55	0.22	40.39	26.31	1.76	0.0717	5.39E+04
376	297752	24536.7	-1.173	66.81	-0.53	0.12	40.57	26.22	1.84	0.0702	5.59E+04
378	296788	24528.8	-1.169	66.85	-0.53	-0.01	40.75	26.13	1.91	0.0687	5.80E+04
380	295828	24520.7	-1.164	66.88	-0.52	-0.13	40.94	26.04	1.99	0.0673	6.02E+04
382	294873	24515.0	-1.160	66.92	-0.51	-0.27	41.13	26.02	2.09	0.0657	6.30E+04
384	293922	24514.7	-1.154	66.97	-0.46	-0.37	41.32	26.08	2.20	0.0640	6.66E+04
386	292976	24514.4	-1.149	67.02	-0.34	-0.42	41.35	26.14	2.32	0.0624	7.04E+04
388	292035	24514.0	-1.143	67.07	-0.12	-0.40	41.24	26.20	2.44	0.0608	7.44E+04
390	291098	24513.5	-1.138	67.12	0.20	-0.35	41.07	26.26	2.57	0.0593	7.87E+04
392	290167	24513.0	-1.132	67.17	0.58	-0.24	40.81	26.32	2.70	0.0578	8.31E+04
394	289240	24512.4	-1.126	67.22	1.01	-0.10	40.47	26.38	2.84	0.0563	8.77E+04
396	288319	24511.7	-1.120	67.26	1.19	-0.03	40.07	26.43	2.99	0.0549	9.26E+04
398	287403	24511.0	-1.113	67.31	1.33	-0.01	39.63	26.48	3.14	0.0536	9.77E+04
400	286493	24510.3	-1.107	67.36	1.47	0.06	39.23	26.52	3.31	0.0522	1.03E+05
402	285588	24509.6	-1.101	67.41	1.43	0.18	39.02	26.57	3.47	0.0510	1.09E+05
404	284689	24508.7	-1.094	67.46	1.29	0.20	39.04	26.61	3.65	0.0497	1.14E+05
406	283795	24507.8	-1.087	67.51	1.07	0.15	39.08	26.66	3.84	0.0485	1.21E+05
408	282908	24506.7	-1.080	67.56	0.78	0.04	39.21	26.70	4.03	0.0473	1.27E+05
410	282027	24505.5	-1.072	67.61	0.47	-0.10	39.45	26.73	4.22	0.0462	1.33E+05
412	281152	24504.0	-1.064	67.66	0.24	-0.21	39.80	26.64	4.39	0.0453	1.38E+05
414	280285	24502.5	-1.056	67.71	0.13	-0.26	40.25	26.55	4.55	0.0445	1.42E+05
416	279424	24500.7	-1.048	67.76	0.20	-0.19	40.77	26.46	4.72	0.0437	1.47E+05
418	278571	24498.7	-1.039	67.81	0.38	-0.07	41.19	26.37	4.90	0.0429	1.51E+05
420	277726	24496.5	-1.030	67.86	0.60	0.05	41.48	26.29	5.08	0.0421	1.56E+05
422	276889	24494.2	-1.020	67.92	0.78	0.13	41.58	26.20	5.27	0.0414	1.61E+05
424	276060	24491.8	-1.011	67.97	0.90	0.13	41.49	26.12	5.46	0.0406	1.66E+05
426	275239	24489.2	-1.001	68.02	0.99	0.06	41.24	26.05	5.66	0.0399	1.71E+05
428	274427	24486.5	-0.991	68.07	1.08	0.10	40.84	26.00	5.86	0.0392	1.77E+05
430	273624	24483.8	-0.981	68.12	1.12	0.14	40.31	25.95	6.08	0.0385	1.83E+05
432	272830	24481.0	-0.970	68.17	1.09	0.12	39.72	25.90	6.29	0.0378	1.89E+05
434	272044	24478.0	-0.960	68.23	1.06	0.06	39.33	25.86	6.52	0.0371	1.95E+05
436	271268	24473.6	-0.949	68.28	1.08	0.08	39.12	25.84	6.76	0.0365	2.02E+05
438	270501	24469.0	-0.938	68.34	1.10	0.21	39.00	25.82	7.01	0.0358	2.10E+05
440	269744	24464.4	-0.927	68.40	1.03	0.23	39.01	25.80	7.26	0.0352	2.17E+05

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
442	268997	24459.6	-0.916	68.45	0.89	0.18	39.18	25.78	7.52	0.0345	2.25E+05
444	268259	24454.9	-0.904	68.52	0.77	0.11	39.53	25.75	7.77	0.0340	2.32E+05
446	267531	24450.0	-0.892	68.58	0.72	0.08	40.04	25.71	8.02	0.0334	2.39E+05
448	266815	24444.9	-0.880	68.64	0.75	0.08	40.64	25.67	8.28	0.0329	2.46E+05
450	266109	24439.5	-0.867	68.71	0.87	0.12	41.13	25.64	8.55	0.0324	2.54E+05
452	265414	24434.1	-0.853	68.77	1.02	0.20	41.42	25.60	8.81	0.0319	2.61E+05
454	264732	24428.9	-0.839	68.83	1.02	0.30	41.55	25.56	9.08	0.0314	2.68E+05
456	264061	24423.6	-0.825	68.90	0.80	0.23	41.44	25.52	9.34	0.0309	2.76E+05
458	263403	24418.3	-0.811	68.96	0.51	0.10	41.09	25.48	9.61	0.0305	2.83E+05
460	262757	24412.9	-0.796	69.02	0.34	0.05	40.51	25.45	9.89	0.0301	2.90E+05
462	262123	24408.4	-0.781	69.09	0.25	0.06	39.86	25.42	10.17	0.0296	2.99E+05
464	261503	24405.4	-0.766	69.14	0.14	0.07	39.37	25.42	10.48	0.0292	3.07E+05
466	260896	24402.2	-0.751	69.20	0.02	0.06	39.12	25.42	10.78	0.0288	3.16E+05
468	260303	24398.7	-0.735	69.26	-0.12	0.05	39.04	25.41	11.08	0.0284	3.25E+05
470	259723	24395.0	-0.718	69.32	-0.24	0.06	39.16	25.41	11.39	0.0280	3.34E+05
472	259157	24391.0	-0.701	69.38	-0.36	0.07	39.50	25.41	11.69	0.0276	3.43E+05
474	258607	24386.4	-0.683	69.44	-0.48	0.07	39.99	25.40	12.00	0.0272	3.52E+05
476	258072	24381.4	-0.665	69.50	-0.63	0.08	40.59	25.40	12.30	0.0269	3.61E+05
478	257553	24375.7	-0.646	69.56	-0.77	0.09	41.05	25.39	12.60	0.0266	3.70E+05
480	257050	24369.8	-0.626	69.62	-0.92	0.09	41.30	25.38	12.90	0.0263	3.79E+05
482	256565	24363.4	-0.606	69.68	-1.07	0.09	41.27	25.38	13.19	0.0260	3.88E+05
484	256097	24356.9	-0.585	69.73	-1.23	0.10	40.88	25.37	13.48	0.0257	3.96E+05
486	255647	24350.6	-0.565	69.79	-1.55	0.47	40.31	25.36	13.77	0.0254	4.05E+05
488	255214	24344.6	-0.545	69.84	-3.75	1.65	39.81	25.36	14.05	0.0251	4.13E+05
490	254798	24338.4	-0.525	69.90	-9.08	1.13	39.69	25.35	14.32	0.0249	4.21E+05
492	254399	24332.1	-0.504	69.95	-15.42	0.28	39.78	25.34	14.59	0.0246	4.29E+05
494	254017	24325.4	-0.485	69.99	-21.54	0.11	40.00	25.34	14.84	0.0244	4.37E+05
496	253652	24318.5	-0.466	70.04	-27.48	0.15	40.30	25.33	15.09	0.0242	4.45E+05
498	253303	24311.2	-0.447	70.08	-33.39	0.19	40.53	25.32	15.34	0.0240	4.52E+05
500	252969	24303.5	-0.430	70.12	-39.29	0.20	40.63	25.31	15.57	0.0238	4.59E+05
502	252650	24295.8	-0.414	70.16	-45.23	0.19	40.56	25.31	15.80	0.0236	4.66E+05
504	252343	24287.9	-0.400	70.20	-51.04	-0.15	40.38	25.30	16.02	0.0235	4.72E+05
506	252048	24279.9	-0.388	70.24	-55.23	-0.80	39.98	25.29	16.24	0.0233	4.79E+05
508	251762	24272.2	-0.376	70.27	-57.64	-0.32	39.53	25.28	16.45	0.0231	4.85E+05
510	251486	24264.6	-0.366	70.31	-59.97	0.08	39.20	25.27	16.66	0.0230	4.92E+05
512	251218	24256.8	-0.356	70.35	-62.60	-0.03	39.10	25.27	16.86	0.0228	4.98E+05
514	250959	24249.1	-0.348	70.38	-65.03	-0.24	39.18	25.26	17.05	0.0227	5.04E+05
516	250706	24241.3	-0.340	70.42	-67.07	-0.21	39.43	25.25	17.25	0.0226	5.10E+05
518	250459	24233.2	-0.333	70.45	-68.82	-0.27	39.87	25.24	17.44	0.0224	5.16E+05
520	250218	24224.7	-0.327	70.48	-70.20	-0.29	40.37	25.23	17.63	0.0223	5.21E+05
522	249982	24215.8	-0.321	70.52	-71.21	-0.29	40.71	25.22	17.81	0.0222	5.27E+05
524	249751	24206.7	-0.315	70.55	-71.91	-0.28	40.79	25.21	18.00	0.0221	5.33E+05
526	249525	24197.4	-0.310	70.58	-72.48	-0.24	40.62	25.20	18.18	0.0219	5.38E+05
528	249304	24188.1	-0.305	70.62	-73.03	-0.25	40.29	25.20	18.35	0.0218	5.44E+05
530	249087	24178.2	-0.300	70.65	-73.55	-0.28	39.95	25.19	18.54	0.0217	5.49E+05
532	248873	24168.2	-0.295	70.68	-73.95	-0.25	39.71	25.18	18.72	0.0216	5.55E+05
534	248664	24158.1	-0.291	70.71	-74.22	-0.20	39.63	25.18	18.90	0.0215	5.61E+05
536	248458	24148.0	-0.287	70.74	-74.47	-0.18	39.70	25.17	19.08	0.0214	5.67E+05
538	248256	24137.8	-0.283	70.77	-74.71	-0.12	39.88	25.17	19.26	0.0212	5.72E+05
540	248057	24127.4	-0.279	70.80	-75.09	-0.08	40.07	25.16	19.43	0.0211	5.78E+05
542	247862	24116.6	-0.275	70.83	-75.61	-0.16	40.20	25.16	19.61	0.0210	5.84E+05
544	247669	24105.5	-0.272	70.85	-76.07	-0.25	40.24	25.15	19.78	0.0209	5.89E+05
546	247479	24094.2	-0.269	70.88	-76.38	-0.28	40.20	25.15	19.95	0.0208	5.95E+05
548	247292	24083.0	-0.266	70.91	-76.54	-0.26	40.09	25.14	20.11	0.0207	6.00E+05
550	247108	24071.8	-0.263	70.94	-76.60	-0.21	39.95	25.13	20.28	0.0206	6.06E+05

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
552	246926	24060.6	-0.260	70.97	-76.61	-0.18	39.83	25.13	20.45	0.0205	6.11E+05
554	246746	24049.4	-0.258	71.00	-76.62	-0.18	39.75	25.12	20.61	0.0204	6.17E+05
556	246569	24038.0	-0.255	71.03	-76.57	-0.19	39.78	25.11	20.78	0.0204	6.22E+05
558	246393	24026.6	-0.253	71.05	-76.65	-0.06	39.89	25.10	20.94	0.0203	6.27E+05
560	246220	24015.1	-0.250	71.08	-77.05	-0.17	40.01	25.10	21.10	0.0202	6.33E+05
562	246049	24003.4	-0.248	71.11	-77.40	-0.28	40.10	25.09	21.26	0.0201	6.38E+05
564	245879	23991.7	-0.247	71.14	-77.49	-0.24	40.11	25.08	21.42	0.0200	6.43E+05
566	245710	23979.9	-0.245	71.17	-77.47	-0.17	40.06	25.07	21.58	0.0199	6.49E+05
568	245543	23968.1	-0.244	71.19	-77.45	-0.15	39.98	25.07	21.74	0.0198	6.54E+05
570	245378	23956.3	-0.242	71.22	-77.44	-0.17	39.93	25.06	21.90	0.0197	6.59E+05
572	245213	23944.4	-0.241	71.25	-77.38	-0.19	39.89	25.05	22.06	0.0197	6.65E+05
574	245050	23932.6	-0.240	71.28	-77.38	-0.08	39.86	25.04	22.22	0.0196	6.70E+05
576	244887	23920.7	-0.239	71.31	-77.53	-0.11	39.84	25.03	22.37	0.0195	6.75E+05
578	244726	23908.6	-0.238	71.34	-77.70	-0.16	39.86	25.03	22.53	0.0194	6.81E+05
580	244565	23896.5	-0.237	71.36	-77.73	-0.14	39.91	25.02	22.69	0.0193	6.86E+05
582	244405	23884.3	-0.236	71.39	-77.68	-0.09	39.96	25.01	22.85	0.0193	6.91E+05
584	244246	23871.9	-0.236	71.42	-77.68	-0.08	40.00	25.00	23.01	0.0192	6.97E+05
586	244087	23859.2	-0.235	71.45	-77.68	-0.10	40.02	24.99	23.17	0.0191	7.02E+05
588	243929	23846.0	-0.234	71.47	-77.67	-0.12	40.03	24.98	23.32	0.0190	7.07E+05
590	243771	23832.9	-0.234	71.50	-77.66	-0.15	39.99	24.97	23.48	0.0190	7.13E+05
592	243614	23820.0	-0.234	71.52	-77.62	-0.17	39.92	24.96	23.64	0.0189	7.18E+05
594	243457	23807.1	-0.233	71.55	-77.50	-0.15	39.88	24.95	23.80	0.0188	7.24E+05
596	243300	23794.3	-0.233	71.58	-77.32	-0.12	39.82	24.94	23.96	0.0187	7.29E+05
598	243144	23781.3	-0.233	71.60	-77.15	-0.10	39.80	24.93	24.12	0.0187	7.35E+05
600	242987	23768.1	-0.233	71.63	-77.05	-0.15	39.82	24.93	24.29	0.0186	7.40E+05
602	242831	23755.0	-0.233	71.66	-76.89	-0.19	39.86	24.92	24.45	0.0185	7.46E+05
604	242675	23741.6	-0.233	71.68	-76.66	-0.17	39.91	24.91	24.62	0.0184	7.52E+05
606	242519	23727.5	-0.233	71.71	-76.36	-0.16	39.95	24.90	24.79	0.0184	7.58E+05
608	242364	23713.0	-0.232	71.73	-76.00	-0.12	39.98	24.90	24.97	0.0183	7.64E+05
610	242208	23698.3	-0.232	71.76	-75.71	-0.12	39.98	24.89	25.15	0.0182	7.71E+05
612	242054	23683.7	-0.231	71.78	-75.43	-0.15	39.96	24.89	25.33	0.0181	7.77E+05
614	241899	23669.0	-0.231	71.81	-75.14	-0.17	39.90	24.88	25.51	0.0180	7.84E+05
616	241745	23654.4	-0.231	71.83	-74.77	-0.14	39.84	24.87	25.69	0.0180	7.90E+05
618	241592	23639.5	-0.230	71.86	-74.40	-0.13	39.81	24.87	25.87	0.0179	7.97E+05
620	241440	23624.5	-0.229	71.88	-74.06	-0.16	39.81	24.86	26.05	0.0178	8.04E+05
622	241288	23609.4	-0.228	71.91	-73.67	-0.14	39.86	24.86	26.23	0.0177	8.10E+05
624	241138	23594.3	-0.227	71.93	-73.27	-0.12	39.91	24.85	26.42	0.0177	8.17E+05
626	240989	23579.1	-0.225	71.96	-72.87	-0.10	39.96	24.84	26.60	0.0176	8.23E+05
628	240840	23564.0	-0.224	71.98	-72.48	-0.08	39.96	24.84	26.77	0.0175	8.30E+05
630	240693	23549.1	-0.223	72.01	-72.24	0.01	39.93	24.83	26.95	0.0174	8.37E+05
632	240547	23534.3	-0.222	72.03	-72.32	0.07	39.88	24.82	27.13	0.0174	8.43E+05
634	240402	23519.0	-0.221	72.06	-72.84	0.00	39.84	24.82	27.31	0.0173	8.50E+05
636	240258	23503.5	-0.220	72.08	-73.40	-0.06	39.83	24.81	27.49	0.0172	8.57E+05
638	240114	23488.0	-0.220	72.10	-73.71	-0.15	39.86	24.80	27.67	0.0172	8.63E+05
640	239970	23472.8	-0.220	72.13	-73.70	-0.06	39.90	24.80	27.85	0.0171	8.70E+05
642	239826	23457.5	-0.221	72.15	-73.78	-0.01	39.90	24.79	28.03	0.0170	8.77E+05
644	239681	23442.2	-0.221	72.18	-73.97	-0.03	39.87	24.78	28.21	0.0170	8.84E+05
646	239536	23427.0	-0.222	72.20	-74.18	-0.06	39.83	24.77	28.40	0.0169	8.91E+05
648	239390	23411.6	-0.223	72.23	-74.41	-0.07	39.78	24.77	28.58	0.0168	8.98E+05
650	239243	23396.3	-0.225	72.25	-74.66	-0.09	39.76	24.76	28.77	0.0168	9.05E+05
652	239095	23380.8	-0.227	72.28	-74.90	-0.10	39.77	24.75	28.97	0.0167	9.12E+05
654	238945	23365.2	-0.229	72.30	-75.01	-0.18	39.81	24.75	29.16	0.0166	9.19E+05
656	238794	23349.7	-0.231	72.32	-74.84	-0.19	39.85	24.74	29.36	0.0165	9.27E+05
658	238641	23334.0	-0.233	72.35	-74.46	-0.16	39.88	24.73	29.57	0.0165	9.35E+05
660	238486	23318.2	-0.235	72.37	-74.04	-0.14	39.89	24.73	29.78	0.0164	9.42E+05

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
662	238330	23302.1	-0.237	72.40	-73.63	-0.13	39.86	24.72	29.99	0.0163	9.50E+05
664	238173	23285.9	-0.238	72.42	-73.20	-0.13	39.84	24.71	30.20	0.0163	9.58E+05
666	238014	23269.7	-0.240	72.44	-72.77	-0.16	39.80	24.71	30.44	0.0162	9.67E+05
668	237855	23253.4	-0.241	72.47	-72.24	-0.13	39.76	24.70	30.65	0.0161	9.75E+05
670	237695	23237.4	-0.242	72.49	-71.70	-0.12	39.75	24.69	30.87	0.0160	9.84E+05
672	237534	23221.4	-0.243	72.51	-71.23	-0.17	39.72	24.68	31.09	0.0160	9.92E+05
674	237372	23205.4	-0.244	72.54	-70.62	-0.12	39.71	24.68	31.32	0.0159	1.00E+06
676	237210	23189.1	-0.245	72.56	-70.07	-0.13	39.75	24.67	31.55	0.0158	1.01E+06
678	237047	23172.6	-0.245	72.58	-69.52	-0.16	39.83	24.66	31.78	0.0158	1.02E+06
680	236885	23156.2	-0.244	72.61	-68.90	-0.14	39.88	24.66	32.01	0.0157	1.03E+06
682	236724	23139.7	-0.244	72.63	-68.40	-0.09	39.90	24.65	32.24	0.0156	1.04E+06
684	236562	23123.2	-0.244	72.66	-68.23	-0.11	39.87	24.64	32.48	0.0156	1.05E+06
686	236401	23106.7	-0.243	72.68	-68.09	-0.12	39.83	24.63	32.71	0.0155	1.05E+06
688	236241	23089.8	-0.243	72.70	-67.85	-0.08	39.80	24.63	32.96	0.0154	1.06E+06
690	236081	23072.8	-0.242	72.73	-67.65	-0.05	39.79	24.62	33.19	0.0153	1.07E+06
692	235922	23055.6	-0.242	72.75	-67.49	-0.04	39.79	24.59	33.40	0.0153	1.08E+06
694	235763	23038.3	-0.241	72.78	-67.39	-0.03	39.79	24.57	33.60	0.0152	1.09E+06
696	235604	23020.9	-0.241	72.80	-67.30	-0.01	39.78	24.55	33.80	0.0152	1.09E+06
698	235447	23003.3	-0.240	72.83	-67.29	-0.02	39.81	24.52	34.00	0.0151	1.10E+06
700	235290	22985.5	-0.239	72.85	-67.27	0.01	39.86	24.50	34.20	0.0151	1.11E+06
702	235133	22967.9	-0.239	72.88	-67.28	0.04	39.89	24.48	34.40	0.0150	1.11E+06
704	234977	22950.4	-0.239	72.90	-67.41	0.03	39.86	24.46	34.60	0.0149	1.12E+06
706	234820	22933.0	-0.240	72.93	-67.64	-0.01	39.81	24.43	34.80	0.0149	1.13E+06
708	234663	22915.3	-0.240	72.95	-67.85	0.01	39.78	24.41	35.01	0.0148	1.14E+06
710	234506	22897.1	-0.241	72.98	-68.08	0.02	39.77	24.39	35.21	0.0148	1.14E+06
712	234349	22878.6	-0.241	73.00	-68.30	-0.01	39.79	24.36	35.42	0.0147	1.15E+06
714	234191	22859.9	-0.242	73.02	-68.17	-0.07	39.85	24.34	35.63	0.0147	1.16E+06
716	234033	22840.9	-0.242	73.04	-67.64	0.02	39.88	24.31	35.83	0.0146	1.17E+06
718	233875	22821.6	-0.242	73.07	-67.18	0.06	39.87	24.29	36.04	0.0145	1.17E+06
720	233717	22802.6	-0.242	73.09	-66.81	0.06	39.82	24.26	36.25	0.0145	1.18E+06
722	233560	22783.8	-0.242	73.11	-66.51	0.03	39.79	24.24	36.44	0.0144	1.19E+06
724	233402	22765.1	-0.242	73.13	-66.23	0.01	39.75	24.22	36.62	0.0144	1.19E+06
726	233245	22746.3	-0.242	73.16	-65.94	0.01	39.73	24.19	36.81	0.0143	1.20E+06
728	233088	22727.5	-0.242	73.18	-65.65	0.04	39.79	24.17	36.99	0.0143	1.21E+06
730	232931	22708.1	-0.241	73.20	-65.44	0.06	39.92	24.14	37.17	0.0142	1.21E+06
732	232775	22688.3	-0.240	73.22	-65.27	0.09	40.05	24.12	37.35	0.0142	1.22E+06
734	232620	22668.6	-0.239	73.24	-65.19	0.09	40.05	24.09	37.53	0.0141	1.23E+06
736	232466	22648.7	-0.239	73.27	-65.23	0.09	39.98	24.07	37.71	0.0141	1.23E+06
738	232312	22628.9	-0.238	73.29	-65.29	0.11	39.91	24.04	37.88	0.0140	1.24E+06
740	232158	22609.0	-0.238	73.31	-65.51	0.08	39.87	24.02	38.06	0.0140	1.25E+06
742	232005	22589.4	-0.238	73.33	-65.78	0.06	39.86	23.99	38.24	0.0139	1.25E+06
744	231851	22569.4	-0.239	73.35	-66.07	0.06	39.86	23.97	38.42	0.0139	1.26E+06
746	231697	22548.5	-0.239	73.37	-66.24	-0.00	39.91	23.94	38.60	0.0138	1.27E+06
748	231544	22527.5	-0.239	73.38	-65.53	-0.12	39.87	23.92	38.77	0.0138	1.27E+06
750	231390	22506.6	-0.239	73.40	-64.34	-0.01	39.60	23.89	38.95	0.0138	1.28E+06
752	231237	22486.3	-0.237	73.42	-63.31	0.02	39.32	23.86	39.13	0.0137	1.29E+06
754	231086	22466.1	-0.236	73.44	-62.58	0.07	39.12	23.84	39.31	0.0137	1.29E+06
756	230936	22445.8	-0.234	73.46	-62.02	0.03	39.06	23.81	39.48	0.0136	1.30E+06
758	230788	22425.3	-0.231	73.48	-61.44	0.03	39.10	23.79	39.65	0.0136	1.31E+06
760	230642	22404.8	-0.228	73.50	-60.86	0.06	39.15	23.76	39.82	0.0135	1.31E+06
762	230499	22384.3	-0.225	73.52	-60.31	0.10	39.09	23.74	39.98	0.0135	1.32E+06
764	230358	22363.8	-0.222	73.54	-60.04	0.15	38.99	23.71	40.14	0.0134	1.32E+06
766	230220	22343.3	-0.218	73.56	-60.13	0.15	38.98	23.69	40.29	0.0134	1.33E+06
768	230085	22322.8	-0.215	73.58	-60.34	0.12	38.98	23.66	40.44	0.0134	1.34E+06
770	229952	22302.3	-0.213	73.60	-60.60	0.13	38.98	23.63	40.59	0.0133	1.34E+06

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
772	229821	22281.7	-0.211	73.62	-60.92	0.14	38.96	23.61	40.73	0.0133	1.35E+06
774	229692	22261.0	-0.209	73.64	-61.45	0.08	38.94	23.58	40.87	0.0133	1.35E+06
776	229563	22240.2	-0.208	73.66	-61.94	0.03	38.96	23.56	41.01	0.0132	1.36E+06
778	229436	22219.4	-0.207	73.68	-62.03	0.06	38.99	23.53	41.13	0.0132	1.36E+06
780	229310	22198.7	-0.206	73.70	-62.12	0.12	39.00	23.50	41.25	0.0131	1.37E+06
782	229184	22178.1	-0.206	73.72	-62.38	0.11	38.96	23.47	41.37	0.0131	1.37E+06
784	229057	22157.5	-0.207	73.74	-62.73	0.10	38.94	23.44	41.49	0.0131	1.38E+06
786	228930	22137.0	-0.208	73.76	-63.21	0.05	38.96	23.41	41.61	0.0130	1.38E+06
788	228803	22116.3	-0.210	73.77	-63.69	0.03	39.08	23.37	41.73	0.0130	1.38E+06
790	228674	22095.5	-0.212	73.79	-64.19	0.01	39.25	23.34	41.86	0.0130	1.39E+06
792	228542	22074.3	-0.215	73.81	-64.58	-0.04	39.38	23.31	41.99	0.0129	1.39E+06
794	228409	22053.0	-0.218	73.83	-64.63	-0.06	39.45	23.28	42.12	0.0129	1.40E+06
796	228274	22031.9	-0.221	73.84	-64.49	-0.00	39.41	23.25	42.25	0.0129	1.40E+06
798	228135	22010.6	-0.225	73.86	-64.42	0.01	39.44	23.22	42.41	0.0128	1.41E+06
800	227995	21989.6	-0.229	73.88	-64.38	-0.02	39.57	23.19	42.55	0.0128	1.41E+06
802	227850	21968.7	-0.233	73.90	-64.35	-0.03	39.73	23.15	42.70	0.0128	1.42E+06
804	227703	21947.4	-0.238	73.92	-64.31	-0.06	39.94	23.12	42.85	0.0127	1.43E+06
806	227553	21925.9	-0.242	73.93	-64.24	-0.06	40.13	23.09	43.02	0.0127	1.43E+06
808	227399	21904.1	-0.247	73.95	-64.06	0.01	40.29	23.06	43.18	0.0126	1.44E+06
810	227242	21881.9	-0.251	73.97	-63.93	0.04	40.43	23.02	43.35	0.0126	1.44E+06
812	227082	21859.5	-0.255	73.98	-63.89	0.00	40.48	22.99	43.55	0.0126	1.45E+06
814	226918	21837.1	-0.259	74.00	-63.84	-0.02	40.45	22.95	43.74	0.0125	1.46E+06
816	226752	21814.7	-0.264	74.02	-63.72	-0.00	40.46	22.92	43.93	0.0125	1.46E+06
818	226582	21791.7	-0.268	74.03	-63.54	0.04	40.50	22.88	44.13	0.0124	1.47E+06
820	226410	21768.0	-0.271	74.05	-63.38	0.06	40.53	22.85	44.33	0.0124	1.48E+06
822	226235	21743.9	-0.275	74.06	-63.02	-0.09	40.43	22.81	44.53	0.0123	1.48E+06
824	226059	21720.4	-0.277	74.07	-61.83	-0.07	40.11	22.76	44.67	0.0123	1.49E+06
826	225881	21697.5	-0.278	74.09	-60.52	-0.01	39.81	22.71	44.81	0.0123	1.49E+06
828	225702	21675.1	-0.280	74.10	-59.60	0.09	39.65	22.66	44.96	0.0122	1.49E+06
830	225523	21652.9	-0.281	74.12	-59.01	0.07	39.58	22.61	45.11	0.0122	1.50E+06
832	225343	21630.7	-0.281	74.14	-58.75	0.12	39.68	22.56	45.25	0.0122	1.50E+06
834	225163	21608.2	-0.282	74.15	-58.76	0.10	39.87	22.51	45.40	0.0121	1.51E+06
836	224983	21585.1	-0.282	74.17	-58.76	0.11	39.97	22.46	45.55	0.0121	1.51E+06
838	224803	21561.5	-0.282	74.18	-58.77	0.12	40.01	22.41	45.69	0.0121	1.51E+06
840	224623	21537.9	-0.282	74.19	-58.84	0.11	39.96	22.36	45.84	0.0120	1.52E+06
842	224443	21513.8	-0.282	74.21	-58.97	0.08	40.66	22.31	45.98	0.0120	1.52E+06
844	224264	21489.3	-0.282	74.22	-59.02	0.12	40.15	22.26	46.12	0.0120	1.52E+06
846	224085	21464.8	-0.282	74.23	-59.15	0.10	40.00	22.21	46.26	0.0119	1.53E+06
848	223905	21441.9	-0.284	74.24	-59.32	0.06	38.94	22.16	46.41	0.0119	1.53E+06
850	223724	21418.9	-0.286	74.26	-59.42	0.06	39.17	22.11	46.56	0.0118	1.53E+06
852	223541	21395.5	-0.288	74.27	-58.72	0.47	39.41	22.06	46.71	0.0118	1.54E+06
854	223358	21372.0	-0.290	74.28	-59.40	-0.25	39.43	22.01	46.86	0.0118	1.54E+06
856	223173	21348.4	-0.292	74.29	-59.27	0.09	39.57	21.96	47.02	0.0117	1.55E+06
858	222987	21324.4	-0.295	74.31	-59.45	0.06	39.70	21.91	47.17	0.0117	1.55E+06
860	222799	21300.2	-0.297	74.32	-59.61	0.05	39.72	21.87	47.35	0.0117	1.55E+06
862	222609	21276.0	-0.300	74.33	-59.75	0.04	39.68	21.83	47.54	0.0116	1.56E+06
864	222416	21251.7	-0.304	74.34	-59.82	0.07	39.66	21.78	47.73	0.0116	1.57E+06
866	222222	21227.3	-0.307	74.35	-59.98	0.01	39.69	21.74	47.93	0.0116	1.57E+06
868	222025	21202.9	-0.311	74.36	-60.04	0.02	39.75	21.70	48.13	0.0115	1.58E+06
870	221825	21178.3	-0.315	74.37	-60.04	0.03	39.84	21.66	48.34	0.0115	1.59E+06
872	221622	21153.5	-0.320	74.38	-60.02	0.00	39.95	21.61	48.55	0.0114	1.59E+06
874	221417	21128.4	-0.324	74.39	-59.93	-0.00	40.00	21.57	48.77	0.0114	1.60E+06
876	221208	21103.1	-0.328	74.40	-59.74	0.01	40.00	21.52	48.99	0.0113	1.61E+06
878	220997	21077.7	-0.332	74.41	-59.52	-0.02	39.97	21.48	49.22	0.0113	1.61E+06
880	220783	21052.3	-0.336	74.42	-59.24	-0.05	39.96	21.43	49.45	0.0113	1.62E+06

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
882	220567	21026.7	-0.340	74.43	-58.82	-0.06	39.97	21.39	49.69	0.0112	1.63E+06
884	220348	21000.9	-0.343	74.44	-58.24	-0.02	40.04	21.34	49.93	0.0112	1.64E+06
886	220128	20974.9	-0.345	74.45	-57.62	-0.02	40.06	21.30	50.18	0.0111	1.64E+06
888	219906	20948.6	-0.347	74.46	-57.17	0.01	40.04	21.25	50.43	0.0111	1.65E+06
890	219683	20922.2	-0.348	74.46	-56.72	-0.02	40.01	21.21	50.68	0.0110	1.66E+06
892	219460	20894.9	-0.349	74.47	-56.15	0.00	40.01	21.16	50.94	0.0110	1.67E+06
894	219237	20866.9	-0.350	74.48	-55.56	0.02	40.04	21.12	51.19	0.0109	1.68E+06
896	219013	20838.6	-0.350	74.49	-55.32	0.05	40.09	21.08	51.45	0.0109	1.68E+06
898	218791	20810.1	-0.349	74.50	-55.06	0.05	40.07	21.04	51.71	0.0109	1.69E+06
900	218569	20781.4	-0.349	74.51	-54.75	0.09	40.05	20.99	51.96	0.0108	1.70E+06
902	218348	20752.4	-0.348	74.51	-54.47	0.12	40.01	20.95	52.21	0.0108	1.71E+06
904	218128	20723.3	-0.346	74.52	-54.28	0.12	39.97	20.91	52.46	0.0107	1.72E+06
906	217910	20694.0	-0.344	74.53	-54.17	0.11	39.92	20.86	52.71	0.0107	1.73E+06
908	217693	20664.4	-0.342	74.53	-54.13	0.11	39.83	20.82	52.96	0.0106	1.74E+06
910	217478	20635.1	-0.341	74.54	-54.13	0.11	39.69	20.78	53.20	0.0106	1.75E+06
912	217265	20605.6	-0.339	74.54	-54.19	0.14	39.59	20.73	53.44	0.0105	1.75E+06
914	217053	20575.9	-0.337	74.55	-54.42	0.13	39.61	20.69	53.68	0.0105	1.76E+06
916	216843	20545.6	-0.336	74.55	-54.65	0.01	39.60	20.65	53.91	0.0105	1.77E+06
918	216634	20515.5	-0.334	74.55	-54.46	-0.06	39.41	20.61	54.14	0.0104	1.78E+06
920	216426	20485.6	-0.333	74.56	-54.09	-0.08	39.25	20.56	54.37	0.0104	1.79E+06
922	216219	20456.0	-0.332	74.56	-53.62	-0.07	39.20	20.52	54.57	0.0103	1.80E+06
924	216014	20426.3	-0.330	74.56	-53.18	0.01	39.25	20.47	54.76	0.0103	1.80E+06
926	215811	20396.0	-0.327	74.56	-52.93	0.05	39.26	20.43	54.95	0.0103	1.81E+06
928	215611	20365.7	-0.324	74.56	-52.74	0.09	39.21	20.38	55.13	0.0102	1.81E+06
930	215412	20335.4	-0.321	74.56	-52.64	0.12	39.18	20.33	55.31	0.0102	1.82E+06
932	215217	20304.9	-0.318	74.56	-52.67	0.16	39.19	20.29	55.48	0.0102	1.83E+06
934	215024	20274.0	-0.314	74.56	-52.90	0.18	39.19	20.24	55.65	0.0101	1.83E+06
936	214834	20242.9	-0.311	74.56	-53.42	0.13	39.15	20.20	55.81	0.0101	1.84E+06
938	214645	20212.1	-0.310	74.55	-53.89	0.06	39.07	20.15	55.98	0.0101	1.85E+06
940	214458	20181.2	-0.309	74.55	-54.39	0.01	39.03	20.11	56.13	0.0100	1.85E+06
942	214271	20150.0	-0.309	74.55	-54.92	-0.02	39.08	20.07	56.29	0.0100	1.86E+06
944	214084	20118.7	-0.310	74.54	-55.17	-0.06	39.10	20.02	56.45	0.0100	1.86E+06
946	213897	20087.3	-0.311	74.53	-55.23	-0.01	39.07	19.98	56.61	0.0099	1.87E+06
948	213710	20055.6	-0.312	74.53	-55.39	0.01	39.05	19.93	56.76	0.0099	1.88E+06
950	213522	20023.6	-0.312	74.52	-55.66	-0.01	39.07	19.89	56.92	0.0099	1.88E+06
952	213334	19991.4	-0.314	74.51	-55.92	-0.02	39.11	19.84	57.08	0.0098	1.89E+06
954	213146	19959.0	-0.316	74.50	-56.00	-0.07	39.14	19.80	57.24	0.0098	1.90E+06
956	212956	19926.9	-0.318	74.49	-55.97	-0.10	39.10	19.75	57.40	0.0098	1.90E+06
958	212764	19895.7	-0.321	74.48	-55.83	-0.09	39.06	19.71	57.57	0.0097	1.91E+06
960	212571	19864.6	-0.324	74.47	-55.62	-0.07	39.09	19.67	57.74	0.0097	1.91E+06
962	212376	19833.2	-0.327	74.46	-55.73	0.01	39.25	19.62	57.94	0.0097	1.92E+06
964	212179	19801.5	-0.330	74.45	-56.02	0.02	39.36	19.58	58.11	0.0096	1.93E+06
966	211980	19769.3	-0.334	74.43	-56.32	0.04	39.46	19.53	58.29	0.0096	1.94E+06
968	211780	19736.6	-0.337	74.42	-56.65	0.02	39.52	19.49	58.48	0.0096	1.94E+06
970	211577	19703.6	-0.341	74.40	-56.92	0.03	39.53	19.44	58.66	0.0095	1.95E+06
972	211371	19670.8	-0.347	74.39	-57.12	-0.04	39.53	19.40	58.86	0.0095	1.96E+06
974	211162	19638.0	-0.352	74.37	-56.94	-0.05	39.54	19.35	59.06	0.0095	1.97E+06
976	210949	19605.5	-0.358	74.35	-56.71	-0.07	39.54	19.31	59.27	0.0094	1.97E+06
978	210733	19572.8	-0.364	74.34	-56.65	0.05	39.61	19.26	59.49	0.0094	1.98E+06
980	210513	19539.4	-0.370	74.32	-57.12	0.05	39.78	19.22	59.72	0.0093	1.99E+06
982	210290	19505.6	-0.376	74.30	-57.57	-0.03	39.89	19.17	59.95	0.0093	2.00E+06
984	210062	19471.3	-0.383	74.28	-57.70	-0.02	39.90	19.12	60.18	0.0093	2.01E+06
986	209831	19437.2	-0.390	74.26	-57.72	0.01	39.86	19.08	60.43	0.0092	2.02E+06
988	209595	19403.9	-0.397	74.24	-57.72	0.00	39.86	19.03	60.70	0.0092	2.03E+06
990	209354	19370.4	-0.404	74.21	-57.66	-0.03	39.91	18.99	60.98	0.0091	2.04E+06

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
992	209109	19337.0	-0.412	74.19	-57.47	-0.03	39.93	18.95	61.28	0.0091	2.05E+06
994	208859	19303.4	-0.419	74.17	-57.18	-0.04	39.94	18.90	61.58	0.0091	2.06E+06
996	208606	19269.8	-0.426	74.15	-56.78	-0.04	39.93	18.86	61.90	0.0090	2.08E+06
998	208348	19236.0	-0.432	74.13	-56.34	-0.04	40.00	18.81	62.22	0.0090	2.09E+06
1000	208086	19201.8	-0.438	74.10	-56.00	-0.02	40.09	18.77	62.56	0.0089	2.10E+06
1002	207821	19167.2	-0.443	74.08	-55.90	0.06	40.14	18.73	62.90	0.0089	2.12E+06
1004	207554	19132.1	-0.448	74.05	-55.98	0.06	40.15	18.68	63.24	0.0088	2.13E+06
1006	207284	19096.6	-0.453	74.03	-56.19	-0.01	40.11	18.64	63.59	0.0088	2.14E+06
1008	207011	19061.0	-0.458	74.00	-56.21	-0.08	40.05	18.59	63.96	0.0088	2.16E+06
1010	206736	19025.3	-0.463	73.97	-56.02	-0.09	39.99	18.54	64.32	0.0087	2.17E+06
1012	206457	18989.7	-0.469	73.94	-55.79	-0.11	39.99	18.50	64.70	0.0087	2.19E+06
1014	206176	18954.0	-0.474	73.92	-55.44	-0.11	40.02	18.45	65.09	0.0086	2.20E+06
1016	205892	18917.9	-0.478	73.89	-55.02	-0.10	40.03	18.41	65.49	0.0086	2.22E+06
1018	205606	18881.4	-0.481	73.86	-54.75	-0.08	40.04	18.36	65.89	0.0085	2.23E+06
1020	205318	18844.5	-0.484	73.83	-54.42	-0.05	40.05	18.31	66.29	0.0085	2.25E+06
1022	205030	18807.3	-0.486	73.80	-54.06	-0.02	40.07	18.27	66.69	0.0084	2.27E+06
1024	204742	18769.7	-0.487	73.77	-53.70	0.00	40.06	18.22	67.10	0.0084	2.28E+06
1026	204453	18732.1	-0.487	73.74	-53.35	0.02	39.96	18.17	67.51	0.0083	2.30E+06
1028	204166	18694.2	-0.487	73.71	-53.04	0.06	39.89	18.13	67.92	0.0083	2.31E+06
1030	203879	18656.1	-0.487	73.67	-53.05	0.09	39.83	18.08	68.33	0.0082	2.33E+06
1032	203593	18617.6	-0.487	73.64	-52.40	-0.33	39.81	18.03	68.73	0.0082	2.35E+06
1034	203310	18578.3	-0.479	73.61	-48.97	0.28	39.82	17.99	69.12	0.0082	2.36E+06
1036	203033	18538.9	-0.471	73.58	-49.93	-1.12	39.58	17.95	69.56	0.0081	2.38E+06
1038	202762	18500.0	-0.463	73.55	-48.82	-0.67	39.46	17.91	69.98	0.0081	2.40E+06
1040	202496	18461.2	-0.454	73.52	-47.85	-0.20	39.60	17.87	70.39	0.0080	2.42E+06
1042	202239	18419.9	-0.441	73.49	-47.15	-0.04	40.58	17.83	70.76	0.0080	2.44E+06
1044	201991	18380.1	-0.428	73.46	-46.71	-0.05	38.58	17.79	71.12	0.0079	2.46E+06
1046	201751	18342.5	-0.418	73.44	-46.35	-0.07	38.89	17.75	71.48	0.0079	2.47E+06
1048	201519	18303.1	-0.403	73.41	-46.20	0.29	39.40	17.71	71.80	0.0079	2.49E+06
1050	201297	18262.9	-0.391	73.38	-51.30	0.47	39.58	17.67	72.09	0.0078	2.51E+06
1052	201078	18222.0	-0.393	73.33	-55.72	-0.44	39.49	17.63	72.36	0.0078	2.52E+06
1054	200858	18181.3	-0.398	73.29	-56.73	-0.23	39.28	17.59	72.64	0.0077	2.54E+06
1056	200635	18140.6	-0.404	73.24	-57.41	-0.14	39.22	17.55	72.93	0.0077	2.55E+06
1058	200407	18099.8	-0.412	73.19	-58.09	-0.11	39.24	17.51	73.22	0.0077	2.57E+06
1060	200175	18058.4	-0.421	73.13	-58.53	-0.08	39.24	17.47	73.53	0.0076	2.58E+06
1062	199938	18016.8	-0.431	73.08	-58.93	-0.06	39.25	17.43	73.85	0.0076	2.60E+06
1064	199695	17974.9	-0.442	73.02	-59.37	-0.14	39.25	17.39	74.19	0.0076	2.62E+06
1066	199445	17932.9	-0.453	72.96	-59.29	-0.14	39.24	17.35	74.51	0.0075	2.64E+06
1068	199190	17890.6	-0.464	72.90	-59.01	-0.11	39.24	17.30	74.88	0.0075	2.66E+06
1070	198928	17848.0	-0.474	72.84	-58.69	-0.10	39.24	17.26	75.27	0.0074	2.68E+06
1072	198662	17805.4	-0.484	72.78	-58.29	-0.10	39.23	17.22	75.67	0.0074	2.70E+06
1074	198390	17762.6	-0.492	72.72	-57.79	-0.05	39.25	17.18	76.09	0.0074	2.72E+06
1076	198114	17719.4	-0.499	72.66	-57.35	0.02	39.26	17.13	76.52	0.0073	2.74E+06
1078	197835	17675.9	-0.506	72.60	-57.19	0.04	39.27	17.09	76.96	0.0073	2.76E+06
1080	197552	17632.1	-0.512	72.53	-57.17	0.03	39.27	17.04	77.40	0.0072	2.78E+06
1082	197267	17588.0	-0.519	72.47	-57.22	0.06	39.28	17.00	77.86	0.0072	2.81E+06
1084	196978	17543.5	-0.525	72.40	-57.47	0.05	39.30	16.95	78.32	0.0071	2.83E+06
1086	196687	17498.7	-0.532	72.33	-57.87	0.01	39.32	16.91	78.79	0.0071	2.85E+06
1088	196391	17453.0	-0.540	72.27	-58.36	-0.02	39.30	16.86	79.29	0.0070	2.88E+06
1090	196092	17406.7	-0.549	72.20	-58.70	-0.02	39.29	16.82	79.81	0.0070	2.90E+06
1092	195787	17360.0	-0.559	72.12	-59.09	-0.07	39.28	16.78	80.35	0.0070	2.93E+06
1094	195477	17312.9	-0.570	72.05	-59.09	-0.11	39.27	16.73	80.90	0.0069	2.96E+06
1096	195162	17265.5	-0.580	71.97	-59.03	-0.16	39.26	16.69	81.48	0.0069	2.99E+06
1098	194842	17217.7	-0.589	71.89	-58.85	-0.18	39.24	16.65	82.07	0.0068	3.02E+06
1100	194518	17169.6	-0.598	71.81	-58.54	-0.21	39.23	16.60	82.67	0.0068	3.05E+06

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1102	194189	17121.1	-0.606	71.73	-58.05	-0.24	39.22	16.55	83.29	0.0067	3.08E+06
1104	193858	17072.0	-0.612	71.64	-57.38	-0.24	39.21	16.51	83.92	0.0067	3.12E+06
1106	193525	17022.5	-0.615	71.56	-56.60	-0.20	39.19	16.46	84.56	0.0066	3.15E+06
1108	193192	16973.0	-0.617	71.47	-56.04	-0.14	39.19	16.42	85.19	0.0066	3.18E+06
1110	192859	16923.3	-0.617	71.39	-55.73	-0.16	39.17	16.37	85.83	0.0065	3.22E+06
1112	192528	16873.1	-0.615	71.30	-55.41	-0.15	39.16	16.32	86.46	0.0065	3.25E+06
1114	192199	16822.6	-0.613	71.21	-55.10	-0.15	39.13	16.27	87.08	0.0064	3.29E+06
1116	191873	16771.8	-0.610	71.12	-54.87	-0.16	39.03	16.23	87.69	0.0064	3.32E+06
1118	191550	16721.0	-0.606	71.03	-54.62	-0.16	39.01	16.18	88.29	0.0063	3.35E+06
1120	191231	16669.7	-0.601	70.94	-54.64	-0.10	39.05	16.13	88.88	0.0063	3.39E+06
1122	190915	16618.2	-0.598	70.85	-54.87	-0.11	39.01	16.08	89.45	0.0062	3.42E+06
1124	190603	16566.6	-0.594	70.75	-55.15	-0.06	39.01	16.03	90.02	0.0062	3.45E+06
1126	190293	16514.9	-0.593	70.65	-55.78	-0.07	38.99	15.99	90.57	0.0061	3.48E+06
1128	189985	16463.3	-0.593	70.55	-56.47	-0.05	39.02	15.94	91.13	0.0061	3.52E+06
1130	189677	16411.7	-0.596	70.45	-57.18	-0.00	39.08	15.89	91.69	0.0061	3.55E+06
1132	189368	16359.7	-0.600	70.34	-58.03	0.03	39.13	15.84	92.26	0.0060	3.58E+06
1134	189057	16307.1	-0.608	70.23	-59.02	0.01	39.19	15.79	92.83	0.0060	3.62E+06
1136	188743	16253.6	-0.617	70.11	-59.68	-0.05	39.24	15.74	93.41	0.0059	3.65E+06
1138	188424	16199.6	-0.627	70.00	-60.06	-0.06	39.21	15.70	94.00	0.0059	3.69E+06
1140	188100	16145.5	-0.639	69.88	-60.03	-0.11	39.17	15.65	94.61	0.0058	3.73E+06
1142	187771	16091.4	-0.651	69.75	-59.94	-0.10	39.13	15.60	95.25	0.0058	3.77E+06
1144	187436	16037.2	-0.663	69.63	-59.90	-0.07	39.14	15.55	95.90	0.0058	3.81E+06
1146	187096	15982.5	-0.674	69.51	-59.96	-0.04	39.18	15.50	96.58	0.0057	3.85E+06
1148	186751	15926.9	-0.686	69.38	-60.22	-0.07	39.22	15.44	97.27	0.0057	3.89E+06
1150	186401	15869.9	-0.698	69.25	-60.51	-0.18	39.25	15.39	97.91	0.0056	3.93E+06
1152	186046	15812.1	-0.710	69.11	-59.99	-0.16	39.21	15.33	98.56	0.0056	3.97E+06
1154	185686	15753.9	-0.719	68.98	-59.34	-0.14	39.16	15.27	99.22	0.0055	4.01E+06
1156	185324	15695.3	-0.726	68.84	-58.76	-0.15	39.11	15.21	99.89	0.0055	4.05E+06
1158	184961	15636.5	-0.730	68.70	-58.19	-0.16	39.05	15.15	100.56	0.0054	4.09E+06
1160	184596	15577.6	-0.733	68.57	-57.64	-0.16	39.04	15.09	101.24	0.0054	4.13E+06
1162	184232	15518.4	-0.735	68.43	-57.08	-0.15	39.03	15.03	101.91	0.0054	4.18E+06
1164	183870	15458.9	-0.734	68.29	-56.71	-0.10	38.98	14.97	102.58	0.0053	4.22E+06
1166	183510	15399.2	-0.732	68.15	-56.61	-0.06	38.97	14.91	103.24	0.0053	4.26E+06
1168	183153	15339.1	-0.731	68.01	-57.15	-0.09	38.99	14.85	103.83	0.0052	4.30E+06
1170	182797	15278.9	-0.733	67.86	-57.89	-0.13	39.01	14.79	104.41	0.0052	4.34E+06
1172	182441	15218.4	-0.737	67.72	-58.41	-0.12	39.02	14.72	104.99	0.0051	4.38E+06
1174	182084	15157.4	-0.744	67.57	-59.01	-0.12	39.04	14.66	105.57	0.0051	4.42E+06
1176	181724	15096.0	-0.753	67.41	-59.38	-0.31	39.07	14.60	106.14	0.0051	4.46E+06
1178	181361	15034.2	-0.760	67.25	-54.93	-0.80	39.21	14.53	106.73	0.0050	4.50E+06
1180	181003	14971.3	-0.734	67.12	-45.05	-0.20	39.35	14.46	107.28	0.0050	4.54E+06
1182	180671	14907.9	-0.675	67.01	-35.37	-0.31	39.37	14.40	107.71		4.57E+06
1184	180377	14844.3	-0.589	66.94	-25.52	-0.36	39.43	14.33	107.98		4.60E+06
1186	180135	14780.5	-0.483	66.91	-15.42	-0.37	39.49	14.27	108.03		4.62E+06
1188	179952	14716.2	-0.363	66.93	-5.21	-0.38	39.59	14.20	107.82		4.63E+06
1190	179834	14651.4	-0.239	66.99	5.05	-0.40	39.75	14.14	107.34		4.63E+06
1192	179778	14586.6	-0.120	67.10	15.44	-0.34	39.89	14.08	106.60		4.62E+06
1194	179779	14522.0	-0.016	67.26	25.87	-0.34	40.02	14.01	105.65		4.60E+06
1196	179826	14457.6	0.064	67.46	36.35	-0.32	40.20	13.95	104.55		4.57E+06
1198	179906	14393.5	0.112	67.69	46.84	-0.27	40.35	13.89	103.34		4.54E+06
1200	180000	14330.0	0.122	67.96	57.30	-0.21	40.49	13.83	102.10		4.50E+06
1202	180086	14266.8	0.086	68.26	67.39	-0.01	40.68	13.77	100.90		4.47E+06
1204	180144	14203.8	0.011	68.57	73.03	0.12	40.83	13.71	99.82		4.44E+06
1206	180159	14141.0	-0.079	68.89	75.20	0.01	40.95	13.65	98.89		4.42E+06
1208	180127	14078.1	-0.178	69.21	76.59	0.03	41.16	13.59	98.12		4.41E+06
1210	180045	14014.6	-0.282	69.53	77.16	0.00	41.61	13.53	97.51		4.40E+06

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1212	179912	13949.6	-0.389	69.86	77.30	0.03	41.98	13.46	97.05		4.40E+06
1214	179726	13884.0	-0.495	70.19	76.42	0.04	42.14	13.40	96.76		4.41E+06
1216	179491	13815.3	-0.597	70.52	74.90	0.10	42.46	13.34	96.29		4.41E+06
1218	179209	13748.9	-0.691	70.86	72.05	0.11	42.51	13.27	96.38		4.43E+06
1220	178886	13682.5	-0.769	71.19	68.47	0.04	42.47	13.20	96.62		4.46E+06
1222	178531	13615.9	-0.831	71.52	64.74	0.04	42.44	13.13	96.97		4.50E+06
1224	178152	13549.1	-0.876	71.84	60.93	0.04	42.38	13.06	97.41		4.54E+06
1226	177757	13482.3	-0.906	72.16	57.22	0.03	42.28	12.99	97.90		4.58E+06
1228	177354	13415.5	-0.921	72.47	54.46	-0.00	42.16	12.92	98.43		4.62E+06
1230	176947	13348.9	-0.926	72.78	52.27	0.02	42.00	12.85	98.97		4.67E+06
1232	176541	13284.7	-0.924	73.07	50.59	-0.04	41.90	12.79	99.57		4.72E+06
1234	176138	13220.9	-0.917	73.36	49.44	-0.06	41.75	12.72	100.18		4.77E+06
1236	175742	13157.3	-0.906	73.65	50.74	-0.29	41.70	12.66	100.77		4.82E+06
1238	175349	13093.5	-0.910	73.95	52.91	0.33	41.59	12.60	101.33		4.87E+06
1240	174956	13030.1	-0.912	74.25	51.70	-1.20	41.35	12.53	101.91		4.92E+06
1242	174563	12966.9	-0.918	74.55	53.46	0.08	41.29	12.47	102.49		4.97E+06
1244	174168	12903.1	-0.927	74.86	53.59	0.01	41.98	12.41	103.07		5.02E+06
1246	173772	12836.9	-0.933	75.18	53.76	0.06	41.14	12.34	103.61		5.07E+06
1248	173372	12774.8	-0.945	75.49	53.61	-0.03	40.65	12.29	104.32		5.13E+06
1250	172969	12711.4	-0.955	75.80	53.50	-0.05	40.86	12.23	105.09		5.20E+06
1252	172564	12647.4	-0.962	76.12	52.09	0.19	40.80	12.18	105.85		5.27E+06
1254	172160	12583.3	-0.956	76.43	49.58	-0.26	40.68	12.12	106.61		5.34E+06
1256	171762	12519.0	-0.946	76.74	49.63	0.02	40.39	12.07	107.35		5.41E+06
1258	171369	12456.0	-0.937	77.05	49.41	0.00	39.40	12.01	108.07		5.48E+06
1260	170981	12397.5	-0.934	77.35	49.35	0.04	39.09	11.96	109.03		5.56E+06
1262	170597	12336.7	-0.923	77.67	49.35	0.07	40.47	11.91	110.15		5.65E+06
1264	170220	12272.0	-0.908	77.99	49.18	0.02	40.69	11.84	111.08		5.72E+06
1266	169851	12207.3	-0.893	78.32	47.96	0.30	40.39	11.78	111.83		5.79E+06
1268	169492	12142.9	-0.865	78.64	44.56	0.11	40.06	11.71	112.51		5.85E+06
1270	169149	12078.9	-0.824	78.94	41.07	0.20	39.77	11.64	113.09		5.91E+06
1272	168828	12016.1	-0.769	79.22	38.05	-0.02	39.45	11.58	113.56		5.96E+06
1274	168533	11953.4	-0.712	79.50	39.26	0.08	39.49	11.51	113.88		6.00E+06
1276	168260	11890.8	-0.665	79.79	41.69	0.22	39.24	11.45	114.08		6.04E+06
1278	168006	11828.6	-0.629	80.10	44.02	0.23	39.12	11.38	114.19		6.07E+06
1280	167765	11766.9	-0.605	80.41	46.10	0.25	38.92	11.32	114.22		6.10E+06
1282	167532	11706.2	-0.592	80.73	47.99	0.20	38.81	11.26	114.21		6.13E+06
1284	167303	11645.6	-0.590	81.06	49.88	0.17	38.90	11.20	114.16		6.16E+06
1286	167074	11584.8	-0.596	81.39	51.72	0.16	39.03	11.13	114.09		6.18E+06
1288	166842	11524.4	-0.613	81.73	53.19	0.20	39.13	11.07	114.01		6.21E+06
1290	166601	11464.0	-0.636	82.07	54.08	0.17	39.23	11.01	113.94		6.23E+06
1292	166352	11403.6	-0.665	82.42	54.83	0.14	39.31	10.95	113.88		6.26E+06
1294	166091	11343.2	-0.698	82.77	55.16	0.17	39.42	10.89	113.84		6.29E+06
1296	165817	11282.8	-0.733	83.12	55.21	0.12	39.53	10.83	113.81		6.32E+06
1298	165531	11222.3	-0.768	83.47	55.21	0.12	39.63	10.76	113.81		6.35E+06
1300	165231	11161.6	-0.804	83.82	54.98	0.03	39.67	10.70	113.82		6.38E+06
1302	164919	11100.6	-0.839	84.18	54.99	0.08	39.69	10.64	113.85		6.41E+06
1304	164595	11039.4	-0.875	84.54	55.11	0.13	39.70	10.58	113.89		6.45E+06
1306	164258	10978.0	-0.911	84.90	54.74	0.10	39.69	10.52	113.94		6.48E+06
1308	163910	10916.1	-0.943	85.26	54.28	0.06	39.64	10.45	113.99		6.52E+06
1310	163551	10811.1	-0.977	85.62	53.62	0.21	39.61	10.35	113.41		6.55E+06
1312	163184	10748.0	-1.002	85.98	52.30	0.15	39.52	10.29	113.85		6.61E+06
1314	162810	10685.3	-1.020	86.33	51.03	0.10	39.43	10.23	114.32		6.67E+06
1316	162433	10622.6	-1.033	86.68	50.36	0.02	39.38	10.17	114.81		6.74E+06
1318	162052	10559.8	-1.045	87.03	50.19	0.00	39.32	10.10	115.29		6.81E+06
1320	161669	10497.0	-1.057	87.38	50.22	0.07	39.26	10.04	115.78		6.88E+06

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1322	161284	10434.4	-1.070	87.73	50.10	0.05	39.15	9.98	116.28		6.95E+06
1324	160895	10372.1	-1.083	88.08	49.90	-0.03	39.11	9.92	116.80		7.02E+06
1326	160504	10309.8	-1.097	88.44	50.16	-0.08	39.08	9.86	117.30		7.09E+06
1328	160110	10246.8	-1.114	88.80	50.79	-0.16	39.06	9.79	117.70		7.15E+06
1330	159710	10183.3	-1.135	89.16	51.64	-0.17	39.02	9.73	118.10		7.21E+06
1332	159304	10119.4	-1.161	89.54	52.26	0.01	38.96	9.66	118.50		7.28E+06
1334	158891	10055.3	-1.185	89.92	48.89	0.21	38.96	9.59	118.92		7.34E+06
1336	158477	9990.9	-1.175	90.27	44.39	-0.42	38.86	9.53	119.32		7.41E+06
1338	158073	9926.8	-1.151	90.60	42.21	-0.28	38.65	9.46	119.68		7.47E+06
1340	157680	9862.6	-1.115	90.93	40.27	-0.31	38.53	9.39	119.97		7.53E+06
1342	157304	9798.3	-1.071	91.25	39.01	-0.24	38.29	9.33	120.18		7.58E+06
1344	156945	9734.0	-1.023	91.58	38.37	-0.15	38.08	9.26	120.39		7.65E+06
1346	156605	9670.1	-0.975	91.90	38.12	-0.20	37.87	9.20	120.55		7.71E+06
1348	156282	9606.6	-0.935	92.22	42.07	0.01	37.72	9.14	120.61		7.76E+06
1350	155970	9543.6	-0.918	92.58	43.28	-0.02	37.43	9.08	120.62		7.81E+06
1352	155666	9481.5	-0.899	92.93	43.47	-0.55	37.25	9.02	120.60		7.86E+06
1354	155368	9419.7	-0.891	93.29	44.57	0.15	37.14	8.96	120.55		7.91E+06
1356	155073	9356.3	-0.880	93.66	44.52	-0.04	38.15	8.90	120.43		7.96E+06
1358	154785	9293.5	-0.872	94.03	45.04	0.09	36.56	8.84	120.27		8.00E+06
1360	154497	9234.5	-0.879	94.40	45.40	0.07	36.65	8.79	120.20		8.05E+06
1362	154210	9174.3	-0.883	94.77	45.76	-0.08	36.88	8.73	120.09		8.09E+06
1364	153921	9114.7	-0.896	95.15	46.83	0.01	36.75	8.67	119.98		8.13E+06
1366	153629	9056.3	-0.915	95.53	47.25	-0.10	36.70	8.61	119.86		8.17E+06
1368	153331	8998.2	-0.939	95.92	47.92	-0.11	36.68	8.56	119.75		8.22E+06
1370	153027	8940.4	-0.967	96.31	48.30	-0.13	36.66	8.50	119.68		8.26E+06
1372	152715	8882.9	-1.000	96.70	48.79	-0.16	36.64	8.44	119.64		8.31E+06
1374	152393	8825.6	-1.037	97.10	49.21	-0.10	36.58	8.39	119.64		8.36E+06
1376	152062	8768.6	-1.077	97.50	49.16	-0.21	36.53	8.33	119.69		8.41E+06
1378	151720	8711.7	-1.116	97.90	48.84	-0.23	36.28	8.27	119.77		8.47E+06
1380	151368	8655.4	-1.154	98.30	48.58	-0.12	36.10	8.22	119.91		8.53E+06
1382	151007	8598.8	-1.188	98.70	47.98	-0.04	36.14	8.16	120.07		8.60E+06
1384	150639	8542.0	-1.216	99.11	46.77	0.06	35.98	8.11	120.29		8.67E+06
1386	150266	8486.2	-1.235	99.51	44.75	0.16	35.74	8.06	120.72		8.76E+06
1388	149891	8431.0	-1.242	99.90	42.86	0.19	35.51	8.01	121.19		8.86E+06
1390	149517	8376.5	-1.243	100.28	41.72	0.23	35.33	7.96	121.66		8.96E+06
1392	149146	8322.7	-1.242	100.65	41.31	0.18	35.18	7.92	122.13		9.07E+06
1394	148776	8269.5	-1.243	101.03	41.31	0.11	35.06	7.87	122.59		9.17E+06
1396	148408	8216.8	-1.249	101.40	41.89	0.13	34.96	7.83	123.06		9.27E+06
1398	148039	8164.5	-1.262	101.79	42.73	0.09	34.92	7.78	123.53		9.38E+06
1400	147667	8112.6	-1.284	102.17	41.58	0.70	34.87	7.74	124.02		9.48E+06
1402	147294	8060.3	-1.270	102.53	32.38	-0.08	34.97	7.69	124.47		9.59E+06
1404	146936	8007.7	-1.203	102.81	23.21	0.01	34.89	7.64	124.77		9.68E+06
1406	146603	7954.7	-1.103	103.01	13.71	0.12	34.77	7.59	124.91		9.76E+06
1408	146303	7901.9	-0.983	103.13	4.20	0.24	34.51	7.54	124.87		9.82E+06
1410	146038	7849.4	-0.861	103.17	-5.44	0.34	34.33	7.50	124.65		9.87E+06
1412	145808	7797.2	-0.750	103.11	-15.36	0.37	34.20	7.45	124.24		9.91E+06
1414	145605	7745.4	-0.669	102.97	-25.47	0.42	34.05	7.40	123.69		9.93E+06
1416	145420	7694.3	-0.635	102.75	-35.80	0.41	33.96	7.35	123.06		9.95E+06
1418	145238	7643.7	-0.661	102.45	-46.34	0.29	33.94	7.30	122.43		9.96E+06
1420	145040	7594.1	-0.757	102.09	-53.43	-0.13	33.79	7.26	121.89		9.99E+06
1422	144814	7545.5	-0.883	101.71	-55.62	0.18	33.74	7.21	121.54		1.00E+07
1424	144555	7497.4	-1.026	101.31	-57.29	0.14	33.88	7.17	121.36		1.01E+07
1426	144258	7449.3	-1.177	100.91	-57.95	0.14	33.97	7.12	121.36		1.01E+07
1428	143925	7401.8	-1.334	100.51	-58.11	0.10	34.00	7.08	121.54		1.02E+07
1430	143553	7354.7	-1.489	100.10	-57.47	0.03	34.03	7.03	121.89		1.03E+07

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1432	143145	7307.8	-1.637	99.69	-56.13	-0.01	34.10	6.99	122.43		1.04E+07
1434	142704	7260.3	-1.769	99.28	-53.69	-0.16	34.17	6.94	123.10		1.06E+07
1436	142237	7212.9	-1.872	98.88	-49.08	-0.17	33.97	6.90	123.91		1.07E+07
1438	141751	7166.0	-1.933	98.51	-43.10	0.17	33.76	6.85	124.82		1.09E+07
1440	141259	7119.5	-1.962	98.18	-40.05	0.19	33.43	6.81	125.78		1.10E+07
1442	140765	7074.0	-1.981	97.87	-38.24	0.25	33.14	6.77	126.81		1.12E+07
1444	140269	7029.0	-1.996	97.55	-37.78	0.17	32.91	6.73	128.03		1.14E+07
1446	139774	6984.4	-2.014	97.24	-38.34	0.19	32.73	6.69	129.27		1.16E+07
1448	139276	6940.2	-2.040	96.91	-39.80	0.01	32.56	6.66	130.54		1.18E+07
1450	138775	6896.0	-2.074	96.56	-41.19	-0.09	32.46	6.62	131.83		1.20E+07
1452	138268	6851.6	-2.114	96.21	-42.00	-0.15	32.38	6.58	133.13		1.22E+07
1454	137754	6807.5	-2.157	95.84	-41.90	-0.12	32.20	6.55	134.49		1.24E+07
1456	137235	6762.4	-2.197	95.47	-40.96	-0.05	31.98	6.52	136.14		1.27E+07
1458	136710	6716.5	-2.228	95.10	-39.96	0.13	31.81	6.49	137.98		1.30E+07
1460	136183	6670.4	-2.253	94.73	-39.57	0.07	31.65	6.46	139.85		1.33E+07
1462	135655	6624.7	-2.275	94.35	-38.68	0.05	31.38	6.43	141.77		1.37E+07
1464	135125	6579.6	-2.291	93.99	-37.76	0.16	31.12	6.40	143.74		1.40E+07
1466	134597	6534.6	-2.303	93.63	-37.34	0.11	30.97	6.38	145.80		1.44E+07
1468	134070	6488.8	-2.309	93.27	-36.92	0.24	30.81	6.34	147.63		1.47E+07
1470	133546	6442.2	-2.318	92.93	-37.02	0.21	30.53	6.31	149.27		1.50E+07
1472	133024	6396.0	-2.327	92.59	-36.98	0.25	30.27	6.27	150.92		1.53E+07
1474	132504	6349.4	-2.332	92.24	-37.66	0.22	30.19	6.23	152.53		1.56E+07
1476	131987	6302.1	-2.334	91.87	-38.26	0.09	29.92	6.19	154.08		1.59E+07
1478	131475	6254.7	-2.335	91.49	-38.26	-0.19	29.61	6.16	155.58		1.62E+07
1480	130967	6207.8	-2.326	91.11	-35.42	-0.20	29.25	6.12	157.05		1.65E+07
1482	130466	6163.3	-2.303	90.77	-34.19	-0.10	28.88	6.07	158.11		1.68E+07
1484	129975	6119.5	-2.280	90.43	-34.16	0.11	28.55	6.03	159.14		1.70E+07
1486	129492	6075.9	-2.263	90.08	-35.70	0.25	28.40	5.98	160.11		1.72E+07
1488	129014	6032.4	-2.261	89.71	-37.81	0.31	28.20	5.94	161.04		1.74E+07
1490	128539	5989.1	-2.273	89.31	-39.54	0.26	28.00	5.89	161.96		1.76E+07
1492	128064	5946.2	-2.299	88.90	-40.83	0.23	27.78	5.85	162.88		1.79E+07
1494	127586	5903.7	-2.335	88.47	-41.98	0.21	27.59	5.80	163.82		1.81E+07
1496	127103	5861.7	-2.379	88.01	-42.65	0.16	27.46	5.76	164.78		1.83E+07
1498	126614	5820.1	-2.429	87.54	-42.52	0.15	27.25	5.72	165.80		1.85E+07
1500	126119	5778.9	-2.485	87.06	-43.60	-0.99	27.12	5.67	166.87		1.88E+07
1502	125618	5737.2	-2.499	86.62	-34.61	0.32	27.33	5.63	167.91		1.90E+07
1504	125125	5695.2	-2.465	86.23	-32.79	0.42	26.93	5.59	168.89		1.93E+07
1506	124642	5653.1	-2.430	85.84	-32.94	0.29	27.65	5.54	169.77		1.95E+07
1508	124172	5610.0	-2.393	85.45	-33.24	0.25	26.06	5.50	170.61		1.97E+07
1510	123708	5570.3	-2.398	85.08	-33.67	0.20	26.12	5.46	171.69		2.00E+07
1512	123248	5528.1	-2.377	84.68	-35.79	0.63	26.78	5.42	172.56		2.03E+07
1514	122794	5484.1	-2.392	84.20	-42.40	-0.09	26.72	5.38	173.26		2.05E+07
1516	122337	5441.3	-2.440	83.69	-43.05	-0.13	26.02	5.34	174.02		2.08E+07
1518	121873	5400.4	-2.502	83.19	-42.72	0.02	25.55	5.30	174.94		2.10E+07
1520	121401	5359.8	-2.569	82.68	-43.85	0.13	25.53	5.26	175.92		2.13E+07
1522	120920	5319.0	-2.645	82.16	-45.23	0.05	25.56	5.22	177.05		2.16E+07
1524	120428	5278.4	-2.727	81.62	-45.62	0.05	25.37	5.19	178.37		2.20E+07
1526	119925	5237.9	-2.806	81.08	-45.39	0.16	25.24	5.15	179.77		2.24E+07
1528	119412	5197.4	-2.882	80.54	-45.06	0.17	25.11	5.11	181.24		2.27E+07
1530	118891	5156.9	-2.952	80.00	-44.75	0.17	24.93	5.08	182.79		2.31E+07
1532	118361	5116.7	-3.018	79.45	-43.92	0.18	24.76	5.04	184.40		2.36E+07
1534	117825	5076.8	-3.079	78.91	-43.05	0.22	24.58	5.01	186.09		2.40E+07
1536	117283	5035.8	-3.131	78.37	-42.56	0.23	24.41	4.97	187.65		2.44E+07
1538	116738	4994.4	-3.177	77.82	-42.72	0.12	24.29	4.93	189.20		2.48E+07
1540	116189	4953.3	-3.222	77.26	-42.47	0.09	24.08	4.89	190.78		2.53E+07

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1542	115638	4912.3	-3.262	76.70	-41.52	0.01	23.87	4.85	192.39		2.57E+07
1544	115085	4872.0	-3.298	76.15	-40.85	0.09	23.63	4.81	194.05		2.62E+07
1546	114531	4831.6	-3.329	75.60	-40.75	0.12	23.62	4.78	195.71		2.66E+07
1548	113978	4790.7	-3.352	75.03	-41.09	0.08	23.52	4.74	197.41		2.71E+07
1550	113425	4750.2	-3.385	74.45	-41.38	0.05	23.24	4.70	199.13		2.76E+07
1552	112871	4710.4	-3.424	73.86	-41.55	0.01	22.99	4.67	200.89		2.81E+07
1554	112316	4670.7	-3.465	73.27	-41.21	0.06	22.86	4.63	202.67		2.87E+07
1556	111760	4630.8	-3.497	72.68	-41.10	0.18	22.73	4.59	204.42		2.92E+07
1558	111203	4590.9	-3.530	72.07	-42.04	-0.02	22.55	4.56	206.08		2.97E+07
1560	110646	4551.8	-3.569	71.45	-41.49	-0.05	22.34	4.52	207.50		3.02E+07
1562	110088	4513.3	-3.606	70.84	-41.33	-0.05	22.13	4.48	208.94		3.06E+07
1564	109529	4474.8	-3.640	70.23	-40.66	-0.01	21.94	4.44	210.38		3.11E+07
1566	108970	4436.1	-3.662	69.61	-40.37	-0.05	21.79	4.40	211.76		3.15E+07
1568	108414	4397.4	-3.682	68.99	-40.39	-0.16	21.61	4.36	213.09		3.20E+07
1570	107860	4359.3	-3.701	68.37	-39.40	-0.05	21.41	4.32	214.48		3.25E+07
1572	107308	4322.1	-3.726	67.74	-40.96	-1.08	21.17	4.28	216.04		3.30E+07
1574	106760	4284.9	-3.714	67.16	-35.26	0.28	21.06	4.25	217.54		3.35E+07
1576	106219	4247.8	-3.693	66.58	-35.55	-0.01	21.19	4.21	218.95		3.40E+07
1578	105689	4207.7	-3.614	65.97	-34.99	-0.01	21.62	4.17	219.91		3.45E+07
1580	105177	4169.0	-3.556	65.38	-34.63	-0.06	20.81	4.13	220.82		3.50E+07
1582	104675	4131.8	-3.520	64.81	-34.36	0.07	20.43	4.10	221.75		3.54E+07
1584	104183	4095.3	-3.505	64.23	-36.35	0.15	20.21	4.06	222.64		3.59E+07
1586	103694	4058.8	-3.523	63.61	-39.07	-0.02	20.03	4.02	223.47		3.63E+07
1588	103206	4022.4	-3.564	62.93	-41.23	-0.29	19.81	3.99	224.25		3.68E+07
1590	102715	3986.4	-3.626	62.24	-41.73	-0.30	19.62	3.95	225.07		3.73E+07
1592	102220	3950.8	-3.696	61.55	-41.45	-0.24	19.47	3.92	225.95		3.78E+07
1594	101720	3915.3	-3.762	60.85	-41.09	-0.15	19.39	3.88	226.85		3.83E+07
1596	101216	3878.8	-3.826	60.15	-41.33	-0.09	19.33	3.85	227.97		3.89E+07
1598	100709	3841.3	-3.878	59.46	-36.75	-0.64	19.28	3.82	229.28		3.96E+07
1600	100206	3803.3	-3.818	58.90	-26.48	-0.28	19.27	3.78	230.43		4.02E+07
1602	99724	3765.0	-3.664	58.52	-16.43	-0.27	19.20	3.75	231.29		4.09E+07
1604	99271	3726.6	-3.453	58.33	-6.13	-0.28	19.07	3.72	231.75		4.15E+07
1606	98851	3688.2	-3.225	58.35	4.36	-0.23	18.94	3.68	231.78		4.20E+07
1608	98463	3649.9	-3.022	58.59	14.55	-0.18	18.79	3.65	231.42		4.24E+07
1610	98102	3611.9	-2.886	59.01	24.60	-0.28	18.63	3.61	230.79		4.28E+07
1612	97754	3574.1	-2.853	59.63	35.23	-0.18	18.49	3.58	230.08		4.32E+07
1614	97407	3537.0	-2.943	60.40	41.97	0.03	18.26	3.55	229.41		4.36E+07
1616	97047	3500.2	-3.098	61.24	45.27	0.04	18.18	3.51	228.87		4.41E+07
1618	96670	3463.5	-3.286	62.12	46.24	-0.01	18.16	3.48	228.50		4.46E+07
1620	96273	3426.9	-3.483	63.02	47.04	0.04	18.13	3.45	228.32		4.51E+07
1622	95857	3390.4	-3.686	63.94	46.89	-0.03	18.07	3.42	228.34		4.57E+07
1624	95420	3353.9	-3.890	64.89	47.02	0.12	18.01	3.38	228.54		4.63E+07
1626	94964	3317.6	-4.086	65.83	45.68	0.01	17.94	3.35	228.95		4.70E+07
1628	94492	3281.8	-4.274	66.78	45.35	0.12	17.83	3.32	228.96		4.76E+07
1630	94003	3246.3	-4.452	67.73	44.14	0.14	17.71	3.28	229.05		4.81E+07
1632	93500	3210.8	-4.608	68.68	43.15	0.17	17.58	3.25	229.24		4.87E+07
1634	92986	3175.1	-4.747	69.64	42.45	0.23	17.49	3.21	229.46		4.93E+07
1636	92463	3139.6	-4.872	70.60	41.51	0.24	17.29	3.17	229.74		4.99E+07
1638	91933	3104.4	-4.997	71.56	42.13	-0.04	17.14	3.14	230.08		5.05E+07
1640	91392	3070.4	-5.164	72.55	45.42	1.09	16.78	3.10	230.73		5.12E+07
1642	90839	3037.7	-5.341	73.52	43.69	0.03	16.66	3.07	231.75		5.20E+07
1644	90272	3005.0	-5.534	74.53	44.71	0.19	16.40	3.04	232.89		5.29E+07
1646	89690	2971.5	-5.705	75.59	44.98	0.26	17.19	3.01	233.98		5.37E+07
1648	89099	2938.2	-5.876	76.67	45.13	0.23	16.33	2.97	235.17		5.46E+07
1650	88493	2906.7	-6.093	77.73	43.48	0.72	15.86	2.94	236.74		5.56E+07

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1652	87877	2875.1	-6.194	78.69	36.18	0.25	15.76	2.91	238.38		5.67E+07
1654	87260	2844.0	-6.260	79.57	33.95	0.49	15.59	2.88	240.05		5.77E+07
1656	86645	2812.9	-6.287	80.40	31.81	0.27	15.44	2.85	241.66		5.88E+07
1658	86034	2781.7	-6.300	81.21	30.59	0.40	15.26	2.82	243.17		5.98E+07
1660	85430	2750.8	-6.294	81.99	28.86	0.25	15.13	2.79	244.58		6.09E+07
1662	84833	2720.2	-6.275	82.74	28.33	0.25	14.97	2.76	246.34		6.21E+07
1664	84245	2690.4	-6.254	83.49	28.46	0.26	14.80	2.74	248.71		6.36E+07
1666	83664	2660.5	-6.238	84.26	28.57	0.32	14.74	2.71	250.93		6.52E+07
1668	83093	2630.2	-6.203	85.02	28.35	0.04	14.67	2.69	252.90		6.67E+07
1670	82530	2599.8	-6.183	85.83	29.49	0.34	14.46	2.66	254.69		6.81E+07
1672	81975	2569.8	-6.172	86.62	28.56	0.21	14.34	2.64	256.38		6.96E+07
1674	81426	2539.2	-6.171	87.40	28.98	-0.07	14.21	2.61	257.38		7.09E+07
1676	80884	2508.1	-6.188	88.23	30.54	0.11	14.12	2.58	257.88		7.20E+07
1678	80346	2476.9	-6.222	89.09	30.99	0.20	14.02	2.55	258.22		7.30E+07
1680	79813	2444.8	-6.175	89.87	22.77	-0.04	14.53	2.51	258.20		7.40E+07
1682	79299	2411.0	-5.946	90.46	14.29	0.00	14.92	2.48	257.49		7.49E+07
1684	78816	2376.3	-5.614	90.77	4.57	-0.04	14.91	2.45	256.11		7.57E+07
1686	78369	2341.5	-5.270	90.78	-4.70	0.09	14.65	2.41	254.16		7.63E+07
1688	77954	2305.8	-4.975	90.55	-10.47	0.15	14.55	2.38	251.86		7.68E+07
1690	77568	2269.5	-4.691	90.18	-13.28	0.01	14.63	2.34	248.99		7.72E+07
1692	77211	2233.1	-4.425	89.75	-14.58	-0.09	14.54	2.30	245.65		7.75E+07
1694	76878	2197.0	-4.185	89.29	-14.36	-0.11	14.38	2.27	241.96		7.76E+07
1696	76569	2161.1	-3.965	88.84	-13.92	-0.49	14.11	2.23	237.96		7.77E+07
1698	76280	2126.0	-3.795	88.47	-12.01	-0.11	13.71	2.20	233.84		7.76E+07
1700	76005	2091.9	-3.688	88.10	-12.73	-0.19	13.31	2.16	229.70		7.76E+07
1702	75740	2059.3	-3.675	87.75	-12.40	-0.02	12.81	2.13	225.73		7.75E+07
1704	75476	2028.0	-3.759	87.43	-11.72	0.12	12.22	2.10	222.00		7.74E+07
1706	75207	1998.3	-3.945	87.14	-11.35	0.14	11.75	2.07	218.62		7.74E+07
1708	74926	1969.8	-4.206	86.86	-10.64	0.13	11.31	2.04	215.61		7.75E+07
1710	74628	1942.6	-4.538	86.62	-9.61	0.05	10.87	2.01	213.00		7.77E+07
1712	74311	1916.4	-4.930	86.41	-8.57	0.02	10.53	1.98	210.81		7.80E+07
1714	73970	1891.1	-5.370	86.23	-7.75	0.01	10.30	1.96	209.01		7.84E+07
1716	73605	1866.4	-5.827	86.09	-6.74	0.16	10.23	1.93	207.54		7.90E+07
1718	73214	1842.1	-6.301	85.99	-5.91	0.40	10.11	1.91	206.38		7.97E+07
1720	72797	1818.5	-6.789	85.90	-5.80	0.70	10.01	1.89	205.60		8.05E+07
1722	72355	1795.6	-7.289	85.75	-7.45	0.65	9.94	1.86	205.17		8.14E+07
1724	71888	1773.0	-7.791	85.55	-8.33	0.36	9.92	1.84	205.04		8.25E+07
1726	71396	1750.9	-8.282	85.33	-7.84	-0.01	9.88	1.82	205.20		8.37E+07
1728	70882	1729.1	-8.753	85.17	-5.80	-0.05	9.89	1.80	205.62		8.50E+07
1730	70346	1707.4	-9.205	85.04	-5.41	-0.11	9.90	1.78	206.23		8.65E+07
1732	69792	1685.5	-9.631	84.94	-4.42	-0.03	9.93	1.76	206.95		8.80E+07
1734	69220	1663.9	-10.037	84.89	-3.20	0.28	9.89	1.74	207.83		8.96E+07
1736	68634	1642.4	-10.428	84.81	-4.26	0.41	9.85	1.71	208.85		9.14E+07
1738	68034	1620.9	-10.794	84.65	-5.47	0.03	9.78	1.69	209.96		9.32E+07
1740	67422	1599.3	-11.144	84.49	-5.12	-0.20	9.69	1.67	211.09		9.51E+07
1742	66800	1577.6	-11.473	84.37	-3.96	-0.27	9.60	1.65	212.26		9.71E+07
1744	66169	1556.0	-11.791	84.28	-3.43	-0.25	9.52	1.63	213.47		9.92E+07
1746	65531	1534.0	-12.097	84.20	-3.32	-0.16	9.43	1.61	214.62		1.01E+08
1748	64886	1511.4	-12.392	84.13	-3.17	-0.06	9.37	1.59	215.70		1.04E+08
1750	64236	1488.8	-12.657	84.09	-2.75	0.09	9.29	1.57	216.72		1.06E+08
1752	63583	1466.5	-12.900	84.03	-3.51	0.09	9.20	1.54	217.78		1.08E+08
1754	62929	1444.2	-13.110	83.92	-4.68	-0.10	9.13	1.52	218.77		1.11E+08
1756	62276	1421.8	-13.288	83.72	-4.95	-0.44	9.01	1.50	219.59		1.13E+08
1758	61624	1399.3	-13.465	83.63	-2.84	-0.44	8.89	1.48	220.28		1.16E+08
1760	60974	1378.8	-13.628	83.74	-1.38	-0.07	8.67	1.46	221.42		1.18E+08

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1762	60326	1358.8	-13.806	83.82	-2.14	0.14	8.38	1.44	222.61		1.21E+08
1764	59679	1338.6	-14.013	83.75	-3.87	-0.31	8.17	1.42	223.64		1.23E+08
1766	59031	1318.0	-14.239	83.77	-1.73	-0.46	8.06	1.40	224.44		1.26E+08
1768	58385	1297.1	-14.440	83.89	0.74	-0.05	7.99	1.38	224.80		1.28E+08
1770	57739	1276.2	-14.645	83.94	0.06	0.13	7.88	1.36	224.83		1.30E+08
1772	57096	1255.0	-14.832	83.94	-0.04	-0.01	7.86	1.33	224.64		1.32E+08
1774	56456	1234.3	-15.008	84.09	2.59	0.46	7.72	1.31	224.47		1.35E+08
1776	55820	1214.3	-15.168	84.25	1.51	0.69	7.60	1.29	224.39		1.37E+08
1778	55187	1192.9	-15.339	84.19	-0.60	0.18	7.61	1.27	223.56		1.39E+08
1780	54560	1171.1	-15.507	84.09	-0.25	-0.20	7.57	1.24	222.37		1.41E+08
1782	53937	1149.2	-15.654	84.10	1.59	-0.11	7.58	1.22	220.93		1.42E+08
1784	53321	1127.4	-15.783	84.26	3.18	0.37	7.52	1.20	219.32		1.44E+08
1786	52712	1106.4	-15.904	84.48	1.93	0.84	7.50	1.18	217.78		1.46E+08
1788	52111	1086.1	-15.913	84.46	-2.41	0.55	7.68	1.15	216.28		1.47E+08
1790	51523	1066.2	-15.864	84.30	-3.96	0.35	7.83	1.13	214.29		1.48E+08
1792	50947	1046.9	-15.830	84.12	-4.72	0.00	7.63	1.11	211.71		1.49E+08
1794	50381	1027.8	-15.889	83.92	-3.68	-0.41	7.45	1.09	209.03		1.49E+08
1796	49822	1008.4	-16.035	83.85	-1.80	-0.50	7.29	1.06	206.04		1.49E+08
1798	49268	989.6	-16.246	83.90	-1.64	-0.36	7.25	1.04	203.17		1.50E+08
1800	48716	971.9	-16.485	83.92	-1.70	-0.17	7.34	1.02	200.58		1.50E+08
1802	48166	955.9	-16.692	83.97	-0.16	0.18	7.39	1.00	198.25		1.50E+08
1804	47619	941.5	-16.896	84.11	0.07	0.57	7.49	0.98	196.50		1.50E+08
1806	47073	929.1	-17.120	84.16	-1.64	0.62	7.42	0.97	195.49		1.51E+08
1808	46524	919.3	-17.466	84.11	-2.16	0.39	7.28	0.96	195.54		1.52E+08
1810	45970	912.4	-17.807	84.03	-0.85	-0.11	7.52	0.95	196.82		1.53E+08
1812	45414	904.6	-17.819	84.13	0.51	-0.18	8.03	0.94	197.85		1.55E+08
1814	44864	896.8	-17.788	84.26	0.20	-0.11	8.20	0.93	198.88		1.56E+08
1816	44323	888.5	-17.506	84.39	-0.01	0.14	8.75	0.92	199.53		1.58E+08
1818	43797	880.2	-17.112	84.55	0.39	0.33	8.88	0.91	200.01		1.59E+08
1820	43288	872.3	-16.724	84.82	0.72	0.68	8.73	0.90	201.05		1.61E+08
1822	42793	865.5	-16.473	85.05	0.60	0.75	8.36	0.89	202.43		1.64E+08
1824	42306	859.6	-16.425	85.22	0.08	0.44	7.78	0.88	203.68		1.65E+08
1826	41820	854.7	-16.517	85.43	0.48	0.40	7.89	0.88	205.31		1.67E+08
1828	41338	850.3	-16.416	85.40	-0.97	0.25	7.69	0.87	207.10		1.69E+08
1830	40858	847.4	-16.444	85.21	-2.15	-0.22	7.50	0.86	209.60		1.71E+08
1832	40378	844.8	-16.651	84.77	-4.62	-0.80	6.78	0.86	212.35		1.73E+08
1834	39891	842.3	-16.901	84.35	-3.10	-0.69	7.08	0.86	215.26		1.76E+08
1836	39402	838.4	-16.940	83.99	-3.96	-0.54	7.21	0.85	217.29		1.78E+08
1838	38915	834.0	-16.928	83.54	-5.21	-0.46	7.10	0.84	219.00		1.80E+08
1840	38431	830.4	-16.995	83.19	-4.49	-0.22	6.86	0.84	221.06		1.81E+08
1842	37947	826.7	-17.000	83.11	0.33	-0.18	6.47	0.83	222.99		1.83E+08
1844	37462	823.5	-17.196	83.48	4.49	0.16	6.46	0.83	225.46		1.85E+08
1846	36975	820.6	-17.328	83.98	4.10	0.42	6.41	0.83	228.18		1.88E+08
1848	36487	817.7	-17.400	84.29	3.44	0.18	6.42	0.82	230.97		1.90E+08
1850	35999	814.6	-17.474	84.50	3.94	-0.08	6.26	0.82	233.60		1.93E+08
1852	35511	811.3	-17.483	84.80	4.57	-0.08	6.28	0.81	236.33		1.95E+08
1854	35026	808.7	-17.409	85.28	8.04	0.14	6.13	0.81	239.60		1.99E+08
1856	34542	807.3	-17.500	86.21	12.35	0.21	6.04	0.81	243.43		2.02E+08
1858	34057	806.2	-17.465	86.75	0.94	0.20	6.09	0.80	247.31		2.05E+08
1860	33576	803.4	-17.433	86.72	-1.64	0.21	5.85	0.80	250.04		2.07E+08
1862	33095	798.6	-17.526	86.51	-7.39	0.49	5.72	0.79	251.14		2.08E+08
1864	32614	791.7	-17.812	85.37	-21.55	0.35	5.84	0.78	250.96		2.09E+08
1866	32128	781.0	-18.091	82.98	-31.21	-0.17	6.58	0.77	248.51		2.09E+08
1868	31642	769.6	-18.594	79.85	-38.42	-0.31	6.51	0.76	245.54		2.09E+08
1870	31145	759.3	-19.490	76.10	-46.75	-0.59	6.59	0.75	243.05		2.09E+08

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1872	30628	750.8	-20.725	71.62	-55.83	-0.75	7.41	0.74	241.81		2.10E+08
1874	30086	741.6	-22.035	65.58	-62.11	-0.28	9.32	0.73	240.67		2.11E+08
1876	29517	734.9	-23.484	58.79	-63.11	-0.01	9.86	0.72	242.61		2.15E+08
1878	28923	729.5	-24.583	51.45	-61.98	-0.31	9.75	0.72	247.43		2.22E+08
1880	28310	729.2	-25.279	44.32	-58.43	-0.51	9.36	0.72	253.26		2.27E+08
1882	27687	730.2	-25.460	37.88	-51.78	-0.40	8.88	0.72	259.18		2.31E+08
1884	27066	728.9	-25.222	31.70	-50.50	-0.39	8.80	0.71	263.54		2.34E+08
1886	26451	725.6	-25.144	25.91	-50.23	-0.41	8.68	0.71	266.31		2.36E+08
1888	25841	720.8	-25.059	20.27	-50.19	0.05	9.18	0.70	267.95		2.38E+08
1890	25237	715.0	-25.048	14.80	-46.93	0.42	8.87	0.69	268.81		2.39E+08
1892	24642	708.2	-24.677	9.81	-42.11	0.47	9.00	0.68	268.76		2.40E+08
1894	24064	699.7	-24.111	5.20	-39.06	0.68	8.75	0.67	267.01		2.40E+08
1896	23506	692.2	-23.613	1.16	-36.03	0.81	8.48	0.66	265.88		2.41E+08
1898	22964	685.5	-23.063	-2.43	-33.20	1.17	8.28	0.66	265.14		2.41E+08
1900	22439	678.9	-22.594	-5.98	-31.70	0.76	7.92	0.65	264.58		2.42E+08
1902	21929	672.9	-22.132	-9.40	-30.07	0.33	7.71	0.64	264.39		2.44E+08
1904	21434	666.9	-21.456	-13.30	-35.81	-0.29	8.49	0.63	263.80		2.44E+08
1906	20961	660.6	-20.888	-18.53	-44.09	-0.38	8.04	0.63	262.47		2.44E+08
1908	20493	656.7	-21.198	-24.47	-51.22	-0.26	7.89	0.62	263.19		2.46E+08
1910	20015	654.9	-21.845	-30.81	-51.38	-0.36	8.24	0.62	265.70		2.48E+08
1912	19529	652.8	-21.970	-36.91	-46.74	0.00	8.81	0.62	268.40		2.51E+08
1914	19046	650.3	-21.936	-42.55	-45.09	0.29	8.70	0.61	270.97		2.54E+08
1916	18564	647.6	-21.847	-48.13	-43.78	0.17	8.61	0.61	273.18		2.56E+08
1918	18088	645.0	-21.590	-53.74	-42.34	-0.07	8.07	0.61	275.14		2.58E+08
1920	17618	643.2	-21.453	-58.86	-39.97	0.01	8.01	0.60	277.75		2.61E+08
1922	17154	641.0	-20.941	-64.01	-38.18	0.27	8.61	0.60	280.07		2.63E+08
1924	16710	637.5	-19.904	-69.27	-35.90	0.25	8.71	0.60	281.08		2.65E+08
1926	16292	633.4	-18.617	-74.04	-32.08	0.38	8.16	0.59	281.21		2.66E+08
1928	15898	630.3	-17.764	-77.88	-28.99	0.45	8.51	0.59	282.04		2.68E+08
1930	15537	623.4	-15.767	-82.04	-27.69	0.60	9.41	0.58	279.08		2.67E+08
1932	15221	614.5	-13.976	-85.98	-27.10	0.59	8.84	0.57	274.03		2.66E+08
1934	14939	606.1	-12.905	-89.52	-26.37	0.44	8.10	0.56	269.04		2.64E+08
1936	14677	597.6	-12.082	-92.94	-26.87	0.31	8.78	0.56	263.81		2.63E+08
1938	14440	587.6	-11.159	-96.75	-29.99	-0.05	8.13	0.55	257.14		2.60E+08
1940	14216	578.7	-10.898	-100.71	-31.57	-0.13	8.38	0.54	251.34		2.58E+08
1942	13999	571.8	-10.886	-104.65	-30.74	-0.06	8.26	0.53	247.30		2.57E+08
1944	13783	567.3	-10.993	-108.26	-27.19	0.02	8.23	0.53	245.22		2.56E+08
1946	13566	564.4	-10.924	-111.39	-20.88	-0.02	8.26	0.52	244.60		2.57E+08
1948	13354	561.9	-10.598	-113.60	-11.80	-0.06	8.21	0.52	244.34		2.58E+08
1950	13152	559.0	-9.989	-114.80	-6.27	-0.30	8.10	0.52	243.57		2.58E+08
1952	12960	556.2	-9.885	-115.49	-4.78	-0.22	7.25	0.52	242.79		2.58E+08
1954	12765	553.8	-10.133	-116.17	-6.84	-0.42	7.25	0.51	242.46		2.59E+08
1956	12564	552.0	-10.736	-117.05	-8.64	-0.22	6.95	0.51	242.21		2.59E+08
1958	12353	550.8	-11.272	-117.88	-7.73	0.22	6.88	0.51	242.55		2.60E+08
1960	12129	550.2	-12.015	-118.73	-8.72	0.37	6.90	0.51	243.53		2.61E+08
1962	11892	550.2	-12.676	-119.80	-10.48	0.26	6.96	0.51	245.19		2.62E+08
1964	11644	550.8	-13.207	-120.95	-9.07	0.26	7.02	0.51	247.48		2.64E+08
1966	11387	551.6	-13.503	-122.01	-7.88	0.09	7.35	0.51	250.17		2.66E+08
1968	11127	552.0	-13.498	-123.00	-6.49	-0.14	7.40	0.51	252.48		2.67E+08
1970	10868	551.9	-13.414	-123.52	-1.09	-0.03	7.31	0.51	254.38		2.69E+08
1972	10610	551.5	-13.643	-123.55	0.52	0.07	6.61	0.51	256.04		2.71E+08
1974	10343	551.9	-14.159	-123.53	0.85	0.14	6.56	0.51	258.36		2.72E+08
1976	10066	552.5	-14.698	-123.56	0.92	-0.04	6.55	0.51	261.03		2.74E+08
1978	9783	552.1	-14.528	-123.45	1.60	-0.10	7.37	0.50	262.84		2.76E+08
1980	9512	549.7	-14.022	-123.21	1.63	0.05	6.67	0.50	262.75		2.77E+08

Table B-1. (continued)

TIME (sec)	ALTDE (ft)	VEL A (fps)	GAM A (deg)	HDG A (deg)	SIGMA (deg)	BETA (deg)	ALPHA (deg)	MACH	QBAR (psf)	VBAR	RNUM
1982	9243	548.2	-14.172	-123.07	1.19	-0.01	6.32	0.50	263.49		2.78E+08
1984	8969	547.9	-14.654	-122.97	1.03	-0.18	6.06	0.50	265.42		2.80E+08
1986	8684	548.7	-15.316	-122.85	0.58	-0.19	5.81	0.50	268.56		2.82E+08
1988	8384	550.6	-16.238	-122.79	0.31	-0.11	5.68	0.50	272.99		2.85E+08
1990	8068	552.6	-16.852	-122.75	0.39	-0.19	5.89	0.50	277.68		2.89E+08
1992	7739	554.2	-17.315	-122.55	1.26	0.16	6.24	0.50	282.16		2.92E+08
1994	7408	555.0	-17.269	-122.53	0.77	0.03	6.12	0.50	285.57		2.95E+08
1996	7079	554.9	-17.039	-122.57	0.60	-0.29	6.09	0.50	288.14		2.97E+08
1998	6755	553.5	-16.716	-122.50	1.11	-0.38	6.09	0.50	289.34		2.98E+08
2000	6439	549.9	-16.365	-122.38	1.79	-0.21	6.17	0.50	288.04		2.98E+08
2002	6132	545.9	-16.043	-122.25	0.12	-0.13	6.01	0.49	286.09		2.97E+08
2004	5831	542.9	-15.906	-122.46	-1.76	0.03	5.88	0.49	285.24		2.97E+08
2006	5531	541.0	-16.067	-122.52	-1.95	0.39	5.95	0.49	286.09		2.99E+08
2008	5232	539.4	-15.757	-122.55	-0.92	0.47	6.16	0.49	287.37		3.01E+08
2010	4940	537.5	-15.612	-122.40	-0.25	0.48	5.88	0.48	288.39		3.03E+08
2012	4649	536.7	-15.631	-122.24	0.30	0.60	6.27	0.48	290.44		3.06E+08
2014	4361	535.6	-15.386	-122.05	0.72	0.79	6.08	0.48	292.05		3.08E+08
2016	4076	534.4	-15.353	-122.12	-0.07	0.37	5.82	0.48	293.43		3.10E+08
2018	3790	533.0	-15.522	-122.22	0.69	-0.09	6.02	0.48	294.69		3.12E+08
2020	3505	530.1	-15.189	-122.25	1.82	-0.71	6.60	0.48	294.57		3.13E+08
2022	3230	527.2	-14.782	-121.80	3.59	-0.39	6.73	0.47	294.25		3.15E+08
2024	2971	523.1	-13.602	-121.35	1.50	-0.13	7.12	0.47	292.42		3.15E+08
2026	2736	517.1	-11.862	-121.27	-0.24	0.30	8.09	0.46	288.50		3.15E+08
2028	2539	507.3	-10.044	-121.59	-3.26	0.25	8.27	0.46	281.48		3.15E+08
2030	2381	495.4	-8.110	-122.14	-1.22	0.17	8.20	0.45	271.48		3.12E+08
2032	2259	479.2	-5.747	-122.54	-0.13	-0.21	9.56	0.43	256.38		3.06E+08
2034	2189	459.1	-2.722	-122.32	3.10	-0.09	9.52	0.42	236.60		2.95E+08
2036	2156	441.2	-1.518	-121.71	3.91	-0.07	8.96	0.40	218.87		2.85E+08
2038	2137	424.0	-0.958	-121.29	0.14	-0.13	8.63	0.38	202.40		2.74E+08
2040	2121	408.6	-1.026	-121.32	-1.18	0.10	9.30	0.37	188.35		2.65E+08
2042	2109	393.0	-0.326	-121.63	-2.74	0.36	9.26	0.36	174.75		2.56E+08
2044	2107	378.1	0.150	-122.07	-1.02	0.37	8.68	0.34	161.88		2.46E+08

Table B-1. (concluded)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
November 1991

3. REPORT TYPE AND DATES COVERED
Contractor Report

4. TITLE AND SUBTITLE
Final STS-35 "Columbia" Descent BET Products and Results for LaRC OEX Investigations

5. FUNDING NUMBERS
C NAS1-18937
WU 506-48-11-01

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Flight Mechanics & Control, Inc.
47 East Queen's Way
Hampton, VA 23669

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23665-5225

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA CR-189569

11. SUPPLEMENTARY NOTES
Langley Technical Monitor: Paul M. Siemers III

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited

Subject Category 19

12b. DISTRIBUTION CODE

13. ABSTRACT
Final STS-35 "Columbia" descent Best Estimate Trajectory products have been developed for LaRC Orbiter Experiments investigations. Included are the reconstructed inertial trajectory profile; the Extended BET, which combines the inertial data and, in this instance, the National Weather Service atmospheric information obtained via Johnson Space Center; and the Aerodynamic BET. The inertial BET utilized IMU1 dynamic measurements for deterministic propagation during the ENTREE estimation process. The final estimate was based on the considerable ground-based C-band tracking coverage available as well as TDRSS Doppler data, a unique use of the latter for endo-atmospheric flight determinations. The actual estimate required simultaneous solutions for the spacecraft position and velocity, spacecraft attitude, and six IMU parameters - three gyro biases and three accelerometer scale-factor correction terms. The anchor epoch for this analysis was 19,200 GMT seconds (December 11, 1990) which corresponds to an initial Shuttle altitude of approximately 513 kft. The atmospheric data incorporated were evaluated based on Shuttle-derived considerations as well as comparisons versus the GRAM and AF78 reference models. The AEROBET was developed based on the Extended BET, the measured spacecraft configuration information, final mass properties, and the final Orbiter pre-operational databook. The latter was updated based on aerodynamic consensus incrementals defined by the latest published FAD. The rectified predictions were compared versus the flight computed values and the resultant differences were correlated versus ensemble results from twenty-two previous STS entry flights.

14. SUBJECT TERMS
Orbiter Experiments; Best Estimate Trajectory; Endo-atmospheric Flight; Trajectory Reconstruction; Atmospheric Evaluations; Aerodynamic Comparisons; TDRSS Doppler; C-Band Tracking

15. NUMBER OF PAGES
93

16. PRICE CODE
A05

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT