

UNCLASSIFIED

|                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                |
|                                                                                                                                                                                                |
|                                                                                                                                                                                                |
| AD NUMBER                                                                                                                                                                                      |
| ADB236817                                                                                                                                                                                      |
| NEW LIMITATION CHANGE                                                                                                                                                                          |
| TO<br>Approved for public release, distribution unlimited                                                                                                                                      |
| FROM<br>Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; Jul 1990 Other requests shall be referred to AL/CFBE, Wright Patterson AFB, OH 45433-7901. |
| AUTHORITY                                                                                                                                                                                      |
| 88CG/SCCM [FOIA Office] ltr, 3 Mar 2005                                                                                                                                                        |

THIS PAGE IS UNCLASSIFIED

AAMRL-TR-90-092



NATIONAL AEROSPACE PLANE SPECIAL STUDY ON CREW ESCAPE PHASE IV, VOLUME II

R. E. Zegler  
A. Bermudez  
North American Aircraft Division  
Rockwell International Corporation  
PO Box 92098  
Los Angeles CA 90009

July 1990

19980723 020

Distribution authorized to U. S. Government Agencies and their contractors; critical technology; July 1990.  
Other requests for this document shall be referred to AL/CFBE, 2800 Q Street, Wright-Patterson AFB OH  
45433-7901

AEROSPACE MEDICAL RESEARCH LABORATORY  
AEROSPACE MEDICAL DIVISION  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

## NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner, licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

Federal Government agencies and their contractors registered with Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center  
8725 John J. Kingman Rd., STE 0944  
Ft Belvoir VA 22060-6218

## TECHNICAL REVIEW AND APPROVAL

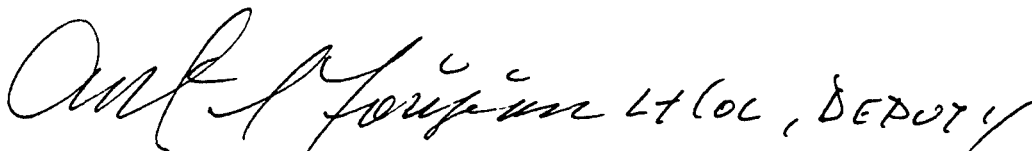
AAMRL-TR-90-092 Volume II

### DISCLAIMER

This Technical Report is published as received and has not been edited by the Air Force Research Laboratory, Human Effectiveness Directorate.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

A handwritten signature in cursive script, appearing to read "Tom J. Moore Lt Col, Deputy".

THOMAS J. MOORE, Chief  
Biodynamics and Biocommunications Division  
Crew Systems Directorate  
Armstrong Laboratory

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0 188), Washington, DC 20503

1. AGENCY USE ONLY (Leave Blank)

2. REPORT DATE  
March 1991

3. REPORT TYPE AND DATES COVERED  
  
Final - 20 Jun 1989-18 March 1991

4. TITLE AND SUBTITLE  
National Aerospace Plane Special Study On Crew Escape Phase IV Final Report  
Volume II

5. FUNDING NUMBERS

Contract: F33657-86-C-2127  
PE: 62202F  
PR: 7231  
TA: 723131  
WU: 72313110

6. AUTHOR(S)

R. E. Zegler  
A. Bermudez

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

North American Aircraft Division  
Rockwell International Corporation  
P. O. Box 92098  
Los Angeles CA 90009

8. PERFORMING ORGANIZATION  
REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Armstrong Laboratory, Crew Systems Directorate  
Human Systems Center  
Air Force Materiel Command  
Wright-Patterson AFB OH 45433-7008

10. SPONSORING/MONITORING  
AGENCY REPORT NUMBER

AAMRL-TR-90-092 Volume II

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution is authorized to U. S. Government Agencies and their contractors; critical technology; July 1990.  
Other requests for this document shall be referred to AL/CFBE, 2800 Q Street, Wright-Patterson AFB OH 45433-7901

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The National AeroSpace Plane (NASP) Special Study on Crew Escape Phase IV has completed feasibility studies and analysis on a new escape system concept for single-stage-to-orbit flight vehicles. The concept, called the Hybrid Separable Forebody, employs an aerodynamically stable forebody which separates from the vehicle using a passive-active separation system (failure initiated, or crew initiated). The forebody provides safe crew descent to an altitude and velocity regime where crew ejection using conventional ejection seats is possible. Early conceptual design was completed under Phases I & III of the study. Additional feasibility analysis and design has been completed under Phase IV. Based upon these analyses and design studies three preferred systems have been defined. These are a Mach 20.0 system covering a large portion of the NASP flight envelope, and two Mach 6.0 systems covering critical flight test events. In addition to these concepts, a set of tools and technologies has been established which can be used for continued NASP escape system development, as well as for follow-on hypervelocity and other high performance vehicle programs. These tools and technologies include a flight phase/failure mode matrix hazard analysis method, a 6 Degree-of-Freedom (DOF) trajectory analysis program with drogue parachute and ballute modeling capability, a separation dynamics analysis code, a number of stability and control methods and systems installations, and a considerable array of separation system technologies.

14. SUBJECT TERMS

Hypersonic escape, escape concepts, forebody escape, flight vehicle separation, forebody flight dynamics, forebody stability, biodynamics acceleration, biothermal hazard, pressure suit burn protection

15. NUMBER OF PAGES

253

16. PRICE CODE

17. SECURITY CLASSIFICATION  
OF REPORT

Unclassified

18. SECURITY CLASSIFICATION  
OF THIS PAGE

Unclassified

19. SECURITY CLASSIFICATION  
OF ABSTRACT

Unclassified

10. LIMITATION OF ABSTRACT  
SAR



THIS PAGE INTENTIONALLY LEFT BLANK

## EXECUTIVE SUMMARY

Airbreathing, hypersonic aircraft offer the potential for extraordinarily enlarged flight envelopes which will range from greater than Mach 6 cruise on up to Mach 25 for Single Stage to Orbit. No previously fielded escape system has covered such a wide flight regime and this poses a challenge for providing escape coverage for operational military and experimental aircraft. The problem is exacerbated by the extreme design constraints associated with such aircraft: the impacts of aerodynamic, propulsion, and aeroheating characteristics are more closely coupled and have less operational margins than in any other class of vehicle designed. Weight penalties are also extreme, especially if the vehicle must achieve Single Stage To Orbit.

These problems are extremely critical for the National AeroSpace Plane (NASP) program and the X-30. An entirely new type of propulsion system is being developed for an experimental aircraft which has as its stated goal achieving Single Stage To Orbit. These flight regimes have never been explored, manned or unmanned. Providing a survivable escape capability is a critical element of the development program's success. However, survivable escape cannot be purchased at the expense of jeopardizing vehicle performance goals through excessive weight or integration penalties; nor require an extremely large test program which financially jeopardizes overall program viability.

With these stated goals, Rockwell, in 1986 under Company provided funds, evaluated a broad range of historical escape options for potential updates with current technology for application on the X-30 and follow-on vehicles. Trade studies indicated that no historical system could provide the degree of coverage desired without unacceptable weight, integration, cost, or schedule risks. Rockwell then developed the concept of an inherently stable separable forebody capsule combined with high performance ejection seats to provide wide envelope coverage at minimal weight, development, integration, and test costs.

The concept, as originally conceived, was to provide a forebody capsule which would separate from the vehicle in the event of a catastrophic explosion. Since the forebody capsule was comprised of the full nose section of the flight vehicle, descent was to be inherently stable to a relatively low altitude, low speed flight regime where the crew could be extracted in a high performance ejection seat. This concept is desirable for a number of reasons. Separation was to be accomplished through the force from the explosion of on-board hydrogen (fuel). This eliminated the need for weighty separation propulsion and clearance systems. By using a conical forebody, weight penalties associated with an Orbital Maneuvering System (if orbital coverage is mandated) and an Attitude Control System are minimized. Much of the weight inherent in conventional capsules is necessary to provide survivable recovery; such items associated with crash attenuation, propulsion, and recovery chutes are eliminated with our concept. Additionally, recoverable capsules do not always provide a high level of survivability after ground impact. They frequently tumble leading to severe crew injury or death; whereas, modern high performance ejection seats, when optioned within their operational envelope, provide extremely high survivability. Furthermore, much of the design, analysis, and testing of the forebody capsule could be bootstrapped off of the existing X-30 development program. Expensive tests associated with capsule recovery, or completely independent aerodynamic and related analyses are not required.

Thus the hybrid escape system concept appeared to offer an ideal solution to the escape problem, drawing upon the best available from both the capsule and ejection seat technology base. Based upon our results, the Armstrong AeroMedical Research Laboratory has since funded Rockwell, as a Special Study under the NASP contract, to more fully explore this and other options for NASP, and eventually for application to derivative aircraft.

The first three Phases of the Special Study were completed in 1988. Phase I of the program defined hypersonic escape system requirements in much more detail than Rockwell had done under company funds. Based upon this, successive levels of escape system coverage were defined, which were thought to come with increasing costs. These levels were:

- 1) Ground Operations Only,
- 2) Ground through Mach 3,
- 3) Ground through Mach 5, and
- 4) Ground through orbital.

In Phase II, a total of twenty-one candidate escape systems were defined for evaluation at these levels of protection. At each level of protection, the systems were formally evaluated and down-selected to a preferred system for that level of protection. (Two systems were left in the evaluation for Ground through Mach 5 operations.) For Ground Operations Only a rapid egress system was selected. Ground through Mach 3 used a supersonic ejection seat such as an updated Rockwell HS-1A. For Ground through Mach 5, the hybrid separable forebody system was selected along with an alternate: encapsulated ejection seats. For Ground through Orbital, the hybrid separable forebody system (with an Orbital Maneuvering System for reentry) was selected. Finally, these five candidate systems were evaluated. The hybrid separable forebody system for ground through Mach 5 was selected as the overall preferred concept. (Orbital capability could be added, at a weight penalty, as a fall forward potential if later analyses suggested that orbital operations are riskier than originally indicated.)

In Phase III, the basic separable forebody concept was refined, and further analyzed. Such refinement included further requirements of separation systems and more detailed internal characteristics of the system. Analysis included studies of anticipated blast overpressure (due to hydrogen detonation) using a hydrocode modelling program and methods for attenuating blast overpressures. Stability analyses on the original and a derivative configuration (having a flared rear section) yielded encouraging results. Static and dynamic stability analyses indicated that inversion of the forebody for reentry was required to provide the desired lift characteristics; however no divergent modes were evident, and crew accelerations appeared survivable.

Based upon these results, AL/CFBE sponsored a follow-on Phase IV Crew Escape Special Study. This study, documented herein, has as its goals to analytically demonstrate the concepts feasibility using more detailed techniques, prior to required empirical testing, along with substantial design development based upon the analyses. Five tasks accomplish these goals (Task V is currently underway):

- I) Forebody and Flight Vehicle Initial Conditions;
- II) Forebody Design Refinement;
- III) Forebody and Flight Vehicle Separation;
- IV) Forebody Flight Dynamics; and
- V) Seat/Forebody Ejection Interaction.

A brief summary of the work which was completed under Tasks I through V follows. (In this summary Task II will be presented after Task IV, since it is based on Tasks I, III and IV. In the detailed task reporting following the summary, results are presented in the order of the tasks with Task V reported in Appendix A.)

It is important to note that the work presented herein defines not only a specific well-studied solution for providing wide envelope hypersonic escape; but defines a basic methodological approach, along with a set of supporting tools to develop other escape systems which rely upon a forward capsule. In that sense, the program has provided both the basis for survivable X-30 escape, and the technology and tool knowledge base to support any number of potential NASP Derived Vehicle (NDV) escape systems.

**Flight Phase/Failure Mode Matrix, Vehicle Initial Conditions at Escape  
(Task I. See page 9 for detailed results.)**

Initial conditions at escape, along with types, severity, and likelihood of emergency conditions is a primary driver for escape system design. Task I of the study reexamined these issues in much greater detail than had been done in the first three Phases of the study, incorporating more recent NASP design data. A set of flight phases was defined which covered all planned X-30 test missions, including envelope expansion. Additionally, failure modes which might be experienced in these flight phases were defined to include both general types of failures associated with all aircraft systems, as well as those associated with the unique aspects of hypersonic flight and vehicles.

A tailored application of MIL-STD-882B was then applied to the failure modes within each flight phase to determine the severity of the potential failure, and its likelihood. These together determined a Hazard Risk Index, which essentially provides guidance as to whether or not to "cover" the hazard with some type of compensatory mechanism (such as escape.) Also as part of this assessment, potential means to counter each emergency were defined.

Worst case vehicle initial conditions at escape were also determined. These conditions were determined through modelling a loss of vehicle control failure caused by hard-over rudder/elevon failure. Optioning forebody escape at these initial conditions would require the largest Attitude Control and Stabilization System. Analyses of these worst case conditions then drove later analysis of the separation dynamics, and was the basis for sizing on-board Attitude Control and Stabilization Systems to provide survivable capsule trajectories.

**Forebody and Flight Vehicle Separation  
(Task III. See page 48 for detailed results.)**

There were two primary objectives for Task III, analyze the effects of aftbody proximity aerodynamics and blast overpressure on forebody separation and trajectory, and further develop a viable forebody separation mechanism.

In order to determine the effects of blast overpressure and interference aerodynamic on the forebody during and immediately after separation, a new computer code had to be developed. The new code, Forebody Aerodynamic Separation Trajectory (FAST) is based on existing flight and test data derived from missile/warhead and space vehicle/external tank separations. For consistency with NASP and NDV applications, emphasis was place on modeling conical shapes ranging from 5° to 10°. With this data a 6 Degree-Of-Freedom (DOF) trajectory simulation was modified to include aftbody interference effects and blast wave effects. The final code has a self-generating aerodynamic database which covers Mach number ranges of 20.0 to 0.6 for normal or blunted cones of 5° to 10°. Mass properties of the forebody can be varied; specific, more detailed aerodynamic characteristics of the forebody (from simple conical shapes) can be included if desired. Blast overpressures of varying sizes can also be modeled.

Following code development, Rockwell applied the code to a generic 7° cone, to establish free flight (no interference) trajectories, then adding aftbody interference, and finally aftbody interference with a representative blast wave overpressure. These analyses were run at three different initial velocities: Mach 20, 6, and 1.5, at both nominal and adverse initial conditions. (The adverse initial conditions were defined in Task I as catastrophic control system failure resulting in hard-over rudder and stuck elevon.) Results of these eighteen cases were compared to determine if successful separation is achievable in light of the external influences and initial conditions, and to determine what, if any, special stability augmentation systems were required.

Results of these analyses indicated that interference aerodynamic effects decrease with increasing Mach number. Fore- aftbody shock interactions are

significant at Mach 5 and decrease at higher velocities. Crew accelerations are aggravated at the low Mach numbers; however no divergent roll, pitch, or yaw modes were found. Because of the accelerations on the crew, it was determined that some type of stability augmentation device would have to be implemented within the first five second of separations (e.g., attitude control system jets).

Blast wave effects were negligible. However, we did not parametrically vary the size of the blast modeled but selected what we (and outside government consultants) thought was a reasonable energy level ( $5.54 \times 10^6$  N-m). However, there is much uncertainty associated with the size of the blast wave, which Special Study program resources did not allow us to investigate. In future analyses this aspect of the separation should be further investigated to insure that structural components are properly sized, and to establish the limits of our conclusions regarding blast wave effects on trajectory.

The second major objective associated with Task III was to establish a preliminary separation system design based on examination and detailed evaluation of a wide range of candidate designs. Rockwell did this through an iterative process of concept definitions, expert evaluations, designs refinement, preferred concept selections, and airframe integration studies.

Separations system concepts considered relied upon mechanical, pyrotechnic, or structural geometry modification. Key issues used in establishing the feasibility of each separation system design concept were: ability to provide a rapid structural break, vehicle structural integrity, reliability, maintainability requirements, weight impacts, and development risks. Additionally, because of the novel structural concepts being used on the NASP, four basic vehicle structural concepts had to be accounted for in the design of the separation systems: Hot Structure, Fully Monocoque; Hot Structure, Semi-Monocoque; Thermally Protected Structure, Fully Monocoque; and Thermally Protected Structure, Semi-Monocoque. Hot structure is located on the vehicle mold line and subject to the high thermal loads associated with hypersonic flight. Thermally protected structure is located under the external mold line, protected by insulation and/or heat shields. Fully Monocoque Structure is a thin shell, load bearing arrangement which uses minimal substructure to support loads. Semi-monocoque structure uses internal substructure (such as longerons and frames). Local load concentrations would be associated with the arrangement of the substructure.

Many different separation system concepts were designed and evaluated, and broken into three general classes: passive (wherein a hydrogen explosion blast overpressure directly provides the force for separation), active (wherein separation is initiated by crew or VMS and carried out by mechanical or pyrotechnic means), and passive-active (which includes both types of separation). The active system finally selected uses a floating shaped charge (pyrotechnic) located circumferentially about the fuel tank at the separation plane. Thermal isolation is provided to prevent convective heating. The preferred passive system uses a pressure baffle located at the separation plane which would concentrate blast overpressure, at that point, associated with a hydrogen detonation. The vehicle structure located in front of the pressure baffle is reinforced to eliminate airframe fracture propagation at that point in the event of an explosion. (It should be noted that this passive system is designed to provide separation only in the case of a large catastrophic blast overpressure propagating from the tank to the forebody. No inherent weaknesses or adverse load concentrations are associated with the design. For other types of stresses and loads, the probability of structural failure at the separation plane should be no greater than other nearby structure.) The final evaluation of the systems indicated that a combined passive-active system is the most desirable; hence, we combined the preferred passive with the preferred active for this system.

**Forebody Flight Dynamics**  
(Task IV. See page 71 for detailed results.)

Having established initial conditions (Task I) and explored expected fore- and aftbody interference effect during and immediately following separation, Task IV had as its goal assessment of the forebody free flight dynamics, including static and dynamic stability from Mach 20.0 through Mach 0.6. Two basic variants on the forebody were analyzed. Configuration refinement 1 used the Special Study Phase III extended length forebody, updated with recent NASP design trends. This configuration had approximately a 60% CG, based on structure and flight test equipment packaging. Configuration 1 used an Attitude Control System to provide the required stability for survivable flight. The roll angle was varied during the return trajectory, (using the ACS thrusters) to minimize trajectory time and provide safe recovery.

Configuration refinement 2 was approximately 45" shorter than configuration refinement 1. The structural arrangement of this configuration required less stringent assumptions about equipment packaging in order to get the required CG. Configuration refinement 2 used an Inflatable Decelerator System (IDS) in order to provide desirable aerodynamic characteristics (positive lift over drag ratio), inversion was not required. Inflated, the IDS provides a rigid aerosurface which can be tailored for the specific aerodynamics and stability requirements. A minimal ACS system (much smaller than for Configuration refinement 1) was required.

Analyses performed on the configurations included static stability analyses to determine the aerodynamic coefficients required for the 6 DOF trajectory analysis. Static margins for Machs 20.0 through 0.6 were determined, along with Lift-to-Drag (L/D) ratios and trim angle of attack ( $\alpha$ ). Dynamic stability derivatives for the configurations were also determined over the Mach range. Techniques used to perform the analyses included Aerodynamic Preliminary Analysis Program II (APAS II) runs and DATCOM calculations. Additional required calculations were based on the Unified Distributed Panel Program (UDP) and Hypersonic Arbitrary Body Program (HABP).

Static stability, and associated characteristics were similar for the two forebody configurations showing stability throughout the Mach range analyzed. Additionally, as mentioned above, trajectory analyses were performed on configuration refinement 2 with the aerosurface concept (IDS) installed. This required some modification of the configuration itself to provide the required IDS installation and aerodynamic characteristics. This tailored configuration refinement 2 (with the IDS) showed good static stability and was used in further trajectory analyses. (Configuration refinement 2, without the IDS, was briefly analyzed in one of the trajectory analysis cases; however, it was dynamically unstable and further study of configuration refinement 2, without the IDS, was terminated.)

A series of trajectory analyses were run on each forebody configuration to determine the dynamic stability of the configurations and determine minimal stability and control requirements based upon the initial conditions determined under Task I. Analyses included assessment of the bioaccelerations acting on the crew to ensure that no deleterious acceleration modes were experienced. Additionally, a drogue parachute analysis subroutine was implemented in the trajectory analysis program to assess low speed stability enhancements offered by a drogue parachute.

The basic trajectory analyses run were post separation using a 2-body 6 DOF program called CETAP (Crew Escape Trajectory Analysis Program.) The program was developed under the Special Study and is based upon validated Rockwell code used to model separation of the Space Shuttle from its external fuel tank. CETAP analyses were run for all configurations tested from Mach 20.0 through Mach 0.6.

A relatively comprehensive test matrix of CETAP analyses were run. Cases were run at Machs 20.0, 6.0, 3.0, and 1.5 to simulate catastrophic failures in various flight regimes. Initial conditions for the runs were varied to include straight and level flight and failure initial conditions derived from Task I. The effects of various control and stabilization devices (for the appropriate configuration refinements as described above) were then modeled. This included inverting the forebody about its velocity vector (inverted or heads-down flight) to get the desired positive Lift-to-Drag ratio (L/D), use of a drogue parachute, use of a ballute, and use of the IDS described above. This lead to a total of twelve detailed analysis cases.

Results clearly demonstrated the need for additional control and stability devices to provide survivable escape. The forebody, without any controls, essentially "dived" into the atmosphere building excessive dynamic pressure (Q bar) to 5,000 psf within the first 45 second of flight (from Mach 20). The assumed structural limit of the forebody is 2500 psf. The forebody also experience uncontrolled tumbling. The test matrix examined various types of control and stabilization. Two methods were deemed particularly desirable. One, using the longer forebody variant (configuration refinement 1) rotated the forebody lift vector about the velocity vector between 80° and 180° (semi-inverted flight) to provide safe efficient descent from high Mach flight regimes. As speed decreased below Mach 5.0, however, instabilities surfaced which were countered with a drogue parachute model. These analyses were done at various initial velocities with essentially the same conclusions. Control requirements were derived from these analyses which sized the forebody design refinements described below.

The second method deemed feasible was to use the IDS aerosurface device on the shortened forebody (configuration refinement 2). These analyses demonstrated that stable heads-up descent was possible; however an Attitude Control System would still be required to offset worst case initial conditions. Note though that the IDS/shortened forebody configuration did not require the use of a drogue for low speed stability.

Bioaccelerations associated with the preferred configurations during descent raised some concern over crew injury risk. Oscillatory profiles were found for the Gy and Gz axes. The amplitudes for the profiles were low in magnitude and frequency, rapidly damped, and not considered life threatening. Analysis performed at AL/CFBE has indicated, however, that some of the Gz profiles were unacceptable. This analysis is reported as preliminary and is continuing.

The Gx accelerations were not oscillatory, but did have a sustained negative component resulting from either drogue shock, the IDS and forebody drag (depending upon the configuration). Combining this -Gx component with the Gy and Gz profiles could result in relative body motion and mispositioning during ejection, both leading to increased modes of crew injury. The severity of these effects can be reduced by tailoring stability and control systems to increase profile damping, and by providing supplemental crew restraint systems. The effects of these multi-axis accelerations should be further investigated along with the methods for reducing severity (especially for crew positioning at ejection).

#### Forebody Design Refinement (Task II. See page 22 for detailed results.)

The objectives of Task II were to update forebody configurations and establish their mass properties, define and size stability and control systems as required based upon the results of Task IV, and integrate forebody configurations with the stability and control systems and preferred separation system defined in Task III. The forebody design refinement task was performed concurrently with other tasks as required data was available. The end products of the task are the preferred escape system concepts based upon all of the results of the other three

tasks. As such, these results are presented here in the Executive Summary as a succinct summary of the end technical products from Tasks I, III and IV.

Initial effort for the task was to refine the forebody capsule designs based on recent Rockwell X-30 design efforts. Outer mold lines (from a Rockwell X-30 configuration) were maintained, while inner equipment packaging and forebody length were driven by Special Study requirements. A primary requirement (from Phase III) was to maintain a forebody CG of 60% or less to insure adequate aerodynamic static stability. Additionally, the internal geometry located the crew member (design eye) as close as possible to the CG in order to minimize the effect of forebody oscillations about the CG on the crew. Internal packaging of flight equipment, distance from most likely location of fuel detonation, estimated flight stability, location of the crew, and location of the forward landing gear within the forebody, combined with the requirement to maintain 60% or less CG then determined the length of the forebody capsule, and thus the separation plane.

Two configurations were established for study. Configuration refinement 1 was 680" in length. CG varied from 60% to 58.2% depending on the amount of expendables on board. The Design Eye position is at 432" (from the tip of the vehicle) with the 60% CG location being nearby at 408.03".

Configuration refinement 2 was a shorter version of configuration refinement 1. This configuration allowed a less restrictive internal packaging of flight equipment to maintain required CG; and thus might be considered more generic. Configuration refinement 2 is 635" in length with a CG at 355.2" (approximately 55% with a full load of expendables.) This CG is somewhat further from the crew design eye.

In Task IV analyses, configuration refinement 2 was found to be dynamically unstable. Sizing an ACS to compensate for this instability would have been prohibitively heavy. However, by tailoring the aerodynamic characteristics of configuration refinement 2 with an inflatable static aerosurface (the IDS) stable descent was possible. Thus two viable configurations were defined configuration refinement 1 and configuration refinement 2 with the IDS. Stability and control systems required for each of the viable configurations are described below.

Stability and control systems considered included Attitude Control Systems (ACS), drogue parachutes, ballutes, and the IDS. The ACS, a system of carefully placed and controlled thrusters, provides the most precise and adaptive method of control. It is capable of providing the required semi-inverted flight for configuration refinement 1, and can provide damping torque required to counter an adverse roll onset rate imparted by the failure initial conditions at escape for both configurations (estimated in Task IV to be 1500 ft-lbs.)

For low speed stability, drogue parachutes were evaluated for use on configuration refinement 1. Drogue chutes are well understood and can provide low speed stability while reducing critical sink rate near the time of ejection, and thus increase the time the forebody is in the safe ejection envelope.

Both ballutes and the IDS (for configuration refinement 2) were investigated. The ballute allowed for heads up flight, but required additional roll stabilization and low speed stability augmentation (a drogue chute). The IDS is a device which attaches around the circumference of the aft separation plane changing the aerodynamic surface configuration (when inflated) of the forebody. RAM air is used to inflate the device, which becomes quite rigid. (A back up system can be provided for inflation if necessary.) The IDS system allowed for heads up with minimal additional roll stabilization. No additional low speed stabilization was required.

Multiple ACS system concepts were defined to meet the control and stabilization requirements. The two major variants were a three-axis system (roll, pitch, and



yaw of the forebody) and a single axis system, both controlling roll about the forebody velocity vector. The single axis system used a canted roll thruster scheme to roll about the velocity vector, as opposed to full three axis roll control of the forebody oriented about the body axis system. The single axis roll scheme eliminated roll thruster induced perturbations in vehicle trim, and thus, eliminated the need for compensating pitch and yaw thrust. This combined with re-sizing and re-definition of the system resulted in a substantial savings in weight for the single axis system as compared to the three axis system while still providing required control.

The refined system uses hydrazine as the propellant with back-pressurization being provided by an inert gas (helium). Hydrazine was selected based upon its superior thrust to volume performance. However, hydrazine is an extremely toxic substance and will require special handling and design of the system. (This has been safely done on other systems and is therefore considered acceptable.) Eight thrusters are included in the system.

For configuration refinement 1, the system was sized to provide full suborbital (defined as through Mach 20.0) and minimal critical event coverage (defined as through Mach 6.0). Critical events are defined as propulsion mode changes and other critical flight test events which cannot be gradually approached. (The specific Mach number which covers all critical events will depend on the specific configuration and flight test plan, and will likely vary somewhat from Mach 6.0.) The Mach 20.0 semi-inverted ACS system (configuration refinement 1) weighed 354.7 lbs. The down-sized Mach 6.0 semi-inverted ACS system weighed 163.9 lbs.

For configuration refinement 2 with the IDS, a minimal amount of roll control is required for damping both the adverse roll onset rate, and slight roll instabilities encountered during descent. As a result, the ACS system is considerably smaller. The Mach 20.0 system weighed 92.2 lbs, and the Mach 6.0 System weighed 86.8 lbs. Essentially the roll damping requirements are very similar, and thus only small weight penalties are required with the IDS system to provide full suborbital coverage (as compared to critical event coverage.) However, it should be noted that the IDS technology has more risk associated with it than other more conventional systems used for semi-inverted flight.

A drogue chute was sized and installed for configuration refinement 1 to provide the required low speed stability. The 15 foot drogue is composed of high strength Kevlar and can be deployed up to dynamic pressures of 2500 psf and Mach 4.0. The installed weight of this system is approximately 120.0 lbs.

The IDS system for configuration refinement 2, reduces the required size of the ACS system and negates the need for a drogue chute for low speed stability. The IDS system sized for the configuration provided a slightly positive lift-to-drag ratio, trimming the forebody at a slightly positive angle of attack. The IDS was sized to minimize safe return trajectory time; however, it can be sized to provide a specific cross range and down range capability. The IDS would be composed of Nextel jacketed Kevlar which can withstand temperatures up to 2200°F. Inflation is with ram air scoops with dry nitrogen providing a backup capability. The installed weight of the system is approximately 110.5 lbs, with a required volume of 2.6 cubic feet.

Finally, the preferred passive-active separation system was installed on each of the forebodies. As described above, separation would be passively performed by the blast overpressure by use of a pressure baffle, with tank reinforcement in the area in front of the baffle. This would concentrate the loads of a blast wave to separate at the desired plane. (However, no stress risers or other structural anomalies are associated with this arrangement. No additional failure modes are induced by such a passive separation system.) The active portion of the system is composed of a floating linear shape charge slightly forward of the pressure baffle. This would cause separation upon crew or system initiation, or could be used as a post passive separation "clean up" system to insure a smooth

separation plane. The installed weight of the passive active separation system is estimated to be about 170 lbs.

#### Preferred System Summary

To summarize, based upon extensive feasibility analyses and design studies, we have defined three preferred systems. Each of the systems can provide survivable escape within the constraints imposed by the NASP program. The systems are:

- 1) Mach 20.0 escape using heads up descent with the IDS/ACS combination,
- 2) Mach 6.0 escape using heads up descent with the IDS/ACS combination, and
- 3) Mach 6.0 escape using semi-inverted flight with the ACS/drogue chute combination.

The Mach 20.0 preferred system is based on a 500" forebody configuration (configuration refinement 2) which uses the described passive-active separation system. An IDS provides a safe heads-up descent trajectory and low speed stability. A minimal roll control ACS system provides roll damping from adverse initial conditions at escape, and roll stability during descent. The total installed weight of the system is estimated at 372.7 lbs. A Mach 20.0 system without the IDS (based on configuration refinement 1 with a Mach 20.0 sized ACS system for semi-inverted flight) was rejected as being prohibitively heavy.

Two Mach 6.0 systems covering critical flight test events were selected, based on each the configuration refinements. The system based on configuration refinement 2 using the IDS/ACS combination is similar to the Mach 20 system described above. Slight differences in ACS propellant are realized due to the shorter total descent duration from Mach 6.0 as compared to Mach 20. The total system weight is estimated at 367.3 lbs, 5.4 pounds lighter than the Mach 20 system.

The second Mach 6.0 system uses an ACS system installed on configuration refinement 1 to provide damping of adverse initial conditions; and to maintain roll control to produce semi-inverted flight required for a safe descent trajectory. The same passive active separation system used in the other two preferred systems is used. A drogue chute is required for low speed stability. The total system weight for this configuration is 453.9 lbs.

Given that there is a negligible weight difference between the Mach 20.0 and Mach 6.0 systems using the IDS, the choice for further development is between the lighter weight Mach 20.0 system using the IDS and the Mach 6.0 system which relies on a larger ACS system and the drogue chute. The IDS relies upon riskier technology, and thus the trade for further X-30 escape system development is weight and performance vs. moderate technology risk.

#### Ejection Seat/Forebody Interaction Dynamics Analysis (Task V. See Appendix A for detailed results.)

Initial effort for Task V was focused on developing the Seat/Forebody Interaction Dynamics (SFID) tool. This tool was built from an existing code originally used to analyze seat ejection from both the B-1B and the Space Shuttle. Used in conjunction with CETAP (used in Task IV), both programs proved to be successful in demonstrating seat and forebody trajectory dynamics during the ejection sequence. For consistency configuration refinement 1 using the bank angle command, ACS, and drogue parachute, and configuration refinement 2 adapted with the IDS were used in the analysis.

The SFID simulation matrix contained eight cases, each using initial conditions derived from the end conditions of CETAP simulations run in Task IV. Redundancies in the end conditions (such as in Mach, gamma, and relative velocity) were changed to broaden the scope of the Task V effort. Cases 1 - 4

simulated ejection from configuration refinement 1 which used purely inverted flight to maintain maximum lift. This was accomplished through a zero attitude error command (a restricted version of the bank angle command). Cases 5 - 8 simulated ejection from configuration refinement 2, which was held at a 0° bank, or purely heads up, using the same zero attitude error command.

Case-by-case results showed that seat ejection from both forebodies was feasible without adding to stability and control systems. Instead, the zero attitude error command (assumed generated by a 1,500 ft-lb ACS counter torque) was used to minimize forebody roll resulting from ejection catapult forces. From this, it was shown that both forebodies were adequately stable during the ejection sequence, and that no seat/forebody recontact problems were present. Moreover, the seats were reasonably stable within the 2 second simulation period (where recovery was assumed successful). Several of the seat trajectories indicated a full 360° roll during seat free flight which was attributed to the divergence rocket motor. Since the seats were assumed as off-the-shelf, no attempt was made to improve the seat stability models used in the analysis. In addition, results also showed that initial condition parameters such as Mach, altitude, and dynamic pressure could be extended to the edges of the assumed seat performance envelope without significant changes in forebody stability during ejection.

The acceleration profiles obtained in the Task V analysis were found to be consistent with previous analyses done for the B-1B. High amplitude oscillations found in the X-axis during relative seat/rail motion were identified, and concluded to be a product of the spring and damper coefficients used in the seat/rail model. Future refinement of this model was suggested for a higher fidelity account of seat/rail contact reactions. This refinement would result in overall lower magnitude Gx profiles.

Both the Gy and Gz axes were relatively uneventful with the exception of moderately high Gy shocks at drogue line stretch. The highest magnitude case, however, was not expected to pose a significant threat to crew safety. The Gz acceleration profiles were all very similar in time duration and total magnitude, and are well within the manufacturer's specification for typical (qualified) ACES II thrust acceleration. In all, none of the acceleration characteristics found in the SFID analysis posed a major concern for crew safety.

The biothermal hazard due to side-by-side seat ejection was also assessed in Task V. Results of a test conducted by NADC on the A6-F showed that the thermal environment generated by a side-by-side sequenced seat ejection from static ground conditions could be safely tolerated by the crew. The NASP ejection scenario (and seating geometry) was similar to the A-6F case, with the added benefit that the NASP crew was assumed donned in full pressure suit gear (while Navy test manikins were donned in summer flight gear). Based on comparison to the Navy A-6F tests, the thermal environment generated by the sequenced ejection of ACES II seats from the forebody was not considered as a significant threat to the crew.

## PREFACE

This report was prepared under Contract Number F33657-86-C-2127, Mod P00024, The National AeroSpace Plane (NASP) Special Study on Crew Escape Phase IV. Tasks I - IV commenced on 20 June 1989, with a completion date of 31 January 1990. Task V commenced on 1 February 1990 with a completion date of 30 June 1990. Preparation of this report revision commenced on 1 June 1990 for submission on 31 September 1990.

Analysis support for the Phase IV effort was provided by the following engineers from the North American Aircraft and Space Transportation Systems divisions of Rockwell International: D. Morgan, K. Ruggles and L. Fanning (trajectory and drogue parachute analysis); D. Olsen and C. Mc Kinney (aerodynamics); E. Minick and R. Shinkawa (mass properties); W. Pierson, C. Unger and J. Goad (stability and control); D. Weston (system safety), and C. Ackers (reliability). Separation dynamics code development and analyses was provided by A. Mansfield of Rockwell International's Space Transportation Systems Division in Huntsville, Alabama.

In addition to trajectory code and drogue chute analysis, D. Morgan was instrumental in establishing both the Crew Escape Trajectory Analysis Program (CETAP), and the Seat/Forebody Interaction Dynamics (SFID) code. His effort on upgrading and applying the SFID analysis tool was key to the successful completion of Task V.

Phase IV technical coordination, configuration systems integration and separation device preliminary design was provided by A. Bermudez of North American Aircraft.

Program Management was provided by Dr. G. Griffin of North American Aircraft.

The government contract monitor for this effort was L. Specker of AL/CFBE, WPAFB

## TABLE OF CONTENTS

|                                                                                                |       |
|------------------------------------------------------------------------------------------------|-------|
| EXECUTIVE SUMMARY . . . . .                                                                    | iii   |
| PREFACE . . . . .                                                                              | xiii  |
| TABLE OF CONTENTS . . . . .                                                                    | xv    |
| LIST OF FIGURES . . . . .                                                                      | xviii |
| LIST OF TABLES . . . . .                                                                       | xix   |
| INTRODUCTION . . . . .                                                                         | 1     |
| Background . . . . .                                                                           | 1     |
| Special Study on Crew Escape Program Summary . . . . .                                         | 1     |
| Phase I Summary . . . . .                                                                      | 2     |
| Phase II Summary . . . . .                                                                     | 2     |
| Phase III Summary . . . . .                                                                    | 3     |
| Summary and Conclusions . . . . .                                                              | 4     |
| Phase IV Problem . . . . .                                                                     | 4     |
| Objectives . . . . .                                                                           | 5     |
| Approach . . . . .                                                                             | 6     |
| TECHNICAL RESULTS OF PHASE IV . . . . .                                                        | 9     |
| Task I - Flight Phase/Failure Mode Matrix, Vehicle Initial<br>Conditions at Escape . . . . .   | 9     |
| Objectives . . . . .                                                                           | 9     |
| Technical Approach . . . . .                                                                   | 9     |
| Results of Flight Phase/Failure Mode Matrix, Vehicle<br>Initial Conditions at Escape . . . . . | 10    |
| Flight Phase/Failure Mode Matrix . . . . .                                                     | 10    |
| Vehicle Flight Phases . . . . .                                                                | 10    |
| Vehicle Failure Modes . . . . .                                                                | 11    |
| Tailored MIL-STD-882B Assessment . . . . .                                                     | 12    |
| Means to Counter Emergencies . . . . .                                                         | 14    |
| Seat/Forebody Performance . . . . .                                                            | 15    |
| Rapid Egress/Ground Egress . . . . .                                                           | 16    |
| On-Board Mission Abort . . . . .                                                               | 16    |
| Design Controls to Reduce Hazard Risk . . . . .                                                | 17    |
| Completed Matrix Structure . . . . .                                                           | 17    |
| Vehicle Initial Conditions at Escape . . . . .                                                 | 22    |
| Task II - Forebody Design Refinement . . . . .                                                 | 22    |
| Objectives . . . . .                                                                           | 22    |
| Technical Approach . . . . .                                                                   | 23    |
| Results of Forebody Configuration Refinement . . . . .                                         | 23    |
| Configuration Refinement 1 . . . . .                                                           | 24    |
| Configuration Refinement 2 . . . . .                                                           | 27    |
| Stability and Control Systems Requirements and<br>Definition . . . . .                         | 27    |
| Stability and Control Requirements . . . . .                                                   | 27    |
| Stability and Control Systems Considered . . . . .                                             | 29    |
| Stability and Control Systems Sizing and Installation . . . . .                                | 31    |
| Attitude Control System Sizing and Installation . . . . .                                      | 31    |
| Mach 20.0 Three - Axis Attitude Control System . . . . .                                       | 32    |
| Thrusters . . . . .                                                                            | 34    |
| Propellant Tank . . . . .                                                                      | 34    |
| Pressurant Tank . . . . .                                                                      | 35    |
| Refined Single - Axis Mach 20.0 Attitude<br>Control System . . . . .                           | 36    |
| Refined Single - Axis Mach 6.0 Attitude<br>Control System . . . . .                            | 37    |
| Mach 20.0 and 6.0 ACS Sizing for Heads Up<br>Flight . . . . .                                  | 39    |
| ACS Sizing and Installation Summary and<br>Conclusions . . . . .                               | 40    |
| Drogue Chute Sizing and Installation . . . . .                                                 | 42    |
| Inflatable Decelerator System Installation . . . . .                                           | 44    |

# TABLE OF CONTENTS (continued)

|                                                             |    |
|-------------------------------------------------------------|----|
| Separation System Installation . . . . .                    | 45 |
| Preferred Forebody Escape System Configurations . .         | 46 |
| Mach 20.0 Preferred Forebody Configuration .                | 46 |
| Mach 6.0 Preferred Forebody Configurations .                | 46 |
| Task III - Forebody and Flight Vehicle Separation . . . . . | 48 |
| Forebody and Flight Vehicle Separation Dynamics . . . . .   | 48 |
| Objectives . . . . .                                        | 48 |
| Technical Approach . . . . .                                | 48 |
| Results of the Separation Dynamics Analysis . . . . .       | 40 |
| Separation Dynamics Analysis Conclusions . . . . .          | 57 |
| Recommendations for Wind Tunnel Testing . . . . .           | 57 |
| Separation System Preliminary Design . . . . .              | 59 |
| Objectives . . . . .                                        | 59 |
| Technical Approach . . . . .                                | 59 |
| Results of the Separation Device Preliminary Design .       | 60 |
| Structural Requirements . . . . .                           | 60 |
| Systems Requirements . . . . .                              | 60 |
| Concept Development . . . . .                               | 60 |
| Preliminary Concept Evaluation . . . . .                    | 63 |
| Final Concept Evaluation . . . . .                          | 64 |
| Controlled Tank Detonation . . . . .                        | 64 |
| Linear Shape Charge on Primary Structure .                  | 64 |
| Floating Linear Shape Charge . . . . .                      | 65 |
| Pressure Diverting Cone . . . . .                           | 65 |
| Locking Pin Pressure Pan . . . . .                          | 65 |
| Hook Retention . . . . .                                    | 66 |
| Final Evaluation Results Summary . . . . .                  | 67 |
| Preferred Separation System . . . . .                       | 69 |
| Concept Development . . . . .                               | 69 |
| Rocket Propelled Option . . . . .                           | 70 |
| Task IV - Forebody Flight Dynamics . . . . .                | 71 |
| Objectives . . . . .                                        | 71 |
| Technical Approach . . . . .                                | 71 |
| Results of Forebody Flight Dynamics Analysis . . . . .      | 71 |
| Forebody Configuration Aerodynamic Analysis . . . . .       | 72 |
| Results for Configuration Refinement 1 . . . . .            | 72 |
| Results for Configuration Refinement 2 . . . . .            | 73 |
| Preliminary Results of the VSAERO . . . . .                 | 74 |
| Forebody Aerosurface Aerodynamic Analysis . . .             | 77 |
| Forebody Flight Trajectory Analysis . . . . .               | 77 |
| Trajectory Run Conditions . . . . .                         | 79 |
| CETAP Case Descriptions for Cases 1 - 12 . . .              | 80 |
| CETAP Case Description for Case 13 . . . . .                | 81 |
| Results of CETAP Mach 20.0 Trajectory Runs:                 |    |
| Cases 1 - 2 . . . . .                                       | 82 |
| Case 1: Mach 20.0, No Controls . . . . .                    | 82 |
| Case 2: Mach 20.0, Purely Inverted Flight                   | 83 |
| Conclusions of Cases 1 and 2 . . . . .                      | 84 |
| Stability and Control Augmentation . . . . .                | 84 |
| Results of CETAP Mach 20.0 Trajectory Runs:                 |    |
| Cases 3 - 5 . . . . .                                       | 85 |
| Case 3: Mach 20.0, Bank Angle Command .                     | 85 |
| Case 4: Mach 20.0, Bank Angle Command                       |    |
| and Droque Chute . . . . .                                  | 86 |
| Case 5: Mach 20.0, High Speed Ballute                       |    |
| Stabilization . . . . .                                     | 88 |
| Forebody Stability and Control Requirements .               | 90 |
| Results of CETAP Trajectory Runs: Cases 6-12 .              | 90 |

# TABLE OF CONTENTS (Continued)

|                                                                        |     |
|------------------------------------------------------------------------|-----|
| Cases 6 - 8: Machs 6.0, 3.0, and 1.5                                   |     |
| Bank Angle Command/Drogue Parachute                                    |     |
| Analysis Results . . . . .                                             | 90  |
| Case 9: Mach 20.0, Trajectory Run Results                              |     |
| Using the Inflatable Decelerator System                                | 94  |
| Cases 10 - 12: Machs 6.0, 3.0, and 1.5                                 |     |
| Inflatable Decelerator System Results                                  | 97  |
| Results of CETAP Analysis for Configuration                            |     |
| Refinement 2: Case 13 . . . . .                                        | 99  |
| Summary of Significant Results and Conclusions                         | 100 |
| SUMMARY OF PHASE IV EFFORT . . . . .                                   | 104 |
| BIBLIOGRAPHY . . . . .                                                 | 106 |
| APPENDIX A: Task V Ejection Seat/Forebody Interaction Dynamics         |     |
| Analysis . . . . .                                                     | 108 |
| APPENDIX B: Flight Phase/Failure Mode Matrix Individual Cases . . . .  | 229 |
| APPENDIX C: Aircraft Dynamic Simulation of Vehicle Loss of Control     |     |
| Failure . . . . .                                                      | 331 |
| APPENDIX D: Separation Dynamics Analysis Output Plots for Cases 1 - 18 | 357 |
| APPENDIX E: Aerodynamic Analysis Results . . . . .                     | 449 |
| APPENDIX F: Trajectory Analysis Output Plots for Cases 1 - 13 . . . .  | 492 |

# LIST OF FIGURES

| FIGURE |                                                                      | PAGE |
|--------|----------------------------------------------------------------------|------|
| 1      | Summary of Preferred Escape System Concepts . . . . .                | 3    |
| 2      | Phase IV Technical Tasks and Design Cycle 8 . . . . .                | 7    |
| 3      | Final Matrix Structure . . . . .                                     | 12   |
| 4      | Frequency of Occurrence per MIL - STD - 882B . . . . .               | 13   |
| 5      | Hazard Category per MIL - STD - 882B . . . . .                       | 13   |
| 6      | Hazard Risk Index Matrix . . . . .                                   | 14   |
| 7      | Special Study Assumed Seat / Forebody Envelopes . . . . .            | 15   |
| 8      | Completed Flight Phase / Failure Mode Matrix . . . . .               | 18   |
| 9      | Vehicle Loss of Control Failure Example . . . . .                    | 18   |
| 10     | Special Study Configuration Evolution . . . . .                      | 25   |
| 11     | Configuration Refinement 1 Layout . . . . .                          | 26   |
| 12     | Configuration Refinement 2 Layout . . . . .                          | 28   |
| 13     | Forebody Flight Dynamics Analysis Tasks . . . . .                    | 29   |
| 14     | Forebody General Stability and Control Requirements . . . . .        | 30   |
| 15     | Three - Axis Attitude Control System Schematic . . . . .             | 34   |
| 16     | Refined Single - Axis Attitude Control System Schematic . . . . .    | 38   |
| 17     | Heads Up Flight Attitude Control System Schematic . . . . .          | 40   |
| 18     | Three - Axis Attitude Control System Forebody Integration . . . . .  | 41   |
| 19     | Refined Attitude Control System Forebody Integration . . . . .       | 41   |
| 20     | Generic Drogue Parachute Installation . . . . .                      | 43   |
| 21     | Inflatable Decelerator System Installation . . . . .                 | 44   |
| 22     | Preferred Separation System Integration . . . . .                    | 45   |
| 23     | Preferred Mach 20.0 Forebody Configuration . . . . .                 | 47   |
| 24     | Preferred Mach 6.0 Forebody Configurations . . . . .                 | 47   |
| 25     | Case 1 Free Flight Results for Mach 1.5 Nominal Conditions . . . . . | 50   |
| 26     | Case 2 Interference Aero for Mach 1.5 Nominal Conditions . . . . .   | 51   |
| 27     | Case 4 Free Flight Results for Mach 1.5 Failure Conditions . . . . . | 52   |
| 28     | Case 5 Interference Aero for Mach 1.5 Failure Conditions . . . . .   | 52   |
| 29     | Cases 7 and 8 Results for Mach 6.0 Nominal Conditions . . . . .      | 53   |
| 30     | Cases 10 and 11 Results for Mach 6.0 Failure Conditions . . . . .    | 54   |
| 31     | Cases 13 and 14 Results for Mach 20.0 Nominal Conditions . . . . .   | 55   |
| 32     | Cases 16 and 18 Results for Mach 20.0 Failure Conditions . . . . .   | 56   |
| 32A    | Separation Dynamics Verification Road Map . . . . .                  | 58   |
| 32B    | Separation Dynamics Wind Tunnel Test Concept . . . . .               | 59   |
| 33     | Separation System Preliminary Design Approach . . . . .              | 59   |
| 34     | Cartridge Actuated Thruster Concepts . . . . .                       | 61   |
| 35     | Pyrotechnic Device Concepts . . . . .                                | 61   |
| 36     | Passive Separation Device Concepts . . . . .                         | 62   |
| 37     | Controlled Tank Detonation Concept . . . . .                         | 63   |
| 38     | Linear Shape Charge on Primary Structure . . . . .                   | 65   |
| 39     | Floating Linear Shape Charge Concept . . . . .                       | 65   |
| 40     | Pressure Diverting Cone Concept . . . . .                            | 66   |
| 41     | Pressure Pan Concept . . . . .                                       | 66   |
| 42     | Hook Retention Concept . . . . .                                     | 67   |
| 43     | Final Evaluation Results Summary . . . . .                           | 68   |
| 44     | Reinforced Tank, Pressure Baffle Separation Concept . . . . .        | 69   |
| 45     | Preferred Passive - Active Separation System . . . . .               | 70   |
| 46     | Separation Rocket Installation . . . . .                             | 71   |
| 47     | Configuration Refinement 1 Aerodynamics . . . . .                    | 73   |
| 48     | Configuration Refinement 2 Aerodynamics . . . . .                    | 74   |
| 49     | APAS II / VSAERO Lift and Pitch Comparisons . . . . .                | 75   |
| 50     | APAS II / VSAERO Drag Polar Comparisons . . . . .                    | 75   |
| 51     | Lateral VSAERO Data at 6.0 Degree Angle of Attack . . . . .          | 76   |
| 52     | APAS II / VSAERO Pitch Sweep at 5.0 Degree Side Slip . . . . .       | 76   |
| 53     | Inflatable Decelerator System Aerodynamic Model . . . . .            | 77   |
| 54     | Case 1 Mach 20.0 Free Flight Results . . . . .                       | 82   |
| 55     | Case 2 Mach 20.0 Purely Inverted Flight Results . . . . .            | 83   |
| 56     | Case 3 Mach 20.0 Bank Angle Command Control Results . . . . .        | 86   |
| 57     | Case 4 Mach 20.0 with Low Speed Drogue Parachute . . . . .           | 87   |



# LIST OF FIGURES

| FIGURE |                                                               | PAGE |
|--------|---------------------------------------------------------------|------|
| 58     | Case 4 Mach 20.0 Bioacceleration Data . . . . .               | 88   |
| 59     | Case 5 Mach 20.0 with High Speed Ballute . . . . .            | 89   |
| 60     | Forebody General Stability and Control Requirements . . . . . | 91   |
| 61     | Case 6 Mach 6.0 Bioacceleration Data . . . . .                | 93   |
| 62     | Case 7 Mach 3.0 Bioacceleration Data . . . . .                | 93   |
| 63     | Case 8 Mach 1.5 Bioacceleration Data . . . . .                | 94   |
| 64     | Case 9 Mach 20.0 Inflatable Decelerator System . . . . .      | 95   |
| 65     | Case 9 Mach 20.0 Bioacceleration Data . . . . .               | 96   |
| 66     | Case 10 Mach 6.0 Bioacceleration Data . . . . .               | 98   |
| 67     | Case 11 Mach 3.0 Bioacceleration Data . . . . .               | 98   |
| 68     | Case 12 Mach 1.5 Bioacceleration Data . . . . .               | 99   |
| 69     | Case 13 Configuration Refinement 2 Results . . . . .          | 100  |

# LIST OF TABLES

| TABLE |                                                                     | PAGE |
|-------|---------------------------------------------------------------------|------|
| 1     | Preliminary Vehicle Flight Phases . . . . .                         | 10   |
| 2     | Final Vehicle Flight Phases . . . . .                               | 10   |
| 3     | Flight Phase Envelope Proximity . . . . .                           | 11   |
| 4     | Preliminary Vehicle Failure Modes . . . . .                         | 12   |
| 5     | Final Vehicle Failure Modes . . . . .                               | 12   |
| 6     | Means to Counter Emergencies . . . . .                              | 14   |
| 7     | Critical Vehicle Parameters . . . . .                               | 22   |
| 8     | Vehicle Initial Conditions at Escape . . . . .                      | 23   |
| 9     | Attitude Control System Requirements . . . . .                      | 33   |
| 10    | Component Locations . . . . .                                       | 35   |
| 11    | Weight Statement . . . . .                                          | 36   |
| 12    | Weight Summary for the Refined Mach 20.0 ACS . . . . .              | 37   |
| 13    | Weight Summary for the Refined Mach 6.0 ACS . . . . .               | 39   |
| 14    | Weight Summary for the Machs 20.0 and 6.0 IDS/ACS Systems . . . . . | 40   |
| 15    | Separation Dynamics Test Case Matrix . . . . .                      | 49   |
| 16    | Inflatable Decelerator System Aerodynamic Data . . . . .            | 78   |
| 17    | List of CETAP Parameters . . . . .                                  | 78   |
| 18    | Vehicle Failure Initial Conditions at Escape . . . . .              | 80   |
| 19    | Test Cases 1 - 12 . . . . .                                         | 81   |

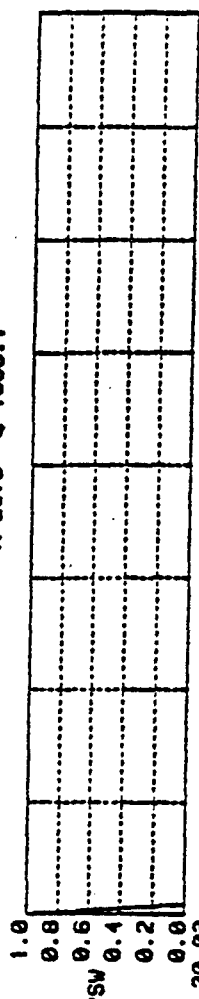
## APPENDIX C

### Aircraft Dynamic Simulation of Vehicle Loss of Control Failure

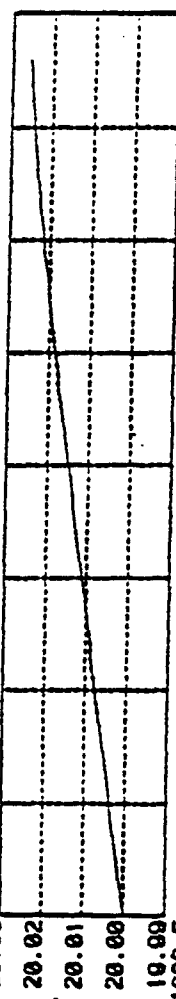
This appendix contains the plotted output of the Aircraft Dynamic Simulation runs of Task I for the loss of vehicle control failure condition. The failure simulated was a 20° hard-over rudder combined with a stuck elevon. The Mach number initial conditions run were 0.6, 1.5, 3.0, 6.0, and 20.0. The tabulated values on the left margin of the time histories indicate the parameter value at the start and end of the run, as well as the maximum and minimum value with the associated time of occurrence. Parameter labels monitored are presented below. Refer to Task I of this report for further information.

| ADS<br>Label | Definition                                | Units                |
|--------------|-------------------------------------------|----------------------|
| PSW          | pitch failure switch                      |                      |
| MACH NO      | Mach number                               | non dim              |
| Q DYNAM      | Dynamic pressure                          | lbs/sq ft            |
| ALTITUDE     | Altitude                                  | ft                   |
| NZ(G'S)      | normal acceleration                       | g's                  |
| ALPHA        | angle of attack                           | deg                  |
| P DOT        | Roll acceleration about principal X axis  | deg/sec <sup>2</sup> |
| Q DOT        | Pitch acceleration about principal Y axis | deg/sec <sup>2</sup> |
| R DOT        | Yaw acceleration about principal Z axis   | deg/sec <sup>2</sup> |
| DTEO         | Elevator deflection                       | deg                  |
| DTAOP        | Aileron deflection                        | deg                  |
| DVTL         | Rudder deflection                         | deg                  |
| PB           | Roll rate about X body axis               | deg/sec              |
| QB           | Roll rate about Y body axis               | deg/sec              |
| RB           | Roll rate about Z body axis               | deg/sec              |
| NX(G'S)      | Axial acceleration                        | g's                  |
| NY(G'S)      | Lateral acceleration                      | g's                  |
| BETA         | Angle of sideslip                         | deg                  |
| RSW          | Yaw failure switch                        |                      |
| DEDOT        | Elevator rate                             | deg/sec              |
| DADOT        | Aileron rate                              | deg/sec              |
| DRDOT        | Rudder rate                               | deg/sec              |
| HMR          | Right elevon hinge moment                 | in-lbs               |
| HML          | Left elevon hinge moment                  | in-lbs               |
| HMV          | Rudder hinge moment                       | in-lbs               |

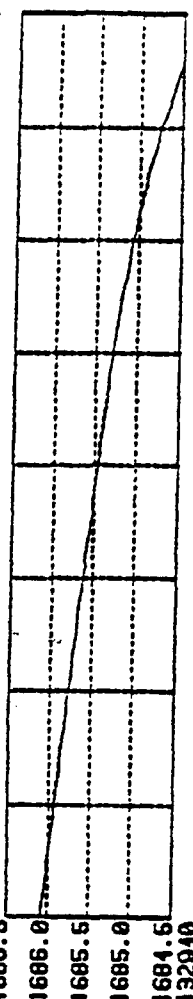
POWERED, CREW ESCAPE - STOP'S AT NZ(2.5,-1), NY(+1)  
H=20.0 Q=1686.1



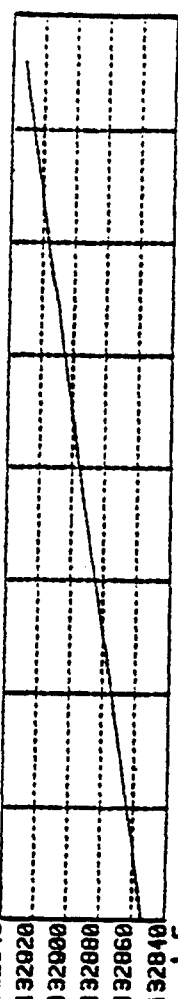
START  
FINAL  
MINIMUM  
MAXIMUM



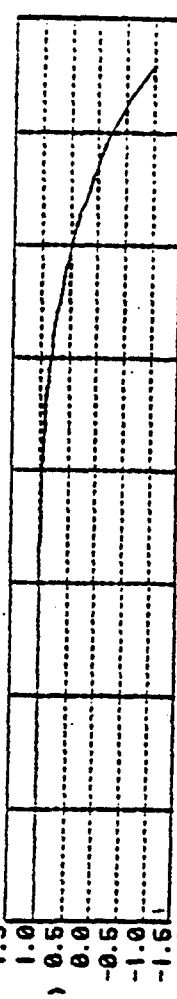
START  
FINAL  
MINIMUM  
MAXIMUM



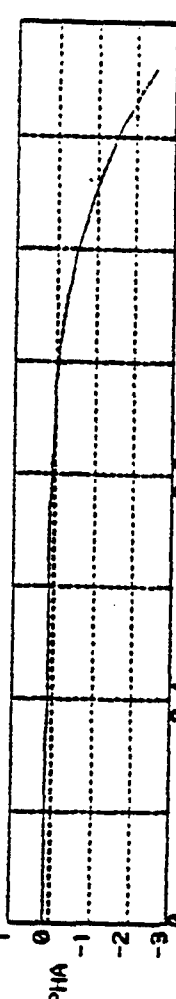
START  
FINAL  
MINIMUM  
MAXIMUM



START  
FINAL  
MINIMUM  
MAXIMUM



START  
FINAL  
MINIMUM  
MAXIMUM

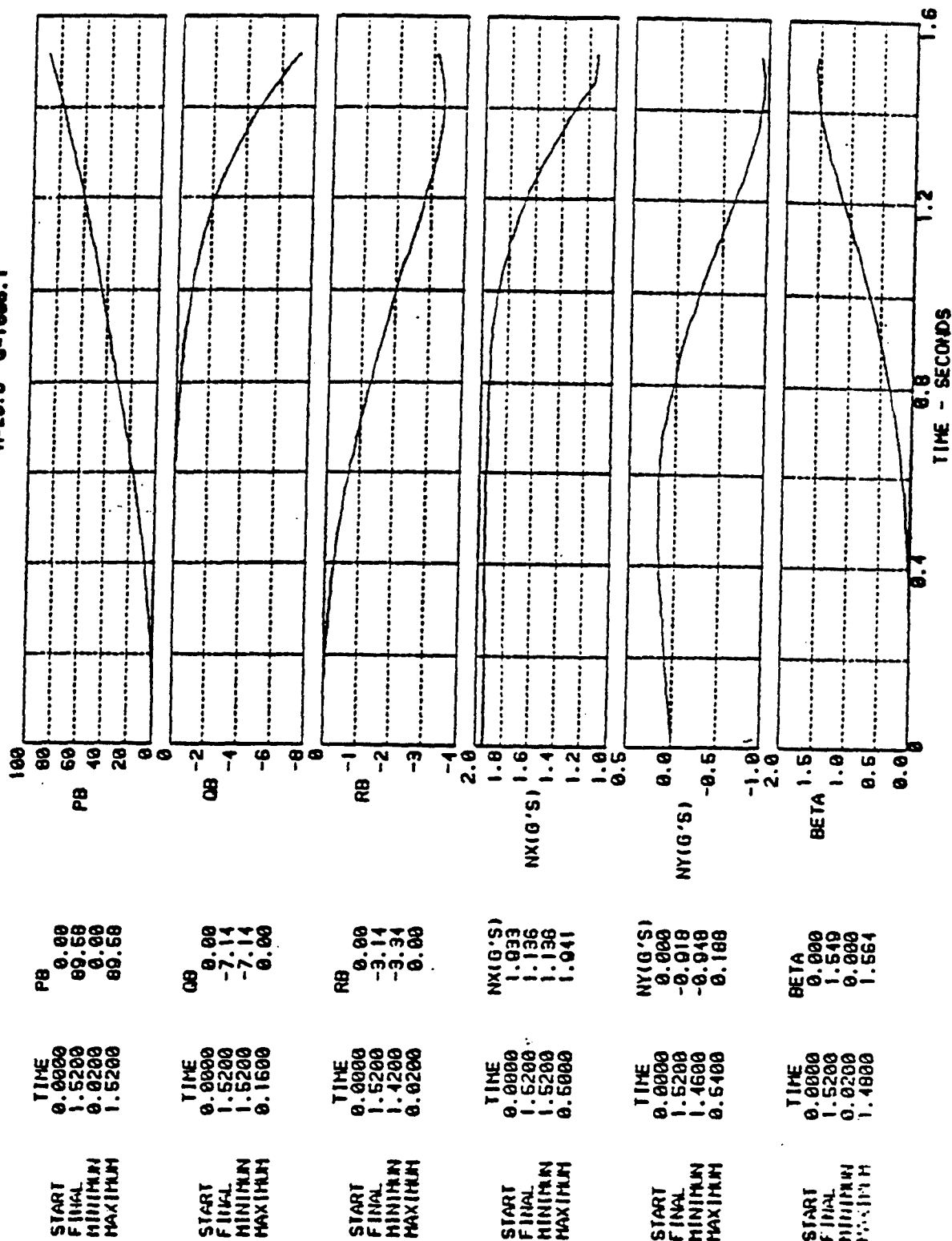


START  
FINAL  
MINIMUM  
MAXIMUM

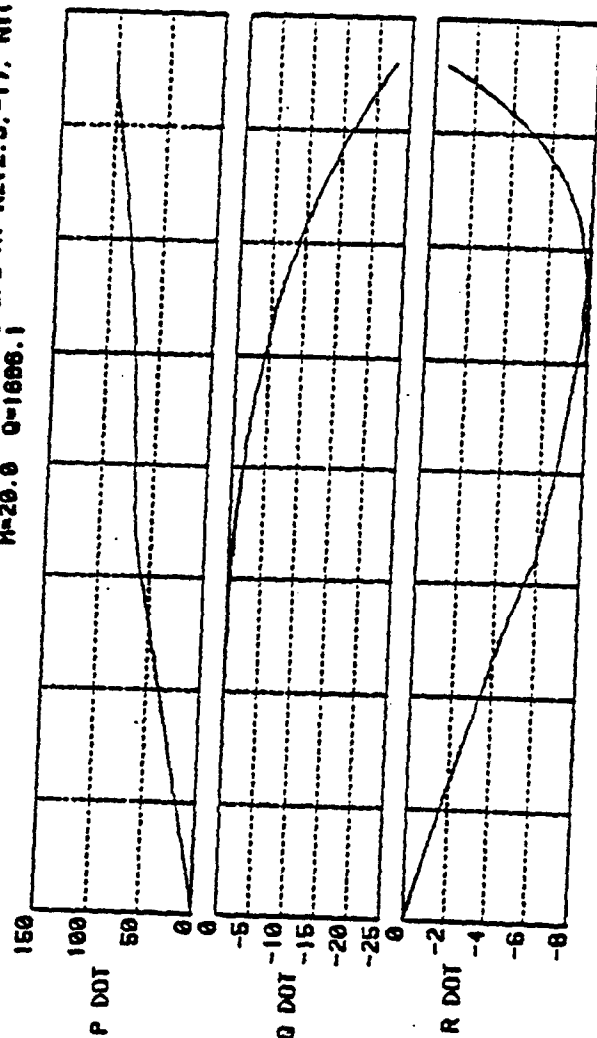
POWERED, CREW ESCAPE - STOPS AT NZ(2.5,-1), NY(+1)  
M=20.0 Q=1698.1

Mach 20.0

Q1



POWERED, CREW ESCAPE - STOPS AT NZ(2.5,-1), NY(+1)



P DOT  
0.00  
100.25  
0.00  
100.25

TIME  
0.0000  
1.5200  
0.0000  
1.5200

START  
FINAL  
MINIMUM  
MAXIMUM

Q DOT  
0.00  
-22.83  
-22.83  
0.00

TIME  
0.0000  
1.5200  
0.0000  
1.5200

START  
FINAL  
MINIMUM  
MAXIMUM

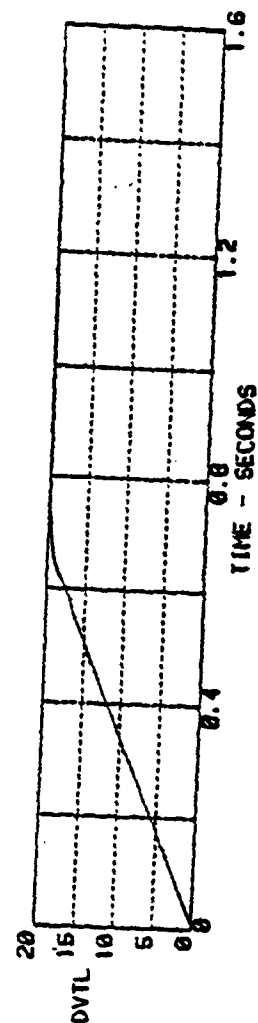
R DOT  
0.00  
-0.70  
-7.86  
0.00

TIME  
0.0000  
1.5200  
0.0000  
1.5200

START  
FINAL  
MINIMUM  
MAXIMUM

DTEO - -0.486314678E+01

DTAOP - 0



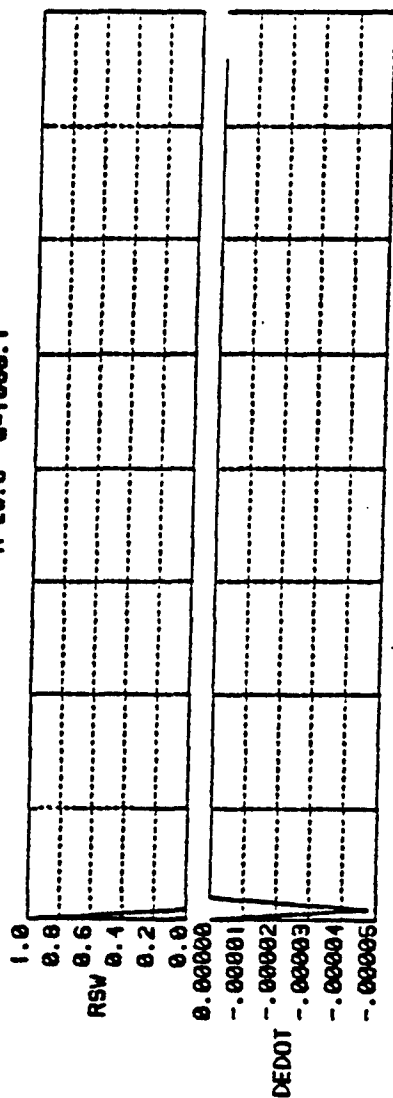
DVTL  
0.00  
20.00  
0.00  
20.00

TIME  
0.0000  
1.5200  
0.0000  
1.5200

START  
FINAL  
MINIMUM  
MAXIMUM

Mach 20.0

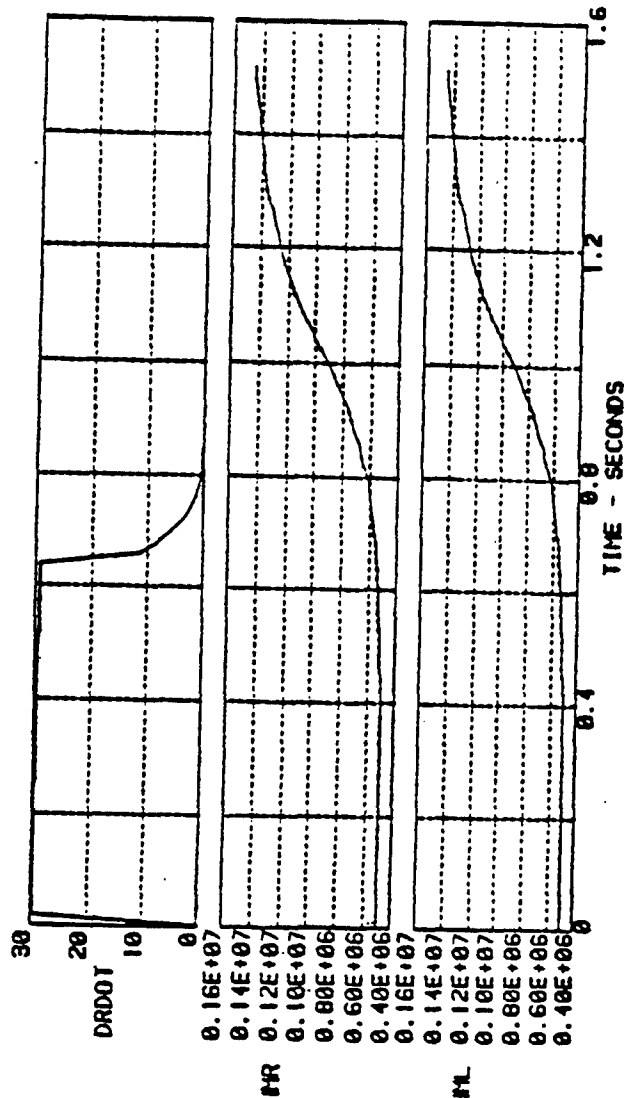
POWERED, CREW ESCAPE - STOPS AT NZ(2.5,-1), NY(+1)  
H=20.0 Q=1888.1



START 0.0000  
FINAL 1.5200  
MINIMUM 0.0200  
MAXIMUM 0.0000

ZE raised at 400E13/4361001  
START to 1.5200  
MINIMUM 0.0200  
MAXIMUM 0.0000

DEDOT = 0

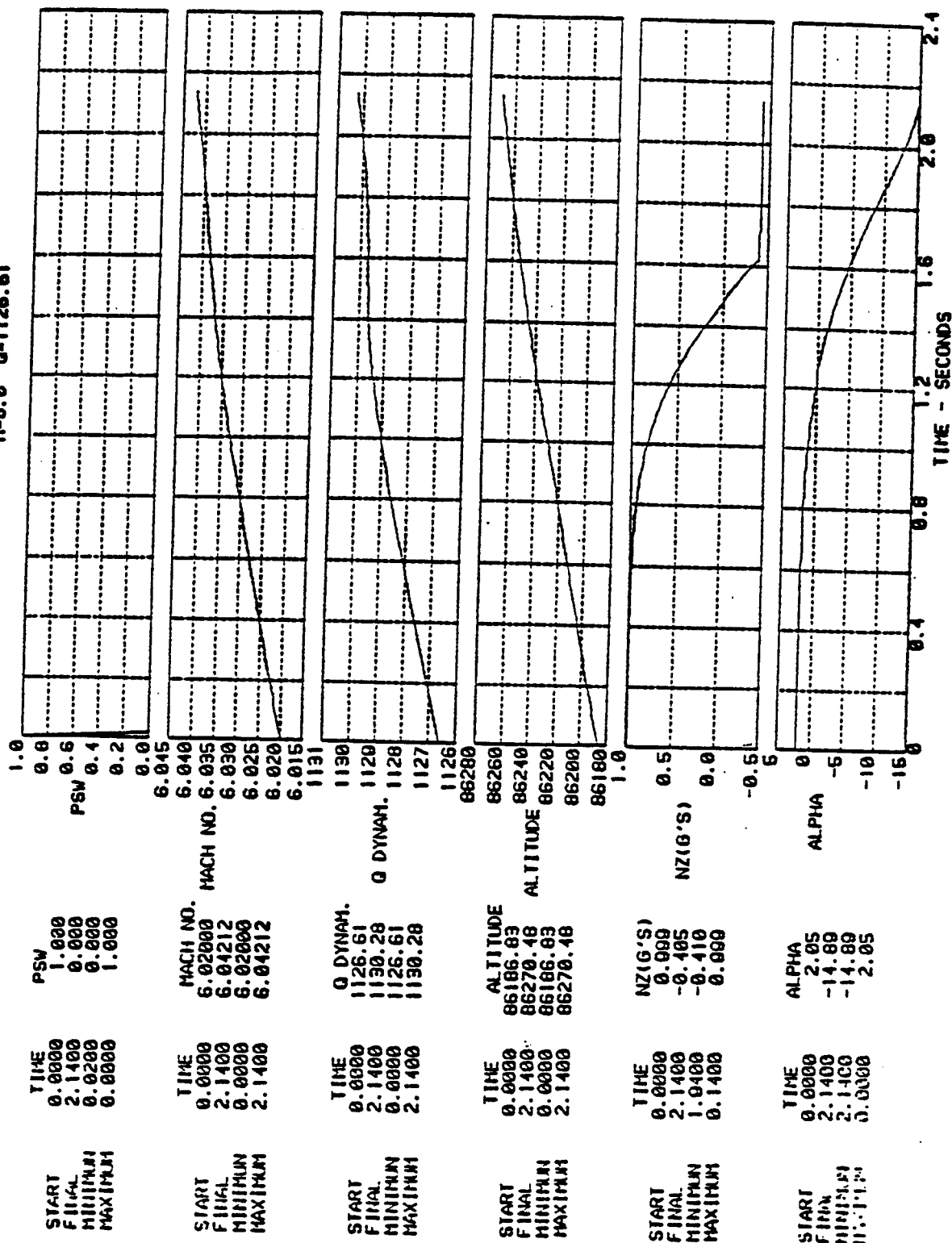


START 0.0000  
FINAL 1.5200  
MINIMUM 0.0200  
MAXIMUM 0.0000

START 0.0000  
FINAL 1.5200  
MINIMUM 0.0200  
MAXIMUM 0.0000

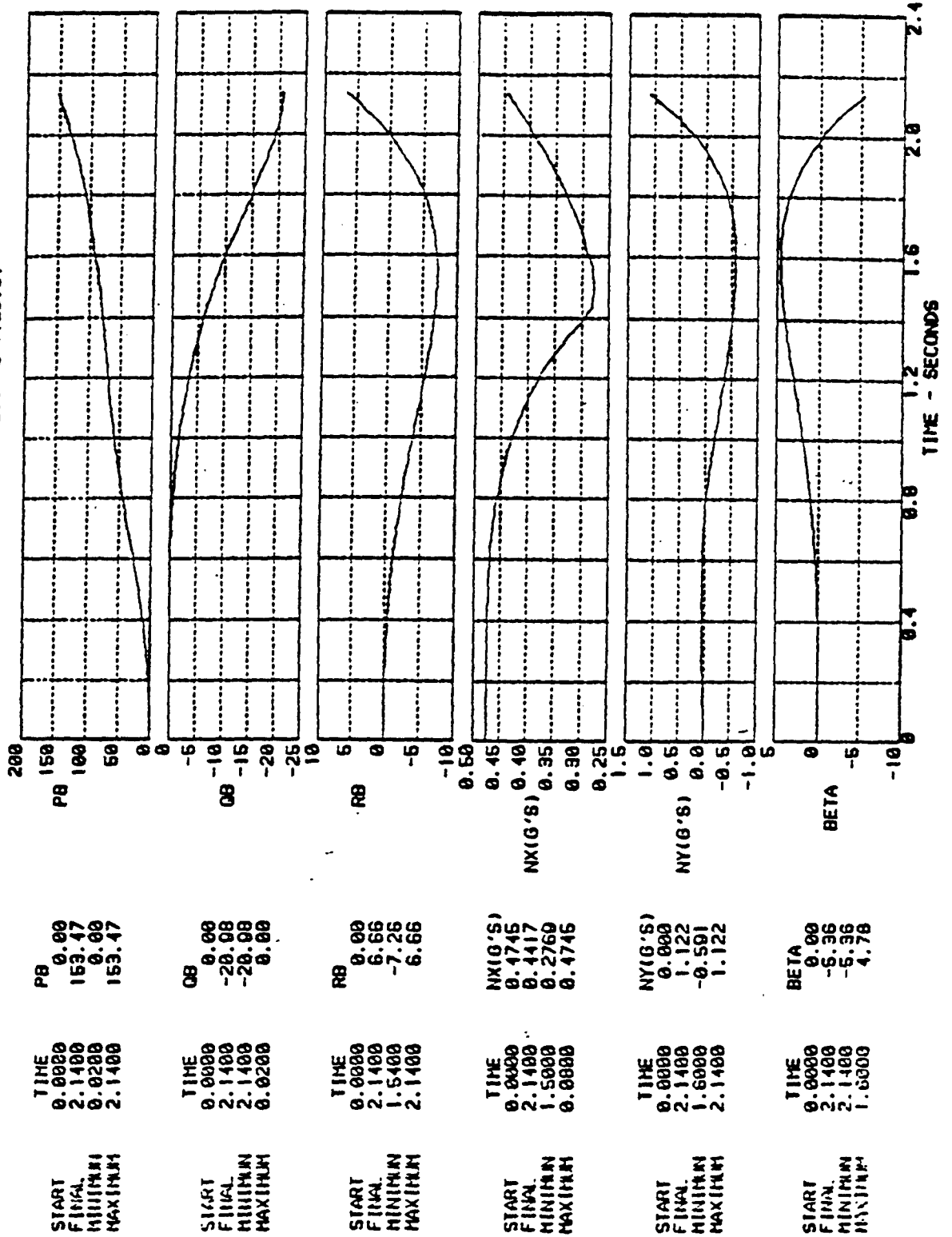
START 0.0000  
FINAL 1.5200  
MINIMUM 0.0200  
MAXIMUM 0.0000

POWERED, CREW ESCAPE - STOPS AT NZ(2.5,-1), NY(+1)  
M=6.0 Q=1126.61

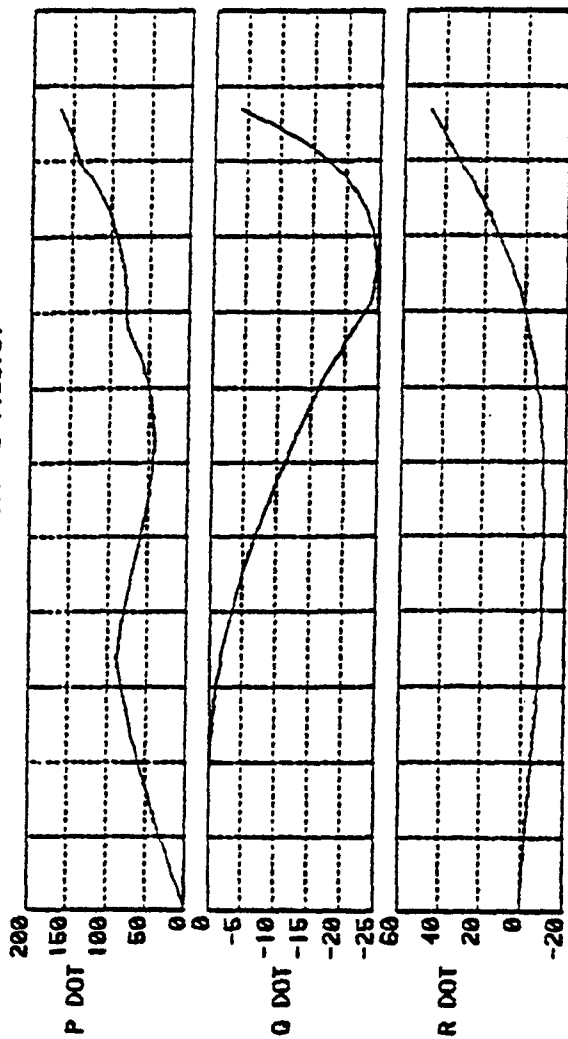




POWERED, CREW ESCAPE - STOPS AT NZ(2.5, -1), NY(+1)  
H=6.0 Q=1128.61



POWERED, CREW ESCAPE - STOPS AT NZ(2.5,-1), NY(+1)  
M=6.8 Q=1128.61



TIME  
0.0000  
2.1400  
0.0000  
2.1400

START  
FINAL  
MINIMUM  
MAXIMUM

P DOT  
0.00  
166.66  
0.00  
166.66

TIME  
0.0000  
2.1400  
1.7400  
0.0000

START  
FINAL  
MINIMUM  
MAXIMUM

Q DOT  
0.00  
-4.02  
-24.64  
0.00

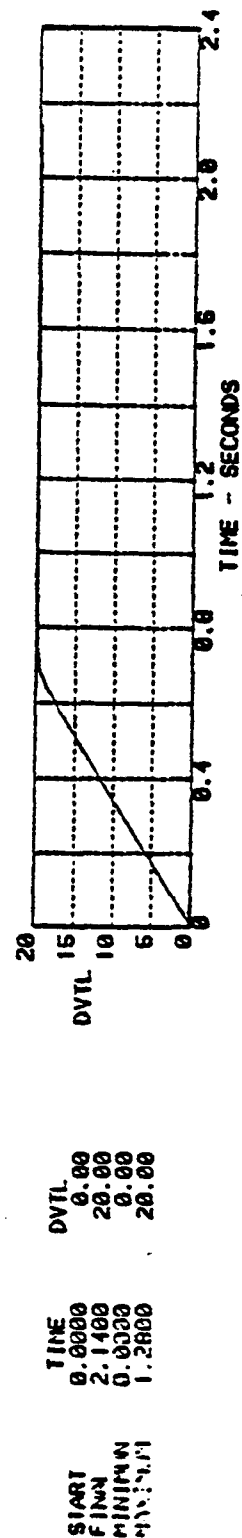
TIME  
0.0000  
2.1400  
1.0400  
2.1400

START  
FINAL  
MINIMUM  
MAXIMUM

R DOT  
0.00  
47.39  
-10.65  
47.39

DTEO = 7.36721

DTADP = 0



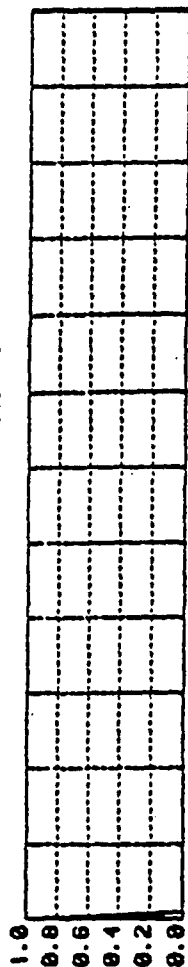
TIME  
0.0000  
2.1400  
0.0000  
1.2800

START  
FINAL  
MINIMUM  
MAXIMUM

DVTL  
0.00  
20.00  
0.00  
20.00

Mach 6.0

POWERED, CREW ESCAPE - STOPS AT NZ(2.5,-1), NY(+1)  
M=6.0 Q=128.0



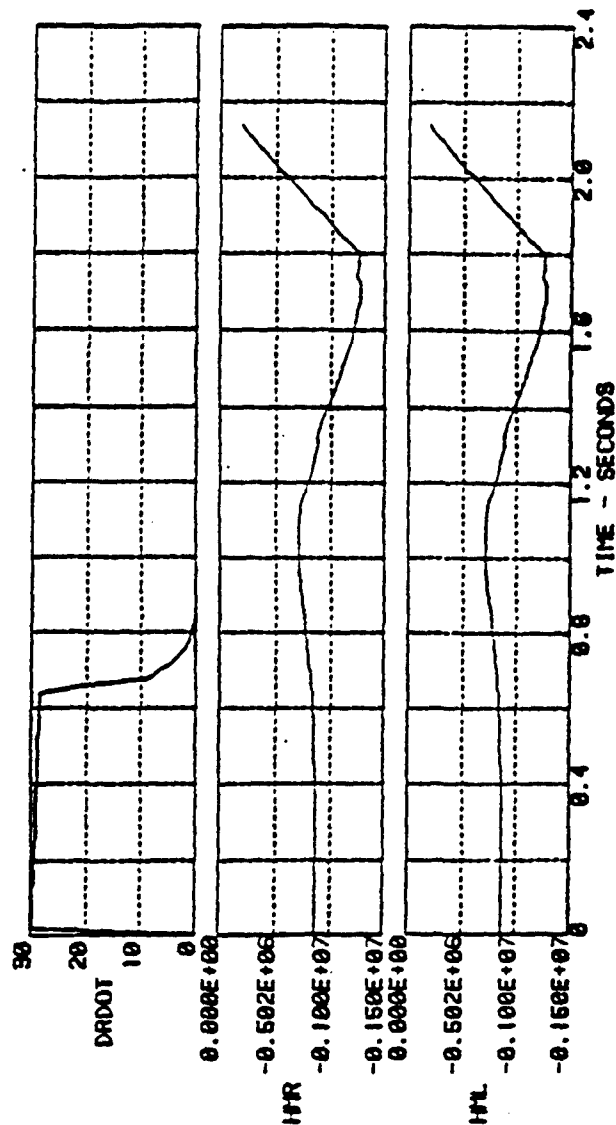
START  
FINAL  
MINIMUM  
MAXIMUM

TIME  
0.0000  
2.1400  
0.0200  
0.0000

RSW  
1.000  
0.000  
0.000  
1.000

DEDOT - 0

DADOT - 0



START  
FINAL  
MINIMUM  
MAXIMUM

TIME  
0.0000  
2.1400  
1.3000  
0.0200

DEDOT  
0.00  
0.00  
0.00  
30.00

START  
FINAL  
MINIMUM  
MAXIMUM

TIME  
0.0000  
2.1400  
1.7200  
2.1400

HFR  
-0.7804E+06  
-0.20044E+06  
-0.12858E+07  
-0.20044E+06

START  
FINAL  
MINIMUM  
MAXIMUM

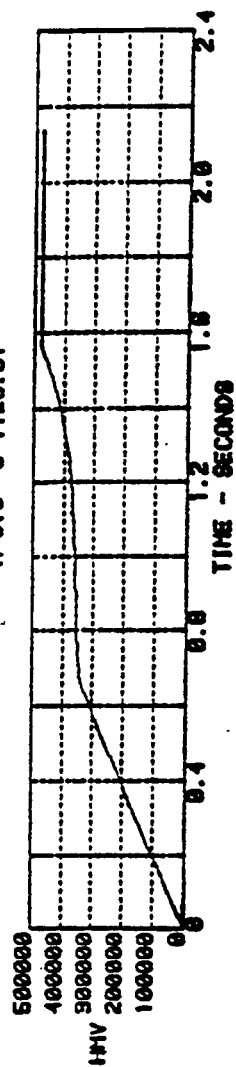
TIME  
0.0000  
2.1400  
1.7200  
2.1400

HPL  
-0.7804E+06  
-0.20044E+06  
-0.12858E+07  
-0.20044E+06

Mach 6.0

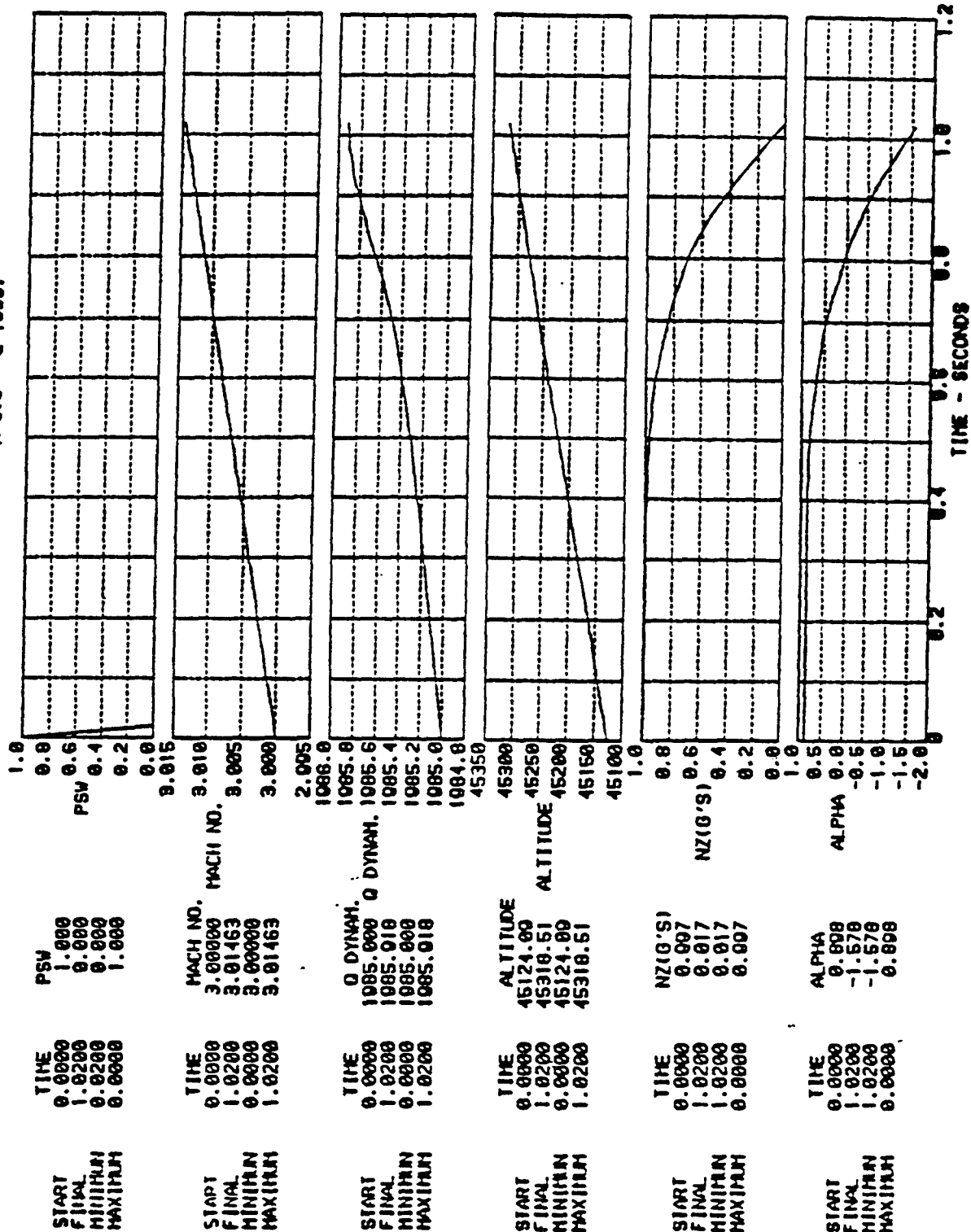
Mach 6.0

POWERED, CREW ESCAPE - STOPS AT NZ(2.5,-1), NY(+1)  
 H=6.0 Q=1128.61

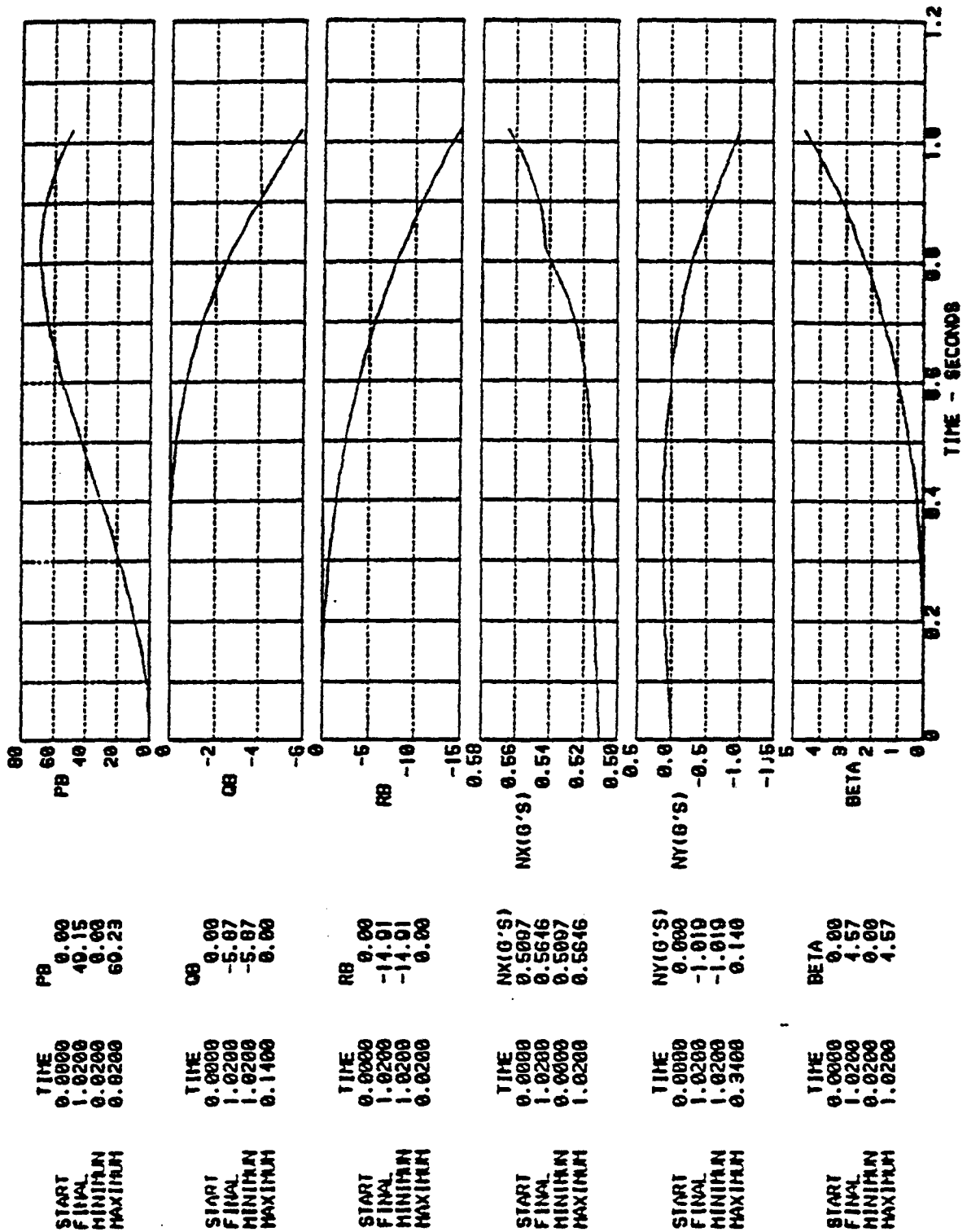


| START   | TIME   | HMV       |
|---------|--------|-----------|
| FINAL   | 0.0000 | 0.00      |
| MINIMUM | 2.1400 | 470371.37 |
| MAXIMUM | 0.0000 | 0.00      |
|         | 2.1400 | 470371.37 |

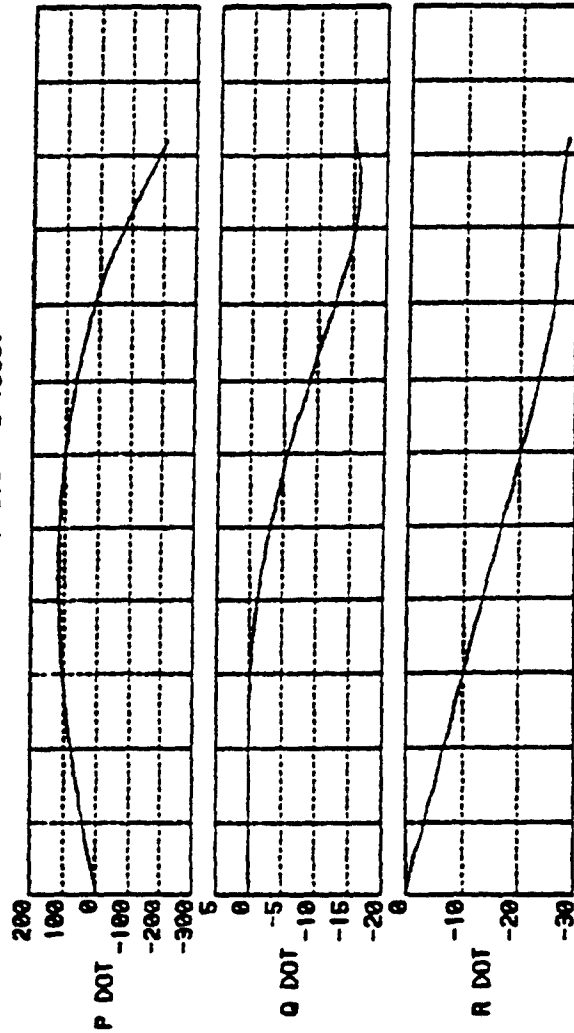
POWERED, CREW ESCAP- STOPS AT NZ(2.5,-1), NY(+1)  
H=3.0 Q=1085.



POWERED, CREW ESCAP - STOPS AT NZ(2.5, -1), NY(+1)  
M=3.0 Q=1085.

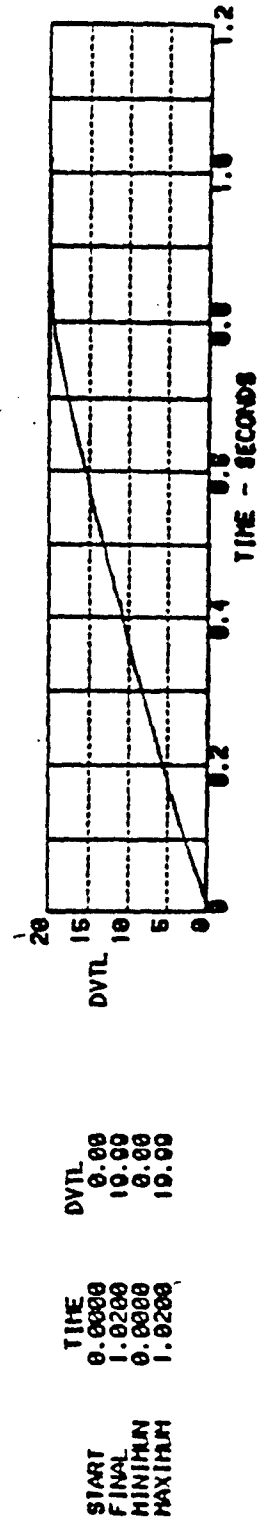


POWERED, CREW ESCAP- STOPS AT NZ(2.5,-1), NY(+1)  
H=9.0 Q=1005.

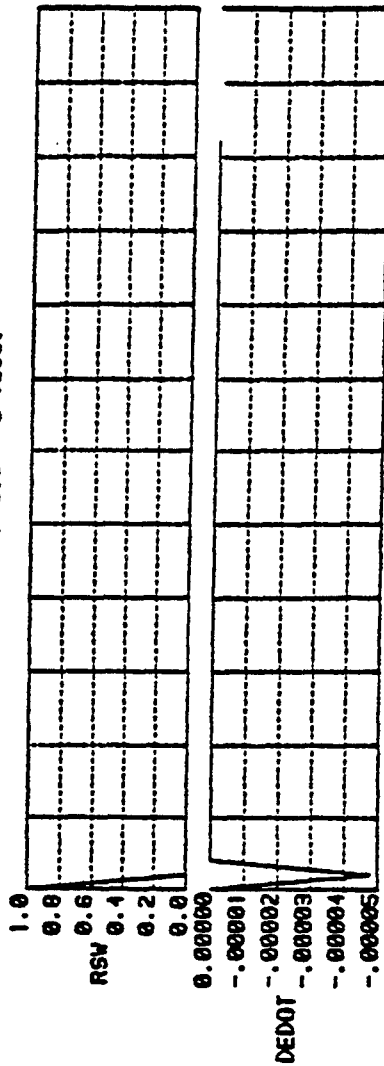


DTEO - -0.45565683E+01

DTADP - 0

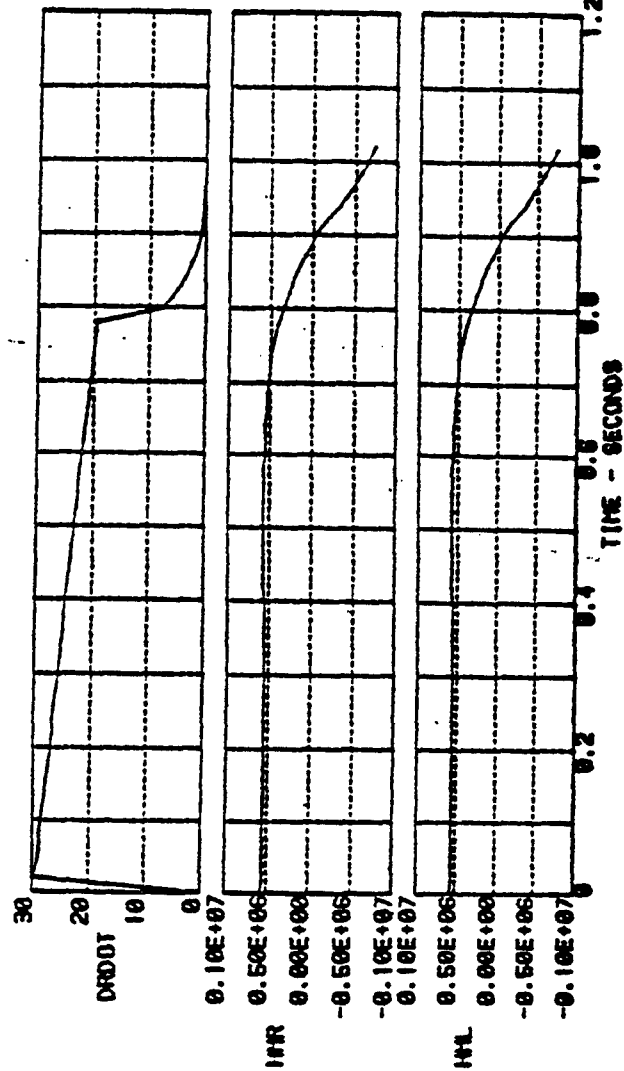


POWERED, CREW ESCAP- STOPS AT NZ(2.5,-1), NY(+,-1)  
M=3.0 Q=1005.



TIME 0.0000 1.000  
START 0.0000 0.000  
FINAL 0.0200 0.000  
MINIMUM 0.0000 1.000  
MAXIMUM 0.0000 0.000

DADOT - 0



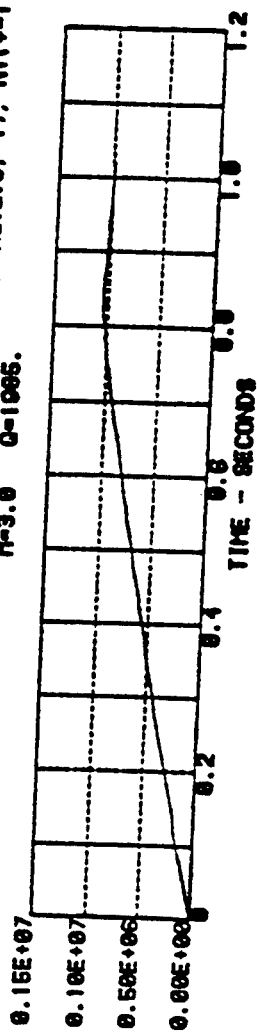
TIME 0.0000 0.00  
START 0.0000 0.11  
FINAL 0.0200 0.00  
MINIMUM 0.0000 30.00  
MAXIMUM 0.0200 0.00

TIME 0.0000,50063E+06  
START 0.0000,50063E+06  
FINAL 1.0200,-74401E+06  
MINIMUM 1.0200,-74401E+06  
MAXIMUM 0.5200,50368E+06

TIME 0.0000,50063E+06  
START 0.0000,50063E+06  
FINAL 1.0200,-74401E+06  
MINIMUM 1.0200,-74401E+06  
MAXIMUM 0.5200,50368E+06



POWERED, CREW ESCAP - STOPS AT NZ(2.5,-1), NY(+,-1)  
 H=3.0 Q=1005.



0.15E+07

0.10E+07

0.50E+06

0.00E+00

H=V

TIME - SECONDS

TIME H=V

0.0000.0000

1.0200.0760E+06

0.0000.0000

0.0200.1030E+07

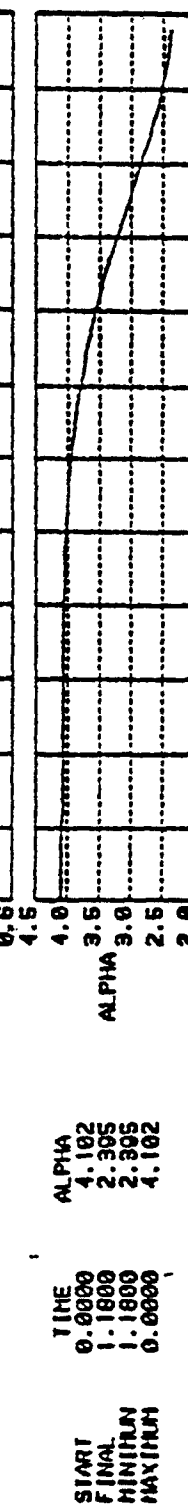
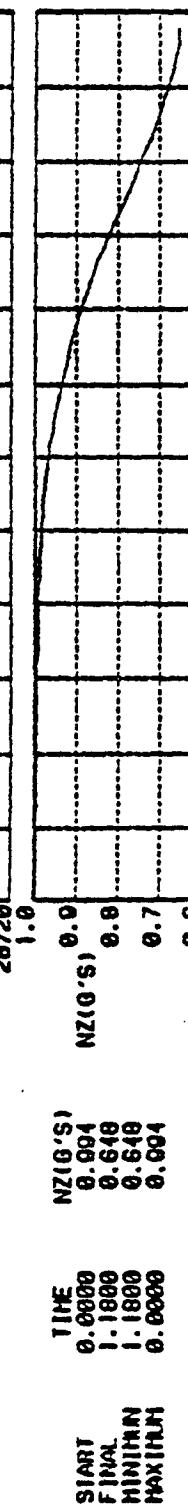
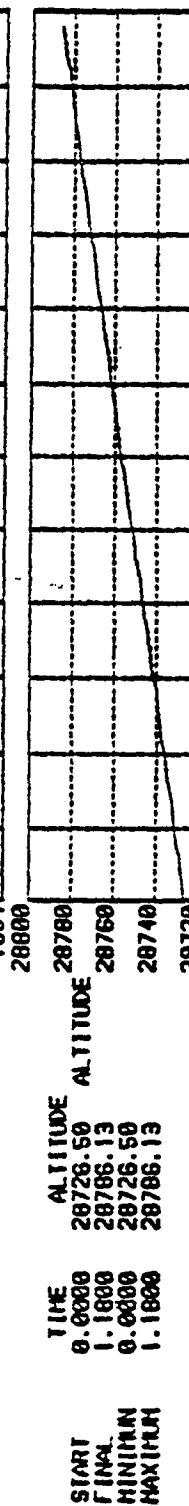
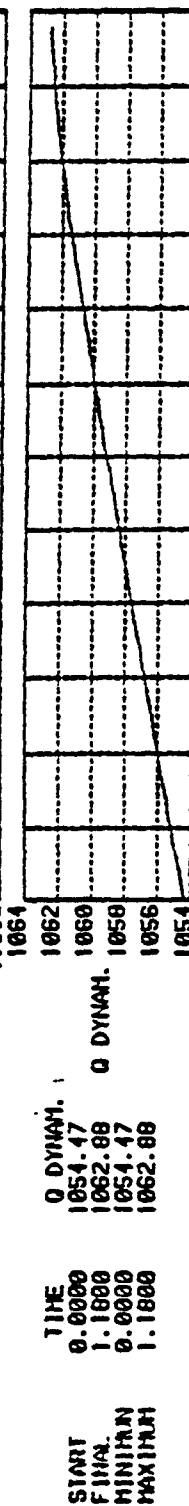
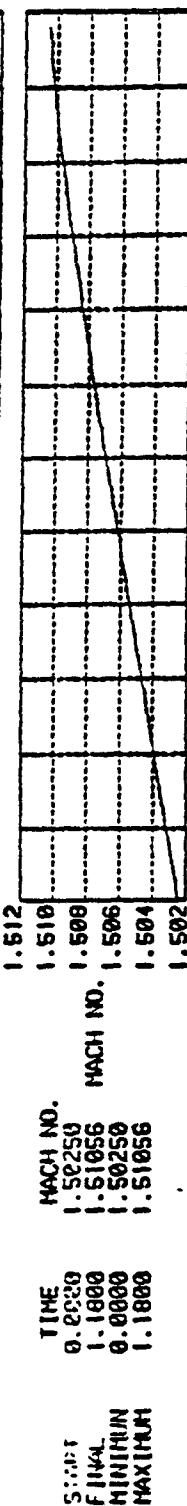
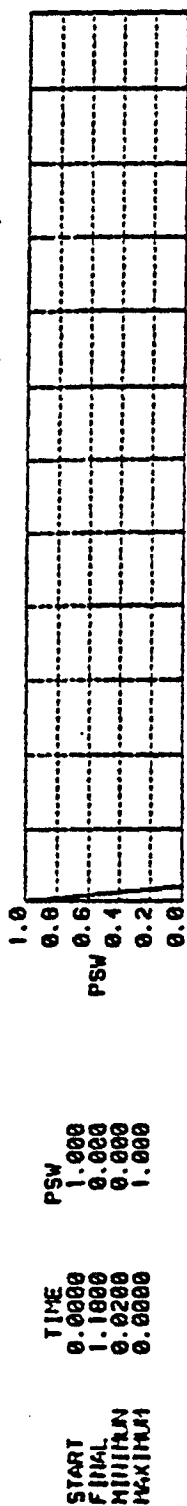
START

FINAL

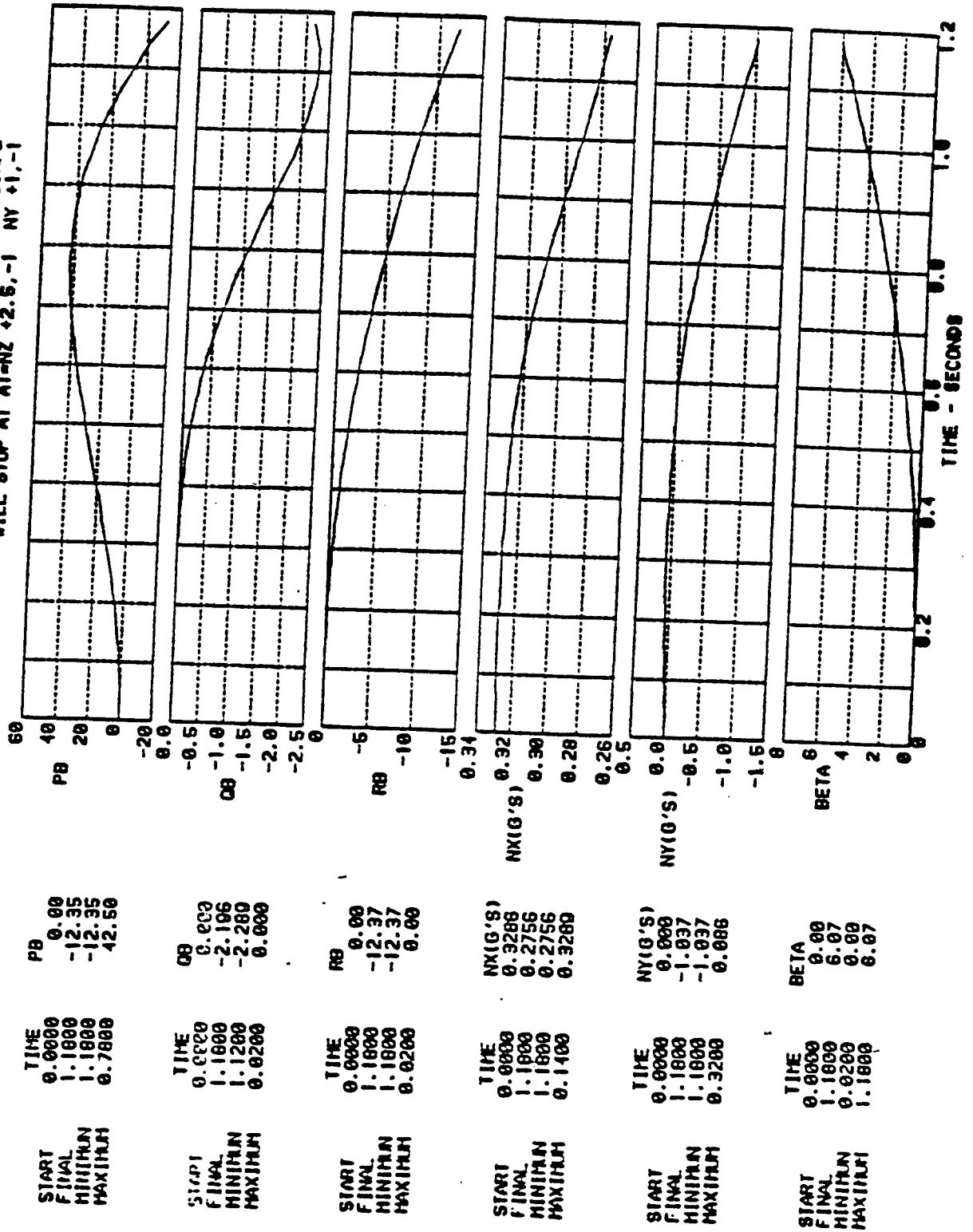
H=V

MAXIMUM

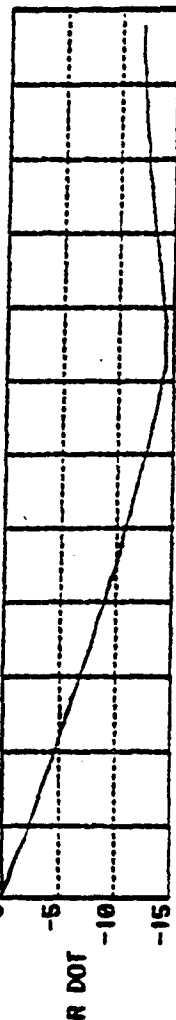
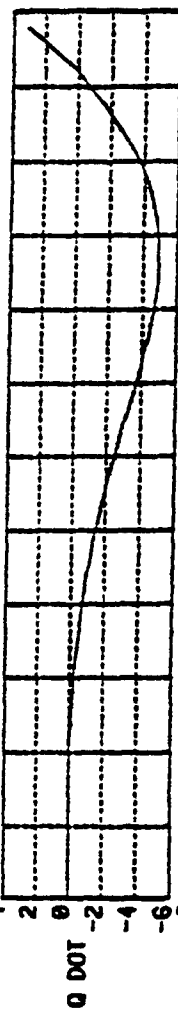
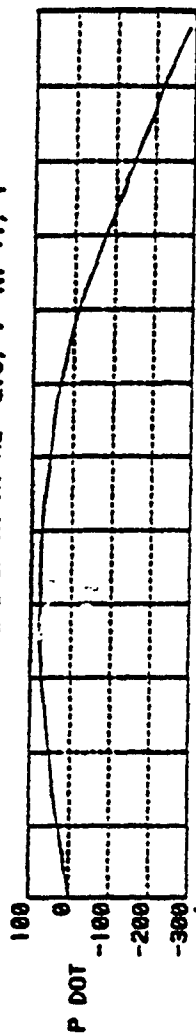
POWERED, CREW ESCAPE  
WILL STOP AT A1-NZ +2.5,-1 NY +1,-1



WILL STOP AT AT-NZ +2.5, -1 NY +1, -1

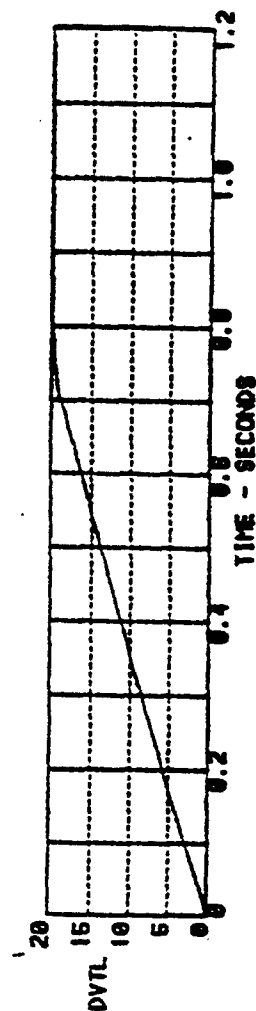


POWERED, CREW ESCAPE  
WILL STOP AT AT-NZ +2.5, -1 NY +1, -1

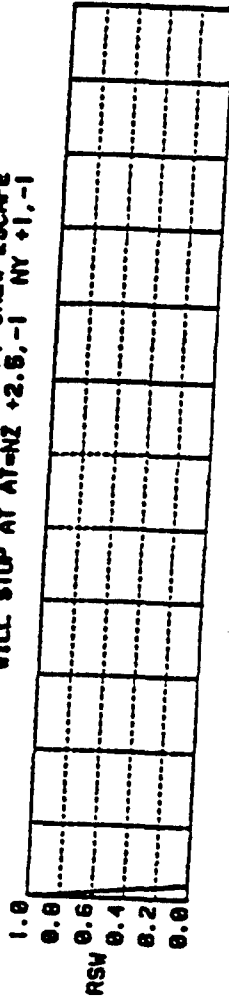


DTED = -6.1704

DTAOP = 0



POWERED, CREW ESCAPE  
WILL STOP AT AT-NZ +2.5,-1 NY +1,-1



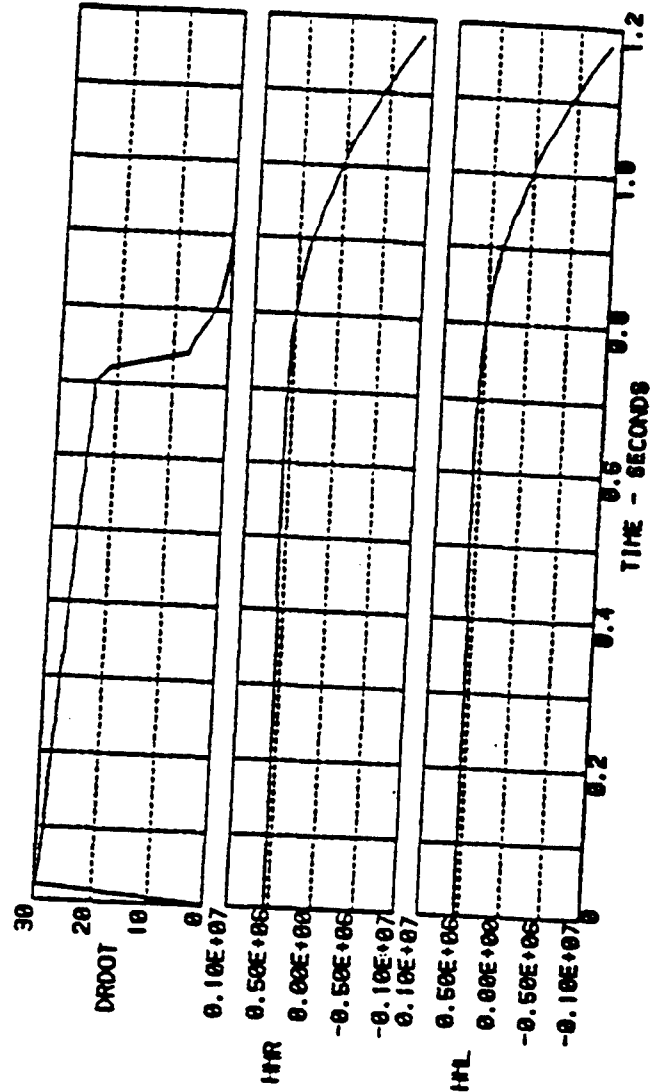
START  
FINAL  
MINIMUM  
MAXIMUM

TIME  
0.0000  
0.1000  
0.2000  
0.3000

RSW  
1.000  
0.000  
0.000  
1.000

DEDOT

DADOT



START  
FINAL  
MINIMUM  
MAXIMUM

TIME  
0.0000  
0.1000  
0.2000  
0.3000

DROOT  
0.00  
0.00  
0.00  
30.00

START  
FINAL  
MINIMUM  
MAXIMUM

TIME  
0.0000  
0.1000  
0.2000  
0.3000

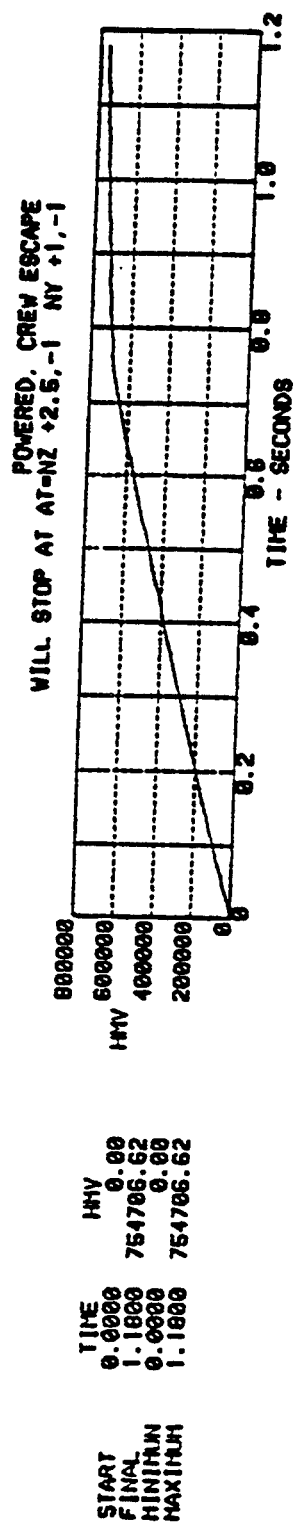
IHR  
0.50E+08  
0.10E+08  
0.00E+08  
0.50E+08

START  
FINAL  
MINIMUM  
MAXIMUM

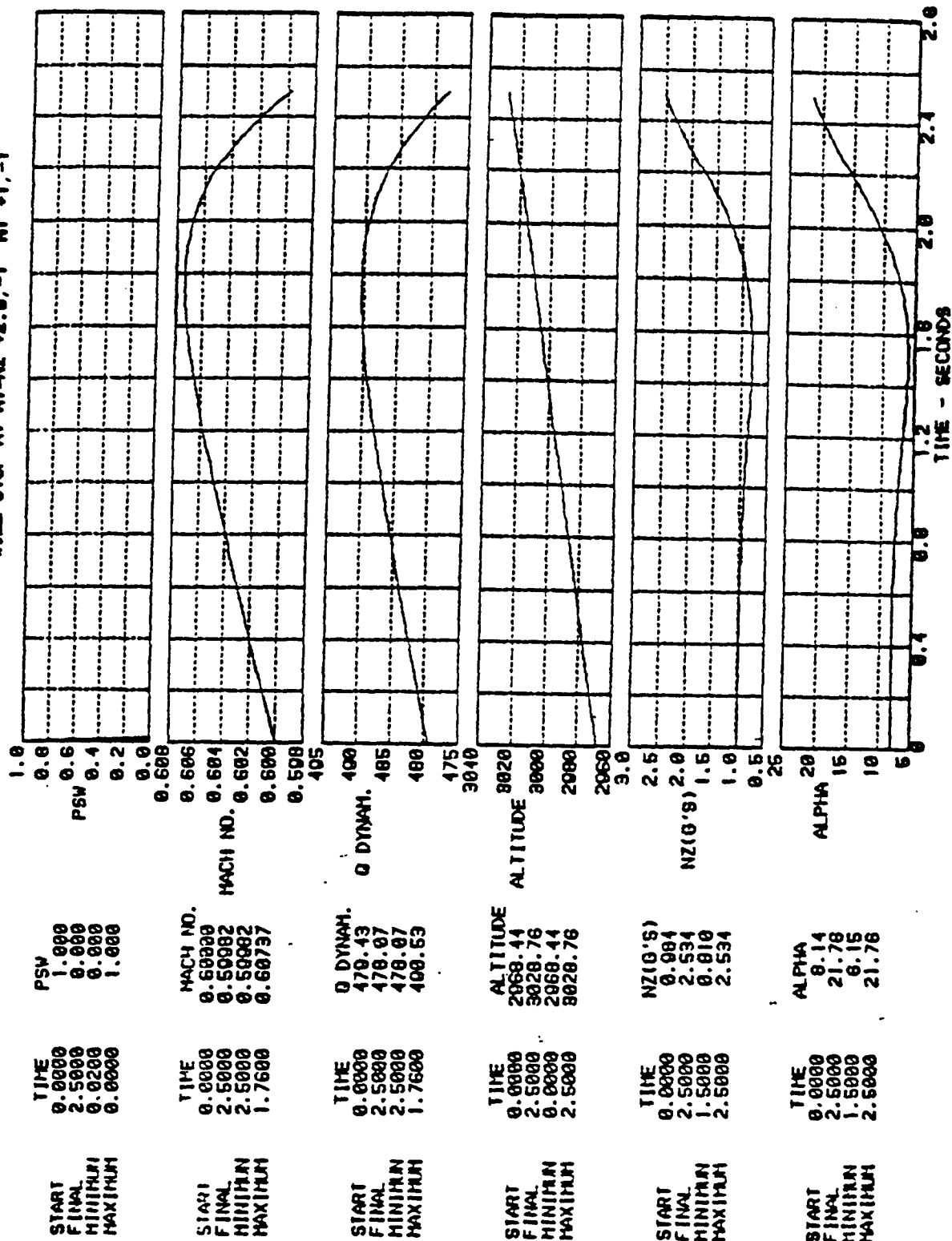
TIME  
0.0000  
0.1000  
0.2000  
0.3000

IHL  
0.50E+08  
0.10E+08  
0.00E+08  
0.50E+08

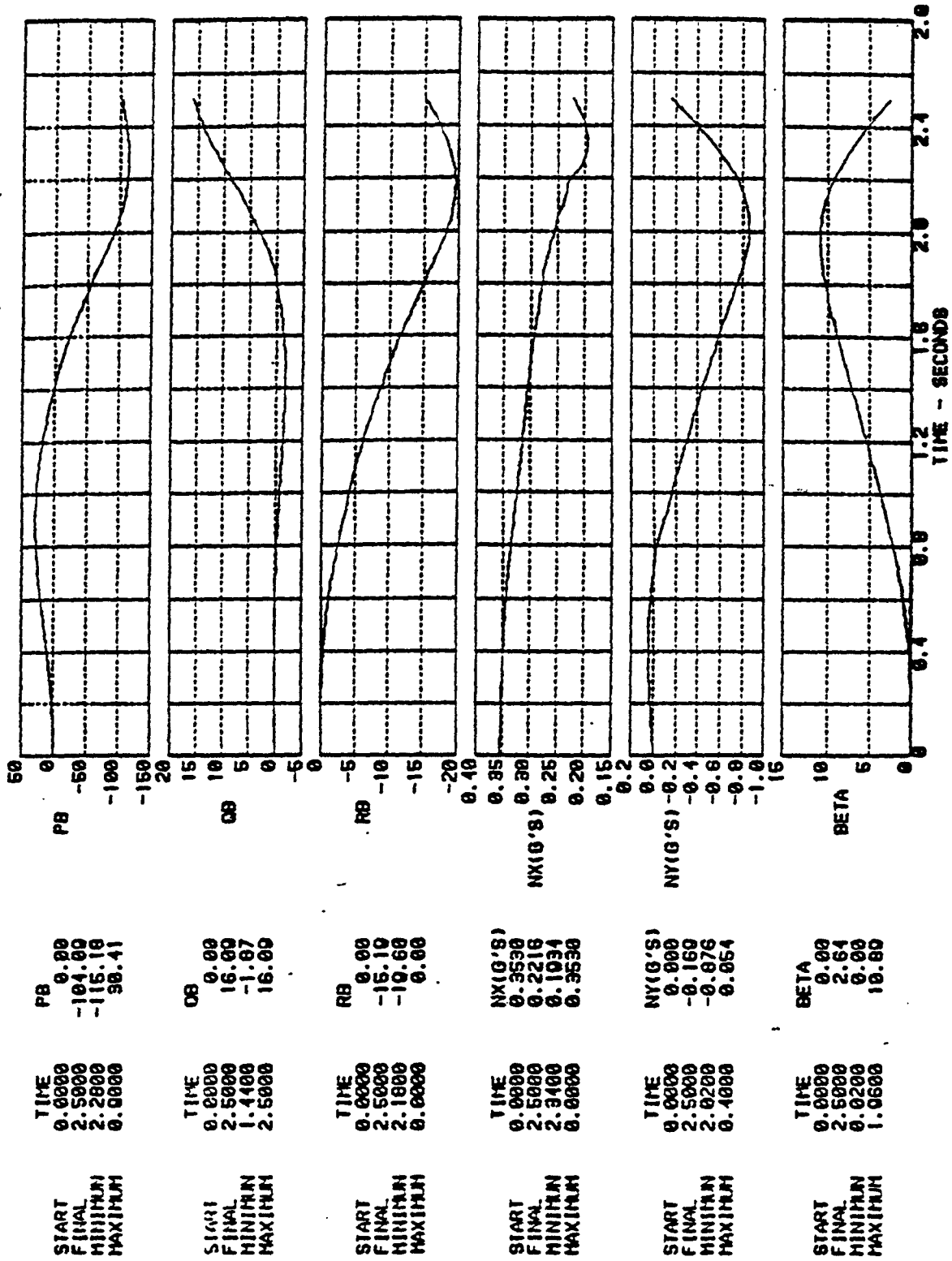
Mach 1.5



POWERED, CREW ESCAPE  
WILL STOP AT AT-NZ +2.6, -1 NY +1, -1

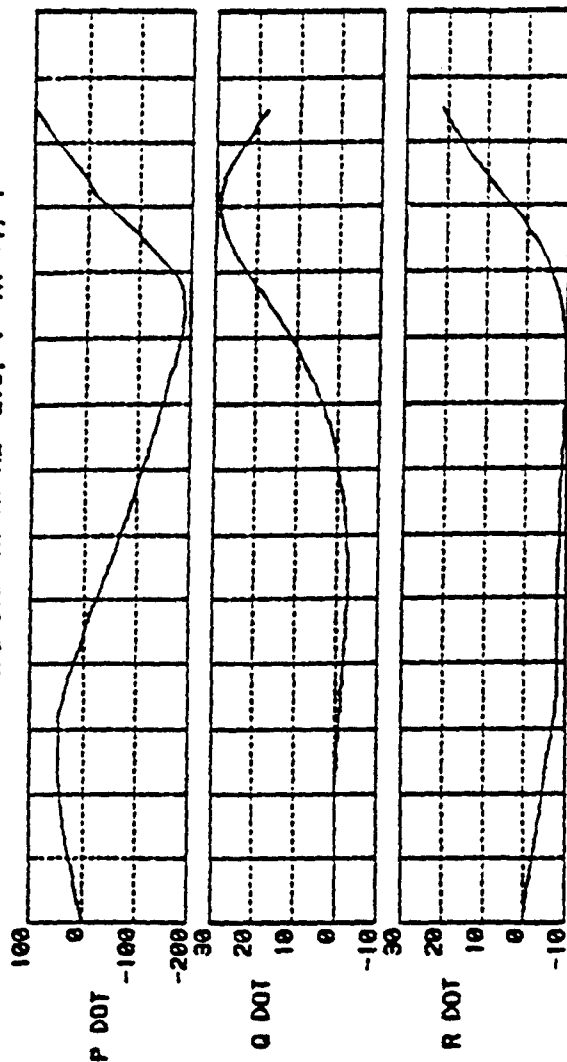


POWERED, CREW ESCAPE  
WILL STOP AT AT-NZ +2.5, -1 NY +1, -1





POWERED, CREW ESCAPE  
WILL STOP AT AT-NZ +2.5, -1 NY +1, -1



TIME  
0.0000  
2.5000  
1.8000  
2.5000

START  
FINAL  
MINIMUM  
MAXIMUM

P DOT  
0.00  
90.20  
-166.68  
90.20

TIME  
0.0000  
2.5000  
1.8000  
2.2000

START  
FINAL  
MINIMUM  
MAXIMUM

Q DOT  
0.00  
17.01  
-2.04  
20.03

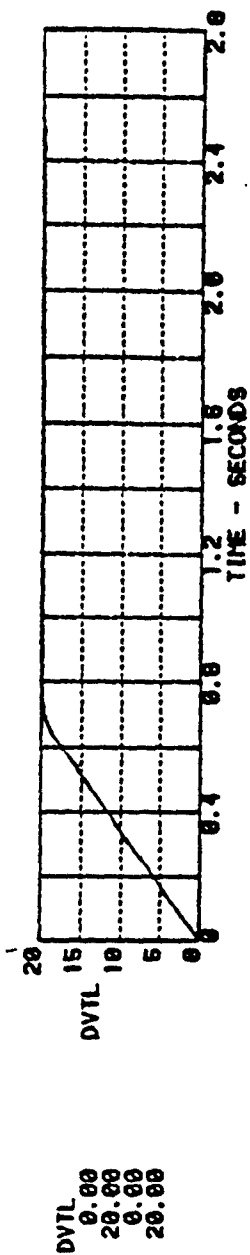
TIME  
0.0000  
2.5000  
1.7000  
2.5000

START  
FINAL  
MINIMUM  
MAXIMUM

R DOT  
0.00  
21.91  
-0.87  
21.91

DTEO - 0.92481

DTAOP - 0



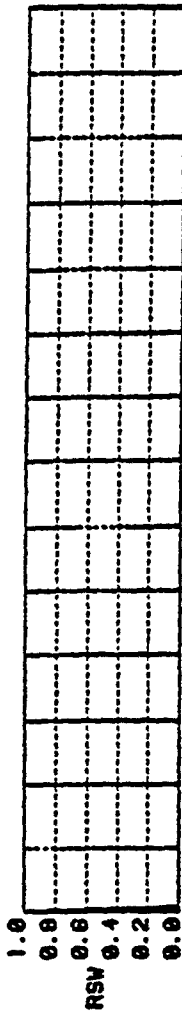
TIME  
0.0000  
2.5000  
0.0000  
1.2000

START  
FINAL  
MINIMUM  
MAXIMUM

DVTL  
0.00  
20.00  
0.00  
20.00

Mach 0.6

POWERED, CREW ESCAPE  
WILL STOP AT AT=NZ +2.5,-1 NY +1,-1



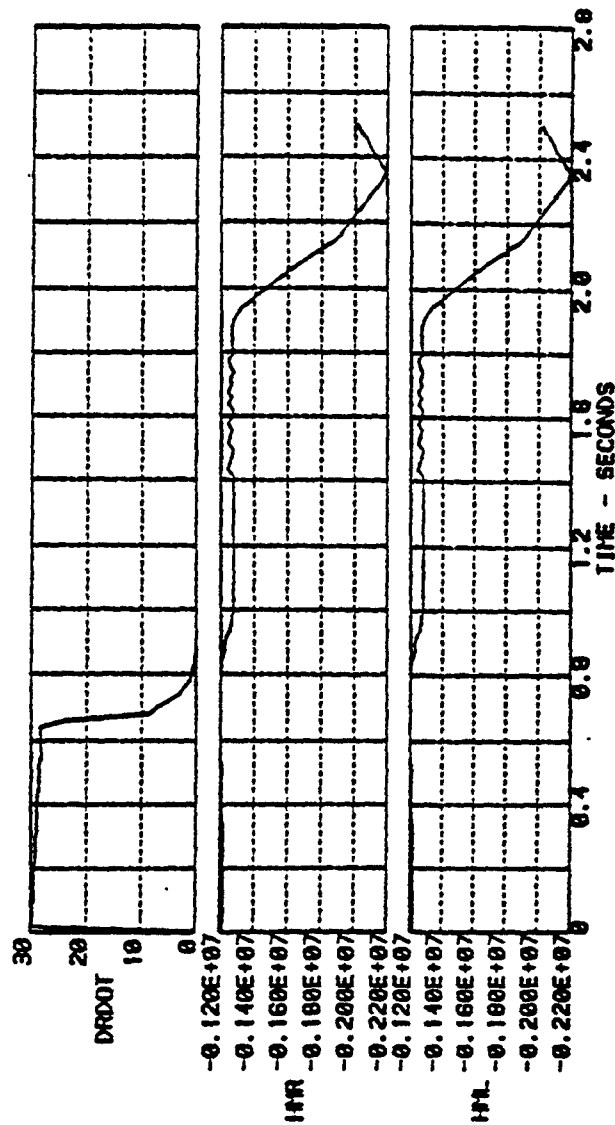
TIME  
0.000  
0.500  
1.000  
1.500  
2.000  
2.500  
3.000  
3.500  
4.000  
4.500  
5.000  
5.500  
6.000  
6.500  
7.000  
7.500  
8.000  
8.500  
9.000  
9.500  
10.000

RSW  
1.000  
0.000  
0.000  
0.000  
1.000

START  
FINAL  
MINIMUM  
MAXIMUM

DEDOT = 0

DADOT = 0



TIME  
0.000  
0.500  
1.000  
1.500  
2.000  
2.500  
3.000  
3.500  
4.000  
4.500  
5.000  
5.500  
6.000  
6.500  
7.000  
7.500  
8.000  
8.500  
9.000  
9.500  
10.000

DRDOT  
0.00  
0.00  
0.00  
0.00  
30.00

START  
FINAL  
MINIMUM  
MAXIMUM

TIME  
0.000  
0.500  
1.000  
1.500  
2.000  
2.500  
3.000  
3.500  
4.000  
4.500  
5.000  
5.500  
6.000  
6.500  
7.000  
7.500  
8.000  
8.500  
9.000  
9.500  
10.000

IPR  
0.000  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07

START  
FINAL  
MINIMUM  
MAXIMUM

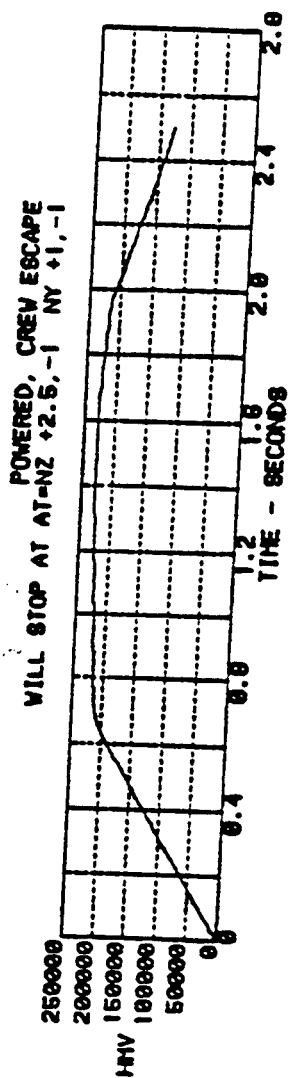
TIME  
0.000  
0.500  
1.000  
1.500  
2.000  
2.500  
3.000  
3.500  
4.000  
4.500  
5.000  
5.500  
6.000  
6.500  
7.000  
7.500  
8.000  
8.500  
9.000  
9.500  
10.000

IML  
0.000  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07  
0.120E+07

START  
FINAL  
MINIMUM  
MAXIMUM

Mach 0.6

Mach 0.6



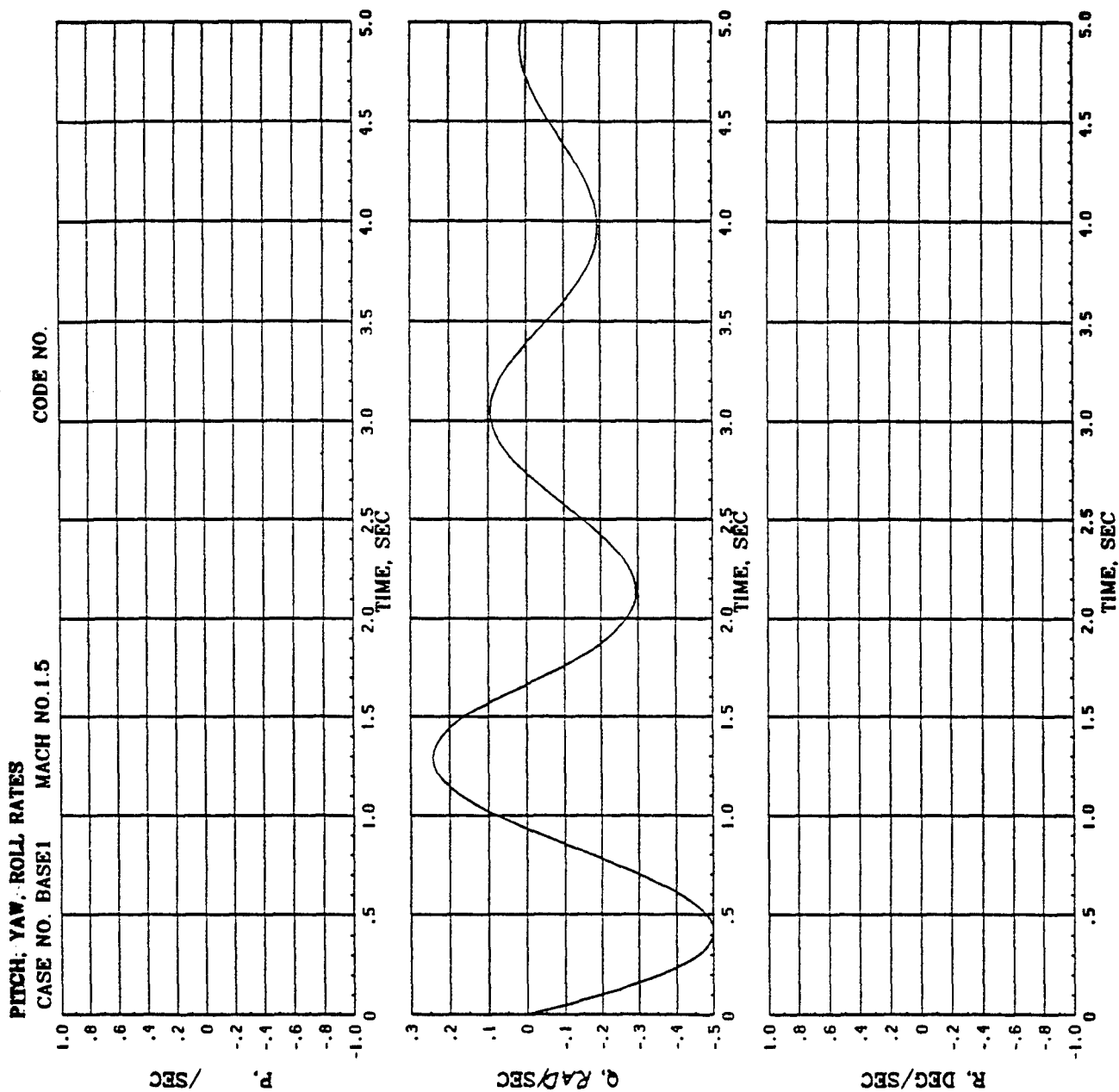
|         |        |           |
|---------|--------|-----------|
| START   | TIME   | MMV       |
| FINAL   | 0.000  | 0.00      |
| MINIMUM | 2.5000 | 128785.17 |
| MAXIMUM | 0.8000 | 0.00      |
|         | 1.5200 | 220408.87 |

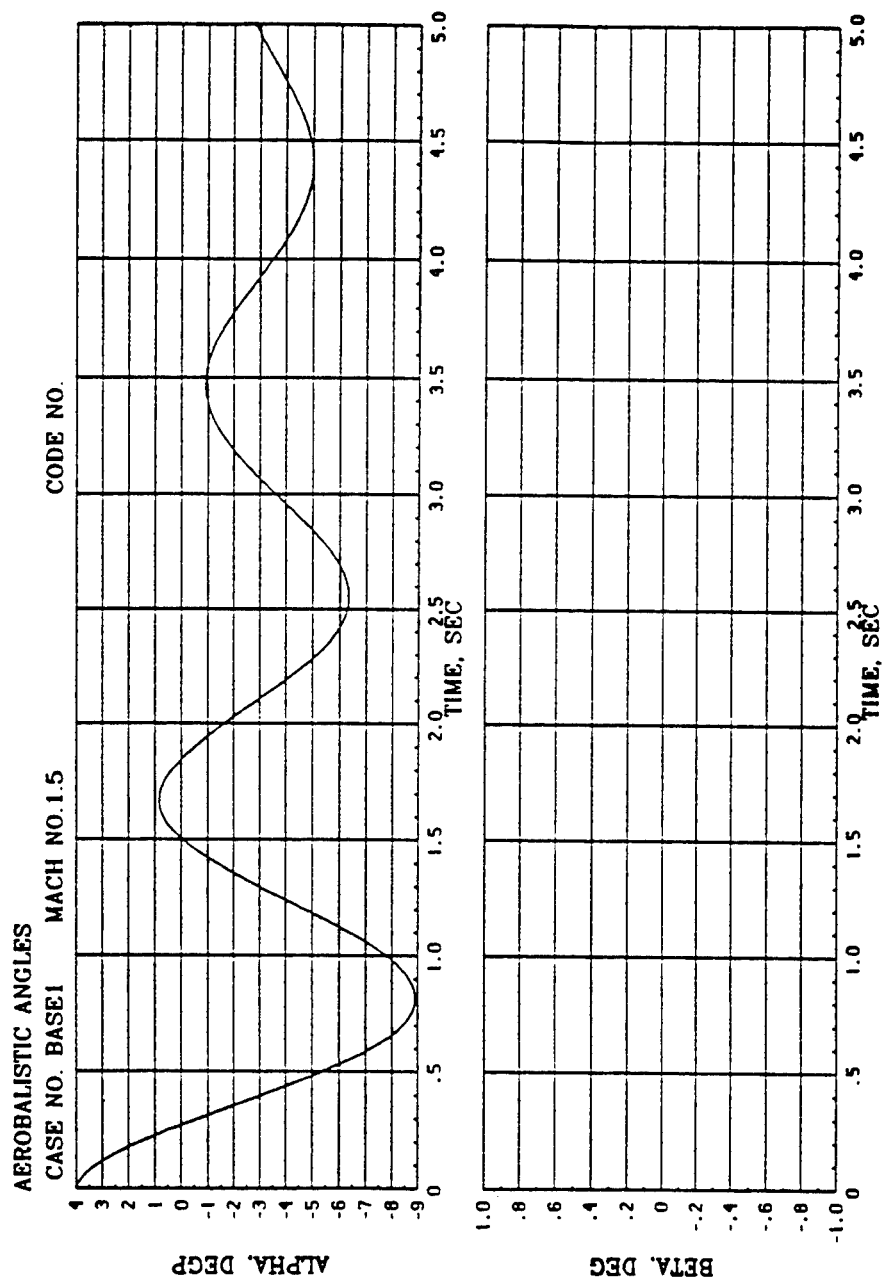
## APPENDIX D

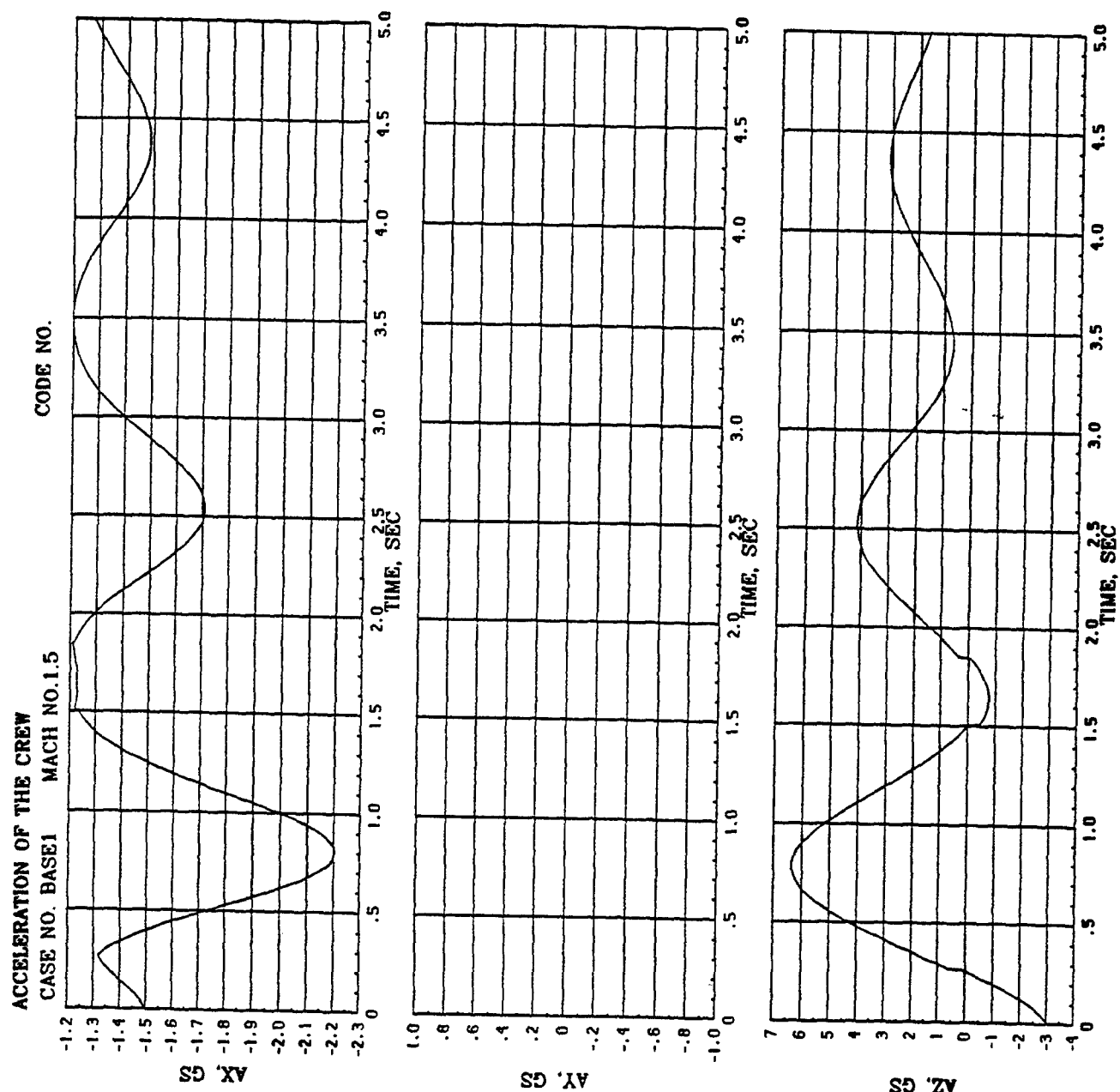
### Separation Dynamics Analysis Output Plots for Cases 1 - 18

This appendix contains the plotted output for the separation dynamics analysis performed under Task III. The plotted results are presented case-by-case according to the matrix below. Information regarding these results is found in Task III of this report.

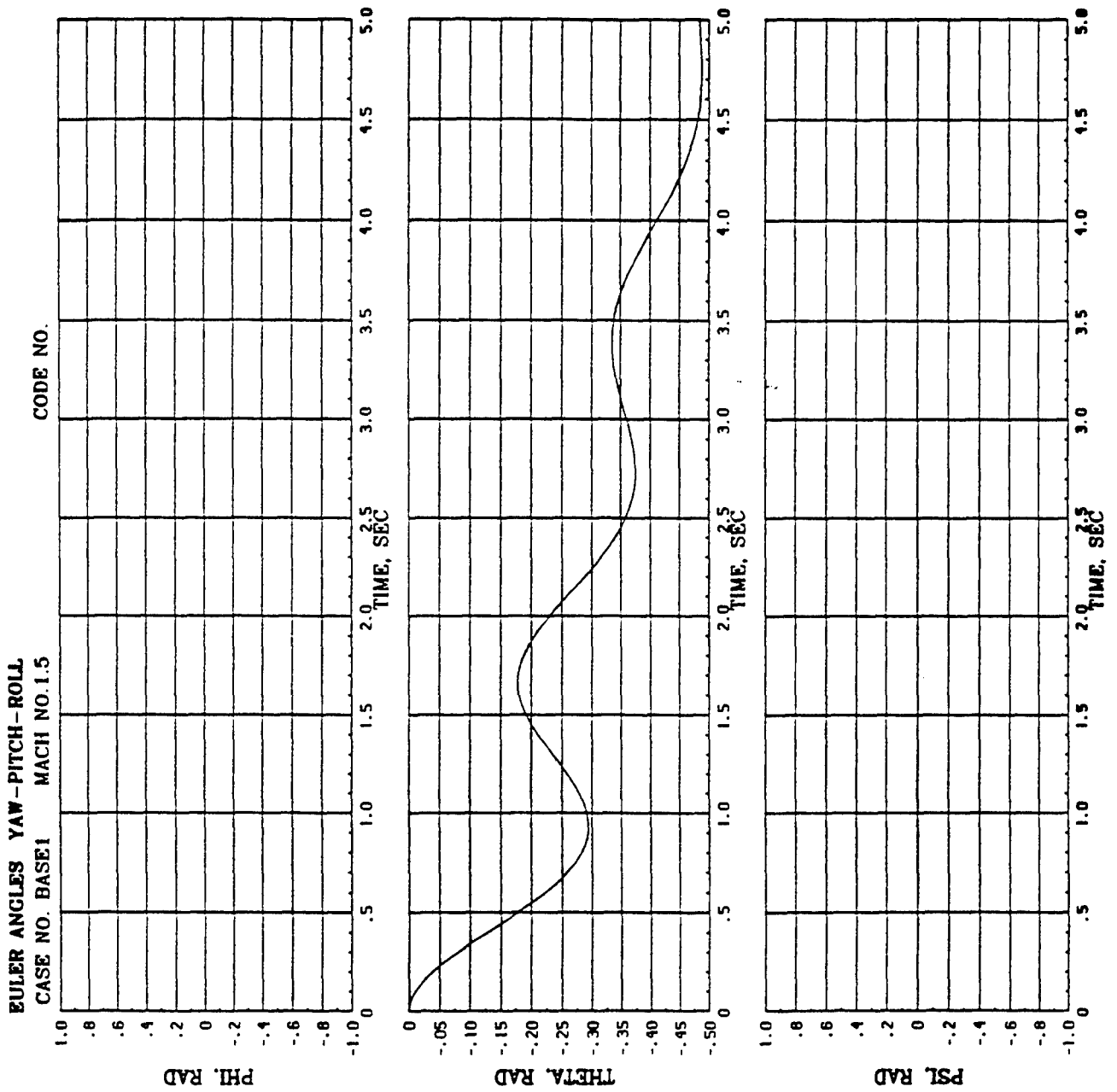
| External Influences                                  | Mach 1.5<br>Initial conditions |         | Mach 6.0<br>Initial conditions |         | Mach 20.0<br>Initial conditions |         |
|------------------------------------------------------|--------------------------------|---------|--------------------------------|---------|---------------------------------|---------|
|                                                      | Nominal                        | Adverse | Nominal                        | Adverse | Nominal                         | Adverse |
| Free Flight                                          | Case 1                         | Case 4  | Case 7                         | Case 10 | Case 13                         | Case 16 |
| Aftbody Interference<br>Aerodynamics                 | Case 2                         | Case 5  | Case 8                         | Case 11 | Case 14                         | Case 17 |
| Aftbody Interference<br>Aerodynamics +<br>Blast Wave | Case 3                         | Case 6  | Case 9                         | Case 12 | Case 15                         | Case 18 |

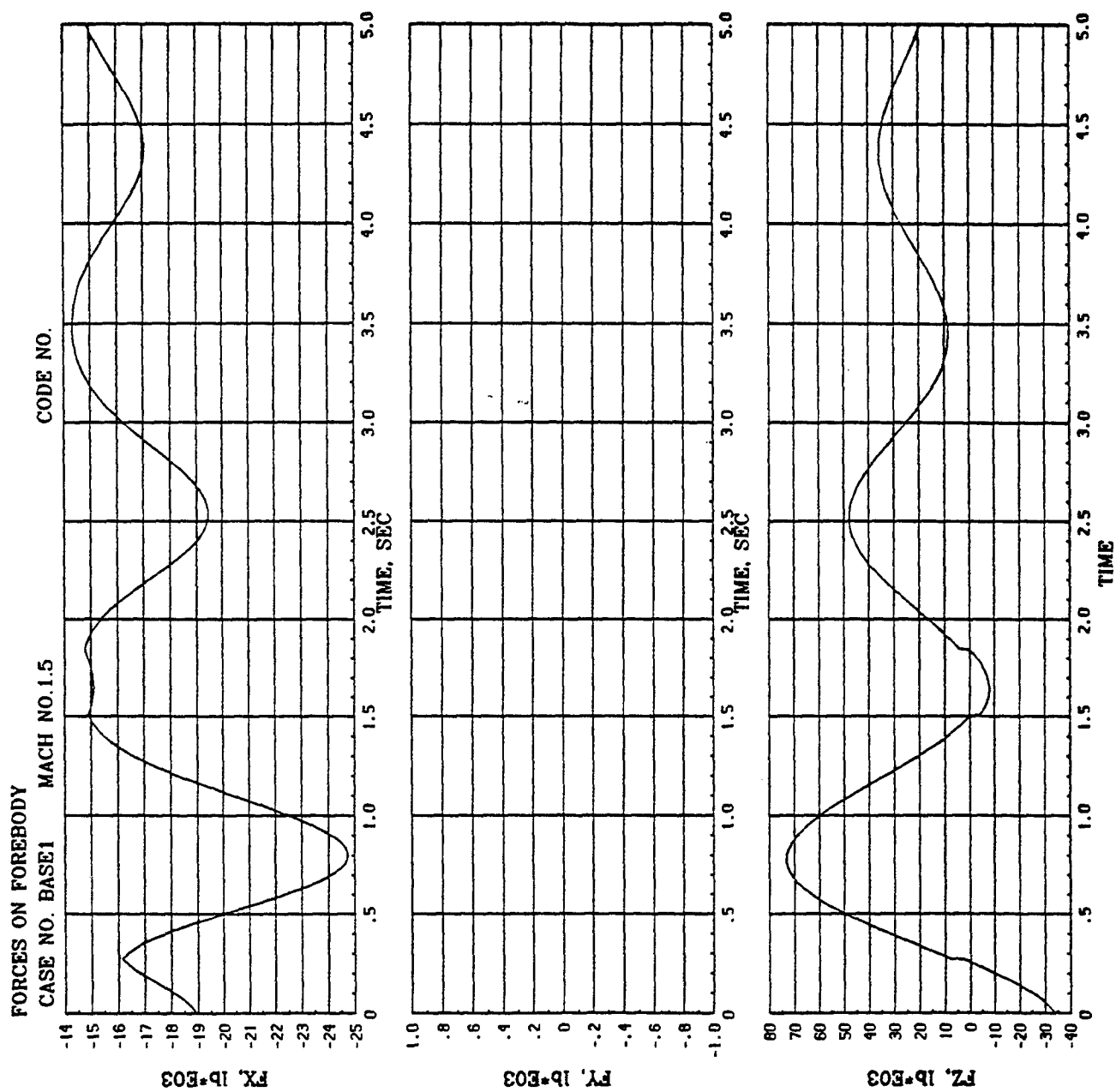


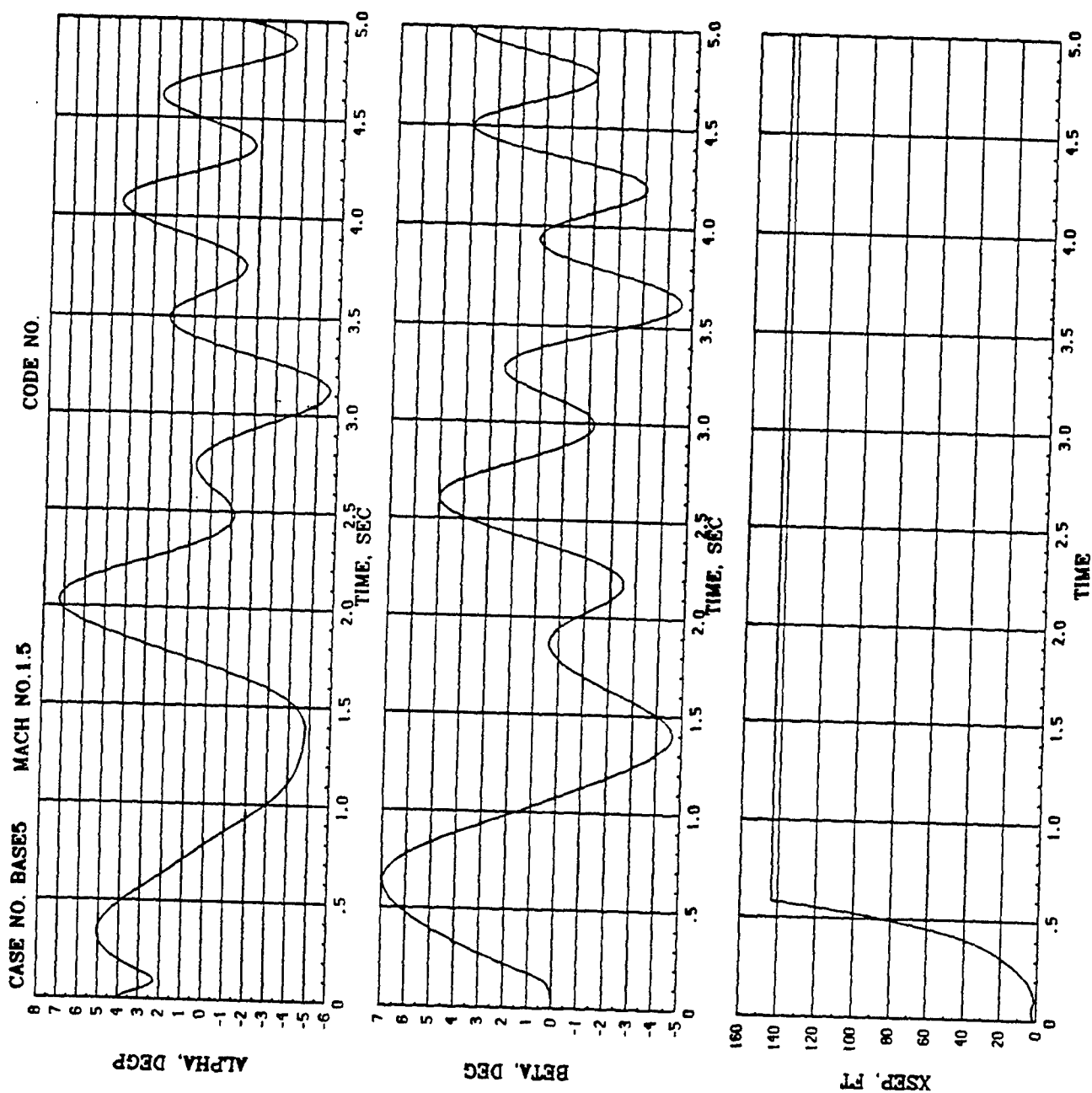


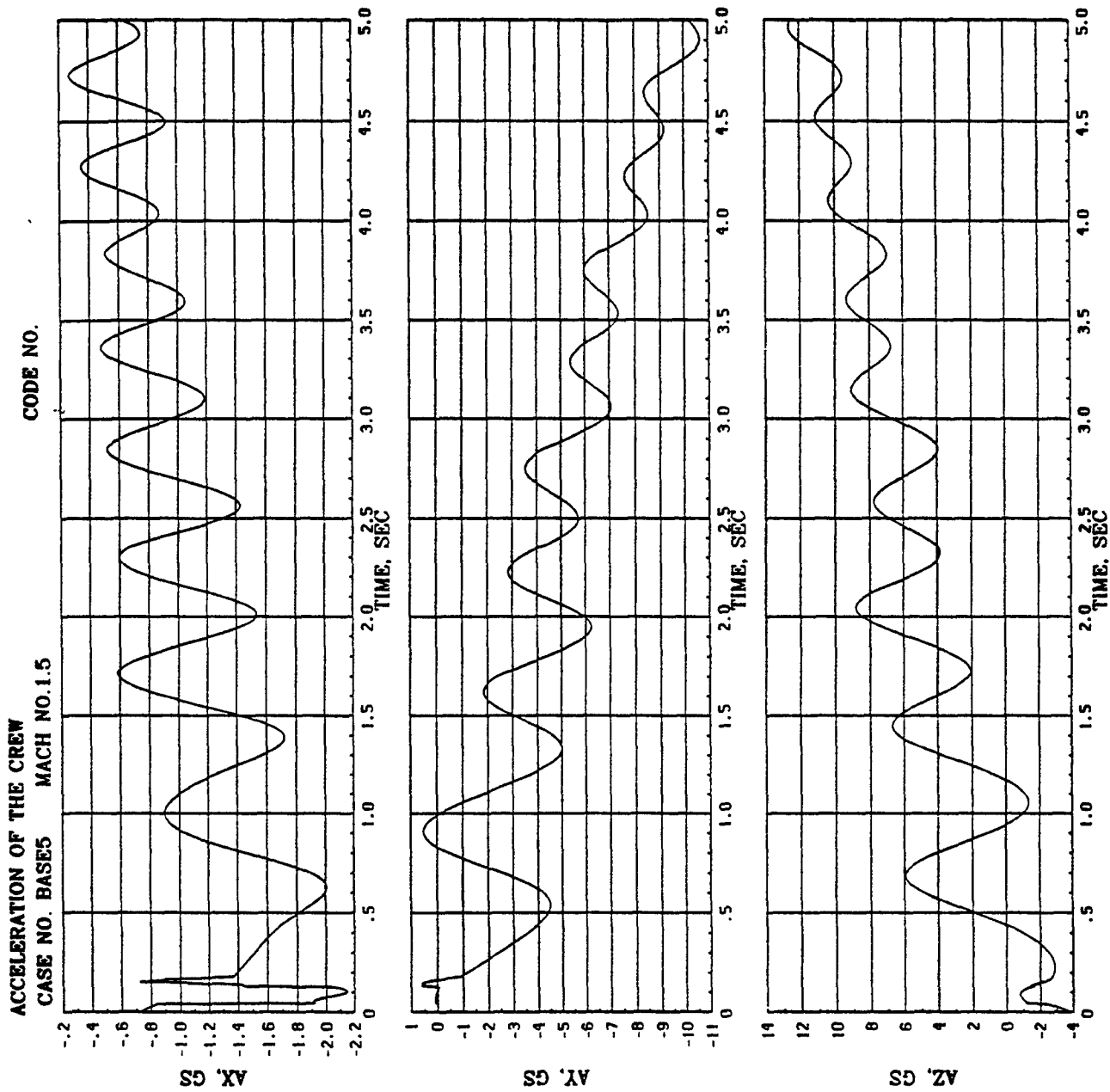








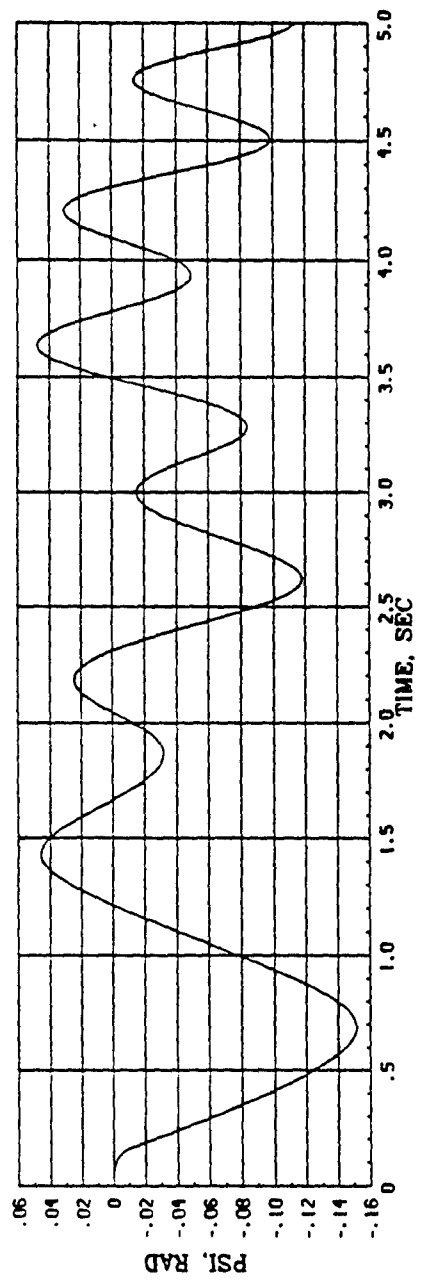
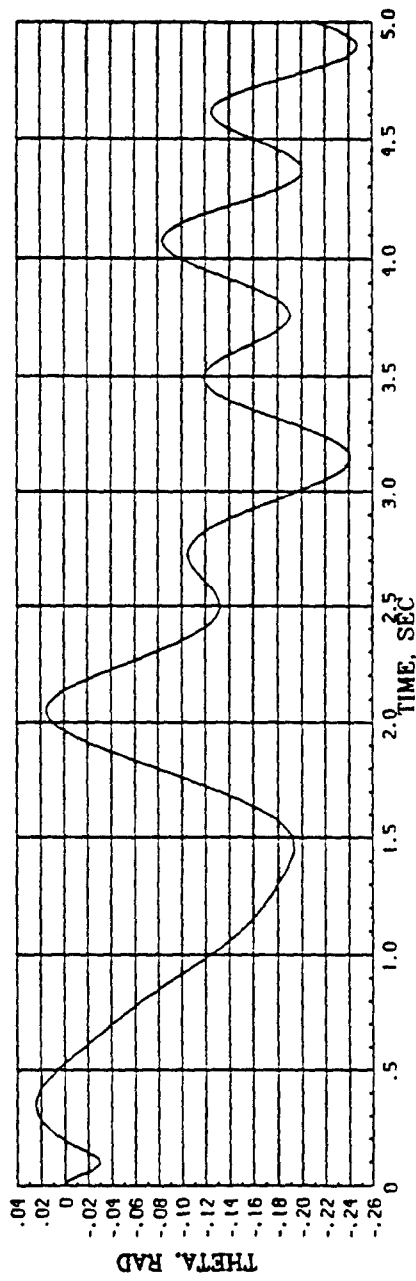
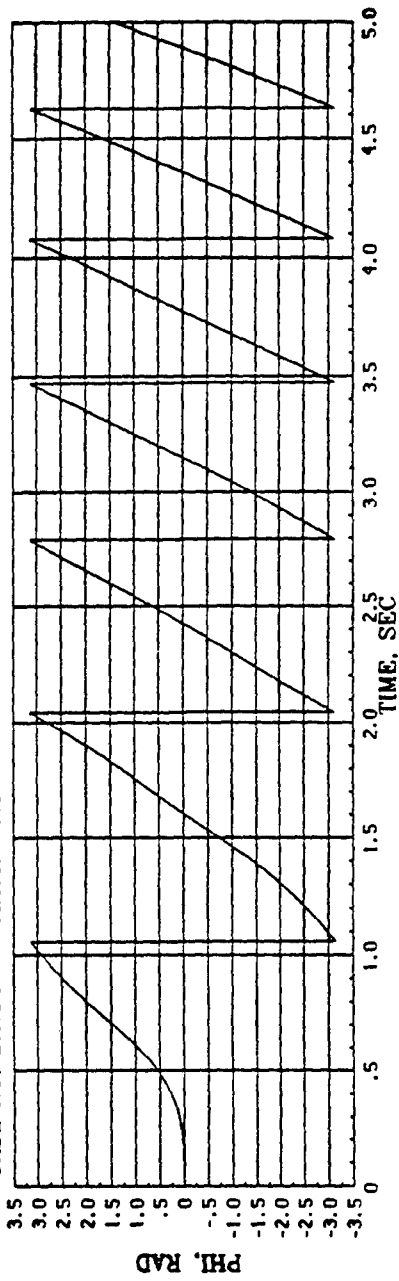


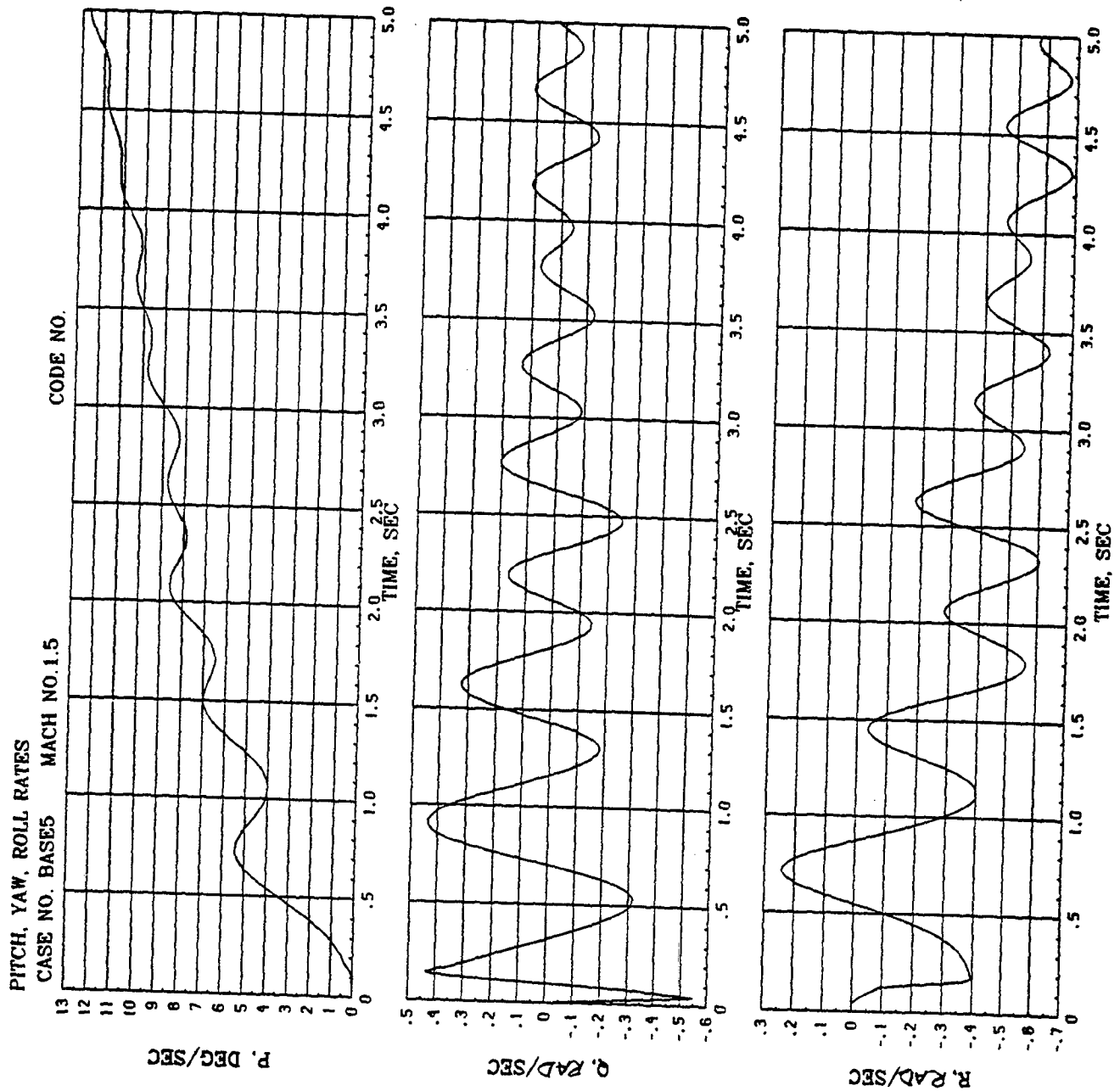


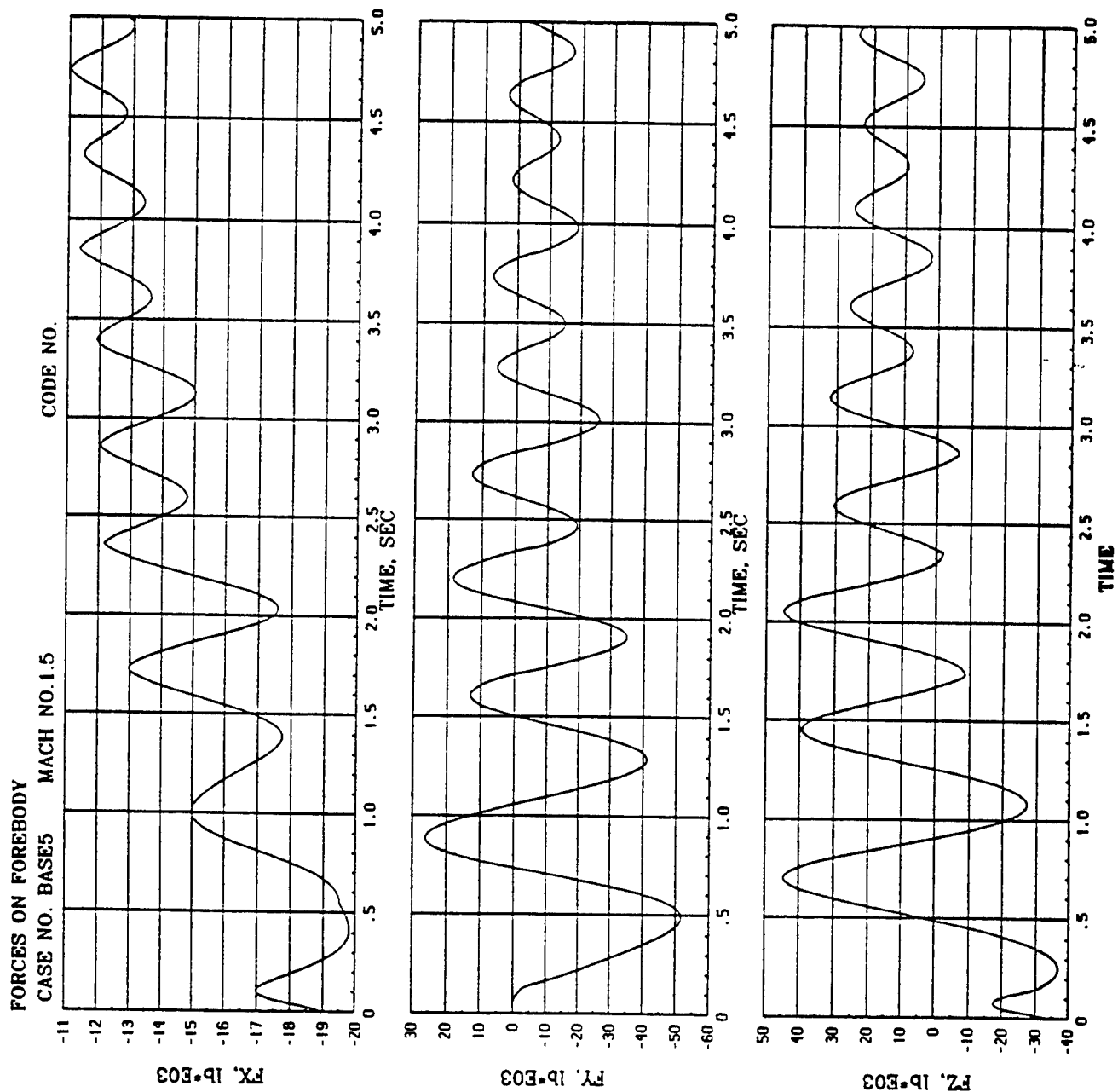
EULER ANGLES YAW-PITCH-ROLL

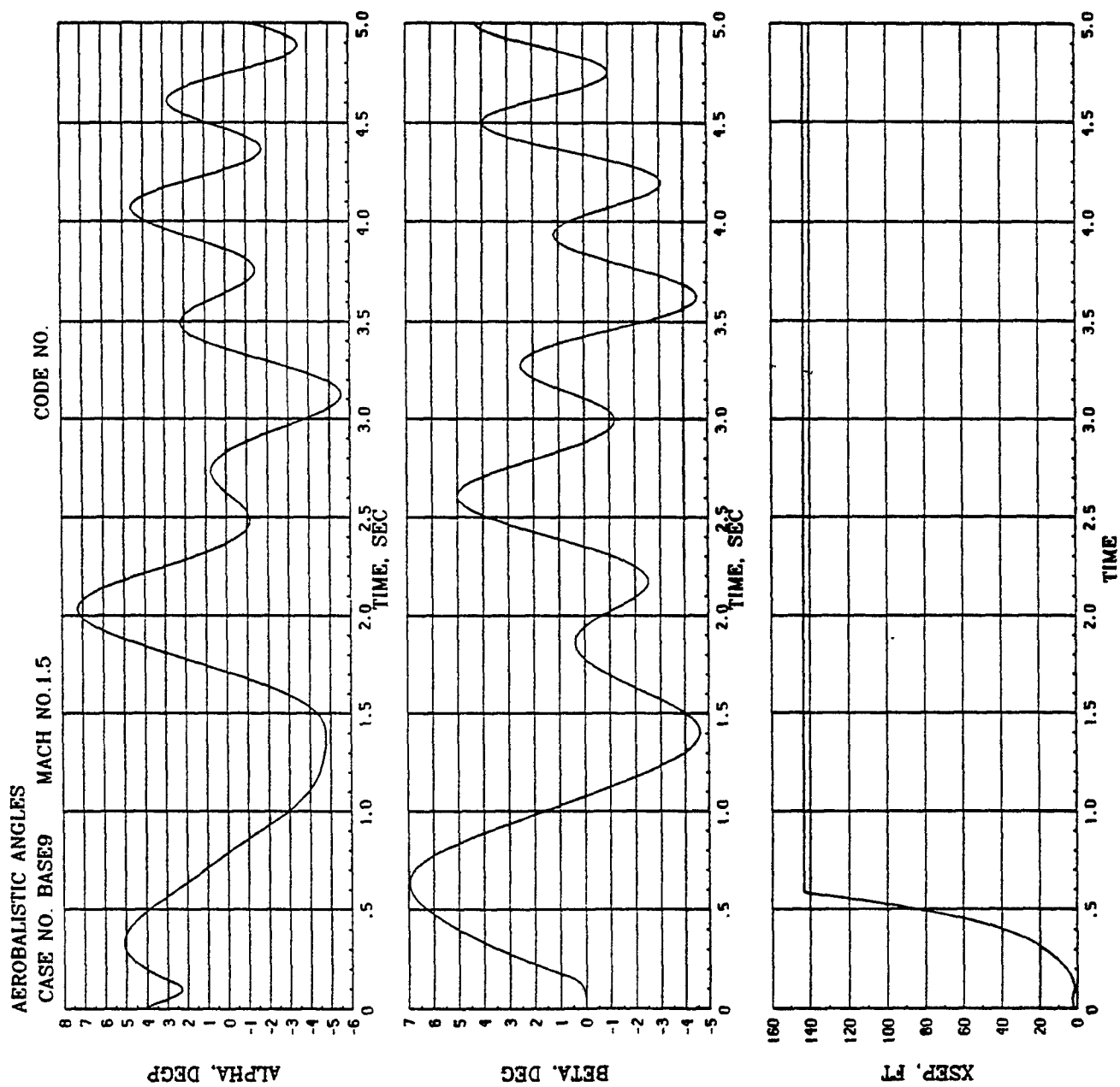
CASE NO. BASE5 MACH NO.1.5

CODE NO.

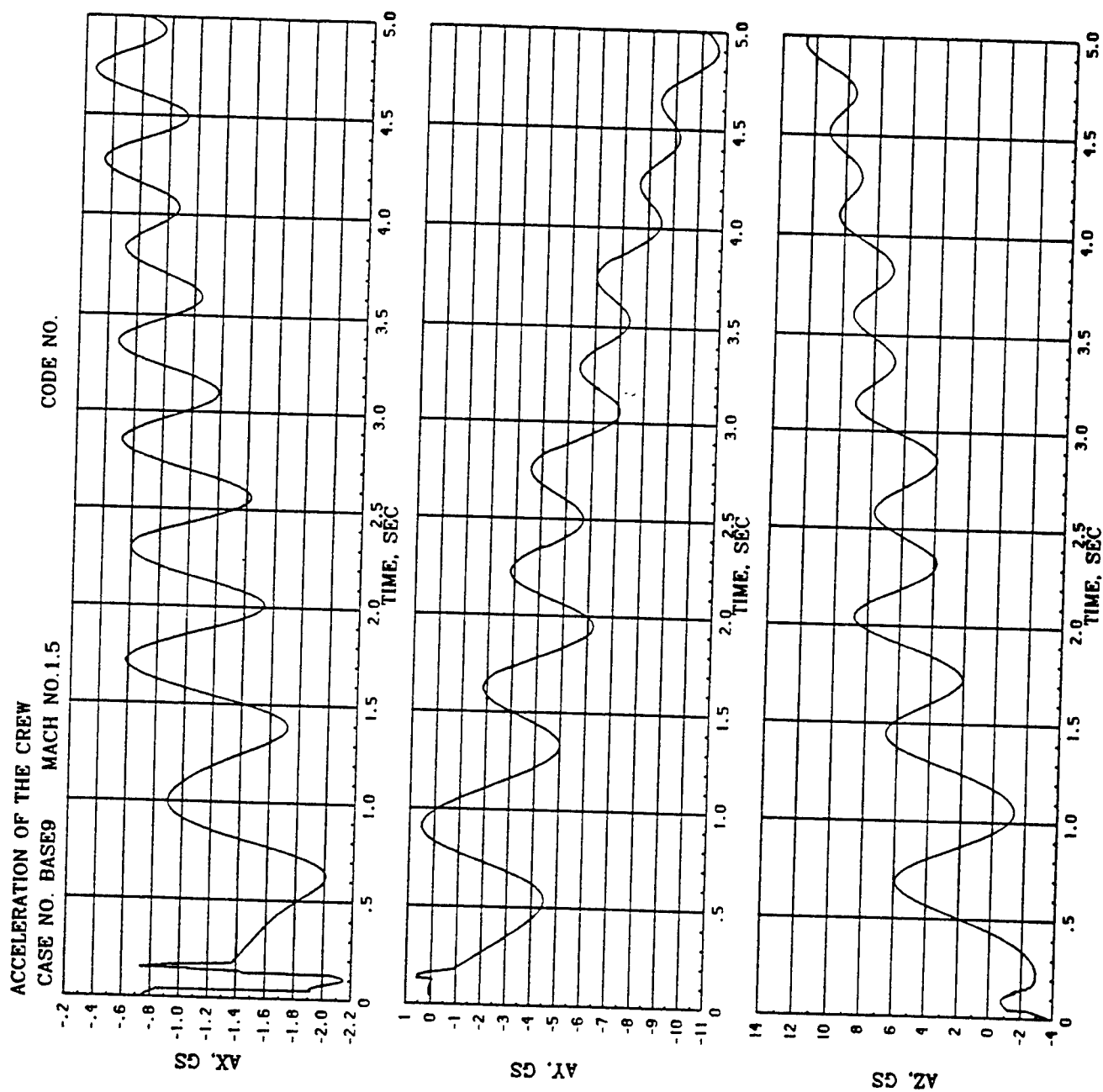






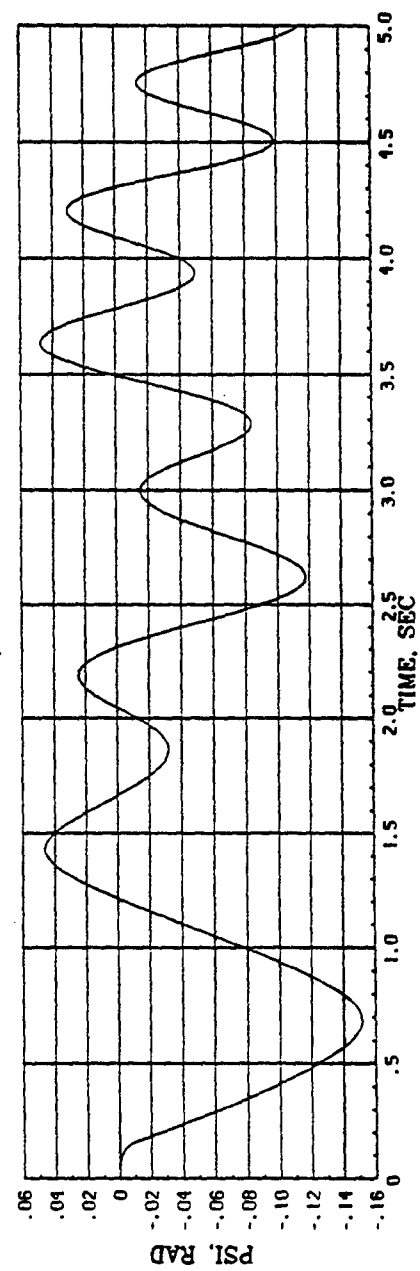
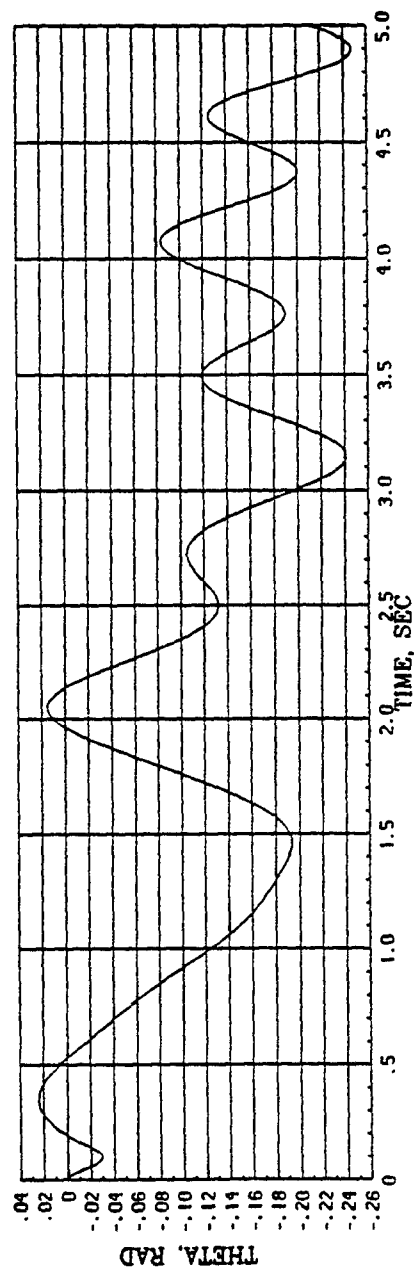
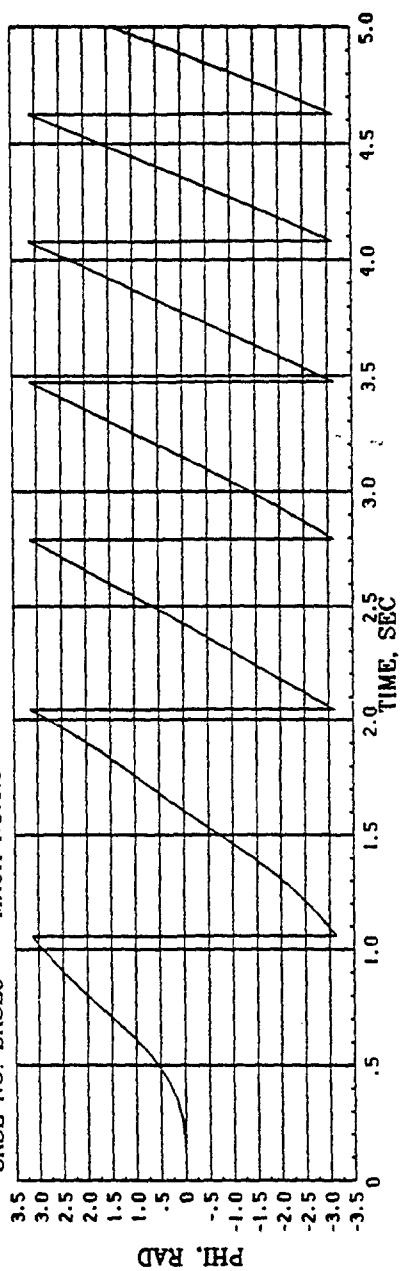


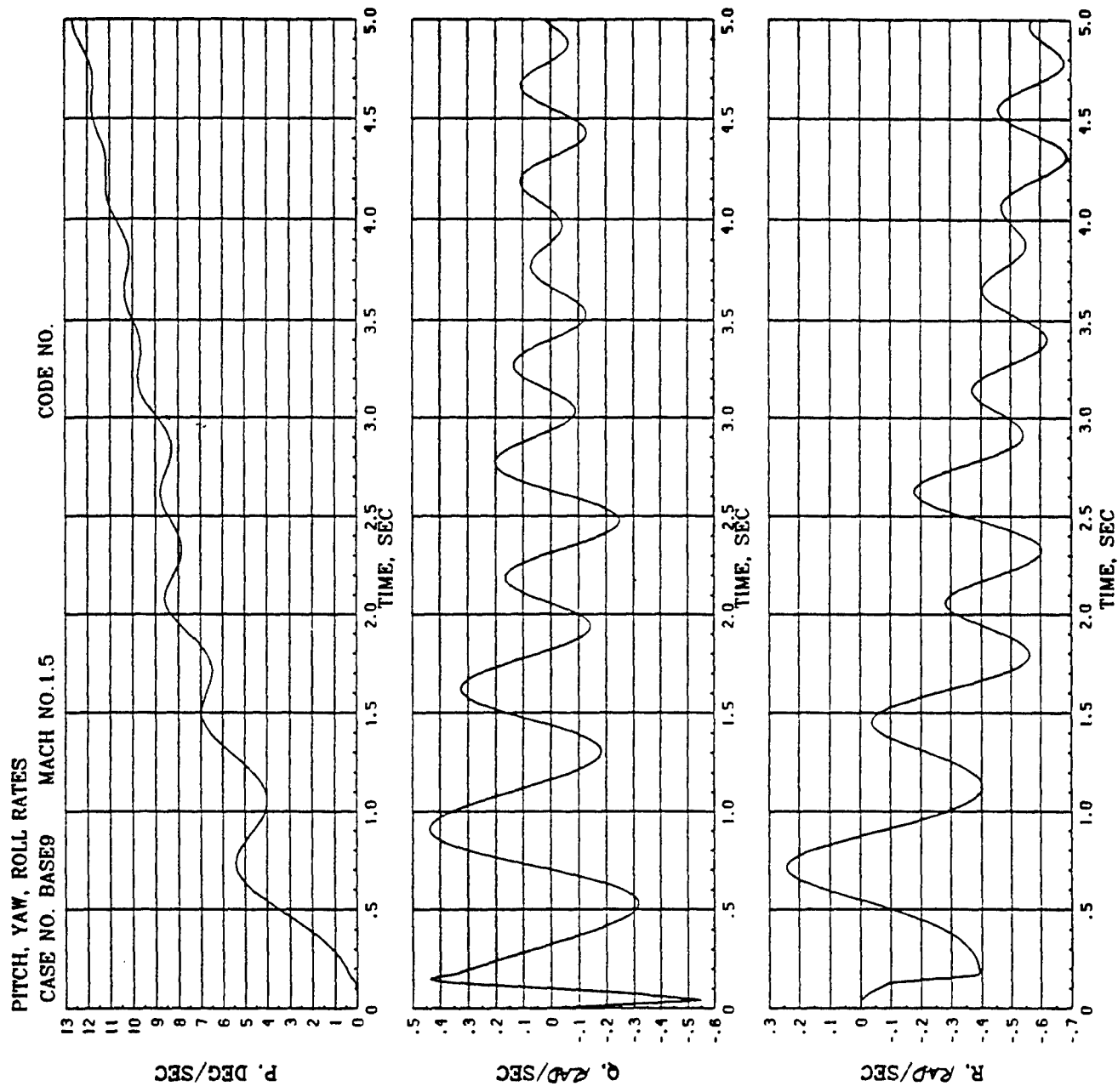


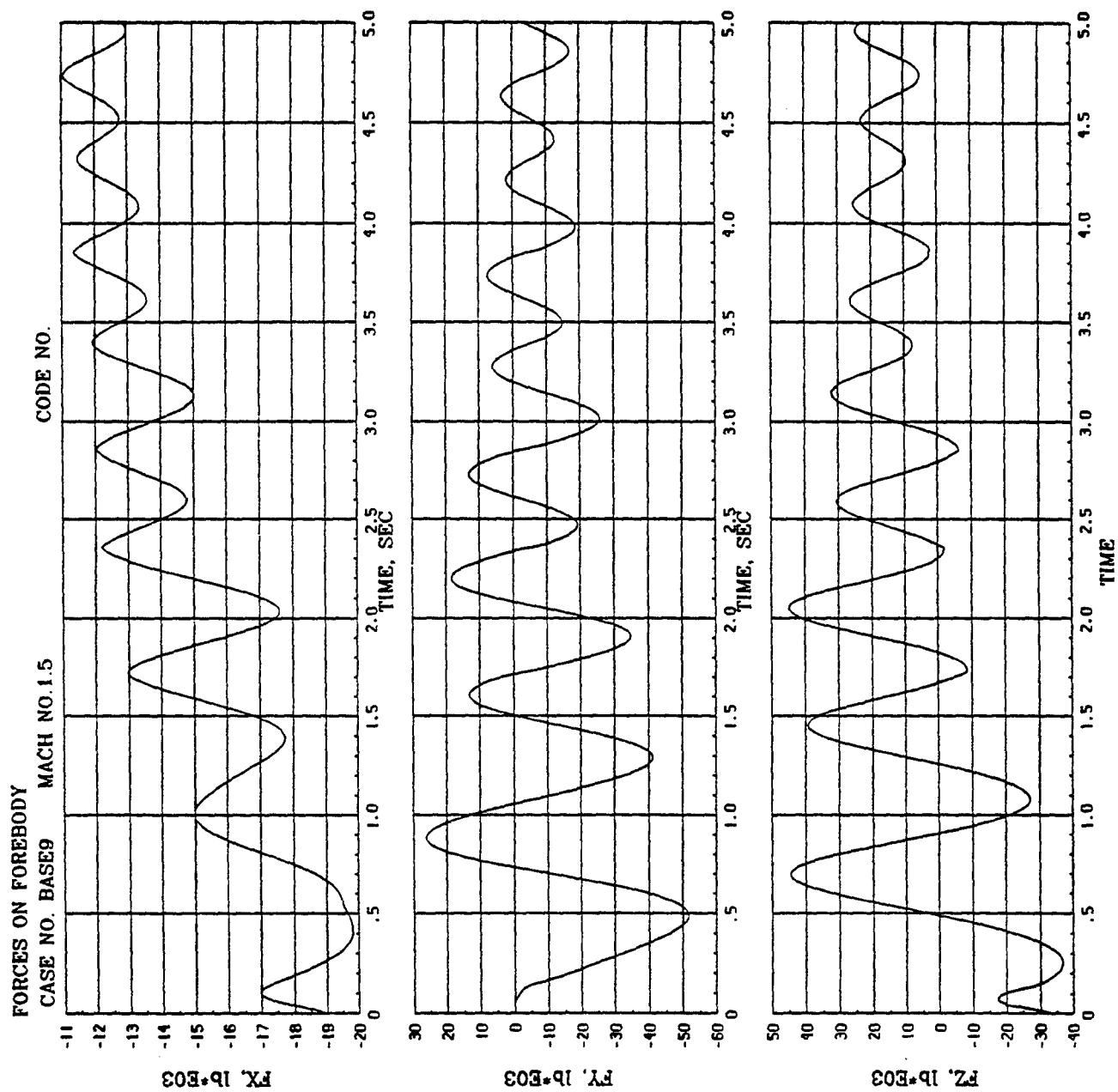


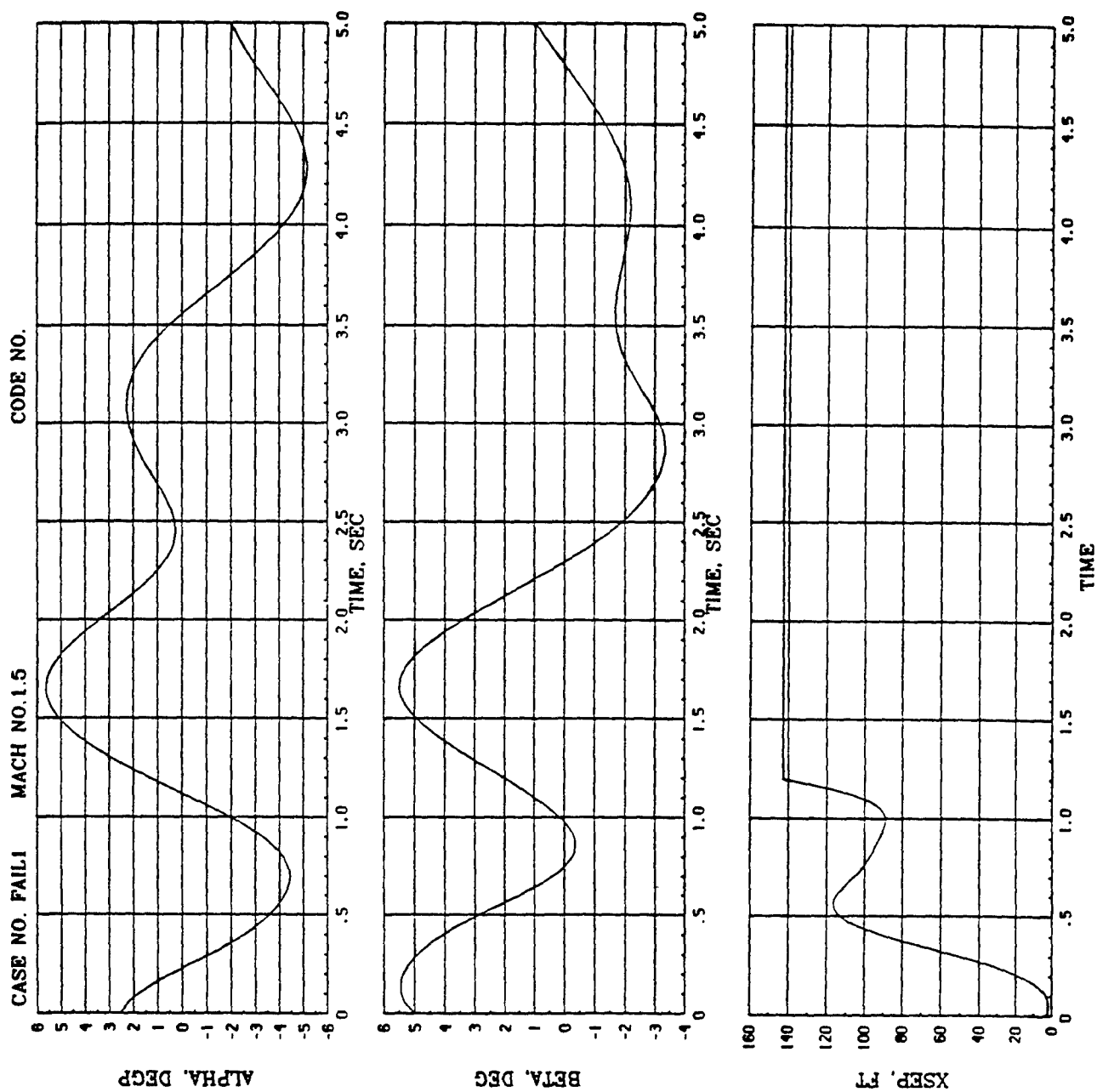
EULER ANGLES YAW - PITCH - ROLL  
CASE NO. BASE9 MACH NO.1.5

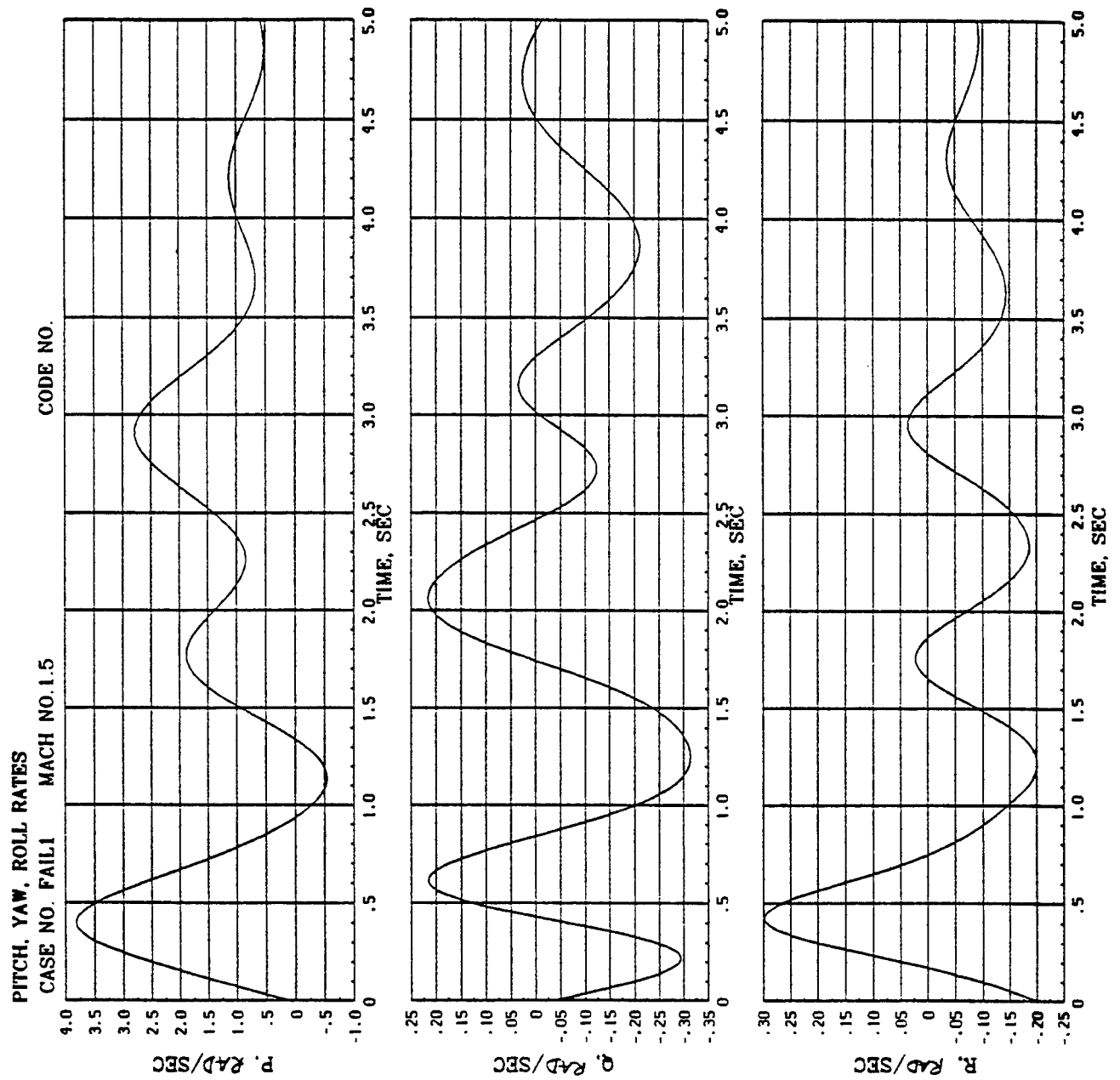
CODE NO.

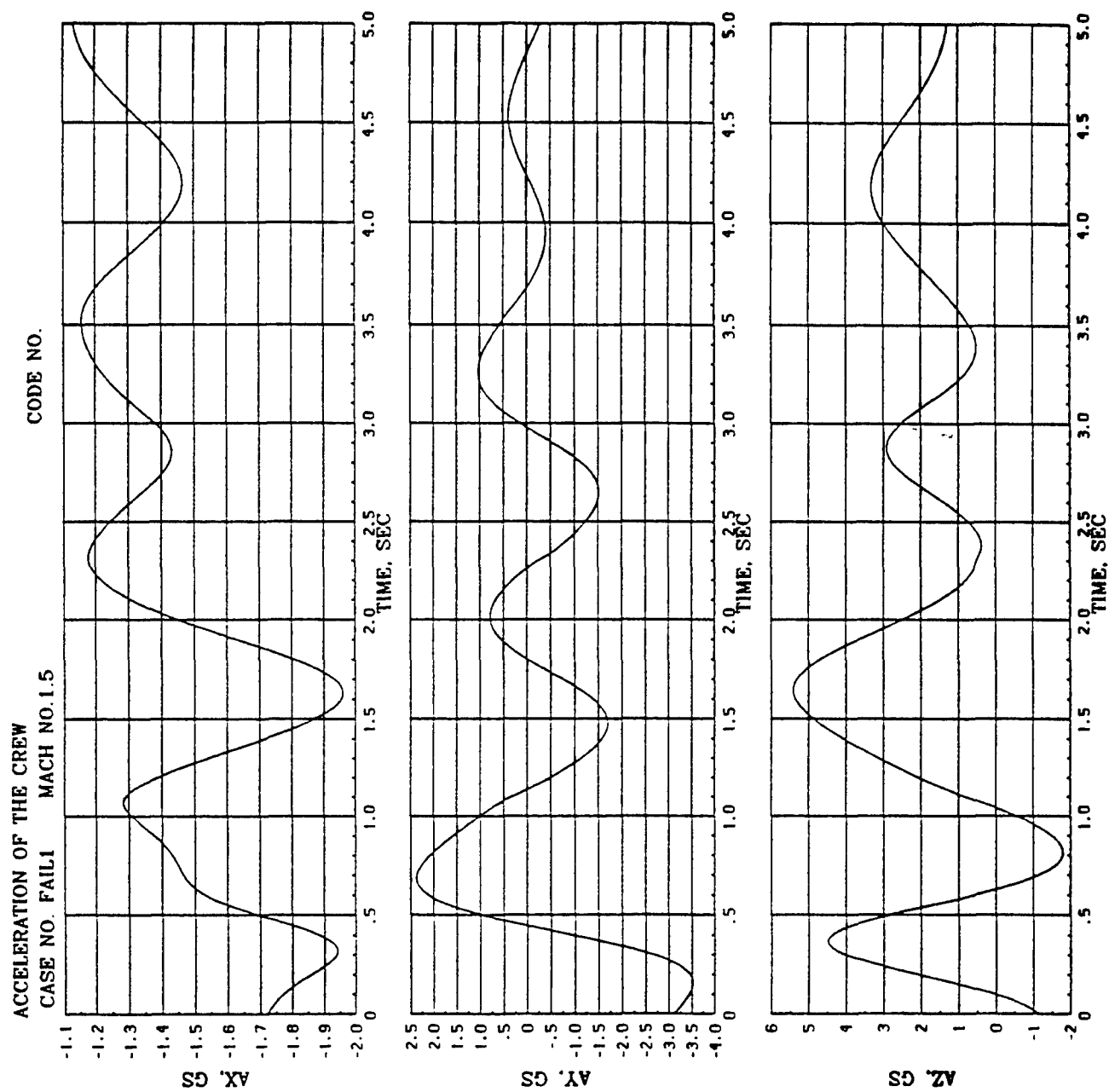


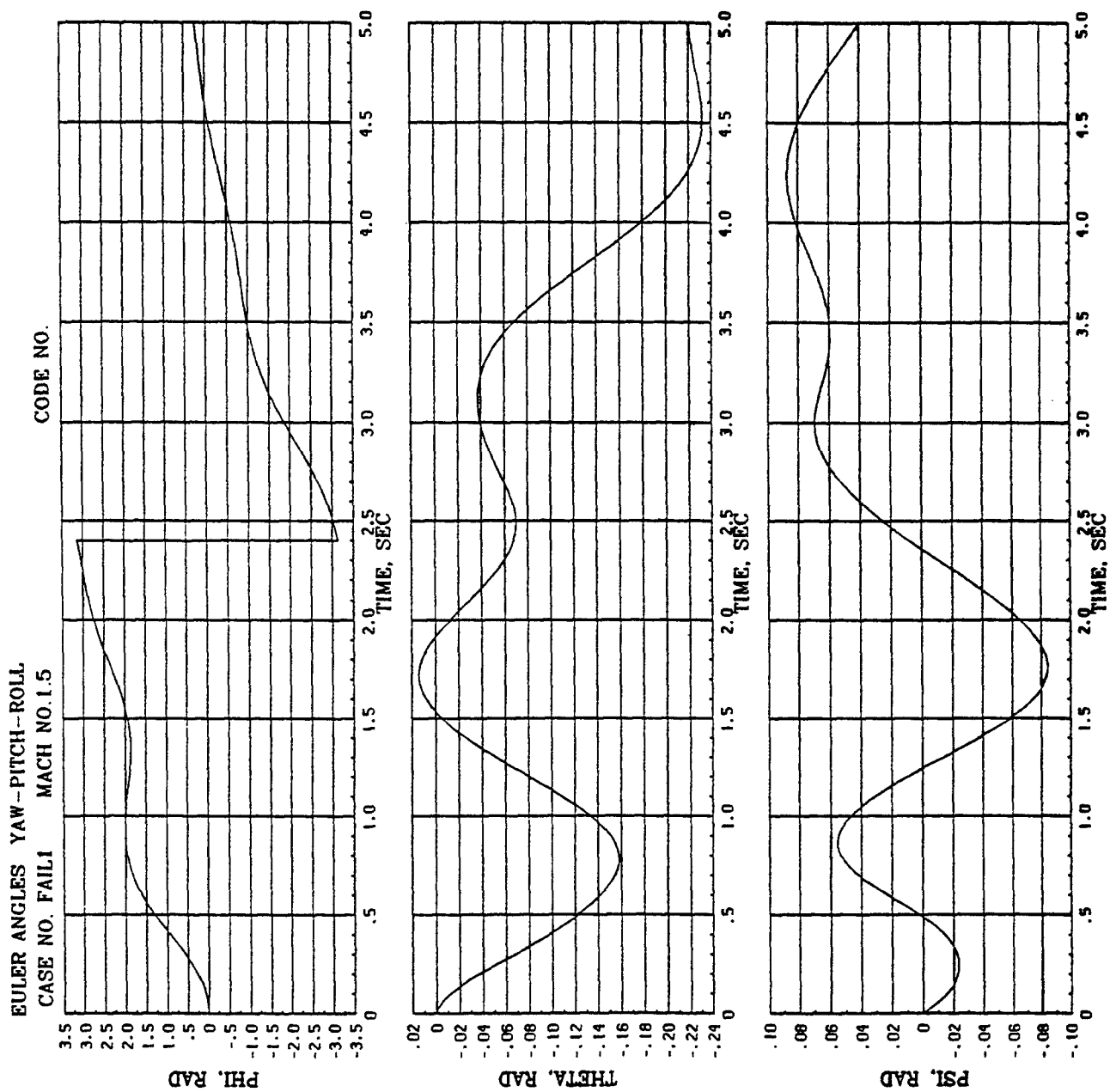




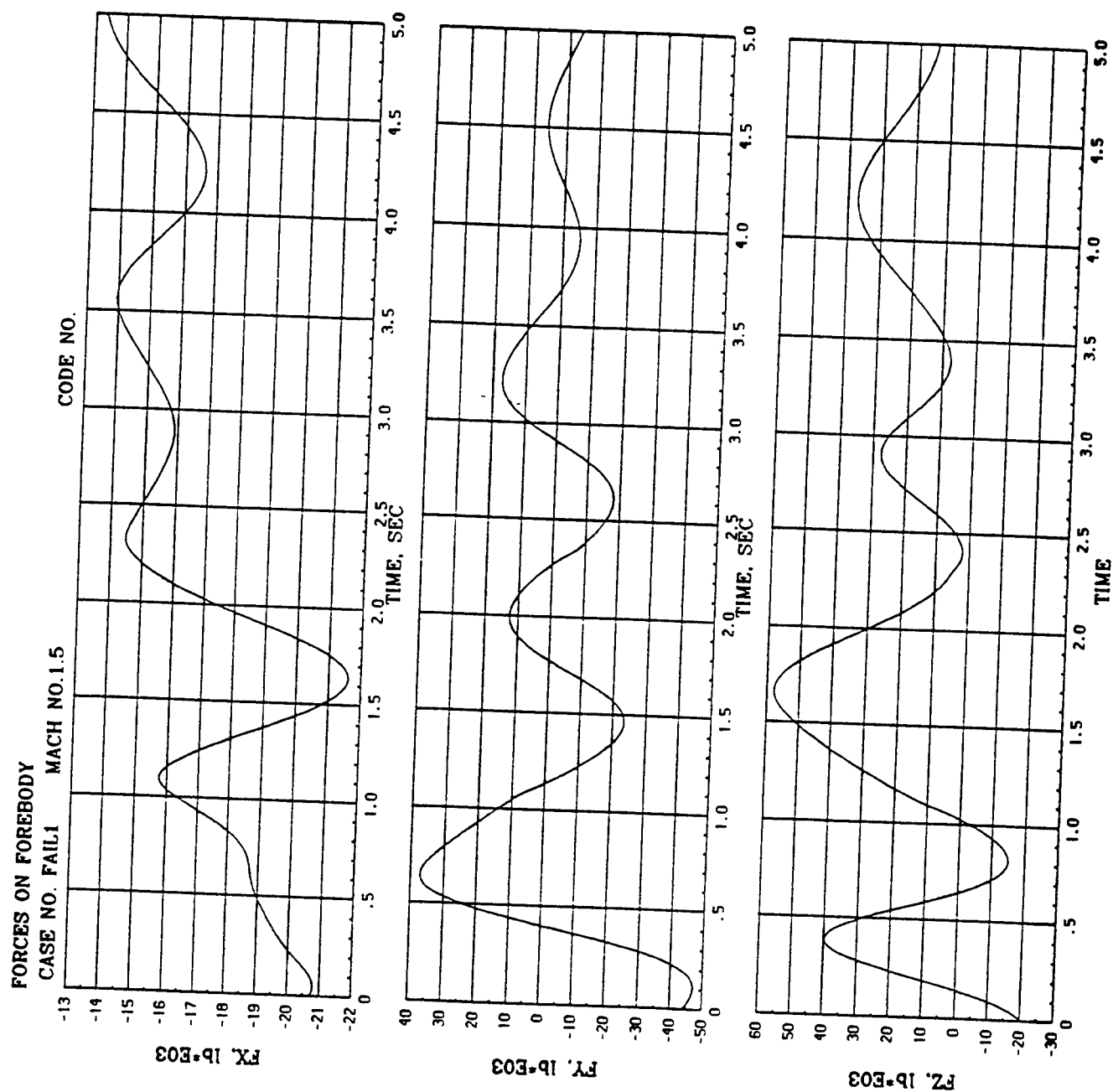


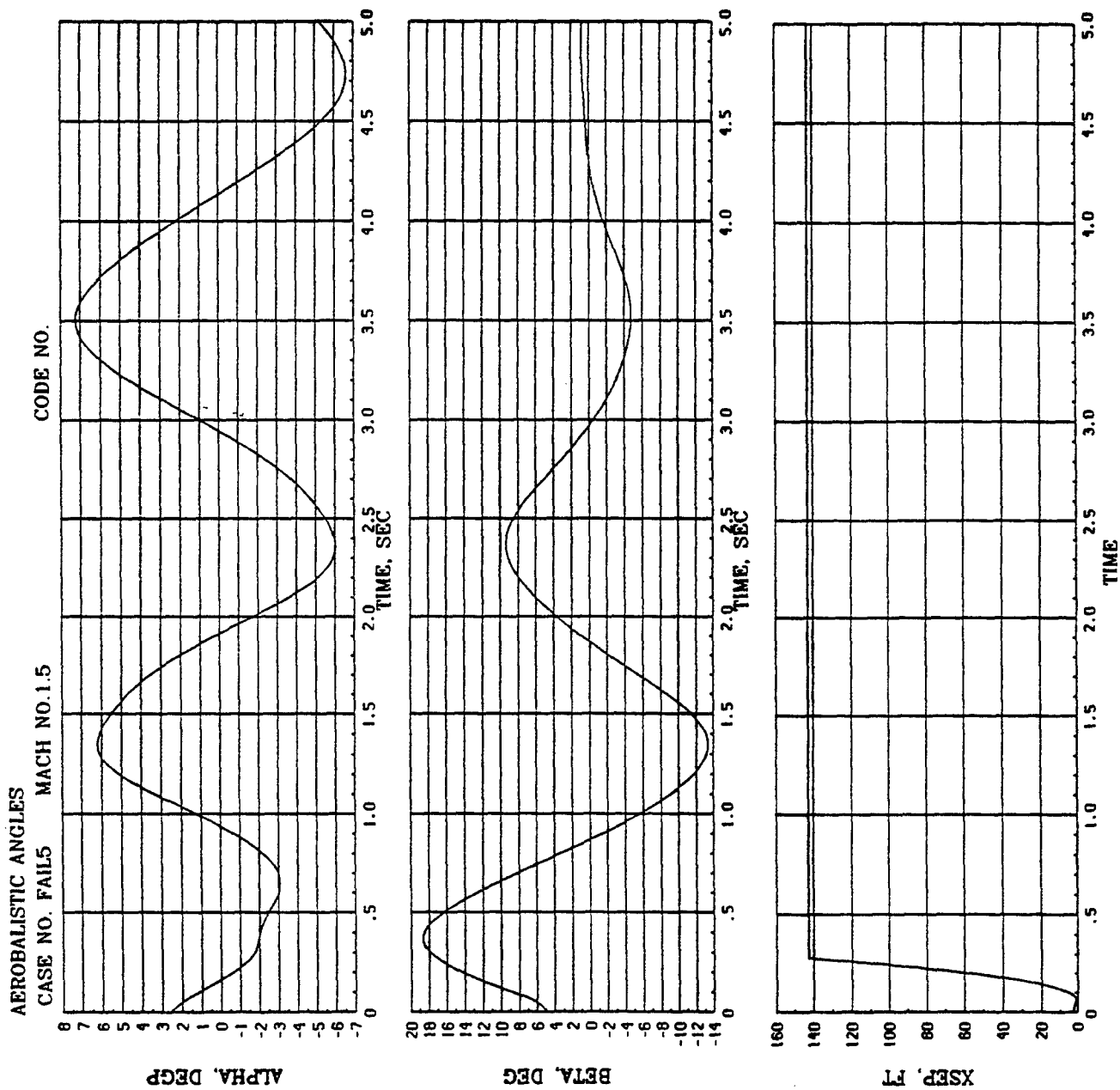


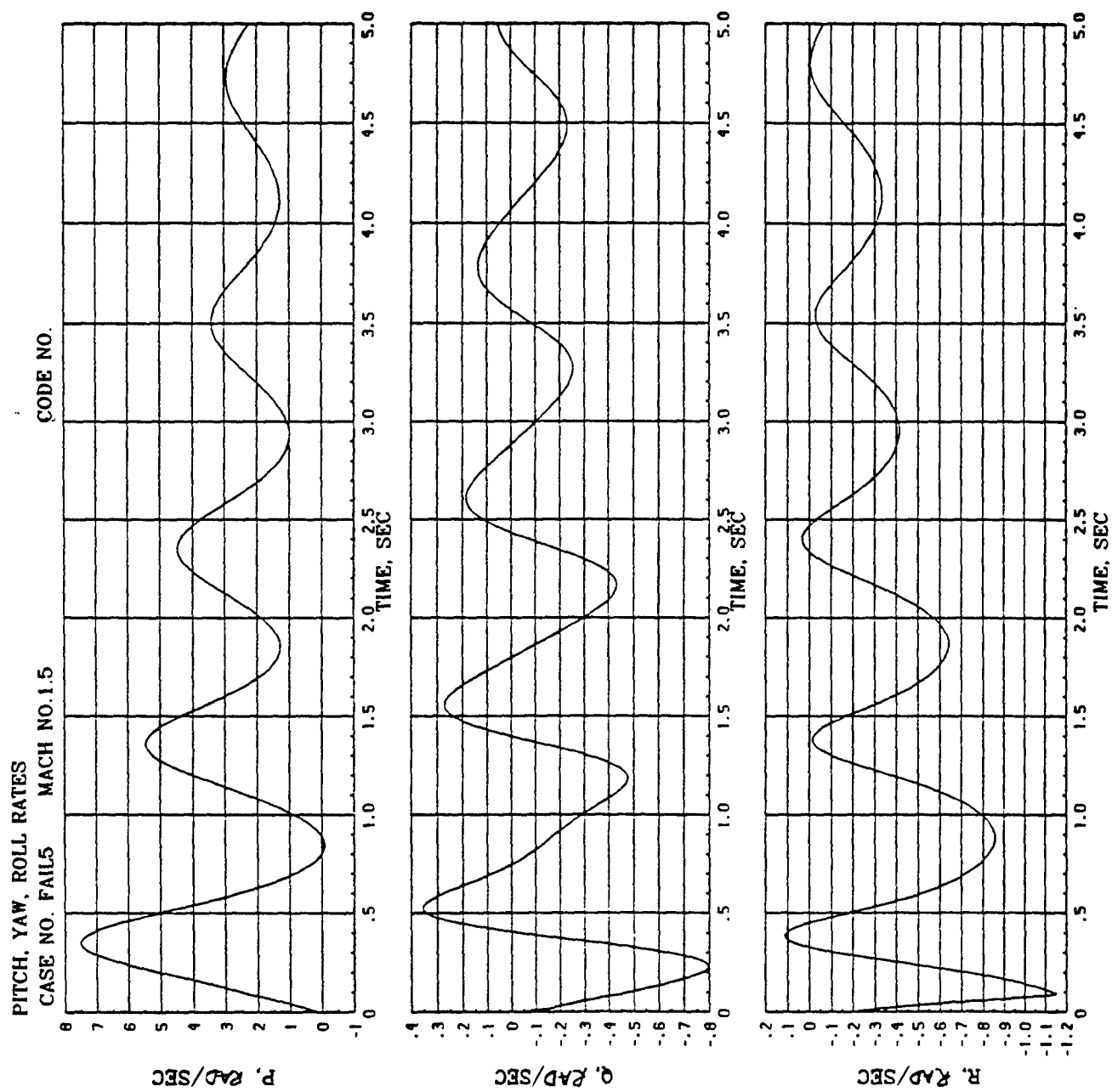


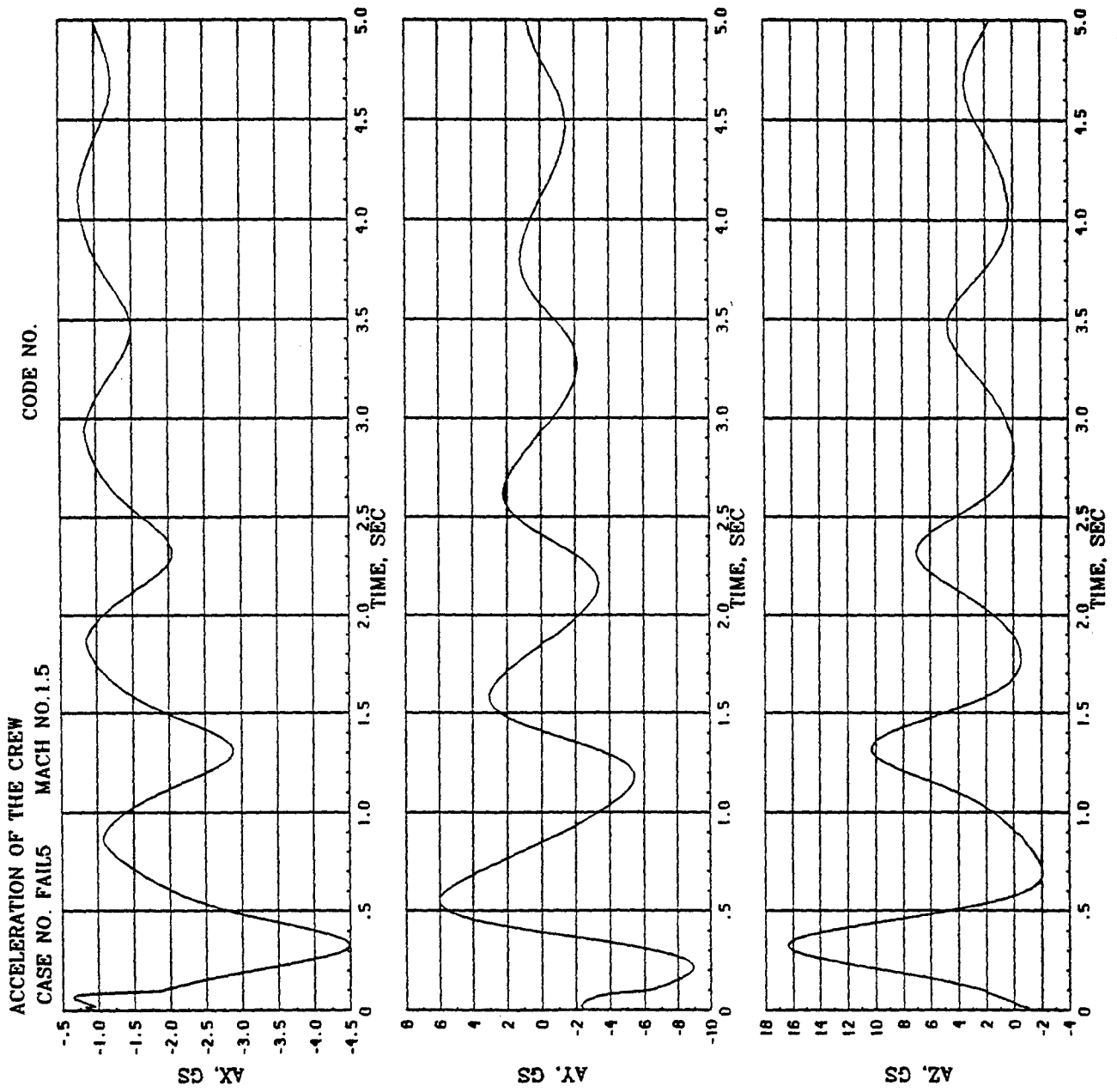


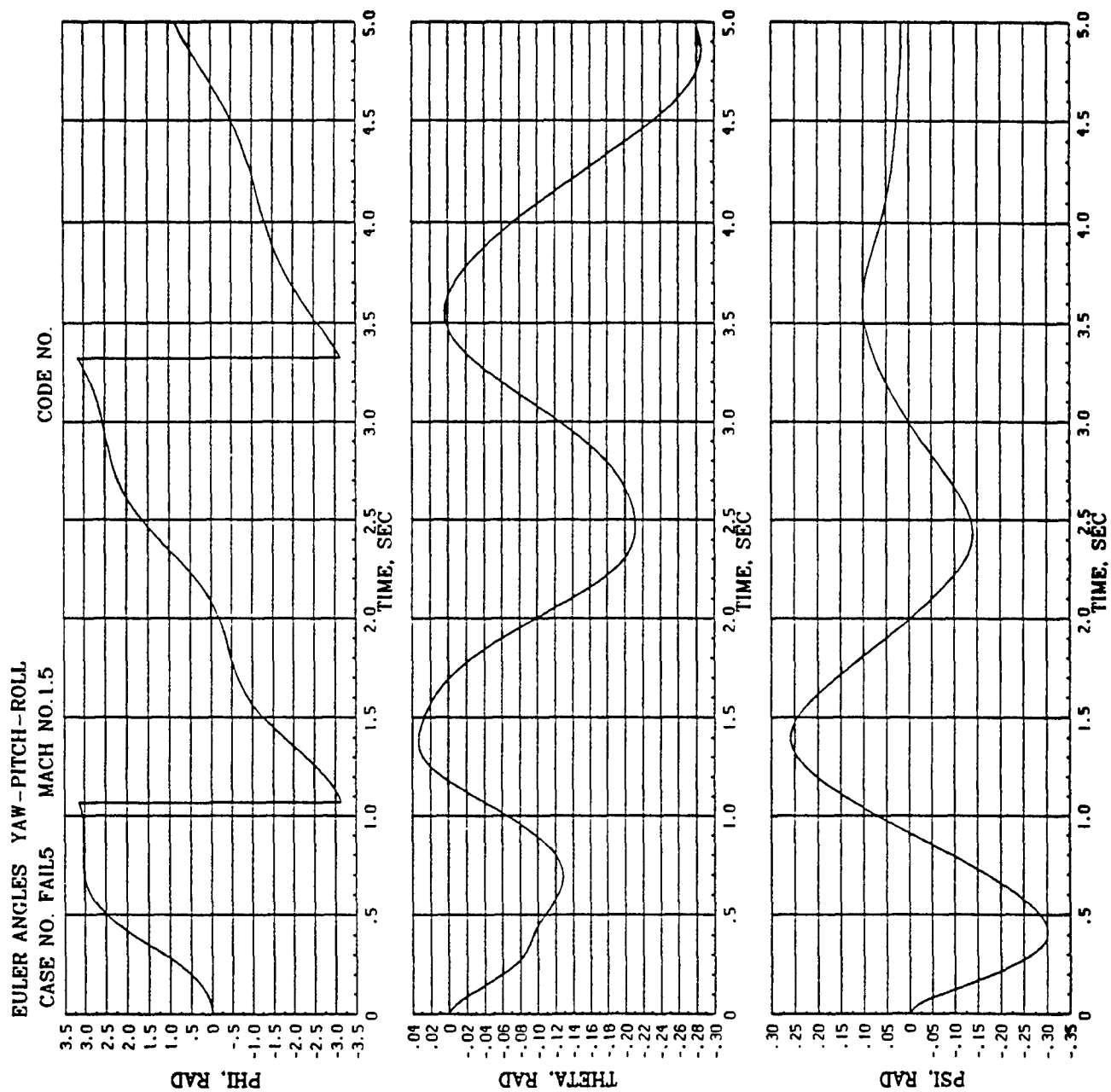


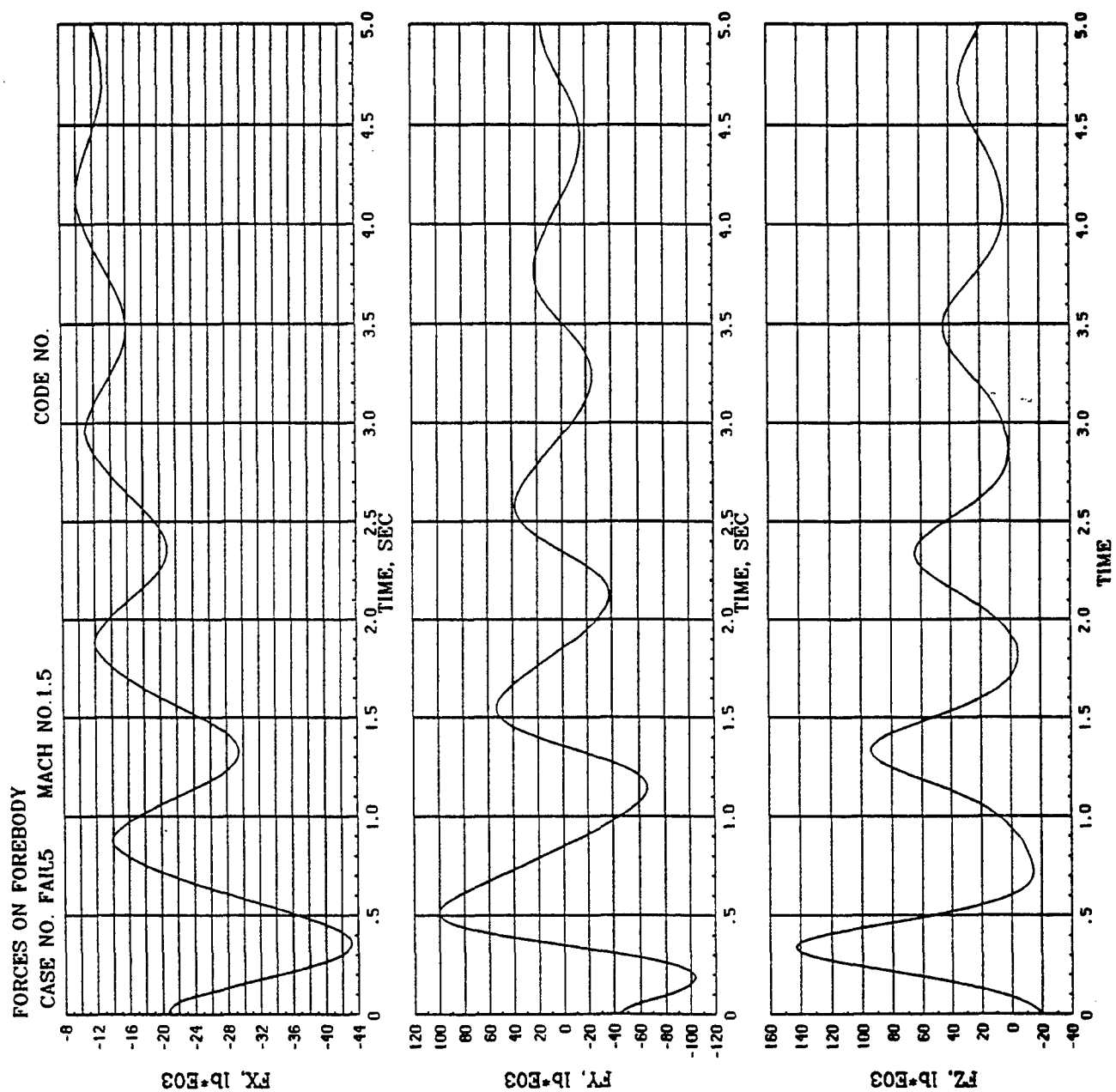


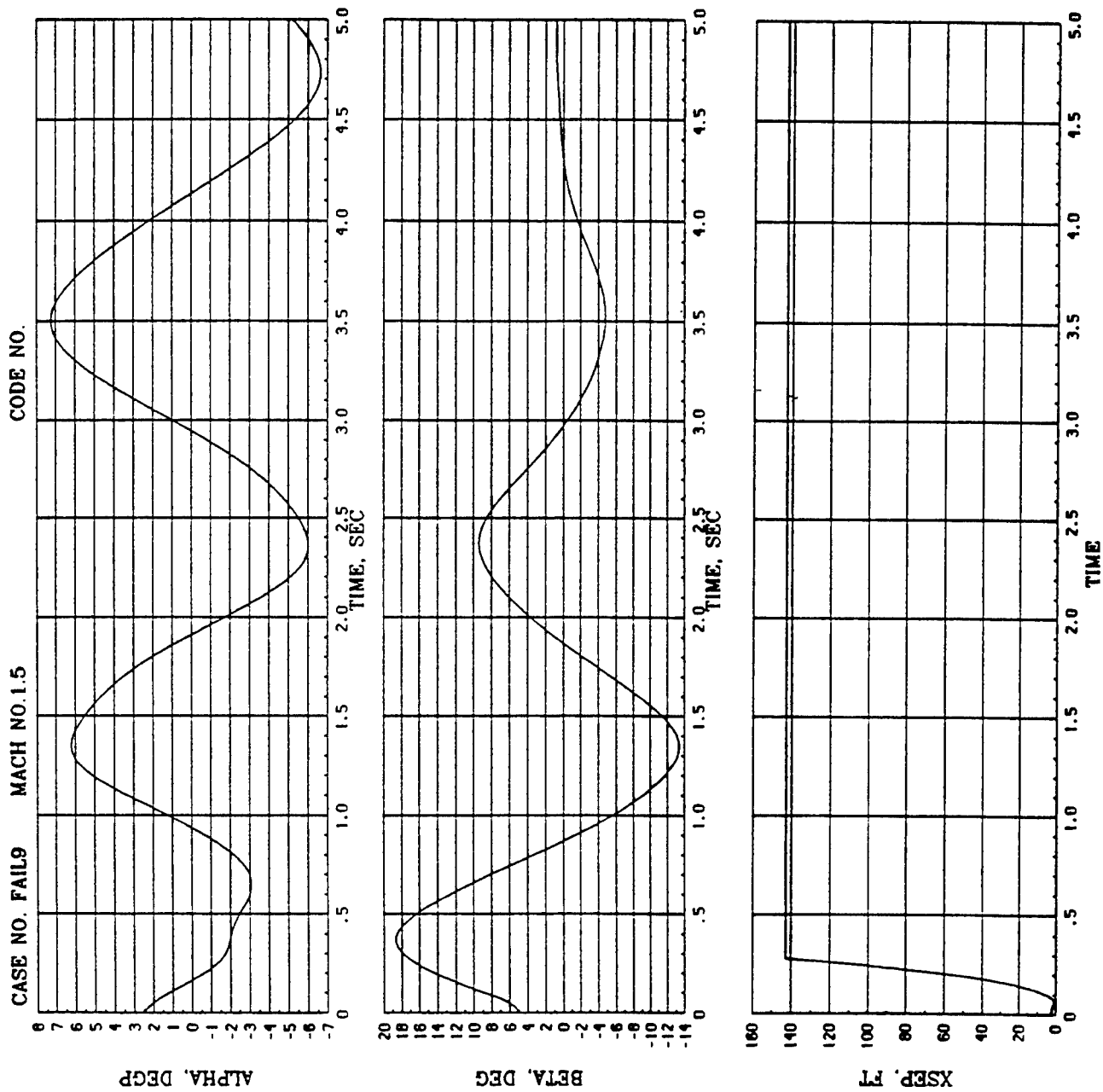


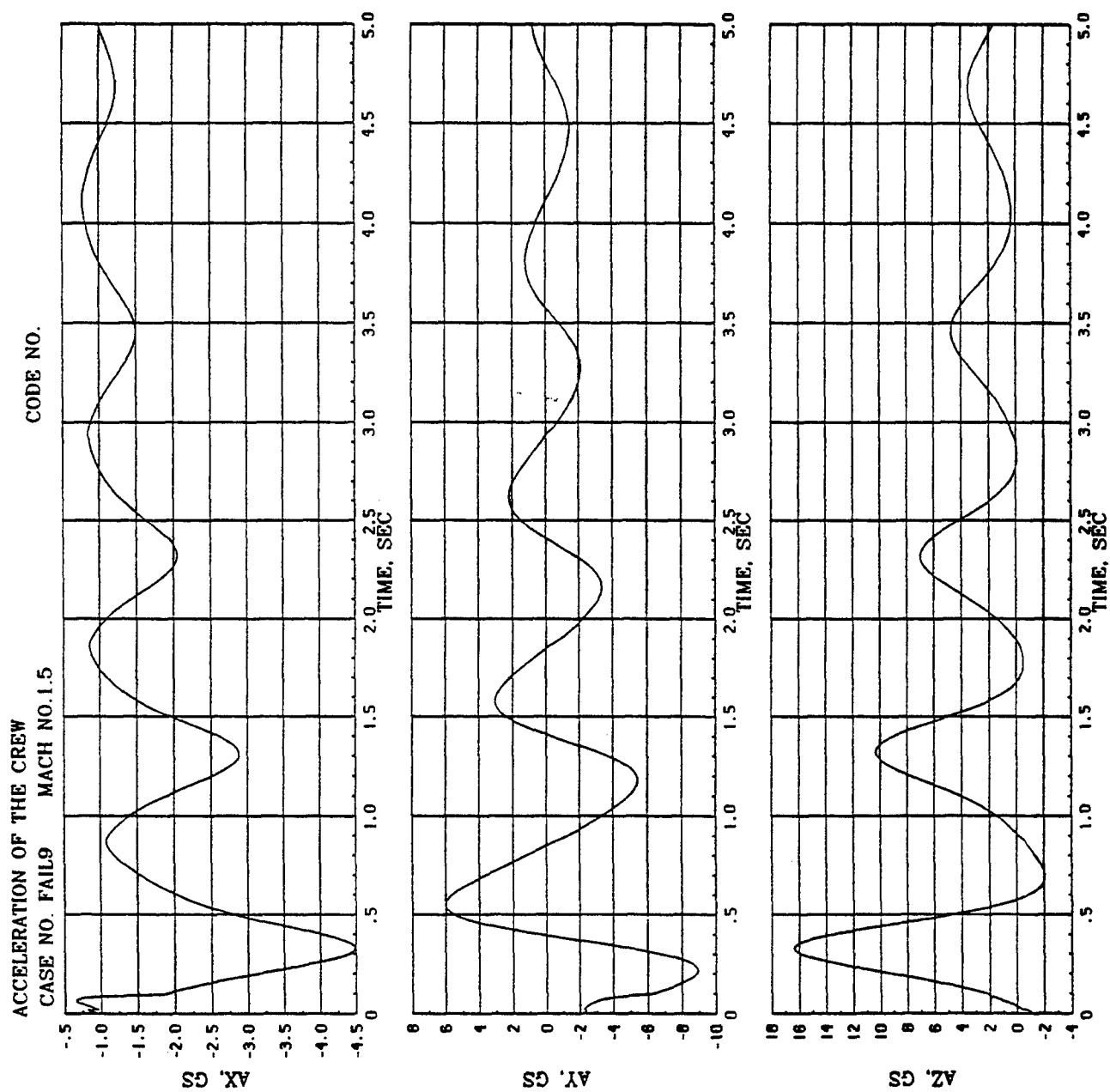




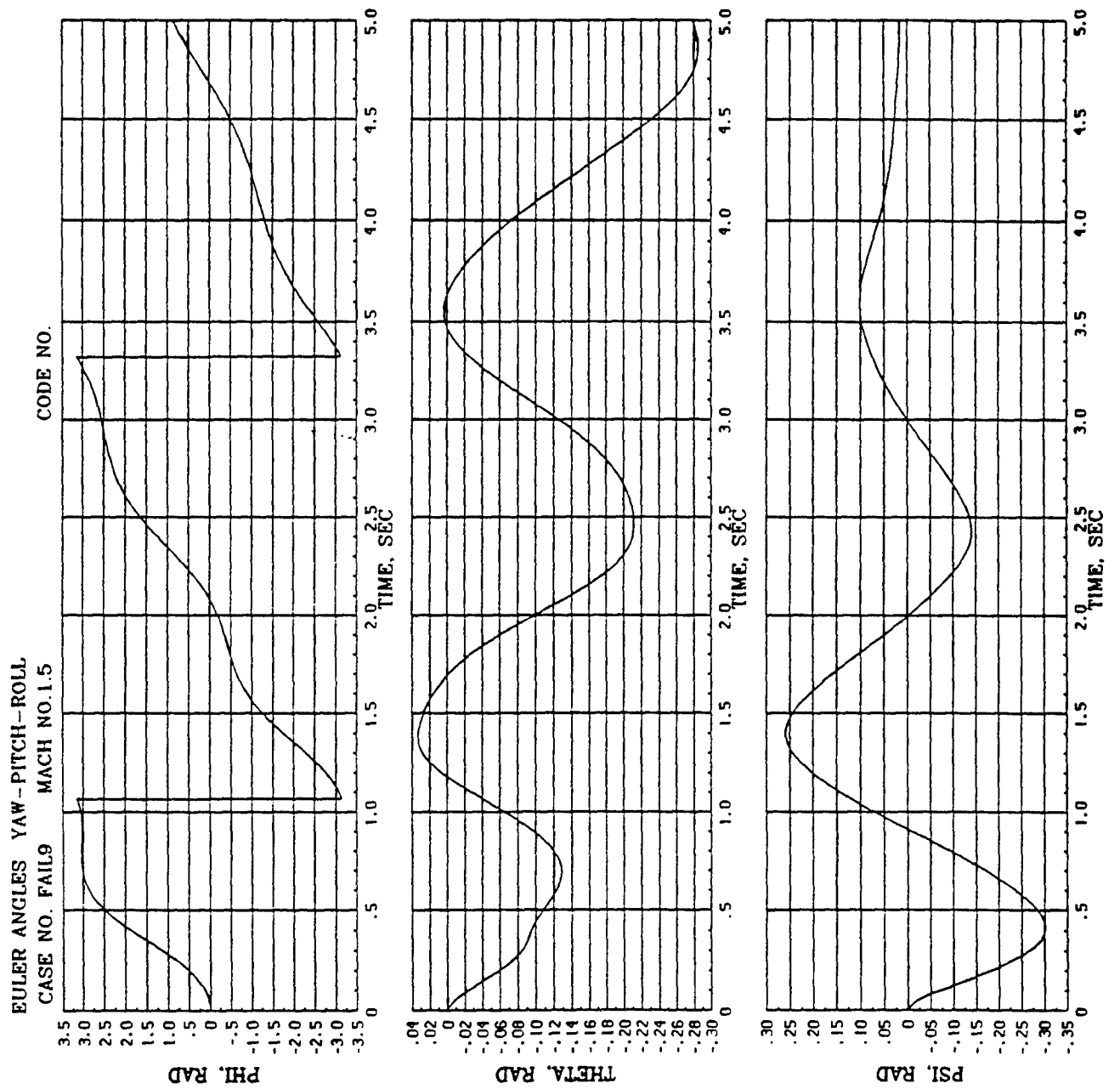


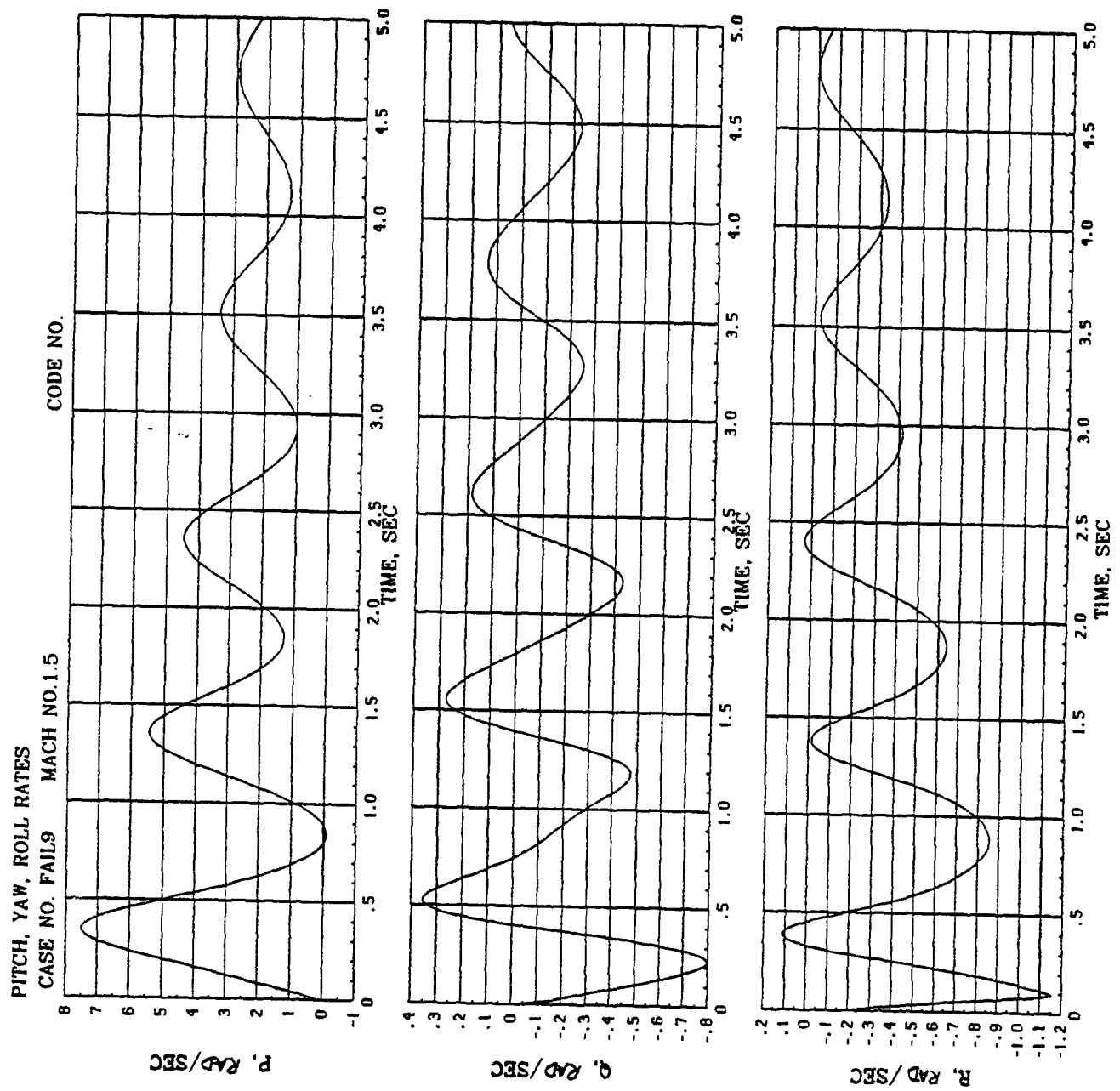


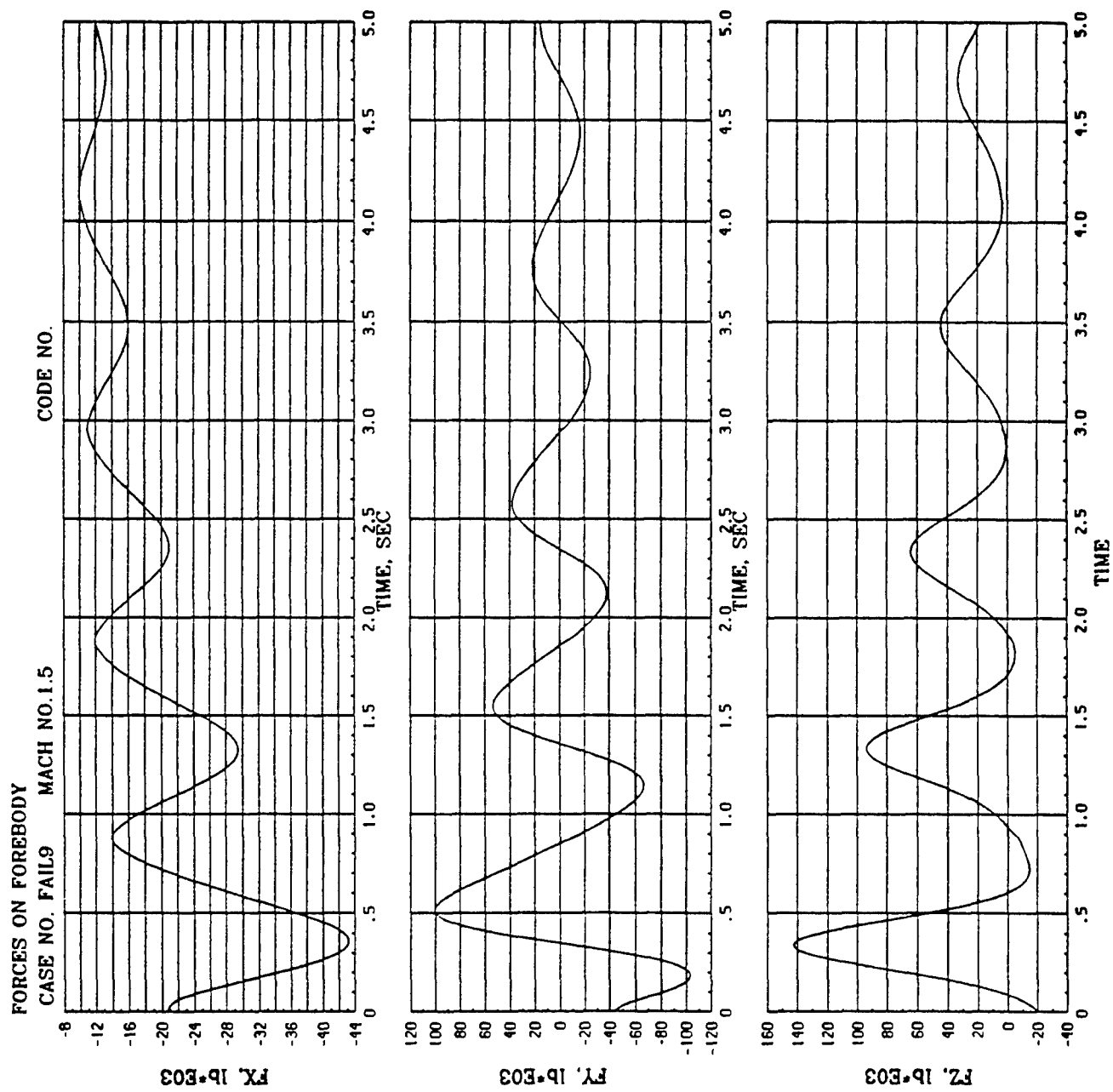


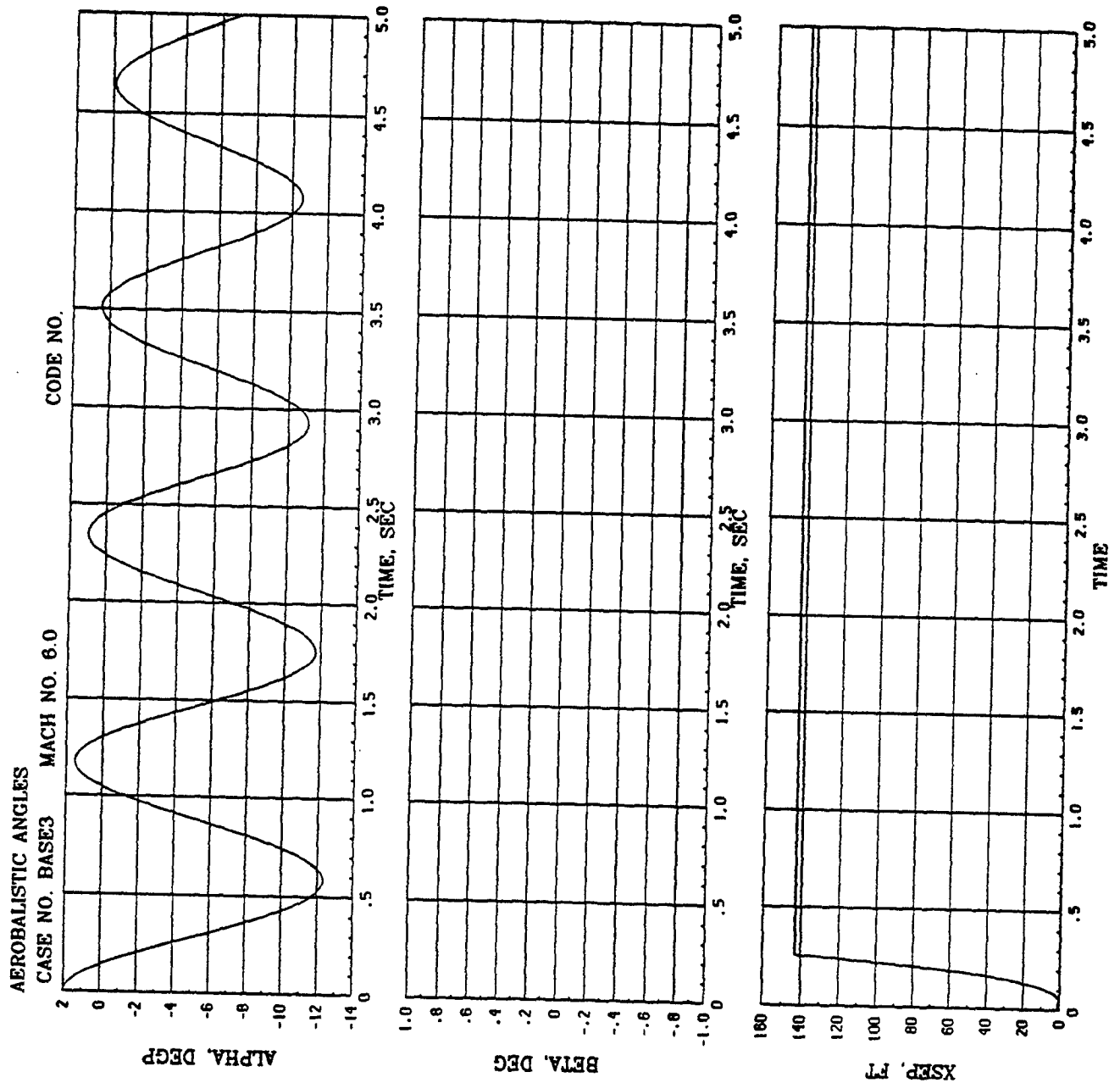


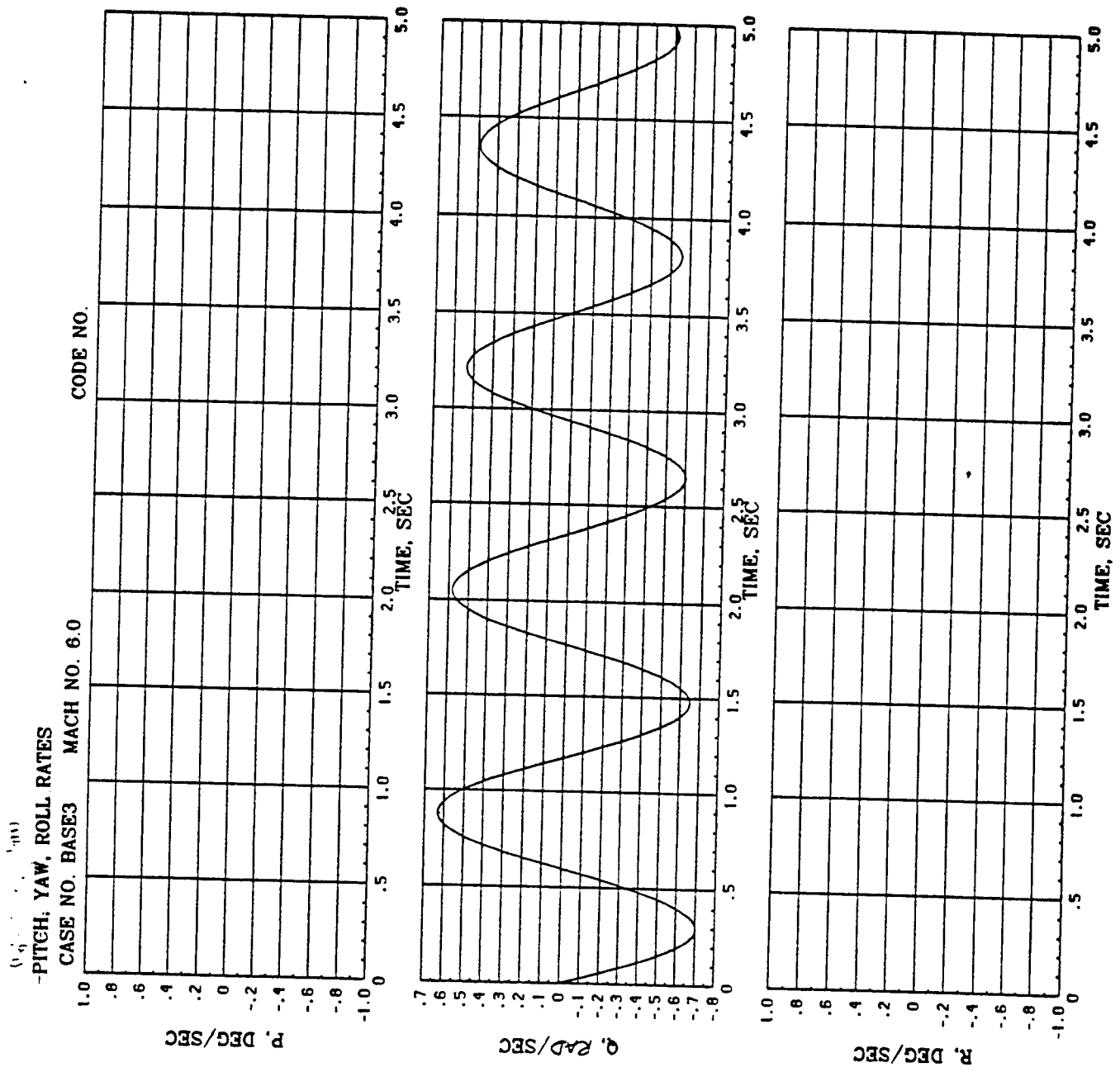


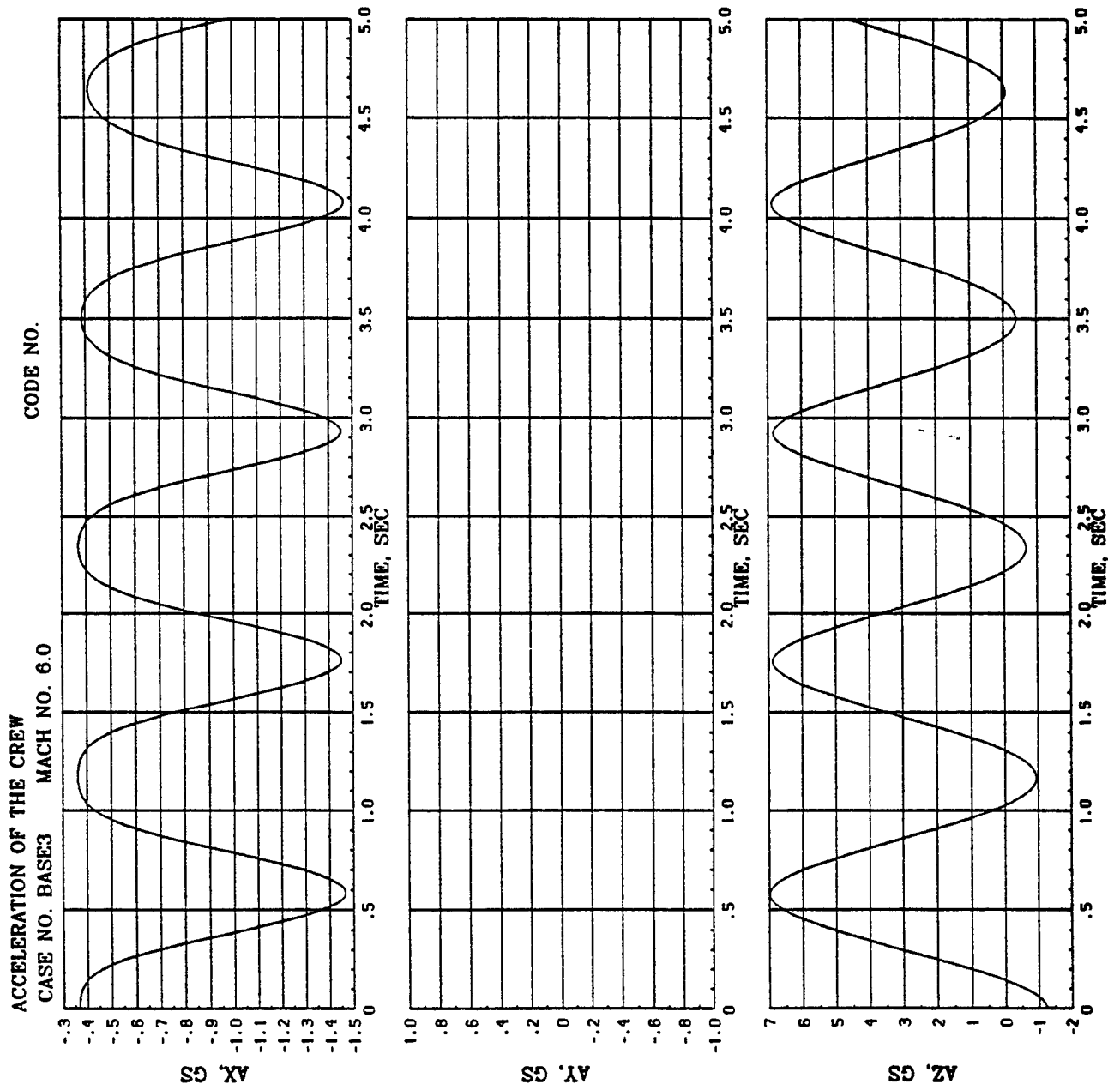


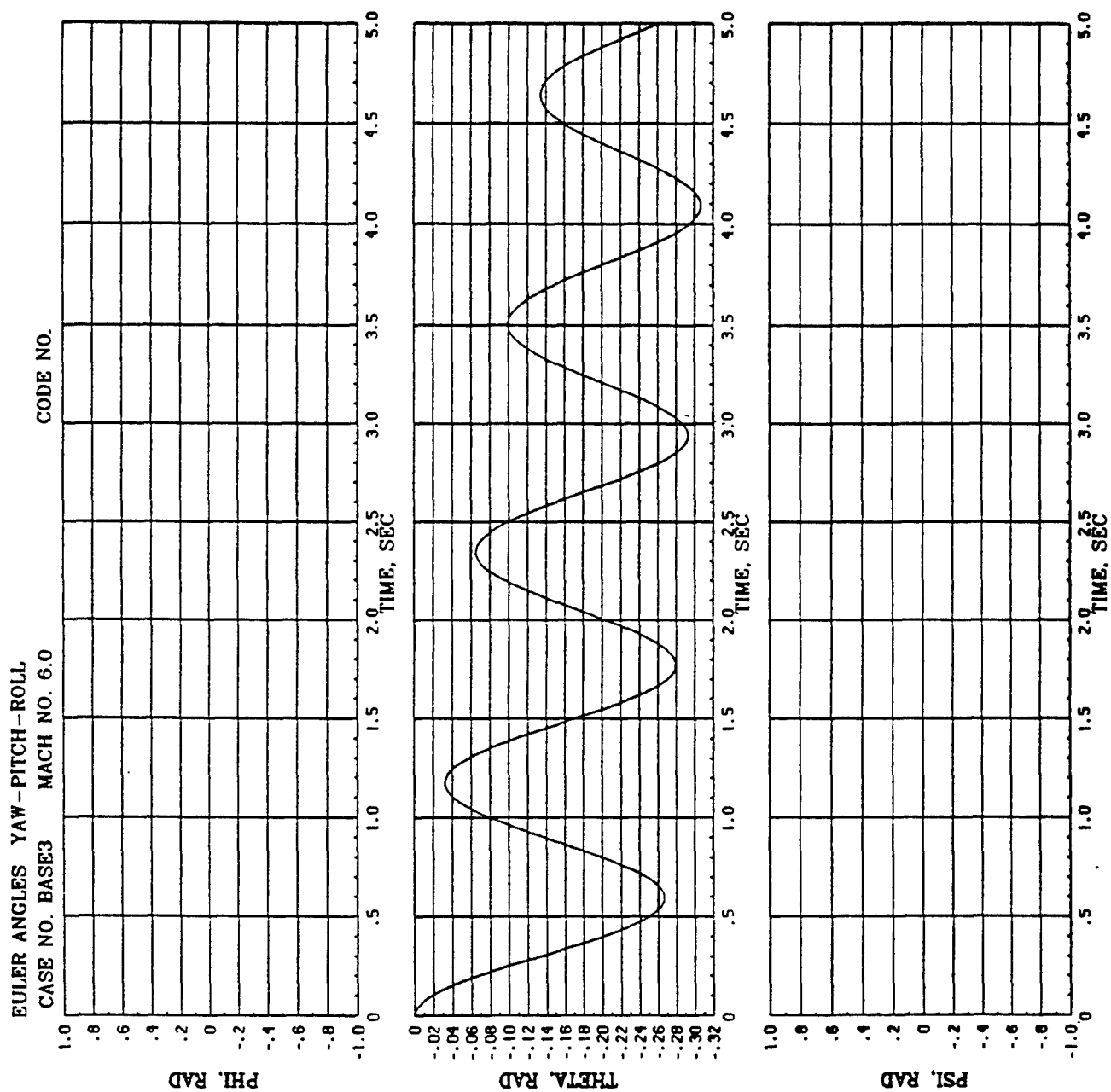


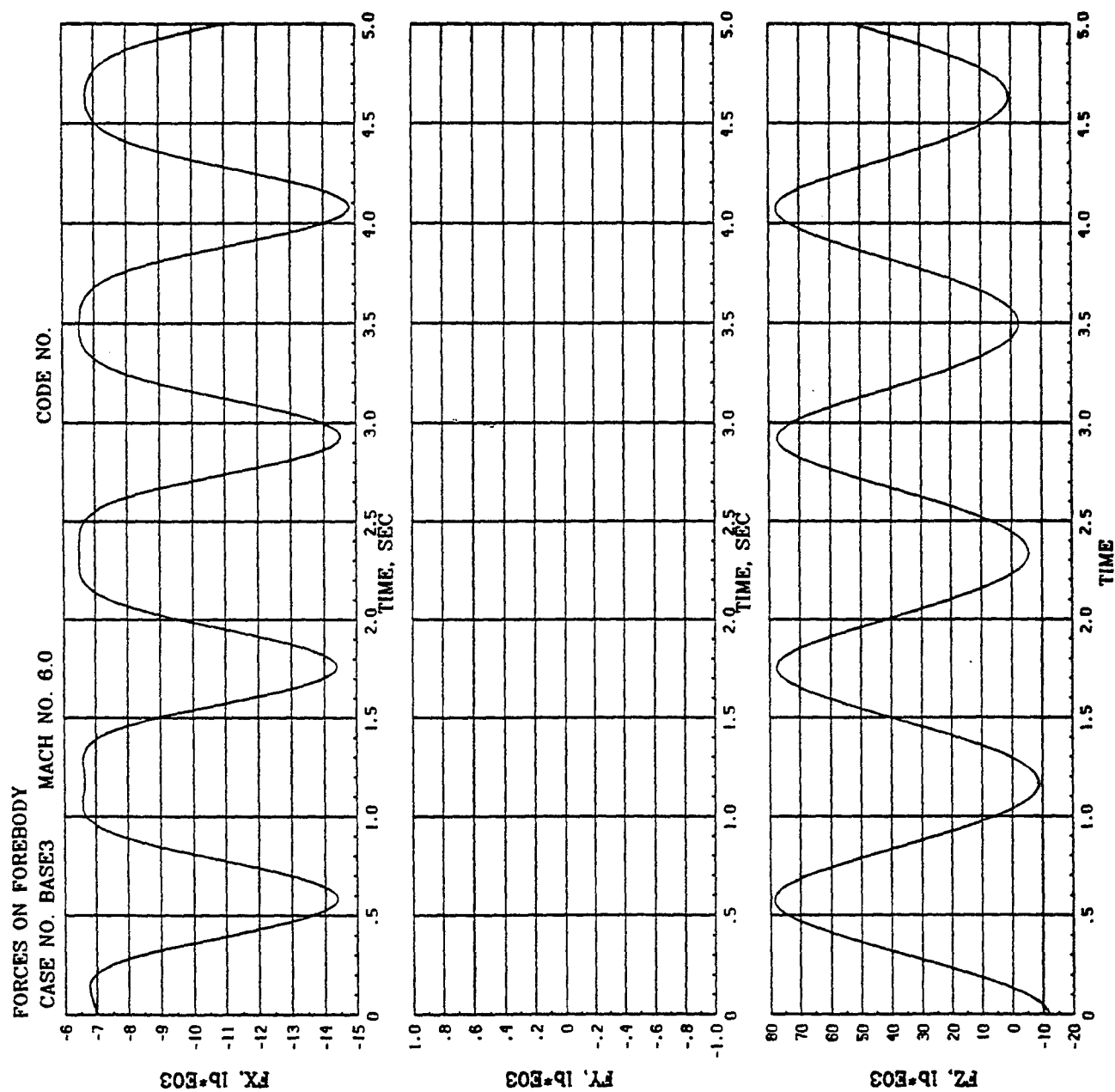




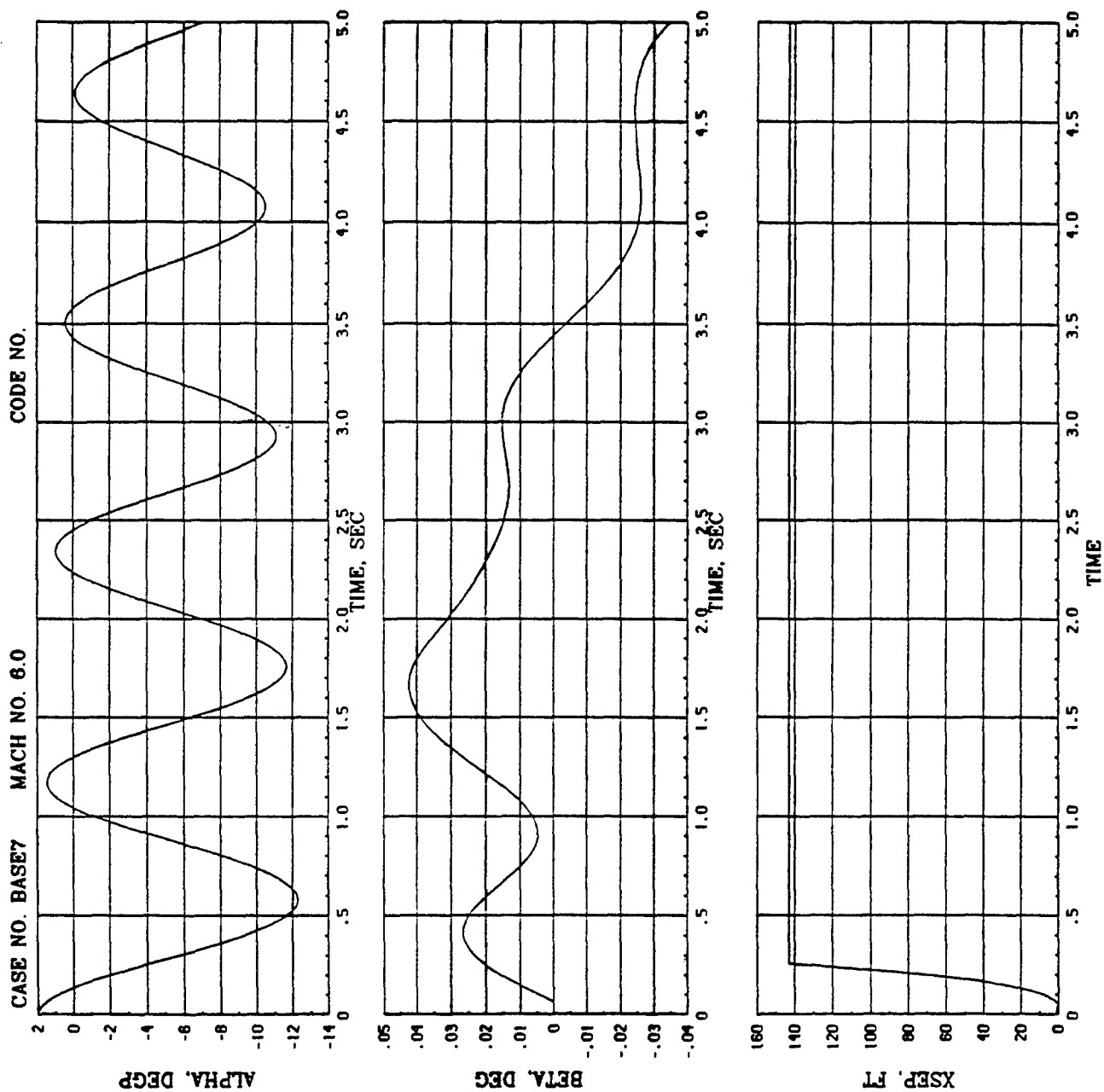


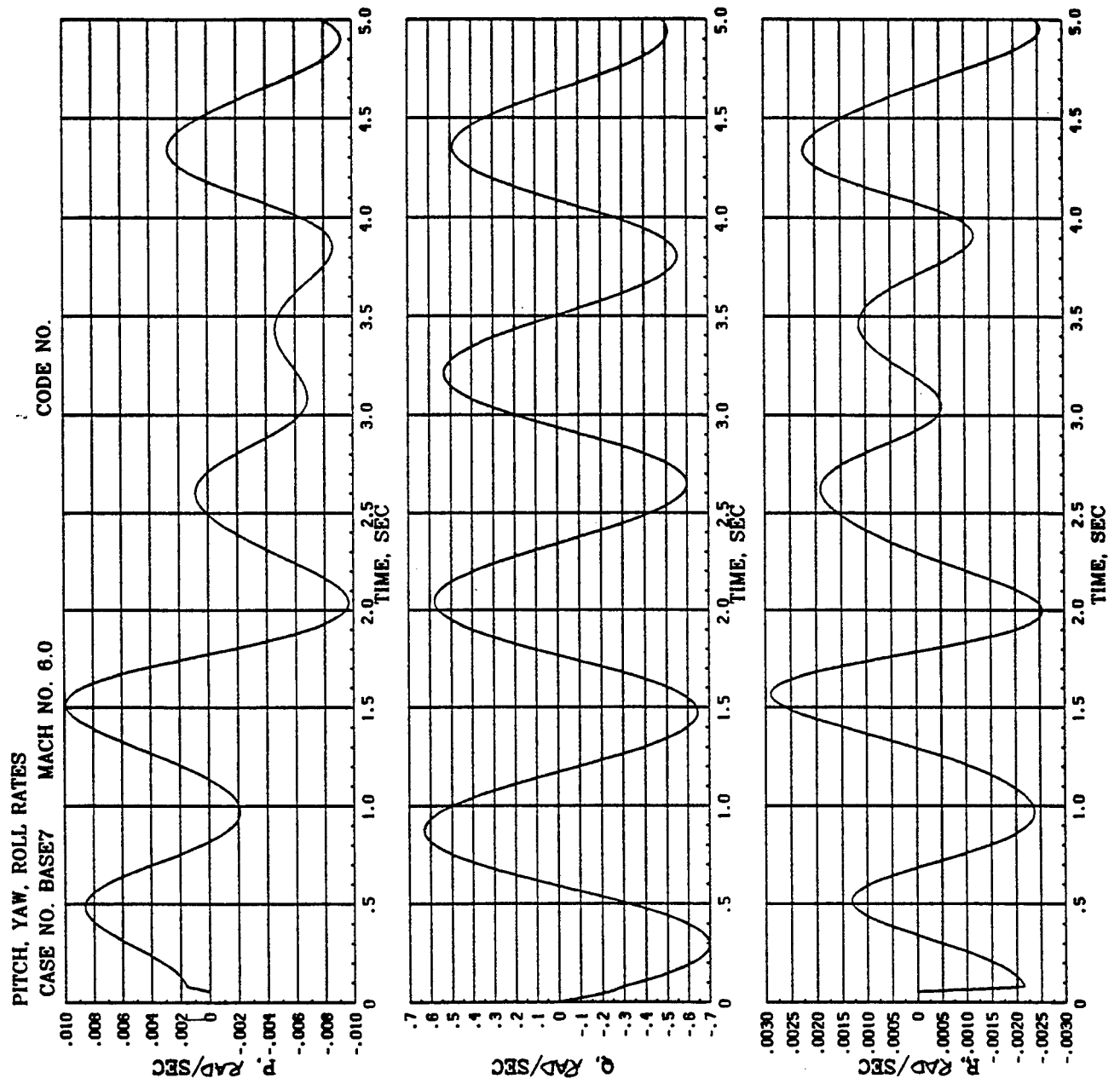


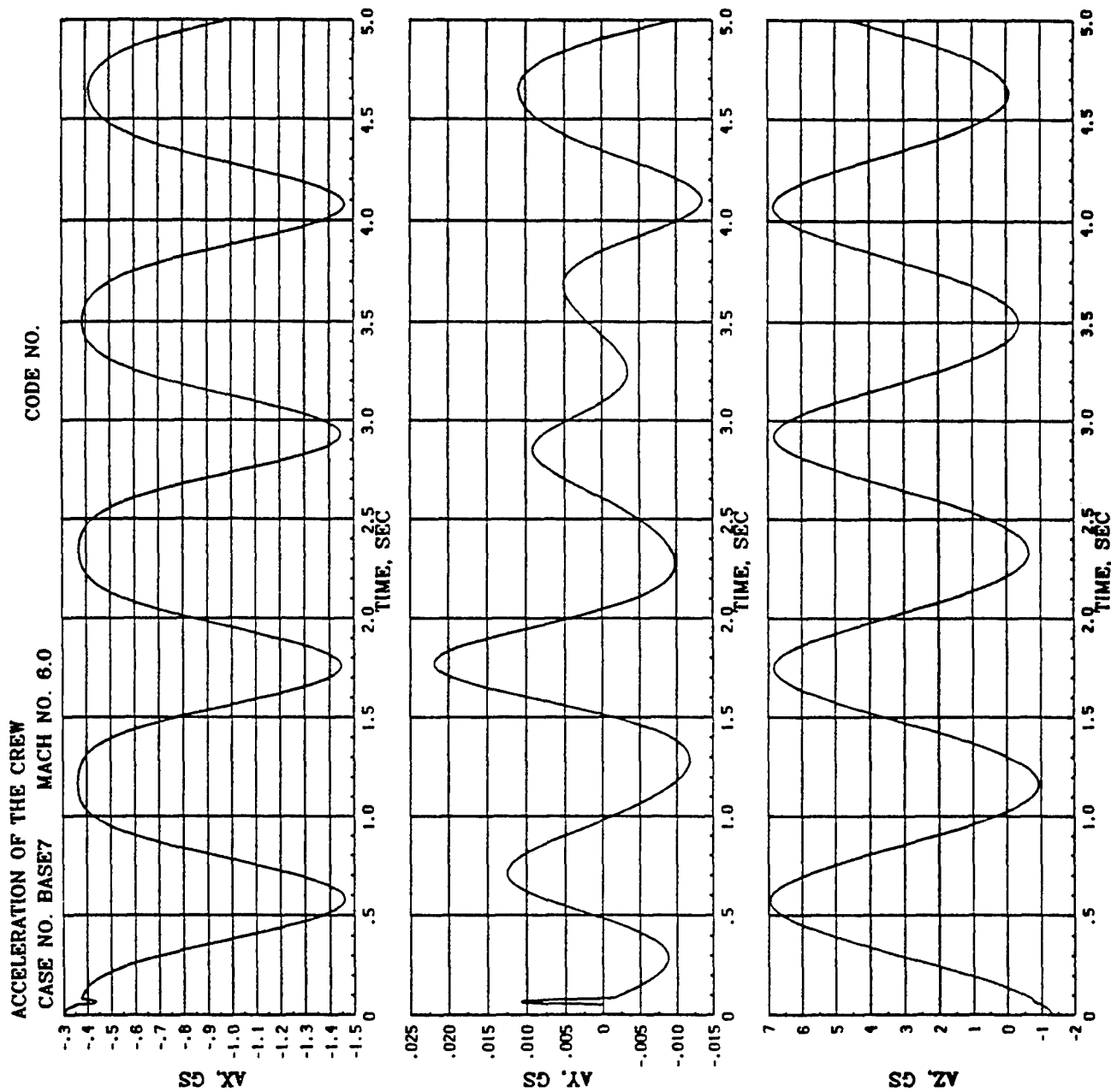


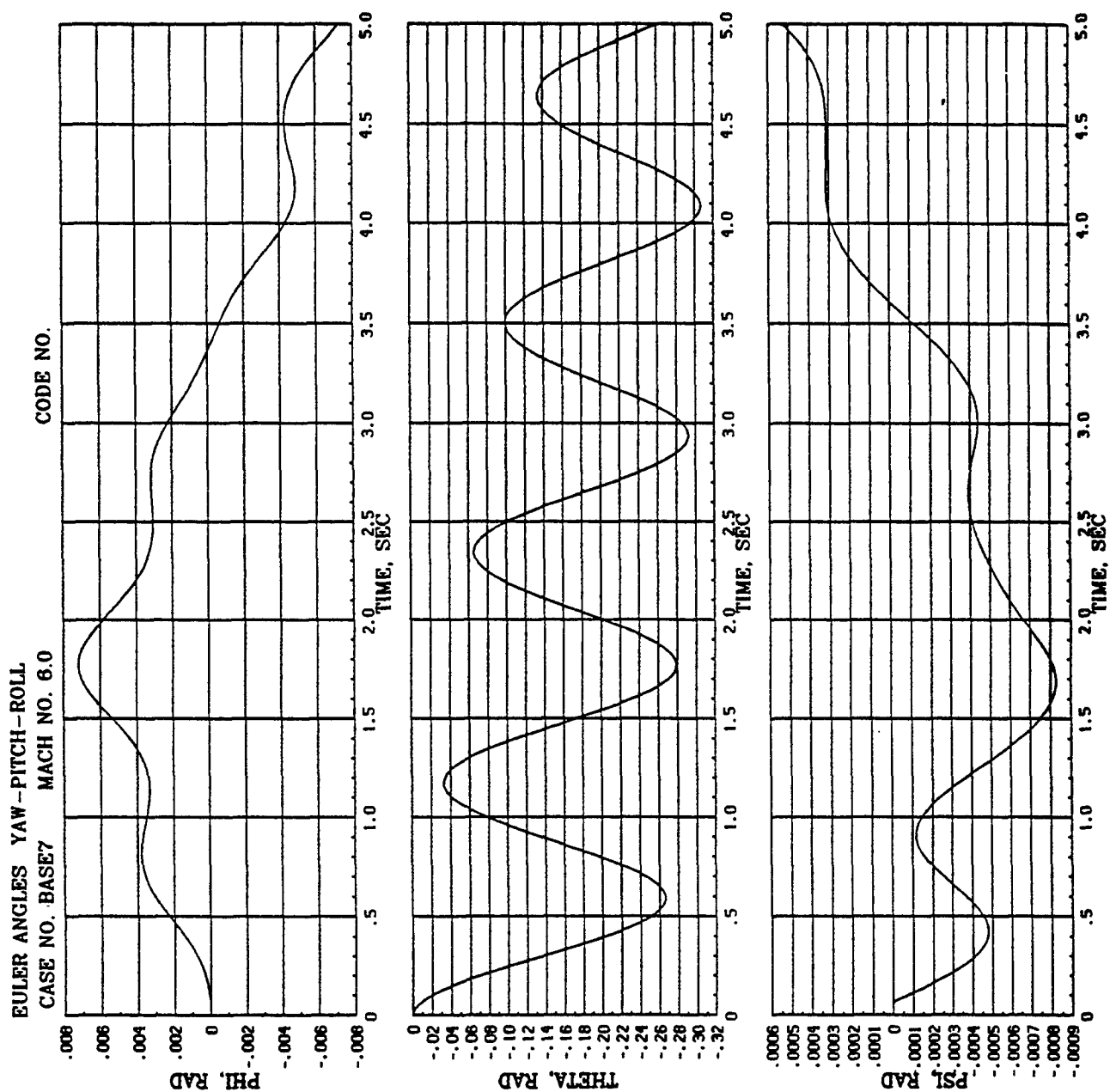


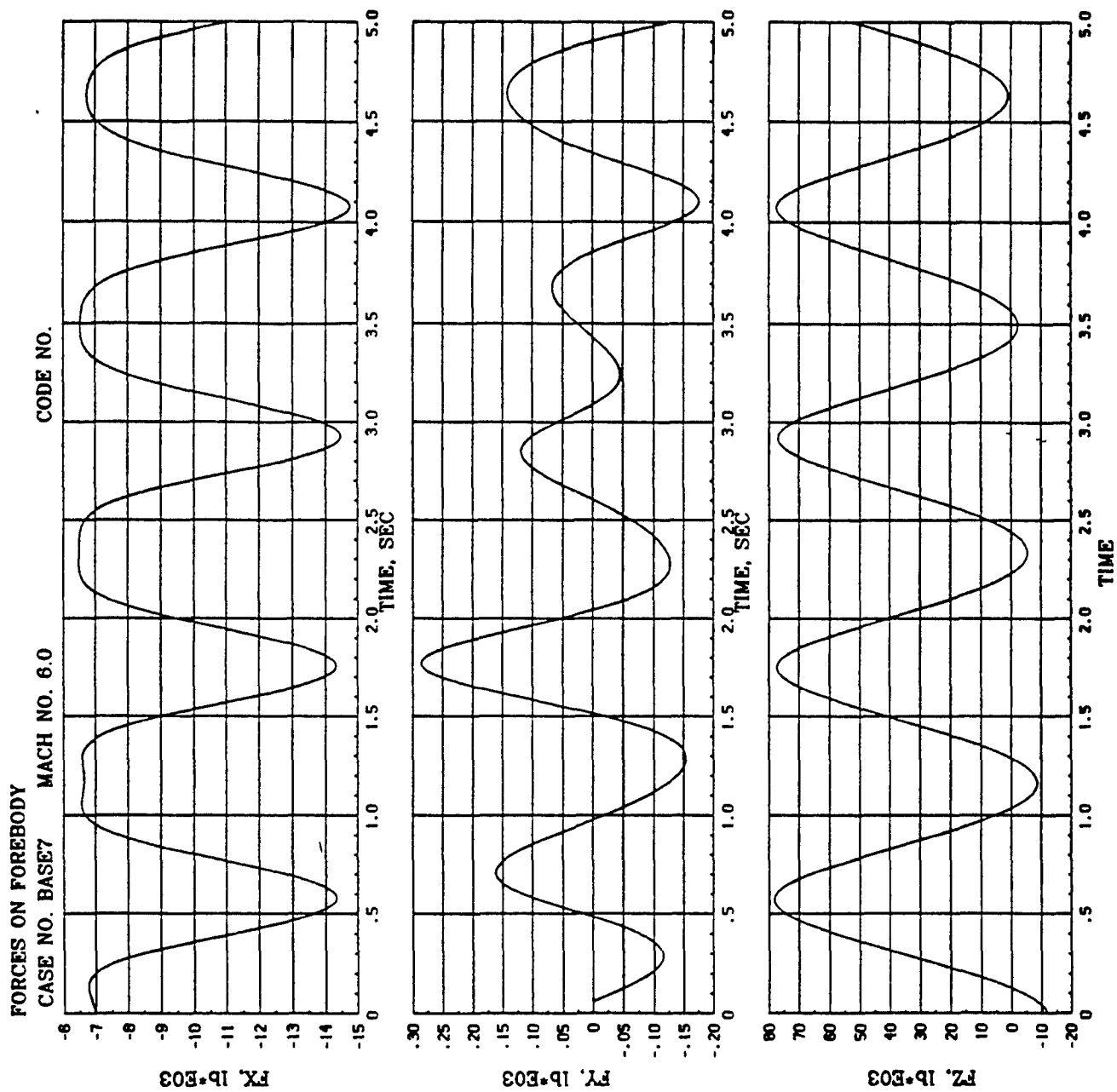


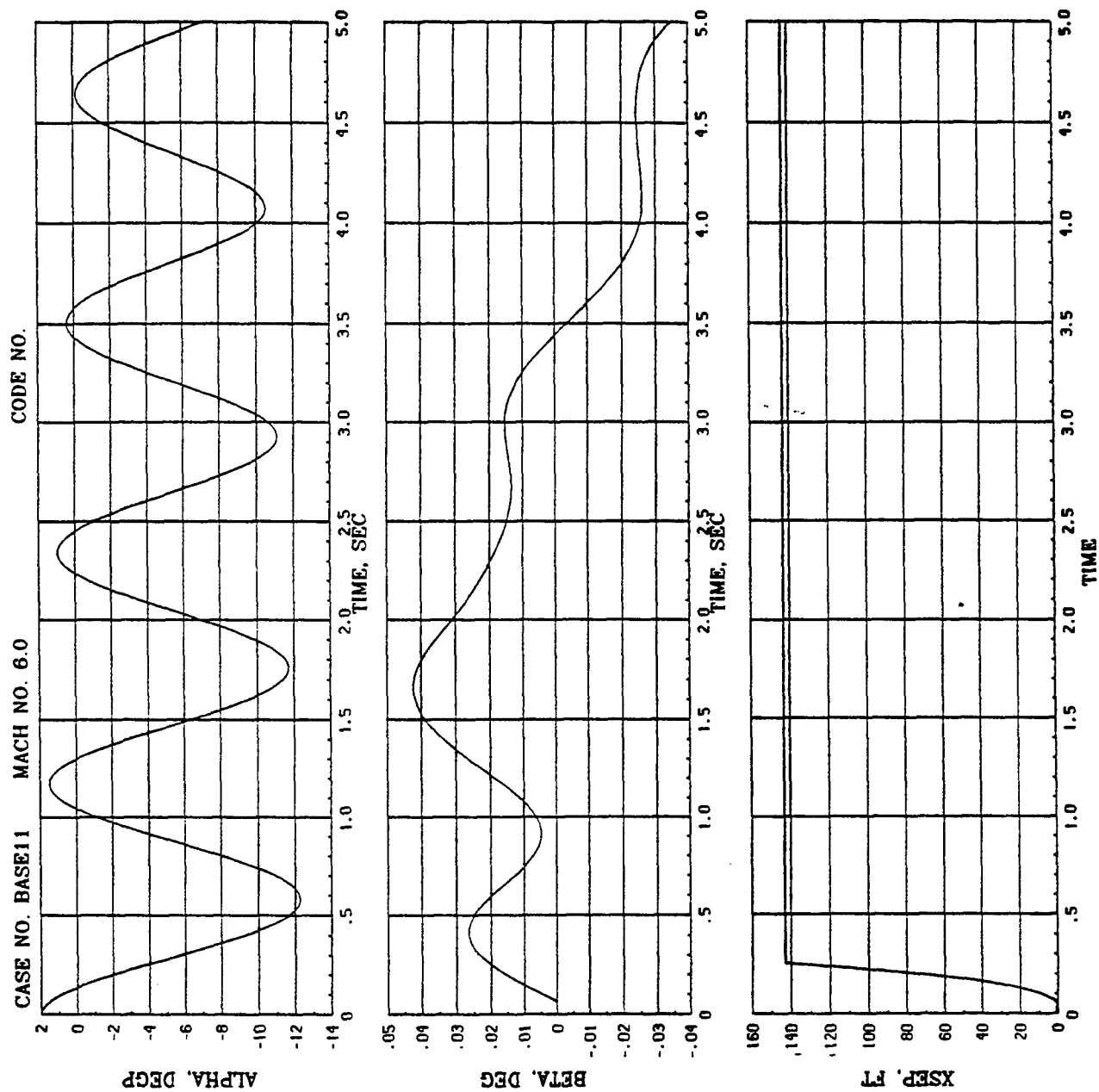


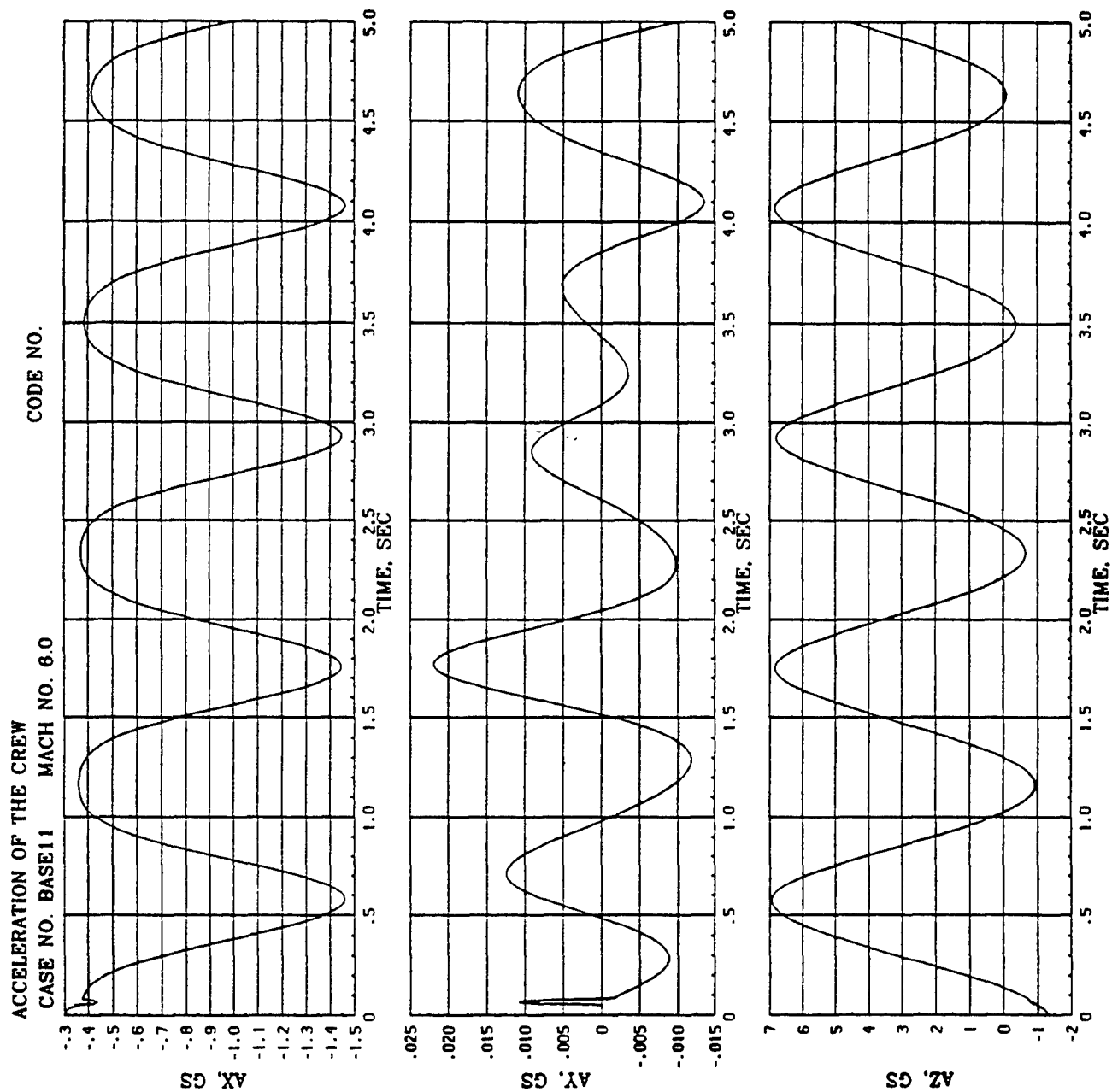


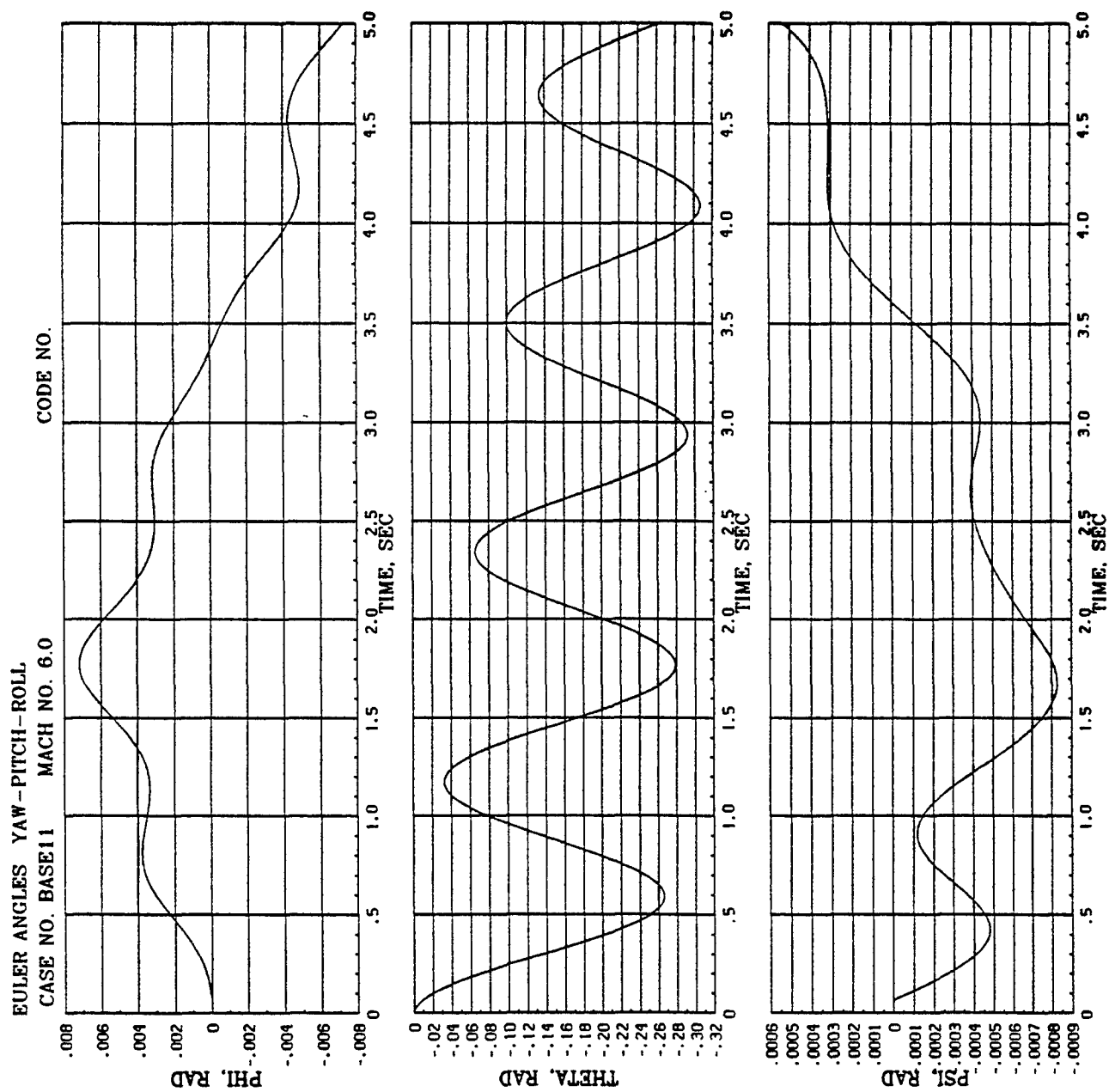




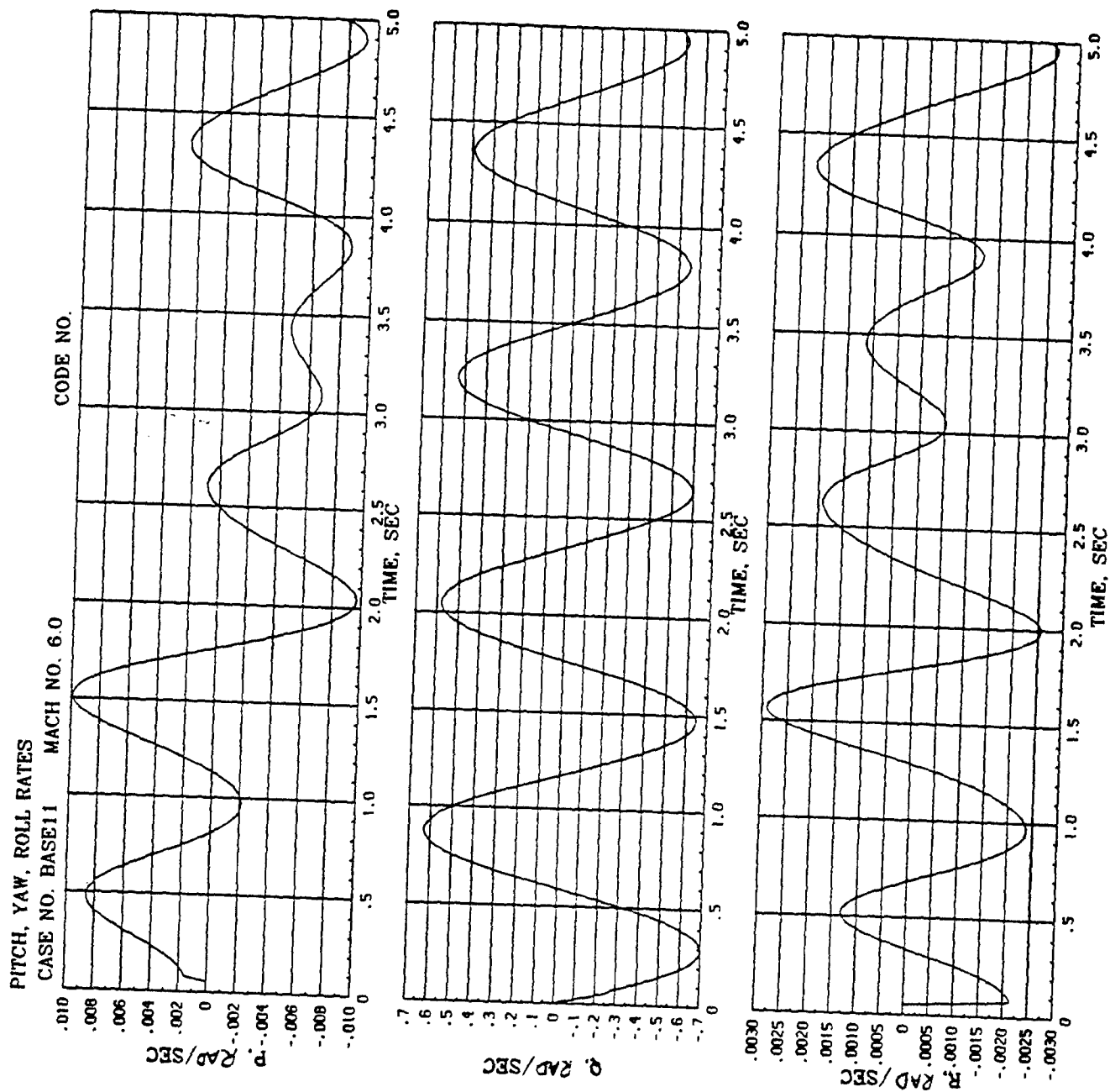


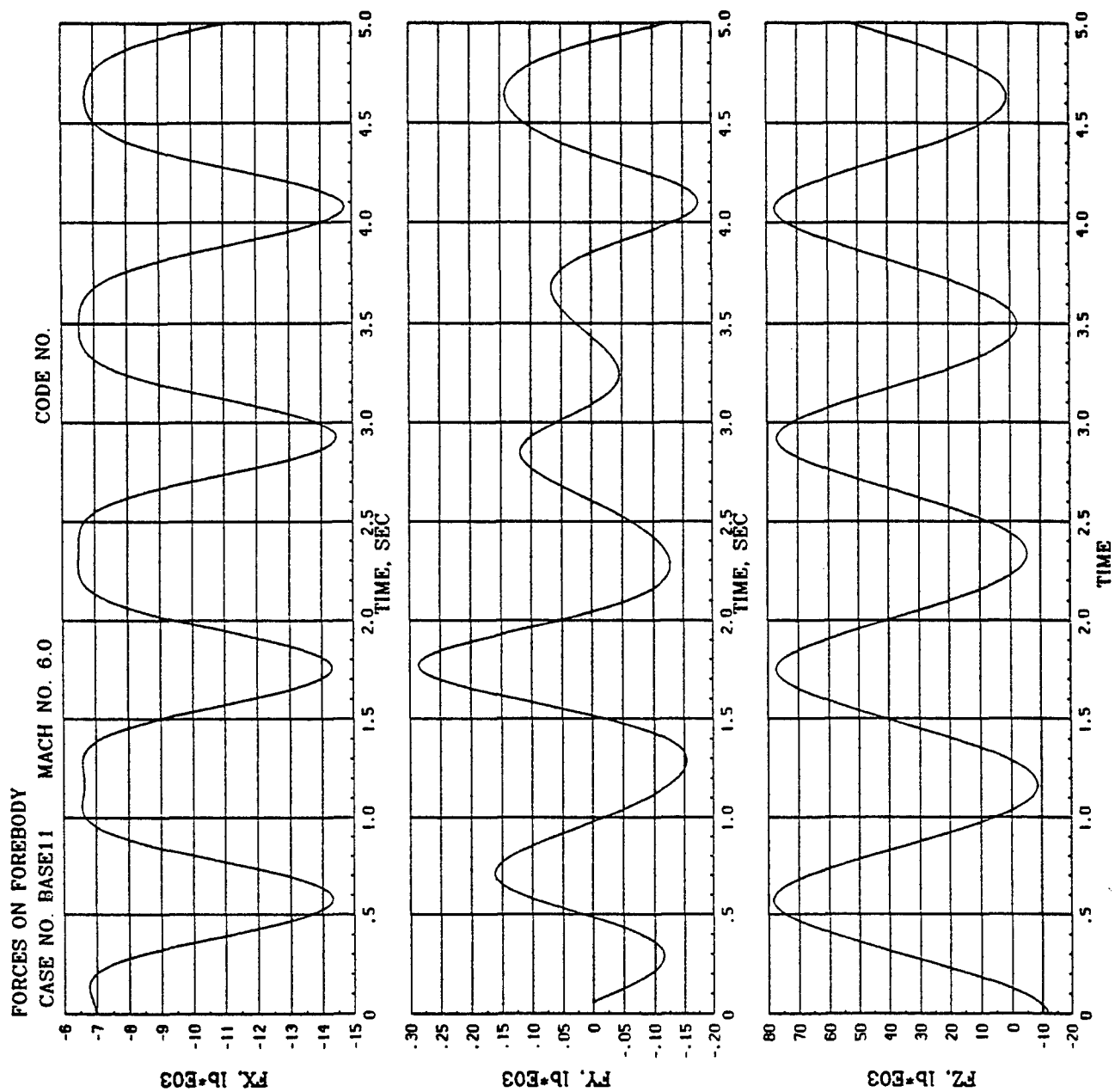


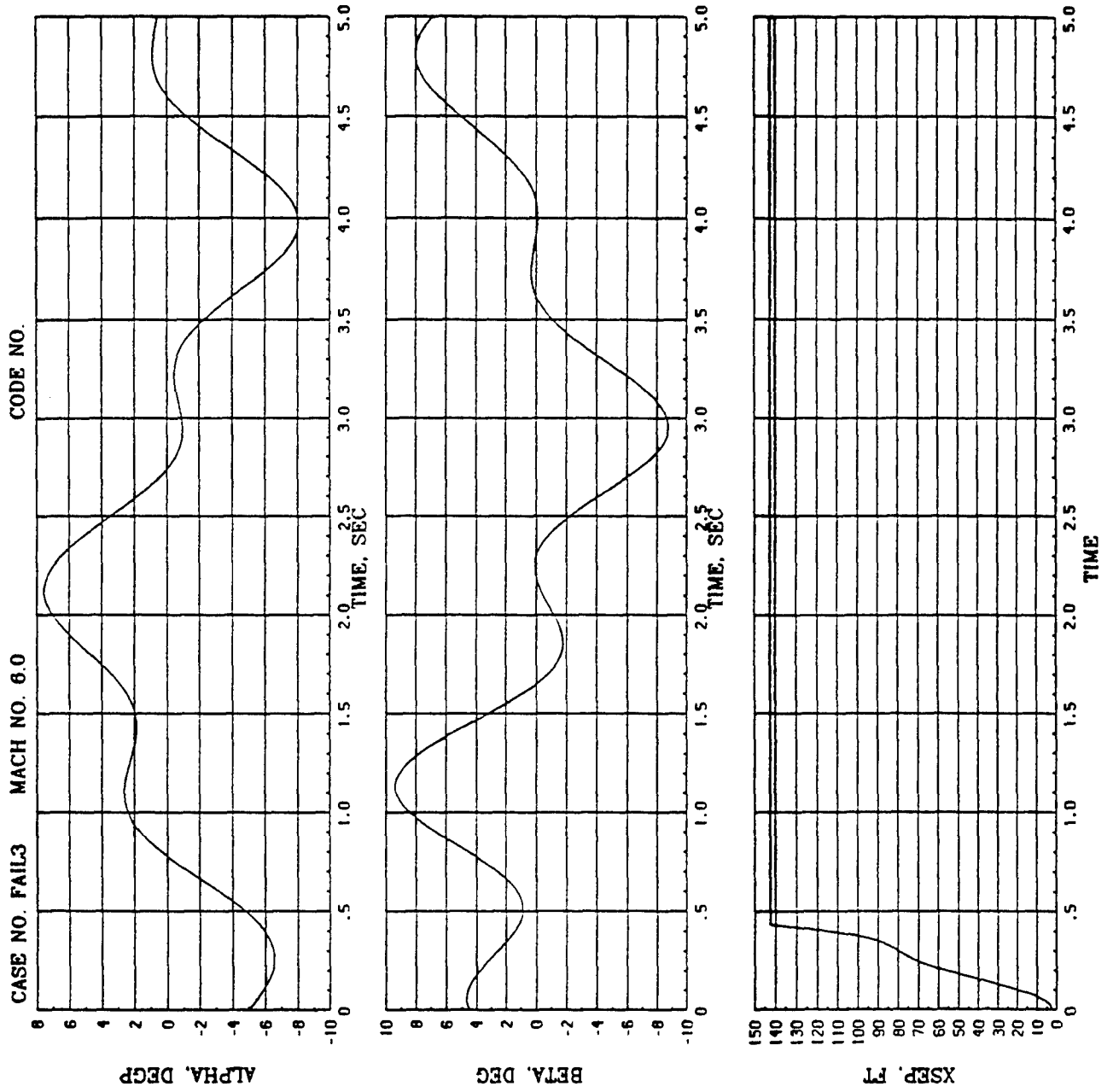


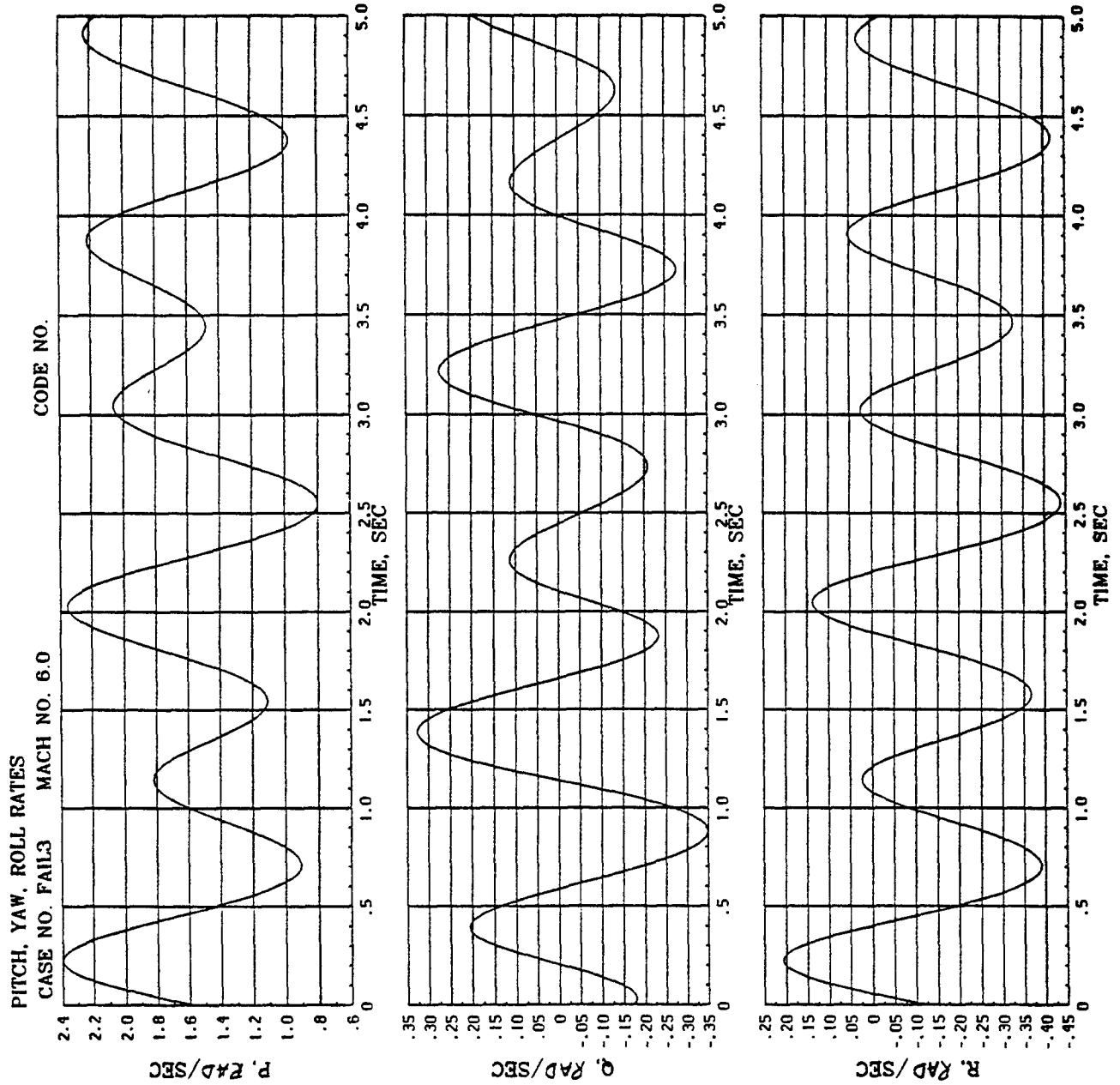


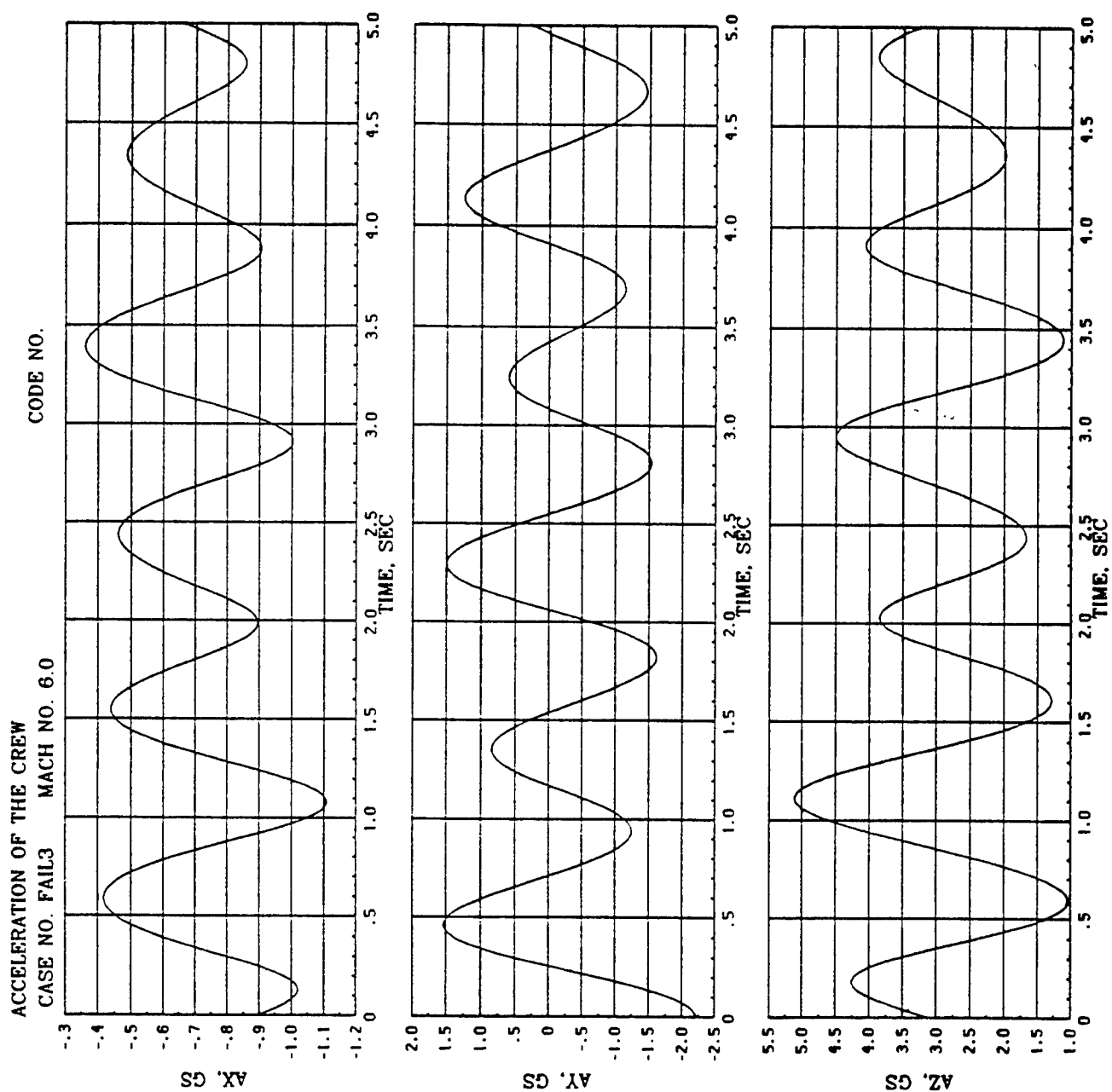


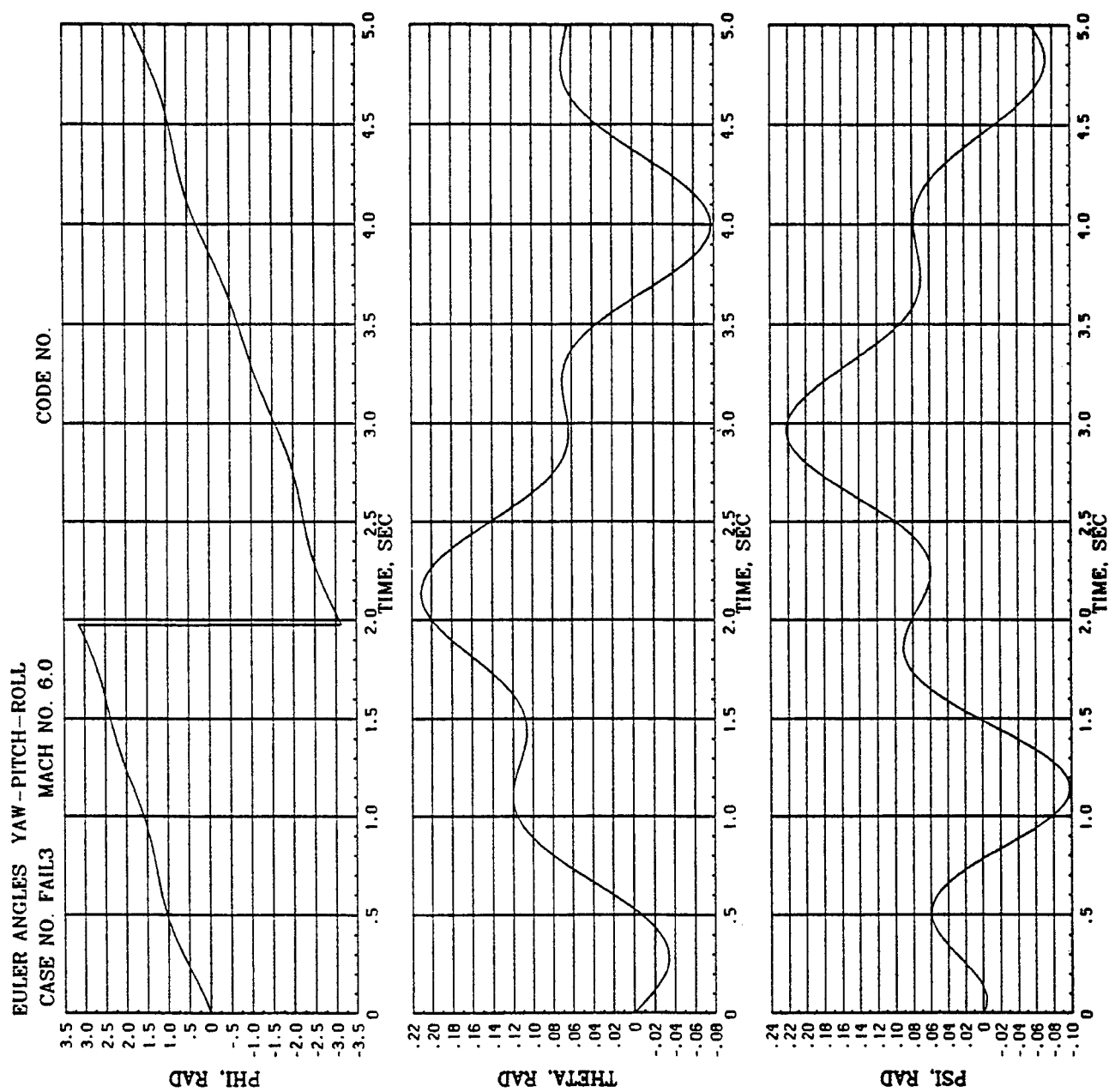


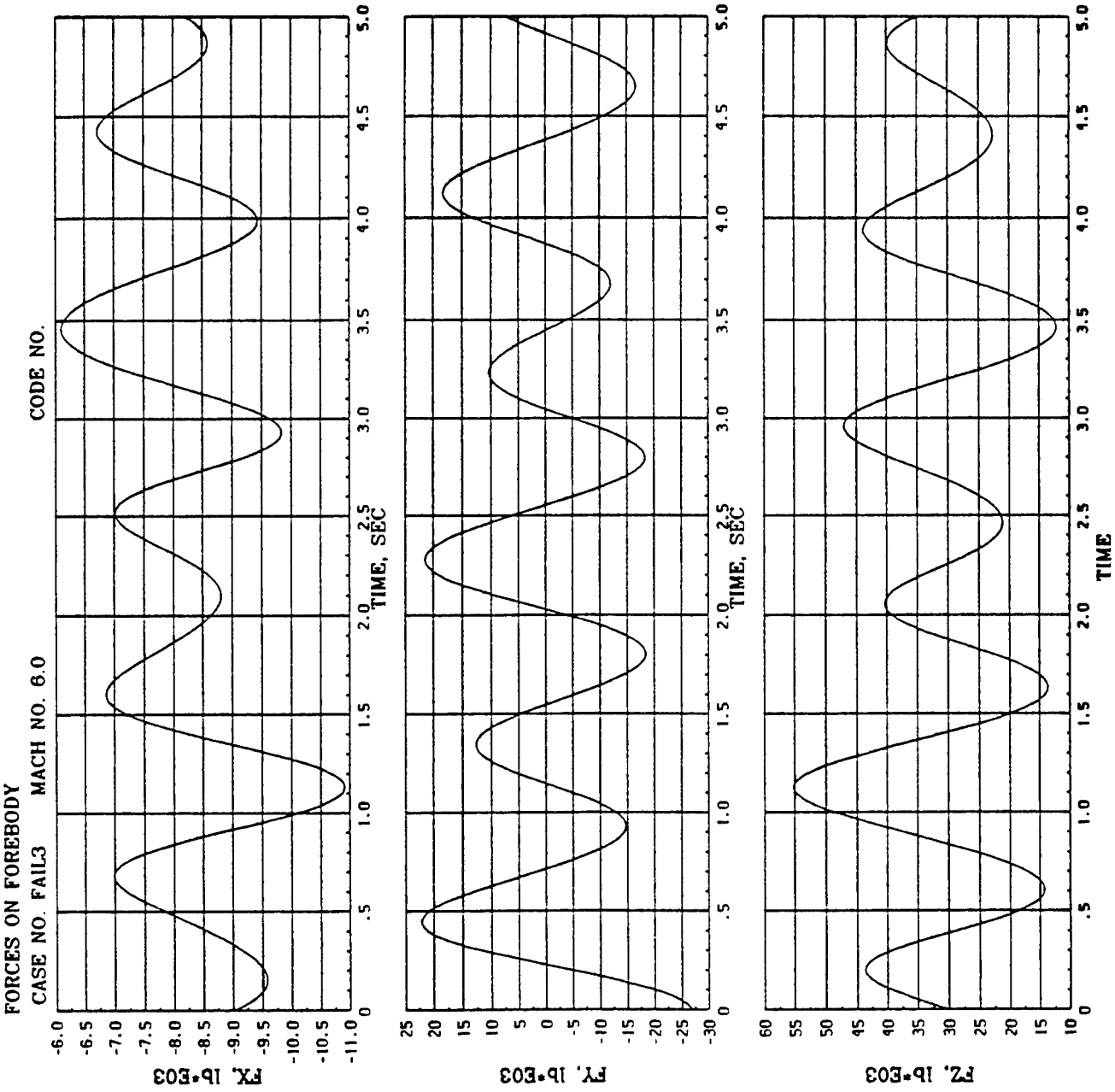


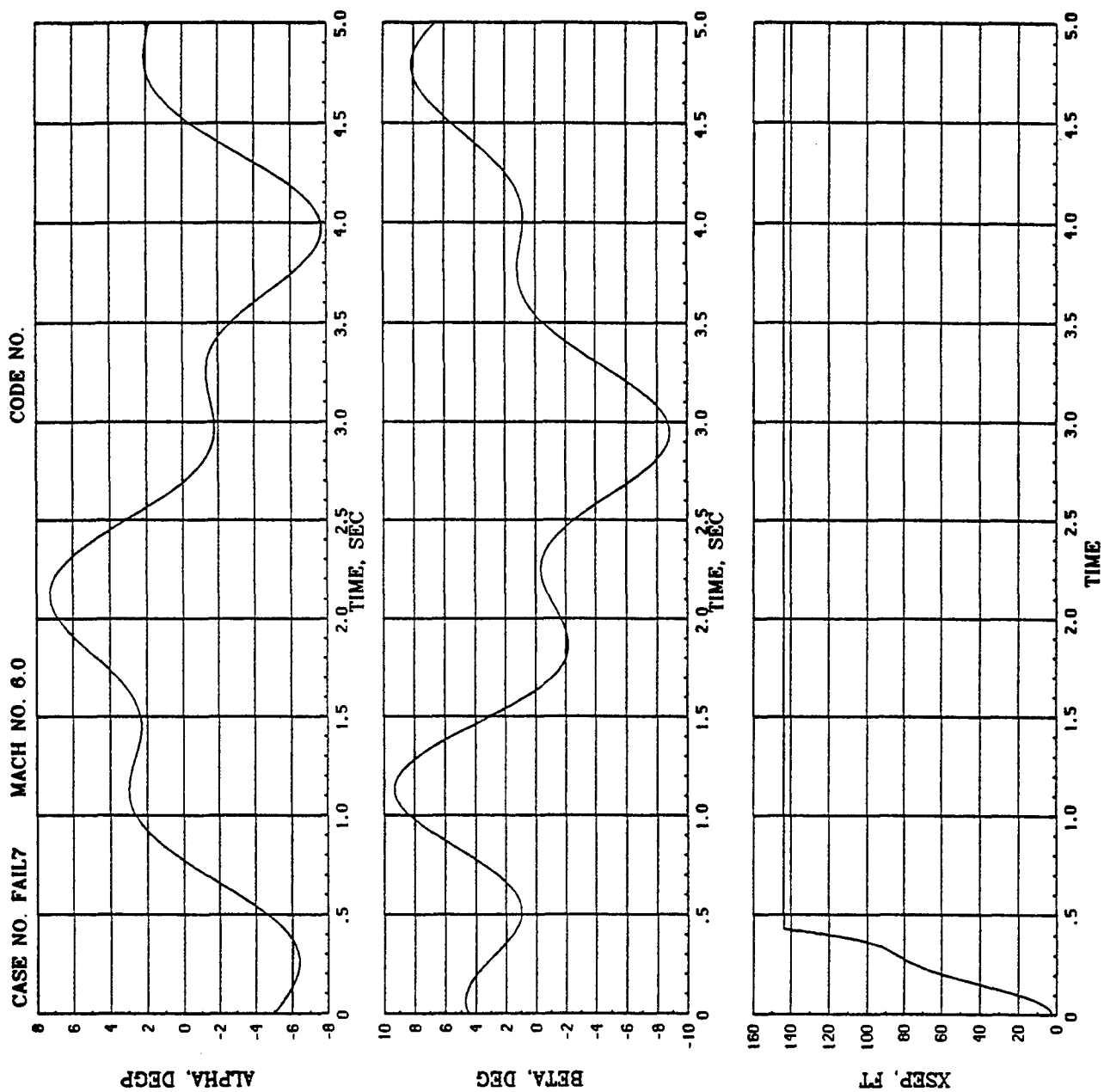




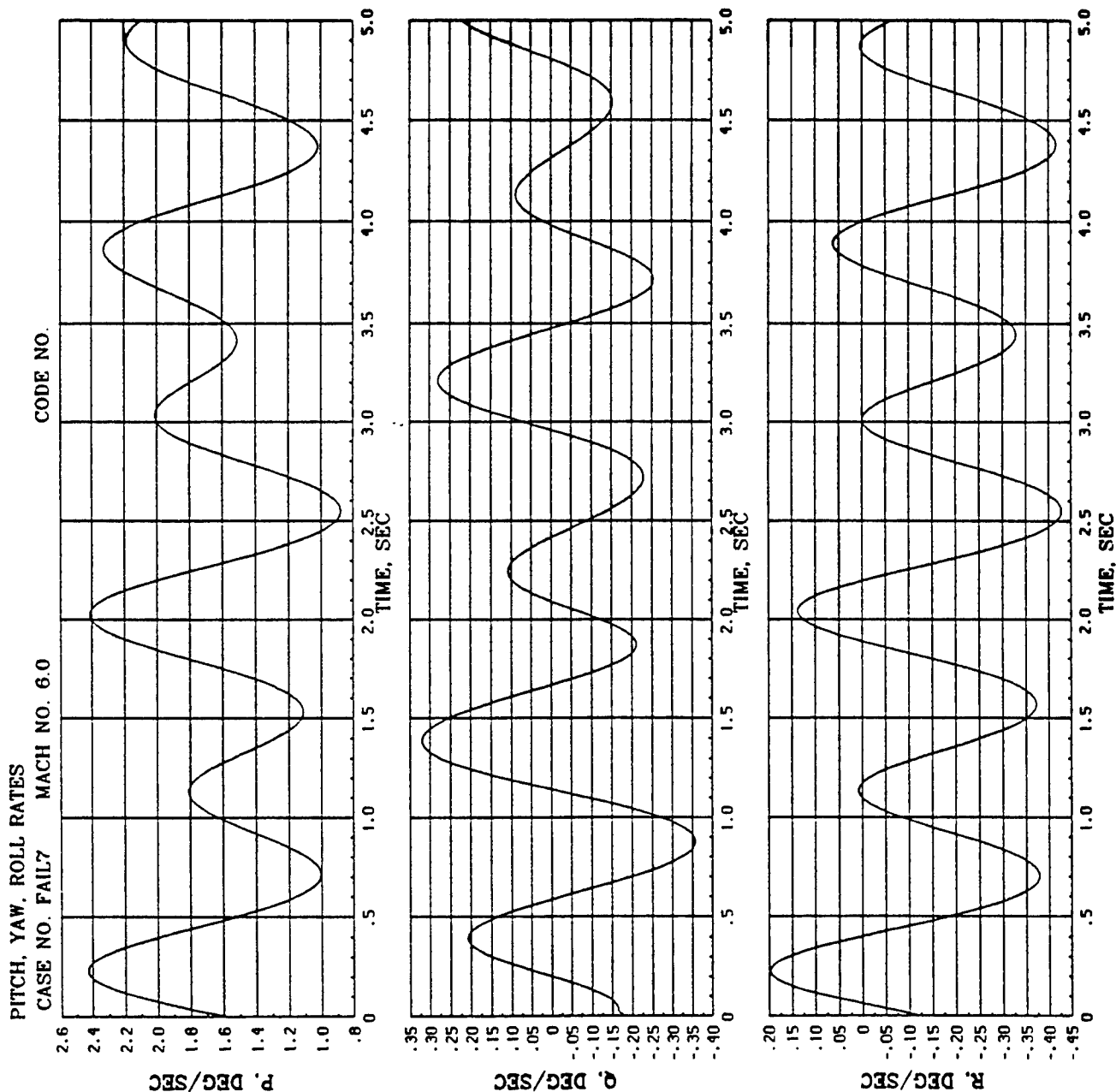


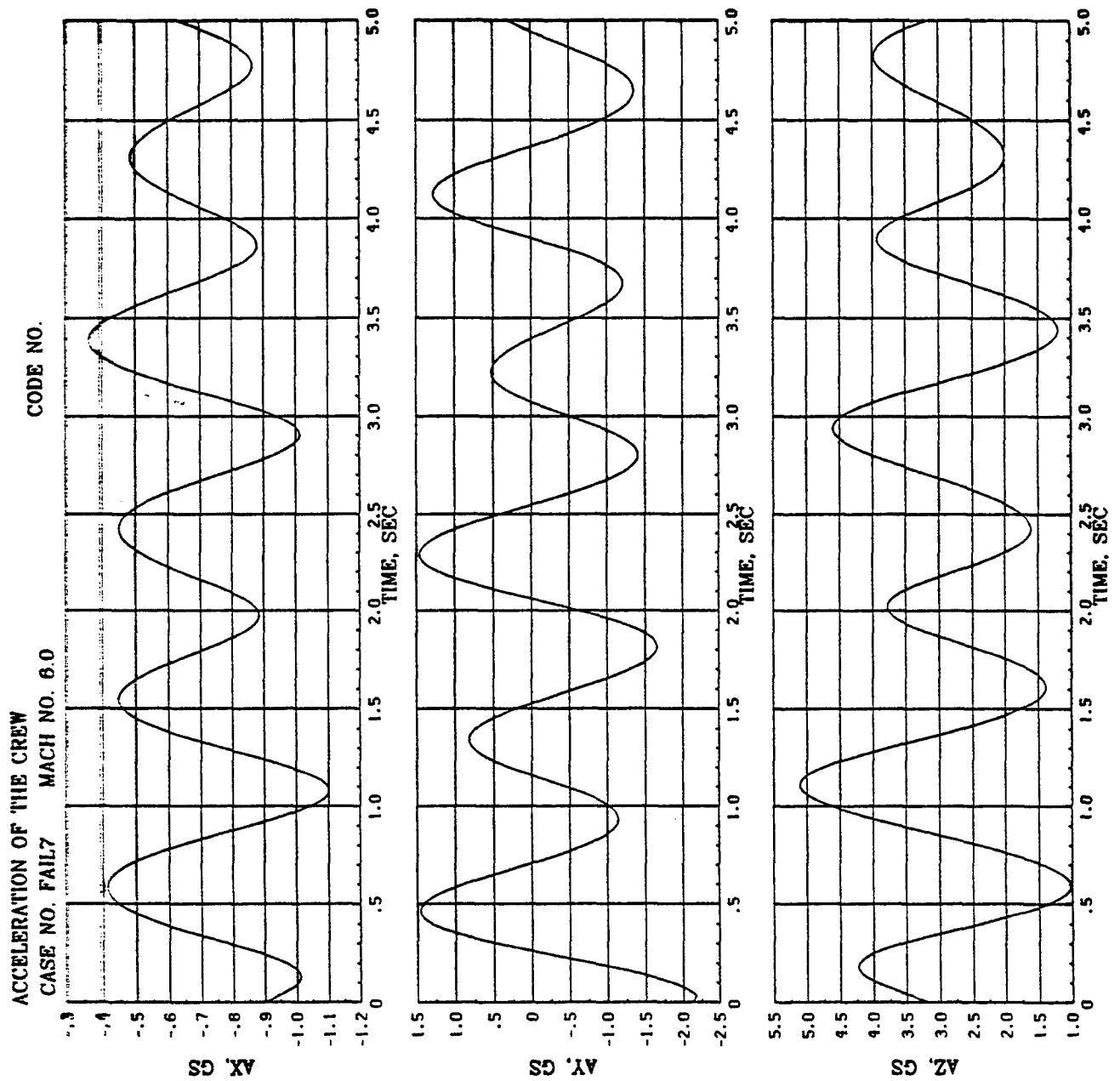


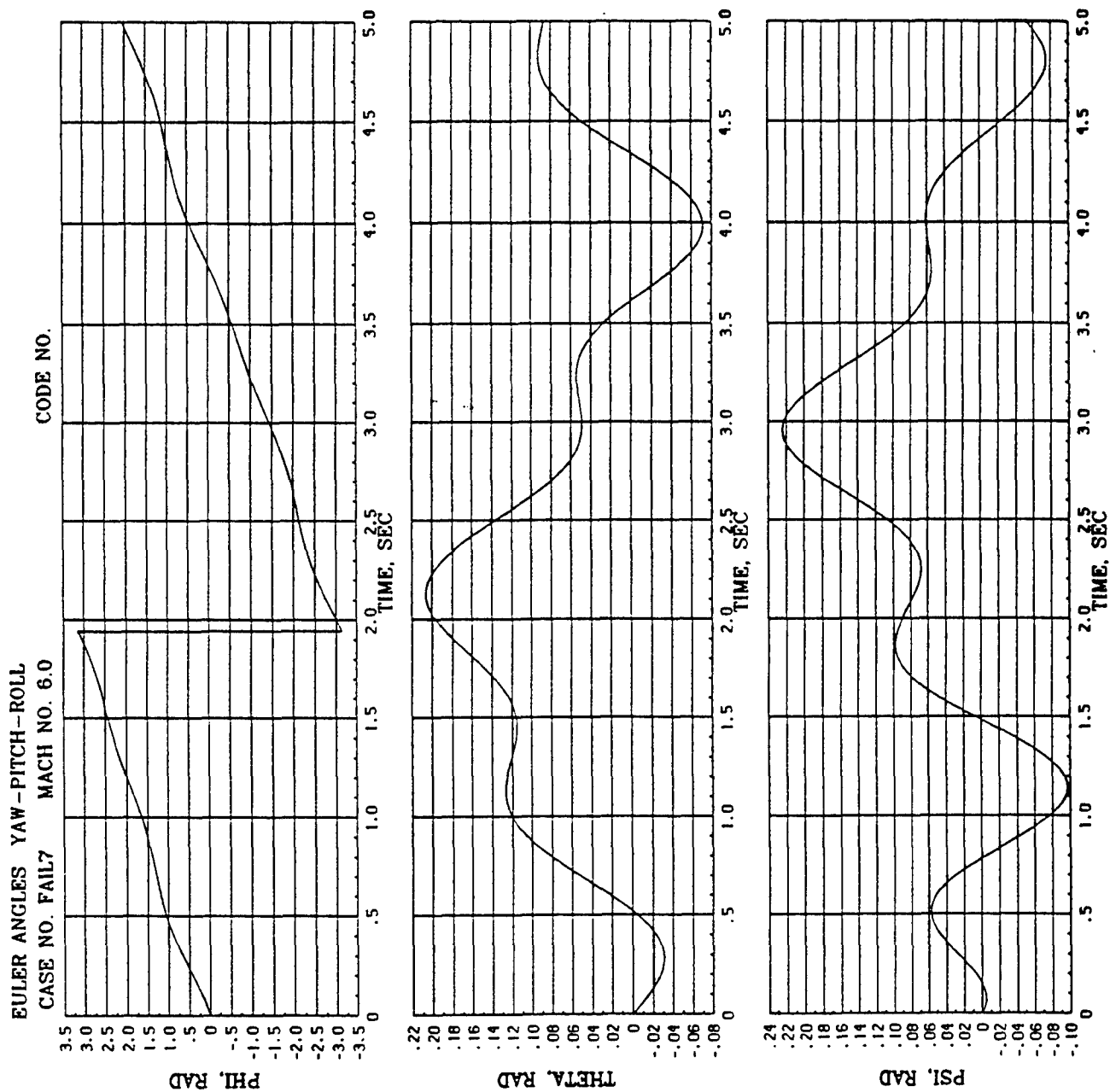


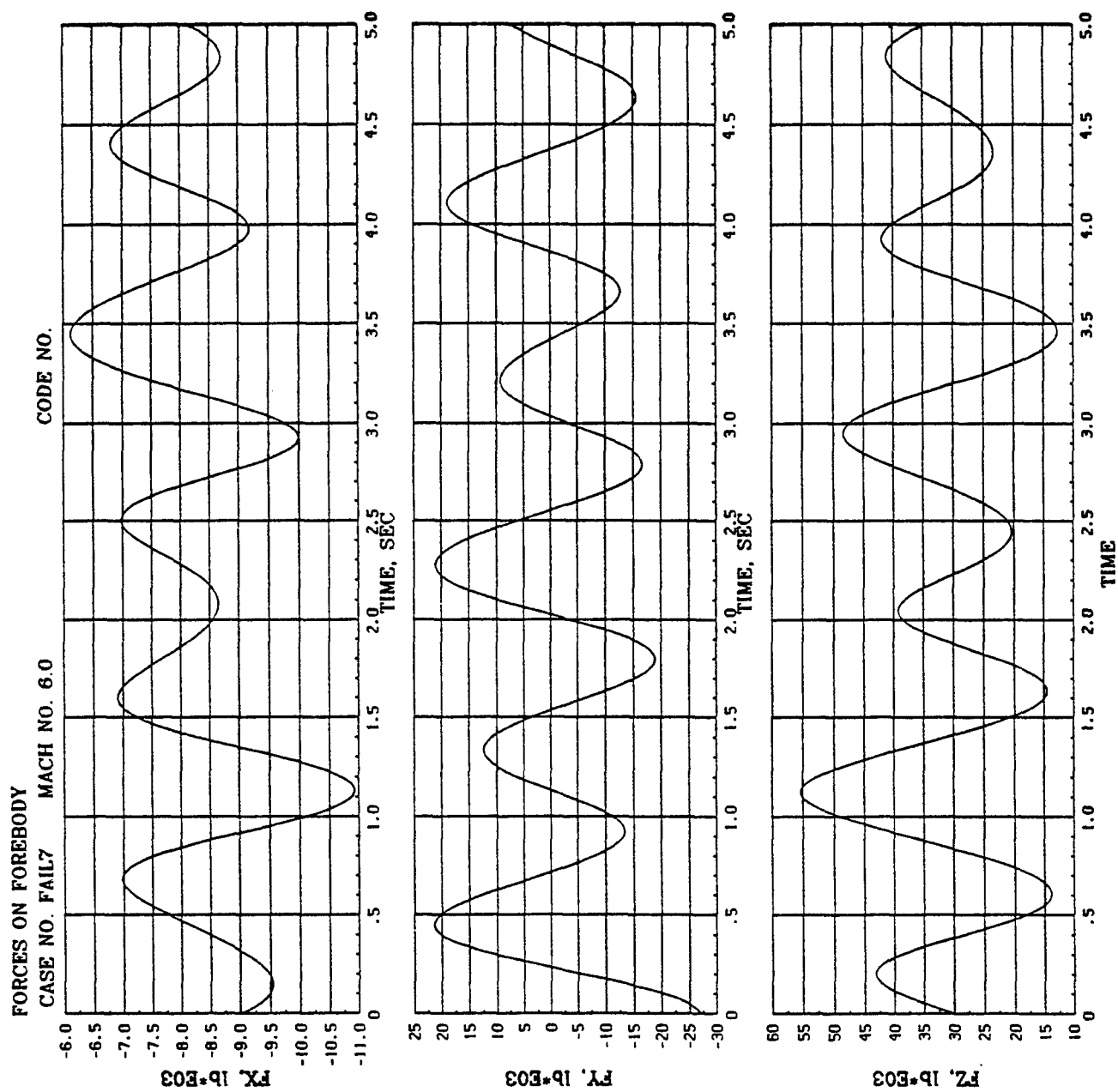


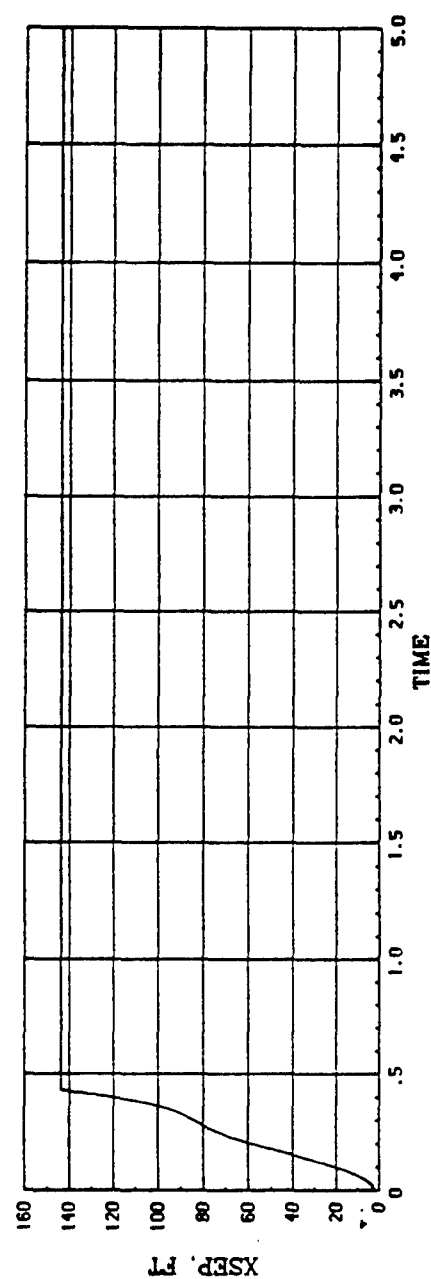
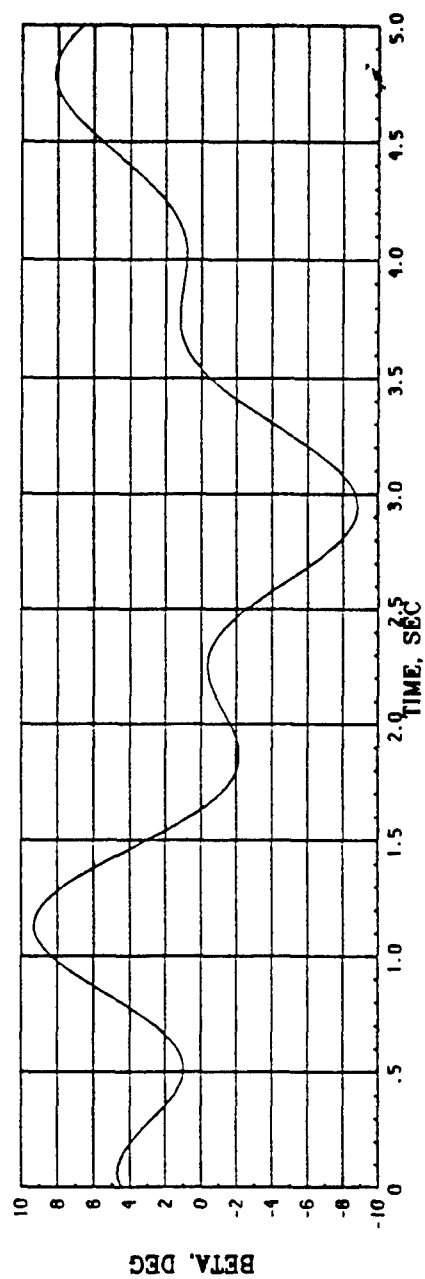
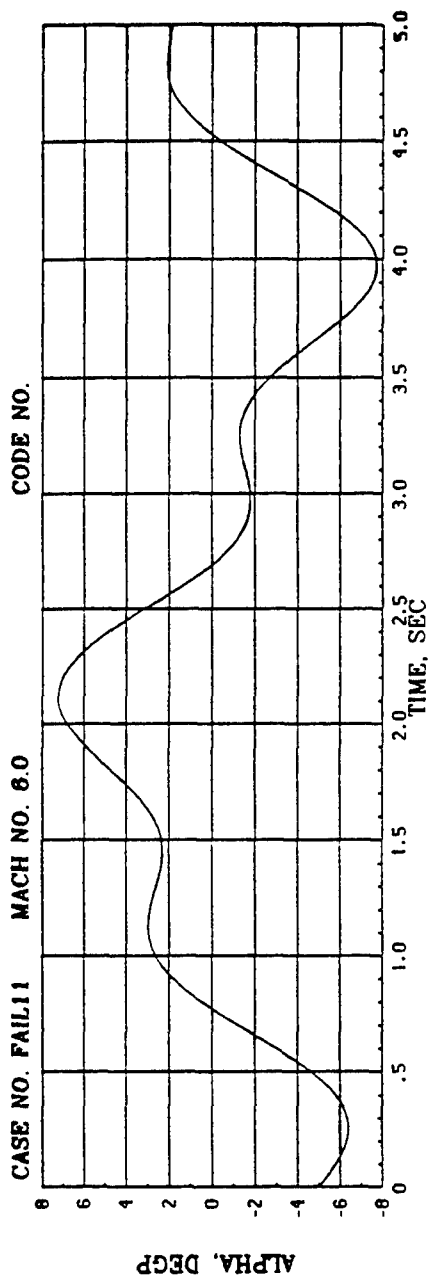


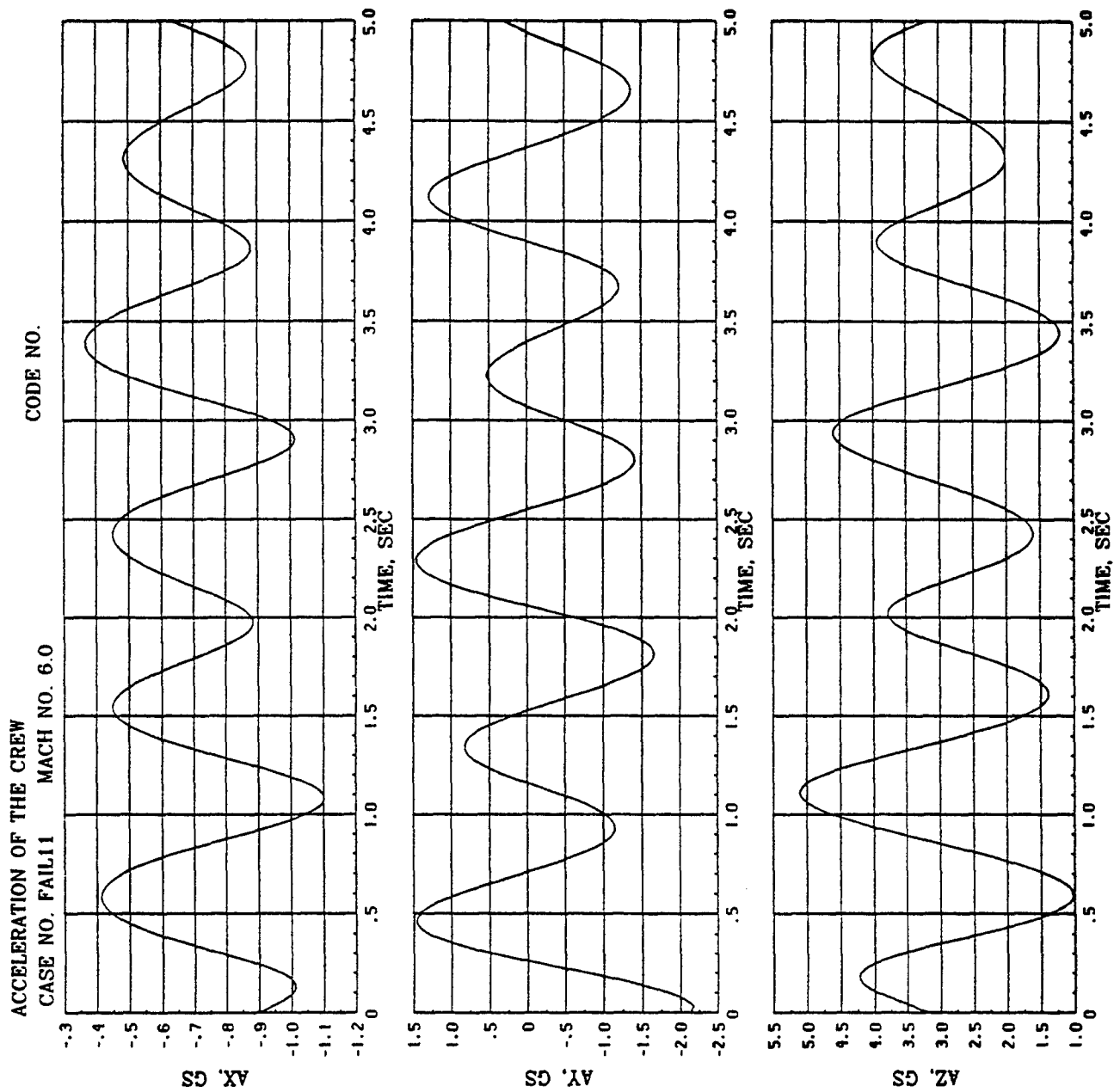


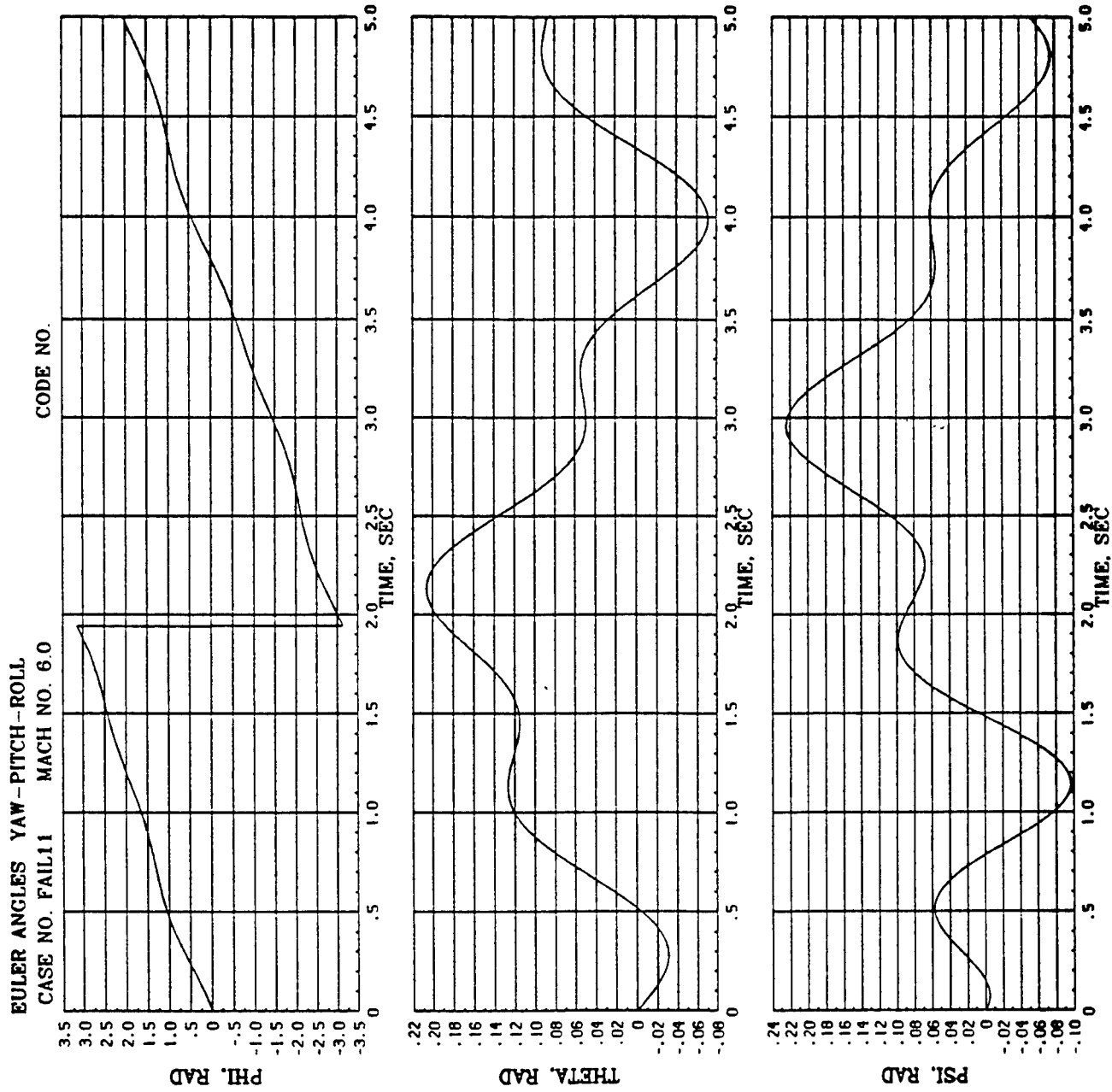


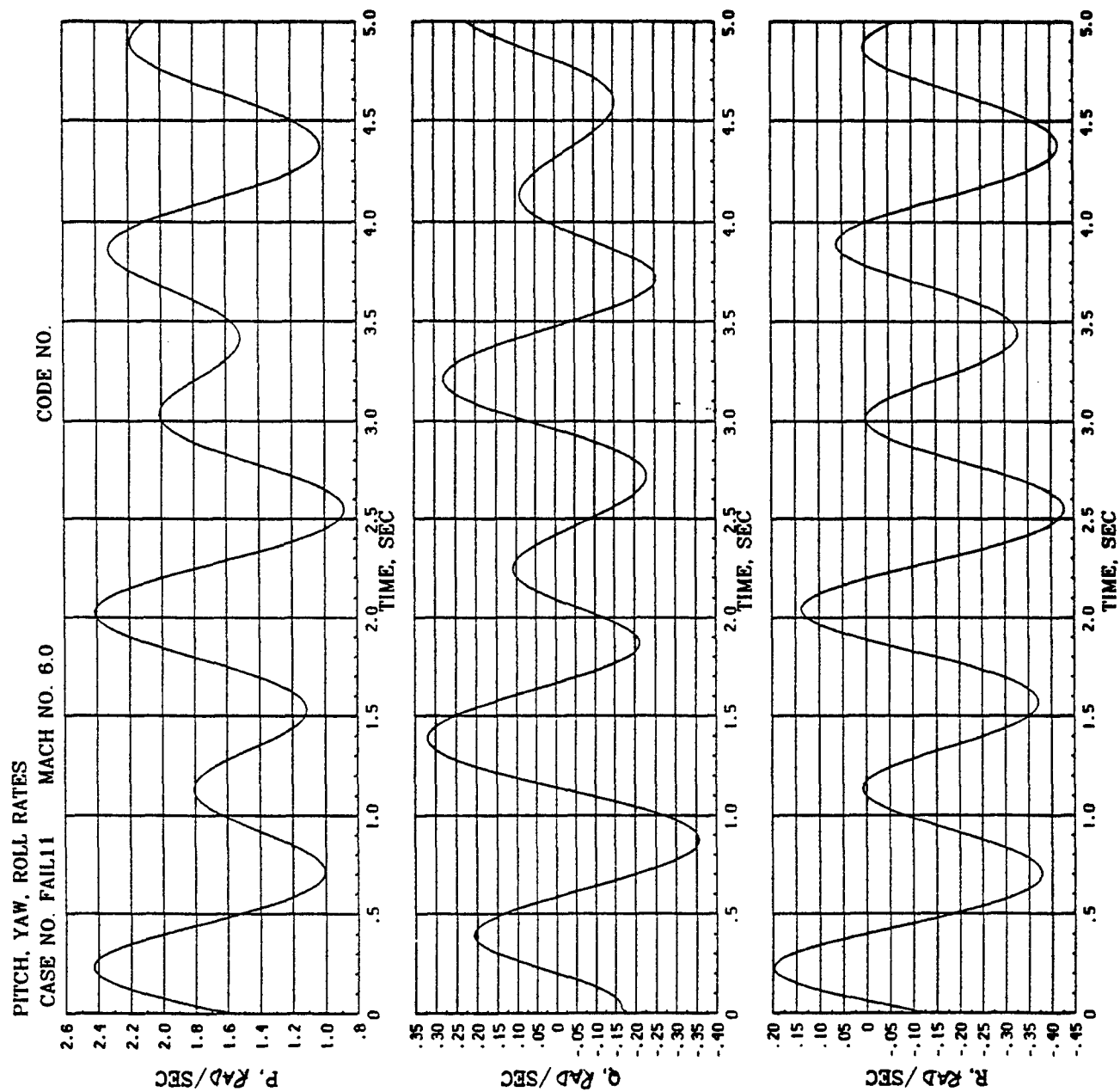




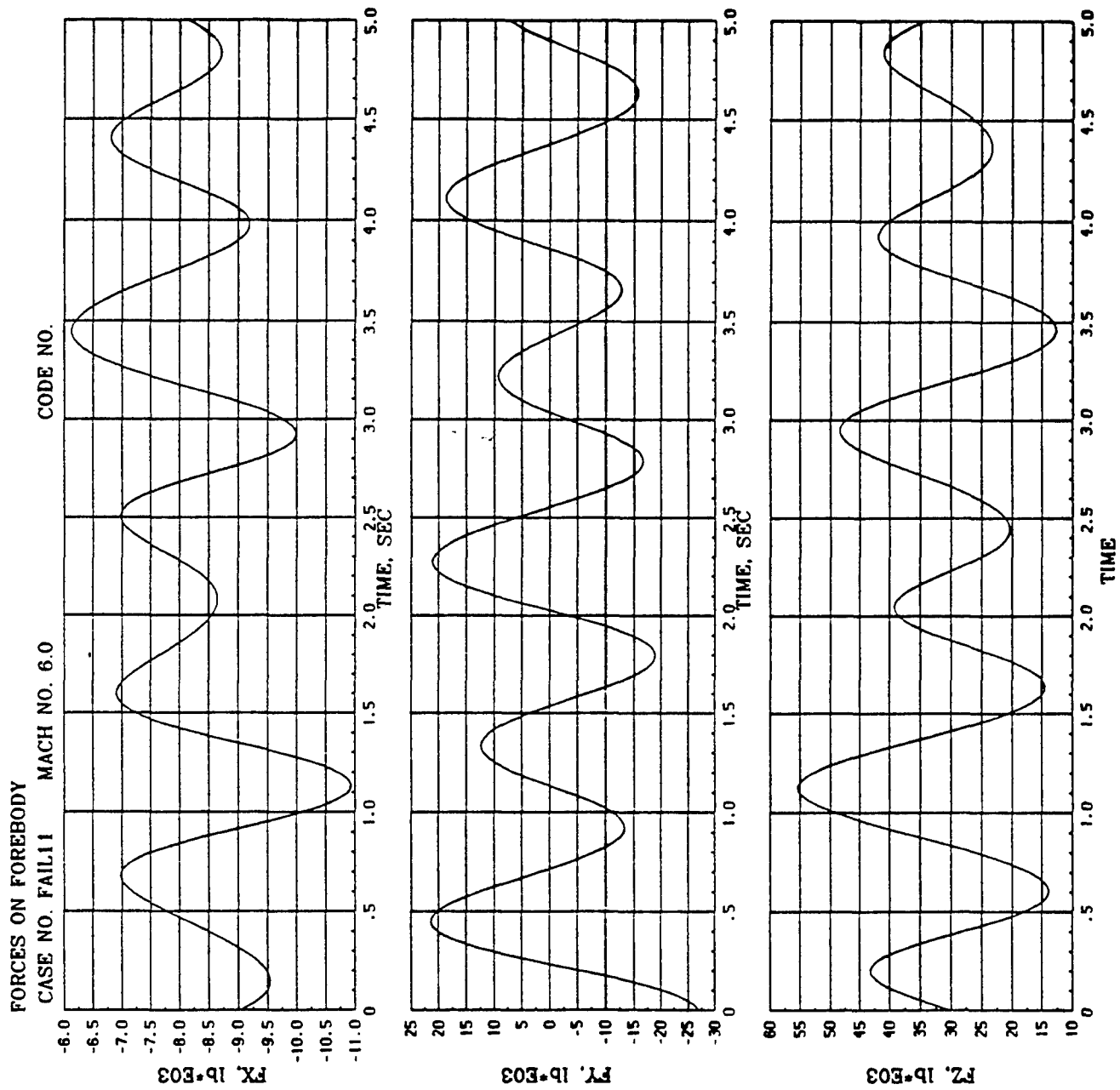


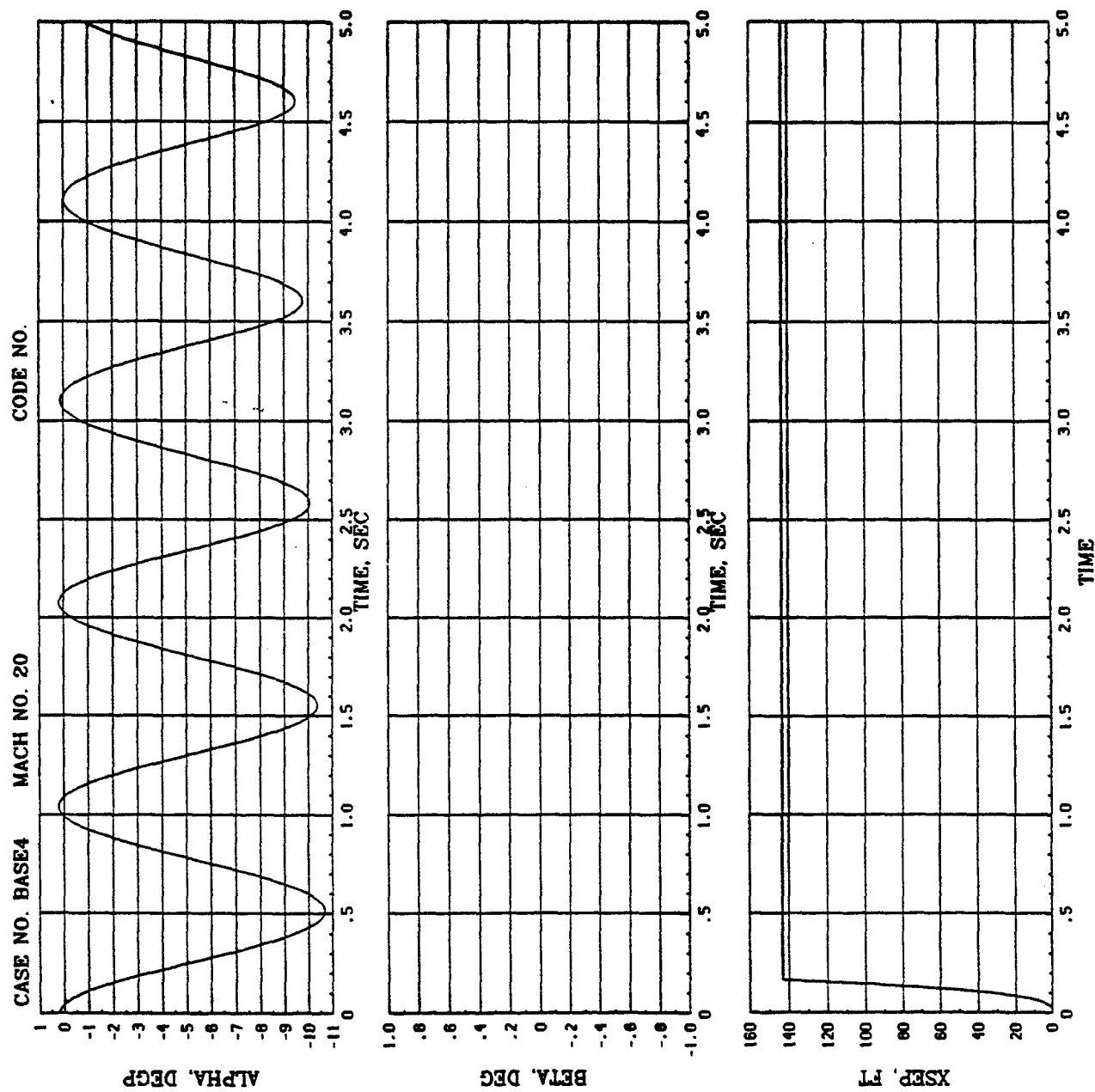


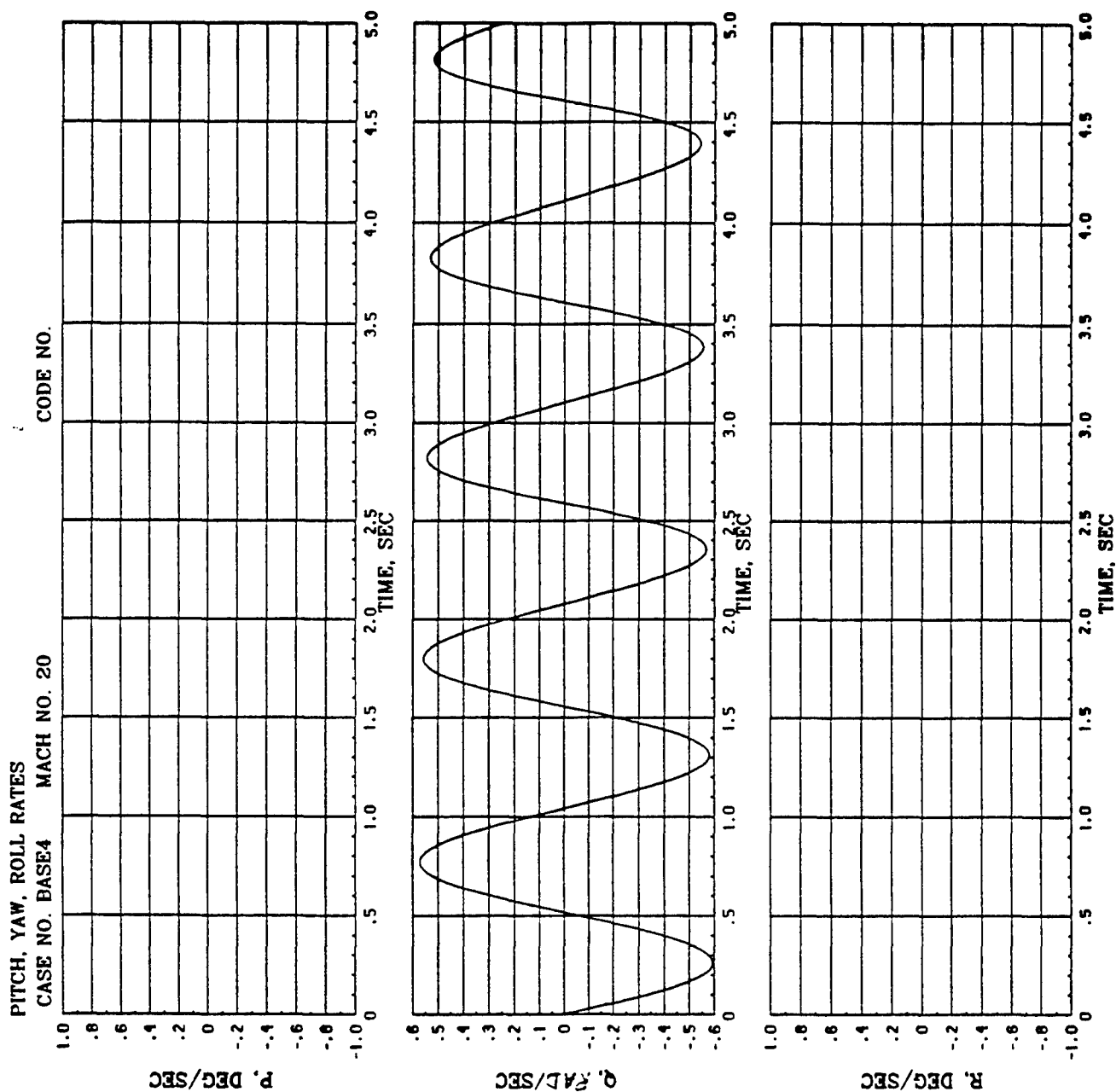


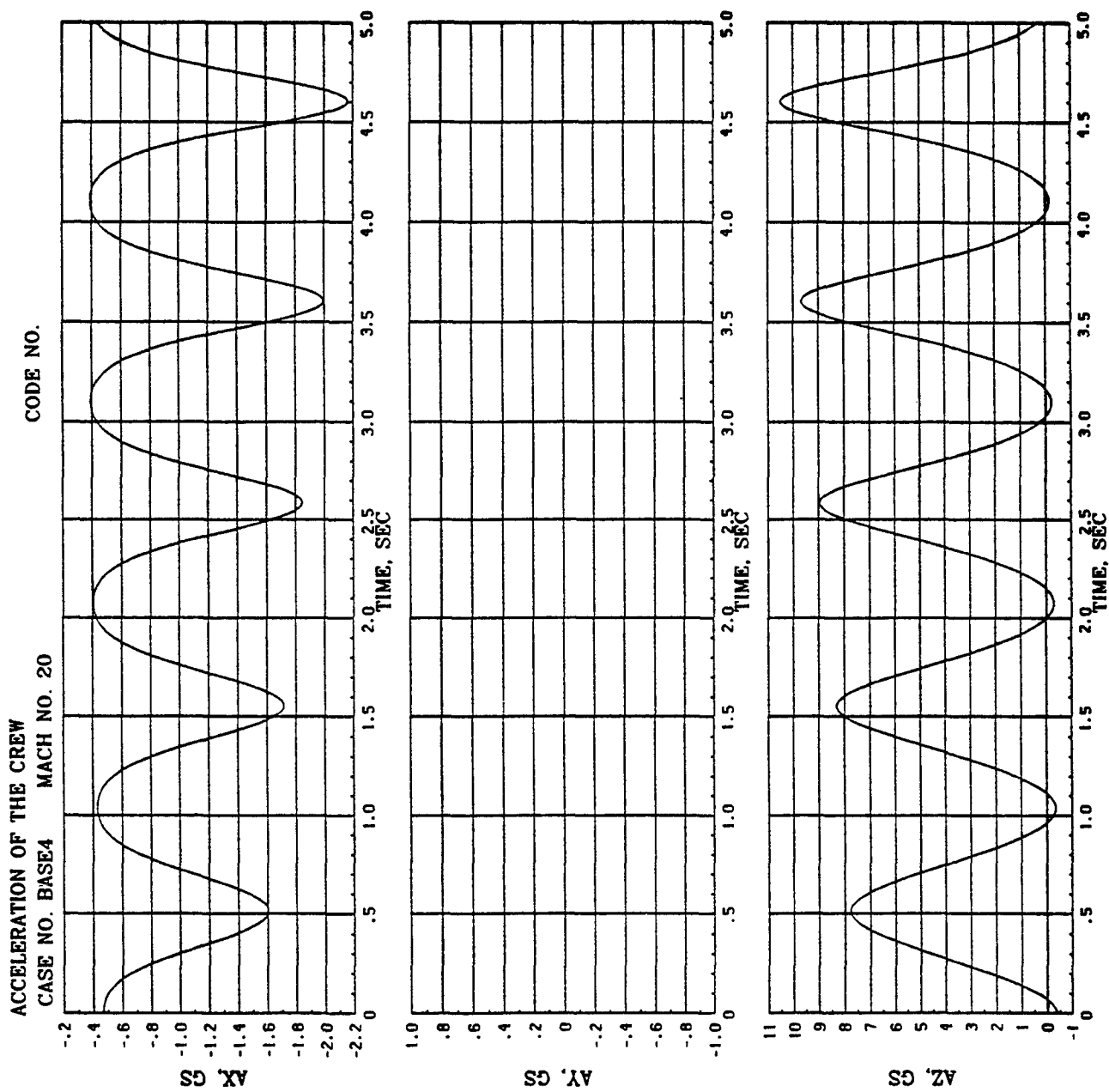








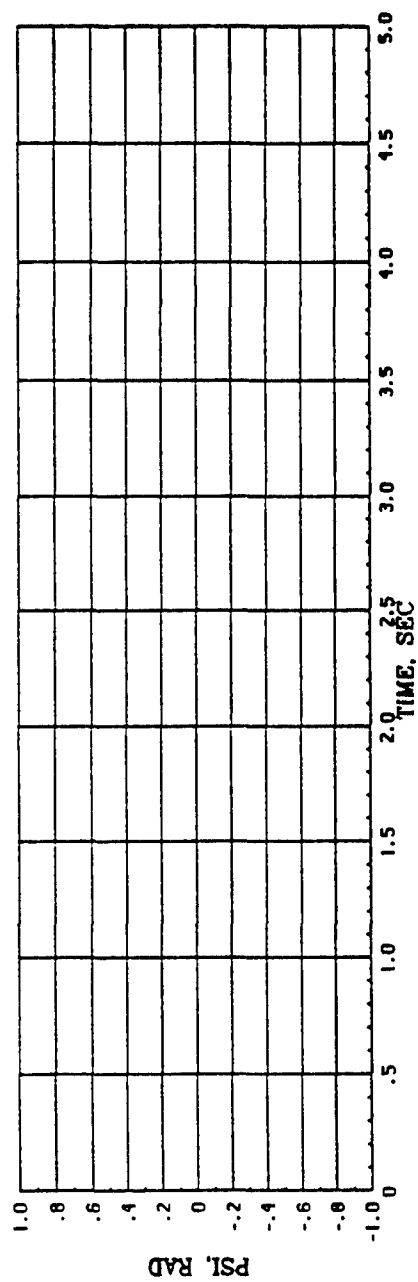
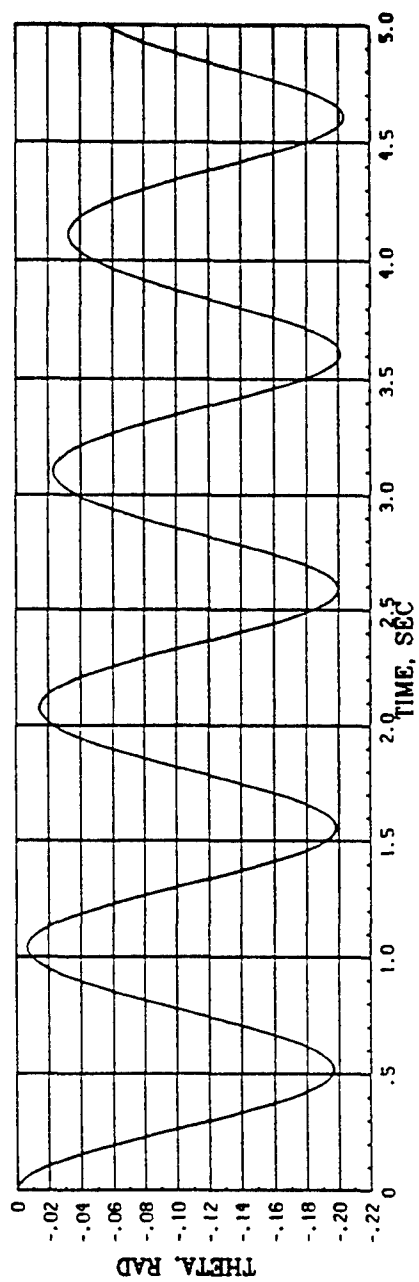
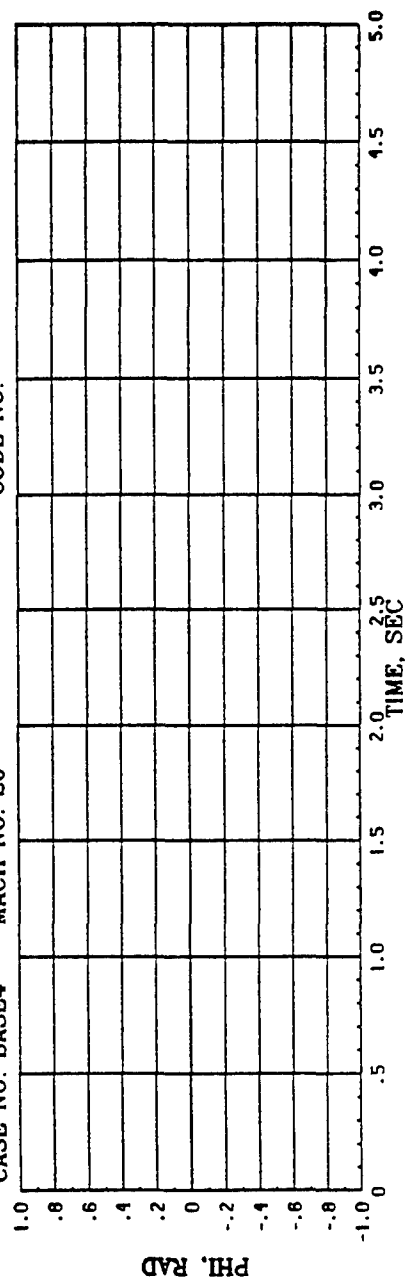


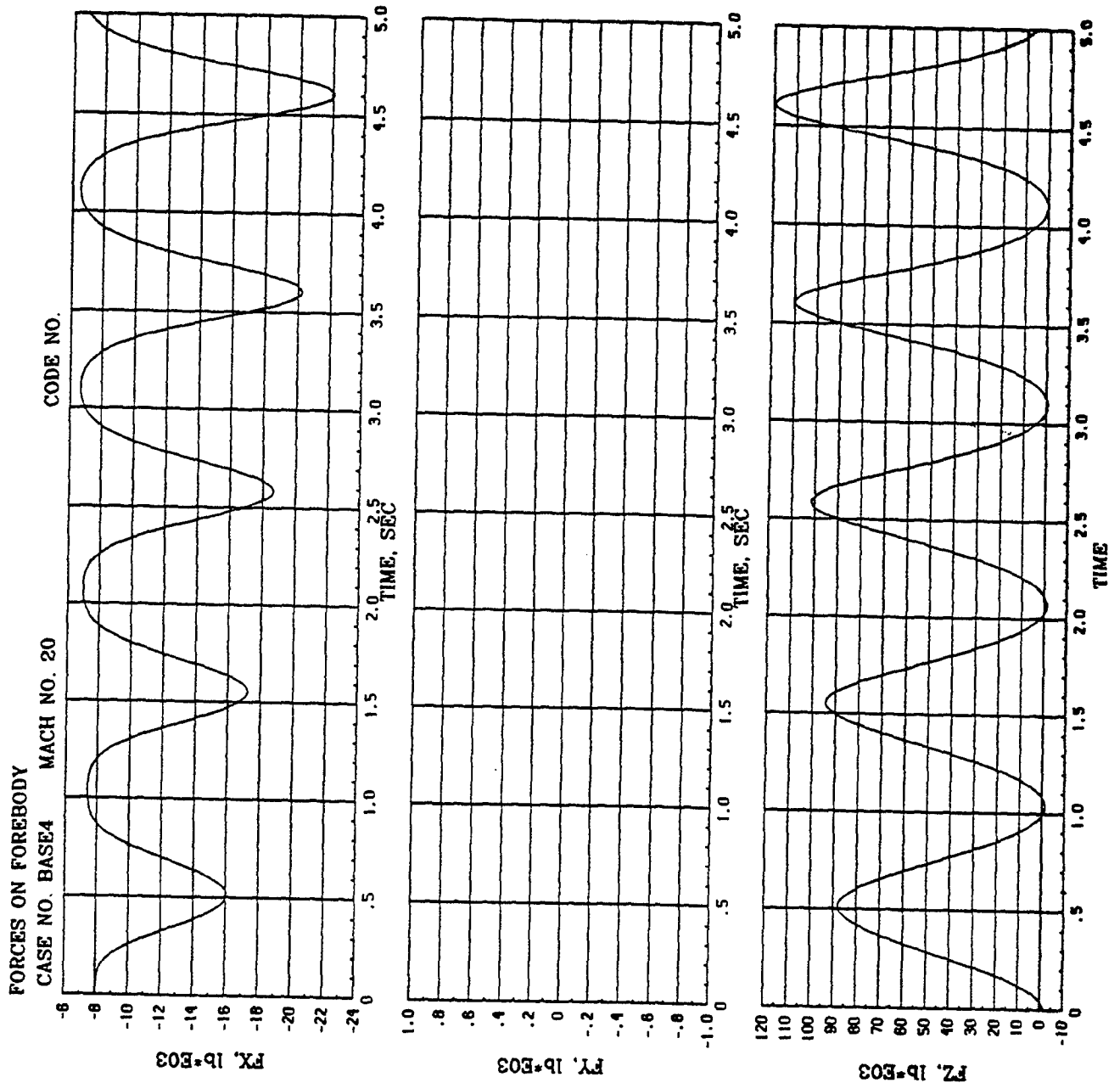


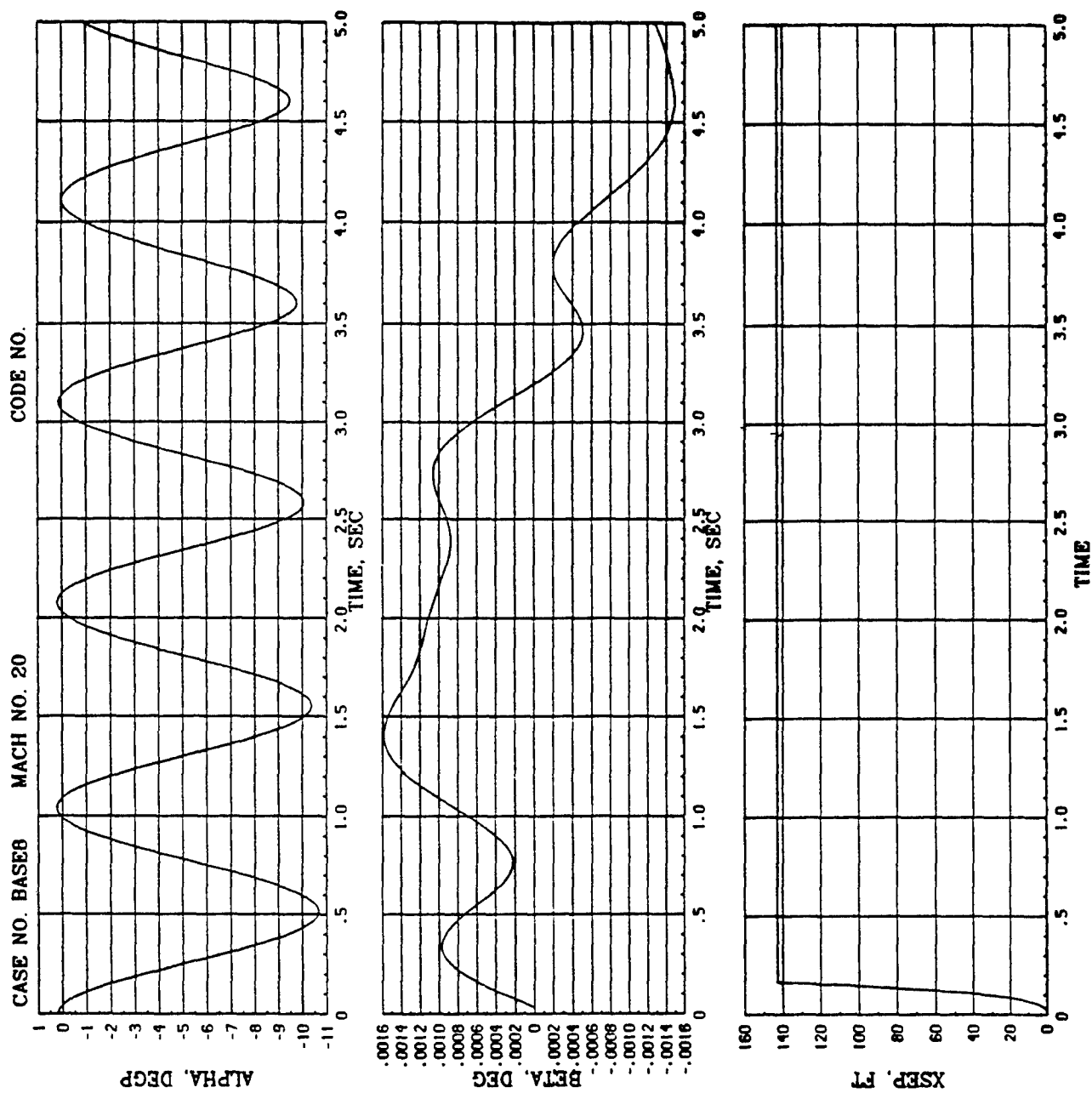
## EULER ANGLES YAW-PITCH-ROLL

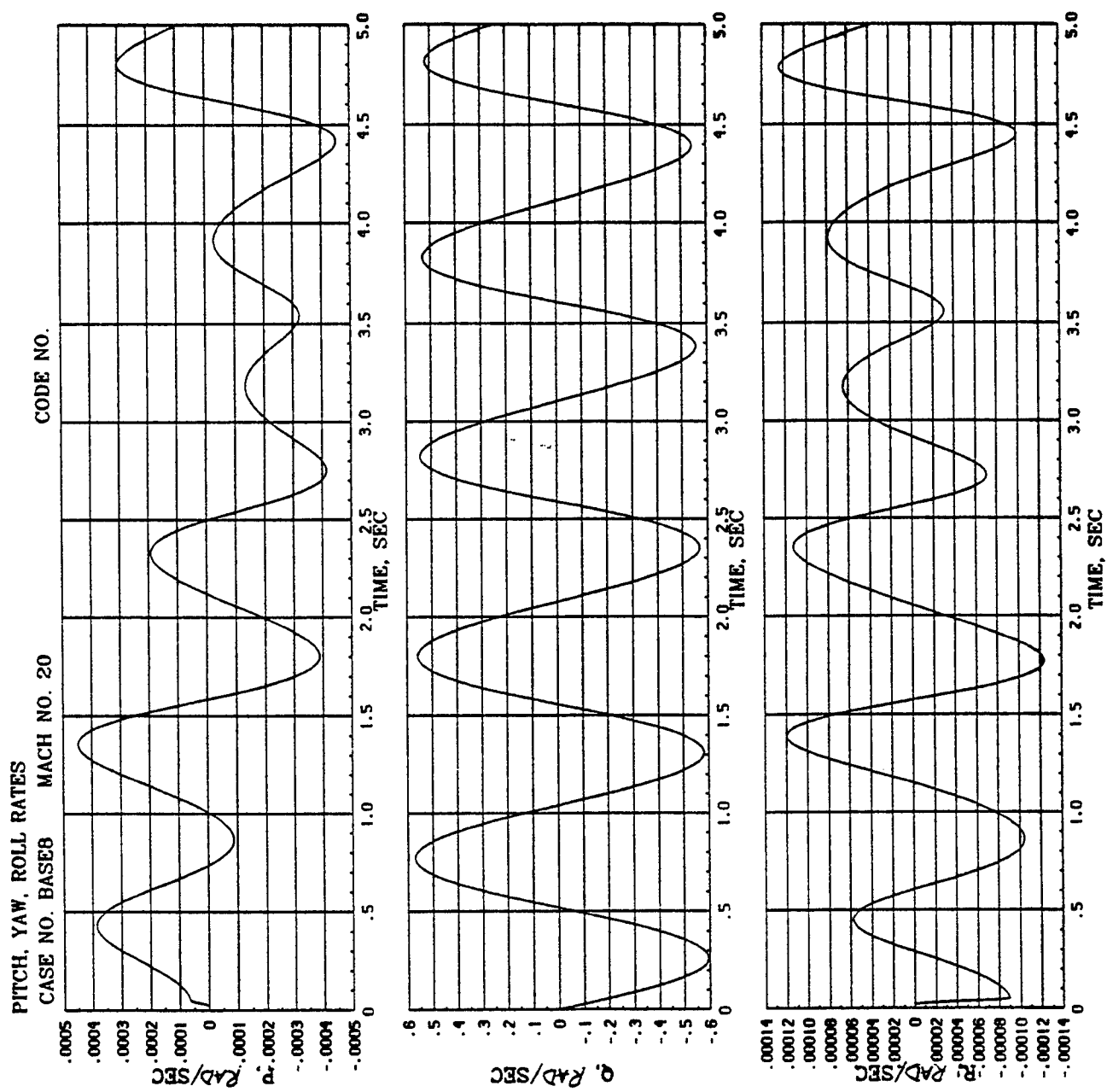
CASE NO. BASE4 MACH NO. 20

CODE NO.

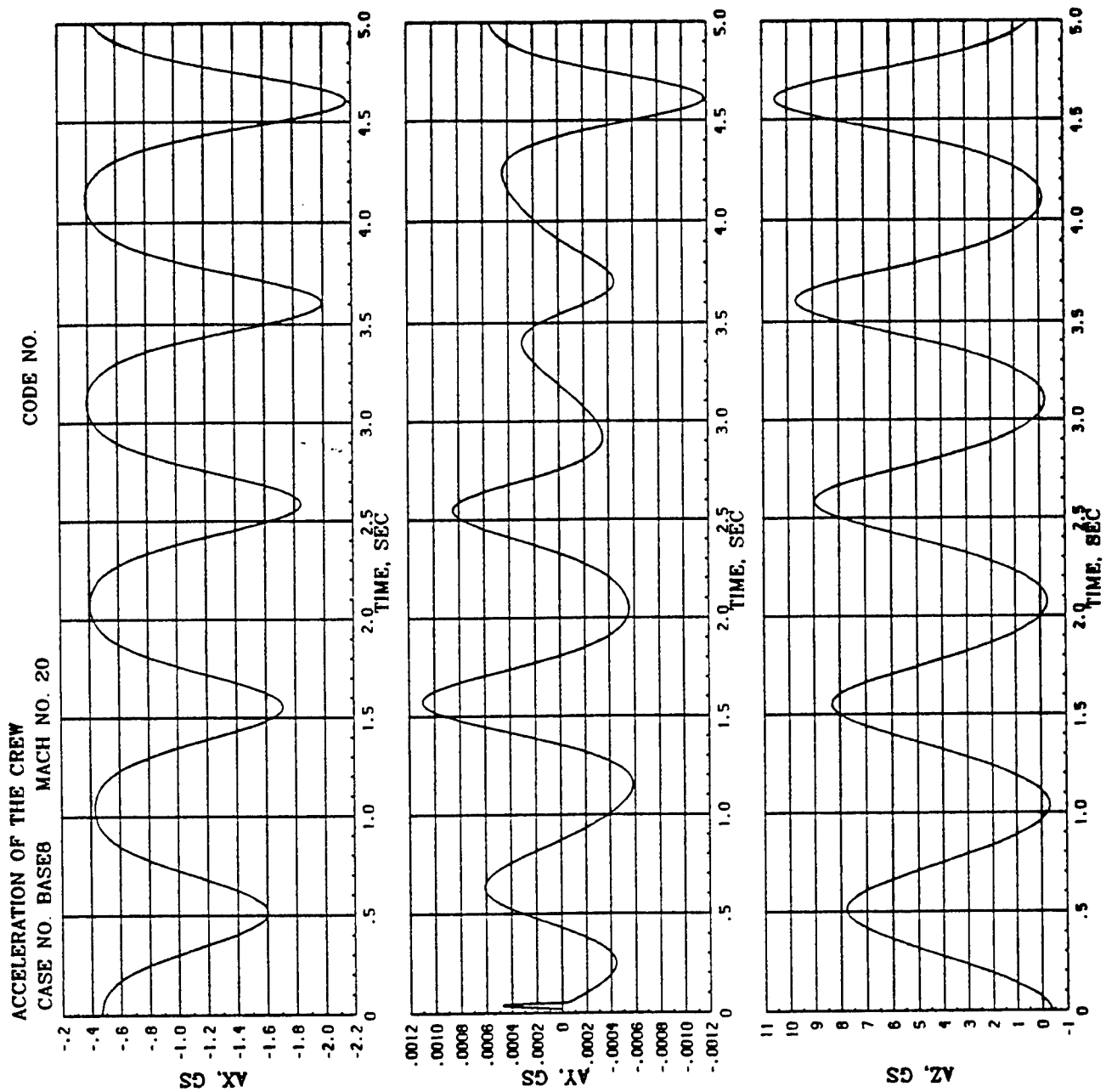






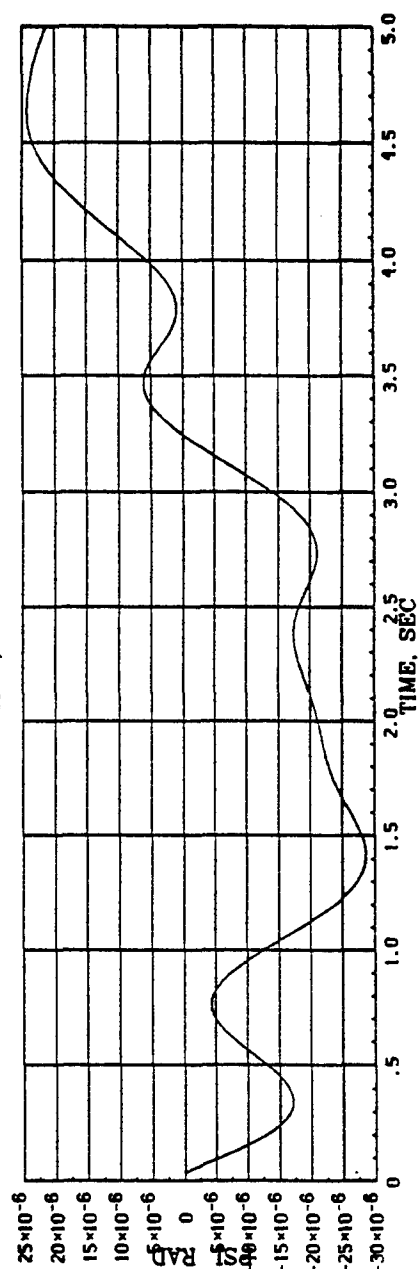
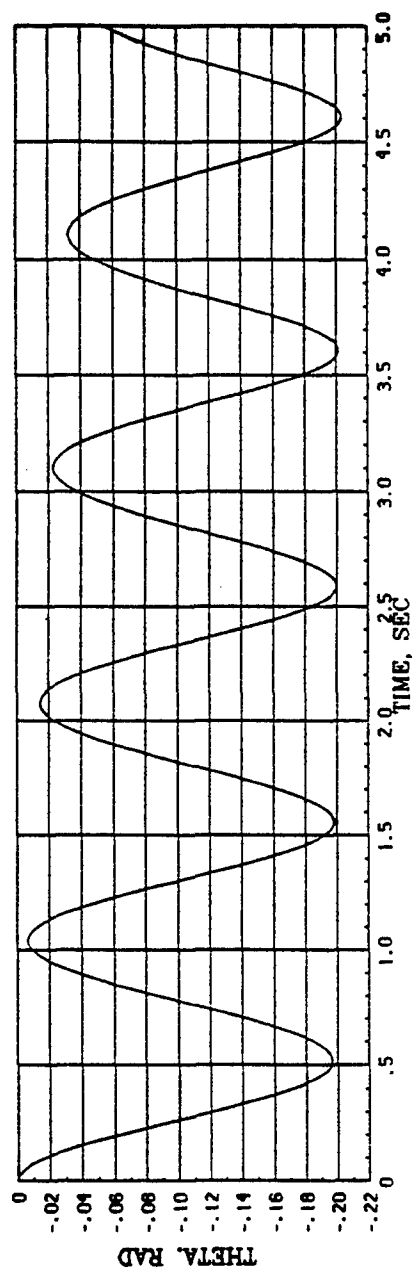
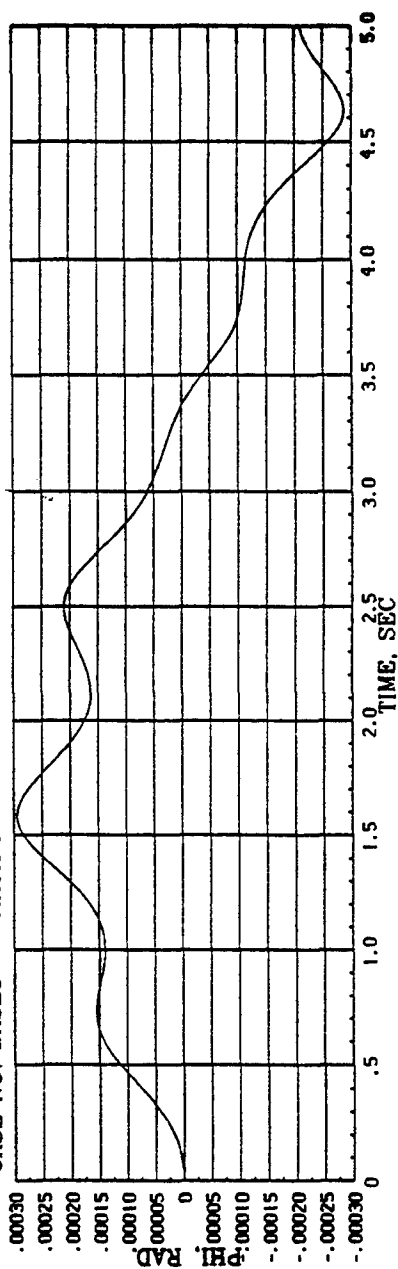


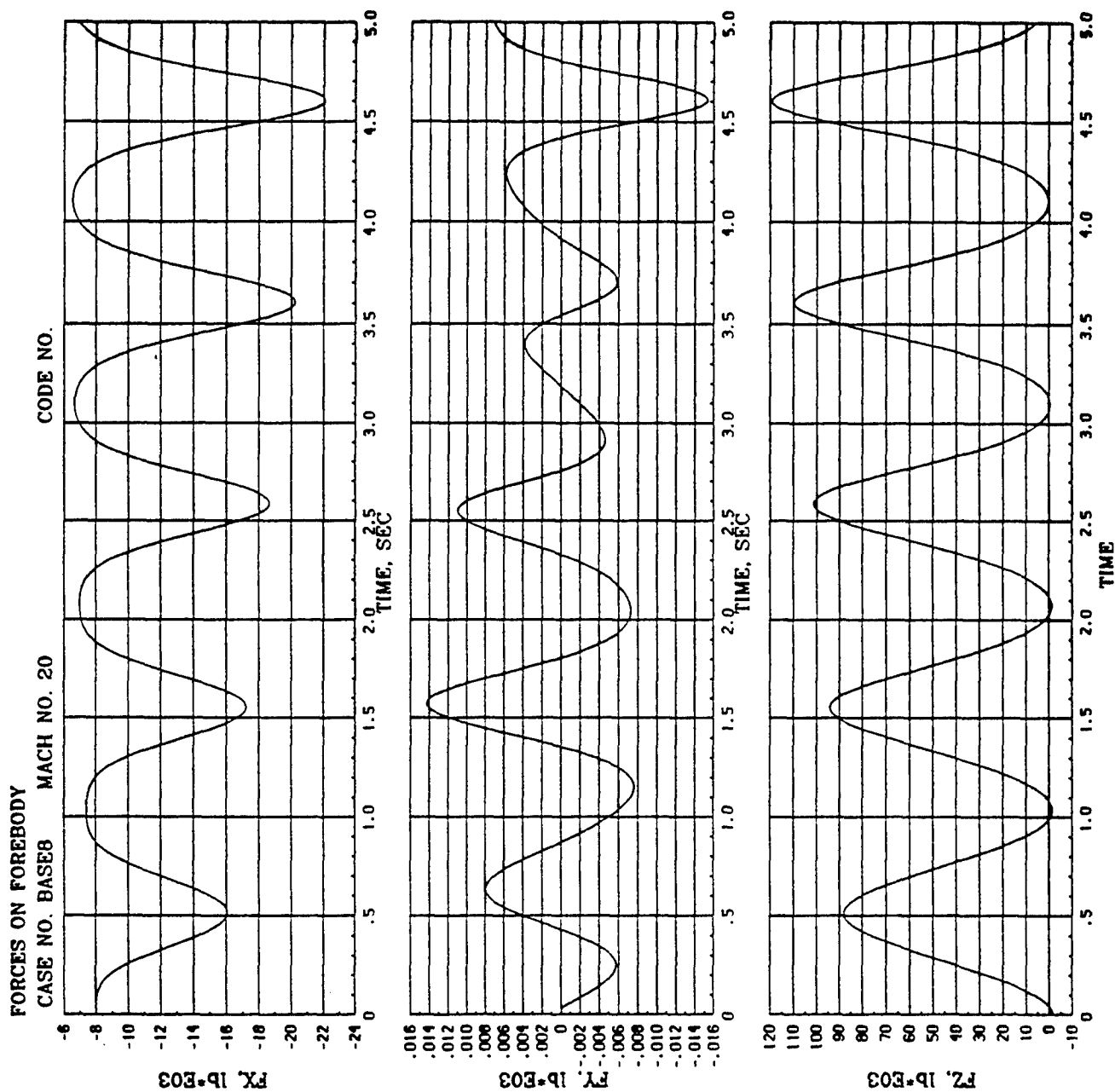


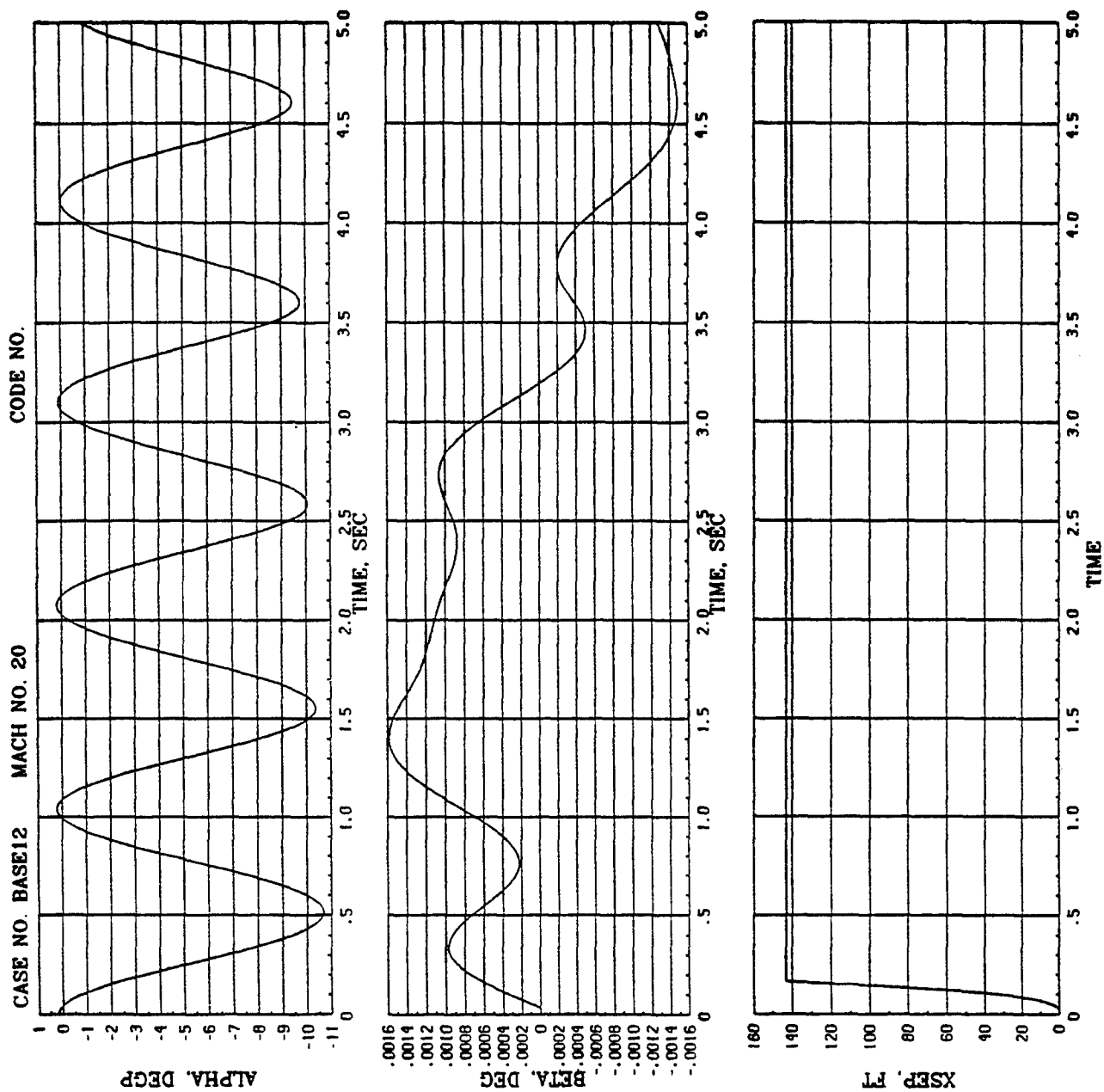


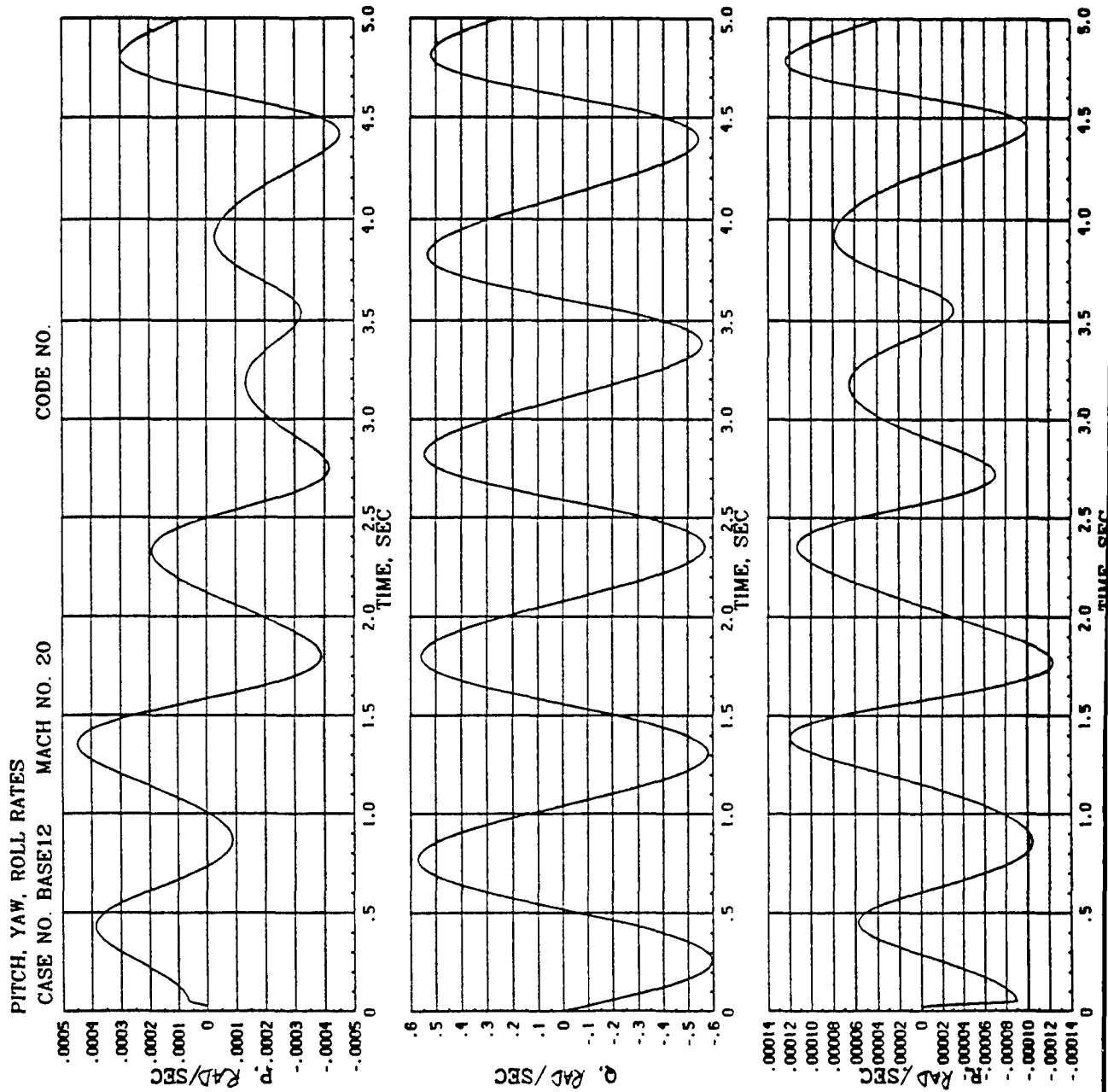
EULER ANGLES YAW-PITCH-ROLL  
CASE NO. BASE8 MACH NO. 20

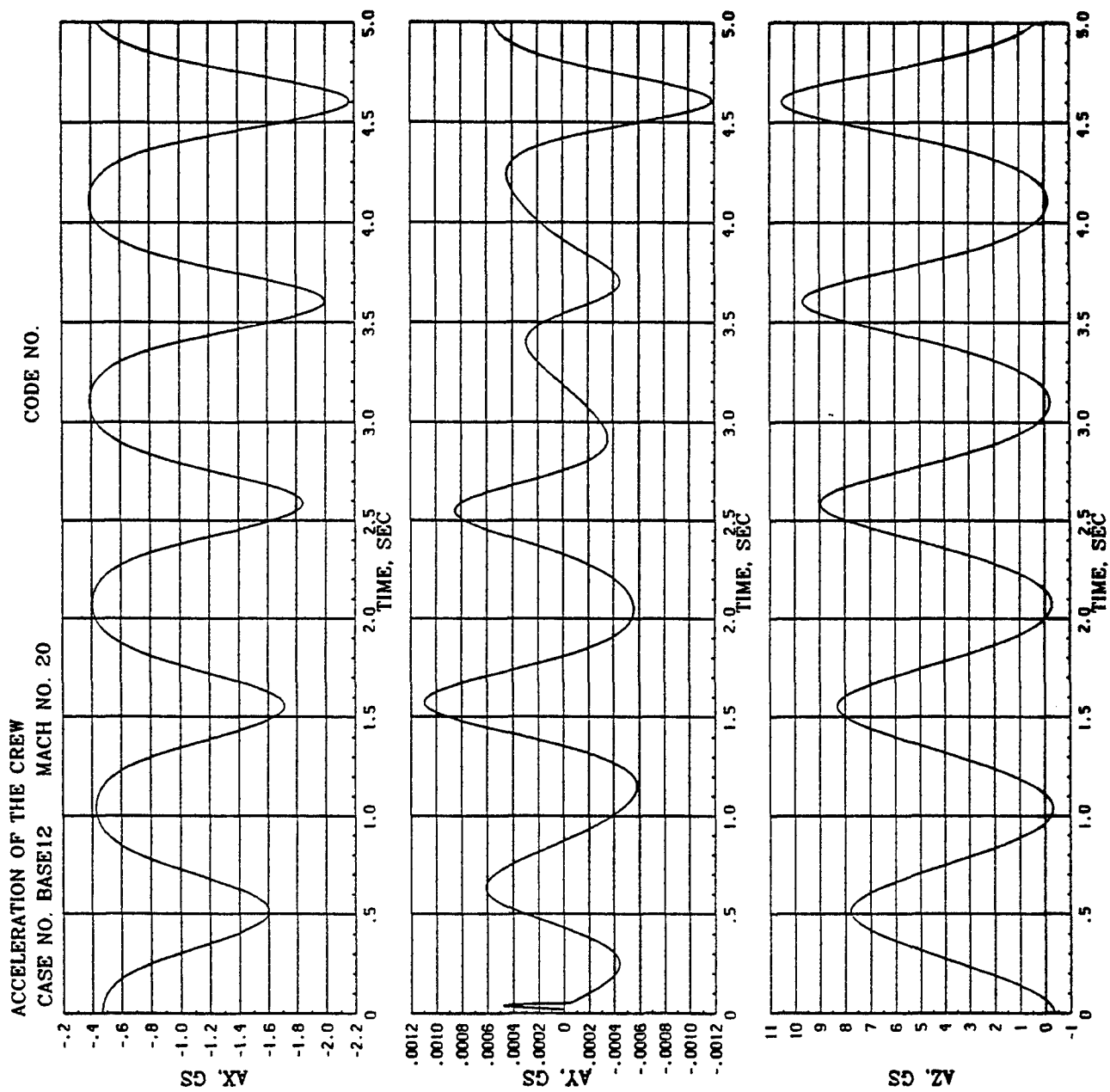
CODE NO.

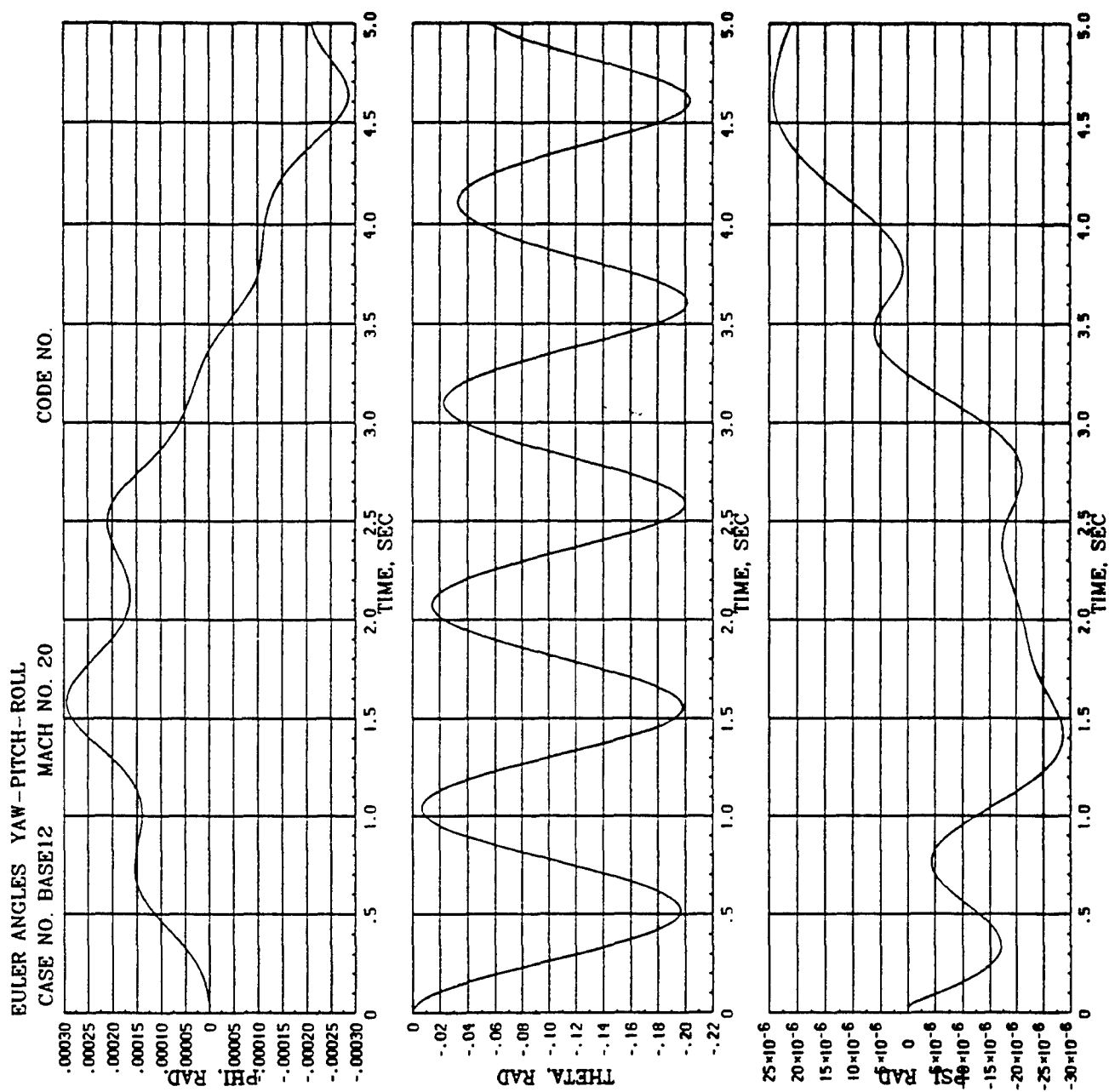


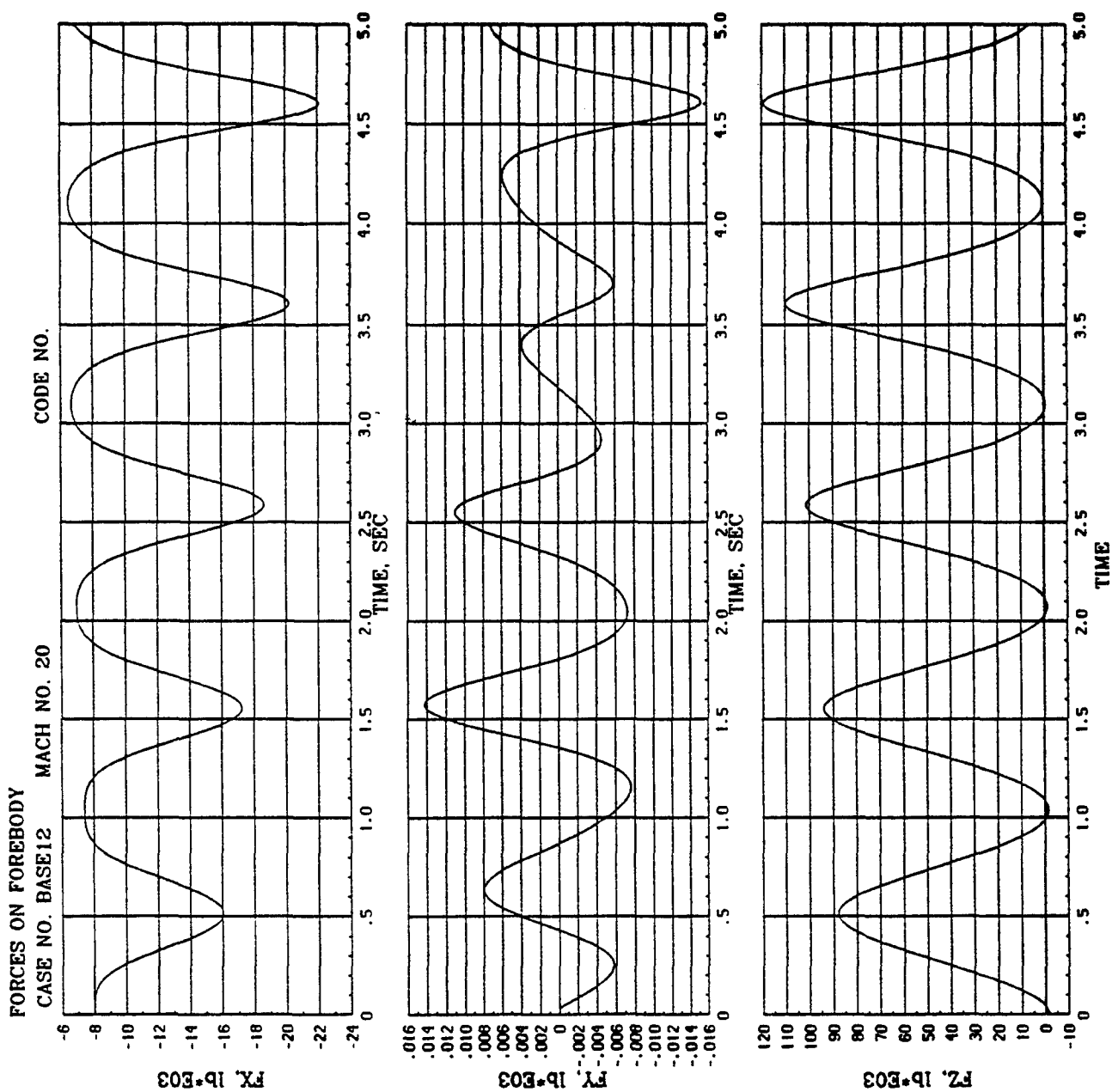




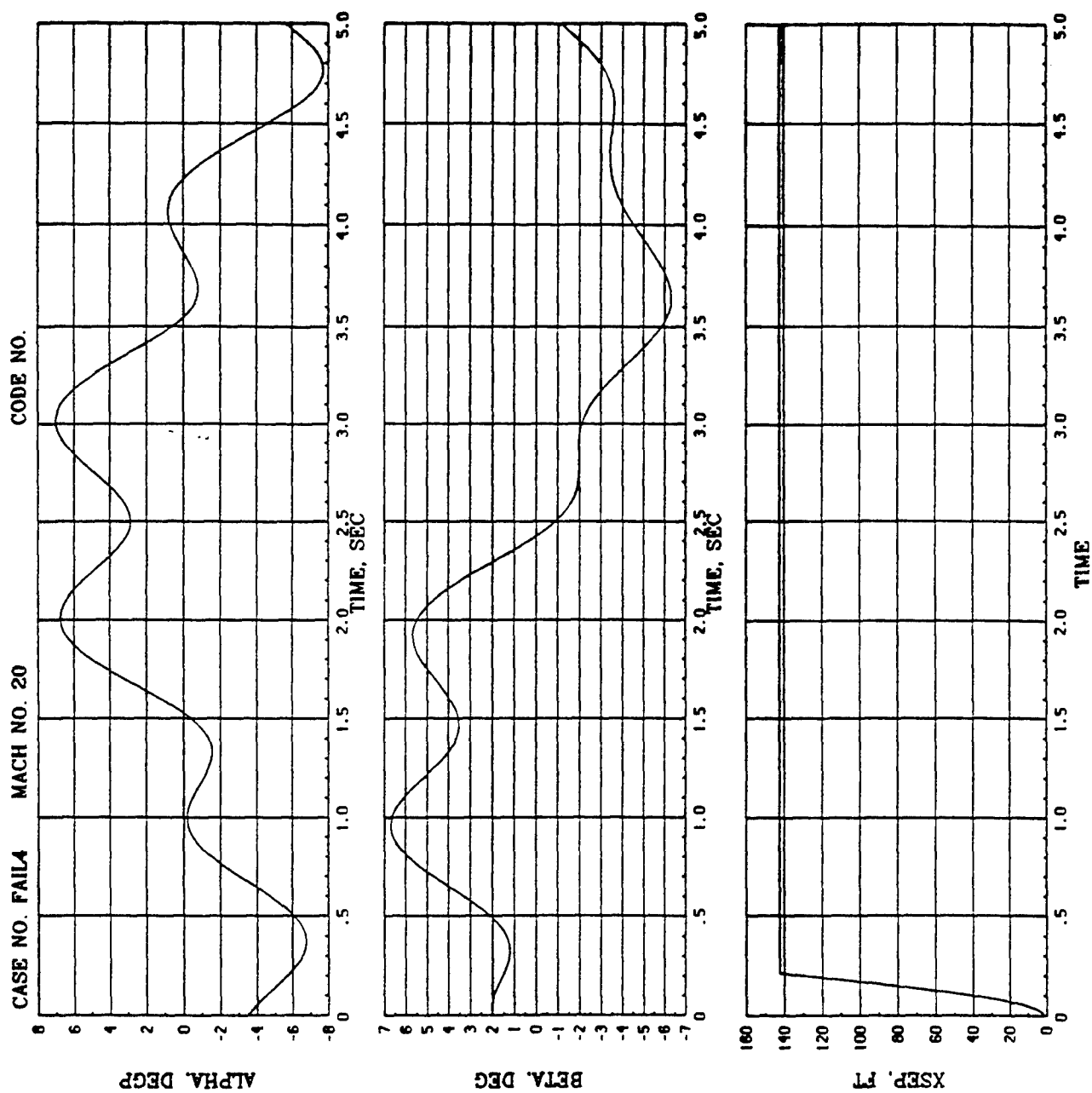


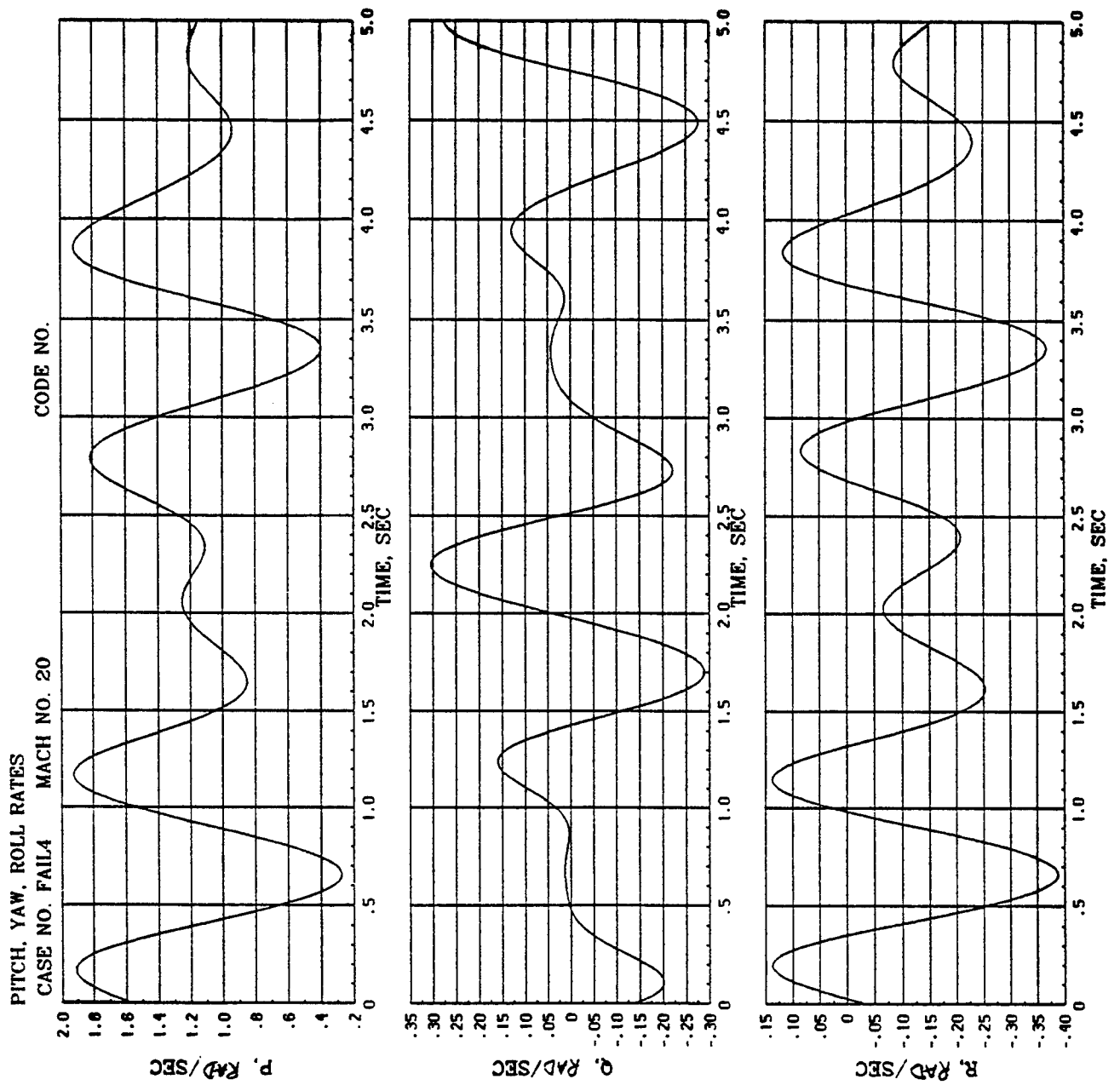


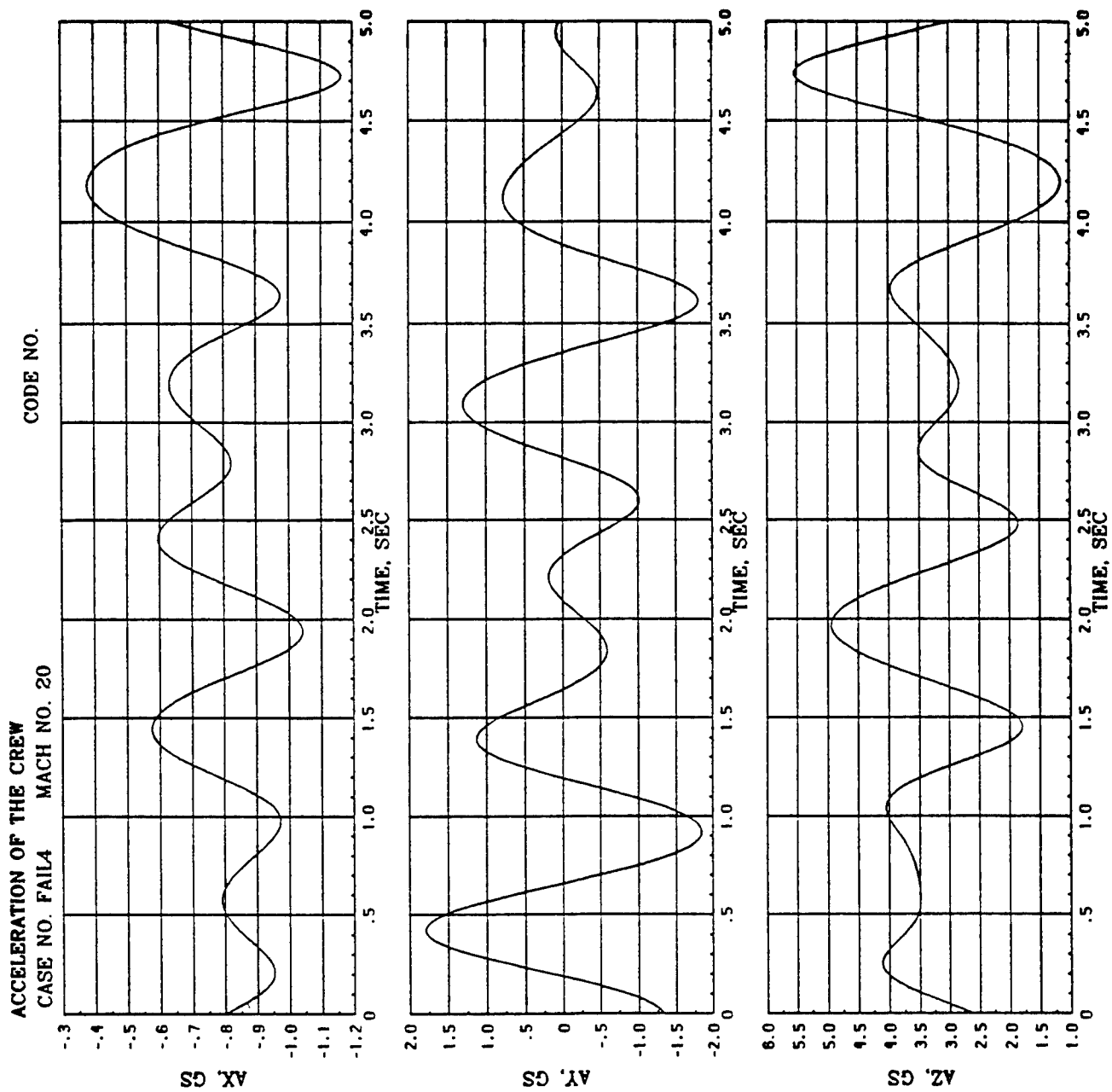






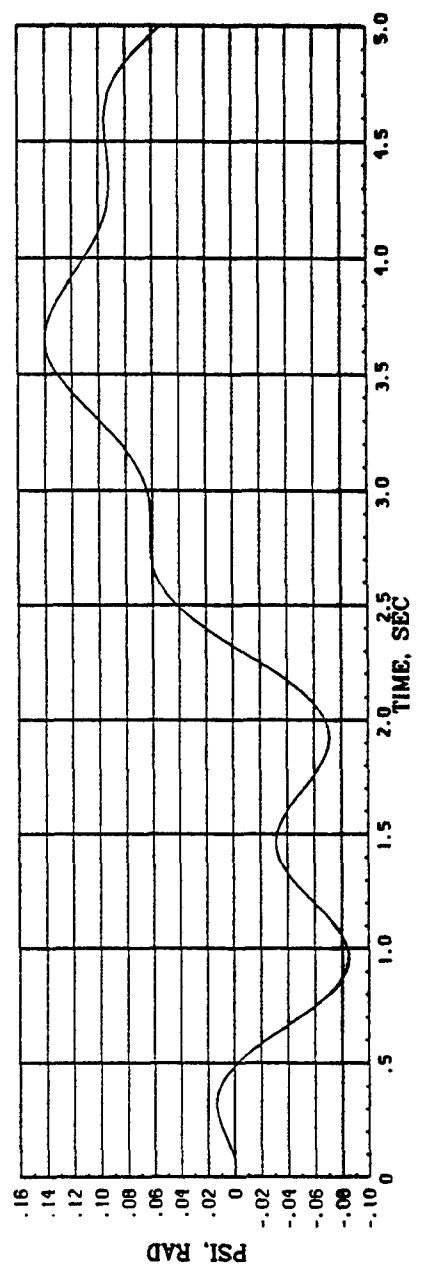
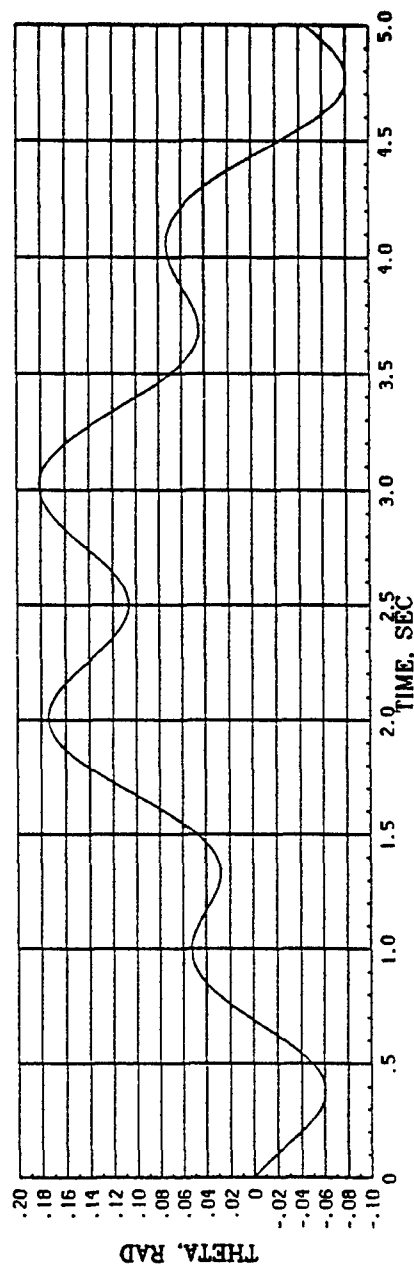
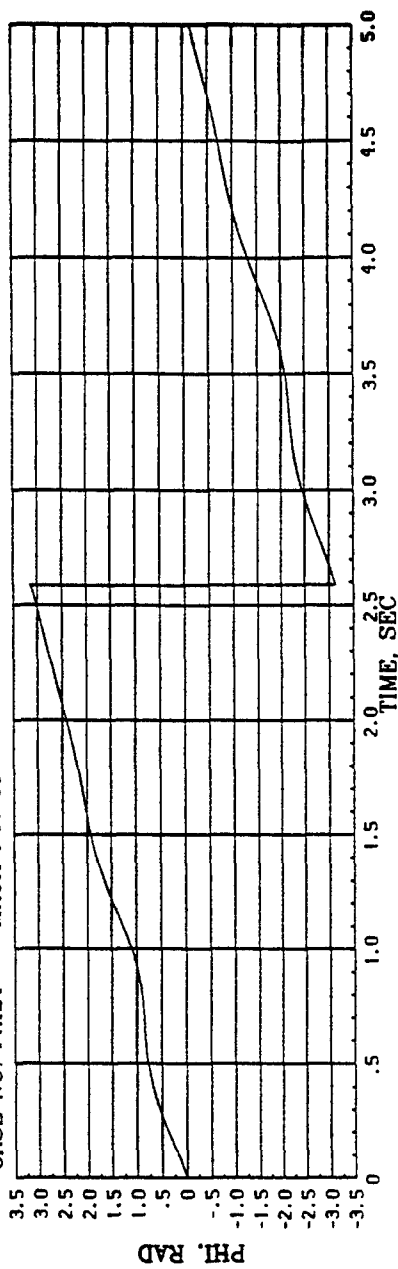


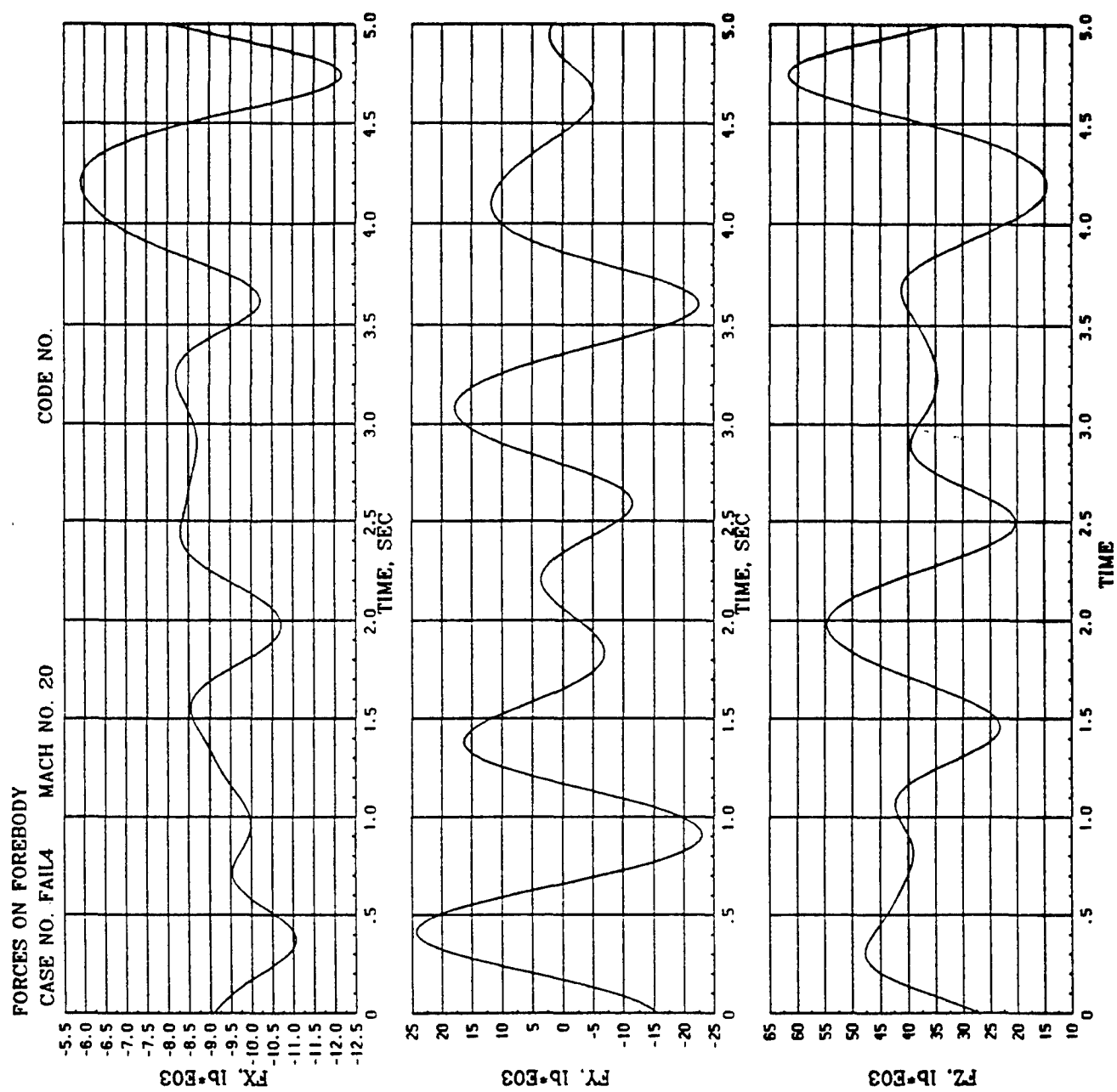


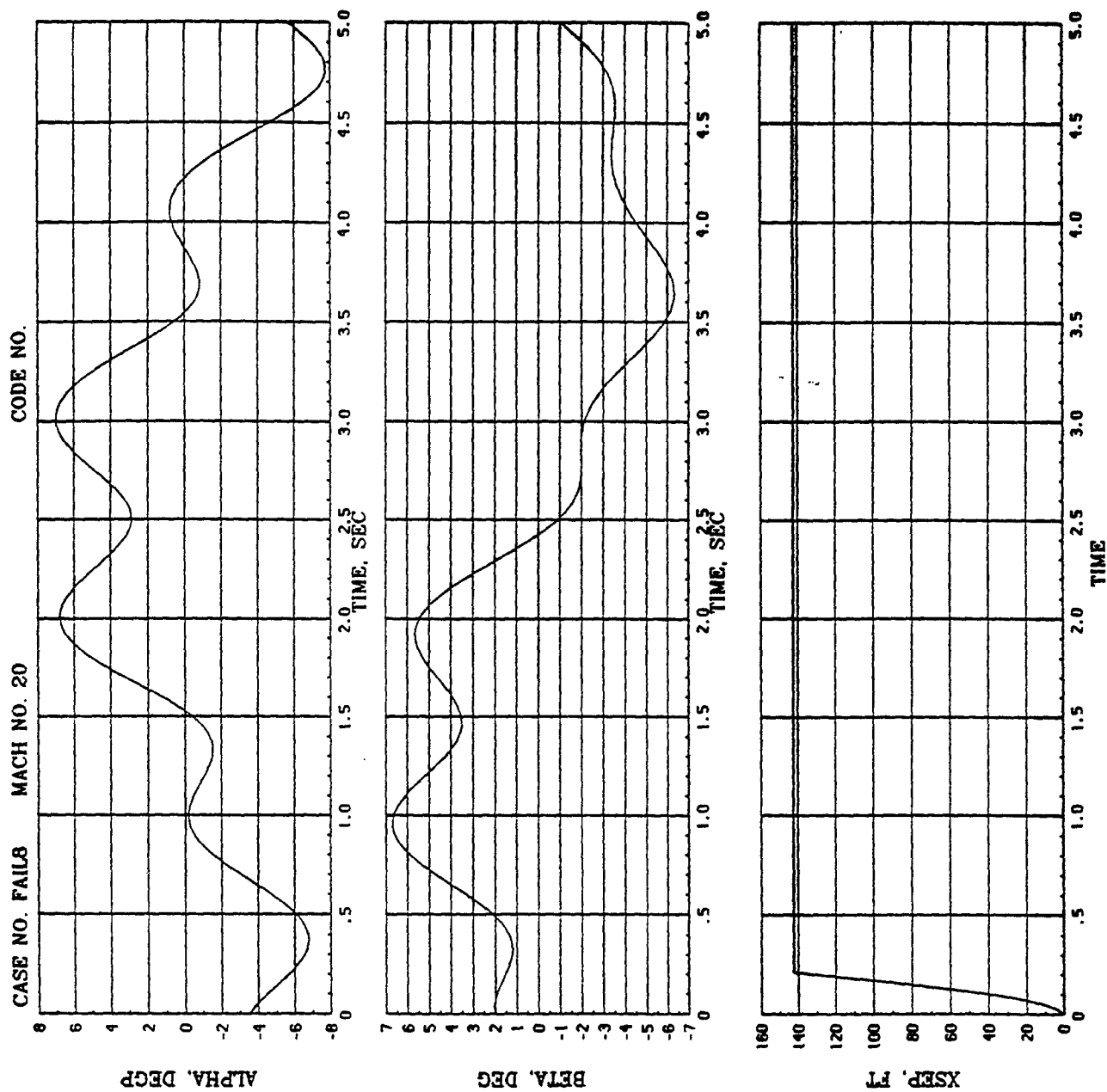


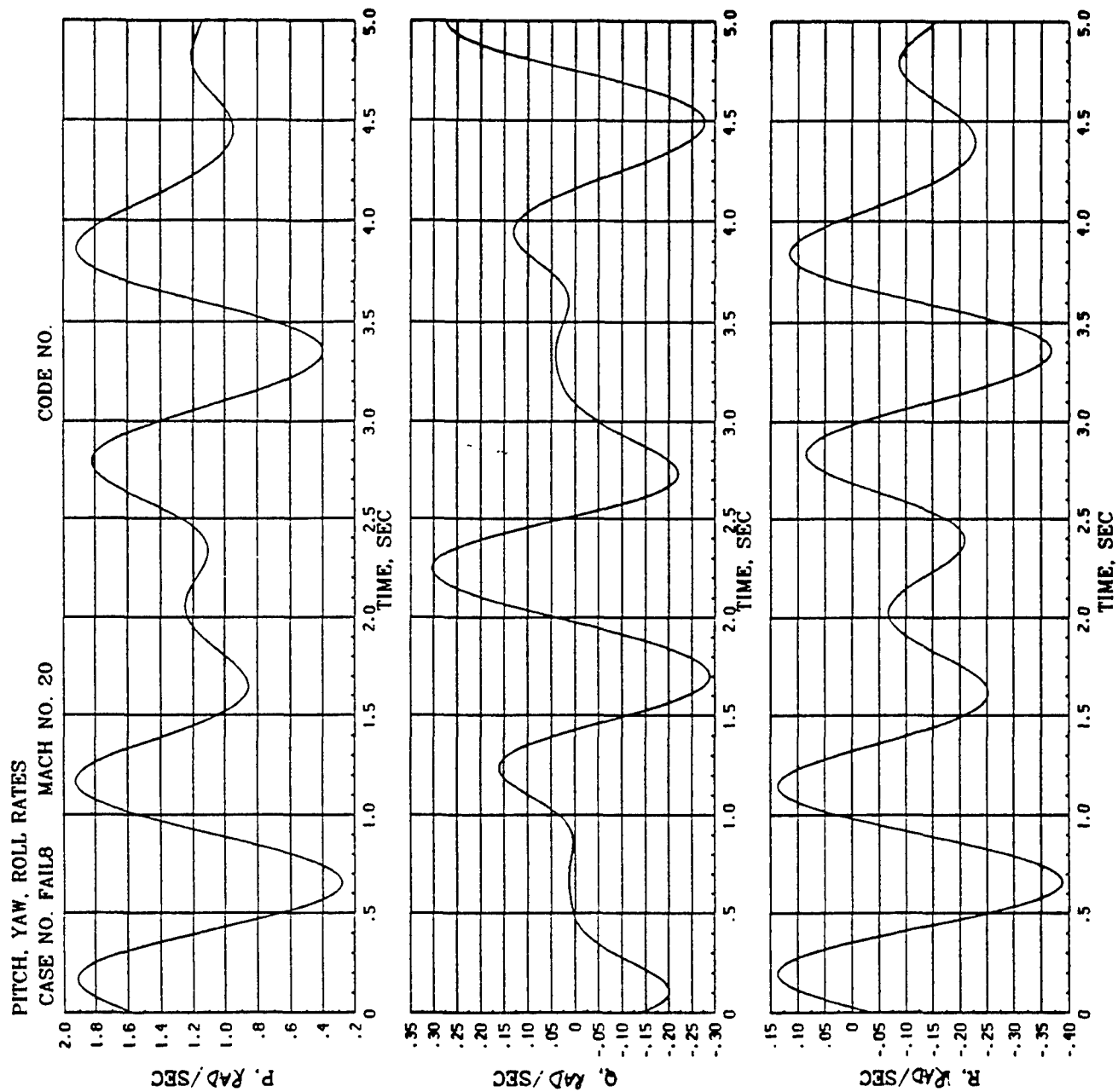
EULER ANGLES YAW-PITCH-ROLL  
CASE NO. FAIL4 MACH NO. 20

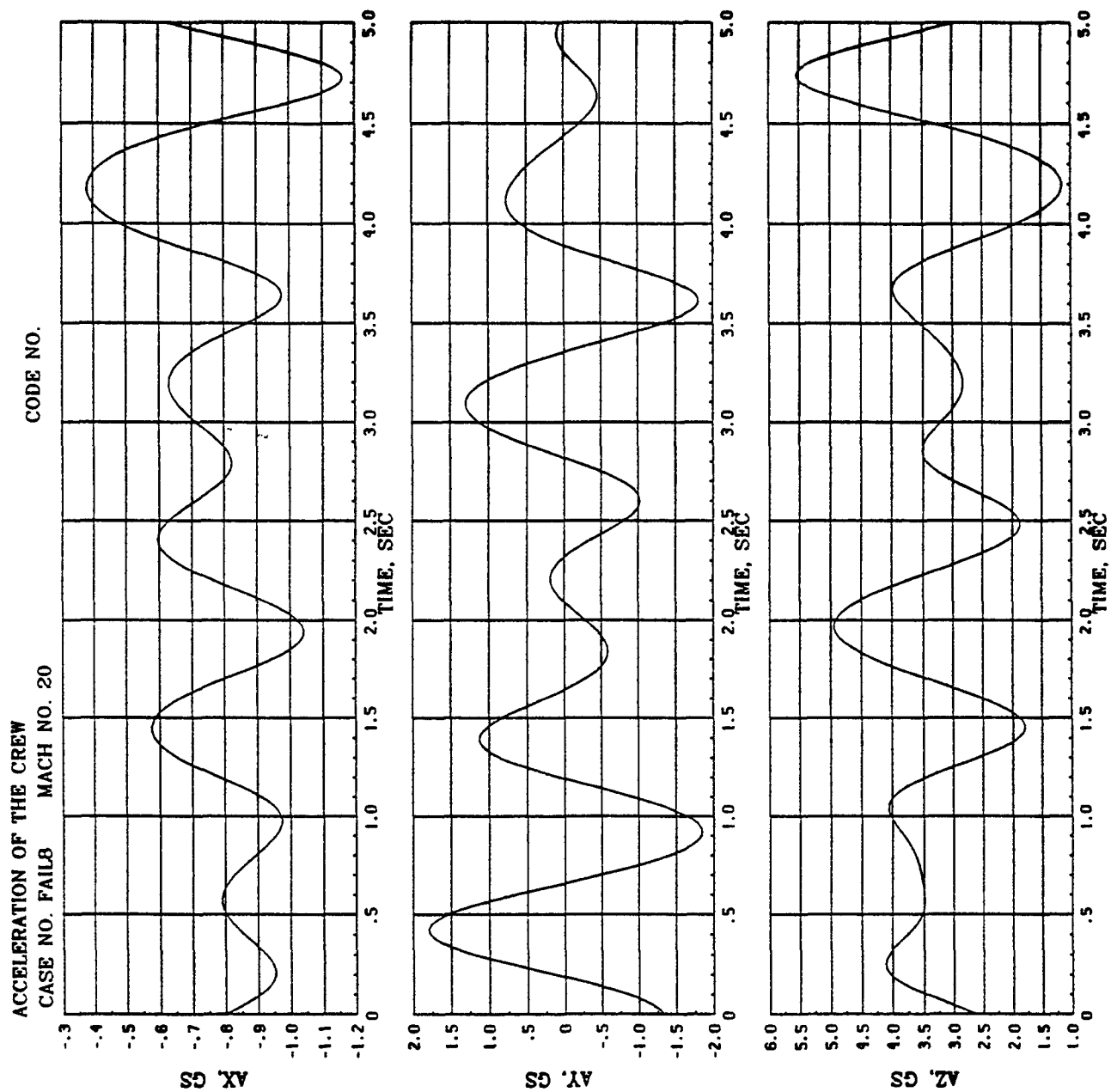
CODE NO.



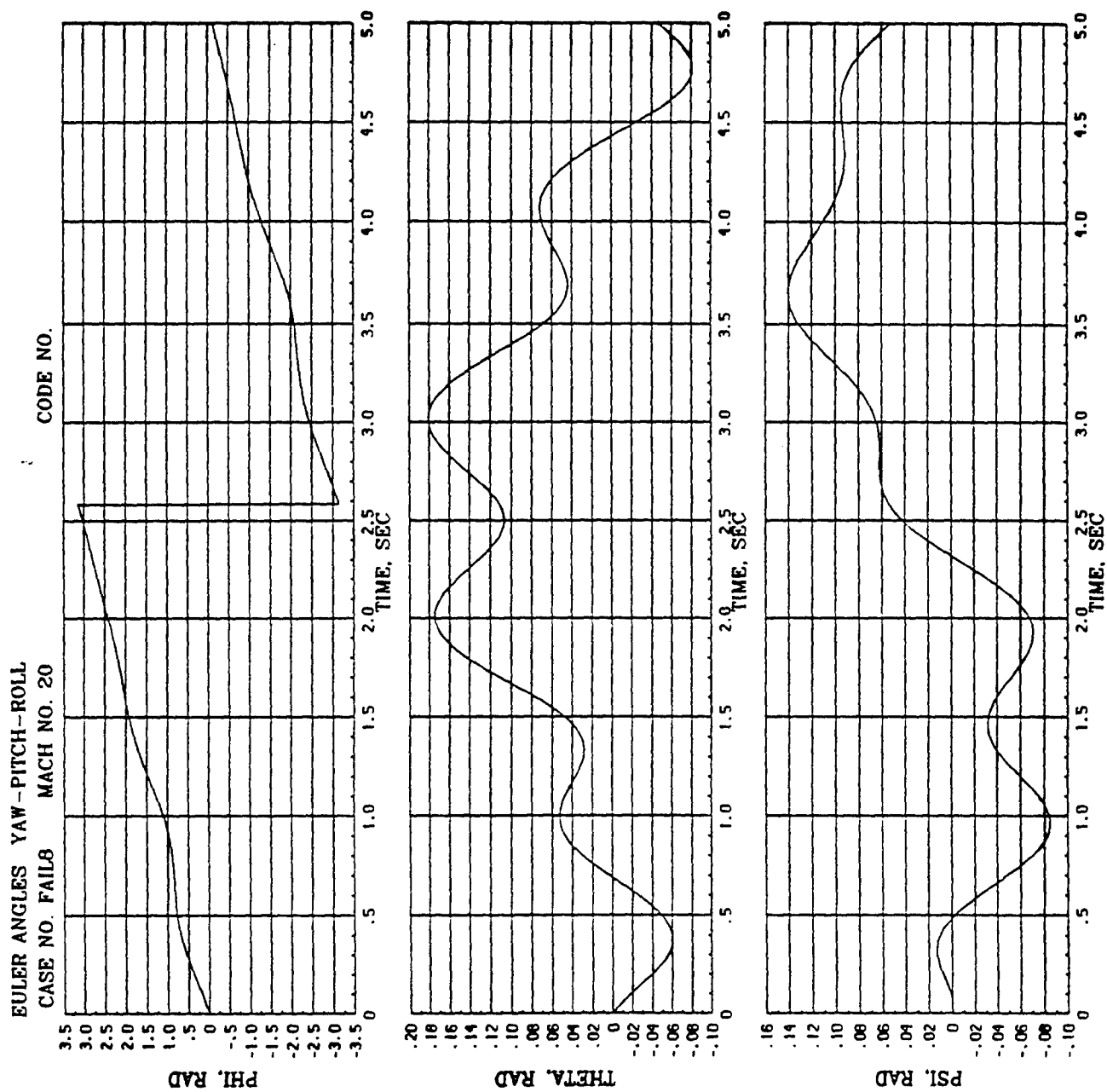


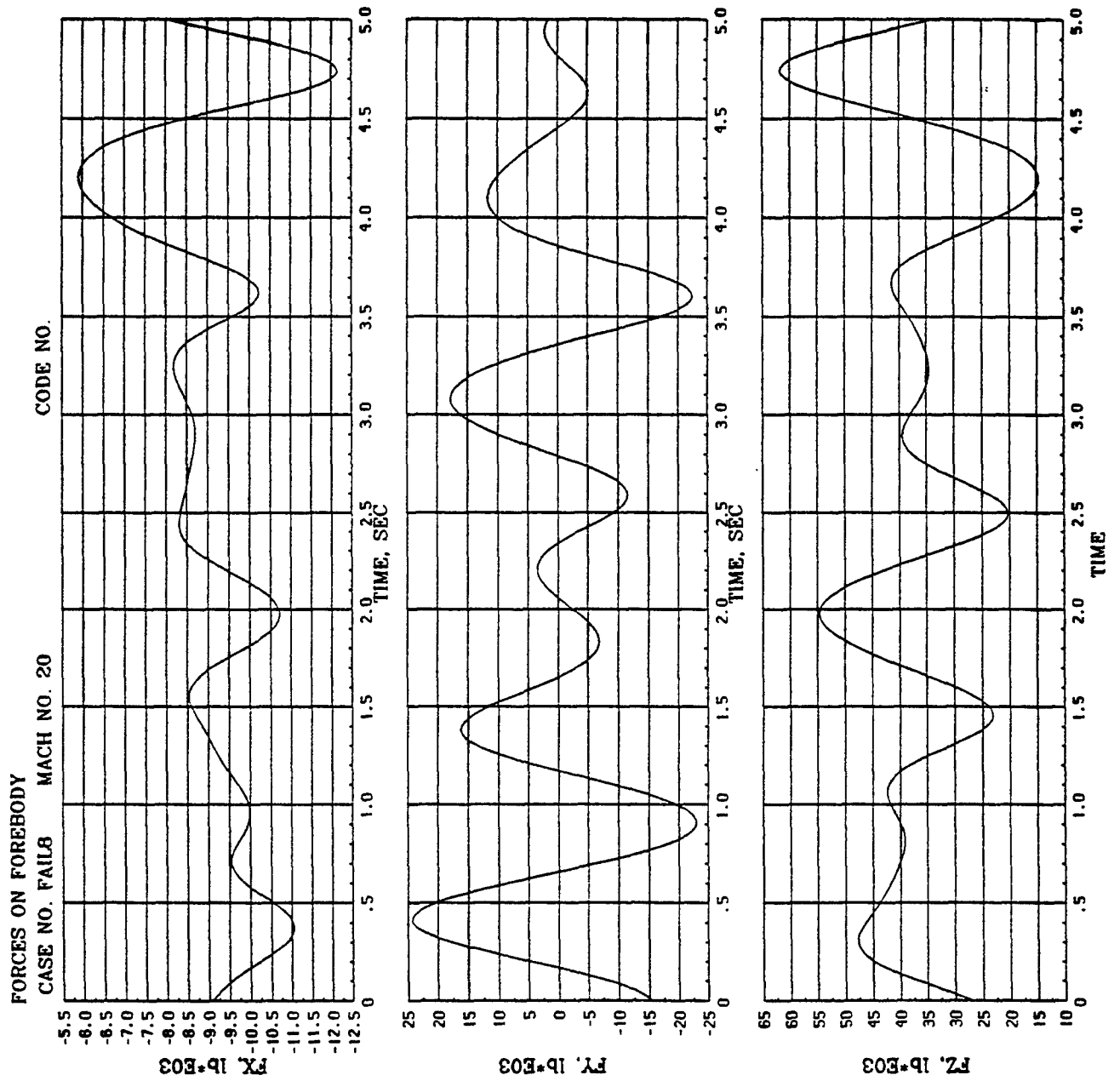


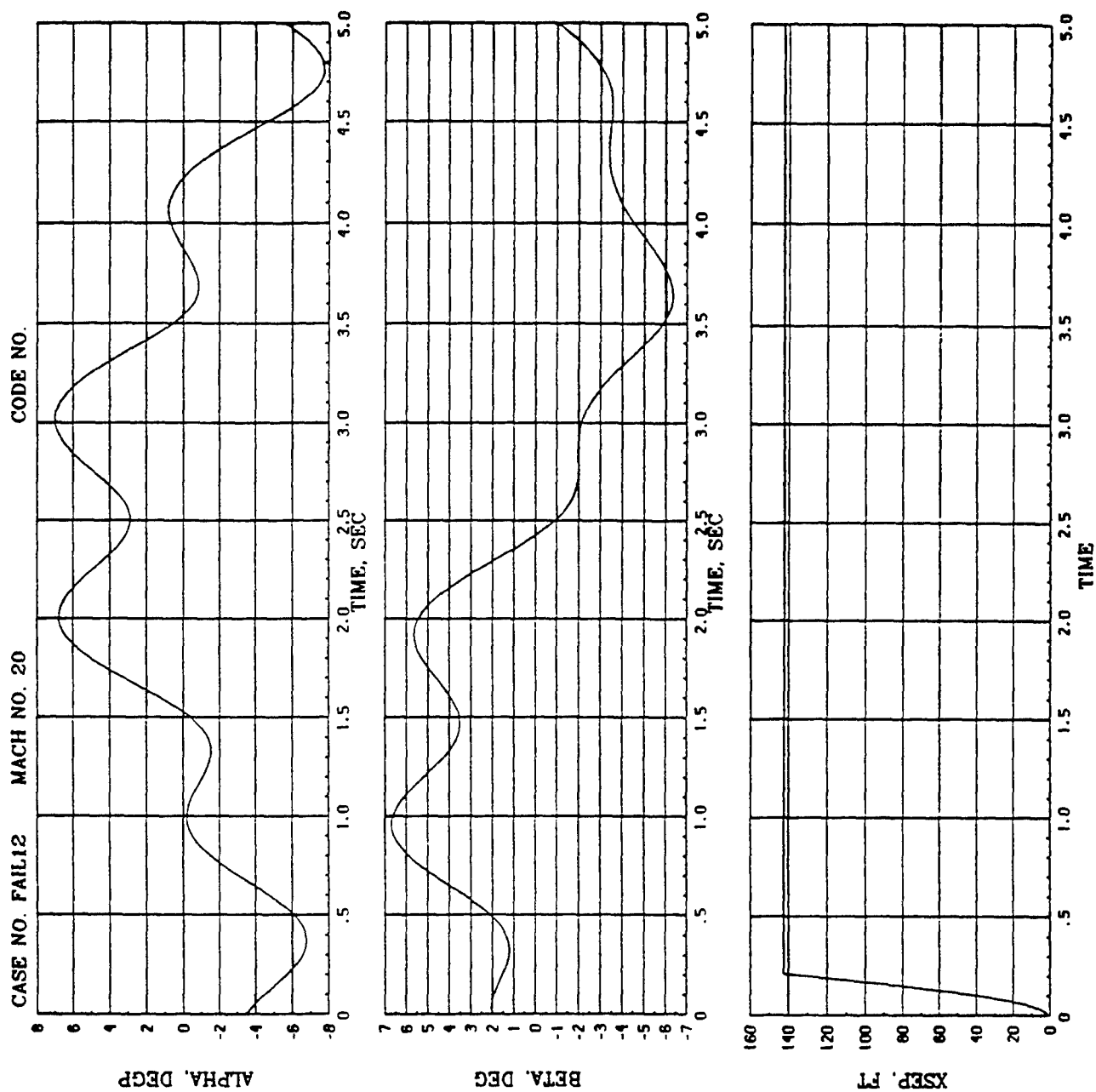


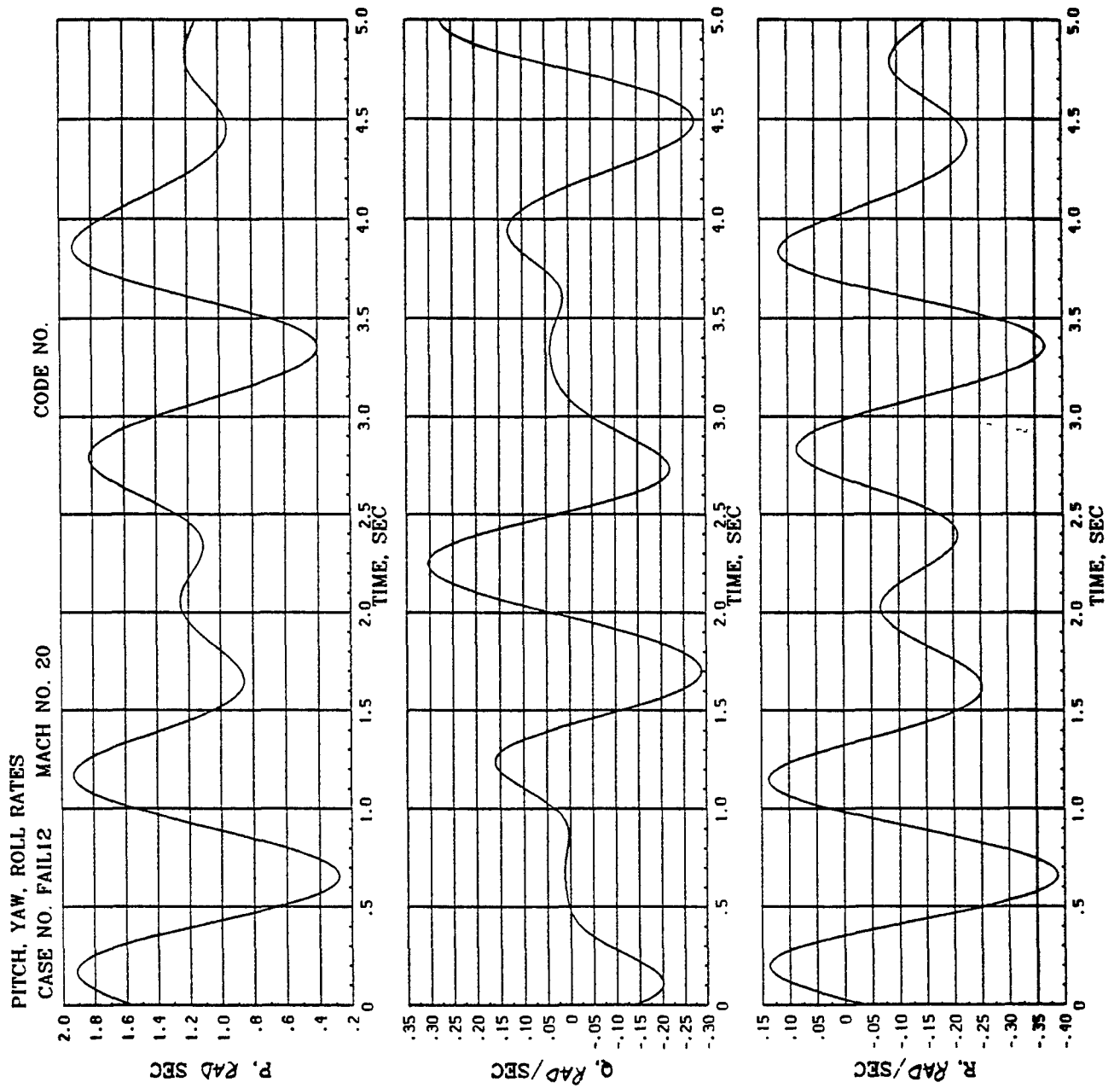


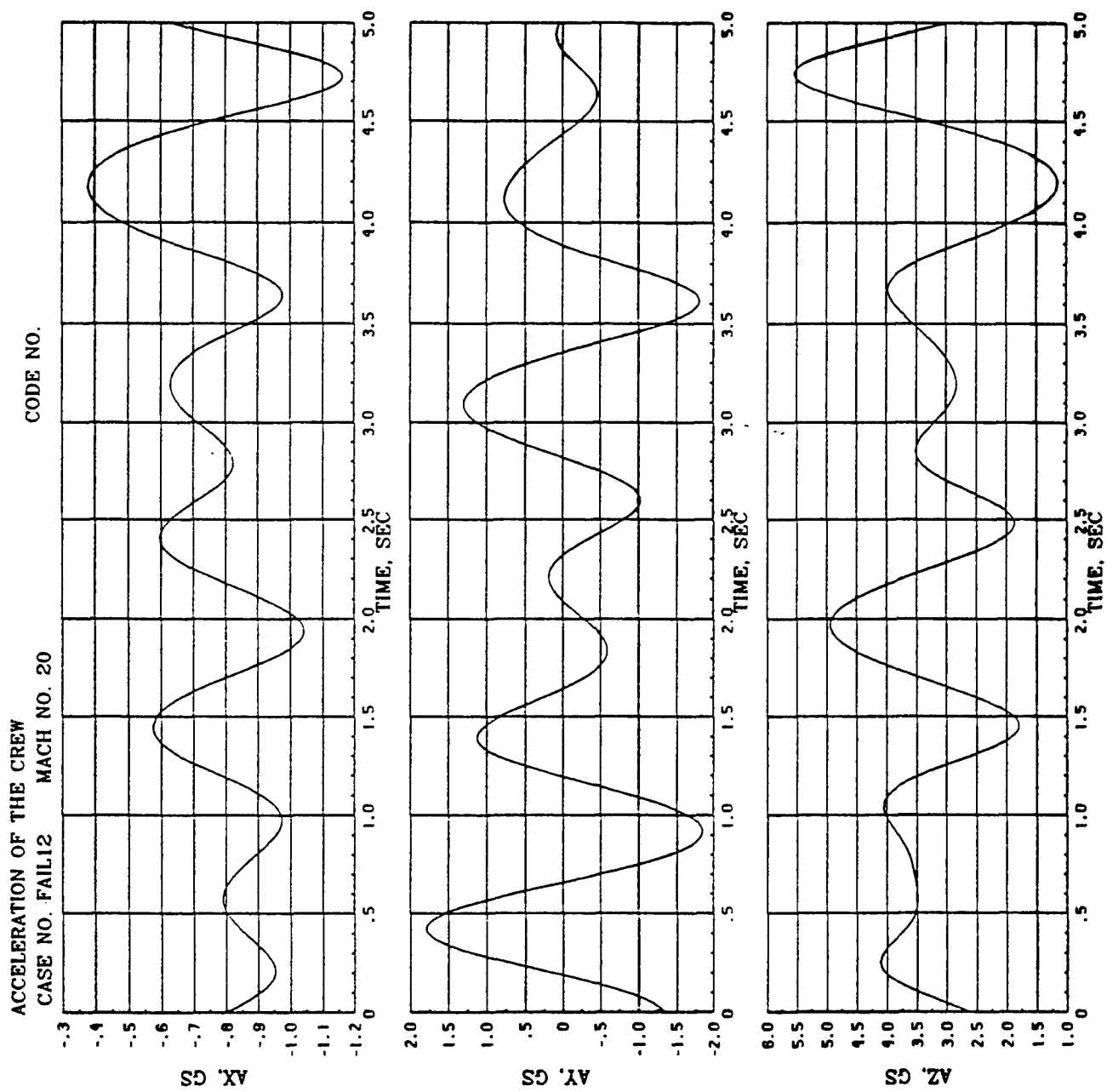






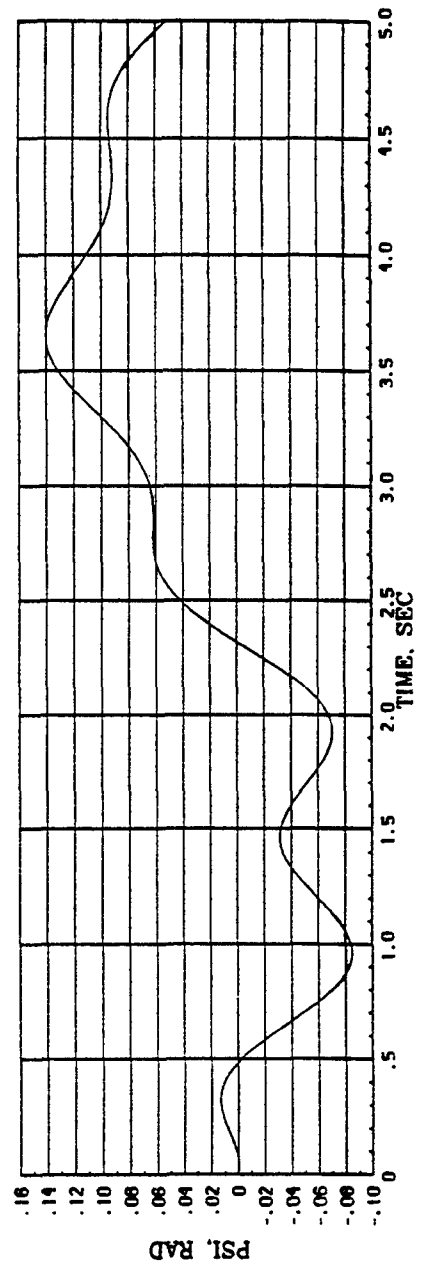
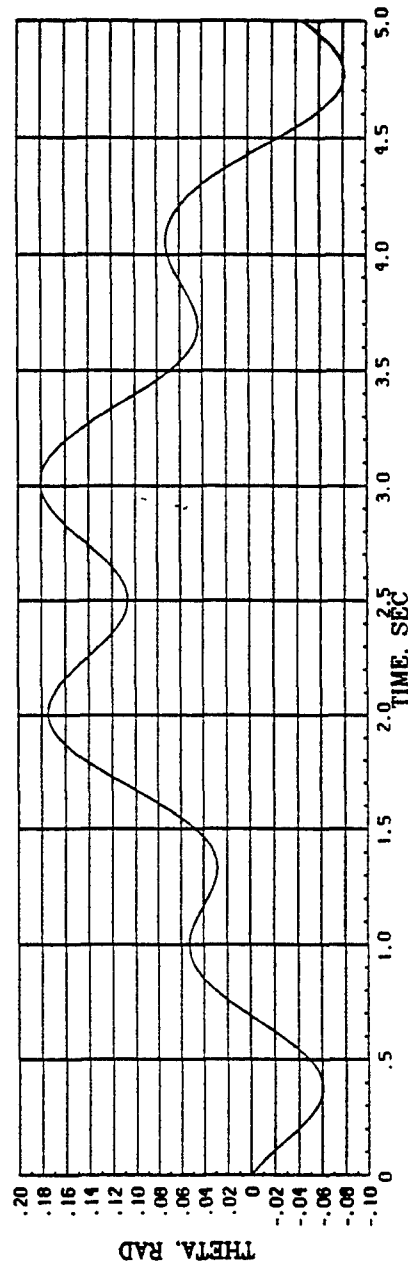
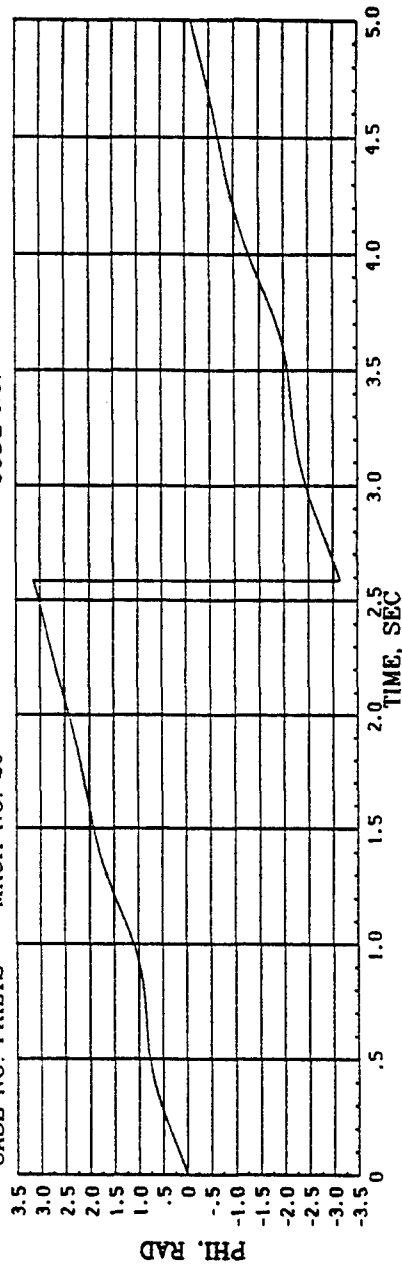


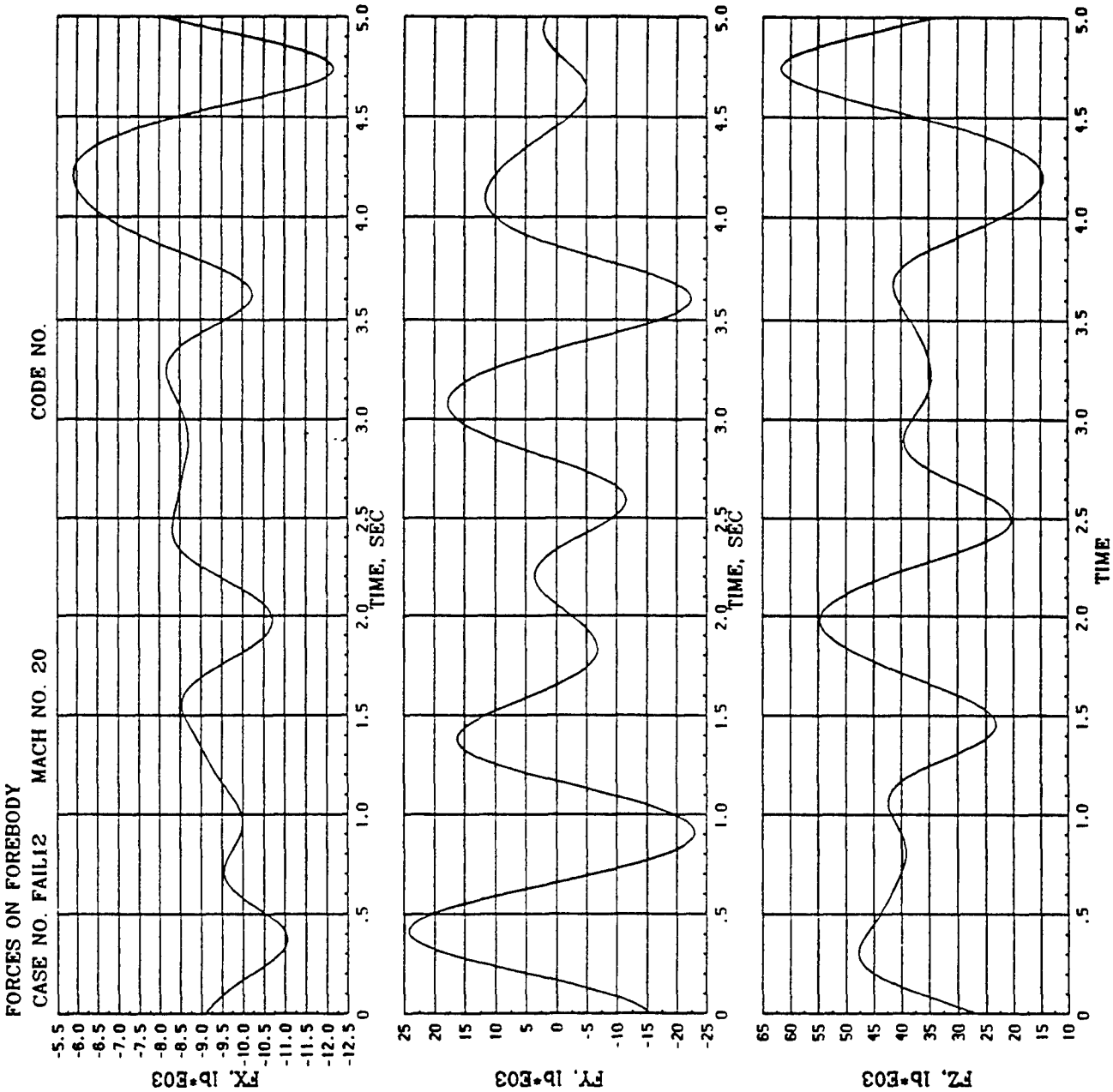




EULER ANGLES YAW-PITCH-ROLL  
CASE NO. FAIL12 MACH NO. 20

CODE NO.





**APPENDIX E**  
**Aerodynamics Analysis Results**



This appendix contains the results of the aerodynamic analysis performed under Task IV. The results are presented for configuration refinements 1 and 2, and configuration refinement 2 adapted with the Inflatable Decelerator System. Refer to Tasks II and IV of this report for more information on each configuration and its associated aerodynamics.

## LONGITUDINAL AERO

## Configuration Refinement 1

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 0.60 | 32000.00 | 0.         | 2979.55  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02599 | 0.01792    | 0.00154  | -1.45034 | -0.05764 | 0.001492 |
| -15.00 | 0.00 | -0.01853 | 0.01386    | 0.00111  | -1.33694 | -0.05906 | 0.001490 |
| -10.00 | 0.00 | -0.01108 | 0.01125    | 0.00067  | -0.98489 | -0.06032 | 0.001492 |
| -5.00  | 0.00 | -0.00362 | 0.00985    | 0.00022  | -0.36751 | -0.05898 | 0.001492 |
| 0.00   | 0.00 | 0.00384  | 0.00944    | -0.00022 | 0.40678  | -0.05898 | 0.001492 |
| 5.00   | 0.00 | 0.01130  | 0.00985    | -0.00066 | 1.14721  | -0.06040 | 0.001490 |
| 10.00  | 0.00 | 0.01875  | 0.01125    | -0.00111 | 1.66667  | -0.05898 | 0.001492 |
| 15.00  | 0.00 | 0.02521  | 0.01386    | -0.00155 | 1.89105  | -0.05764 | 0.001492 |
| 20.00  | 0.00 | 0.03367  | 0.01792    | -0.00198 | 1.87891  | -0.05764 | 0.001492 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 0.90 | 37000.00 | 0.         | 2979.55  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02599 | 0.02351    | 0.00206  | -1.10549 | -0.07507 | 0.001492 |
| -15.00 | 0.00 | -0.01853 | 0.01945    | 0.00150  | -0.95270 | -0.07651 | 0.001490 |
| -10.00 | 0.00 | -0.01108 | 0.01684    | 0.00093  | -0.63796 | -0.07641 | 0.001492 |
| -5.00  | 0.00 | -0.00362 | 0.01544    | 0.00036  | -0.23446 | -0.07775 | 0.001492 |
| 0.00   | 0.00 | 0.00384  | 0.01503    | -0.00022 | 0.25549  | -0.07775 | 0.001492 |
| 5.00   | 0.00 | 0.01130  | 0.01544    | -0.00080 | 0.73187  | -0.07651 | 0.001490 |
| 10.00  | 0.00 | 0.01875  | 0.01684    | -0.00137 | 1.11342  | -0.07641 | 0.001492 |
| 15.00  | 0.00 | 0.02521  | 0.01945    | -0.00194 | 1.34756  | -0.07507 | 0.001492 |
| 20.00  | 0.00 | 0.03367  | 0.02351    | -0.00250 | 1.43216  | -0.07507 | 0.001492 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 1.10 | 39000.00 | 0.         | 2979.55  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02599 | 0.02865    | 0.00230  | -0.90716 | -0.08311 | 0.001492 |
| -15.00 | 0.00 | -0.01853 | 0.02450    | 0.00168  | -0.75633 | -0.08456 | 0.001490 |
| -10.00 | 0.00 | -0.01108 | 0.02186    | 0.00105  | -0.50686 | -0.08445 | 0.001492 |
| -5.00  | 0.00 | -0.00362 | 0.02044    | 0.00042  | -0.17710 | -0.08579 | 0.001492 |
| 0.00   | 0.00 | 0.00384  | 0.02003    | -0.00022 | 0.19171  | -0.08579 | 0.001492 |
| 5.00   | 0.00 | 0.01130  | 0.02044    | -0.00086 | 0.55284  | -0.08456 | 0.001490 |
| 10.00  | 0.00 | 0.01875  | 0.02186    | -0.00149 | 0.85773  | -0.08445 | 0.001492 |
| 15.00  | 0.00 | 0.02521  | 0.02450    | -0.00212 | 1.06980  | -0.08311 | 0.001492 |
| 20.00  | 0.00 | 0.03367  | 0.02865    | -0.00274 | 1.17522  | -0.08311 | 0.001492 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 1.20 | 41500.00 | 0.         | 2979.55  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02599 | 0.02772    | 0.00224  | -0.93759 | -0.08177 | 0.001492 |
| -15.00 | 0.00 | -0.01853 | 0.02357    | 0.00163  | -0.78617 | -0.08188 | 0.001490 |
| -10.00 | 0.00 | -0.01108 | 0.02093    | 0.00102  | -0.52938 | -0.08311 | 0.001492 |
| -5.00  | 0.00 | -0.00362 | 0.01951    | 0.00040  | -0.18555 | -0.08311 | 0.001492 |
| 0.00   | 0.00 | 0.00384  | 0.01910    | -0.00022 | 0.20105  | -0.08311 | 0.001492 |
| 5.00   | 0.00 | 0.01130  | 0.01951    | -0.00084 | 0.57919  | -0.08322 | 0.001490 |
| 10.00  | 0.00 | 0.01875  | 0.02093    | -0.00146 | 0.89584  | -0.08177 | 0.001492 |
| 15.00  | 0.00 | 0.02521  | 0.02357    | -0.00207 | 1.11201  | -0.08177 | 0.001492 |
| 20.00  | 0.00 | 0.03367  | 0.02772    | -0.00258 | 1.21465  | -0.08177 | 0.001492 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF    | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|---------|----------|----------|----------|
| BASIC  | 1.50 | 45500.00 | 0.         | 2979.55 | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM      | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02599 | 0.02417    | 0.00194 | -1.07510 | -0.07239 | 0.001492 |

# Configuration Refinement 1

|        |      |          |         |          |          |          |          |
|--------|------|----------|---------|----------|----------|----------|----------|
| -10.00 | 0.00 | -0.01108 | 0.01719 | 0.00087  | -0.64456 | -0.07173 | 0.001492 |
| -5.00  | 0.00 | -0.00362 | 0.01576 | 0.00032  | -0.22970 | -0.07239 | 0.001492 |
| 0.00   | 0.00 | 0.00384  | 0.01534 | -0.00022 | 0.23033  | -0.07239 | 0.001492 |
| 5.00   | 0.00 | 0.01130  | 0.01576 | -0.00076 | 0.71700  | -0.07383 | 0.001490 |
| 10.00  | 0.00 | 0.01875  | 0.01719 | -0.00131 | 1.09075  | -0.08443 | 0.001492 |
| 15.00  | 0.00 | 0.02521  | 0.01991 | -0.00194 | 1.31642  | -0.05898 | 0.001492 |
| 20.00  | 0.00 | 0.03367  | 0.02417 | -0.00238 | 1.39305  | -0.05898 | 0.001492 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 2.00 | 31000.00 | 0.         | 2979.33  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02599 | 0.01995    | 0.00153  | -1.30276 | -0.05898 | 0.001492 |
| -15.00 | 0.00 | -0.01853 | 0.01534    | 0.00109  | -1.20795 | -0.05772 | 0.001490 |
| -10.00 | 0.00 | -0.01108 | 0.01245    | 0.00066  | -0.88996 | -0.05898 | 0.001492 |
| -5.00  | 0.00 | -0.00362 | 0.01095    | 0.00022  | -0.33059 | -0.05898 | 0.001492 |
| 0.00   | 0.00 | 0.00384  | 0.01052    | -0.00022 | 0.36502  | -0.05898 | 0.001492 |
| 5.00   | 0.00 | 0.01130  | 0.01095    | -0.00066 | 1.03196  | -0.05906 | 0.001490 |
| 10.00  | 0.00 | 0.01875  | 0.01245    | -0.00110 | 1.50602  | -0.06702 | 0.001492 |
| 15.00  | 0.00 | 0.02521  | 0.01534    | -0.00160 | 1.70860  | -0.06702 | 0.001492 |
| 20.00  | 0.00 | 0.03367  | 0.02100    | -0.00210 | 1.60333  | -0.06702 | 0.001492 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 3.00 | 62000.00 | 0.         | 2979.33  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02599 | 0.01656    | 0.00132  | -1.56944 | -0.06836 | 0.001492 |
| -15.00 | 0.00 | -0.01853 | 0.01123    | 0.00081  | -1.64711 | -0.04698 | 0.001490 |
| -10.00 | 0.00 | -0.01108 | 0.00818    | 0.00046  | -1.35452 | -0.04538 | 0.001492 |
| -5.00  | 0.00 | -0.00362 | 0.00638    | 0.00012  | -0.56740 | -0.04358 | 0.001492 |
| 0.00   | 0.00 | 0.00384  | 0.00593    | -0.00022 | 0.64755  | -0.04021 | 0.001492 |
| 5.00   | 0.00 | 0.01130  | 0.00638    | -0.00052 | 1.77216  | -0.05503 | 0.001490 |
| 10.00  | 0.00 | 0.01875  | 0.00818    | -0.00093 | 2.29218  | -0.06702 | 0.001492 |
| 15.00  | 0.00 | 0.02521  | 0.01380    | -0.00143 | 1.89928  | -0.06300 | 0.001492 |
| 20.00  | 0.00 | 0.03367  | 0.01950    | -0.00190 | 1.72567  | -0.06300 | 0.001492 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 5.00 | 76000.00 | 0.         | 2979.33  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02750 | 0.01258    | 0.00109  | -2.16877 | -0.04824 | 0.001700 |
| -15.00 | 0.00 | -0.01900 | 0.00786    | 0.00068  | -2.41730 | -0.04750 | 0.001600 |
| -10.00 | 0.00 | -0.01100 | 0.00479    | 0.00030  | -2.29645 | -0.04143 | 0.001400 |
| -5.00  | 0.00 | -0.00400 | 0.00343    | 0.00001  | -1.16618 | -0.03426 | 0.001518 |
| 0.00   | 0.00 | 0.00359  | 0.00328    | -0.00025 | 1.09451  | -0.04336 | 0.001522 |
| 5.00   | 0.00 | 0.01120  | 0.00479    | -0.00058 | 2.33820  | -0.04819 | 0.001660 |
| 10.00  | 0.00 | 0.01950  | 0.00786    | -0.00098 | 2.48092  | -0.05474 | 0.001900 |
| 15.00  | 0.00 | 0.02900  | 0.01210    | -0.00150 | 2.39649  | -0.05789 | 0.001900 |
| 20.00  | 0.00 | 0.03850  | 0.01850    | -0.00205 | 2.08108  | -0.05789 | 0.001900 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 10.00 | 106000.00 | 0.         | 2979.33  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02787  | 0.01099    | 0.00089  | -2.53394 | -0.04028 | 0.001738 |
| -15.00 | 0.00  | -0.01918  | 0.00649    | 0.00054  | -2.95532 | -0.03585 | 0.001618 |
| -10.00 | 0.00  | -0.01109  | 0.00355    | 0.00025  | -3.12394 | -0.03385 | 0.001418 |
| 0.00   | 0.00  | -0.00400  | 0.00209    | 0.00001  | -1.91388 | -0.03631 | 0.001432 |
| 5.00   | 0.00  | 0.00316   | 0.00196    | -0.00025 | 1.61224  | -0.04253 | 0.001532 |
| 10.00  | 0.00  | 0.01092   | 0.00349    | -0.00058 | 3.12394  | -0.05098 | 0.001844 |
| 10.00  | 0.00  | 0.02014   | 0.00652    | -0.00104 | 1.00000  | 0.00000  | 0.00000  |

# Configuration Refinement 1

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 16.00 | 140000.00 | 0.         | 2979.33  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02684  | 0.01023    | 0.00081  | -2.62366 | -0.03878 | 0.001702 |
| -15.00 | 0.00  | -0.01833  | 0.00590    | 0.00048  | -3.10678 | -0.03403 | 0.001528 |
| -10.00 | 0.00  | -0.01069  | 0.00308    | 0.00022  | -3.47078 | -0.03230 | 0.001354 |
| -5.00  | 0.00  | -0.00392  | 0.00164    | 0.00000  | -2.39024 | -0.03429 | 0.001400 |
| 0.00   | 0.00  | 0.00308   | 0.00151    | -0.00024 | 2.03973  | -0.04111 | 0.001508 |
| 5.00   | 0.00  | 0.01062   | 0.00302    | -0.00033 | 3.51656  | -0.04983 | 0.001766 |
| 10.00  | 0.00  | 0.01945   | 0.00594    | -0.00099 | 3.27441  | -0.05677 | 0.002008 |
| 15.00  | 0.00  | 0.02949   | 0.01041    | -0.00156 | 2.83285  | -0.06157 | 0.002144 |
| 20.00  | 0.00  | 0.04021   | 0.01682    | -0.00222 | 2.39061  | -0.06157 | 0.002144 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 20.00 | 177000.00 | 0.         | 2979.33  | 34.00    | -0.97    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02648  | 0.01041    | 0.00080  | -2.54371 | -0.03787 | 0.001690 |
| -15.00 | 0.00  | -0.01803  | 0.00610    | 0.00048  | -2.95574 | -0.03467 | 0.001500 |
| -10.00 | 0.00  | -0.01053  | 0.00331    | 0.00022  | -3.18127 | -0.03163 | 0.001328 |
| -5.00  | 0.00  | -0.00389  | 0.00189    | 0.00001  | -2.05820 | -0.03453 | 0.001390 |
| 0.00   | 0.00  | 0.00306   | 0.00176    | -0.00023 | 1.73864  | -0.04172 | 0.001486 |
| 5.00   | 0.00  | 0.01049   | 0.00325    | -0.00034 | 3.22769  | -0.05178 | 0.001738 |
| 10.00  | 0.00  | 0.01918   | 0.00615    | -0.00099 | 3.11870  | -0.05617 | 0.001994 |
| 15.00  | 0.00  | 0.02915   | 0.01059    | -0.00153 | 2.75260  | -0.06268 | 0.002138 |
| 20.00  | 0.00  | 0.03984   | 0.01698    | -0.00222 | 2.34629  | -0.06268 | 0.002138 |

# LATERAL-DIRECTIONAL AERO

## Configuration Refinement 1

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 0.60 | 32000.00 | 0.         | 2979.33  | 34.00   | 0.00     | -0.97    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00092 | 0.00002  | -0.00923 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00083 | 0.00001  | -0.00837 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00074 | 0.00001  | -0.00746 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00066 | 0.00000  | -0.00663 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00063 | -0.00002 | -0.00632 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00063 | -0.00004 | -0.00637 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00070 | -0.00006 | -0.00702 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00074 | -0.00009 | -0.00746 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00079 | -0.00011 | -0.00791 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 0.90 | 37000.00 | 0.         | 2979.33  | 34.00   | 0.00     | -0.97    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00130 | 0.00002  | -0.01113 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00118 | 0.00001  | -0.01010 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00105 | 0.00001  | -0.00899 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00094 | 0.00000  | -0.00802 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00089 | -0.00002 | -0.00762 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00093 | -0.00004 | -0.00792 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00099 | -0.00006 | -0.00847 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00104 | -0.00009 | -0.00890 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00111 | -0.00011 | -0.00933 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 1.10 | 39000.00 | 0.         | 2979.33  | 34.00   | 0.00     | -0.97    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00147 | 0.00002  | -0.01163 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00134 | 0.00001  | -0.01239 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00119 | 0.00001  | -0.01103 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00106 | 0.00000  | -0.00984 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00101 | -0.00002 | -0.00933 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00103 | -0.00004 | -0.00971 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00112 | -0.00006 | -0.01039 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00119 | -0.00009 | -0.01104 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00125 | -0.00011 | -0.01170 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 1.20 | 41500.00 | 0.         | 2979.33  | 34.00   | 0.00     | -0.97    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00143 | 0.00002  | -0.01138 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00130 | 0.00001  | -0.01232 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00116 | 0.00001  | -0.01097 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00103 | 0.00000  | -0.00978 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00098 | -0.00002 | -0.00930 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00102 | -0.00004 | -0.00966 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00109 | -0.00006 | -0.01033 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00116 | -0.00009 | -0.01098 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00123 | -0.00011 | -0.01163 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF    | XCG     | ZCG     | YCG      |
|--------|------|----------|------------|---------|---------|---------|----------|
| BASIC  | 1.30 | 45500.00 | 0.         | 2979.33 | 34.00   | 0.00    | -0.97    |
| ALPHA  | BETA | CL       | CD         | CM      | C YAW   | C ROLL  | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000 | 0.00122 | 0.00002 | -0.01143 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000 | 0.00110 | 0.00001 | -0.01129 |

# Configuration Refinement 1

|        |       |           |            |          |         |          |           |
|--------|-------|-----------|------------|----------|---------|----------|-----------|
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00098 | 0.00001  | -0.01086  |
| -5.00  | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00087 | 0.00000  | -0.00968  |
| 0.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00083 | -0.00002 | -0.00920  |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00086 | -0.00004 | -0.00956  |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00092 | -0.00006 | -0.01022  |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00098 | -0.00009 | -0.01087  |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00104 | -0.00011 | -0.01151  |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
| BASIC  | 2.00  | 51000.00  | 0.         | 2979.55  | 34.00   | 0.00     | -0.97     |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00092 | 0.00002  | -0.01329  |
| -15.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00083 | 0.00001  | -0.01206  |
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00074 | 0.00001  | -0.01074  |
| -5.00  | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00066 | 0.00000  | -0.00957  |
| 0.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00063 | -0.00002 | -0.00910  |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00063 | -0.00004 | -0.00943  |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00070 | -0.00006 | -0.01011  |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00074 | -0.00009 | -0.01073  |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00079 | -0.00011 | -0.01138  |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
| BASIC  | 3.00  | 62000.00  | 0.         | 2979.55  | 34.00   | 0.00     | -0.97     |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00082 | 0.00002  | -0.01296  |
| -15.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00072 | 0.00001  | -0.01177  |
| -10.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00060 | 0.00001  | -0.01048  |
| -5.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00054 | 0.00000  | -0.00934  |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00051 | -0.00002 | -0.00887  |
| 5.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00053 | -0.00004 | -0.00923  |
| 10.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00057 | -0.00006 | -0.00987  |
| 15.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00060 | -0.00009 | -0.01049  |
| 20.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00064 | -0.00011 | -0.01110  |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
| BASIC  | 5.00  | 76000.00  | 0.         | 2979.55  | 34.00   | 0.00     | -0.97     |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00081 | 0.00002  | -0.011130 |
| -15.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00070 | 0.00001  | -0.010119 |
| -10.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00061 | 0.00001  | -0.009010 |
| -5.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00049 | 0.00000  | -0.008029 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00043 | -0.00002 | -0.007635 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00048 | -0.00004 | -0.007934 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00052 | -0.00006 | -0.008485 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00055 | -0.00009 | -0.009017 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00057 | -0.00011 | -0.009550 |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
| BASIC  | 10.00 | 106000.00 | 0.         | 2979.55  | 34.00   | 0.00     | -0.97     |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00079 | 0.00003  | -0.010119 |
| -15.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00066 | 0.00003  | -0.009024 |
| -10.00 | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00054 | 0.00002  | -0.008007 |
| -5.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00044 | 0.00000  | -0.007208 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00037 | -0.00002 | -0.006808 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00038 | -0.00004 | -0.006854 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00039 | -0.00007 | -0.007171 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00041 | -0.00009 | -0.007611 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00044 | -0.00012 | -0.008139 |

# Configuration Refinement 1

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF    | XCG     | ZCG      | YCG       |
|--------|-------|-----------|------------|---------|---------|----------|-----------|
| BASIC  | 16.00 | 140000.00 | 0.         | 2979.33 | 34.00   | 0.00     | -0.97     |
| ALPHA  | BETA  | CL        | CD         | CM      | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00077 | 0.00003  | -0.009897 |
| -15.00 | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00063 | 0.00003  | -0.008749 |
| -10.00 | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00051 | 0.00002  | -0.007739 |
| -5.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00041 | 0.00000  | -0.007023 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00034 | -0.00002 | -0.006617 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00033 | -0.00005 | -0.006534 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00034 | -0.00007 | -0.006769 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00036 | -0.00009 | -0.007198 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00039 | -0.00012 | -0.007736 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF    | XCG     | ZCG      | YCG       |
|--------|-------|-----------|------------|---------|---------|----------|-----------|
| BASIC  | 20.00 | 177000.00 | 0.         | 2979.33 | 34.00   | 0.00     | -0.97     |
| ALPHA  | BETA  | CL        | CD         | CM      | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00077 | 0.00003  | -0.009857 |
| -15.00 | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00063 | 0.00003  | -0.008688 |
| -10.00 | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00051 | 0.00002  | -0.007672 |
| -5.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00041 | 0.00000  | -0.006984 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00035 | -0.00002 | -0.006576 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00032 | -0.00005 | -0.006451 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00033 | -0.00007 | -0.006670 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00035 | -0.00009 | -0.007106 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | 0.00000 | 0.00038 | -0.00012 | -0.007652 |

### Configuration Refinement 1

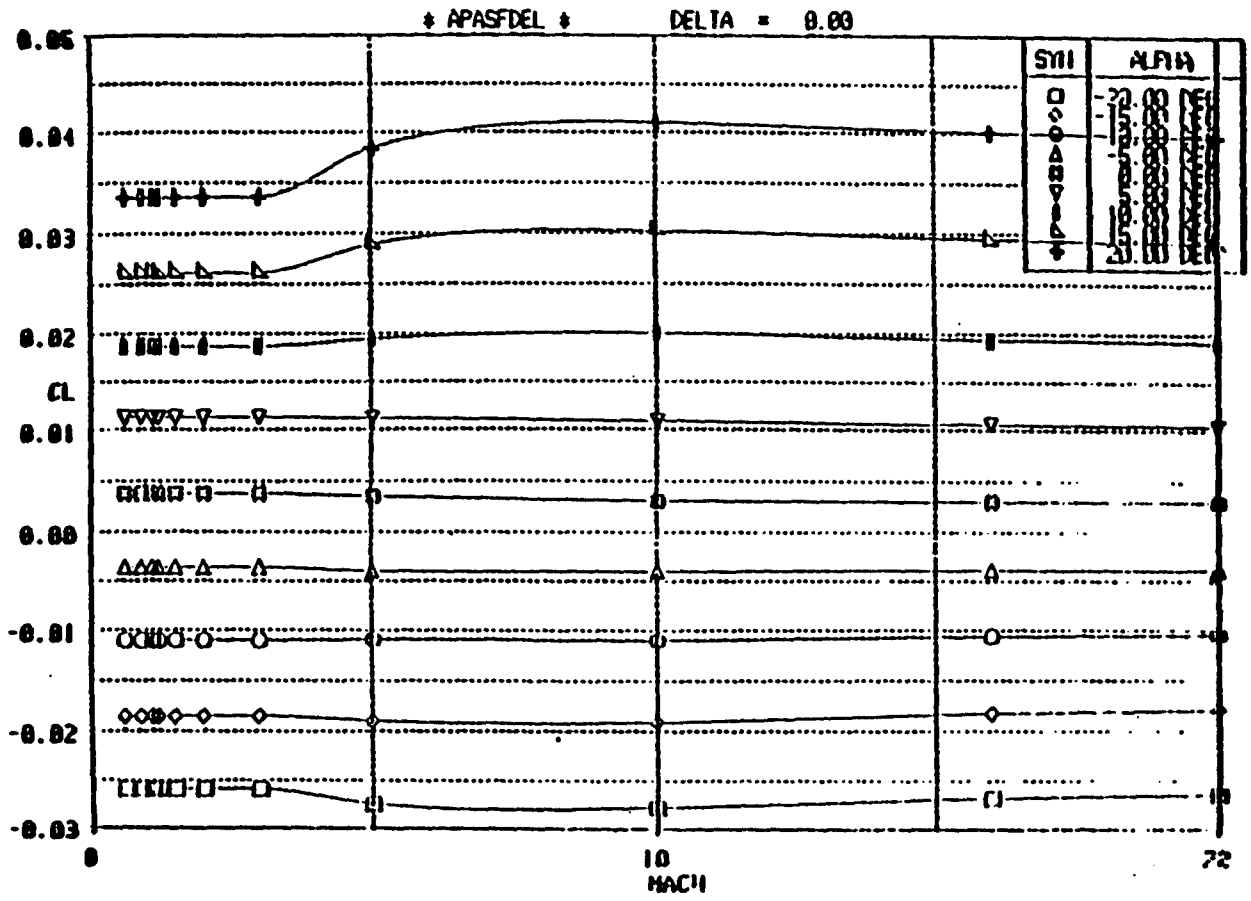
## DYNAMIC DERIVATIVES

| M    | $C_{T_p}$ | $C_{L_p}$ | $C_{D_p}$ | $C_{L_c}$ | $C_{D_c}$ | $C_{T_r}$ | $C_{L_r}$ | $C_{D_r}$ |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 0.6  | .00552    | -.00009   | -.00172   | .04501    | -.00825   | .07574    | -.00074   | -.0269    |
| 0.7  | .00611    | -.00009   | -.00191   | .04733    | -.00880   | .08456    | -.00092   | -.02996   |
| 1.1  | .00633    | -.00010   | -.00220   | .04923    | -.00943   | .09602    | -.00091   | -.03447   |
| 1.2  | .00632    | -.00010   | -.00203   | .05021    | -.00971   | .09449    | -.00091   | -.03470   |
| 1.3  | .00493    | -.00010   | -.00133   | .04753    | -.00947   | .08506    | -.00090   | -.03267   |
| 2.0  | .0045     | -.00009   | -.00134   | .04446    | -.00911   | .06973    | -.00079   | -.0251    |
| 3.0  | .00291    | -.00008   | -.00094   | .03109    | -.00817   | .04310    | -.00051   | -.01569   |
| 5.0  | .00153    | -.00004   | -.00073   | .02133    | -.00424   | .01960    | -.00033   | -.00707   |
| 10.0 | .00077    | -.00002   | -.00037   | .01071    | -.00208   | .00476    | -.00017   | -.00347   |
| 16.0 | .00056    | -.00001   | -.00027   | .00773    | -.00149   | .00332    | -.00012   | -.00247   |
| 25.0 | .00042    | -.00001   | -.00021   | .00574    | -.00109   | .00219    | -.00009   | -.00187   |

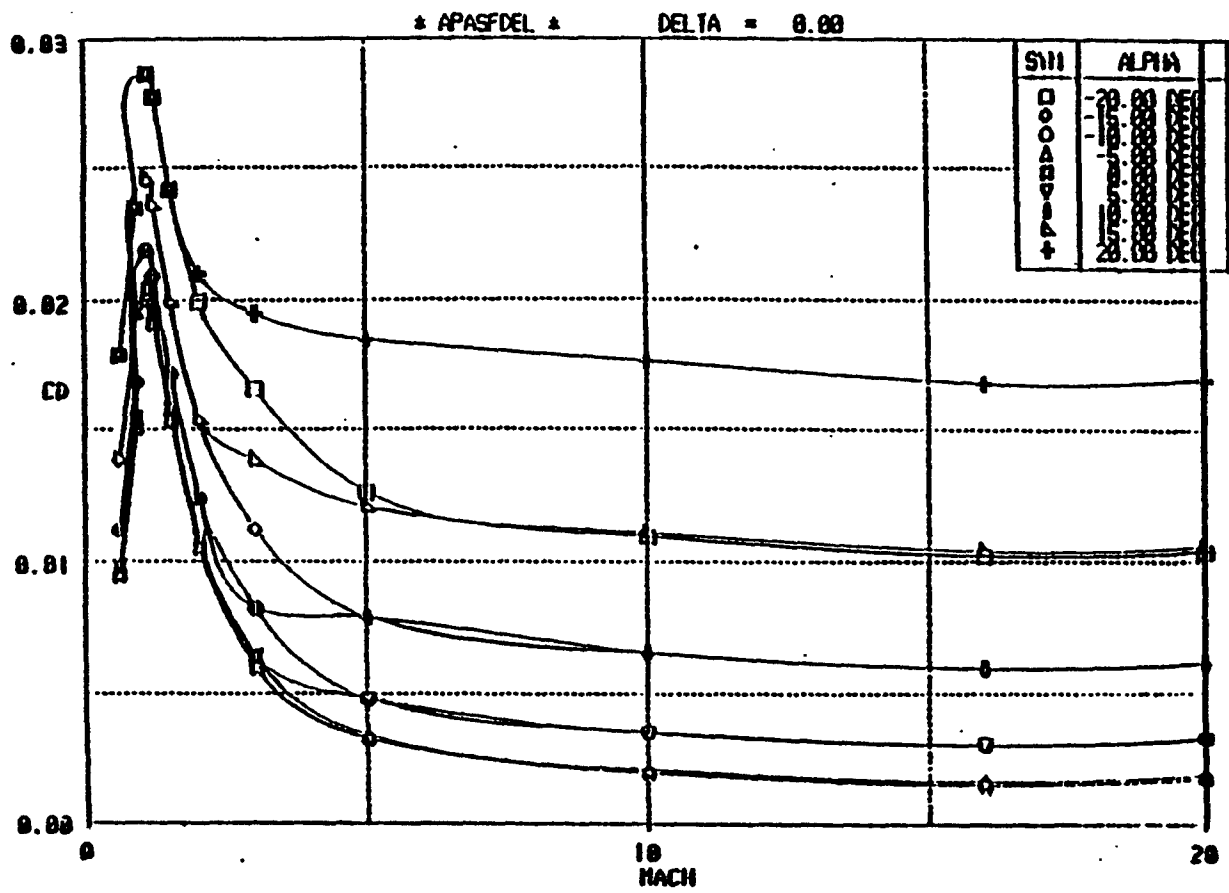
Note: All derivatives are per unit rotation (rad/sec)



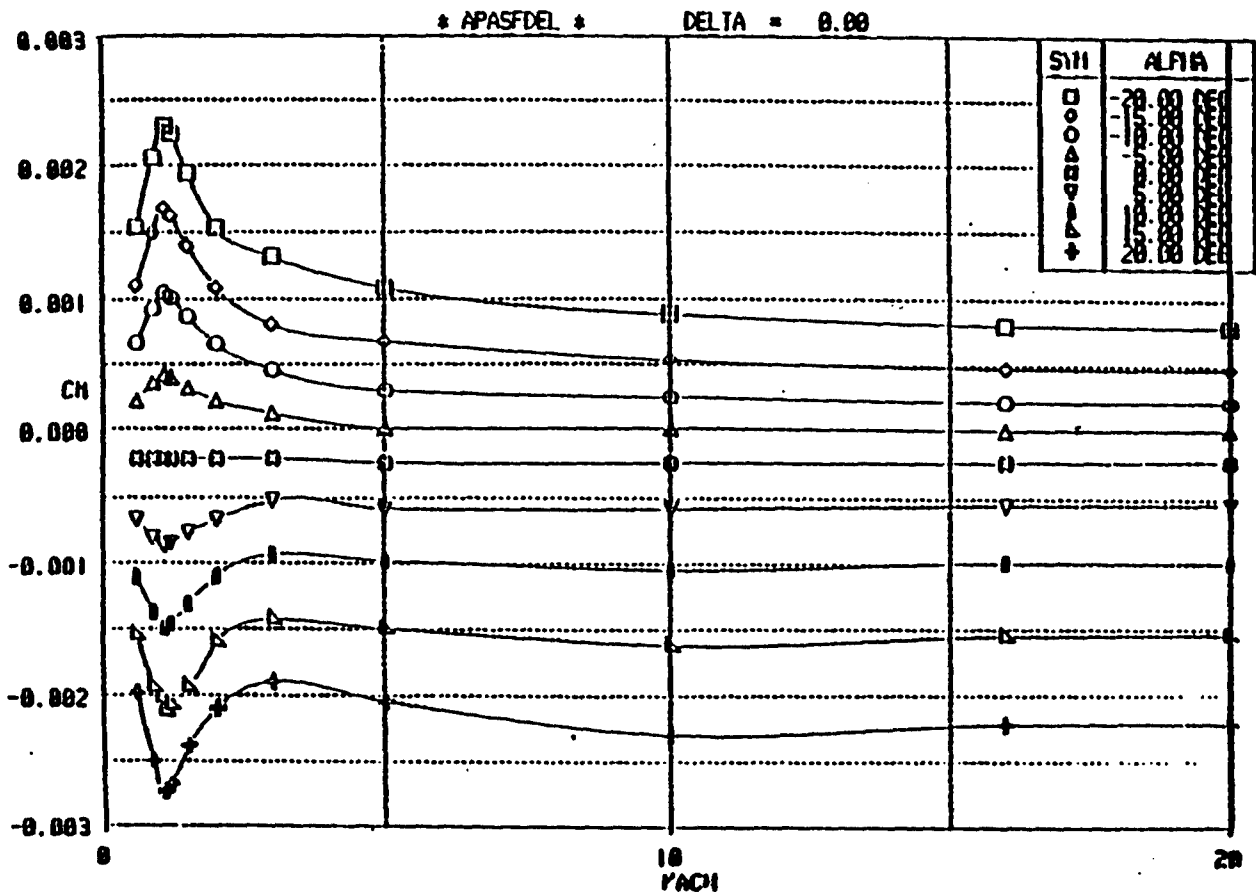
LIFT COEFFICIENT VERSUS MACH NUMBER



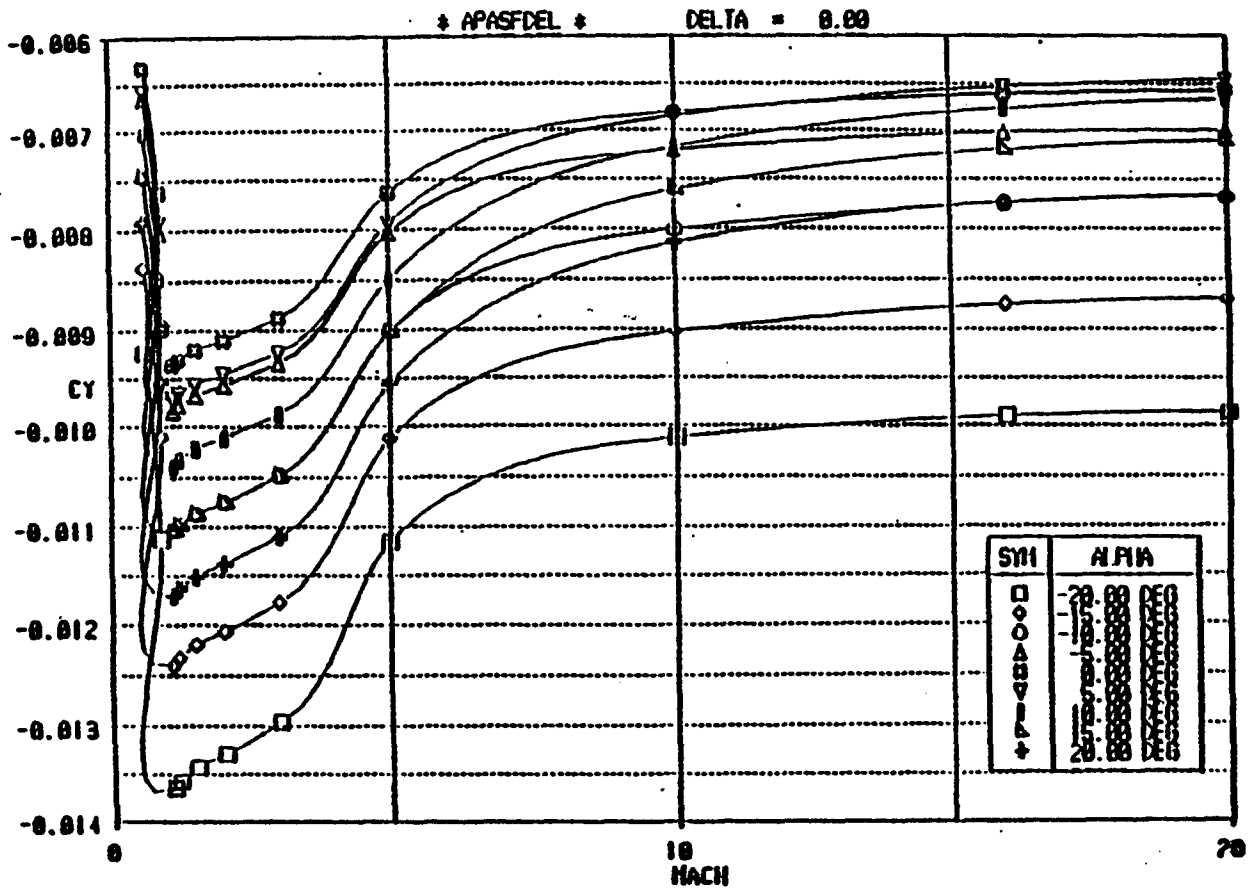
DRAG COEFFICIENT VERSUS MACH NUMBER



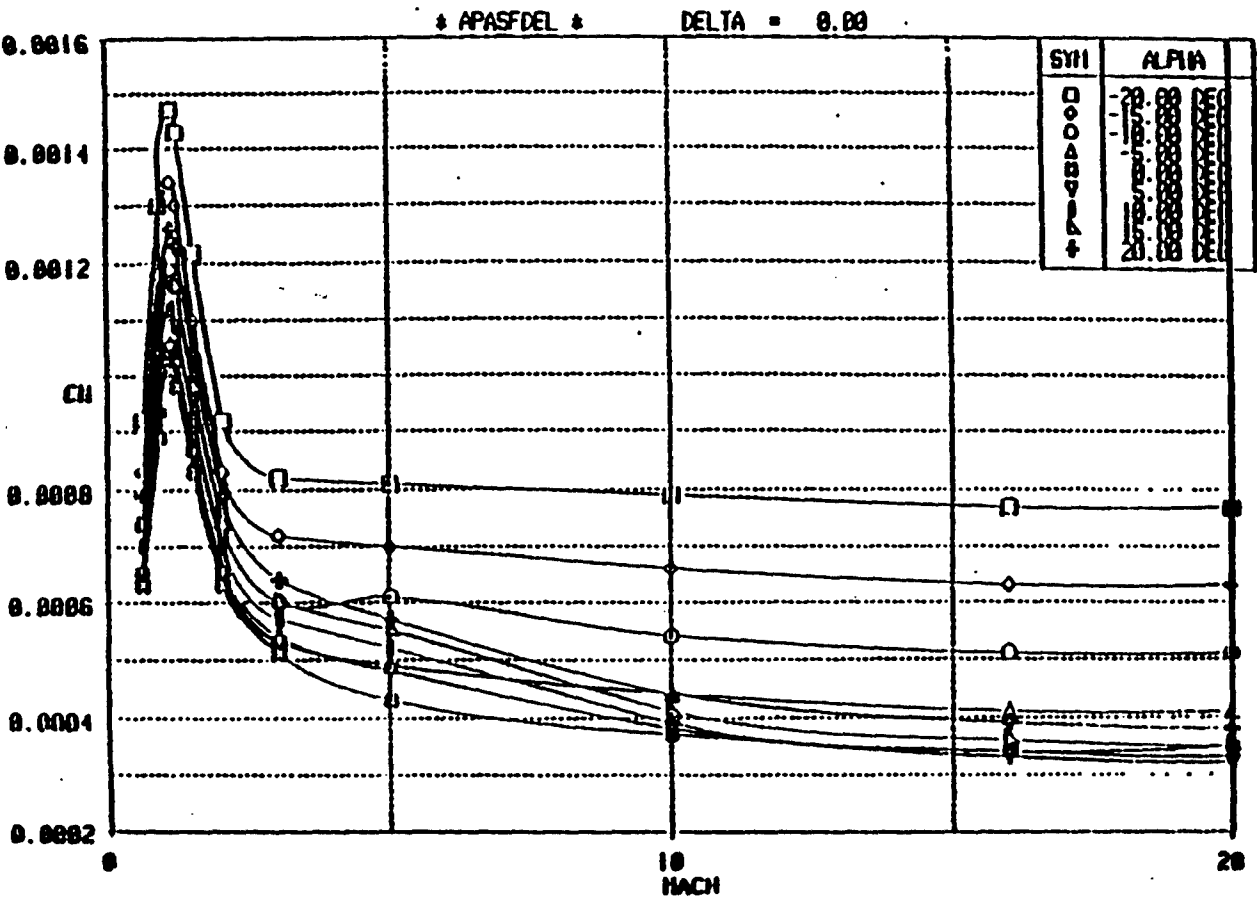
PITCHING MOMENT COEFFICIENT VERSUS MACH NUMBER



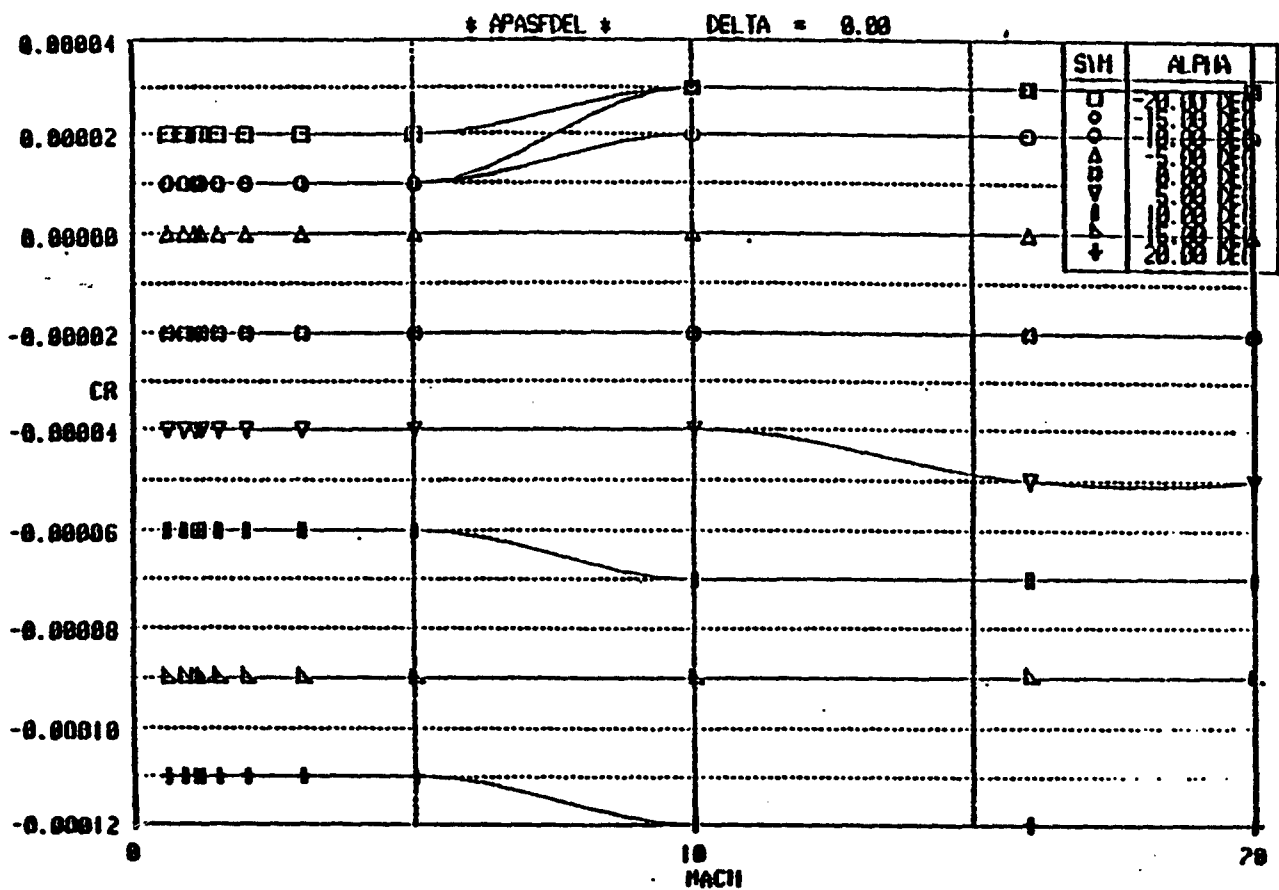
SIDE FORCE COEFFICIENT VERSUS MACH NUMBER, BETA=5

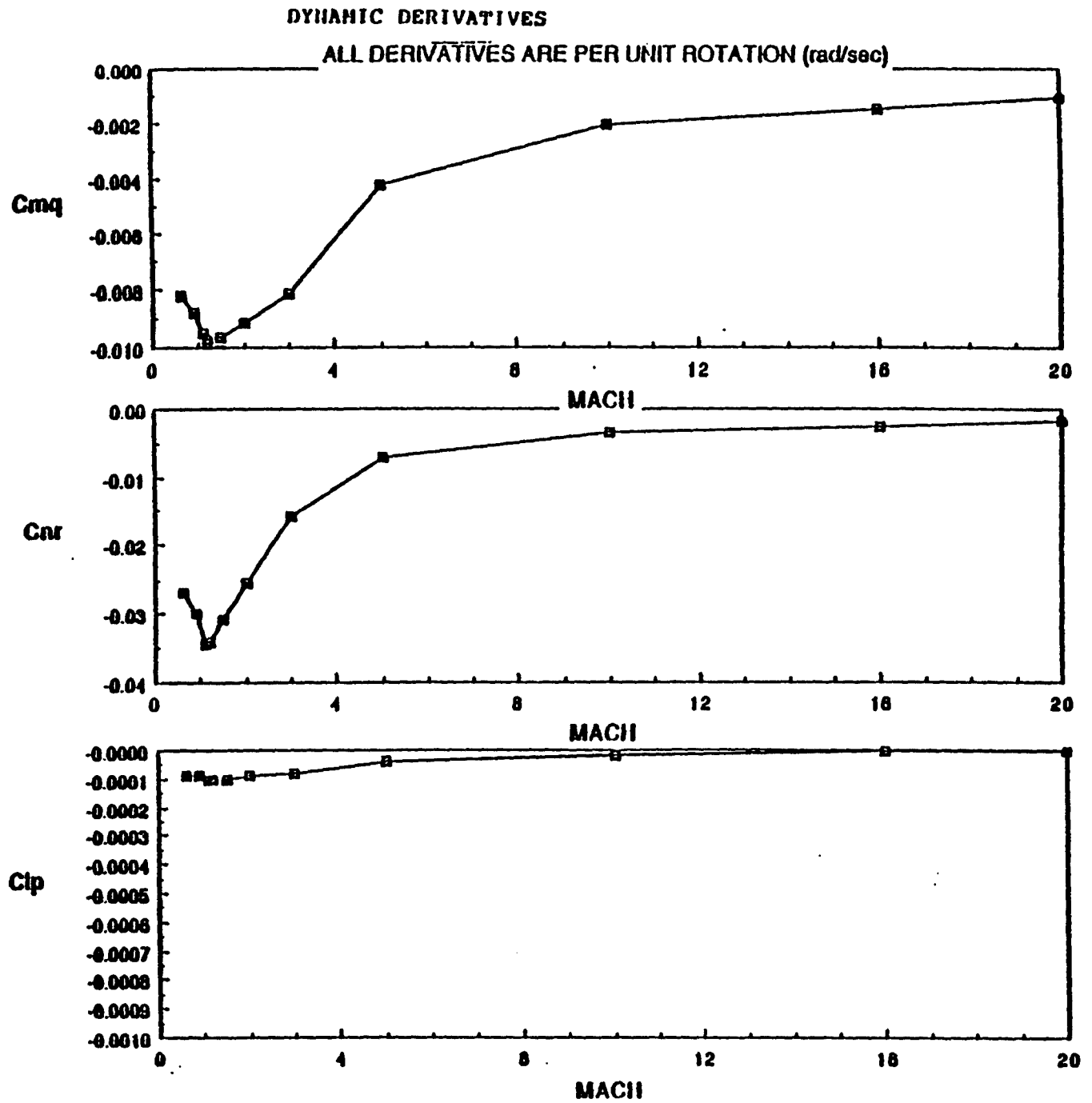


YAWING MOMENT COEFFICIENT VERSUS MACH NUMBER, BETA=5

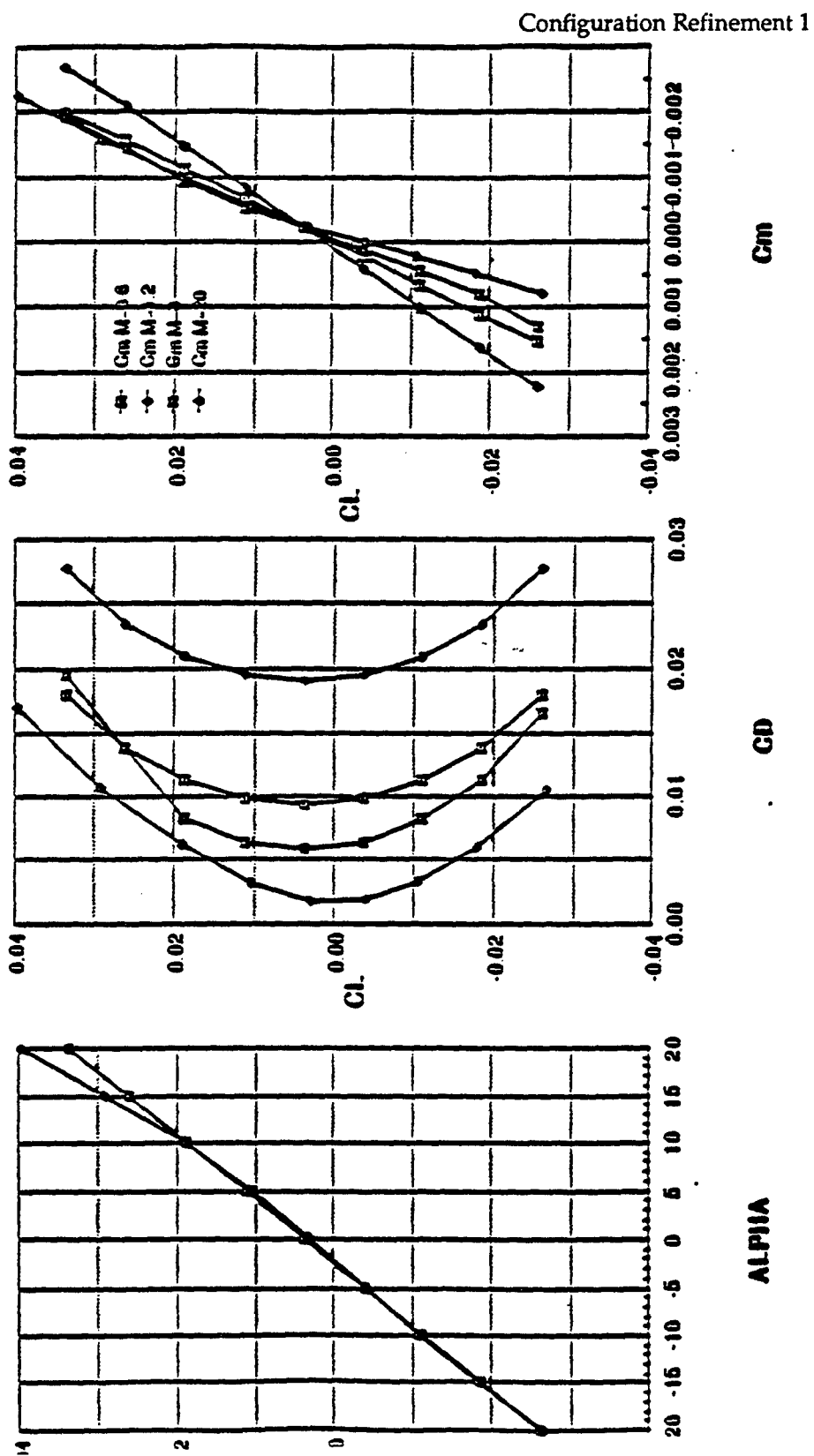


ROLLING MOMENT COEFFICIENT VERSUS MACH NUMBER, BETA=5



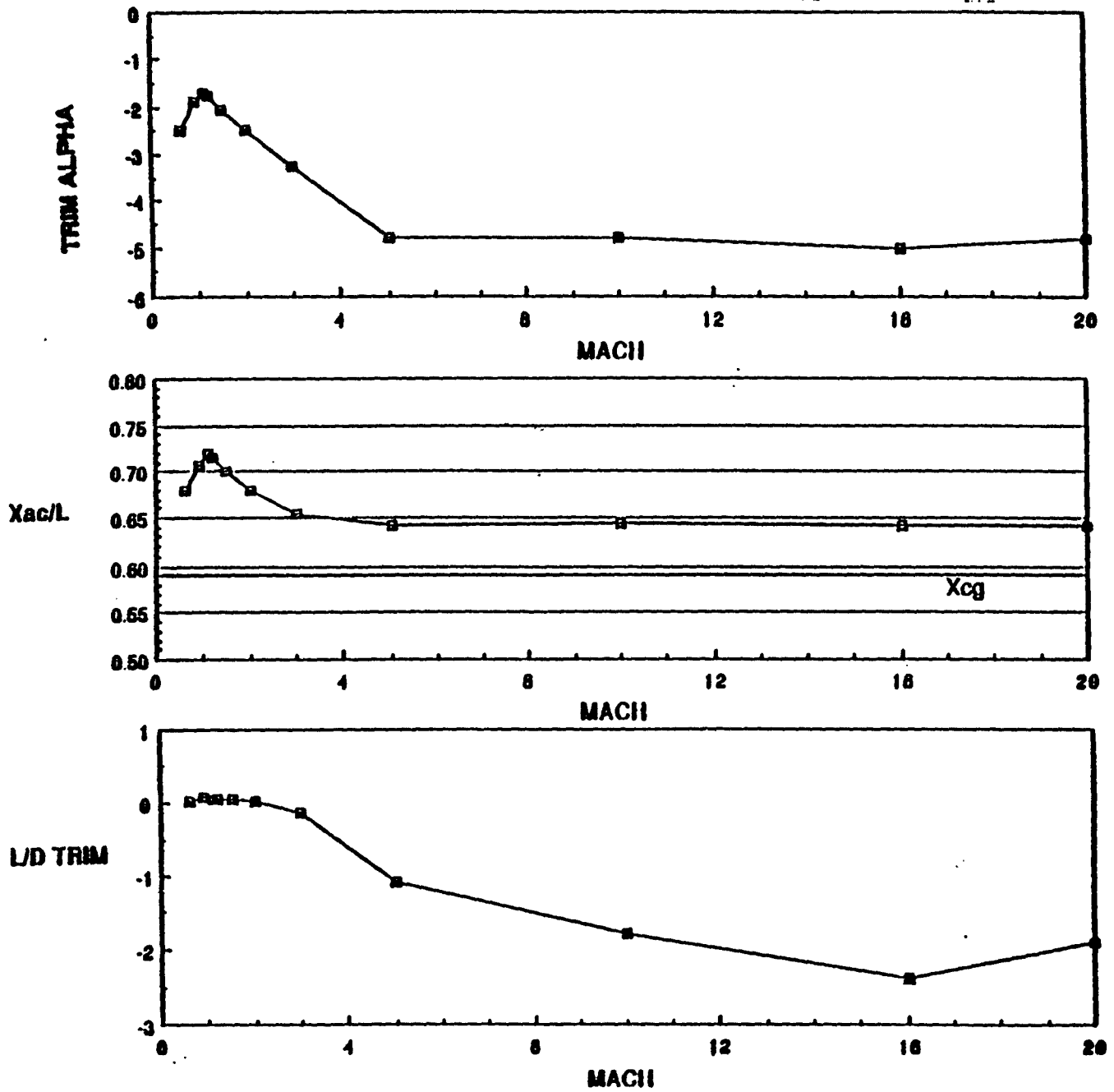


# LONGITUDINAL AERODYNAMIC CHARACTERISTICS

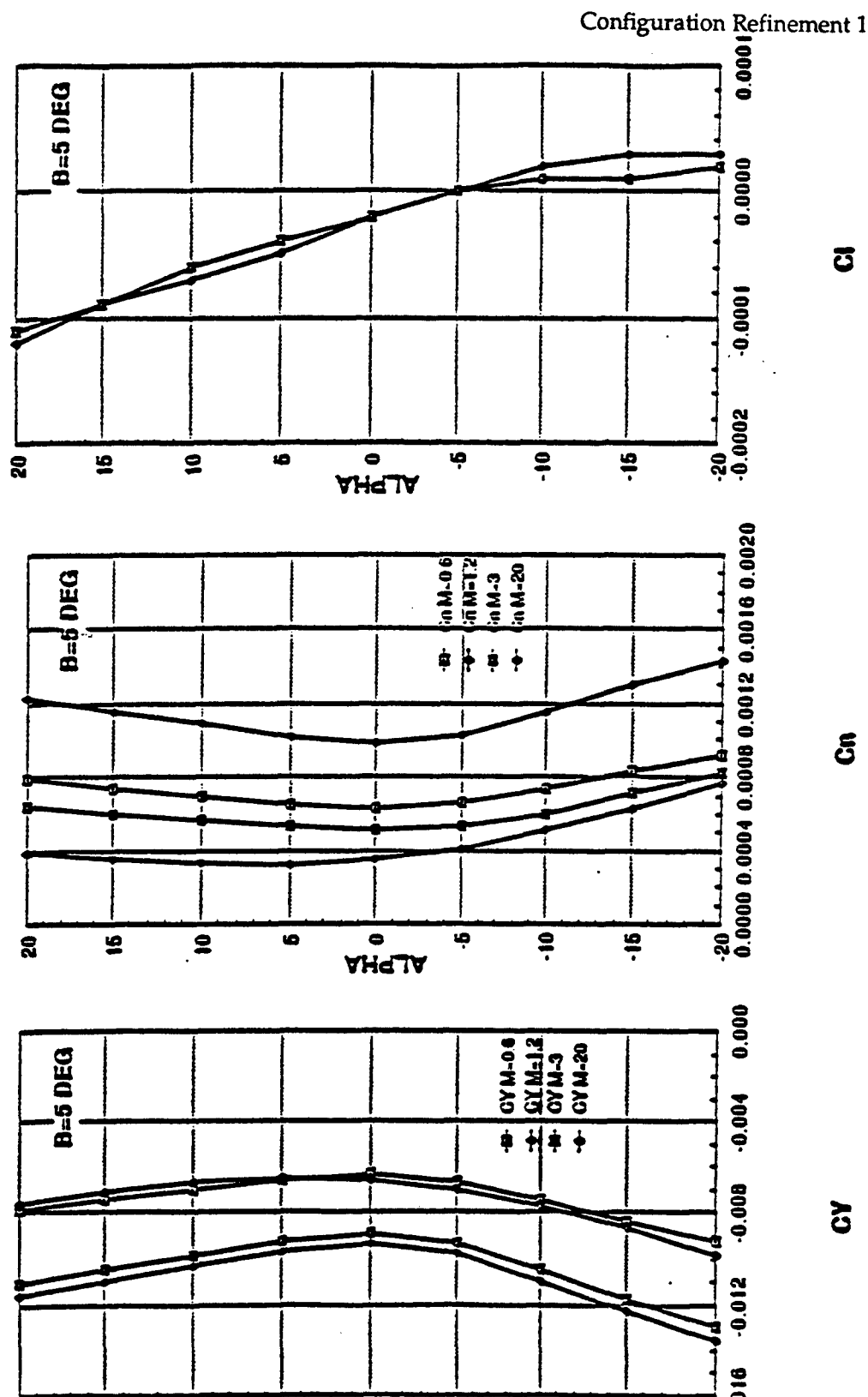




STATIC STABILITY AND PERFORMANCE CHARACTERISTICS



# LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS



## Configuration Refinement 2

## LONGITUDINAL AERO FOR CREW ESCAPE SYSTEM

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 0.60 | 32000.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02219 | 0.01589    | 0.00199  | -1.45941 | -0.08446 | 0.001324 |
| -15.00 | 0.00 | -0.01656 | 0.01230    | 0.00143  | -1.34634 | -0.08308 | 0.001324 |
| -10.00 | 0.00 | -0.00994 | 0.01000    | 0.00088  | -0.99400 | -0.08597 | 0.001324 |
| -5.00  | 0.00 | -0.00331 | 0.00877    | 0.00031  | -0.37742 | -0.08610 | 0.001324 |
| 0.00   | 0.00 | 0.00331  | 0.00840    | -0.00026 | 0.39405  | -0.08597 | 0.001324 |
| 5.00   | 0.00 | 0.00994  | 0.00877    | -0.00083 | 1.11341  | -0.08597 | 0.001324 |
| 10.00  | 0.00 | 0.01657  | 0.01000    | -0.00140 | 1.65700  | -0.08459 | 0.001324 |
| 15.00  | 0.00 | 0.02219  | 0.01230    | -0.00196 | 1.88517  | -0.08296 | 0.001324 |
| 20.00  | 0.00 | 0.02982  | 0.01589    | -0.00251 | 1.87663  | -0.08296 | 0.001324 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 0.90 | 37000.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02319 | 0.02084    | 0.00246  | -1.11276 | -0.09970 | 0.001324 |
| -15.00 | 0.00 | -0.01657 | 0.01725    | 0.00180  | -0.96058 | -0.10407 | 0.001324 |
| -10.00 | 0.00 | -0.00994 | 0.01495    | 0.00111  | -0.66488 | -0.10256 | 0.001324 |
| -5.00  | 0.00 | -0.00331 | 0.01372    | 0.00043  | -0.24125 | -0.10423 | 0.001324 |
| 0.00   | 0.00 | 0.00331  | 0.01335    | -0.00025 | 0.24794  | -0.10407 | 0.001324 |
| 5.00   | 0.00 | 0.00994  | 0.01372    | -0.00095 | 0.72449  | -0.10256 | 0.001324 |
| 10.00  | 0.00 | 0.01657  | 0.01495    | -0.00163 | 1.10836  | -0.10407 | 0.001324 |
| 15.00  | 0.00 | 0.02320  | 0.01725    | -0.00232 | 1.34493  | -0.10121 | 0.001324 |
| 20.00  | 0.00 | 0.02982  | 0.02084    | -0.00299 | 1.43090  | -0.10121 | 0.001324 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 1.10 | 39000.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02127 | 0.02539    | 0.00259  | -0.91550 | -0.11011 | 0.001324 |
| -15.00 | 0.00 | -0.01664 | 0.02175    | 0.00196  | -0.76506 | -0.11027 | 0.001324 |
| -10.00 | 0.00 | -0.01002 | 0.01944    | 0.00123  | -0.51543 | -0.11312 | 0.001324 |
| -5.00  | 0.00 | -0.00339 | 0.01821    | 0.00048  | -0.18616 | -0.11161 | 0.001324 |
| 0.00   | 0.00 | 0.00324  | 0.01784    | -0.00025 | 0.18161  | -0.11011 | 0.001324 |
| 5.00   | 0.00 | 0.00987  | 0.01821    | -0.00099 | 0.54201  | -0.11312 | 0.001324 |
| 10.00  | 0.00 | 0.01650  | 0.01944    | -0.00174 | 0.84877  | -0.11027 | 0.001324 |
| 15.00  | 0.00 | 0.02112  | 0.02175    | -0.00247 | 1.06299  | -0.11011 | 0.001324 |
| 20.00  | 0.00 | 0.02975  | 0.02539    | -0.00320 | 1.17172  | -0.11011 | 0.001324 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 1.20 | 41500.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02127 | 0.02458    | 0.00252  | -0.94670 | -0.10709 | 0.001324 |
| -15.00 | 0.00 | -0.01664 | 0.02092    | 0.00191  | -0.79541 | -0.10725 | 0.001324 |
| -10.00 | 0.00 | -0.01002 | 0.01860    | 0.00120  | -0.53871 | -0.11011 | 0.001324 |
| -5.00  | 0.00 | -0.00339 | 0.01737    | 0.00047  | -0.19516 | -0.11011 | 0.001324 |
| 0.00   | 0.00 | 0.00324  | 0.01700    | -0.00025 | 0.19059  | -0.11011 | 0.001324 |
| 5.00   | 0.00 | 0.00987  | 0.01737    | -0.00099 | 0.56822  | -0.11011 | 0.001324 |
| 10.00  | 0.00 | 0.01650  | 0.01860    | -0.00172 | 0.88710  | -0.10574 | 0.001324 |
| 15.00  | 0.00 | 0.02112  | 0.02092    | -0.00242 | 1.10516  | -0.10860 | 0.001324 |
| 20.00  | 0.00 | 0.02975  | 0.02458    | -0.00314 | 1.21033  | -0.10860 | 0.001324 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF    | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|---------|----------|----------|----------|
| BASIC  | 1.50 | 45500.00 | 0.         | 2979.55 | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM      | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02124 | 0.02141    | 0.00237 | -1.08547 | -0.09789 | 0.001324 |
| -15.00 | 0.00 | -0.01660 | 0.01760    | 0.00172 | -0.94318 | -0.09789 | 0.001324 |

# Configuration Refinement 2

|        |      |          |         |          |          |          |          |
|--------|------|----------|---------|----------|----------|----------|----------|
| -10.00 | 0.00 | -0.00996 | 0.01325 | 0.00107  | -0.65311 | -0.10106 | 0.001326 |
| -5.00  | 0.00 | -0.00333 | 0.01402 | 0.00040  | -0.23752 | -0.09940 | 0.001328 |
| 0.00   | 0.00 | 0.00331  | 0.01363 | -0.00025 | 0.24249  | -0.09940 | 0.001328 |
| 5.00   | 0.00 | 0.00993  | 0.01402 | -0.00092 | 0.70970  | -0.10090 | 0.001328 |
| 10.00  | 0.00 | 0.01539  | 0.01325 | -0.00139 | 1.08787  | -0.09789 | 0.001328 |
| 15.00  | 0.00 | 0.02323  | 0.01760 | -0.00224 | 1.31989  | -0.09804 | 0.001325 |
| 20.00  | 0.00 | 0.02986  | 0.02141 | -0.00239 | 1.39468  | -0.09804 | 0.001325 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 2.00 | 53000.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02327 | 0.01760    | 0.00290  | -1.32216 | -0.08283 | 0.001328 |
| -15.00 | 0.00 | -0.01663 | 0.01339    | 0.00143  | -1.24197 | -0.08571 | 0.001330 |
| -10.00 | 0.00 | -0.00998 | 0.01097    | 0.00088  | -0.90975 | -0.08584 | 0.001328 |
| -5.00  | 0.00 | -0.00334 | 0.00973    | 0.00031  | -0.34327 | -0.08571 | 0.001330 |
| 0.00   | 0.00 | 0.00331  | 0.00936    | -0.00025 | 0.35363  | -0.08434 | 0.001328 |
| 5.00   | 0.00 | 0.00993  | 0.00973    | -0.00082 | 1.02241  | -0.08722 | 0.001330 |
| 10.00  | 0.00 | 0.01660  | 0.01097    | -0.00140 | 1.51322  | -0.09789 | 0.001328 |
| 15.00  | 0.00 | 0.02324  | 0.01339    | -0.00205 | 1.73562  | -0.08571 | 0.001330 |
| 20.00  | 0.00 | 0.02989  | 0.01840    | -0.00262 | 1.62446  | -0.08571 | 0.001330 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 3.00 | 62000.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02317 | 0.01378    | 0.00177  | -1.68142 | -0.08157 | 0.001324 |
| -15.00 | 0.00 | -0.01655 | 0.00960    | 0.00123  | -1.72396 | -0.08157 | 0.001324 |
| -10.00 | 0.00 | -0.00993 | 0.00693    | 0.00069  | -1.43290 | -0.07240 | 0.001328 |
| -5.00  | 0.00 | -0.00330 | 0.00566    | 0.00021  | -0.58304 | -0.07100 | 0.001324 |
| 0.00   | 0.00 | 0.00332  | 0.00529    | -0.00025 | 0.62760  | -0.07100 | 0.001324 |
| 5.00   | 0.00 | 0.00994  | 0.00566    | -0.00073 | 1.75618  | -0.08610 | 0.001324 |
| 10.00  | 0.00 | 0.01656  | 0.00693    | -0.00130 | 2.38961  | -0.09063 | 0.001324 |
| 15.00  | 0.00 | 0.02318  | 0.01160    | -0.00190 | 1.99823  | -0.08308 | 0.001324 |
| 20.00  | 0.00 | 0.02980  | 0.01710    | -0.00245 | 1.74259  | -0.08308 | 0.001324 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 5.00 | 76000.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.02450 | 0.01135    | 0.00169  | -2.15859 | -0.07673 | 0.001564 |
| -15.00 | 0.00 | -0.01668 | 0.00694    | 0.00109  | -2.40346 | -0.08234 | 0.001336 |
| -10.00 | 0.00 | -0.01000 | 0.00425    | 0.00054  | -2.35294 | -0.06505 | 0.001322 |
| -5.00  | 0.00 | -0.00339 | 0.00306    | 0.00011  | -1.10784 | -0.06646 | 0.001294 |
| 0.00   | 0.00 | 0.00308  | 0.00292    | -0.00032 | 1.05479  | -0.06214 | 0.001384 |
| 5.00   | 0.00 | 0.01000  | 0.00425    | -0.00073 | 2.35294  | -0.08029 | 0.001370 |
| 10.00  | 0.00 | 0.01685  | 0.00694    | -0.00130 | 2.42795  | -0.09112 | 0.001690 |
| 15.00  | 0.00 | 0.02530  | 0.01080    | -0.00207 | 2.34259  | -0.08902 | 0.001640 |
| 20.00  | 0.00 | 0.03350  | 0.01520    | -0.00280 | 2.06790  | -0.08902 | 0.001640 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 10.00 | 106000.00 | 0.         | 2979.55  | 29.60    | -0.85    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02466  | 0.00986    | 0.00142  | -2.50101 | -0.06789 | 0.001532 |
| -15.00 | 0.00  | -0.01700  | 0.00573    | 0.00090  | -2.95652 | -0.06171 | 0.001426 |
| -10.00 | 0.00  | -0.00987  | 0.00316    | 0.00046  | -3.12342 | -0.05742 | 0.001354 |
| -5.00  | 0.00  | -0.00360  | 0.00187    | 0.00010  | -1.92513 | -0.05864 | 0.001262 |
| 0.00   | 0.00  | 0.00271   | 0.00175    | -0.00027 | 1.54857  | -0.06745 | 0.001364 |
| 5.00   | 0.00  | 0.00953   | 0.00309    | -0.00073 | 3.08414  | -0.07444 | 0.001612 |
| 10.00  | 0.00  | 0.01739   | 0.00538    | -0.00133 | 3.25952  | -0.08237 | 0.001786 |
| 15.00  | 0.00  | 0.02652   | 0.00995    | -0.00207 | 2.64533  | -0.09062 | 0.001876 |
| 20.00  | 0.00  | 0.03590   | 0.01344    | -0.00292 | 2.12362  | -0.09062 | 0.001876 |

# Configuration Refinement 2

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 16.00 | 140000.00 | 0.         | 2979.33  | 29.60    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02377  | 0.00918    | 0.00133  | -2.58932 | -0.06667 | 0.001500 |
| -15.00 | 0.00  | -0.01627  | 0.00523    | 0.00083  | -3.11090 | -0.05926 | 0.001350 |
| -10.00 | 0.00  | -0.00932  | 0.00276    | 0.00043  | -3.44928 | -0.05676 | 0.001198 |
| -5.00  | 0.00  | -0.00353  | 0.00149    | 0.00009  | -2.36913 | -0.05663 | 0.001236 |
| 0.00   | 0.00  | 0.00263   | 0.00136    | -0.00026 | 1.94853  | -0.06495 | 0.001324 |
| 5.00   | 0.00  | 0.00927   | 0.00290    | -0.00069 | 3.19655  | -0.07513 | 0.001544 |
| 10.00  | 0.00  | 0.01699   | 0.00491    | -0.00127 | 3.46028  | -0.08096 | 0.001754 |
| 15.00  | 0.00  | 0.02576   | 0.00933    | -0.00198 | 2.76099  | -0.09081 | 0.001872 |
| 20.00  | 0.00  | 0.03512   | 0.01471    | -0.00283 | 2.38749  | -0.09081 | 0.001872 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 20.00 | 177000.00 | 0.         | 2979.33  | 29.60    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02344  | 0.00935    | 0.00132  | -2.50695 | -0.06720 | 0.001488 |
| -15.00 | 0.00  | -0.01600  | 0.00541    | 0.00082  | -2.95749 | -0.05891 | 0.001324 |
| -10.00 | 0.00  | -0.00938  | 0.00297    | 0.00043  | -3.15825 | -0.05612 | 0.001176 |
| -5.00  | 0.00  | -0.00350  | 0.00171    | 0.00010  | -2.04678 | -0.05873 | 0.001226 |
| 0.00   | 0.00  | 0.00263   | 0.00159    | -0.00026 | 1.65409  | -0.06432 | 0.001306 |
| 5.00   | 0.00  | 0.00916   | 0.00290    | -0.00068 | 3.15882  | -0.07632 | 0.001320 |
| 10.00  | 0.00  | 0.01676   | 0.00509    | -0.00126 | 3.29273  | -0.08161 | 0.001740 |
| 15.00  | 0.00  | 0.02546   | 0.00949    | -0.00197 | 2.68282  | -0.09110 | 0.001866 |
| 20.00  | 0.00  | 0.03479   | 0.01487    | -0.00282 | 2.33961  | -0.09110 | 0.001866 |

## Configuration Refinement 2

## LATERAL-DIRECTIONAL AERO FOR CREW ESCAPE. BETA-3

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 0.80 | 32000.00 | 0.         | 2979.33  | 29.60   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00124 | 0.00002  | -0.00820 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00123 | 0.00001  | -0.00743 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00101 | 0.00000  | -0.00646 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00090 | 0.00000  | -0.00593 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00086 | -0.00001 | -0.00567 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00089 | -0.00003 | -0.00588 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00095 | -0.00005 | -0.00629 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00101 | -0.00006 | -0.00648 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00108 | -0.00008 | -0.00709 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 0.90 | 37000.00 | 0.         | 2979.33  | 29.60   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00138 | 0.00002  | -0.00990 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00143 | 0.00001  | -0.00899 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00128 | 0.00000  | -0.00803 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00114 | 0.00000  | -0.00713 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00109 | -0.00001 | -0.00684 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00123 | -0.00003 | -0.00709 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00121 | -0.00005 | -0.00759 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00128 | -0.00006 | -0.00806 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00136 | -0.00008 | -0.00835 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 1.10 | 39000.00 | 0.         | 2979.33  | 29.60   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00174 | 0.00002  | -0.01214 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00158 | 0.00001  | -0.01103 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00141 | 0.00000  | -0.00983 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00126 | 0.00000  | -0.00880 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00120 | -0.00001 | -0.00839 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00124 | -0.00003 | -0.00870 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00133 | -0.00005 | -0.00911 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00141 | -0.00006 | -0.00989 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00150 | -0.00008 | -0.01049 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 1.20 | 41500.00 | 0.         | 2979.33  | 29.60   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00169 | 0.00002  | -0.01207 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00154 | 0.00001  | -0.01079 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00137 | 0.00000  | -0.00979 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00123 | 0.00000  | -0.00875 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00117 | -0.00001 | -0.00834 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00121 | -0.00003 | -0.00863 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00130 | -0.00005 | -0.00926 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00138 | -0.00006 | -0.00983 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00146 | -0.00008 | -0.01042 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF    | XCG     | ZCG     | YCG      |
|--------|------|----------|------------|---------|---------|---------|----------|
| BASIC  | 1.30 | 43500.00 | 0.         | 2979.33 | 29.60   | 0.00    | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM      | C YAW   | C ROLL  | C SIDE   |
| -20.00 | 5.00 | 0.00000  | 0.00000    | 0.00000 | 0.00151 | 0.00002 | -0.01194 |

# Configuration Refinement 2

|        |      |          |         |          |         |          |          |
|--------|------|----------|---------|----------|---------|----------|----------|
| -10.00 | 5.00 | -0.00000 | 0.00000 | 0.00000  | 0.00122 | 0.00000  | -0.00968 |
| -5.00  | 5.00 | -0.00000 | 0.00000 | 0.00000  | 0.00109 | 0.00000  | -0.00865 |
| 0.00   | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00104 | -0.00001 | -0.00825 |
| 5.00   | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00108 | -0.00003 | -0.00836 |
| 10.00  | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00115 | -0.00005 | -0.00916 |
| 15.00  | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00121 | -0.00006 | -0.00973 |
| 20.00  | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00130 | -0.00008 | -0.01031 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 2.00 | 53000.00 | 0.         | 2979.55  | 29.60   | 0.00     | -0.85    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00123 | 0.00002  | -0.01181 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00112 | 0.00001  | -0.01073 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00100 | 0.00000  | -0.00958 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00089 | 0.00000  | -0.00856 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00085 | -0.00001 | -0.00816 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00088 | -0.00003 | -0.00846 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00094 | -0.00005 | -0.00906 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00100 | -0.00006 | -0.00962 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00106 | -0.00008 | -0.01020 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 3.00 | 62000.00 | 0.         | 2979.55  | 29.60   | 0.00     | -0.85    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00115 | 0.00002  | -0.01152 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00104 | 0.00001  | -0.01047 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00090 | 0.00000  | -0.00935 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00081 | 0.00000  | -0.00835 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00077 | -0.00001 | -0.00796 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00080 | -0.00003 | -0.00825 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00086 | -0.00005 | -0.00884 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00091 | -0.00006 | -0.00938 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00096 | -0.00008 | -0.00995 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
|--------|------|----------|------------|----------|---------|----------|-----------|
| BASIC  | 5.00 | 76000.00 | 0.         | 2979.55  | 29.60   | 0.00     | -0.85     |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00111 | 0.00002  | -0.009811 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00099 | 0.00001  | -0.008918 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00090 | 0.00001  | -0.007959 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00076 | 0.00000  | -0.007115 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00069 | -0.00001 | -0.006782 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00074 | -0.00003 | -0.007034 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00080 | -0.00005 | -0.007525 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00085 | -0.00007 | -0.007999 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00089 | -0.00008 | -0.008476 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
|--------|-------|-----------|------------|----------|---------|----------|-----------|
| BASIC  | 10.00 | 106000.00 | 0.         | 2979.55  | 29.60   | 0.00     | -0.85     |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00109 | 0.00003  | -0.008897 |
| -15.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00094 | 0.00002  | -0.007953 |
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00079 | 0.00002  | -0.007077 |
| -5.00  | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00068 | 0.00000  | -0.006394 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00061 | -0.00001 | -0.006056 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00062 | -0.00003 | -0.006098 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00064 | -0.00005 | -0.006383 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00068 | -0.00007 | -0.006776 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00071 | -0.00009 | -0.007247 |

# Configuration Refinement 2

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
|--------|-------|-----------|------------|----------|---------|----------|-----------|
| BASIC  | 16.00 | 140000.00 | 0.         | 2979.55  | 29.60   | 0.00     | -0.85     |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00106 | 0.00003  | -0.008700 |
| -15.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00090 | 0.00003  | -0.007710 |
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00076 | 0.00002  | -0.006842 |
| -5.00  | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00063 | 0.00000  | -0.006233 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00058 | -0.00001 | -0.005891 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00056 | -0.00003 | -0.005823 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00058 | -0.00005 | -0.006035 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00062 | -0.00007 | -0.006420 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00066 | -0.00009 | -0.006899 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG       |
|--------|-------|-----------|------------|----------|---------|----------|-----------|
| BASIC  | 20.00 | 177000.00 | 0.         | 2979.55  | 29.60   | 0.00     | -0.85     |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE    |
| -20.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00106 | 0.00003  | -0.008664 |
| -15.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00090 | 0.00003  | -0.007656 |
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00075 | 0.00002  | -0.006783 |
| -5.00  | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00063 | 0.00000  | -0.006199 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00058 | -0.00001 | -0.005856 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00055 | -0.00003 | -0.005732 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00057 | -0.00005 | -0.005950 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00061 | -0.00007 | -0.006340 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00065 | -0.00009 | -0.006828 |



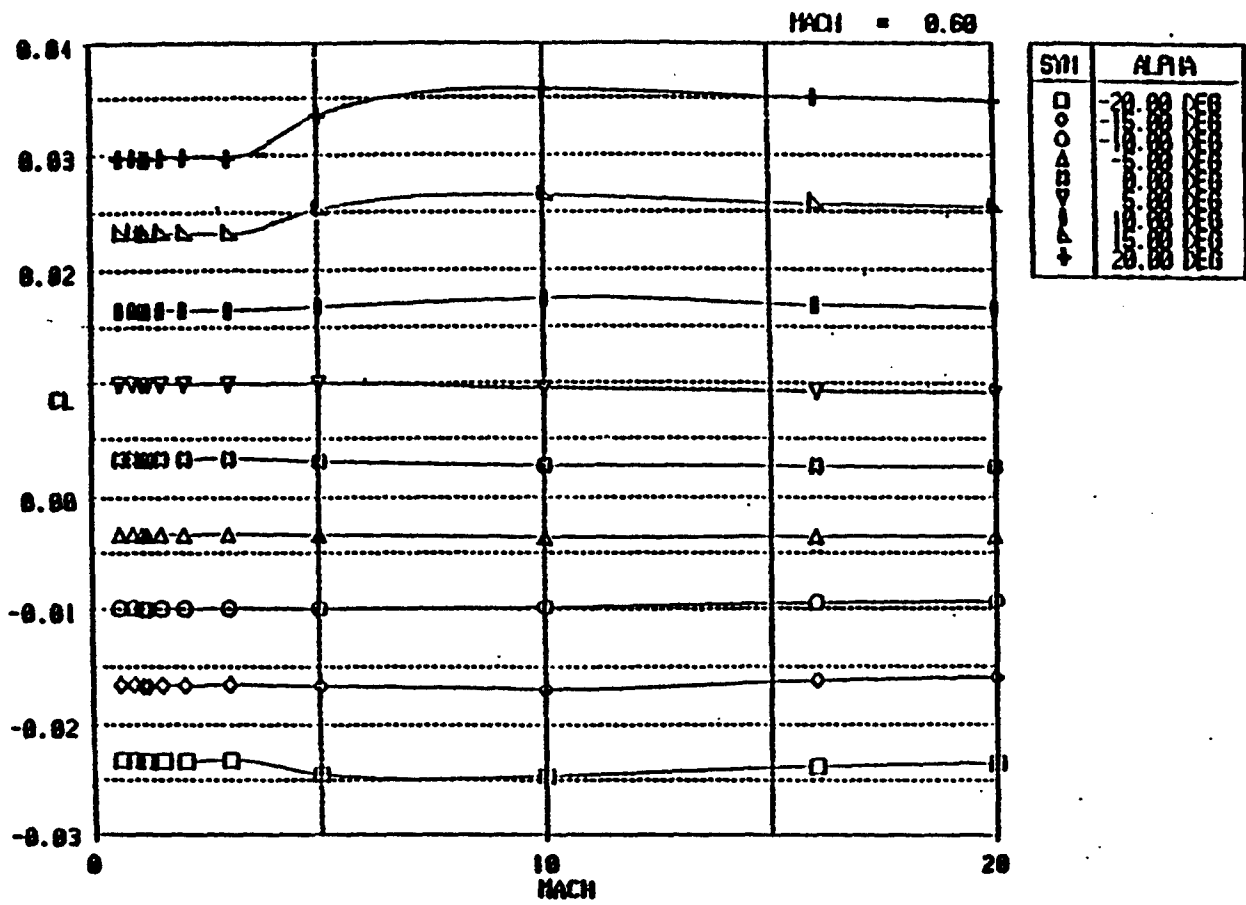
### Configuration Refinement 2

## DYNAMIC DERIVATIVES

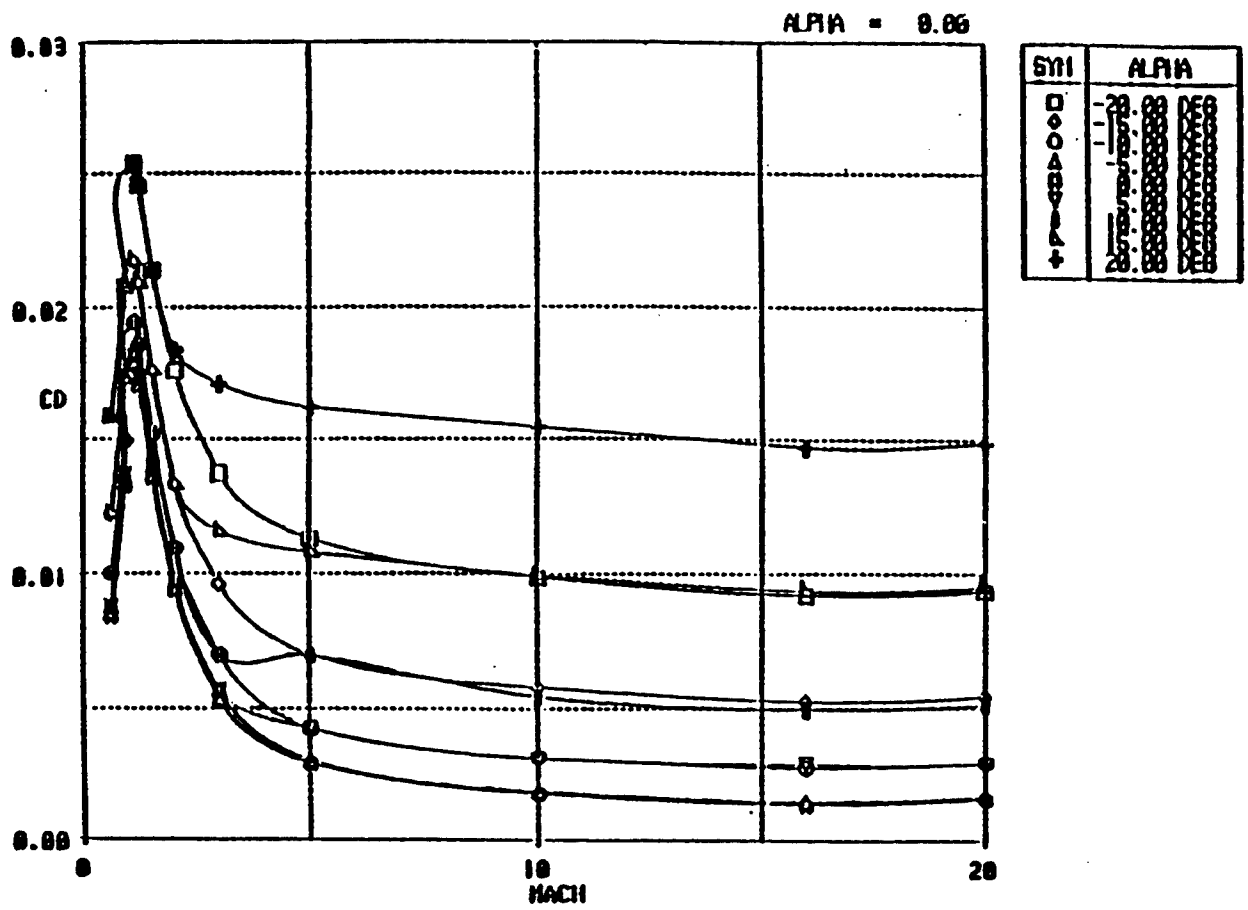
| $\theta$ | $C_{\dot{\theta}}$ | $C_{\dot{\theta}_2}$ | $C_{\dot{\theta}_3}$ | $C_{\dot{\theta}_4}$ | $C_{\dot{\theta}_5}$ | $C_{\dot{\theta}_6}$ | $C_{\dot{\theta}_7}$ | $C_{\dot{\theta}_8}$ | $C_{\dot{\theta}_9}$ |
|----------|--------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| 0.6      | .00452             | -.00006              | -.00156              | .04153               | -.00763              | .07023               | -.00053              | -.02480              |                      |
| 0.9      | .00508             | -.00006              | -.00173              | .04574               | -.00829              | .07341               | -.00066              | -.02783              |                      |
| 1.1      | .00572             | -.00007              | -.00200              | .04904               | -.00883              | .07904               | -.00072              | -.03223              |                      |
| 1.2      | .00525             | -.00007              | -.00184              | .04640               | -.00905              | .07762               | -.00073              | -.03157              |                      |
| 1.5      | .00410             | -.00006              | -.00143              | .04324               | -.00881              | .07887               | -.00072              | -.02850              |                      |
| 2.0      | .00345             | -.00006              | -.00121              | .03831               | -.00849              | .06496               | -.00063              | -.02352              |                      |
| 3.0      | .00242             | -.00006              | -.00086              | .02873               | -.00761              | .03997               | -.00041              | -.01453              |                      |
| 5.0      | .00127             | -.00003              | -.00067              | .01976               | -.00535              | .01818               | -.00026              | -.00657              |                      |
| 10.0     | .00064             | -.00001              | -.00034              | .00990               | -.00194              | .00905               | -.00013              | -.00323              |                      |
| 15.0     | .00047             | -.00001              | -.00025              | .00715               | -.00139              | .00631               | -.00009              | -.00230              |                      |
| 20.0     | .00035             | -.00001              | -.00019              | .00531               | -.00102              | .00481               | -.00007              | -.00168              |                      |

ALL DERIVATIVES ARE PER UNIT ROTATION (RAD/SEC)

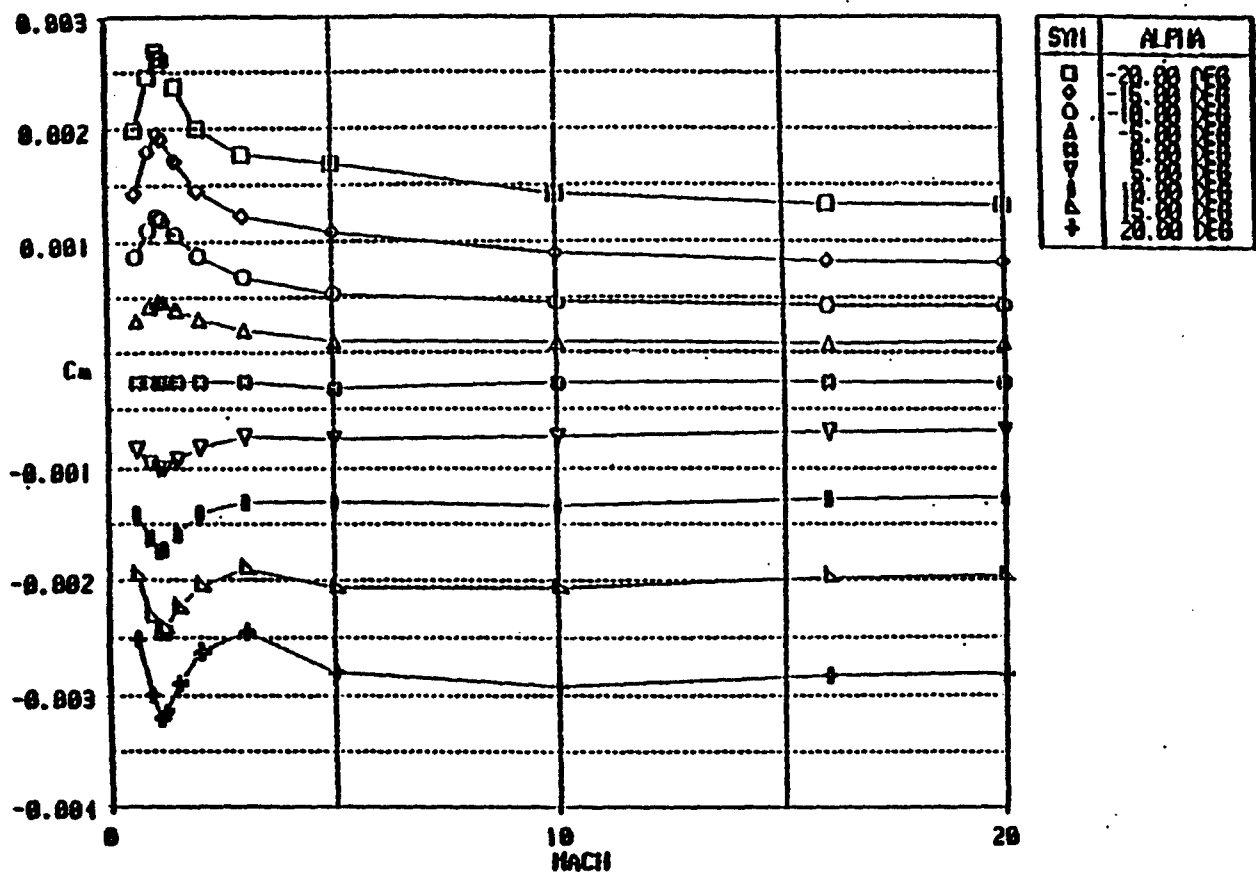
LIFT COEFFICIENT VERSUS MACH NUMBER



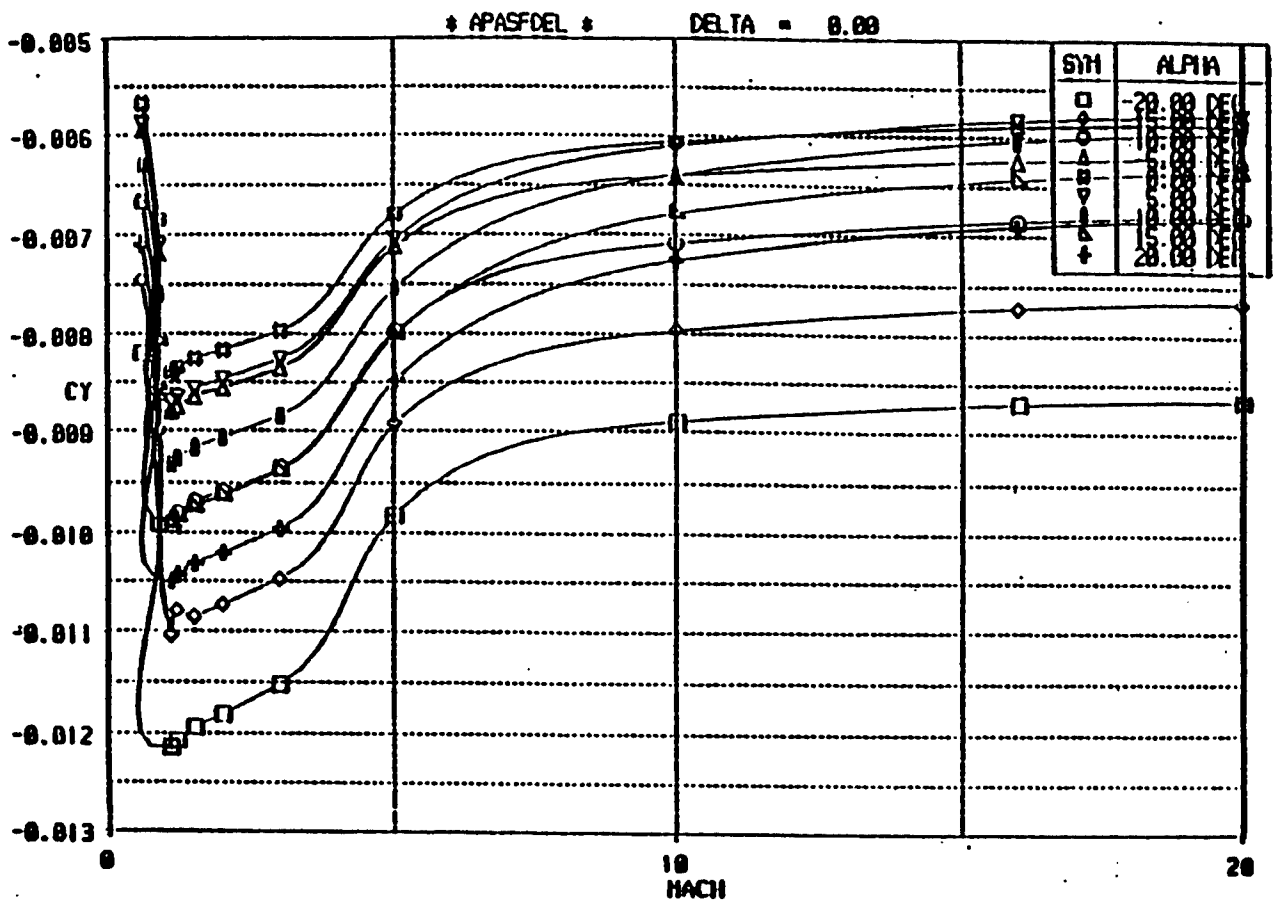
DRAG COEFFICIENT VERSUS MACH NUMBER



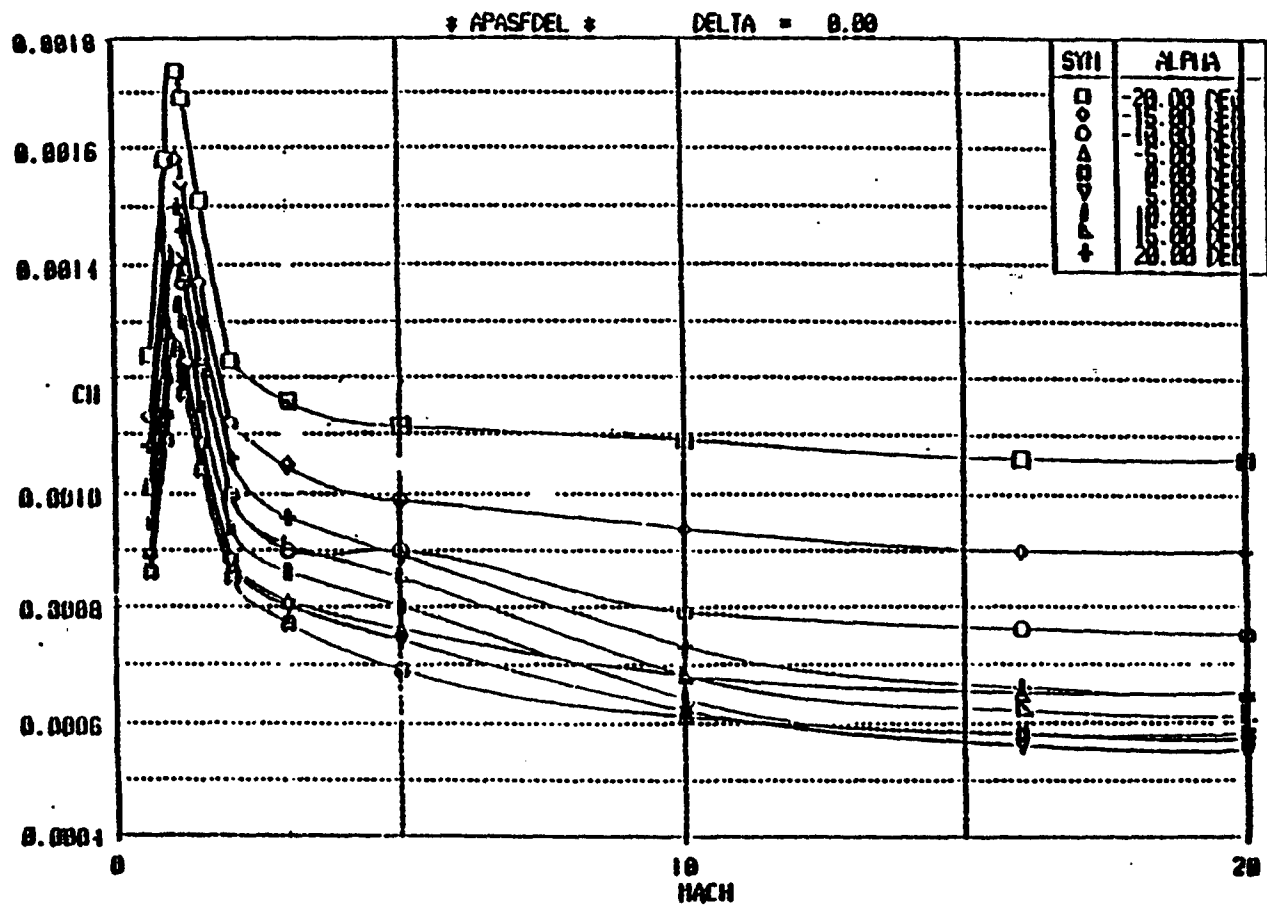
PITCHING MOMENT COEFFICIENT VERSUS MACH NUMBER



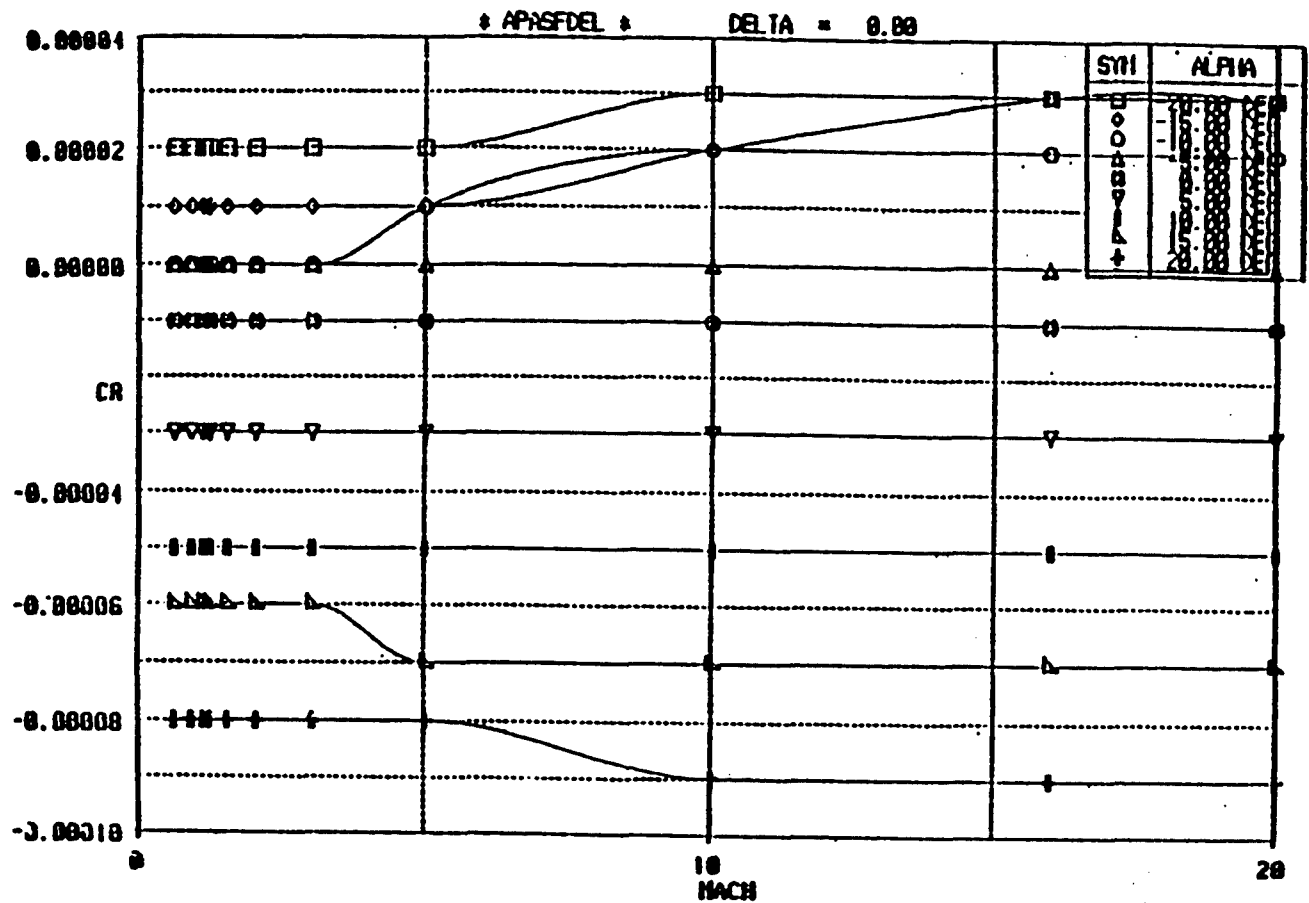
SIDE FORCE COEFFICIENT VERSUS MACH NUMBER, BETA=5

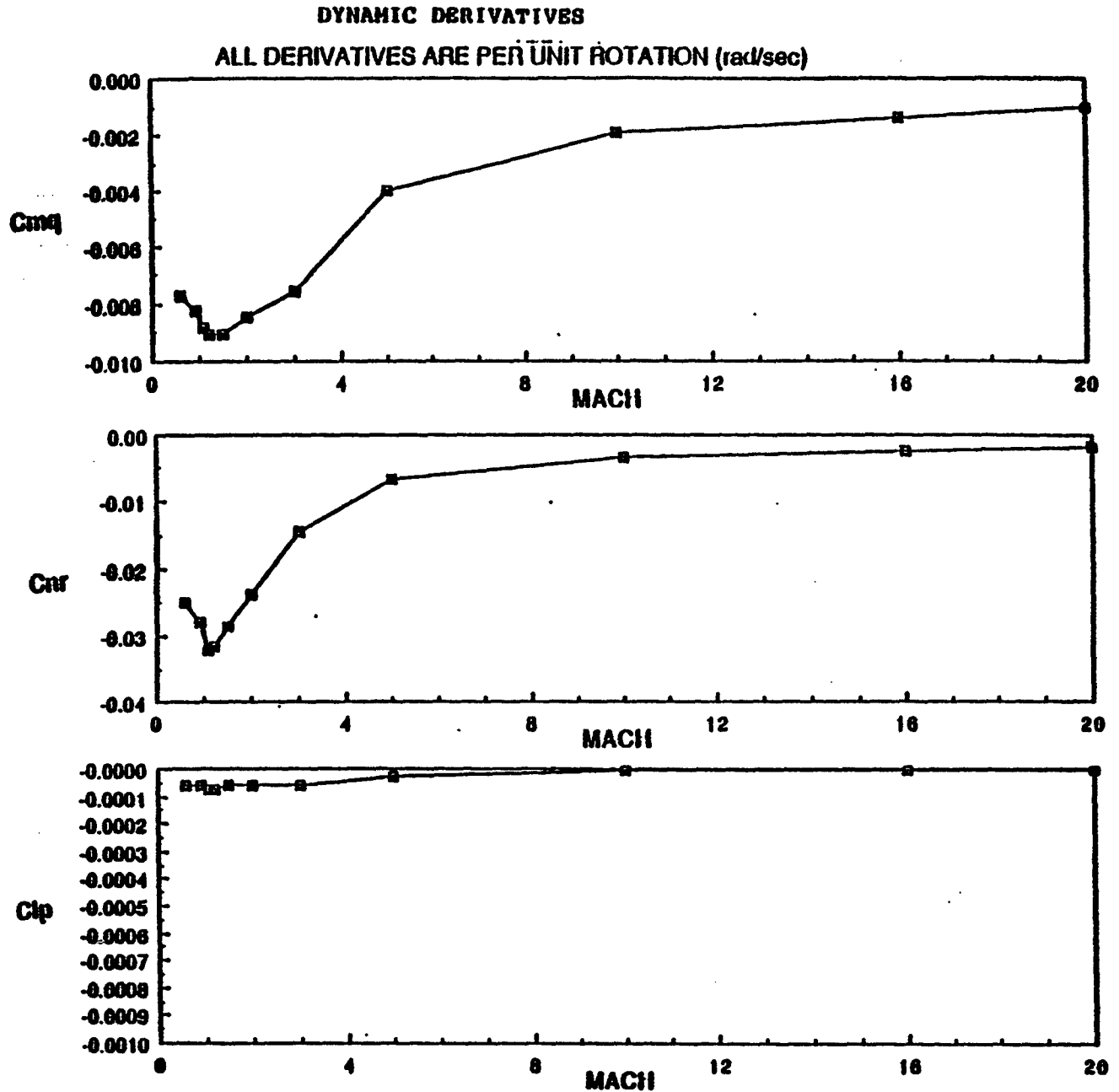


YAWING MOMENT COEFFICIENT VERSUS MACH NUMBER, BETA=5



### ROLLING MOMENT COEFFICIENT VERSUS MACH NUMBER, BETA-5

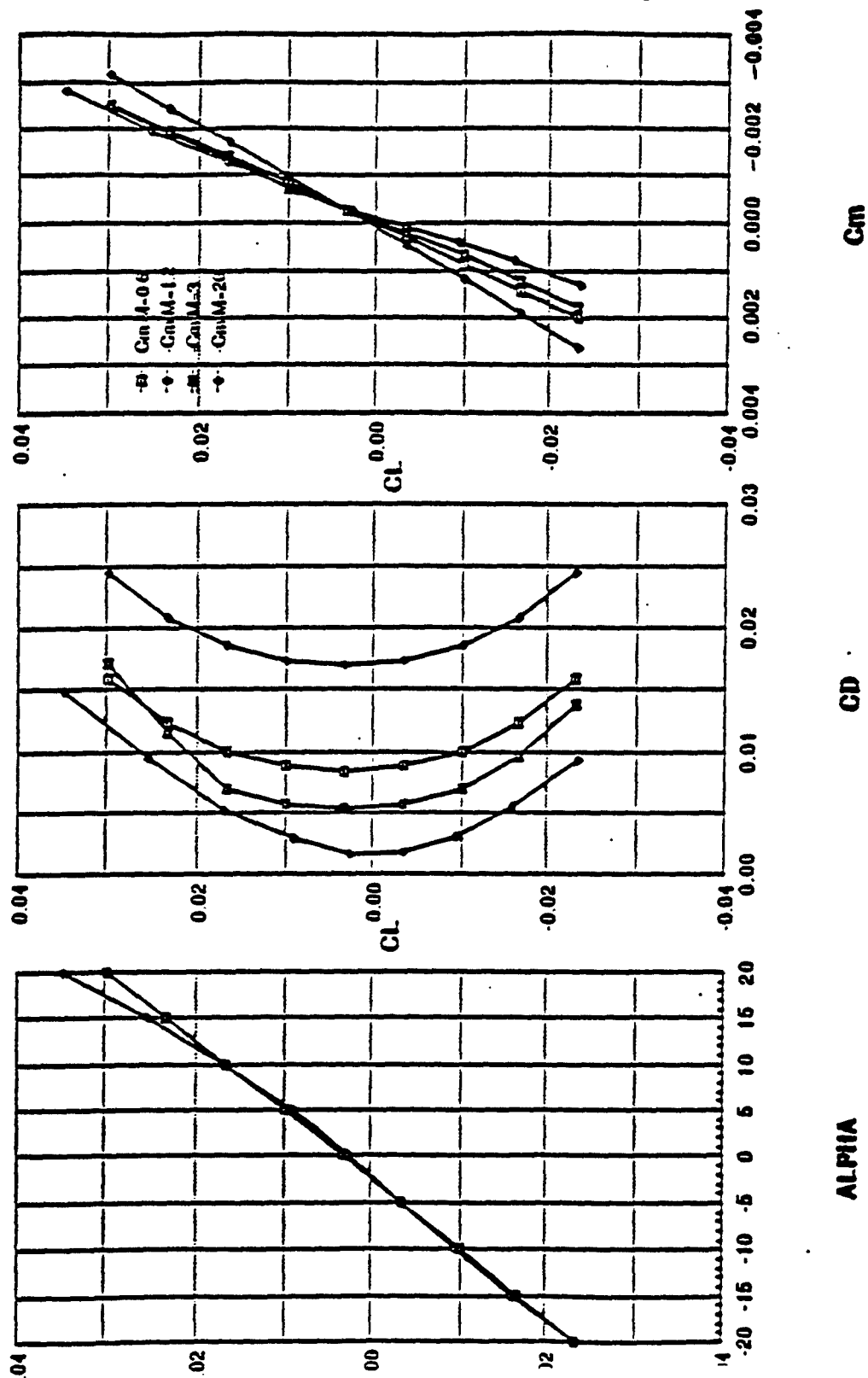




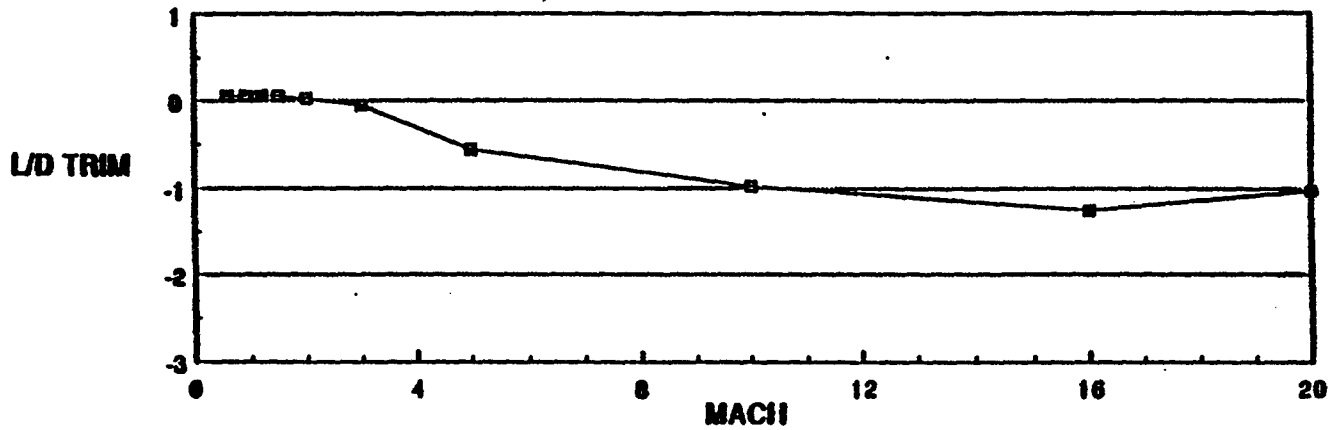
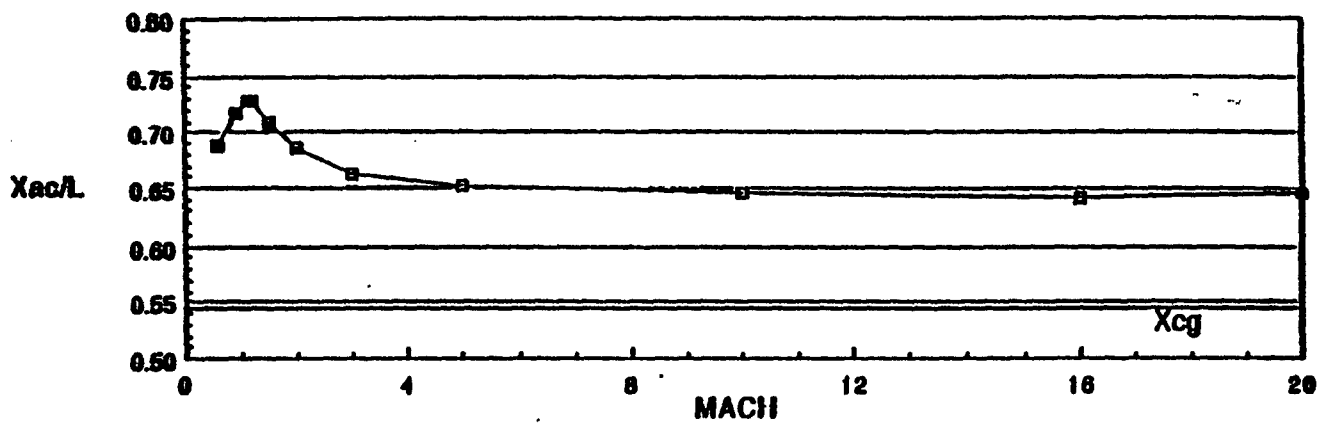
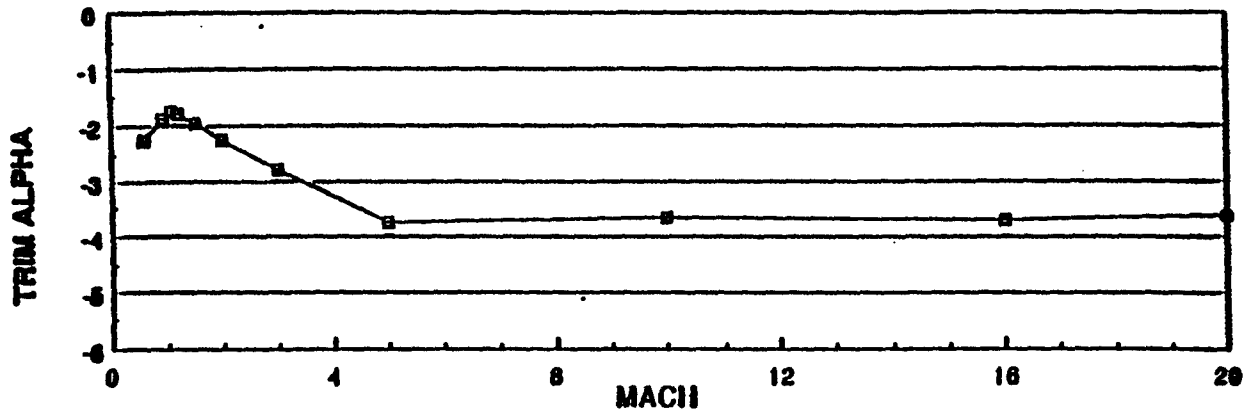


# LONGITUDINAL AERODYNAMIC CHARACTERISTICS

Configuration Refinement 2

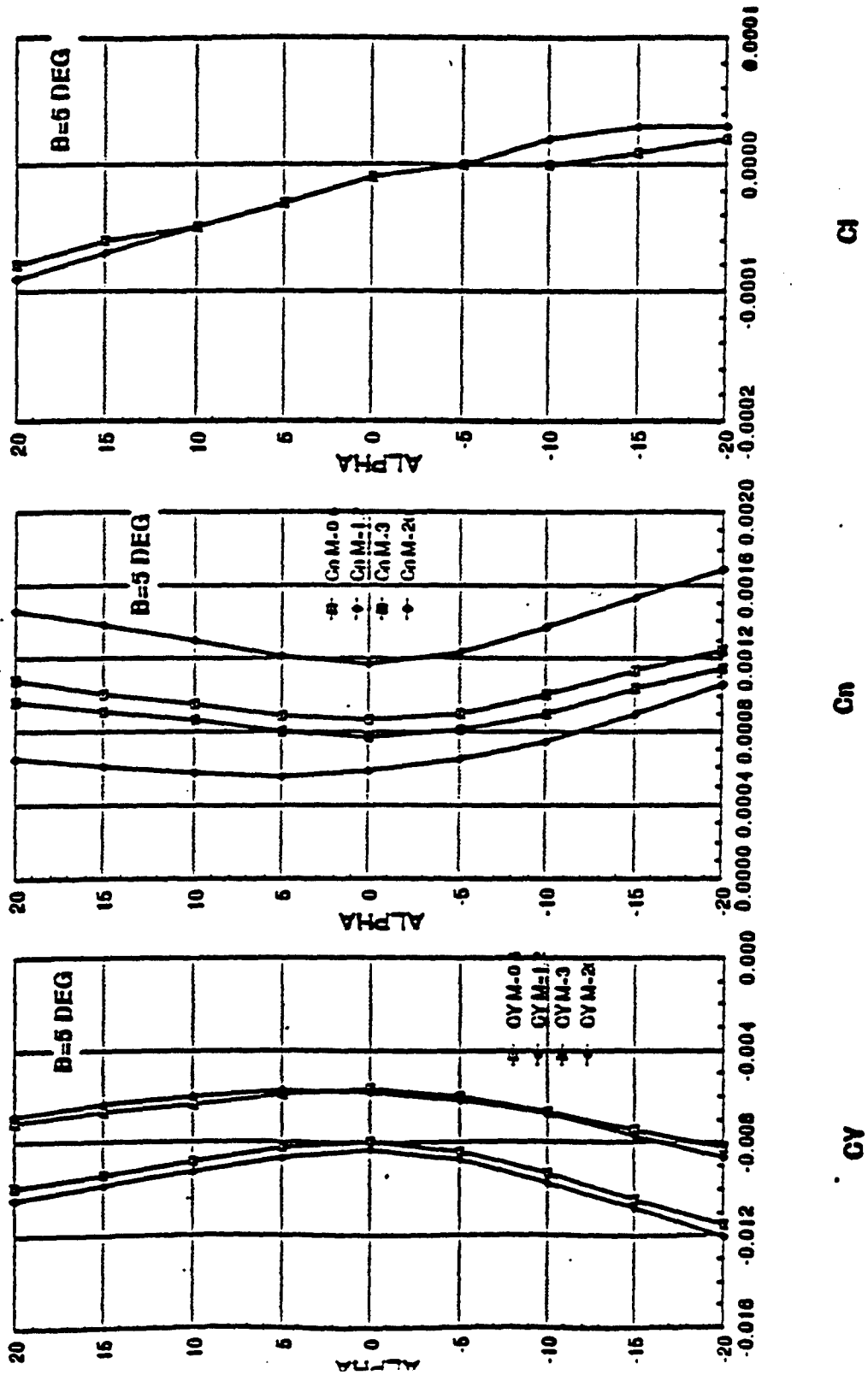


STATIC STABILITY AND PERFORMANCE CHARACTERISTICS



# LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS

Configuration Refinement 2



# Inflatable Decelerator System

| PE     | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 0.60 | 32000.00 | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.03025 | 0.01980    | 0.00239  | -1.52778 | -0.06546 | 0.001436 |
| -15.00 | 0.00 | -0.02307 | 0.01481    | 0.00192  | -1.55773 | -0.06685 | 0.001436 |
| -10.00 | 0.00 | -0.01589 | 0.01156    | 0.00144  | -1.37457 | -0.06695 | 0.001434 |
| -5.00  | 0.00 | -0.00872 | 0.00978    | 0.00096  | -0.89162 | -0.06685 | 0.001436 |
| 0.00   | 0.00 | -0.00154 | 0.00924    | 0.00048  | -0.16667 | -0.06555 | 0.001434 |
| 5.00   | 0.00 | 0.00563  | 0.00978    | 0.00001  | 0.57566  | -0.06825 | 0.001436 |
| 10.00  | 0.00 | 0.01281  | 0.01156    | -0.00048 | 1.10813  | -0.06546 | 0.001436 |
| 15.00  | 0.00 | 0.01999  | 0.01481    | -0.00095 | 1.34976  | -0.06695 | 0.001434 |
| 20.00  | 0.00 | 0.02716  | 0.01980    | -0.00143 | 1.37172  | -0.06695 | 0.001434 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 0.90 | 37000.00 | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.03025 | 0.02530    | 0.00277  | -1.19565 | -0.07799 | 0.001436 |
| -15.00 | 0.00 | -0.02307 | 0.02031    | 0.00221  | -1.13589 | -0.08078 | 0.001436 |
| -10.00 | 0.00 | -0.01589 | 0.01706    | 0.00163  | -0.93142 | -0.07950 | 0.001434 |
| -5.00  | 0.00 | -0.00872 | 0.01528    | 0.00106  | -0.57068 | -0.08078 | 0.001436 |
| 0.00   | 0.00 | -0.00154 | 0.01474    | 0.00048  | -0.10448 | -0.07950 | 0.001434 |
| 5.00   | 0.00 | 0.00563  | 0.01528    | -0.00009 | 0.36846  | -0.08078 | 0.001436 |
| 10.00  | 0.00 | 0.01281  | 0.01706    | -0.00067 | 0.75088  | -0.07939 | 0.001436 |
| 15.00  | 0.00 | 0.01999  | 0.02031    | -0.00124 | 0.98424  | -0.07950 | 0.001434 |
| 20.00  | 0.00 | 0.02716  | 0.02530    | -0.00181 | 1.07352  | -0.07950 | 0.001434 |

| PE     | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 1.10 | 39000.00 | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.03025 | 0.03811    | 0.00295  | -0.79375 | -0.08357 | 0.001436 |
| -15.00 | 0.00 | -0.02307 | 0.03307    | 0.00235  | -0.69761 | -0.08774 | 0.001436 |
| -10.00 | 0.00 | -0.01589 | 0.02981    | 0.00172  | -0.53304 | -0.08508 | 0.001434 |
| -5.00  | 0.00 | -0.00872 | 0.02803    | 0.00111  | -0.31110 | -0.08774 | 0.001436 |
| 0.00   | 0.00 | -0.00154 | 0.02749    | 0.00048  | -0.05602 | -0.08647 | 0.001434 |
| 5.00   | 0.00 | 0.00563  | 0.02803    | -0.00014 | 0.20086  | -0.08635 | 0.001436 |
| 10.00  | 0.00 | 0.01281  | 0.02981    | -0.00076 | 0.42972  | -0.08635 | 0.001436 |
| 15.00  | 0.00 | 0.01999  | 0.03307    | -0.00138 | 0.60448  | -0.08508 | 0.001434 |
| 20.00  | 0.00 | 0.02716  | 0.03811    | -0.00199 | 0.71267  | -0.08508 | 0.001434 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|----------|----------|----------|----------|
| BASIC  | 1.20 | 41500.00 | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.03025 | 0.03470    | 0.00291  | -0.87176 | -0.08357 | 0.001436 |
| -15.00 | 0.00 | -0.02307 | 0.02963    | 0.00231  | -0.77860 | -0.08496 | 0.001436 |
| -10.00 | 0.00 | -0.01589 | 0.02636    | 0.00170  | -0.60281 | -0.08368 | 0.001434 |
| -5.00  | 0.00 | -0.00872 | 0.02458    | 0.00110  | -0.35476 | -0.08635 | 0.001436 |
| 0.00   | 0.00 | -0.00154 | 0.02404    | 0.00048  | -0.06406 | -0.08508 | 0.001434 |
| 5.00   | 0.00 | 0.00563  | 0.02458    | -0.00013 | 0.22905  | -0.08496 | 0.001436 |
| 10.00  | 0.00 | 0.01281  | 0.02636    | -0.00074 | 0.48596  | -0.08357 | 0.001436 |
| 15.00  | 0.00 | 0.01999  | 0.02963    | -0.00134 | 0.67465  | -0.08508 | 0.001434 |
| 20.00  | 0.00 | 0.02716  | 0.03470    | -0.00195 | 0.78271  | -0.08508 | 0.001434 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF    | XCG      | ZCG      | YCG      |
|--------|------|----------|------------|---------|----------|----------|----------|
| BASIC  | 1.50 | 45500.00 | 0.         | 2979.55 | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA | CL       | CD         | CM      | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00 | -0.03025 | 0.02933    | 0.00268 | -1.03137 | -0.07521 | 0.001436 |
| -15.00 | 0.00 | -0.02307 | 0.02408    | 0.00214 | -0.95806 | -0.07660 | 0.001436 |

## Inflatable Decelerator System

|        |       |           |            |          |          |          |          |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| -10.00 | 0.00  | -0.01589  | 0.02078    | 0.00159  | -0.76468 | -0.07671 | 0.001434 |
| -5.00  | 0.00  | -0.00872  | 0.01900    | 0.00104  | -0.45895 | -0.07799 | 0.001436 |
| 0.00   | 0.00  | -0.00154  | 0.01846    | 0.00048  | -0.08342 | -0.07671 | 0.001434 |
| 5.00   | 0.00  | 0.00563   | 0.01900    | -0.00007 | 0.29632  | -0.07799 | 0.001436 |
| 10.00  | 0.00  | 0.01281   | 0.02078    | -0.00063 | 0.61646  | -0.07521 | 0.001436 |
| 15.00  | 0.00  | 0.01999   | 0.02408    | -0.00117 | 0.83015  | -0.09066 | 0.001434 |
| 20.00  | 0.00  | 0.02716   | 0.02933    | -0.00182 | 0.92601  | -0.09066 | 0.001434 |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
| BASIC  | 2.00  | 53000.00  | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.03025  | 0.02451    | 0.00238  | -1.23419 | -0.06546 | 0.001436 |
| -15.00 | 0.00  | -0.02307  | 0.01879    | 0.00191  | -1.22778 | -0.06685 | 0.001436 |
| -10.00 | 0.00  | -0.01589  | 0.01539    | 0.00143  | -1.03249 | -0.06555 | 0.001434 |
| -5.00  | 0.00  | -0.00872  | 0.01360    | 0.00096  | -0.64118 | -0.06685 | 0.001436 |
| 0.00   | 0.00  | -0.00154  | 0.01306    | 0.00048  | -0.11792 | -0.06555 | 0.001434 |
| 5.00   | 0.00  | 0.00563   | 0.01360    | 0.00001  | 0.41397  | -0.07521 | 0.001436 |
| 10.00  | 0.00  | 0.01281   | 0.01539    | -0.00053 | 0.83236  | -0.06825 | 0.001436 |
| 15.00  | 0.00  | 0.01999   | 0.01950    | -0.00102 | 1.02513  | -0.09484 | 0.001434 |
| 20.00  | 0.00  | 0.02716   | 0.02660    | -0.00170 | 1.02105  | -0.09484 | 0.001434 |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
| BASIC  | 3.00  | 62000.00  | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.03025  | 0.02050    | 0.00209  | -1.47561 | -0.05571 | 0.001436 |
| -15.00 | 0.00  | -0.02307  | 0.01482    | 0.00169  | -1.55668 | -0.05571 | 0.001436 |
| -10.00 | 0.00  | -0.01589  | 0.01113    | 0.00129  | -1.42767 | -0.05579 | 0.001434 |
| -5.00  | 0.00  | -0.00872  | 0.00930    | 0.00089  | -0.93763 | -0.05710 | 0.001436 |
| 0.00   | 0.00  | -0.00154  | 0.00876    | 0.00048  | -0.17580 | -0.06974 | 0.001434 |
| 5.00   | 0.00  | 0.00563   | 0.00930    | -0.00002 | 0.60538  | -0.06407 | 0.001436 |
| 10.00  | 0.00  | 0.01281   | 0.01113    | -0.00048 | 1.15094  | -0.06267 | 0.001436 |
| 15.00  | 0.00  | 0.01999   | 0.01670    | -0.00093 | 1.19701  | -0.07950 | 0.001434 |
| 20.00  | 0.00  | 0.02716   | 0.02400    | -0.00150 | 1.13167  | -0.07950 | 0.001434 |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
| BASIC  | 5.00  | 76000.00  | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02683  | 0.01887    | 0.00158  | -1.42183 | -0.04571 | 0.001400 |
| -15.00 | 0.00  | -0.01983  | 0.01306    | 0.00126  | -1.51838 | -0.04795 | 0.001460 |
| -10.00 | 0.00  | -0.01253  | 0.00900    | 0.00091  | -1.39222 | -0.06056 | 0.001354 |
| -5.00  | 0.00  | -0.00576  | 0.00669    | 0.00050  | -0.86099 | -0.06761 | 0.001272 |
| 0.00   | 0.00  | 0.00060   | 0.00609    | 0.00007  | 0.09852  | -0.06506 | 0.001414 |
| 5.00   | 0.00  | 0.00767   | 0.00727    | -0.00039 | 1.05502  | -0.06311 | 0.001426 |
| 10.00  | 0.00  | 0.01480   | 0.01032    | -0.00084 | 1.43411  | -0.05857 | 0.001400 |
| 15.00  | 0.00  | 0.02180   | 0.01537    | -0.00125 | 1.41835  | -0.05417 | 0.001440 |
| 20.00  | 0.00  | 0.02900   | 0.02239    | -0.00164 | 1.29522  | -0.05417 | 0.001440 |
| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
| BASIC  | 10.00 | 106000.00 | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02445  | 0.01710    | 0.00155  | -1.42982 | -0.04897 | 0.001266 |
| -15.00 | 0.00  | -0.01812  | 0.01156    | 0.00124  | -1.56747 | -0.05435 | 0.001288 |
| -10.00 | 0.00  | -0.01168  | 0.00766    | 0.00089  | -1.52480 | -0.06390 | 0.001252 |
| -5.00  | 0.00  | -0.00542  | 0.00541    | 0.00049  | -1.00185 | -0.06843 | 0.001286 |
| 0.00   | 0.00  | 0.00101   | 0.00482    | 0.00005  | 0.20954  | -0.06757 | 0.001332 |
| 5.00   | 0.00  | 0.00767   | 0.00597    | -0.00040 | 1.28476  | -0.06250 | 0.001440 |
| 10.00  | 0.00  | 0.01487   | 0.00892    | -0.00085 | 1.66704  | -0.05683 | 0.001478 |
| 15.00  | 0.00  | 0.02226   | 0.01376    | -0.00127 | 1.61773  | -0.05409 | 0.001442 |
| 20.00  | 0.00  | 0.02947   | 0.02050    | -0.00166 | 1.43756  | -0.05409 | 0.001442 |

# Inflatable Decelerator System

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 16.00 | 140000.00 | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02395  | 0.01618    | 0.00153  | -1.48022 | -0.04815 | 0.001246 |
| -15.00 | 0.00  | -0.01772  | 0.01076    | 0.00123  | -1.64684 | -0.05618 | 0.001246 |
| -10.00 | 0.00  | -0.01149  | 0.00696    | 0.00088  | -1.65086 | -0.06547 | 0.001222 |
| -5.00  | 0.00  | -0.00538  | 0.00475    | 0.00048  | -1.13263 | -0.06740 | 0.001276 |
| 0.00   | 0.00  | 0.00100   | 0.00417    | 0.00005  | 0.23981  | -0.06839 | 0.001316 |
| 5.00   | 0.00  | 0.00758   | 0.00529    | -0.00040 | 1.43289  | -0.06419 | 0.001402 |
| 10.00  | 0.00  | 0.01459   | 0.00816    | -0.00085 | 1.78799  | -0.05769 | 0.001456 |
| 15.00  | 0.00  | 0.02187   | 0.01290    | -0.00127 | 1.69535  | -0.05285 | 0.001438 |
| 20.00  | 0.00  | 0.02906   | 0.01954    | -0.00165 | 1.48721  | -0.05285 | 0.001438 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG      | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|----------|----------|----------|
| BASIC  | 20.00 | 177000.00 | 0.         | 2979.55  | 29.42    | -0.83    | 0.00     |
| ALPHA  | BETA  | CL        | CD         | CM       | L/D      | St Marg  | CLdAlpha |
| -20.00 | 0.00  | -0.02373  | 0.01635    | 0.00153  | -1.45138 | -0.04685 | 0.001238 |
| -15.00 | 0.00  | -0.01754  | 0.01094    | 0.00124  | -1.60329 | -0.05854 | 0.001230 |
| -10.00 | 0.00  | -0.01139  | 0.00715    | 0.00088  | -1.59301 | -0.06623 | 0.001208 |
| -5.00  | 0.00  | -0.00535  | 0.00493    | 0.00048  | -1.08519 | -0.06782 | 0.001268 |
| 0.00   | 0.00  | 0.00099   | 0.00435    | 0.00005  | 0.22759  | -0.06891 | 0.001306 |
| 5.00   | 0.00  | 0.00752   | 0.00547    | -0.00040 | 1.37477  | -0.06494 | 0.001386 |
| 10.00  | 0.00  | 0.01445   | 0.00835    | -0.00085 | 1.73054  | -0.05939 | 0.001448 |
| 15.00  | 0.00  | 0.02169   | 0.01306    | -0.00128 | 1.66080  | -0.05307 | 0.001432 |
| 20.00  | 0.00  | 0.02885   | 0.01969    | -0.00166 | 1.46521  | -0.05307 | 0.001432 |

# Inflatable Decelerator System

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 0.60 | 32000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00118 | -0.00002 | -0.00872 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00110 | -0.00002 | -0.00816 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00102 | -0.00001 | -0.00755 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00094 | -0.00002 | -0.00701 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00091 | -0.00002 | -0.00675 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00092 | -0.00003 | -0.00679 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00094 | -0.00004 | -0.00701 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00097 | -0.00005 | -0.00722 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00100 | -0.00007 | -0.00741 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 0.90 | 37000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00142 | -0.00002 | -0.01023 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00133 | -0.00002 | -0.00958 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00123 | -0.00001 | -0.00886 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00114 | -0.00002 | -0.00823 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00110 | -0.00002 | -0.00792 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00111 | -0.00003 | -0.00797 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00114 | -0.00004 | -0.00823 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00118 | -0.00005 | -0.00847 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00121 | -0.00007 | -0.00870 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 1.10 | 39000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00152 | -0.00002 | -0.01224 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00143 | -0.00002 | -0.01145 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00132 | -0.00001 | -0.01060 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00123 | -0.00002 | -0.00984 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00118 | -0.00002 | -0.00947 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00119 | -0.00003 | -0.00953 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00123 | -0.00004 | -0.00984 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00126 | -0.00005 | -0.01012 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00130 | -0.00007 | -0.01040 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 1.20 | 41500.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00150 | -0.00002 | -0.01217 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00140 | -0.00002 | -0.01139 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00130 | -0.00001 | -0.01054 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00120 | -0.00002 | -0.00979 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00116 | -0.00002 | -0.00942 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00117 | -0.00003 | -0.00948 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00120 | -0.00004 | -0.00979 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00124 | -0.00005 | -0.01007 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00127 | -0.00007 | -0.01034 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF    | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|---------|---------|----------|----------|
| BASIC  | 1.50 | 45500.00 | 0.         | 2979.55 | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM      | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000 | 0.00136 | -0.00001 | -0.01176 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000 | 0.00127 | -0.00001 | -0.01100 |

# Inflatable Decelerator System

|        |      |          |         |          |         |          |          |
|--------|------|----------|---------|----------|---------|----------|----------|
| -10.00 | 5.00 | -0.00000 | 0.00000 | 0.00000  | 0.00117 | -0.00001 | -0.01018 |
| -5.00  | 5.00 | -0.00000 | 0.00000 | 0.00000  | 0.00109 | -0.00001 | -0.00945 |
| 0.00   | 5.00 | 0.00000  | 0.00000 | 0.00000  | 0.00105 | -0.00002 | -0.00910 |
| 5.00   | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00106 | -0.00003 | -0.00915 |
| 10.00  | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00109 | -0.00004 | -0.00945 |
| 15.00  | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00112 | -0.00005 | -0.00973 |
| 20.00  | 5.00 | 0.00000  | 0.00000 | -0.00000 | 0.00115 | -0.00007 | -0.00999 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 2.00 | 53000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00116 | -0.00001 | -0.01118 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00109 | -0.00001 | -0.01046 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00101 | -0.00001 | -0.00968 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00093 | -0.00001 | -0.00899 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00090 | -0.00002 | -0.00865 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00090 | -0.00003 | -0.00870 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00093 | -0.00004 | -0.00899 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00096 | -0.00005 | -0.00925 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00099 | -0.00007 | -0.00950 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 3.00 | 62000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00104 | -0.00001 | -0.01028 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00097 | -0.00001 | -0.00962 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00090 | -0.00001 | -0.00891 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00084 | -0.00001 | -0.00827 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00080 | -0.00002 | -0.00796 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00081 | -0.00003 | -0.00800 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00084 | -0.00004 | -0.00827 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00086 | -0.00005 | -0.00851 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00088 | -0.00007 | -0.00874 |

| TYPE   | MACH | ALTITUDE | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|------|----------|------------|----------|---------|----------|----------|
| BASIC  | 5.00 | 76000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA | CL       | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00090 | -0.00002 | -0.00867 |
| -15.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00083 | -0.00002 | -0.00810 |
| -10.00 | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00075 | -0.00001 | -0.00750 |
| -5.00  | 5.00 | -0.00000 | 0.00000    | 0.00000  | 0.00070 | -0.00002 | -0.00696 |
| 0.00   | 5.00 | 0.00000  | 0.00000    | 0.00000  | 0.00067 | -0.00002 | -0.00670 |
| 5.00   | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00067 | -0.00003 | -0.00675 |
| 10.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00070 | -0.00004 | -0.00697 |
| 15.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00073 | -0.00005 | -0.00717 |
| 20.00  | 5.00 | 0.00000  | 0.00000    | -0.00000 | 0.00075 | -0.00006 | -0.00737 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|---------|----------|----------|
| BASIC  | 10.00 | 106000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00080 | -0.00001 | -0.00805 |
| -15.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00074 | -0.00001 | -0.00746 |
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00070 | -0.00001 | -0.00692 |
| 5.00   | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00067 | -0.00001 | -0.00648 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00067 | -0.00002 | -0.00621 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00065 | -0.00003 | -0.00614 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00066 | -0.00004 | -0.00623 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00067 | -0.00005 | -0.00637 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00068 | -0.00006 | -0.00656 |



# Inflatable Decelerator System

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|---------|----------|----------|
| BIC    | 16.00 | 140000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00080 | -0.00001 | -0.00791 |
| -15.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00074 | -0.00001 | -0.00731 |
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00070 | -0.00001 | -0.00677 |
| -5.00  | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00067 | -0.00001 | -0.00637 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00066 | -0.00002 | -0.00610 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00065 | -0.00003 | -0.00597 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00065 | -0.00004 | -0.00601 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00067 | -0.00005 | -0.00614 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00068 | -0.00006 | -0.00633 |

| TYPE   | MACH  | ALTITUDE  | DEFLECTION | SREF     | XCG     | ZCG      | YCG      |
|--------|-------|-----------|------------|----------|---------|----------|----------|
| BASIC  | 20.00 | 177000.00 | 0.         | 2979.55  | 29.42   | 0.00     | -0.83    |
| ALPHA  | BETA  | CL        | CD         | CM       | C YAW   | C ROLL   | C SIDE   |
| -20.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00080 | -0.00001 | -0.00788 |
| -15.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00074 | -0.00001 | -0.00727 |
| -10.00 | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00070 | -0.00001 | -0.00674 |
| -5.00  | 5.00  | -0.00000  | 0.00000    | 0.00000  | 0.00067 | -0.00001 | -0.00635 |
| 0.00   | 5.00  | 0.00000   | 0.00000    | 0.00000  | 0.00067 | -0.00002 | -0.00608 |
| 5.00   | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00065 | -0.00003 | -0.00593 |
| 10.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00066 | -0.00004 | -0.00596 |
| 15.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00067 | -0.00005 | -0.00610 |
| 20.00  | 5.00  | 0.00000   | 0.00000    | -0.00000 | 0.00068 | -0.00006 | -0.00629 |

Inflatable Decelerator System

DATA SHEET DYNAMIC DERIVATIVES

$L_B = 555 \text{ N.}$

| M                                               | $C_{Y_p}$ | $C_{L_p}$ | $C_{N_p}$ | $C_{L_r}$ | $C_{m_r}$ | $C_{Y_r}$ | $C_{L_r}$ | $C_{N_r}$ |
|-------------------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 0.6                                             | .00131    | -.00005   | -.00036   | .03065    | -.00526   | .05613    | -.00033   | -.01892   |
| 0.9                                             | .00145    | -.00005   | -.00040   | .03223    | -.00561   | .06267    | -.00037   | -.02124   |
| 1.1                                             | .00163    | -.00006   | -.00046   | .03393    | -.00604   | .07116    | -.00041   | -.02444   |
| 1.2                                             | .00150    | -.00006   | -.00042   | .03419    | -.00619   | .07003    | -.00041   | -.02410   |
| 1.5                                             | .00117    | -.00005   | -.00033   | .03238    | -.00617   | .06304    | -.00046   | -.02174   |
| 2                                               | .00098    | -.00005   | -.00028   | .02823    | -.00581   | .05168    | -.00035   | -.01794   |
| 3                                               | .00069    | -.00004   | -.00020   | .02117    | -.00521   | .03194    | -.00023   | -.01112   |
| 5                                               | .00036    | -.00003   | -.00015   | .01456    | -.00270   | .01453    | -.00015   | -.00501   |
| 10                                              | .00018    | -.00002   | -.00008   | .00729    | -.00133   | .00723    | -.00008   | -.00246   |
| 16                                              | .00013    | -.00001   | -.00006   | .00526    | -.00095   | .00520    | -.00005   | -.00175   |
| 20                                              | .00010    | -.00001   | -.00004   | .00391    | -.00064   | .00385    | -.00004   | -.00128   |
| All derivatives are per unit rotation (rad/sec) |           |           |           |           |           |           |           |           |

## APPENDIX F

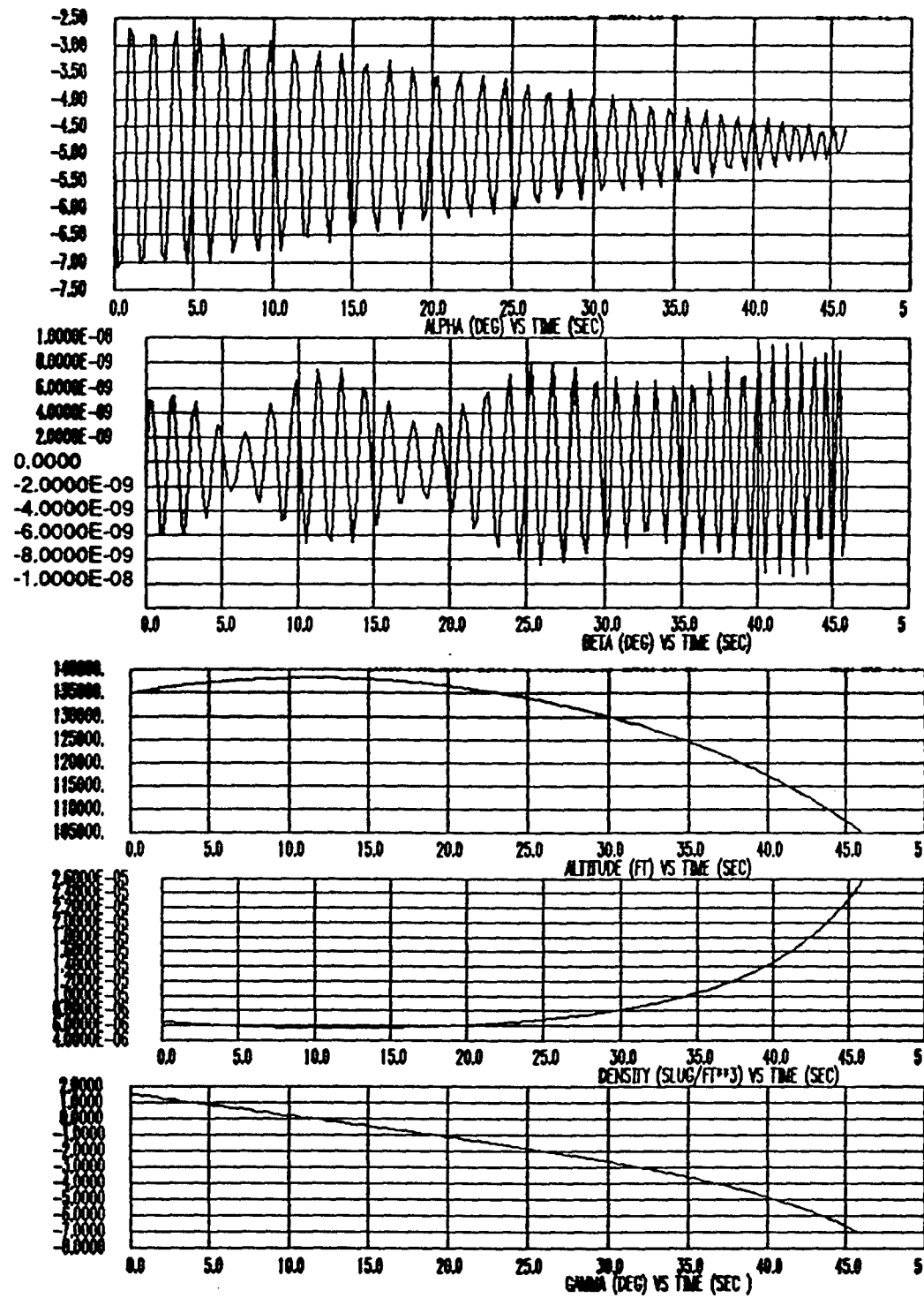
### Trajectory Analysis Output Plots for Cases 1 - 13

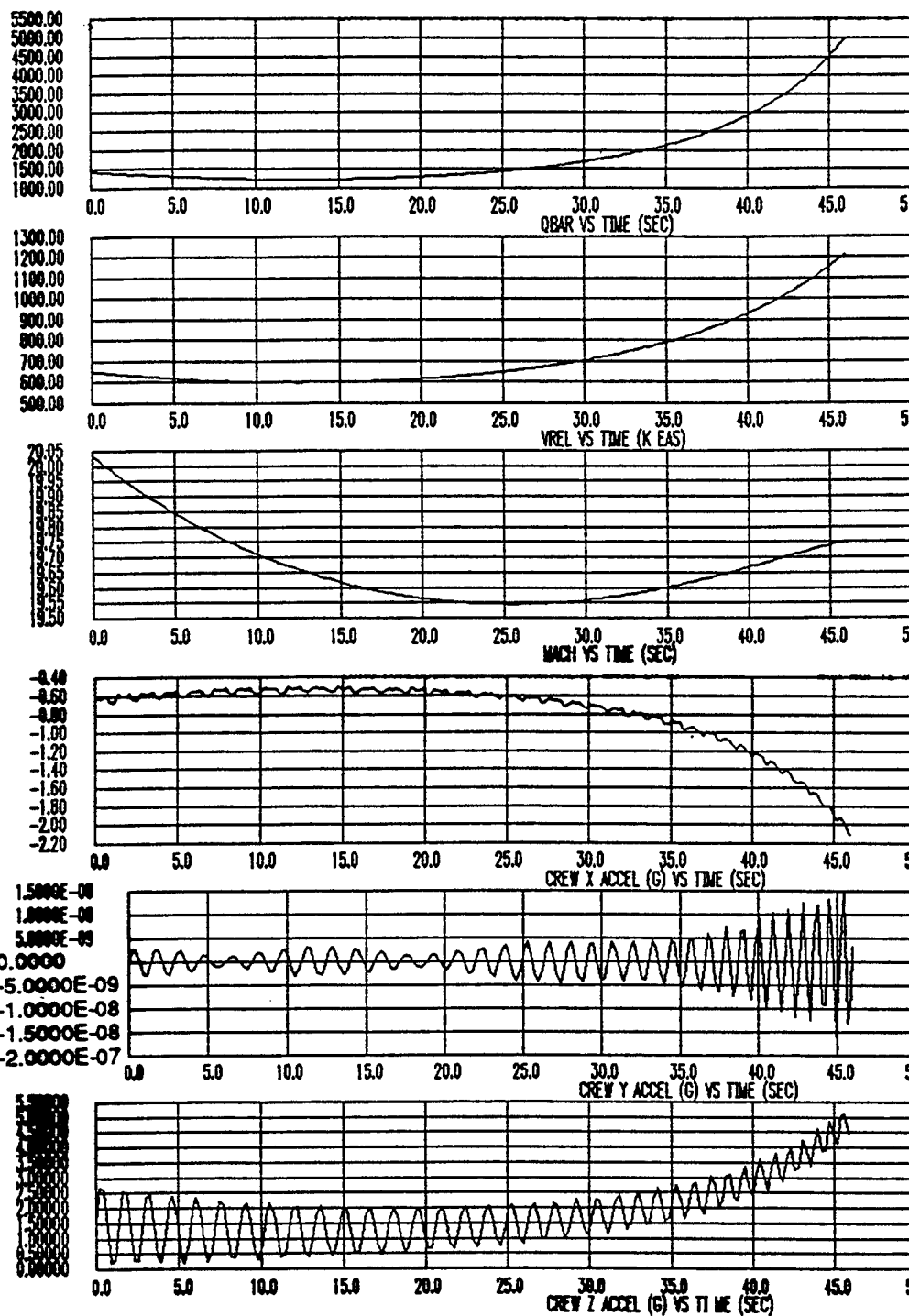
This appendix contains the plotted output for the trajectory analysis performed under Task IV. The plots are presented case-by-case according to the matrix below. Further description of the cases and associated results are found in Task IV of this report.

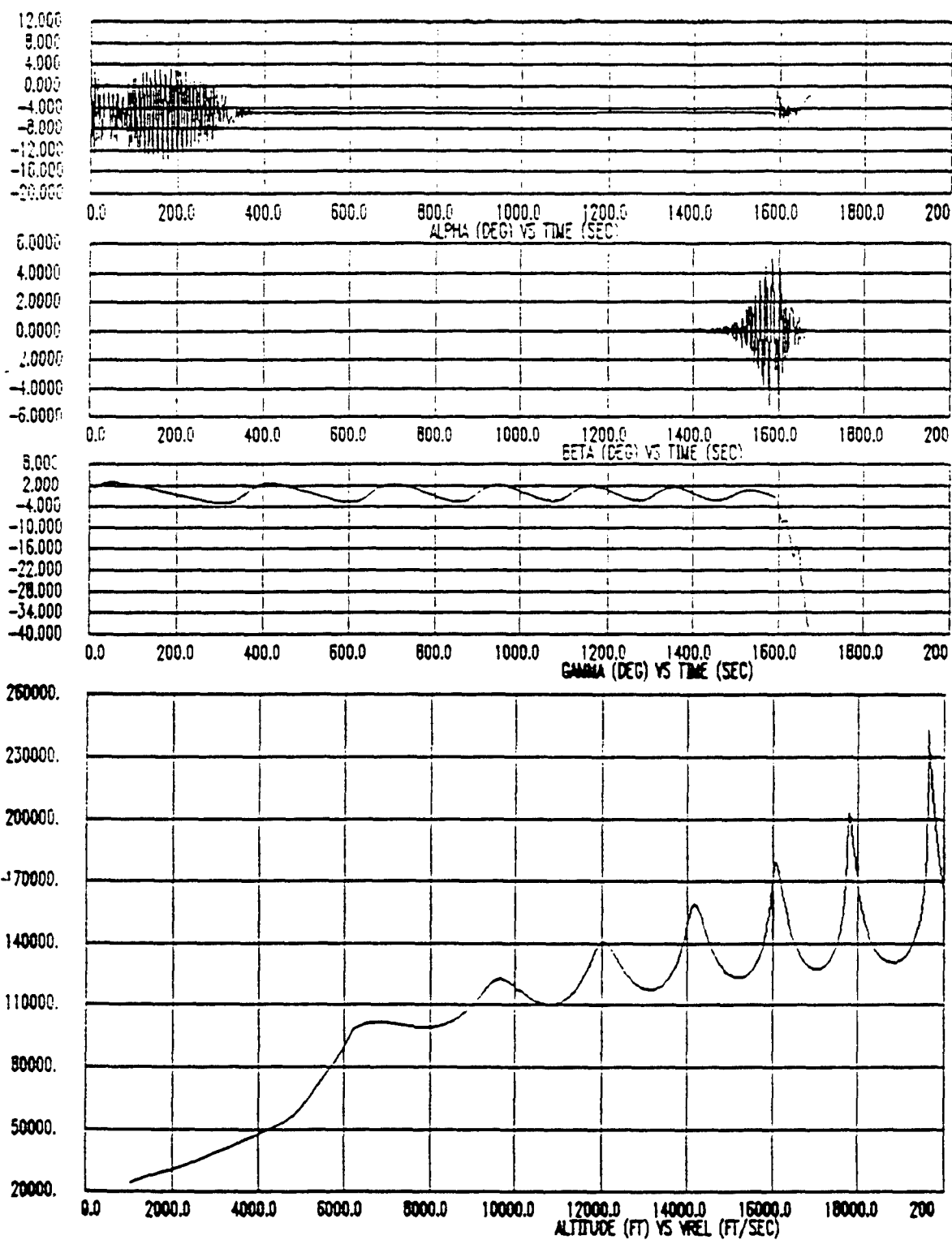
CETAP Cases 1 - 12 run for configuration refinement 1 and the aerosurface system.

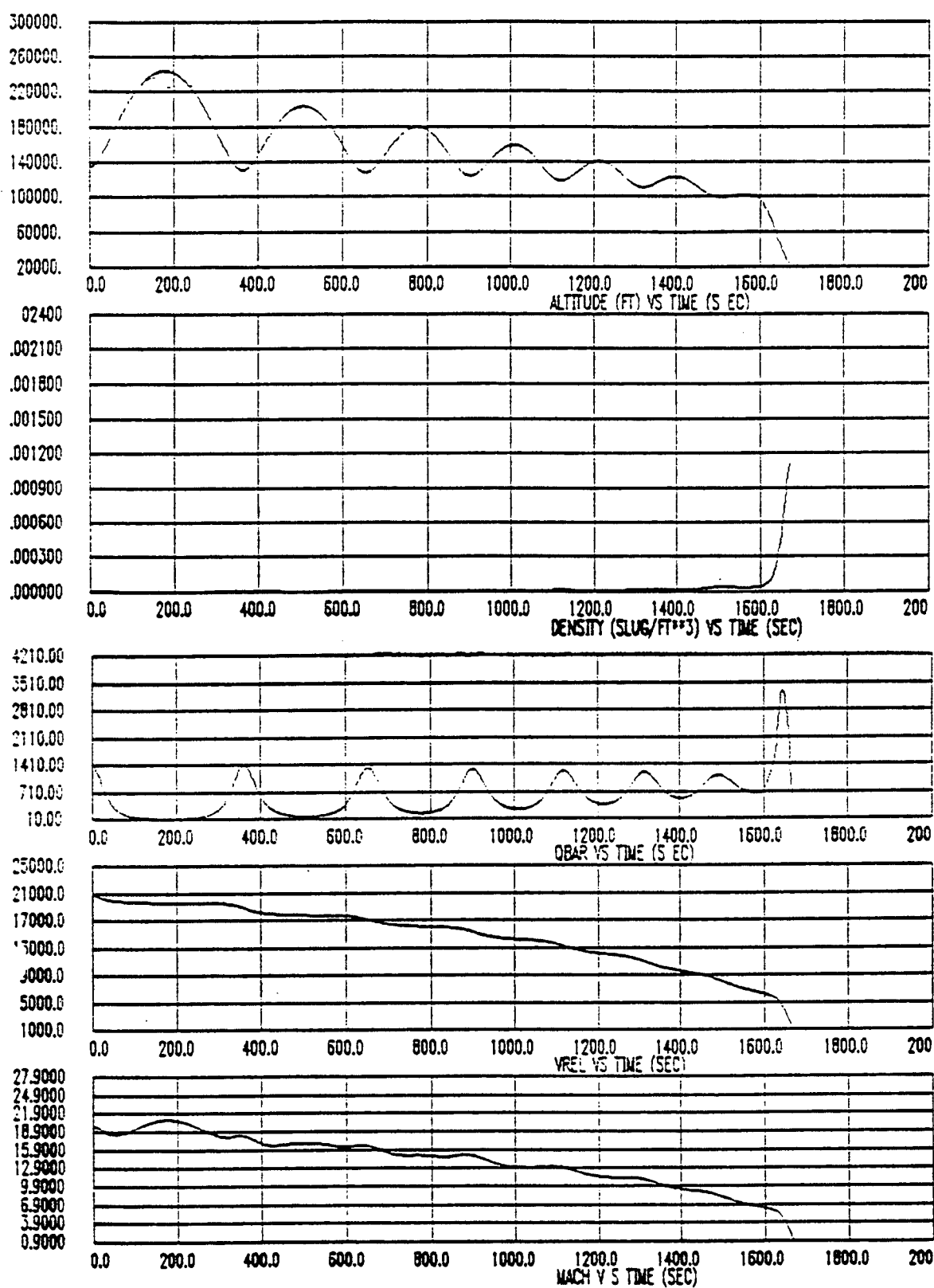
| Initial Mach # | Cases                                      |                                   |                                            |                                                  |                                                   |                                                  |                                                 |                                                 |                                     |                                     |                                     |                                     |
|----------------|--------------------------------------------|-----------------------------------|--------------------------------------------|--------------------------------------------------|---------------------------------------------------|--------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
|                | 1                                          | 2                                 | 3                                          | 4                                                | 5                                                 | 6                                                | 7                                               | 8                                               | 9                                   | 10                                  | 11                                  | 12                                  |
| Mach 20.0      | No Initial Conditions (IC's)<br>No control | No IC's<br>Purely Inverted Flight | Bank Angle Command (BAC),<br>IC's Inverted | BAC, IC's Mach 5.0<br>Drogue Deploy.<br>Inverted | BAC, IC's Mach 20.0<br>Ballute Deploy.<br>Upright |                                                  |                                                 |                                                 | BAC, IC's<br>IDS Deploy.<br>Upright |                                     |                                     |                                     |
| Mach 6.0       |                                            |                                   |                                            |                                                  |                                                   | BAC, IC's Mach 3.0<br>Drogue Deploy.<br>Inverted |                                                 |                                                 |                                     | BAC, IC's<br>IDS Deploy.<br>Upright |                                     |                                     |
| Mach 3.0       |                                            |                                   |                                            |                                                  |                                                   |                                                  | BAC, IC's Mach 3.0<br>Drogue Deploy.<br>Upright |                                                 |                                     |                                     | BAC, IC's<br>IDS Deploy.<br>Upright |                                     |
| Mach 1.5       |                                            |                                   |                                            |                                                  |                                                   |                                                  |                                                 | BAC, IC's Mach 1.5<br>Drogue Deploy.<br>Upright |                                     |                                     |                                     | BAC, IC's<br>IDS Deploy.<br>Upright |

CETAP Case 13 was run for configuration refinement 2 (with an increased span) at Mach 20.0 failure initial conditions.

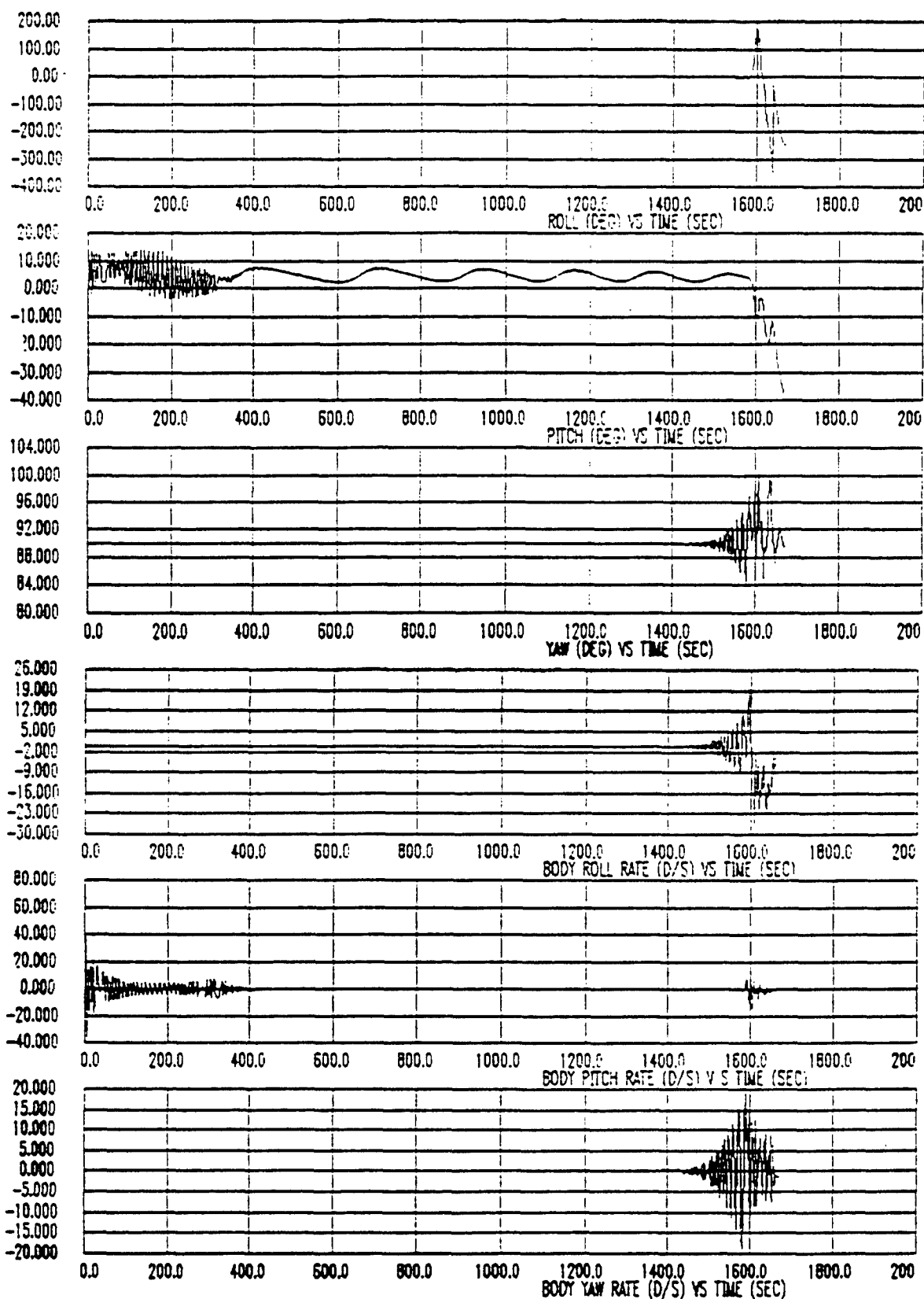


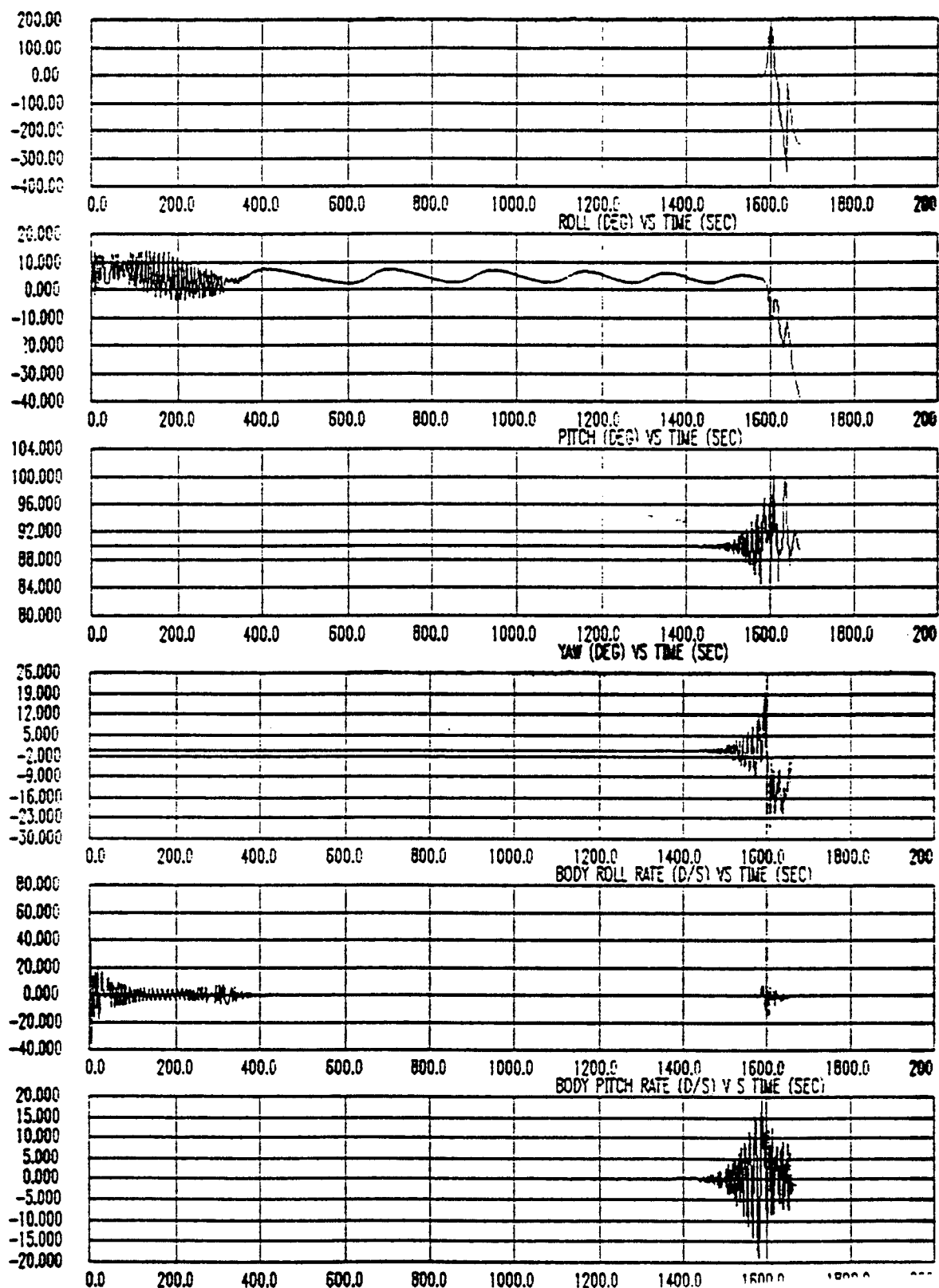




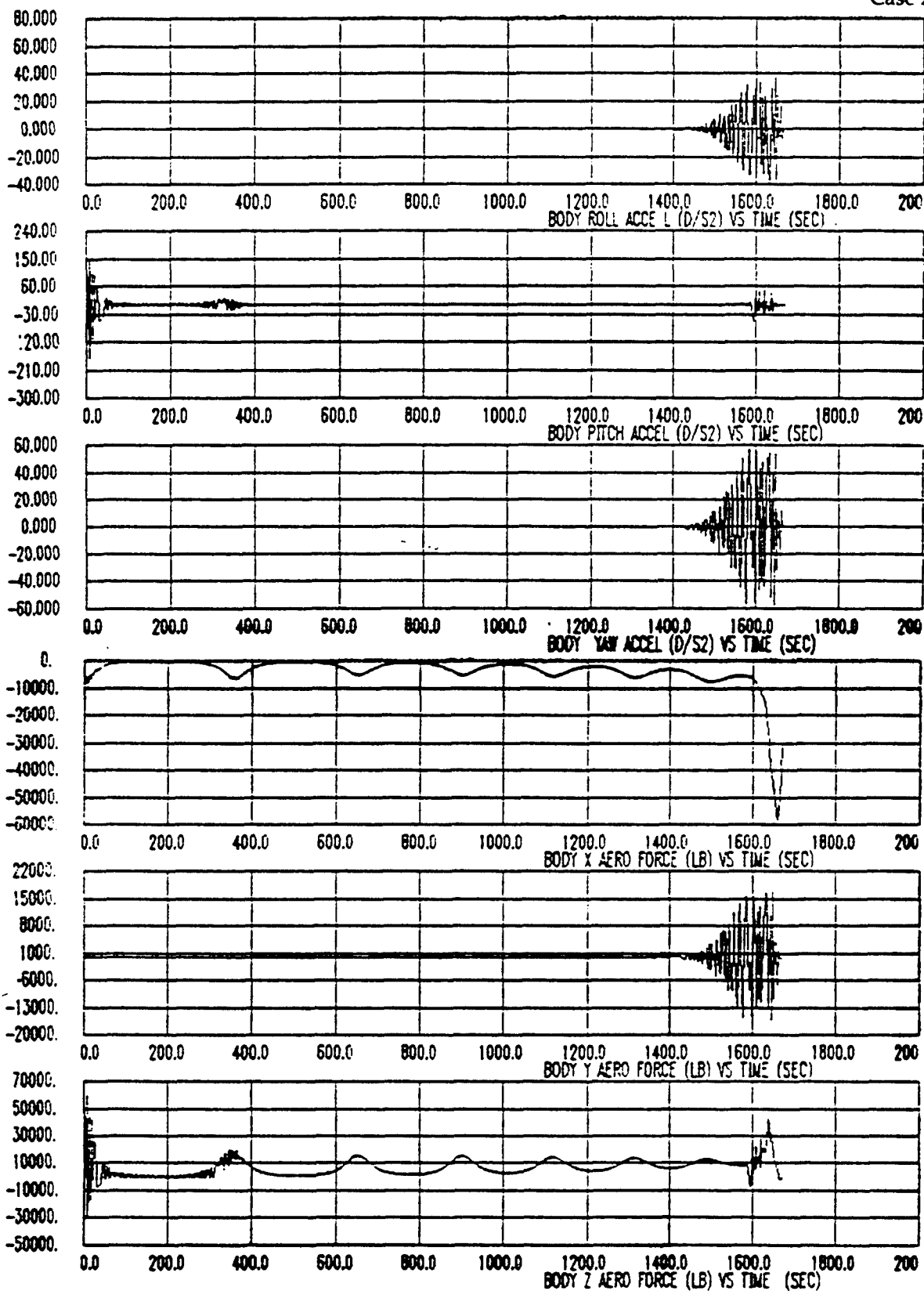




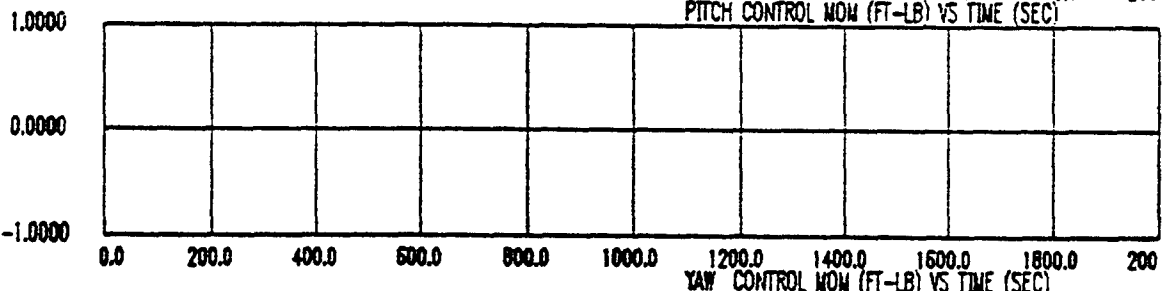
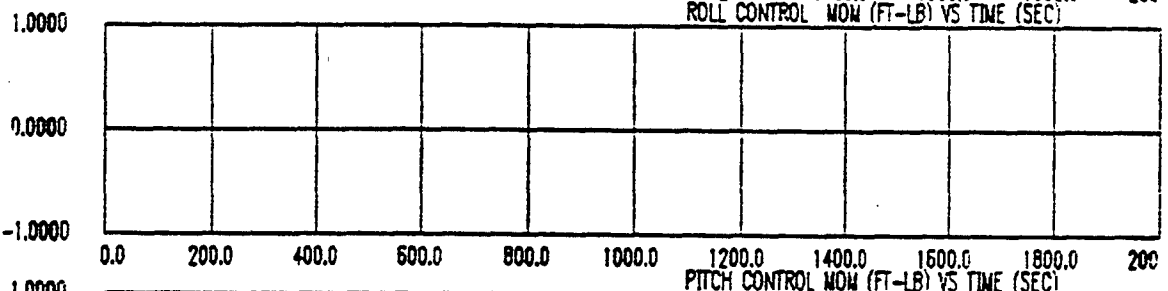
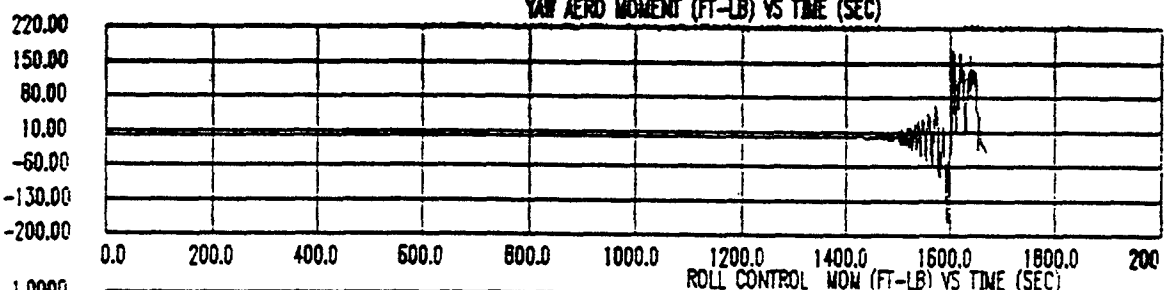
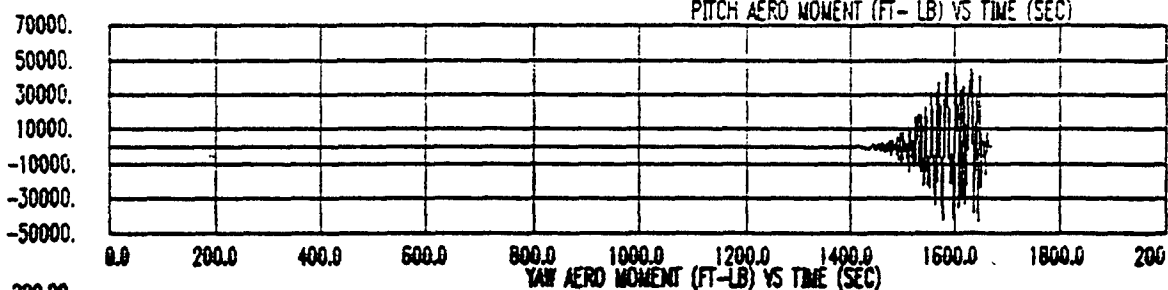
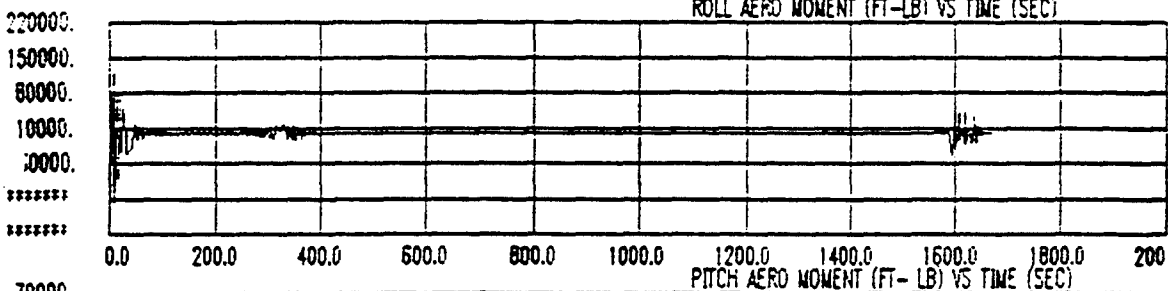
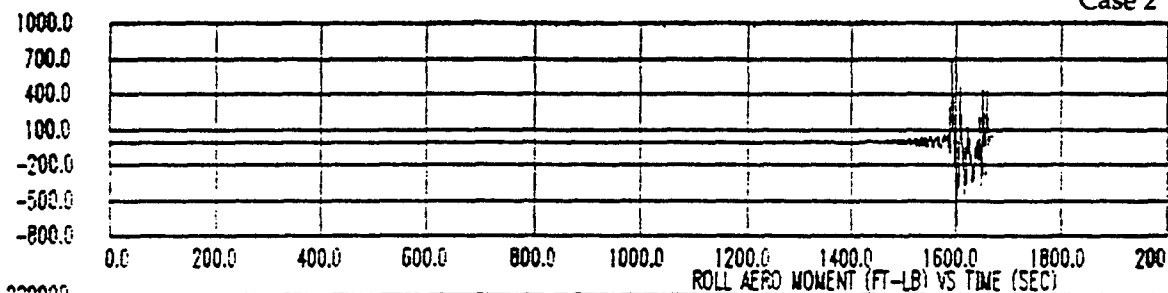


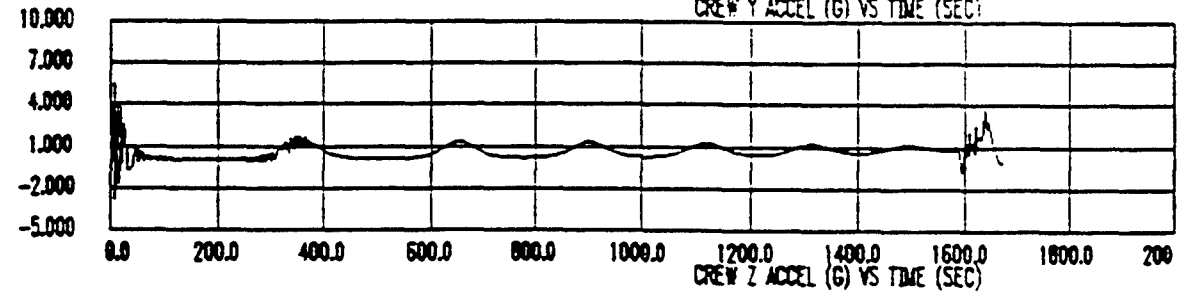
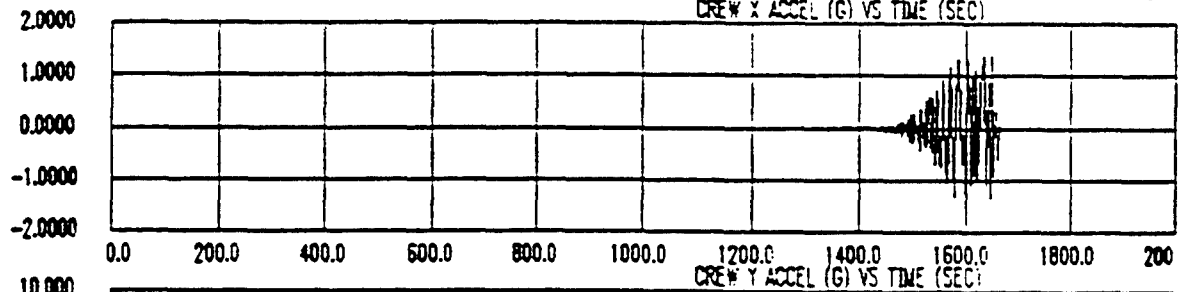
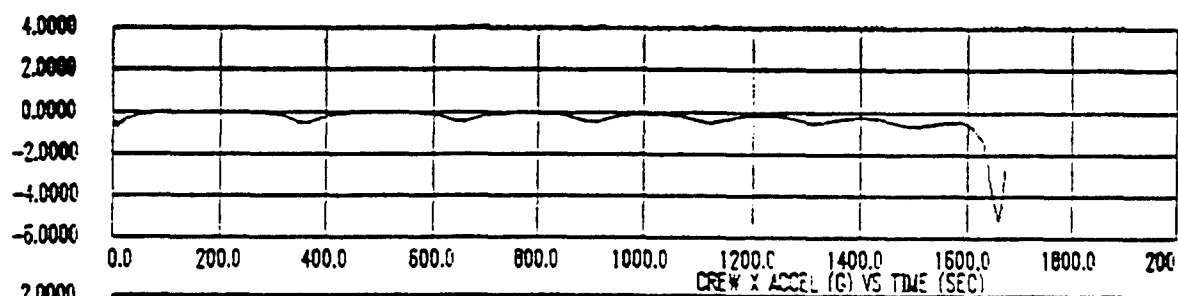
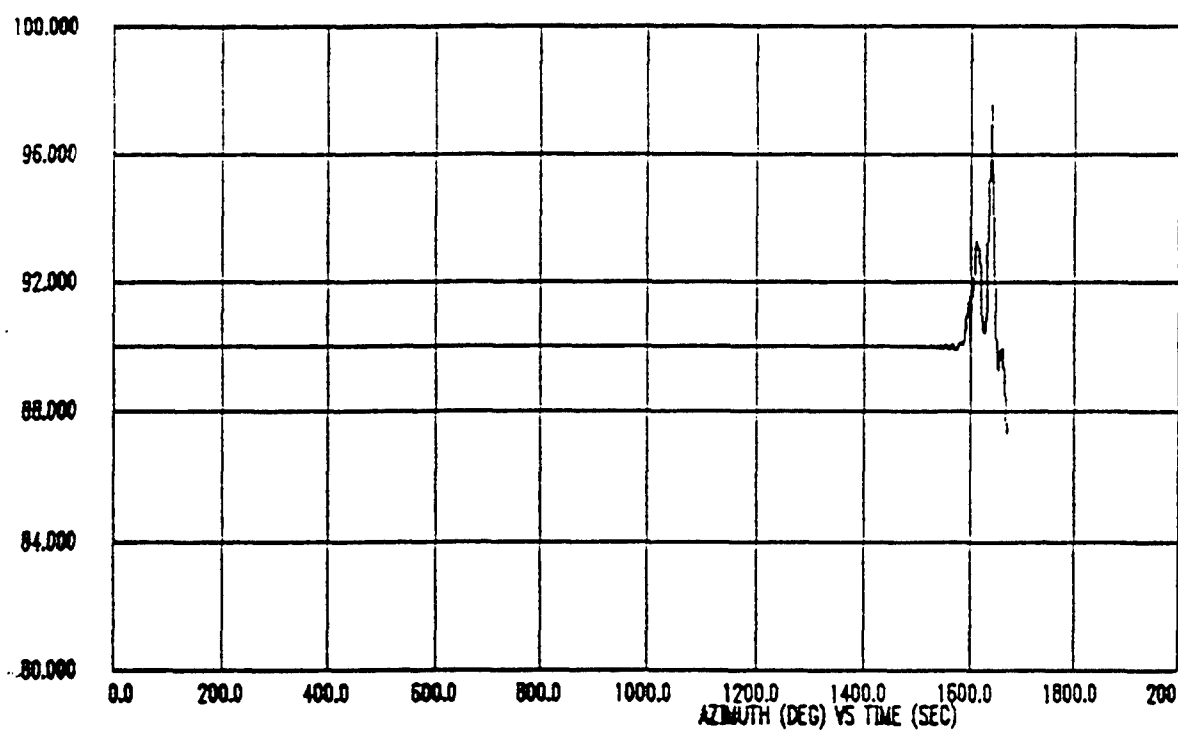


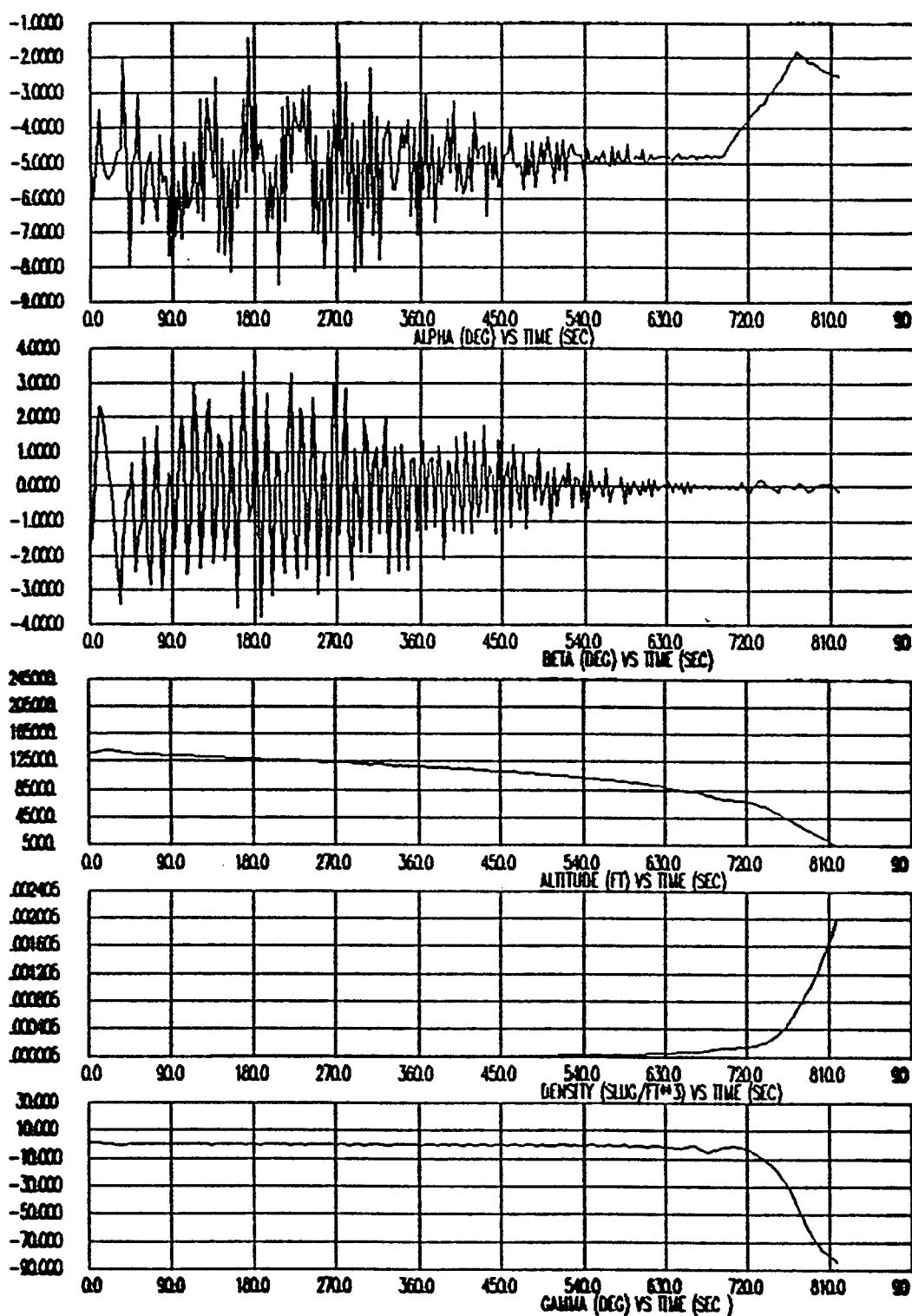
Case 2

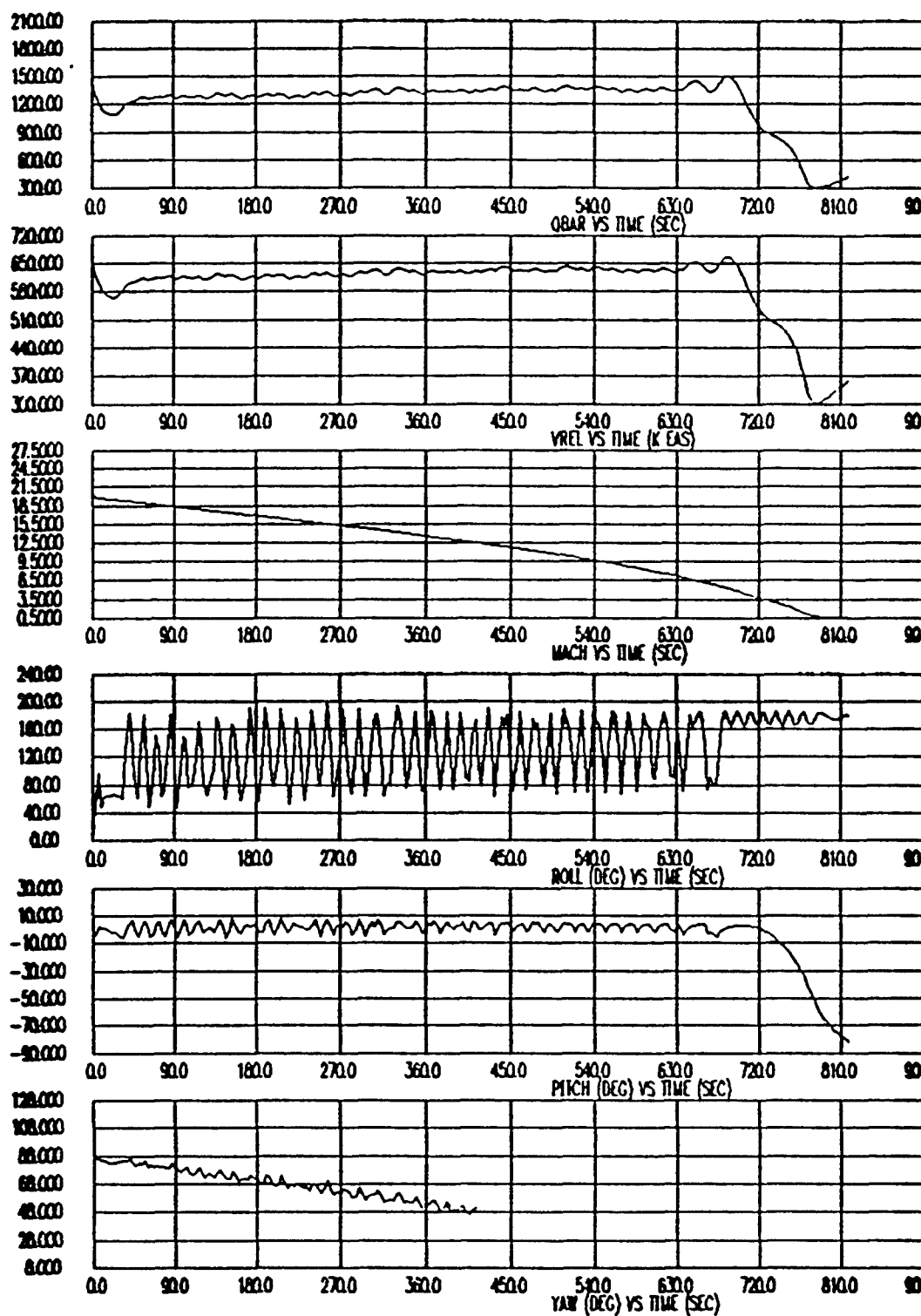


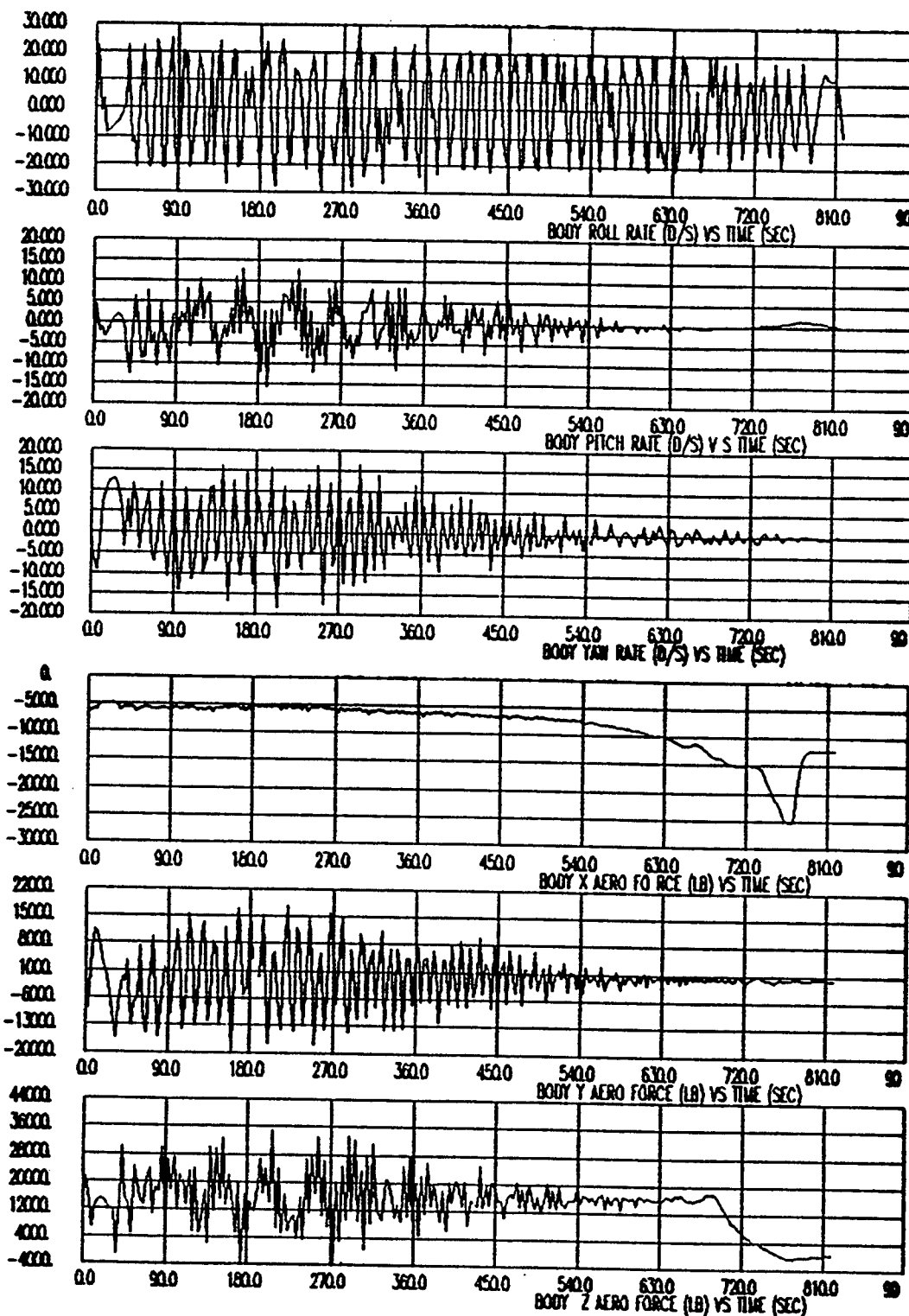
Case 2



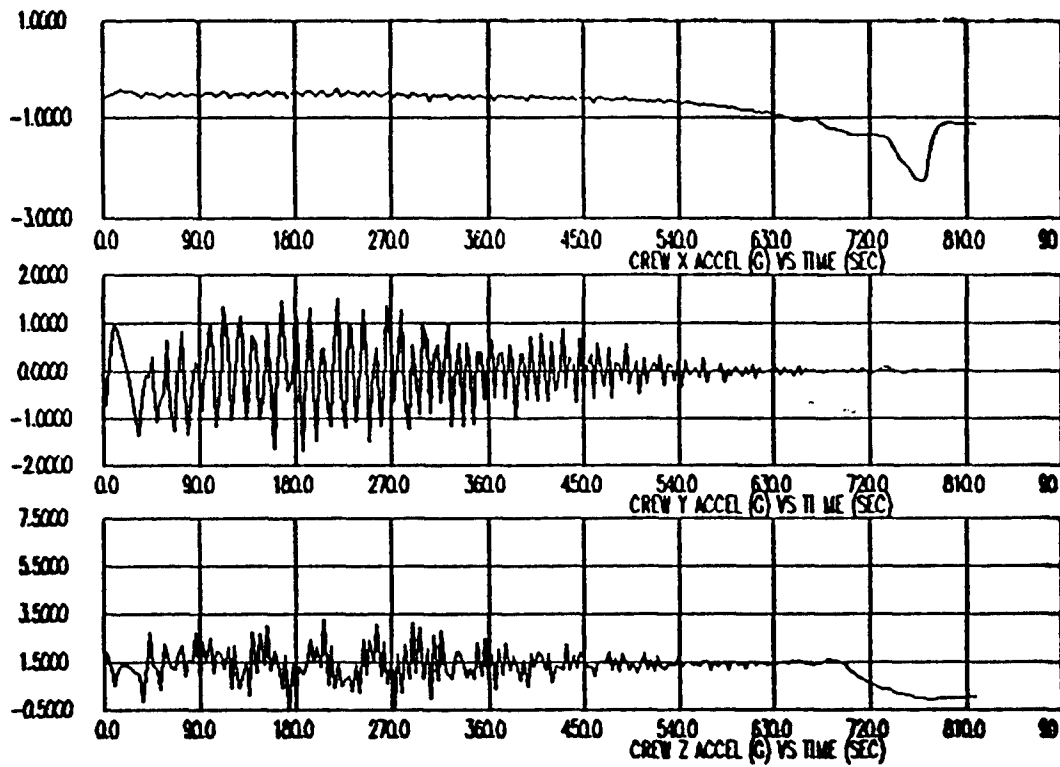


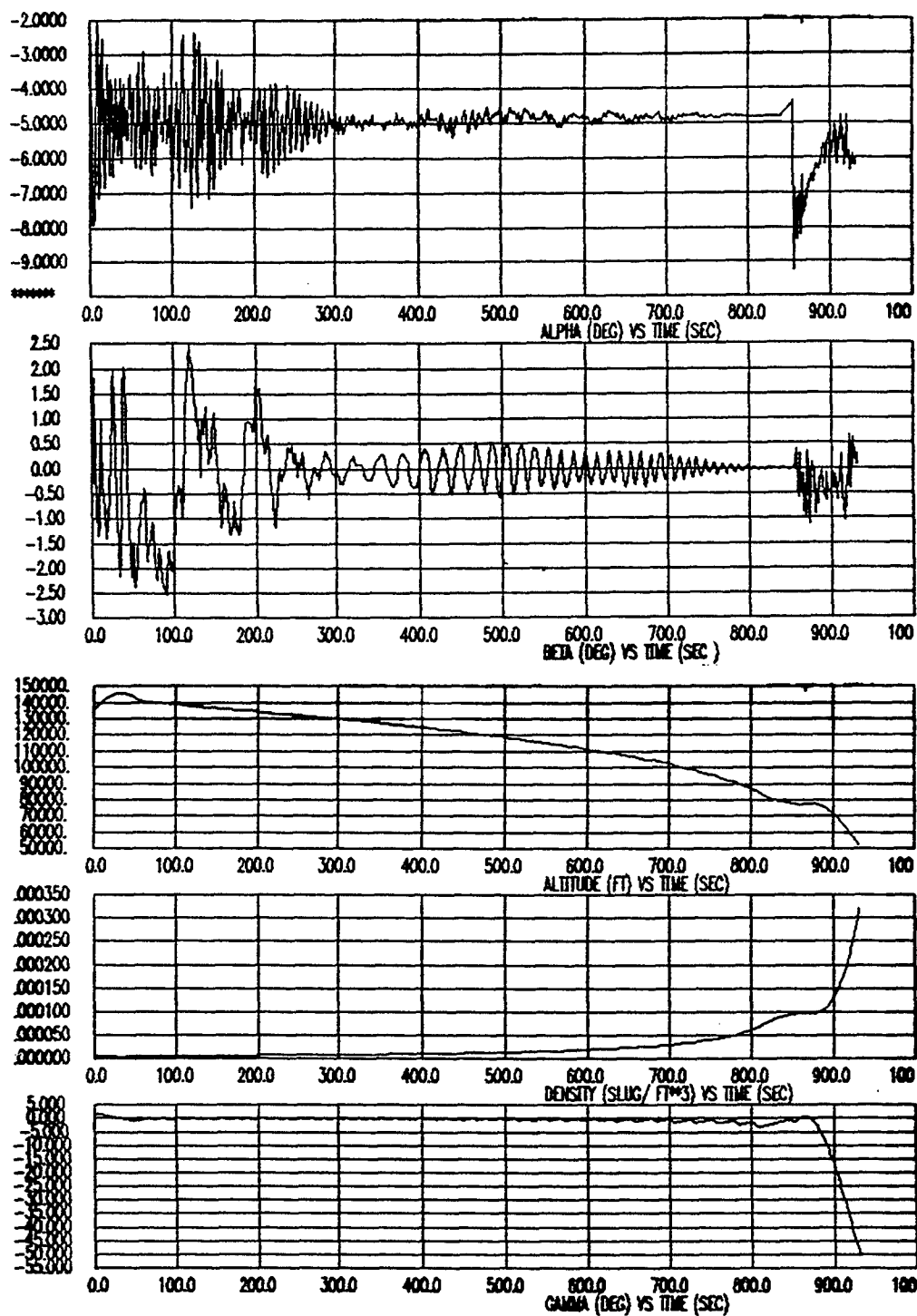


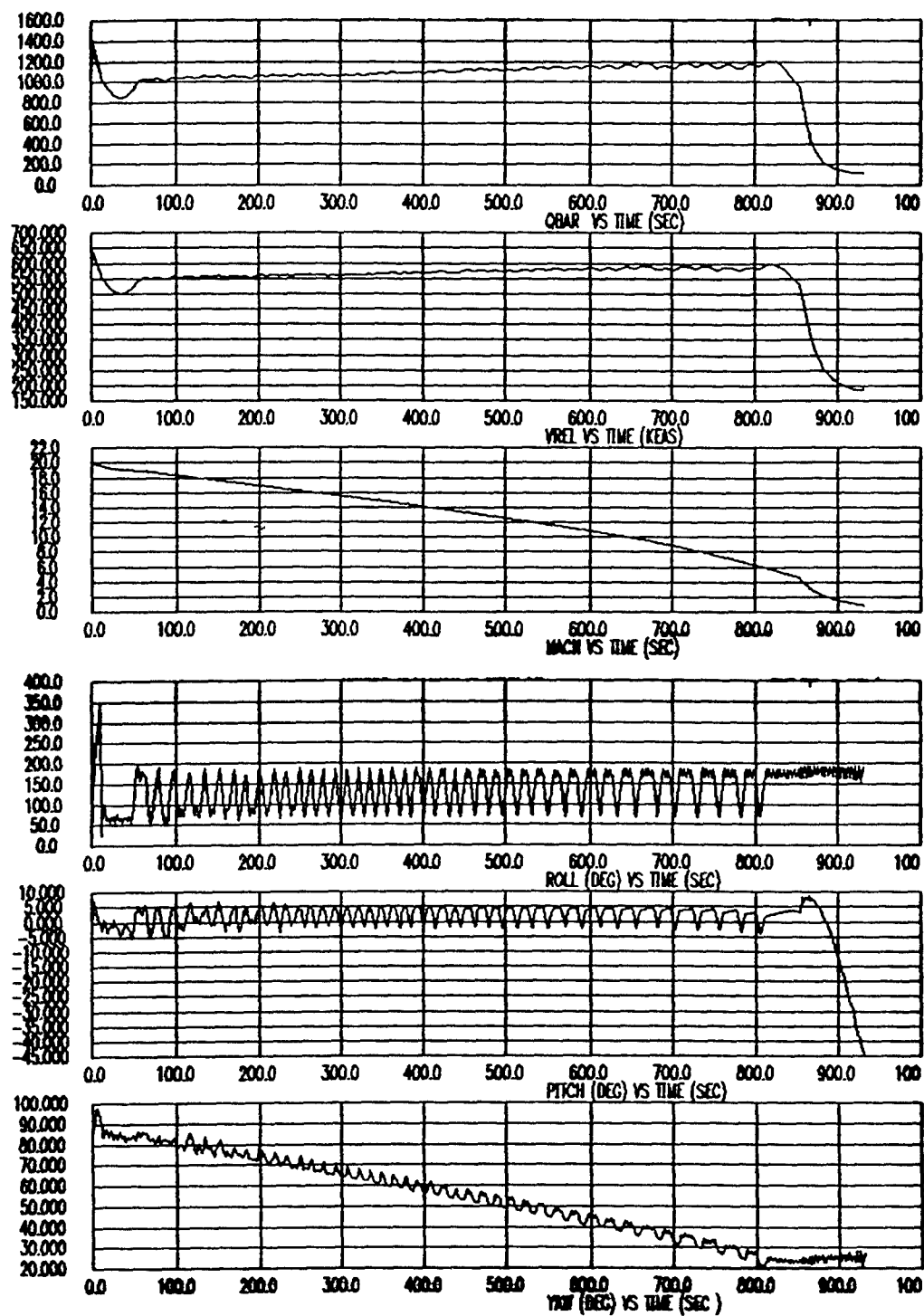


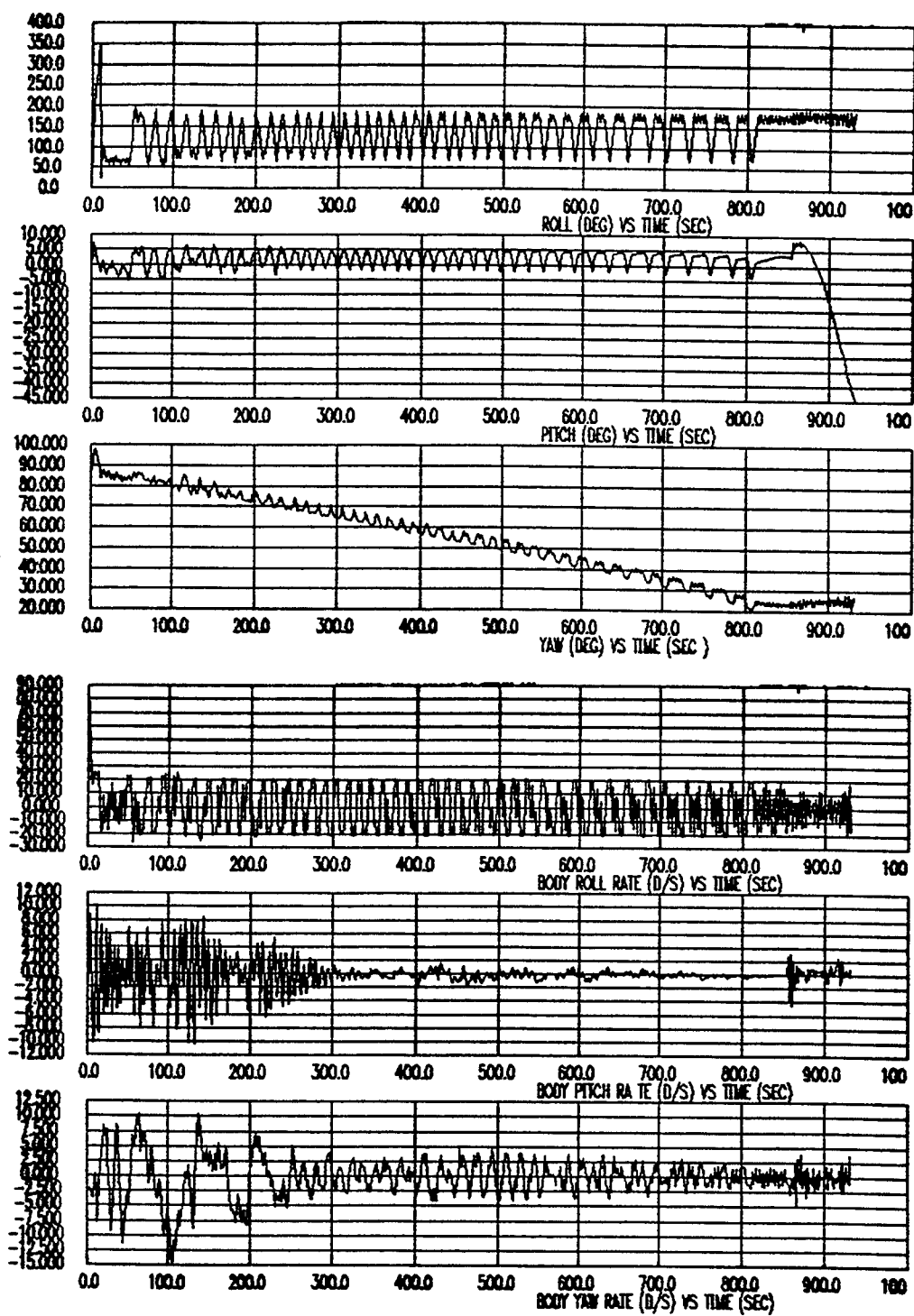


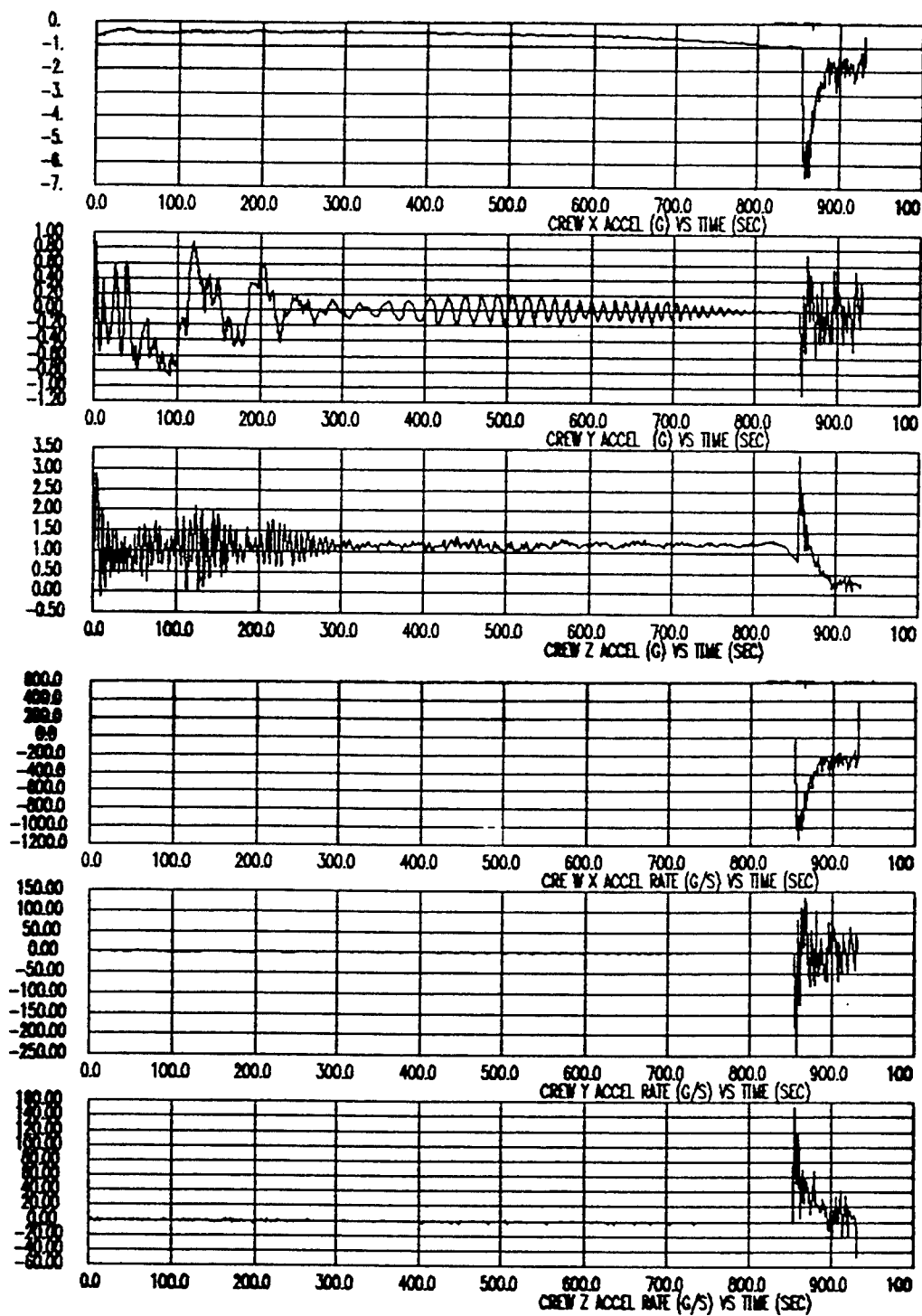


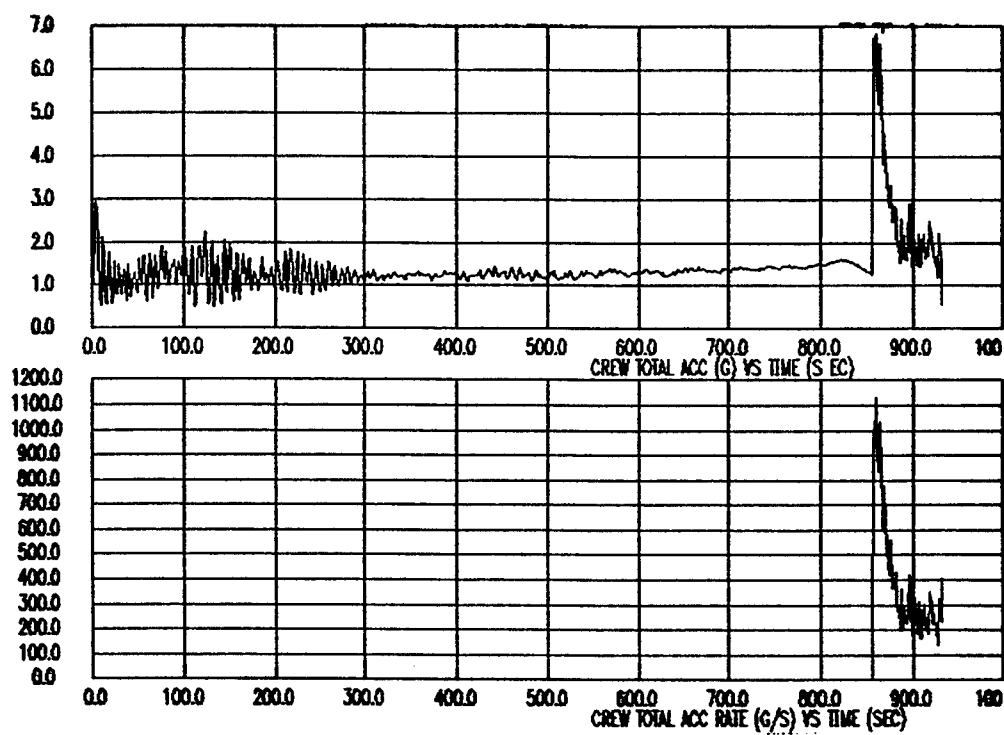


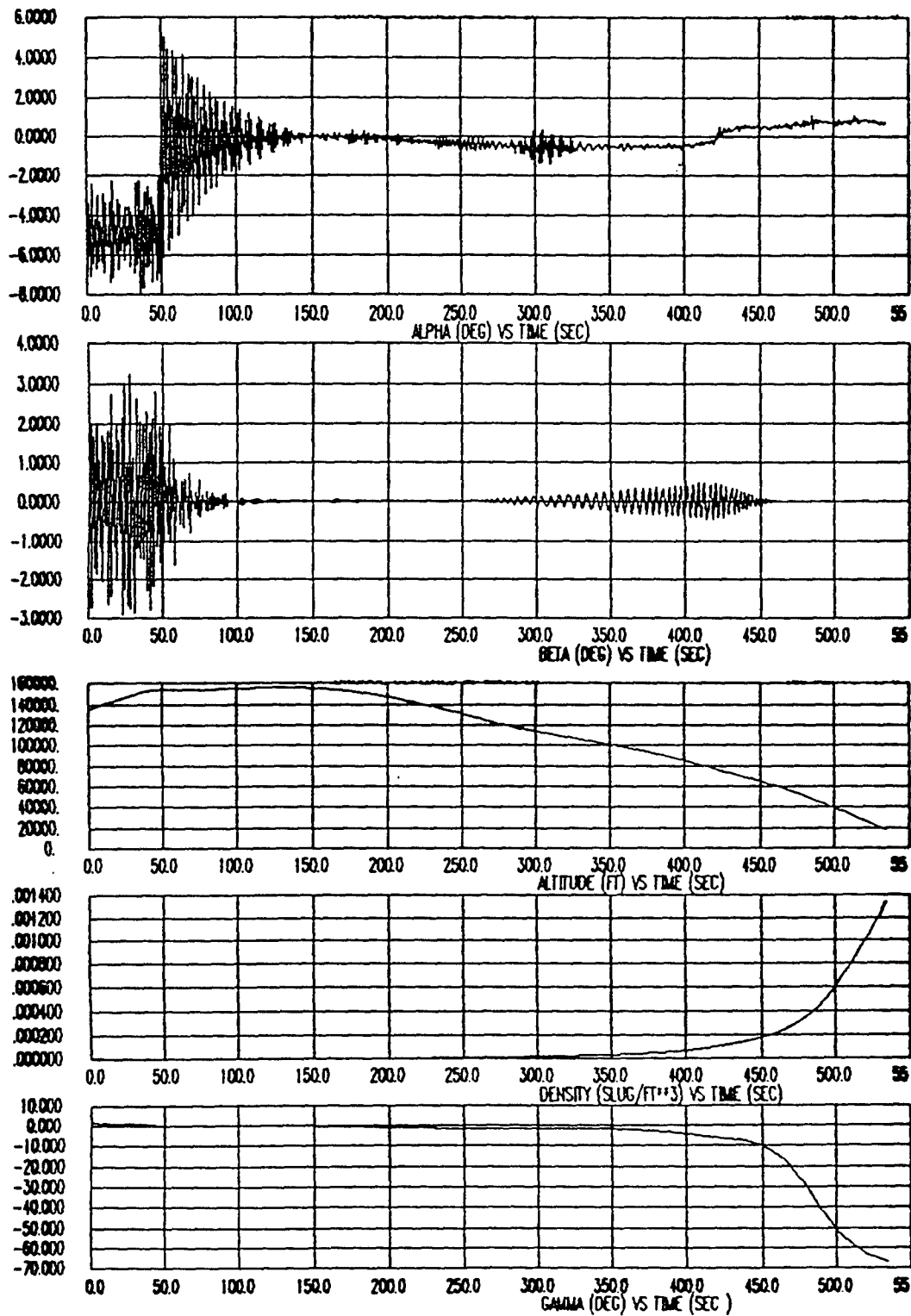




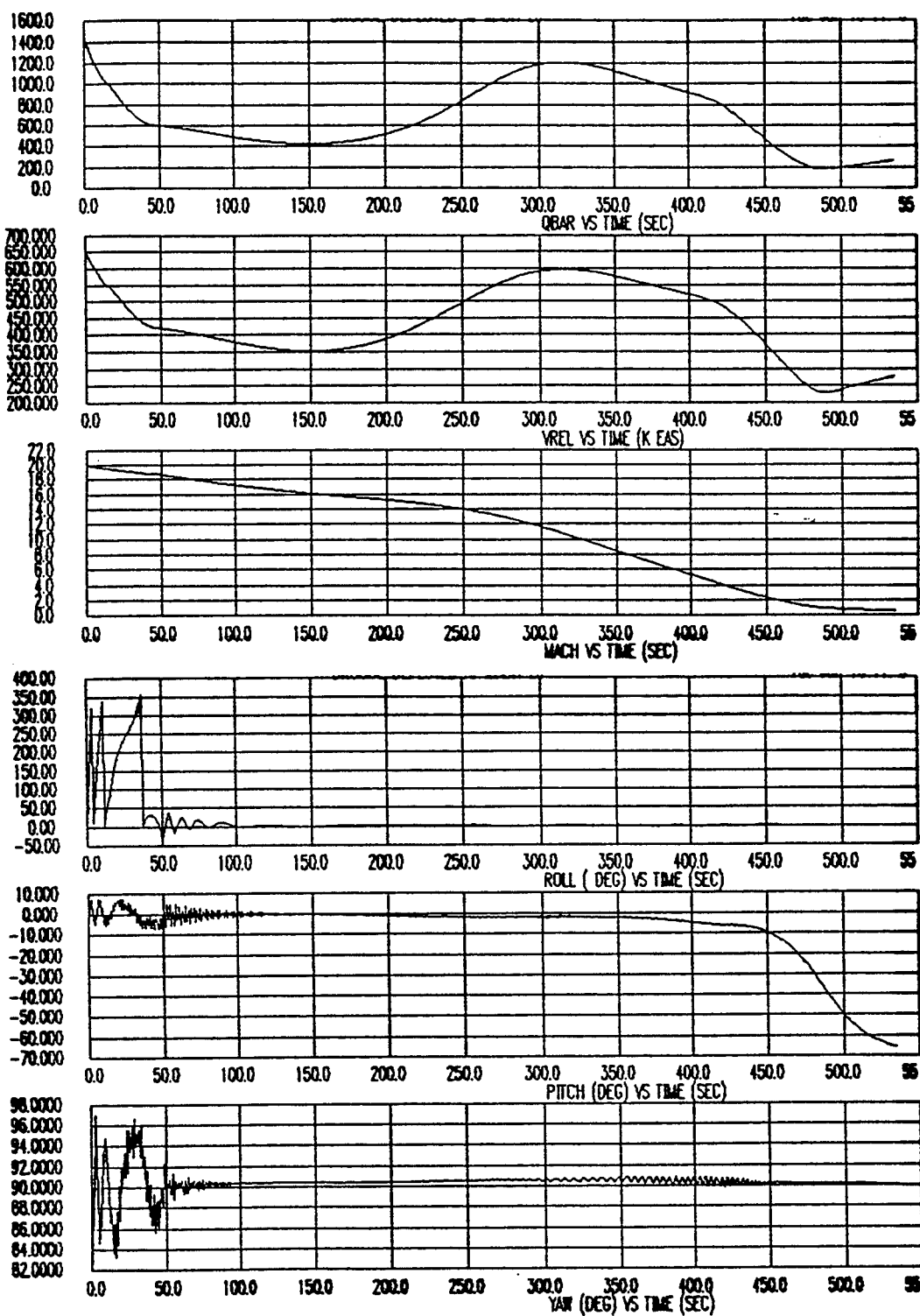




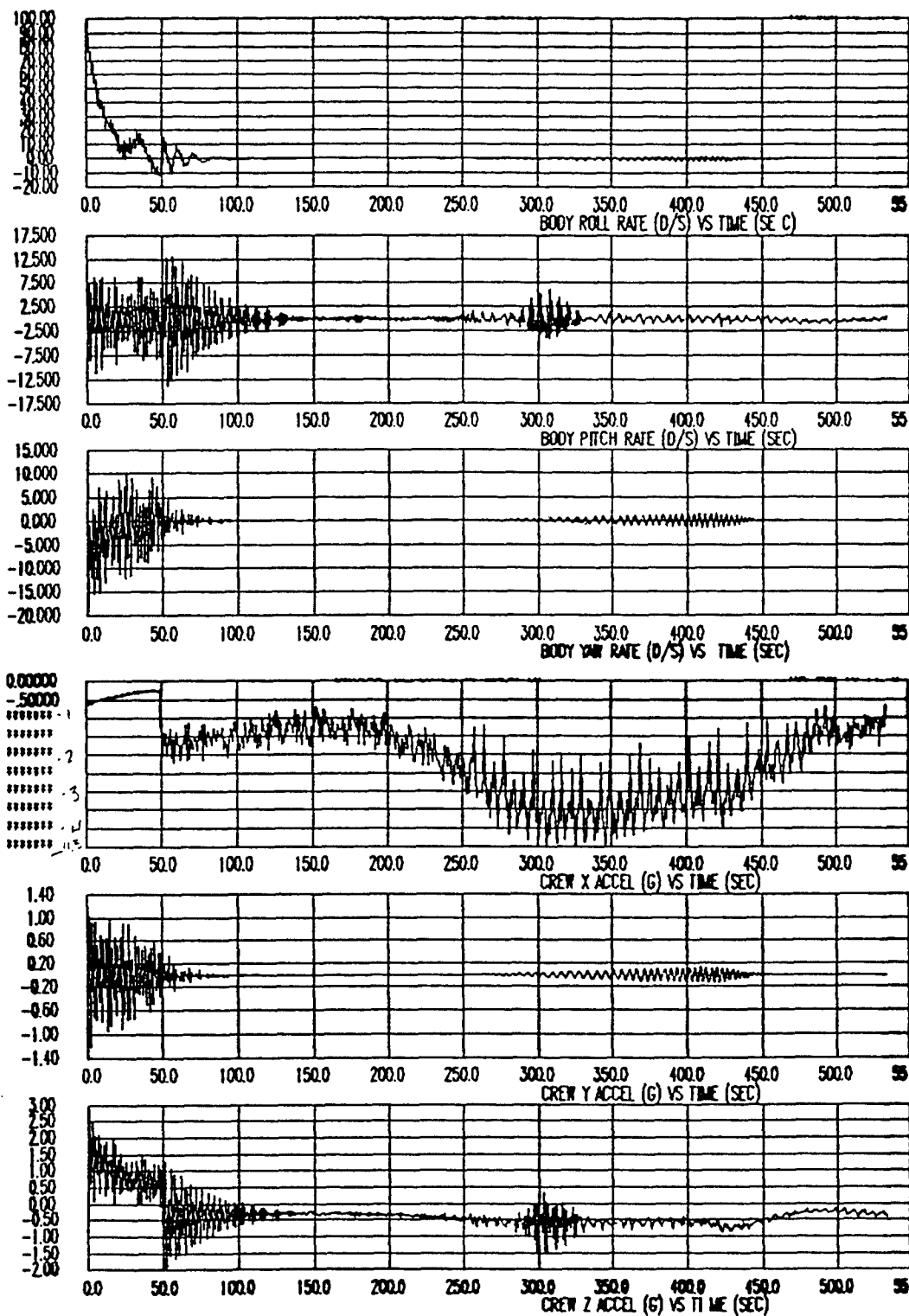


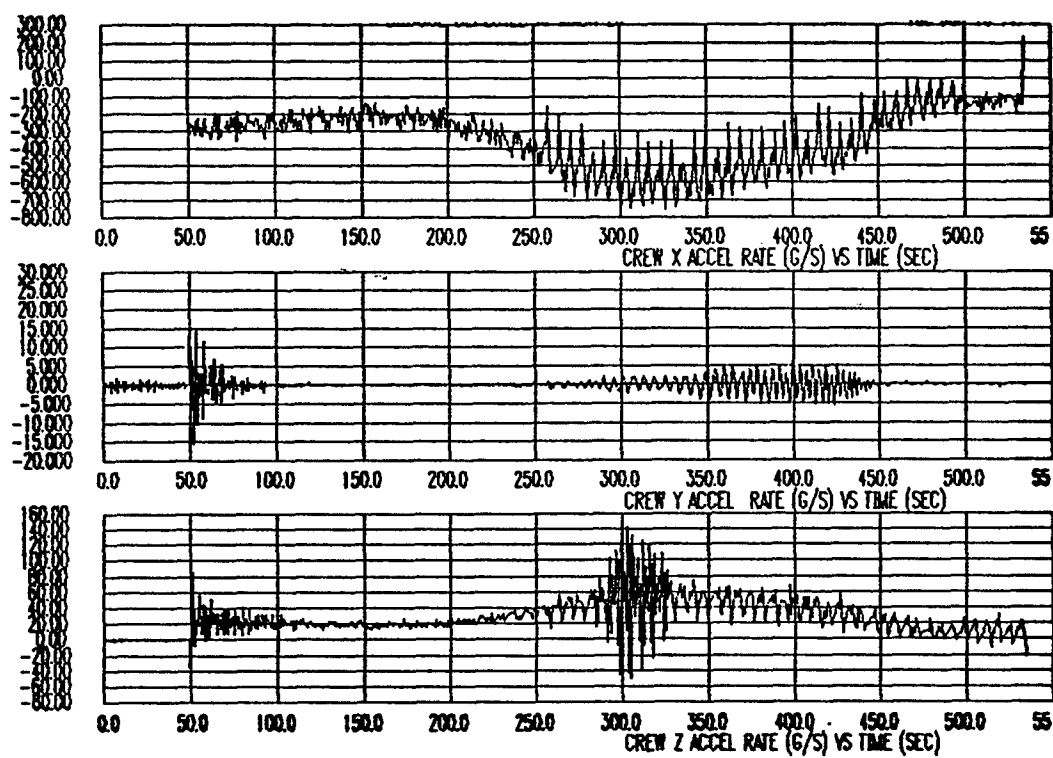


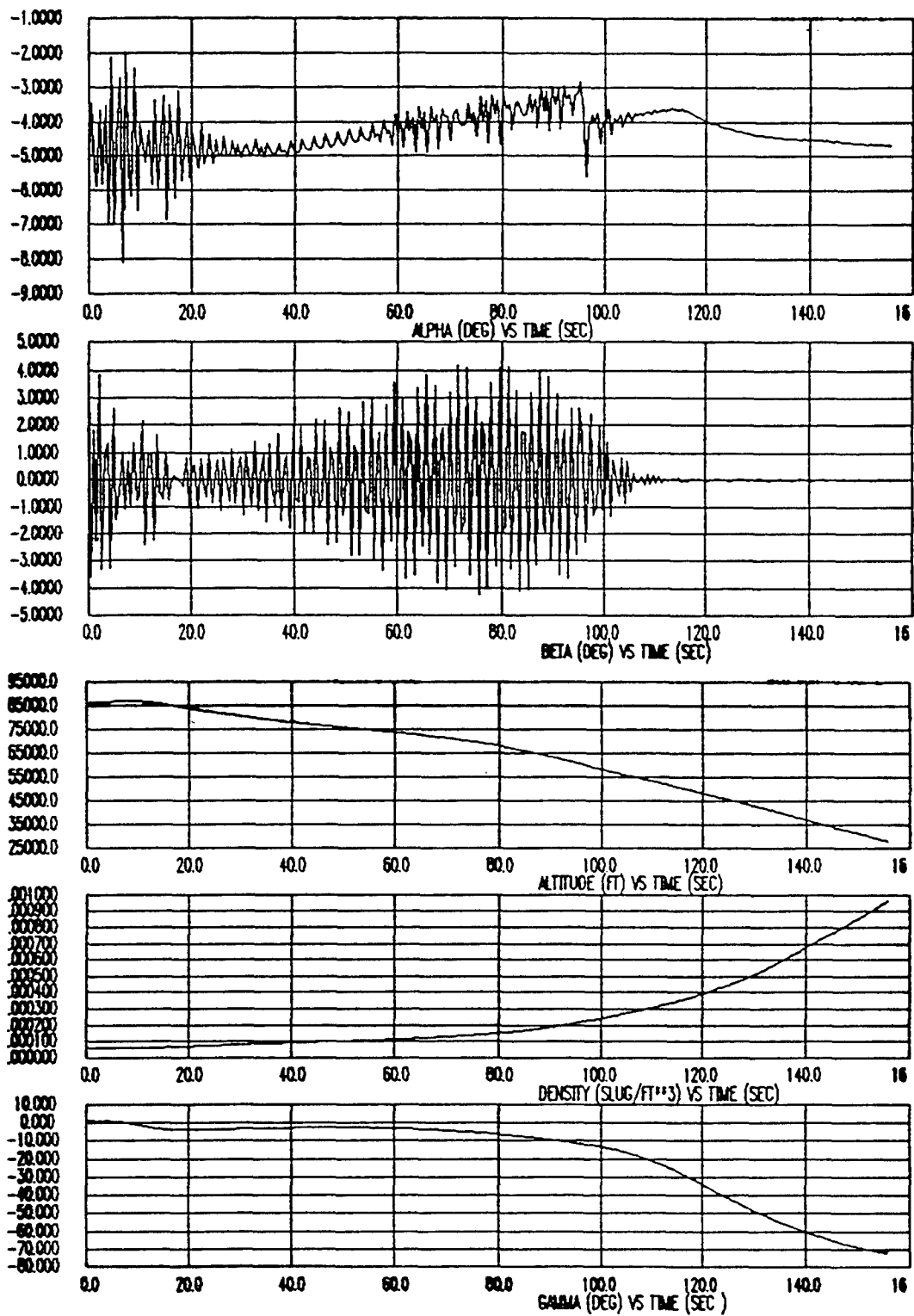
# Case 5

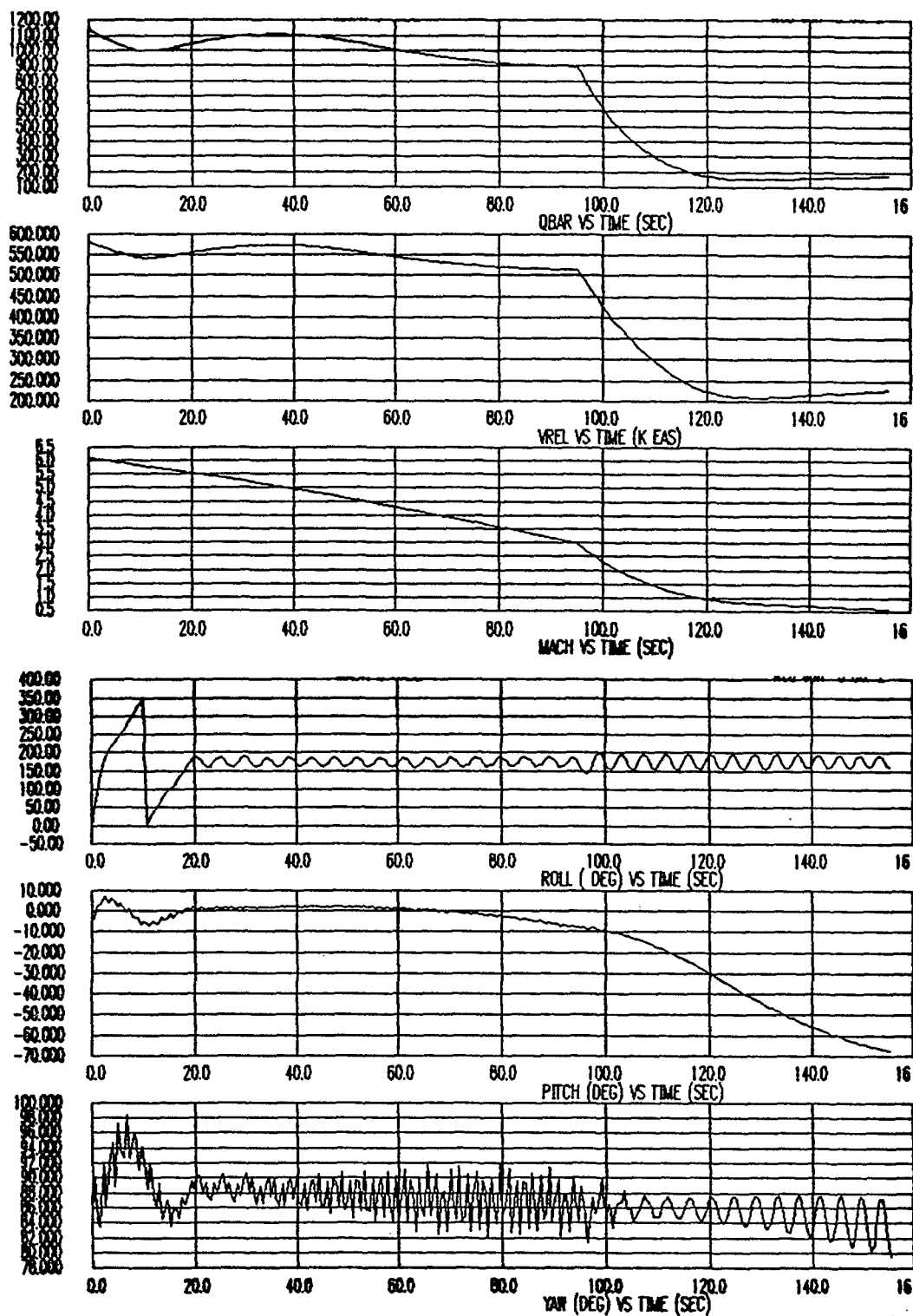


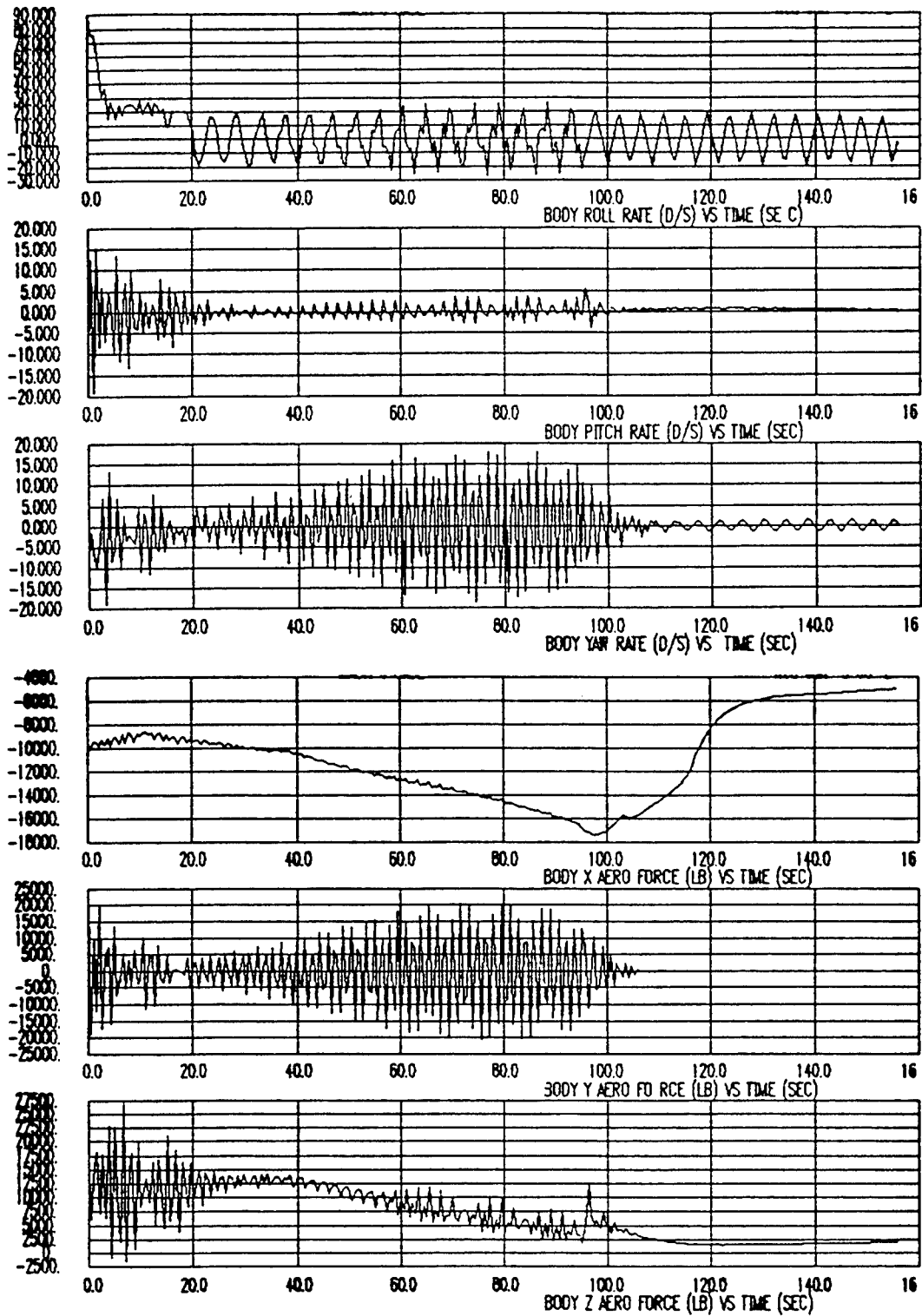




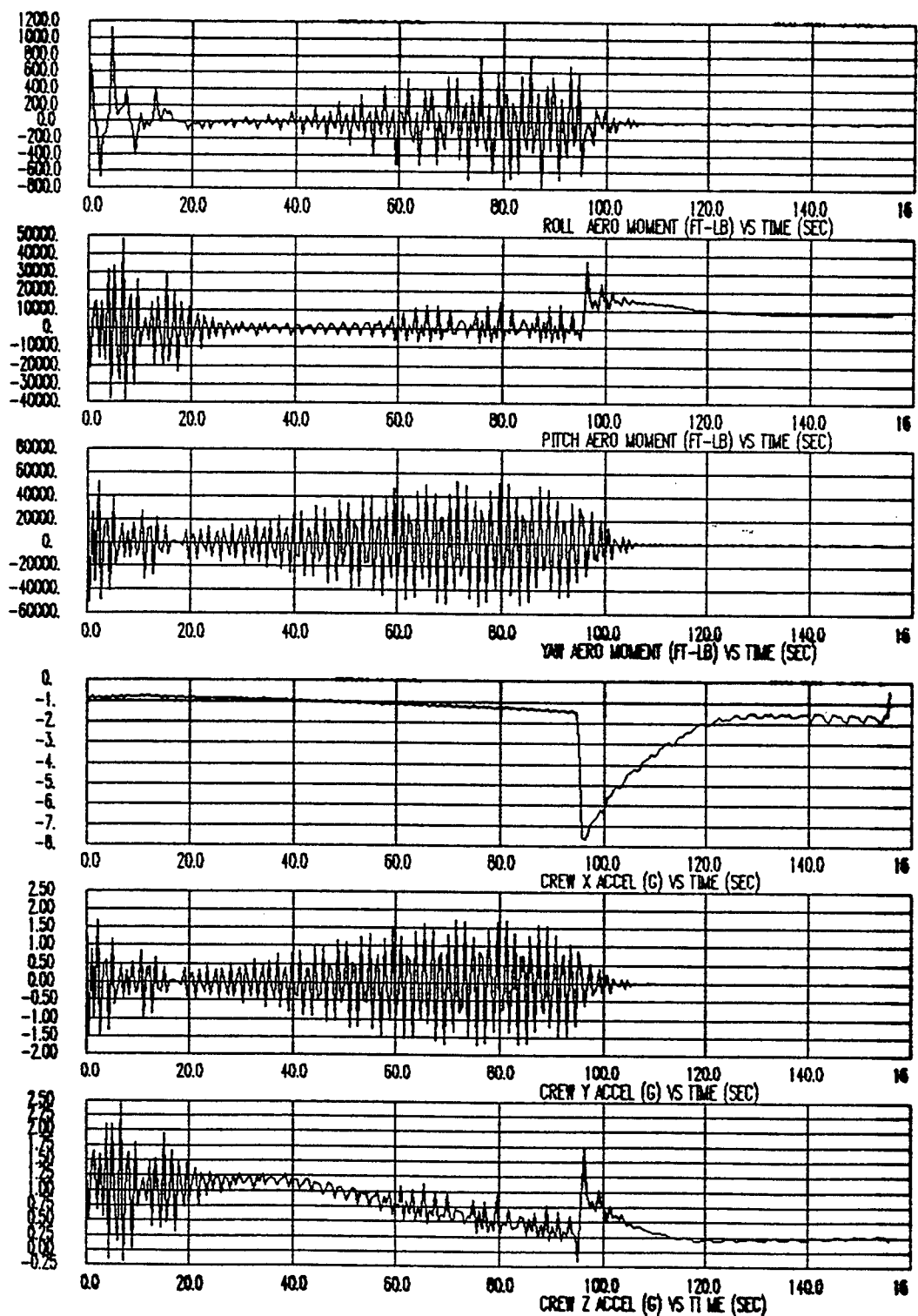




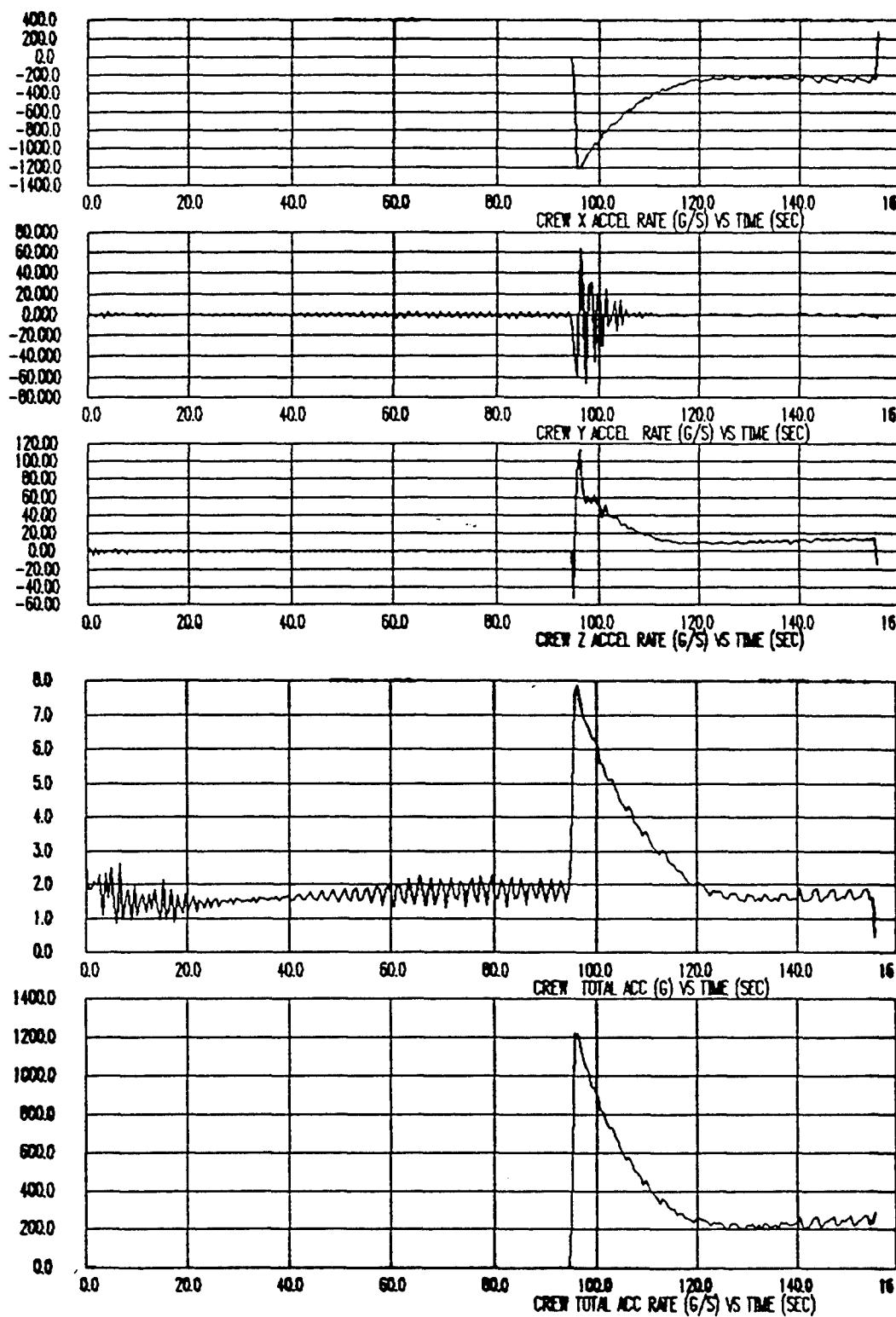


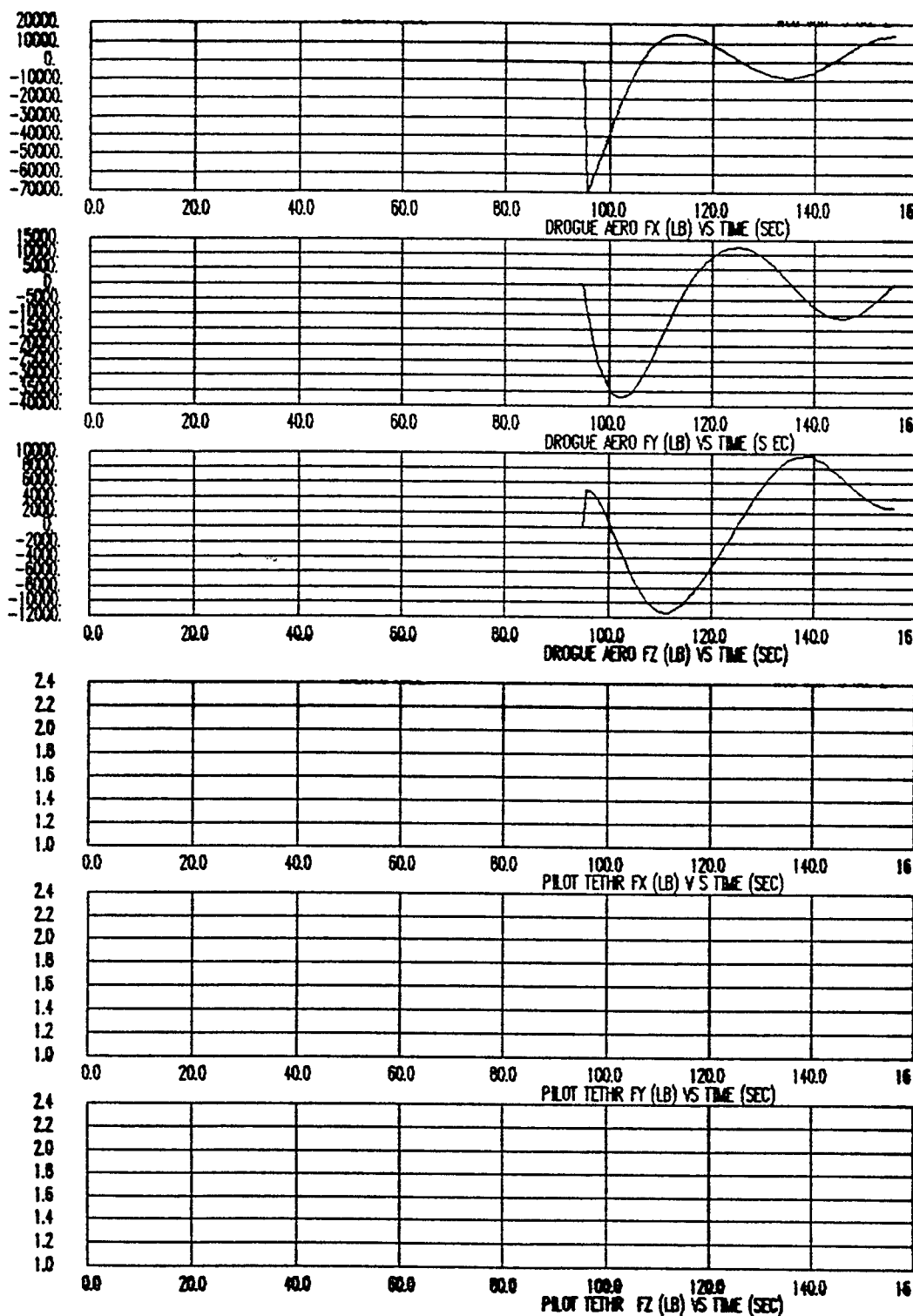


Case 6

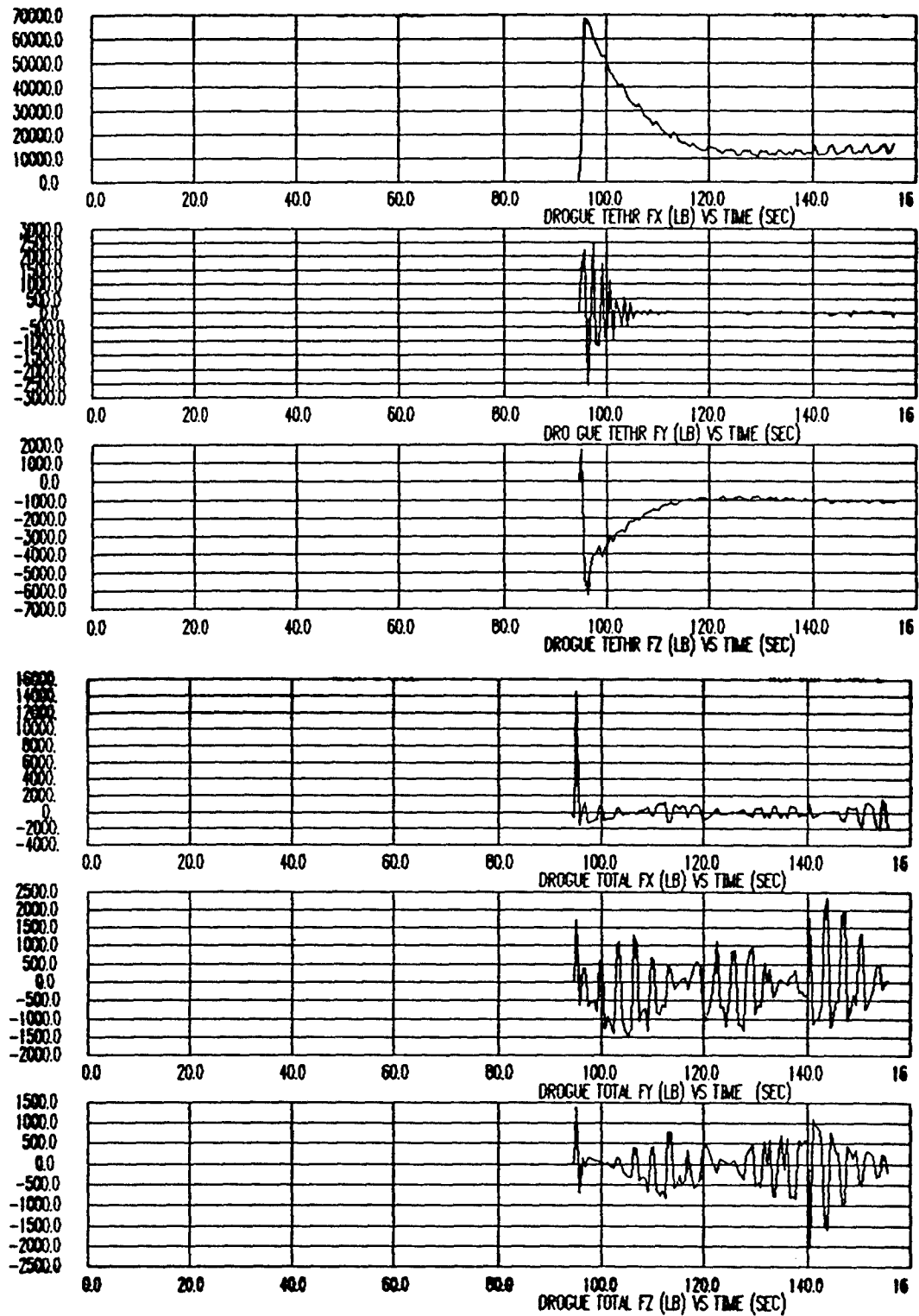


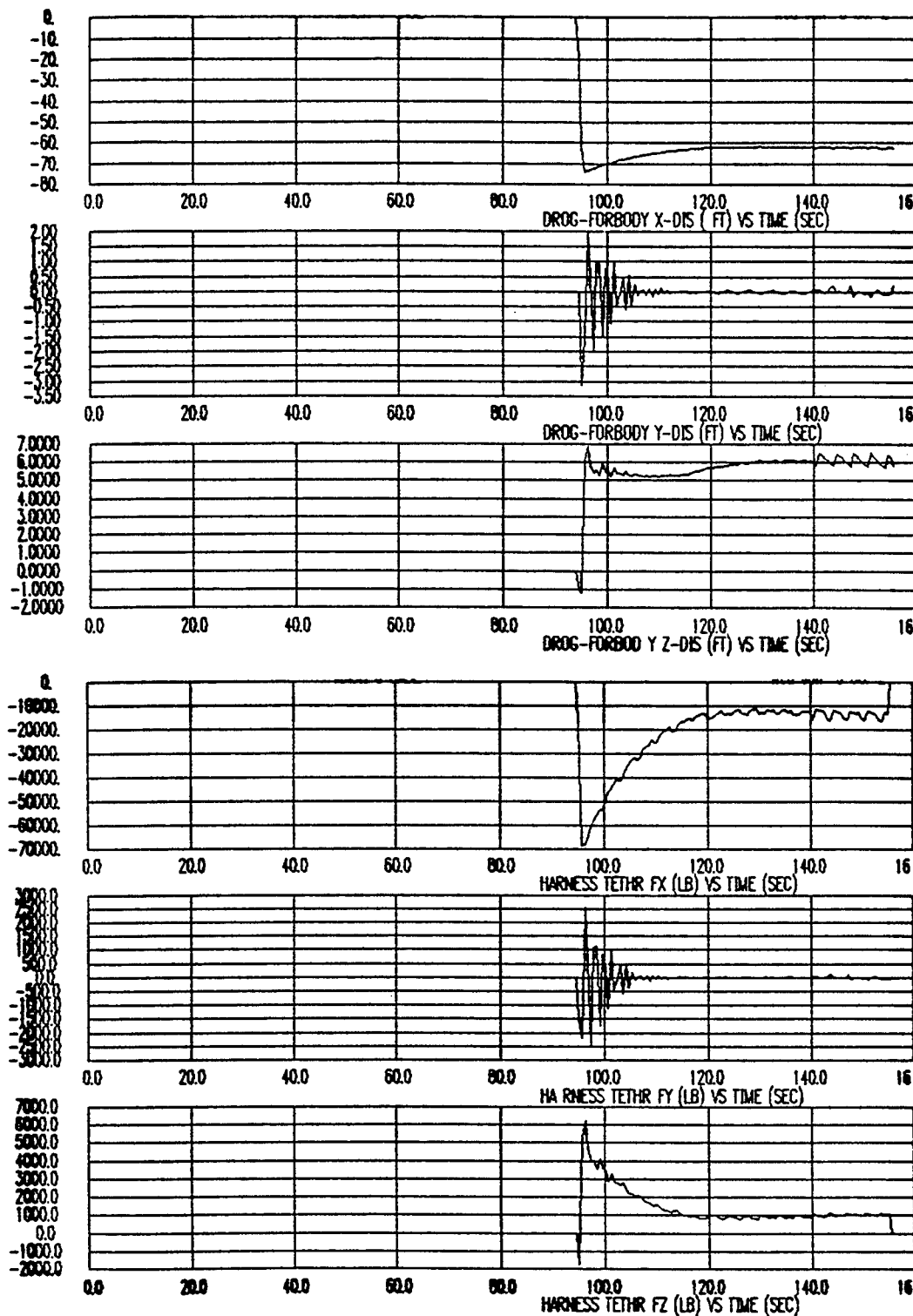
Case 6

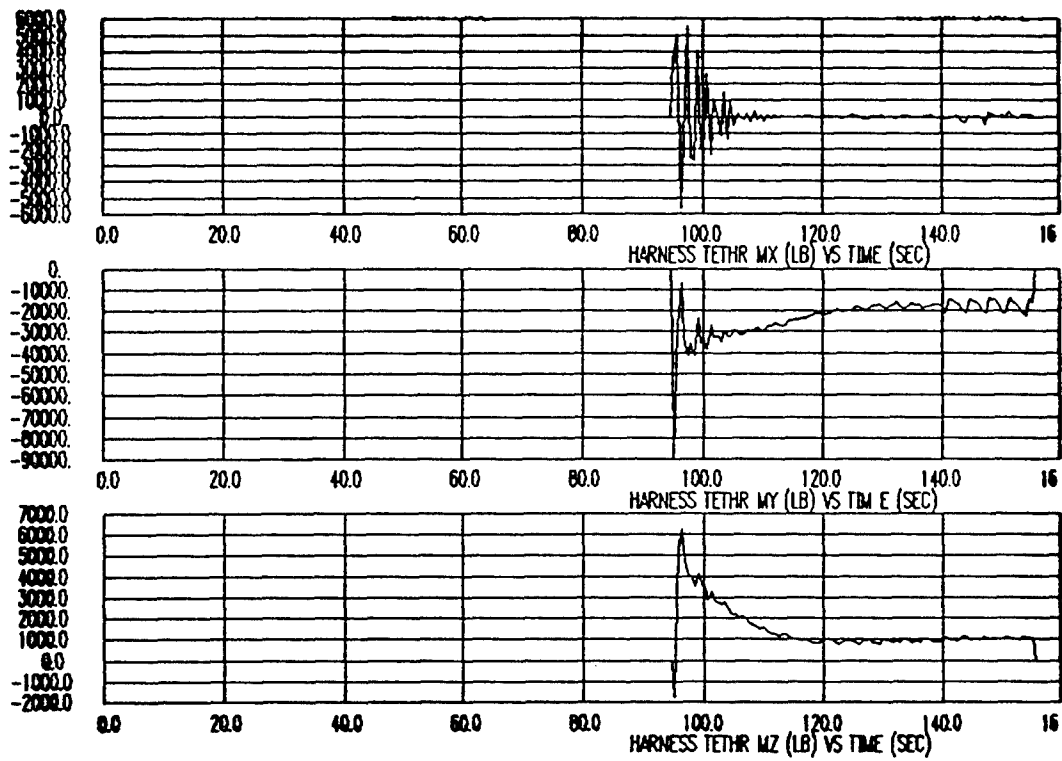




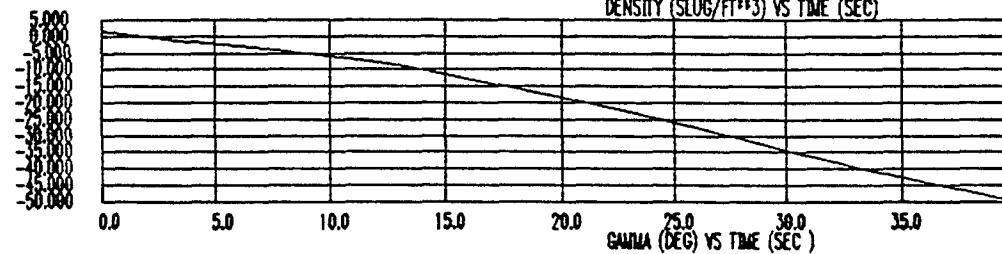
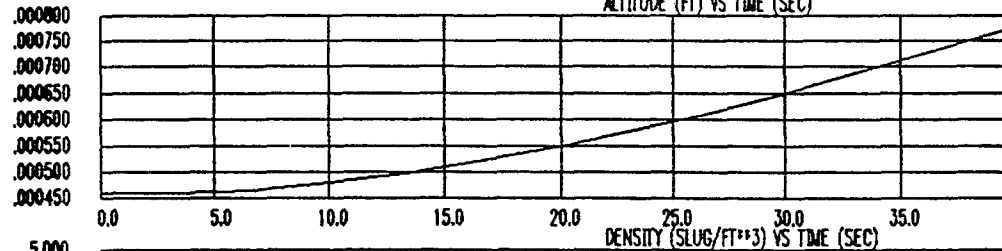
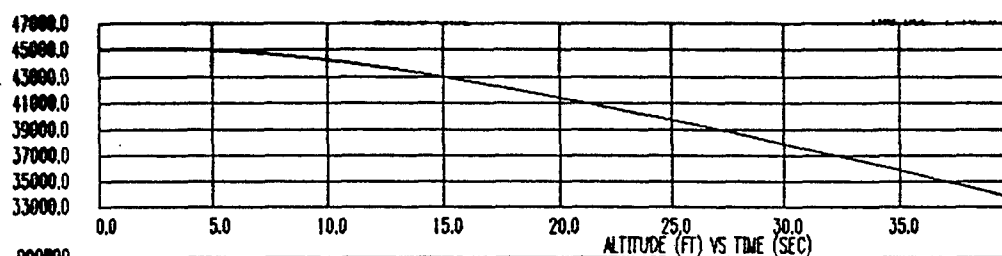
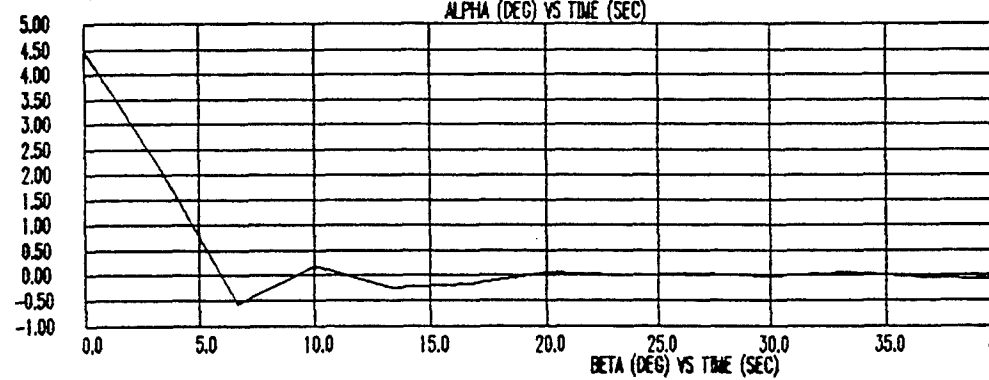
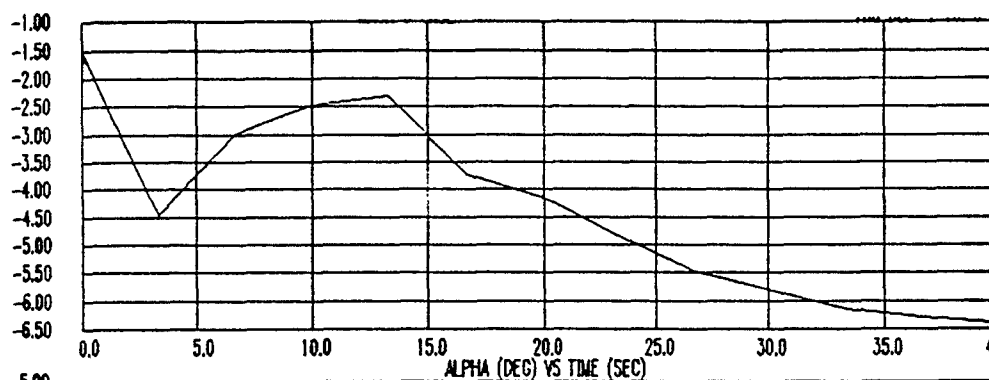




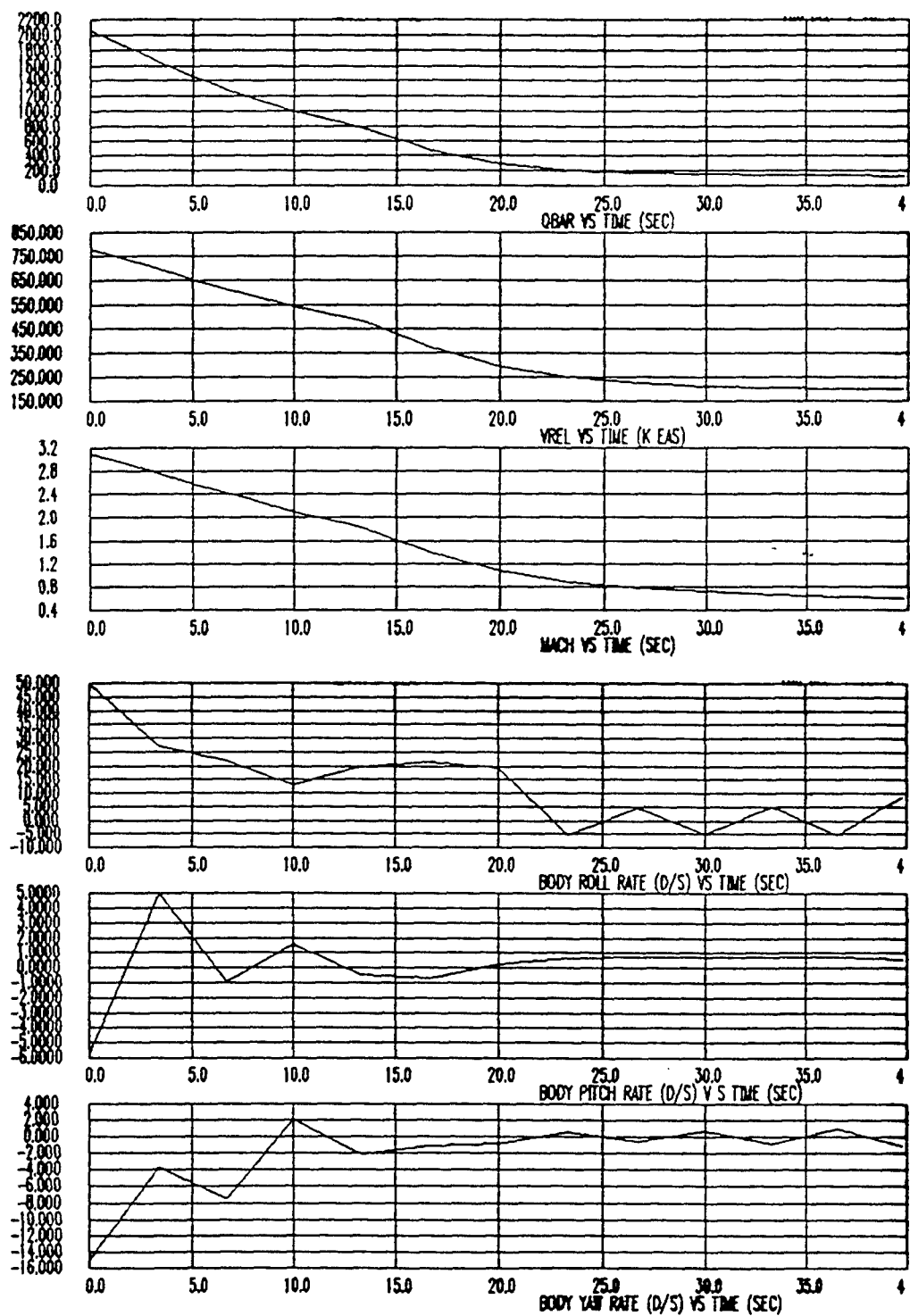


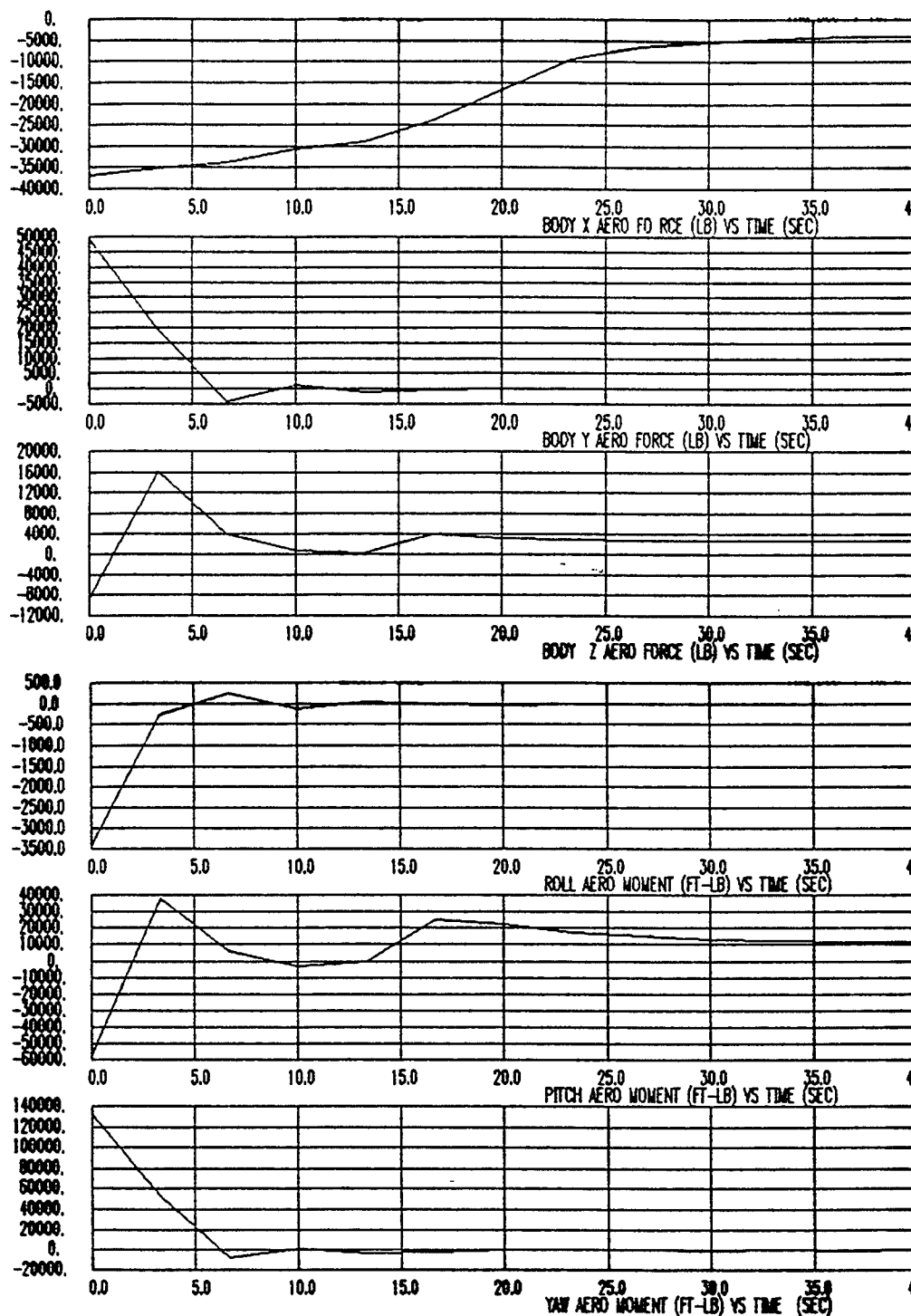


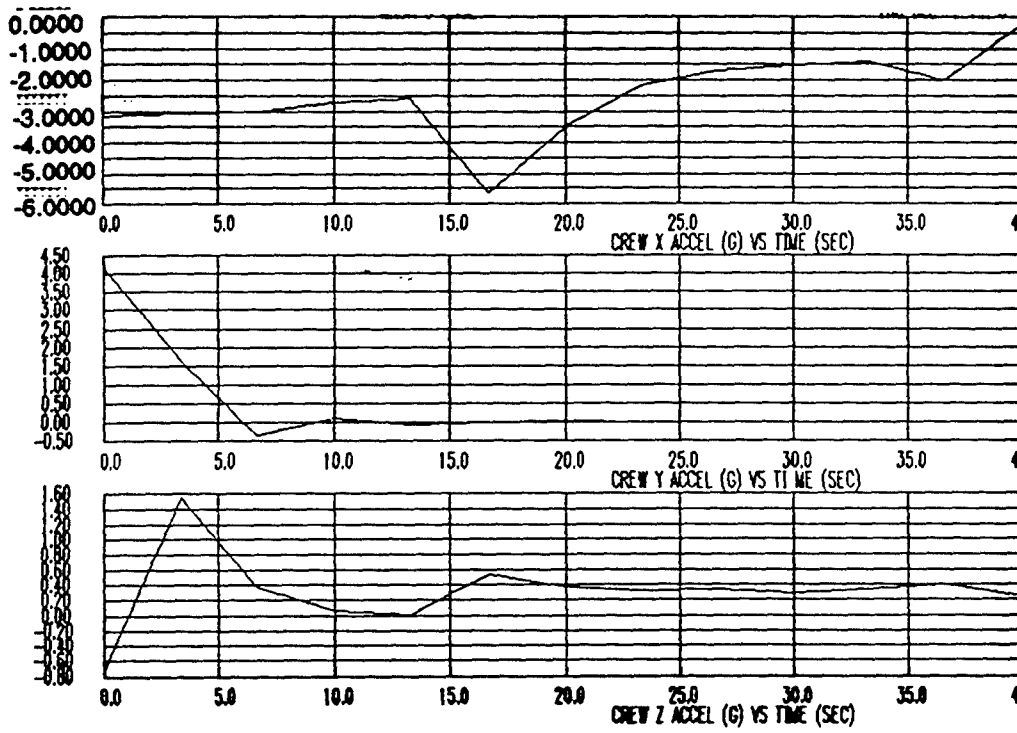
Case 7

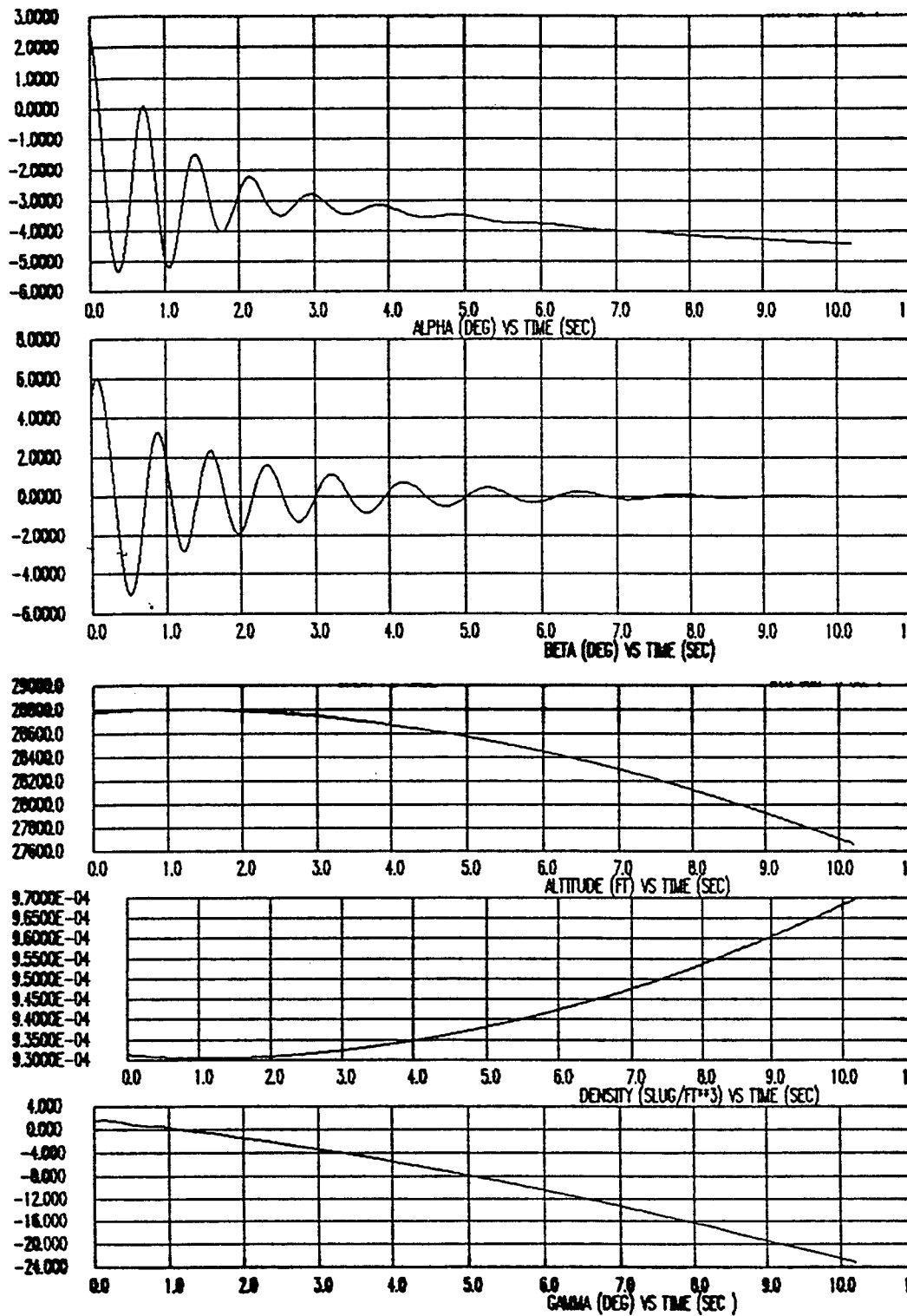


# Case 7

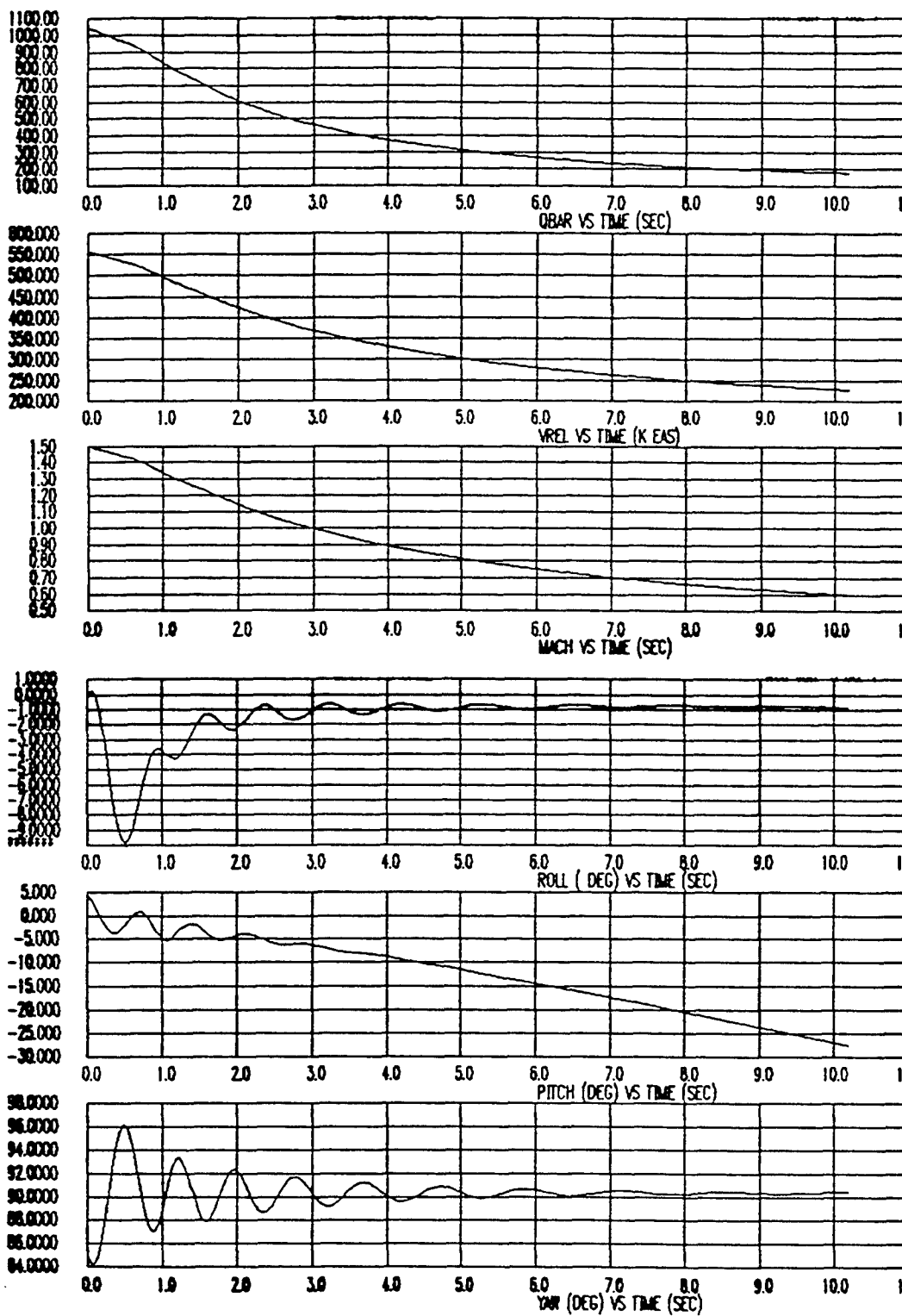


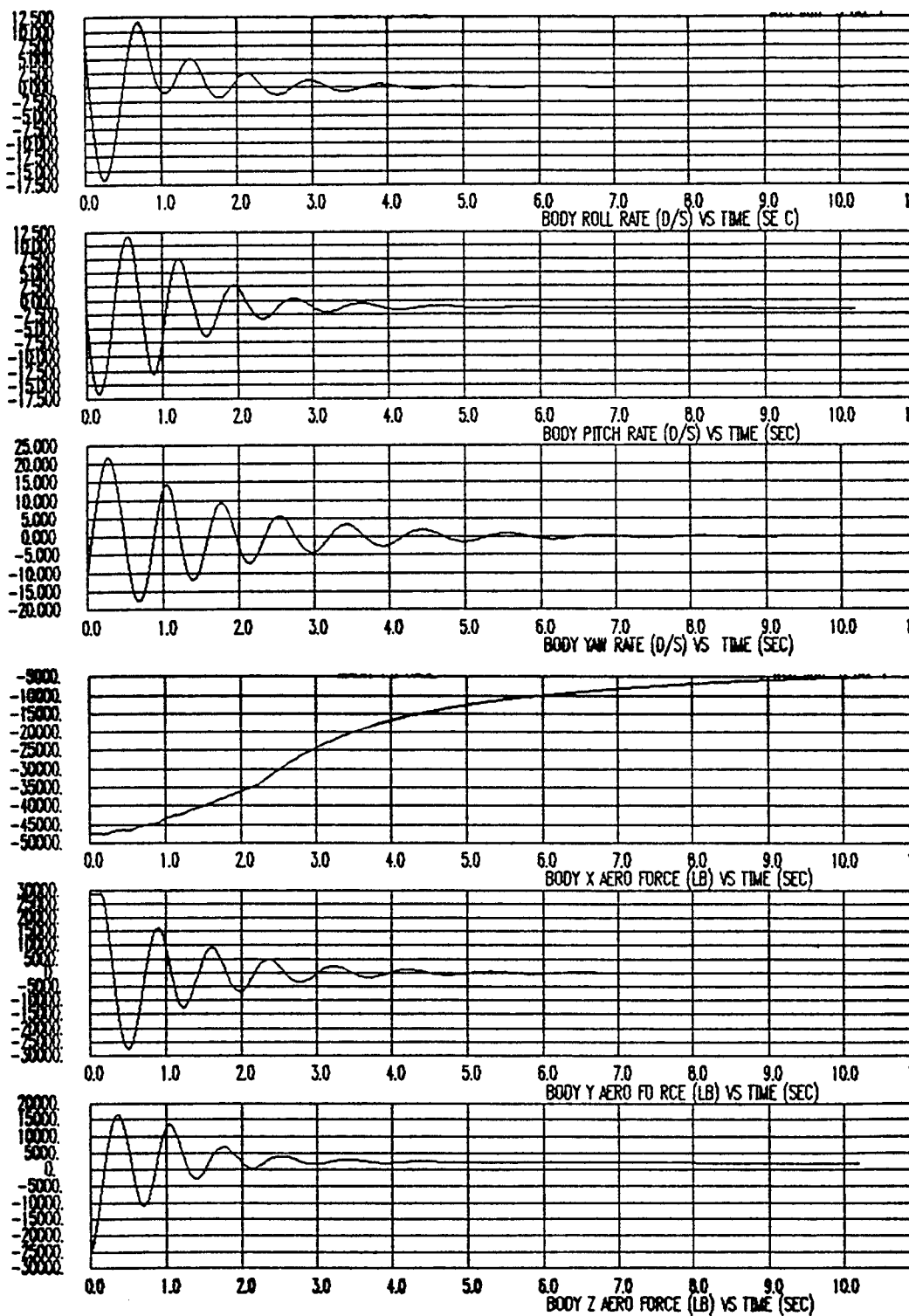


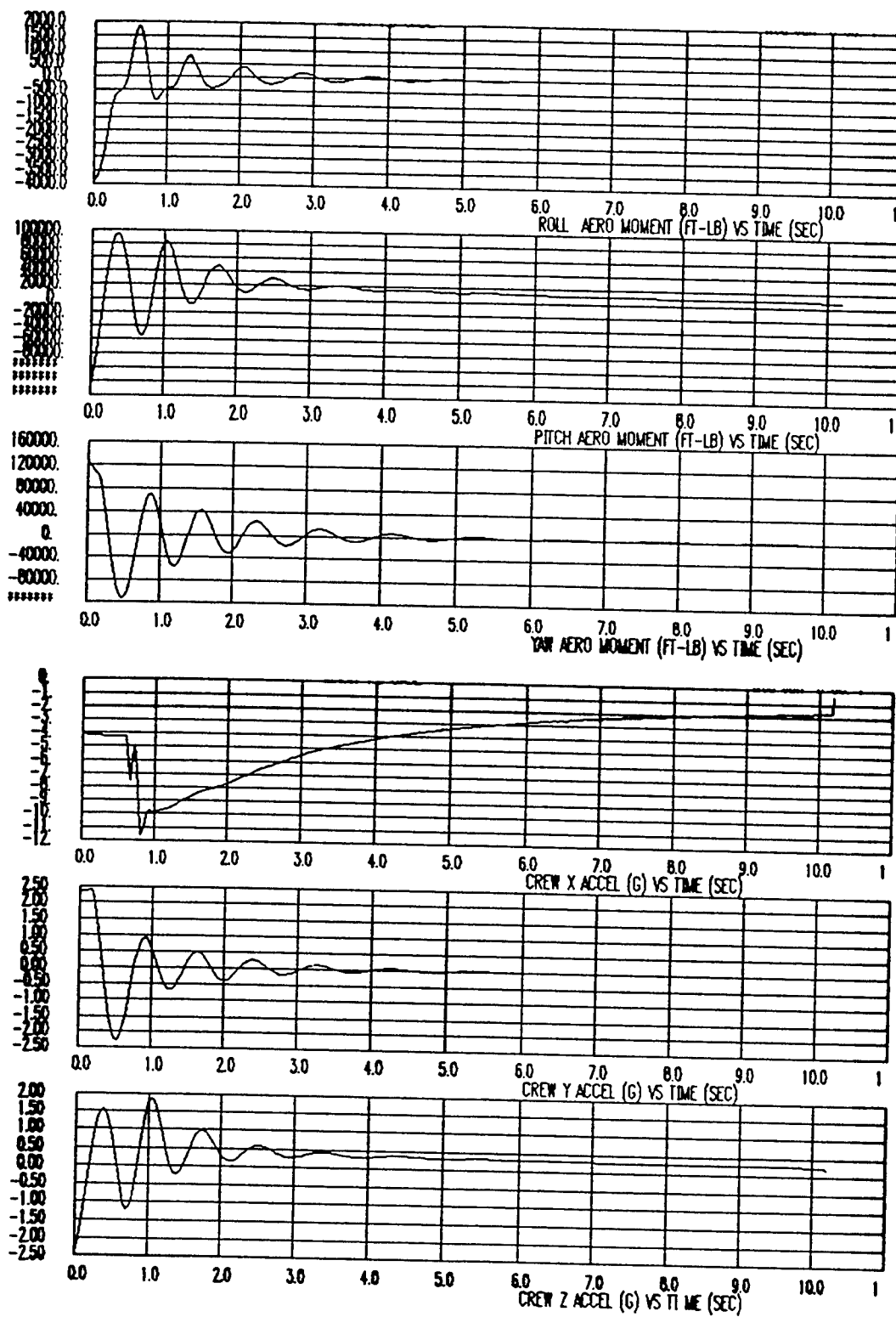


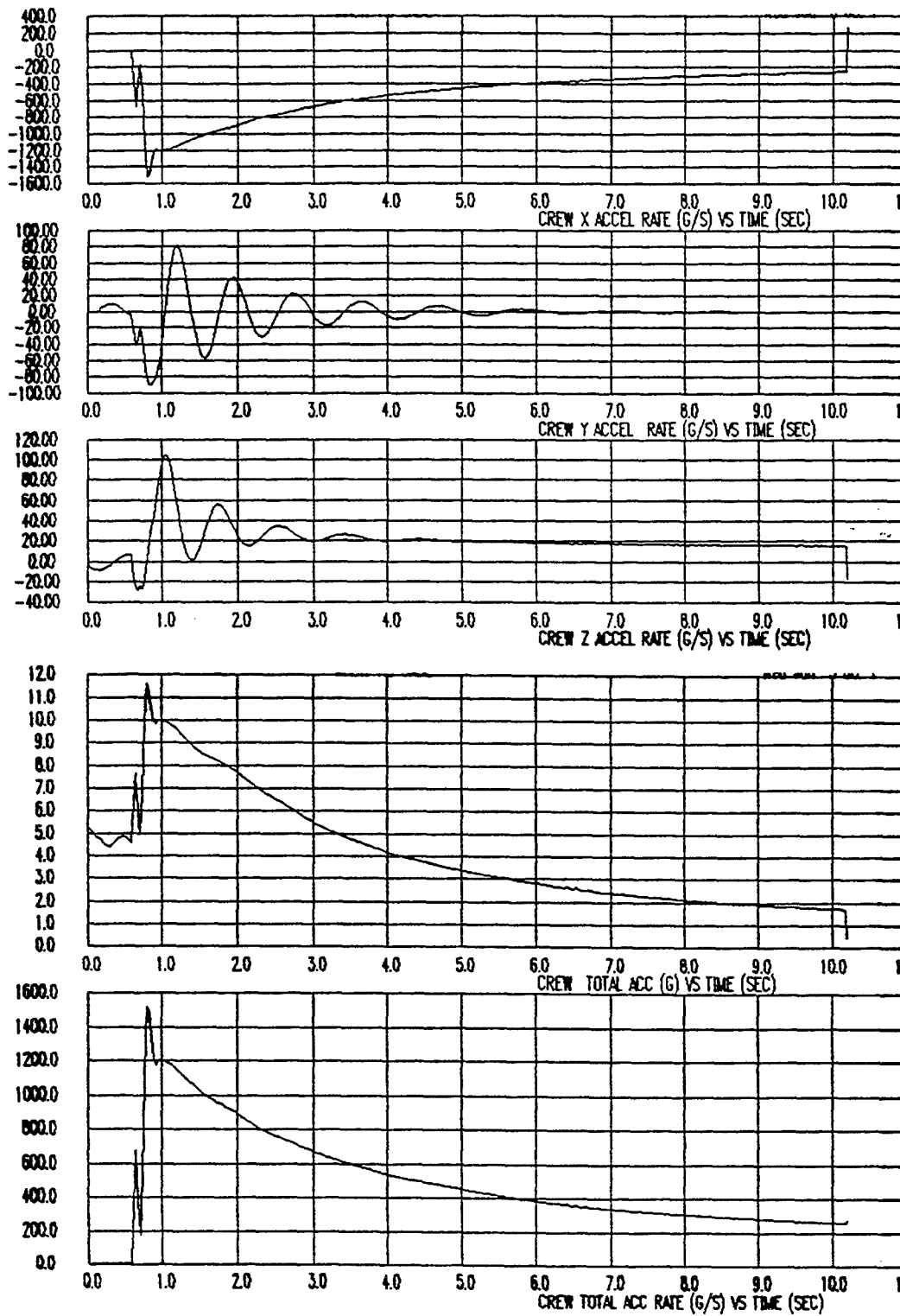


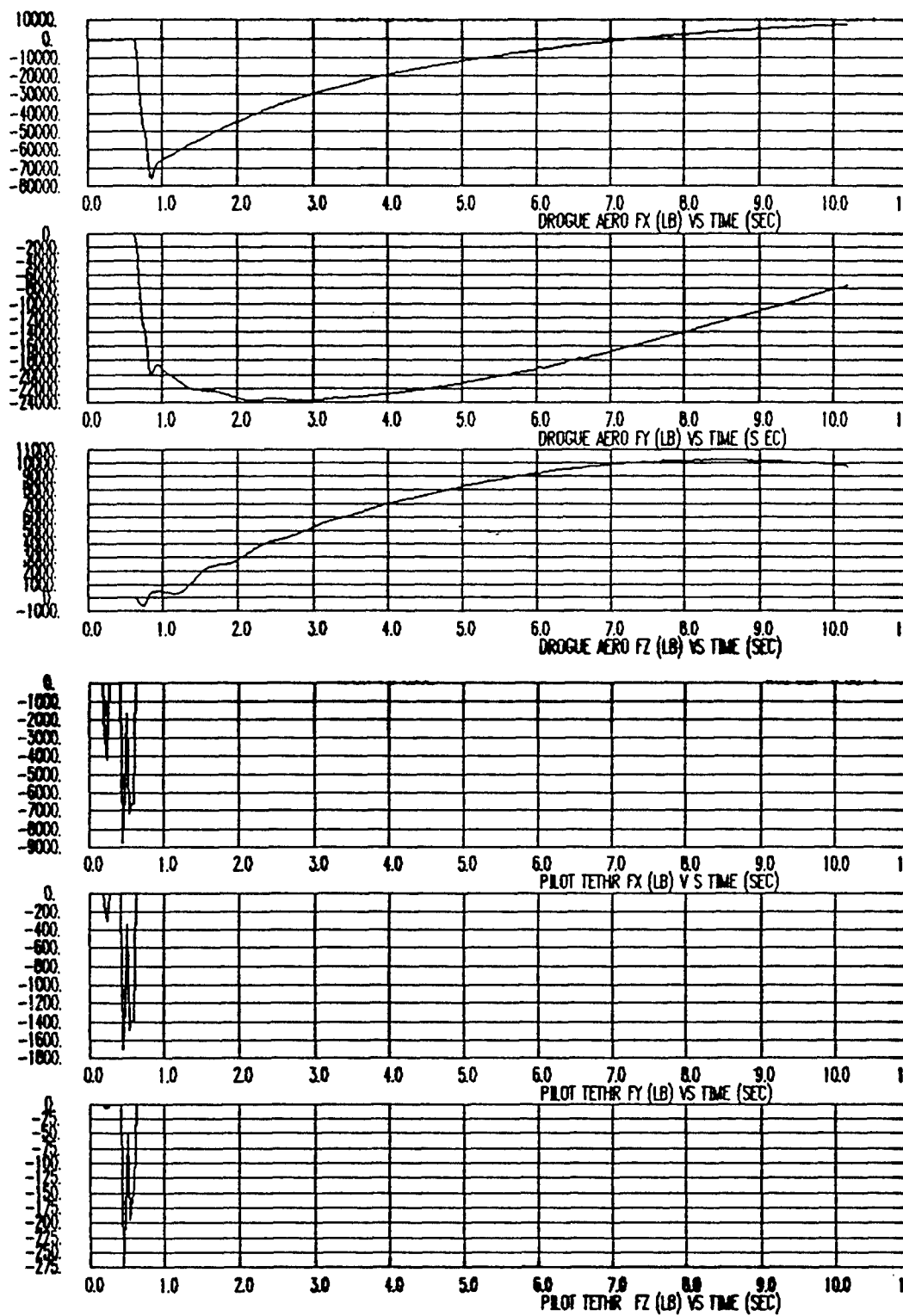


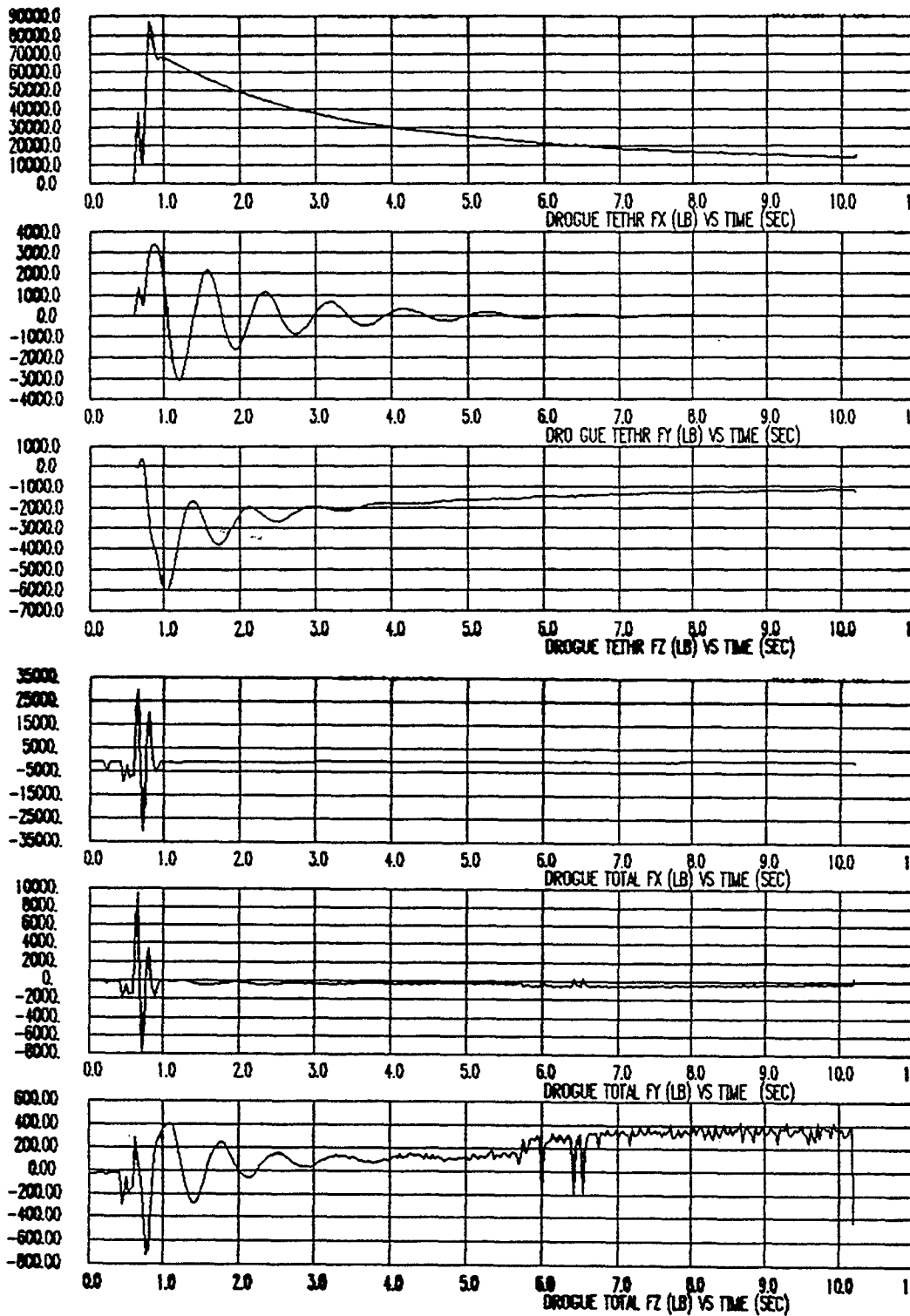


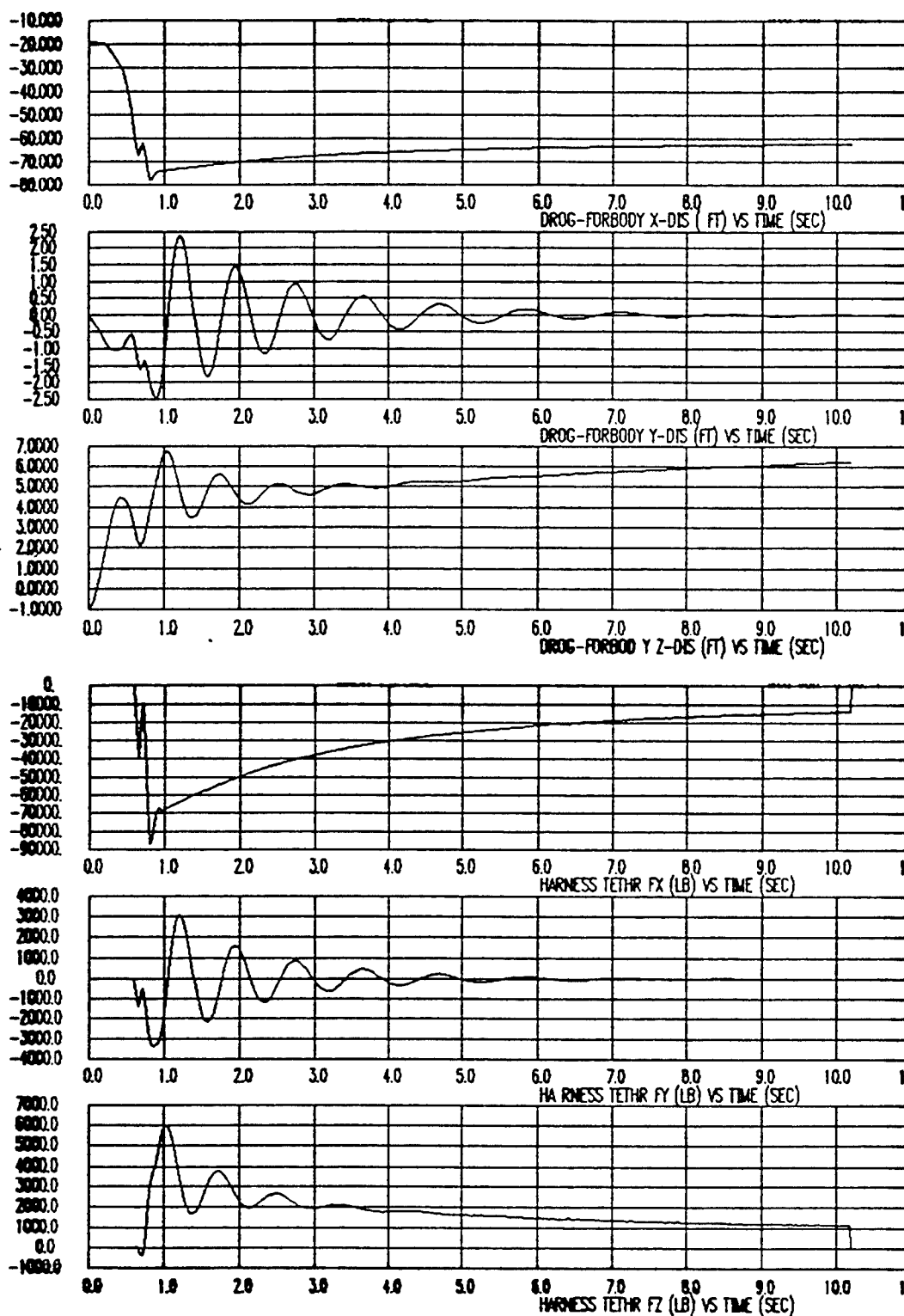


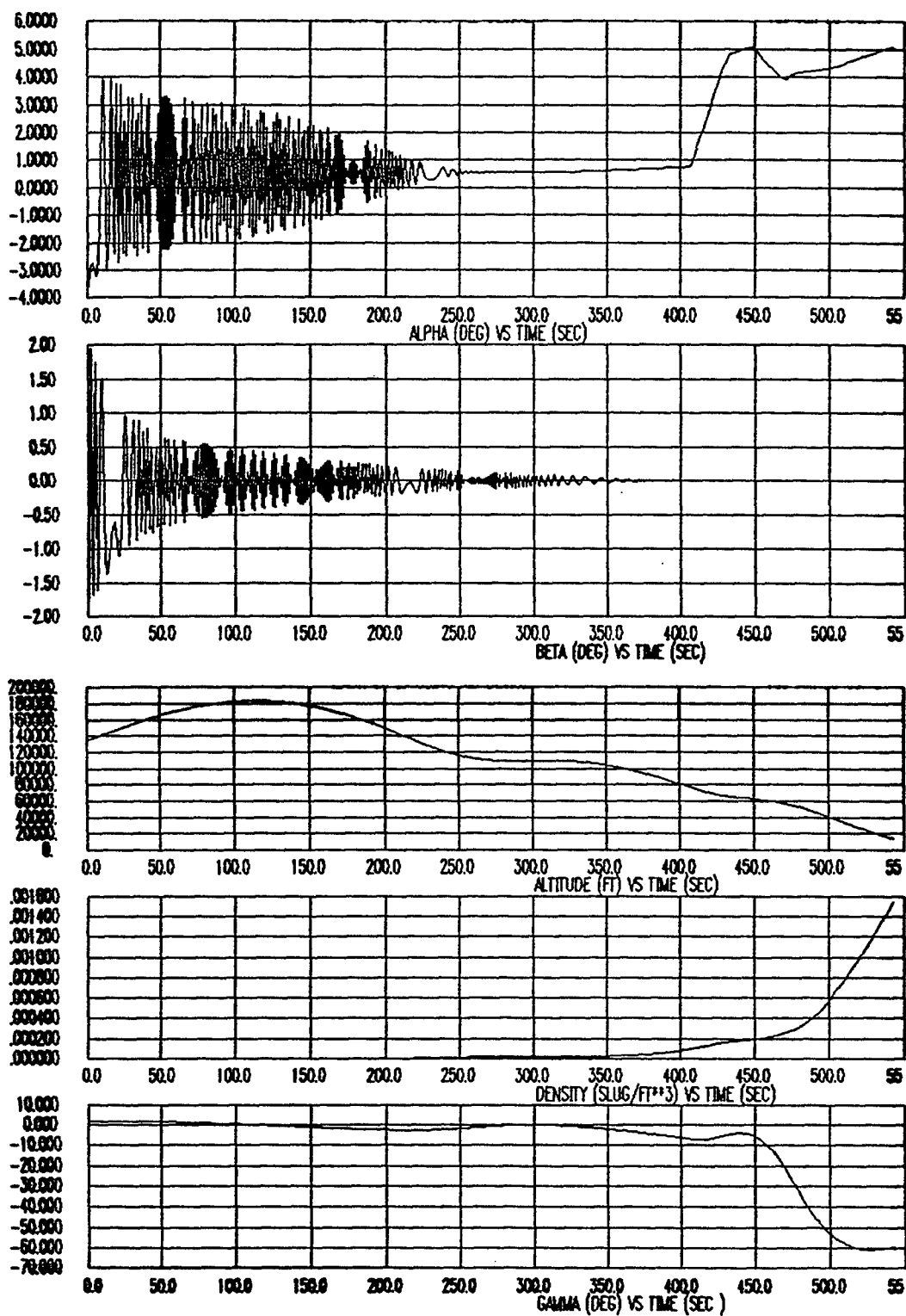




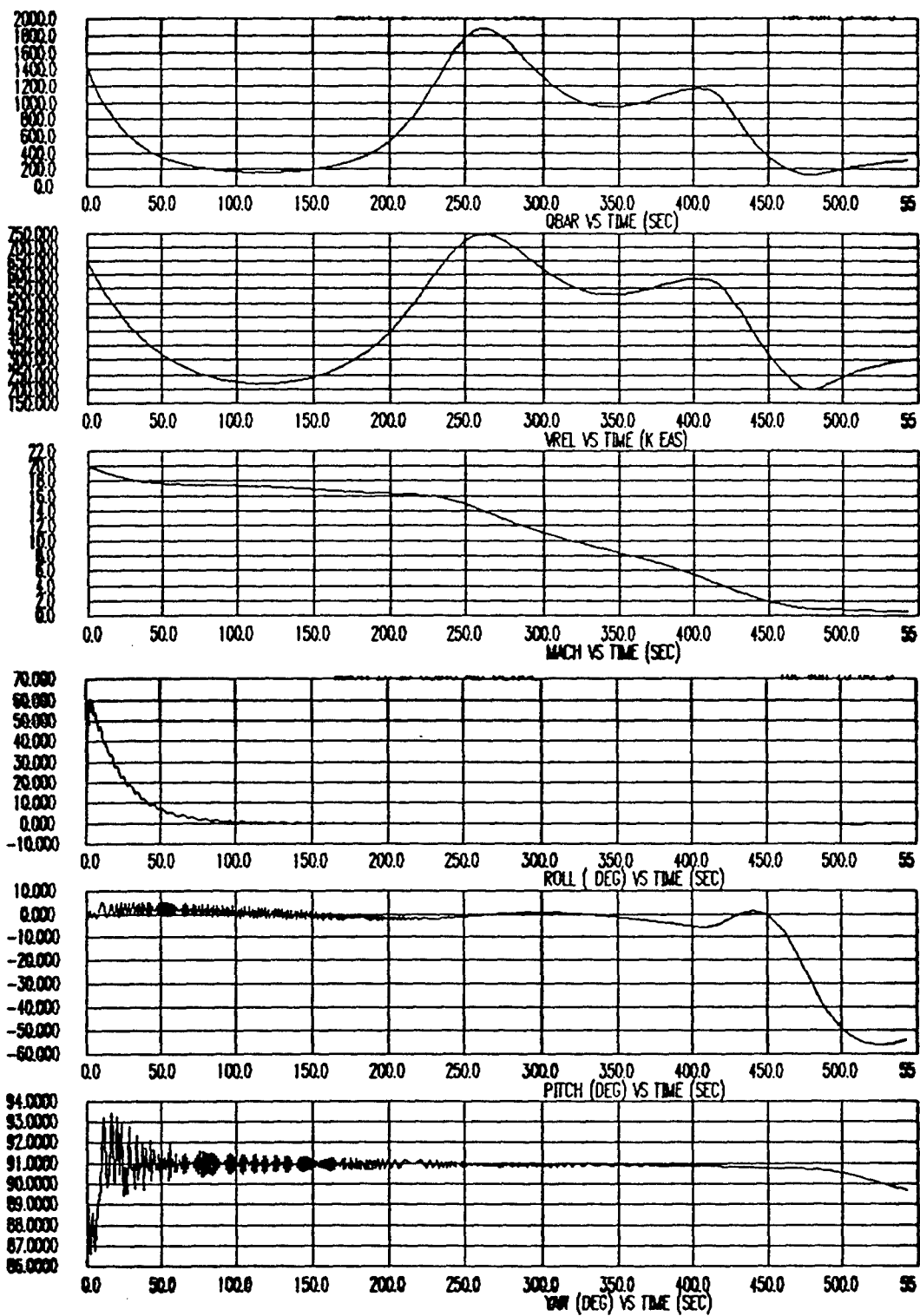


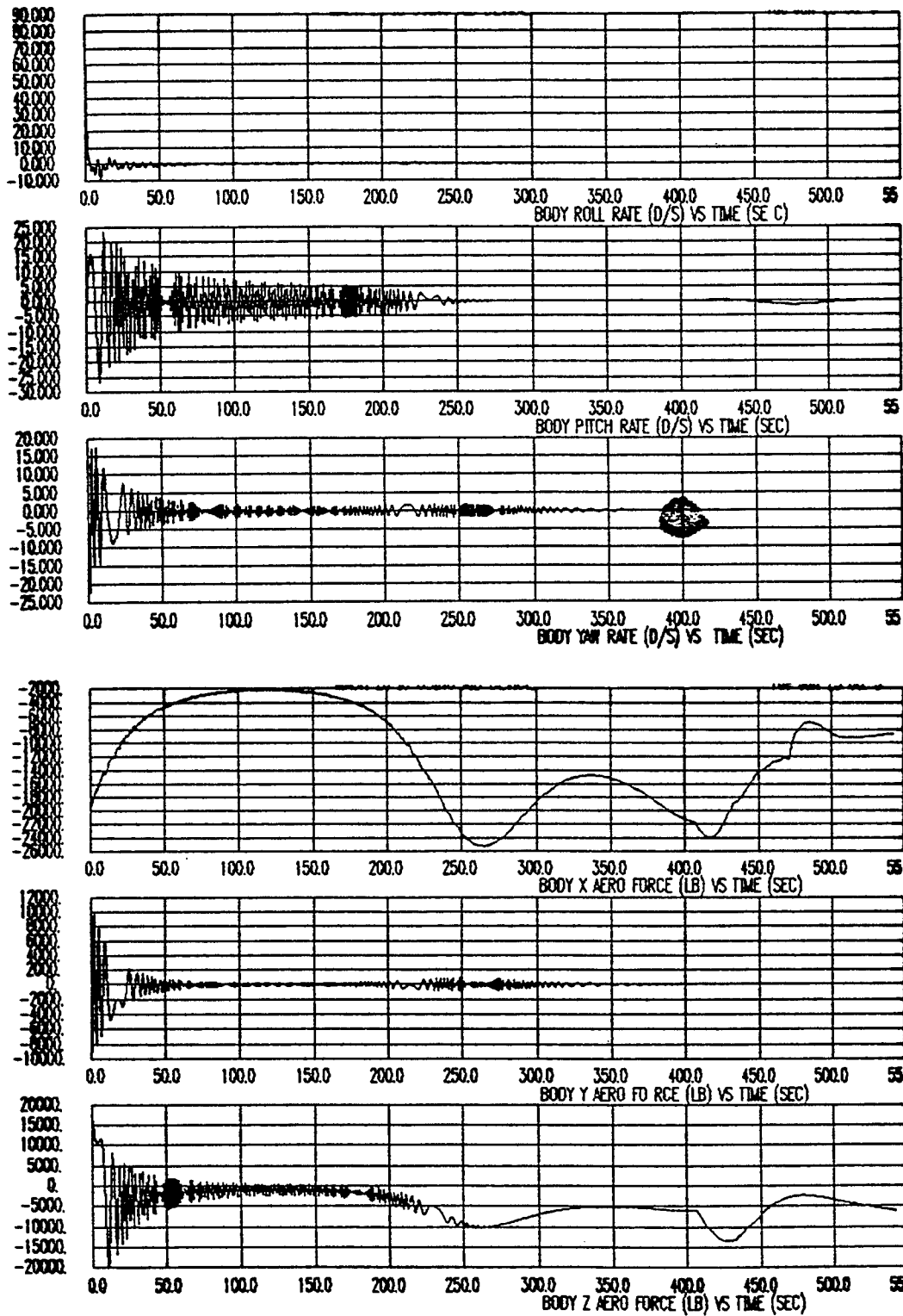


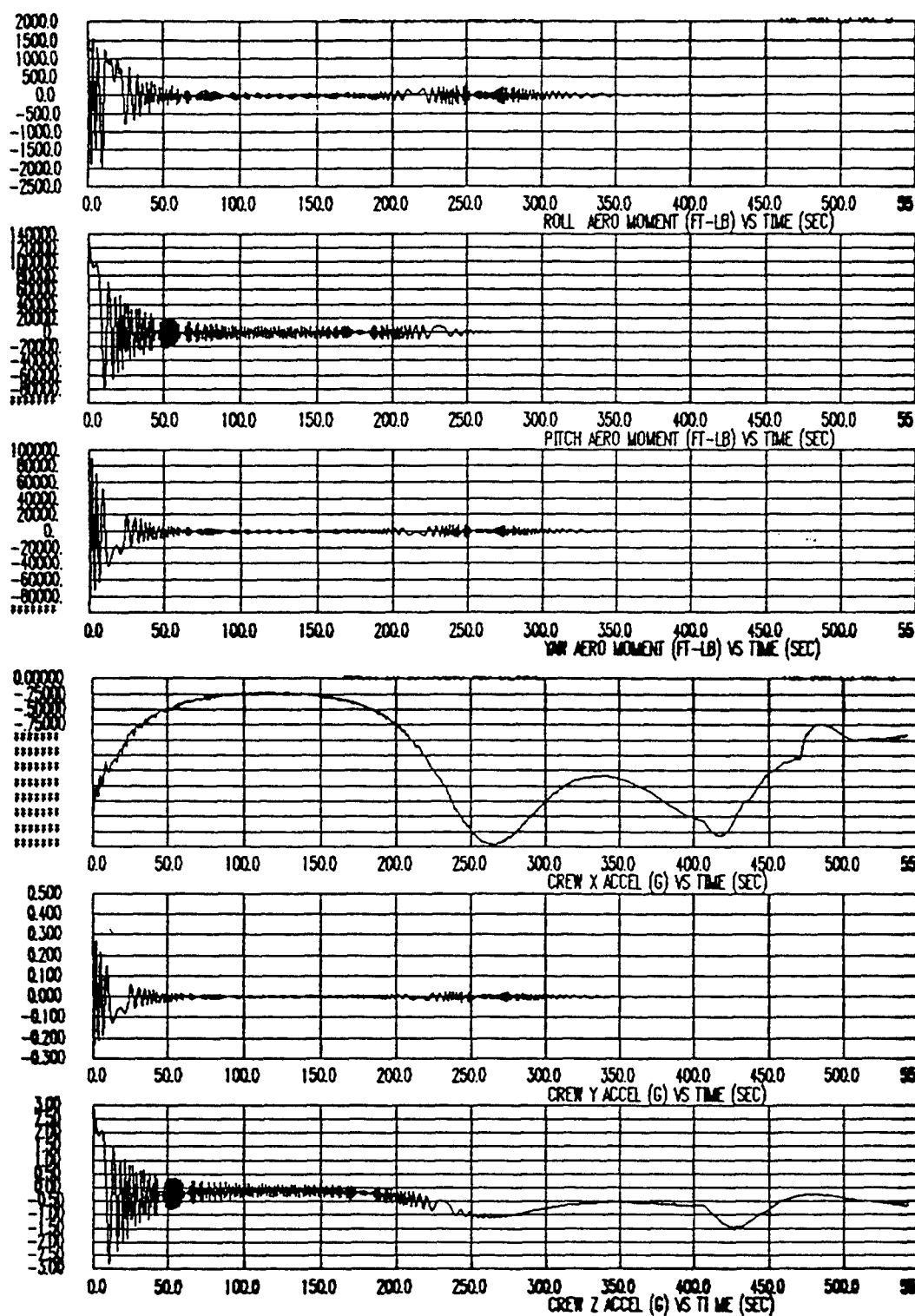


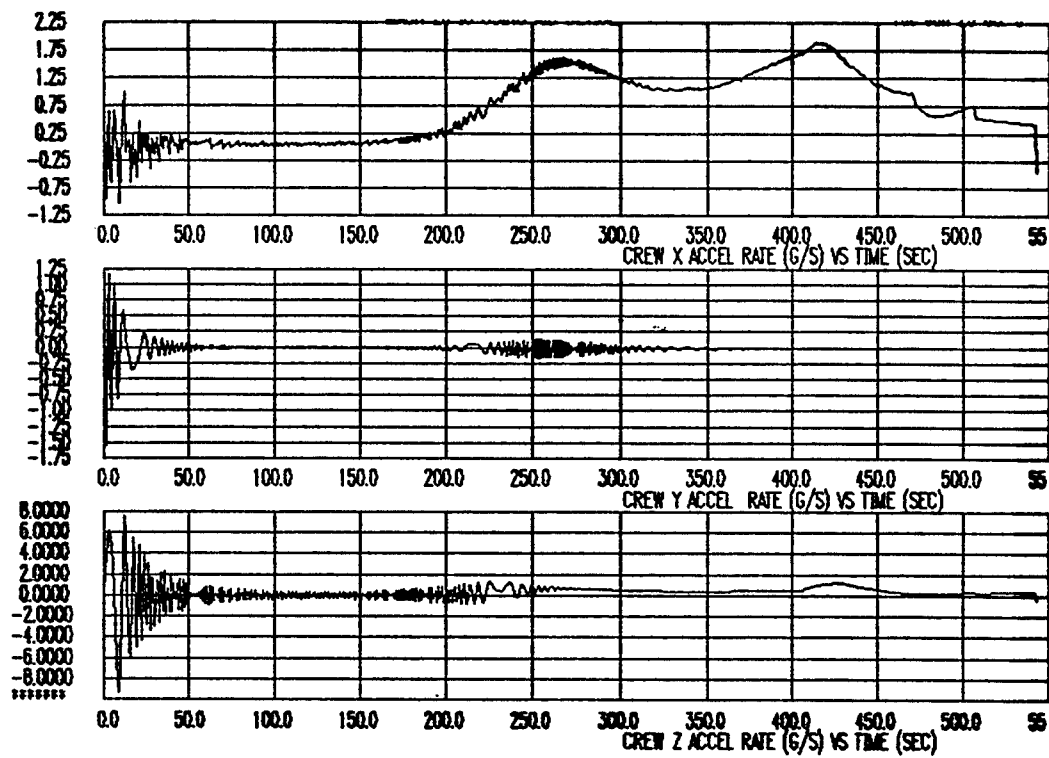


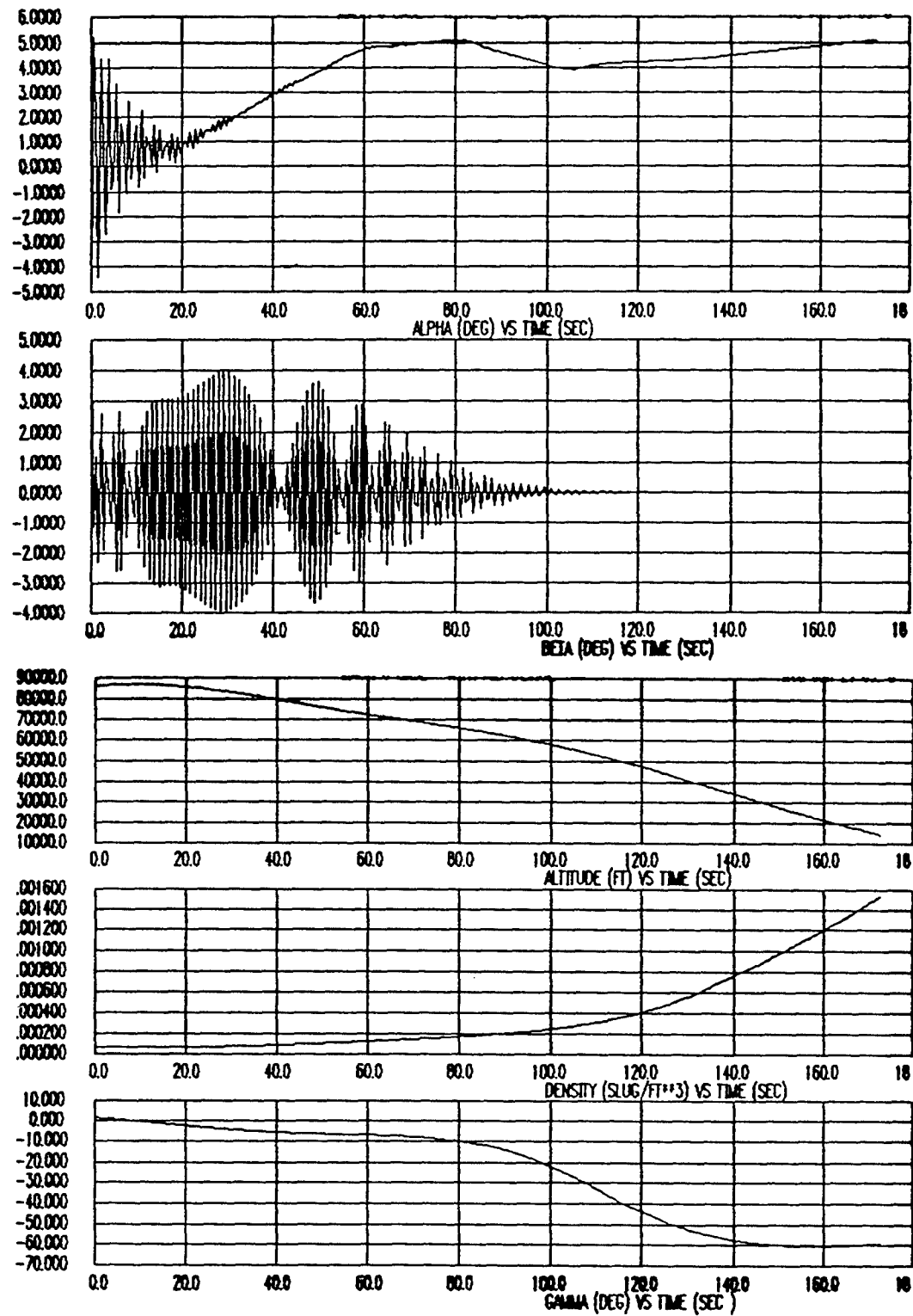


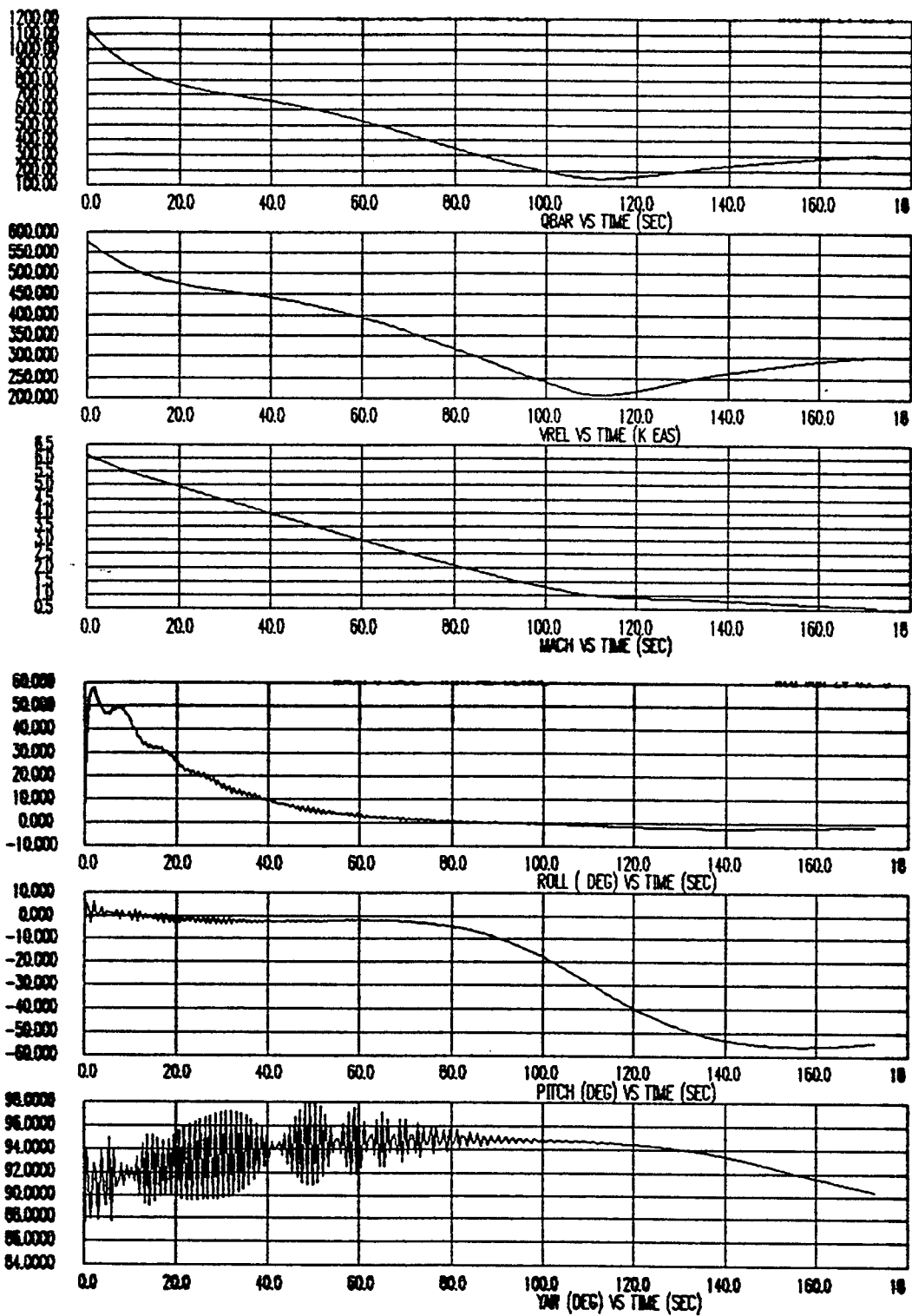


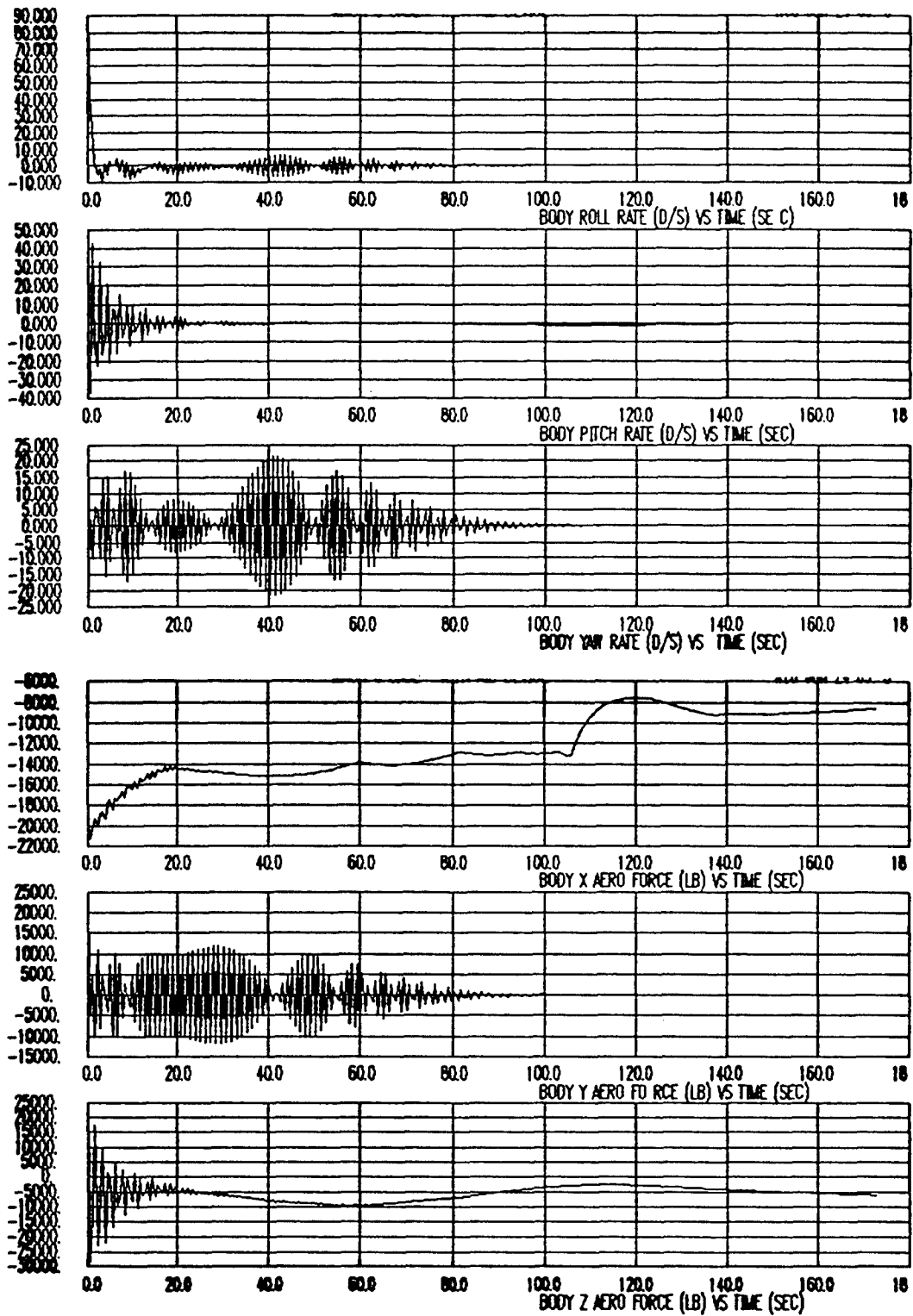


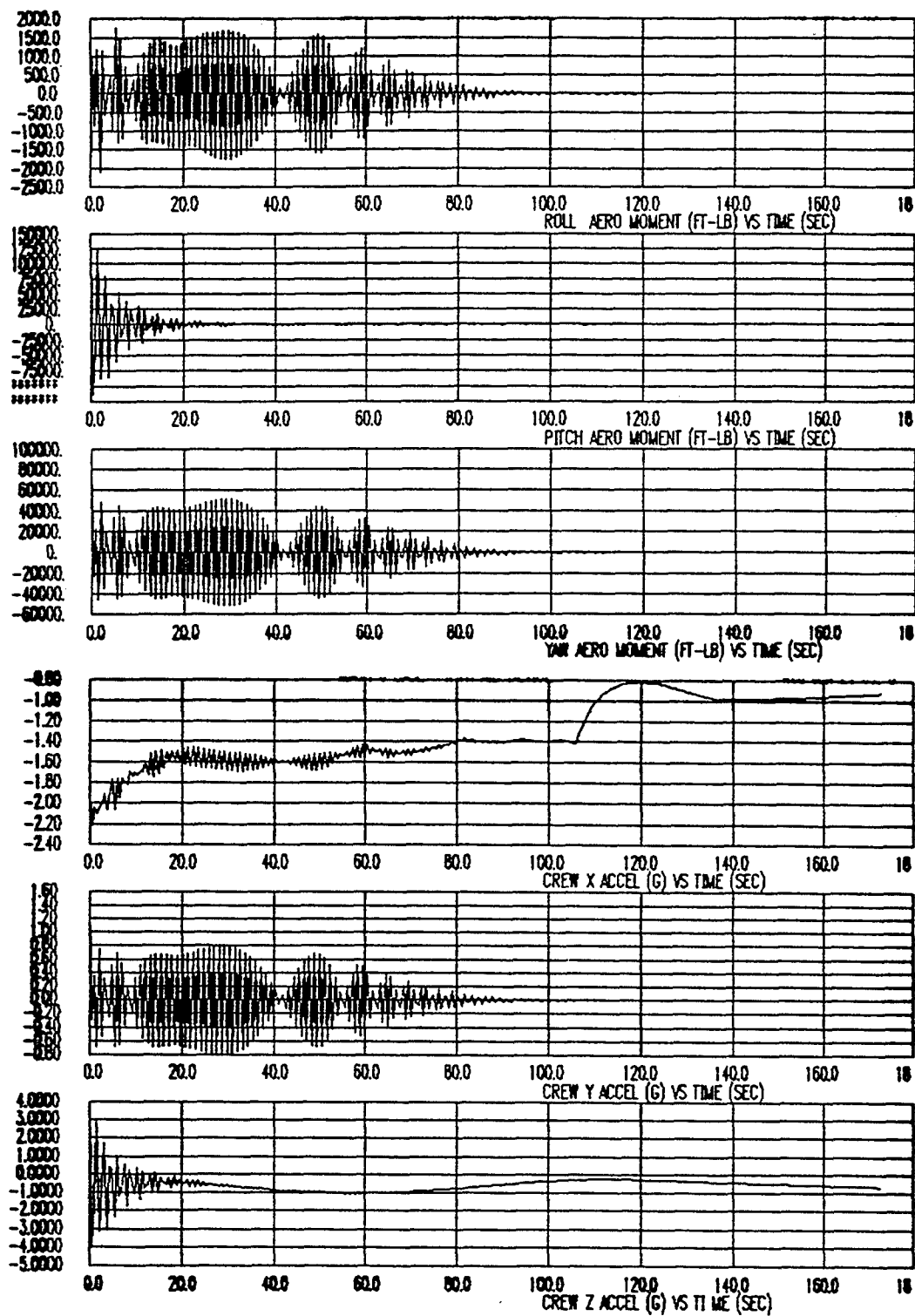




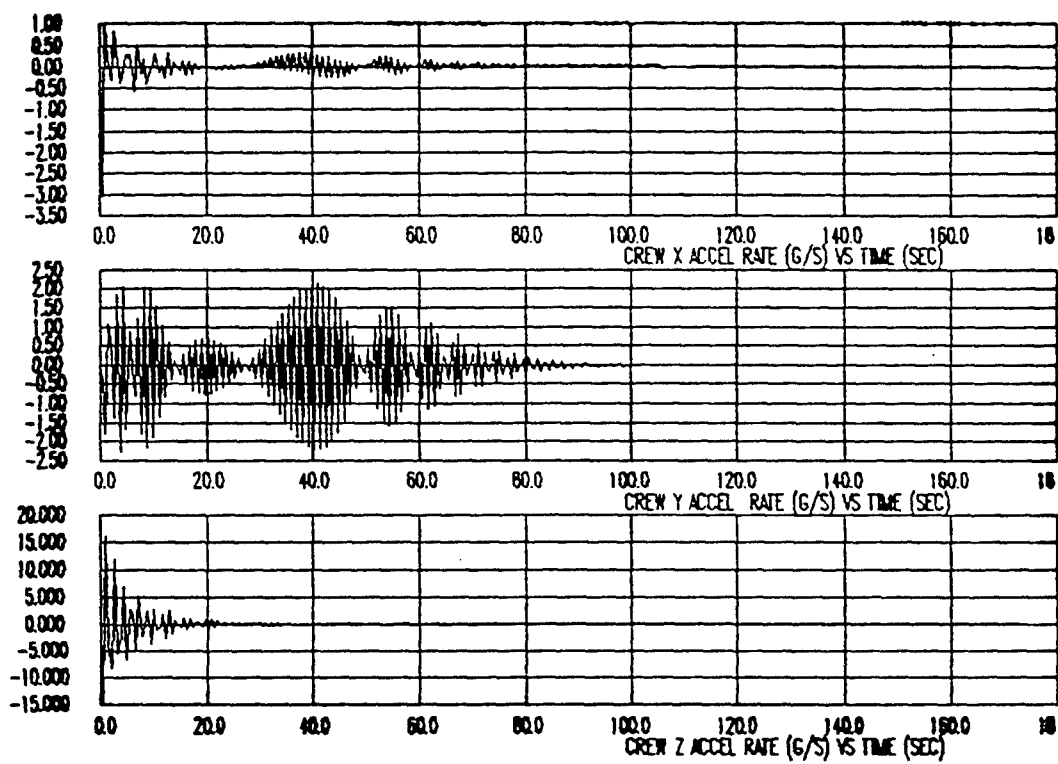




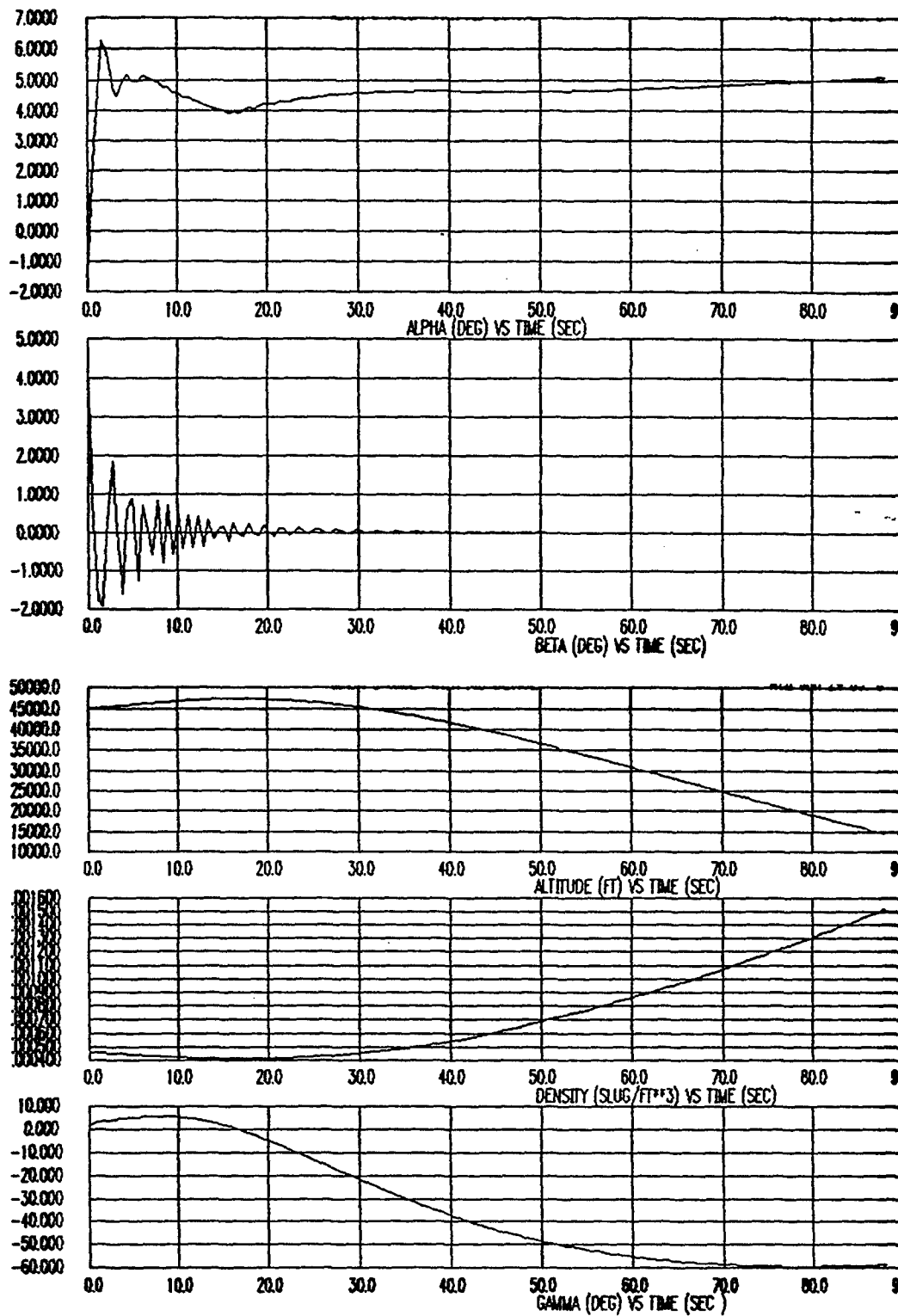


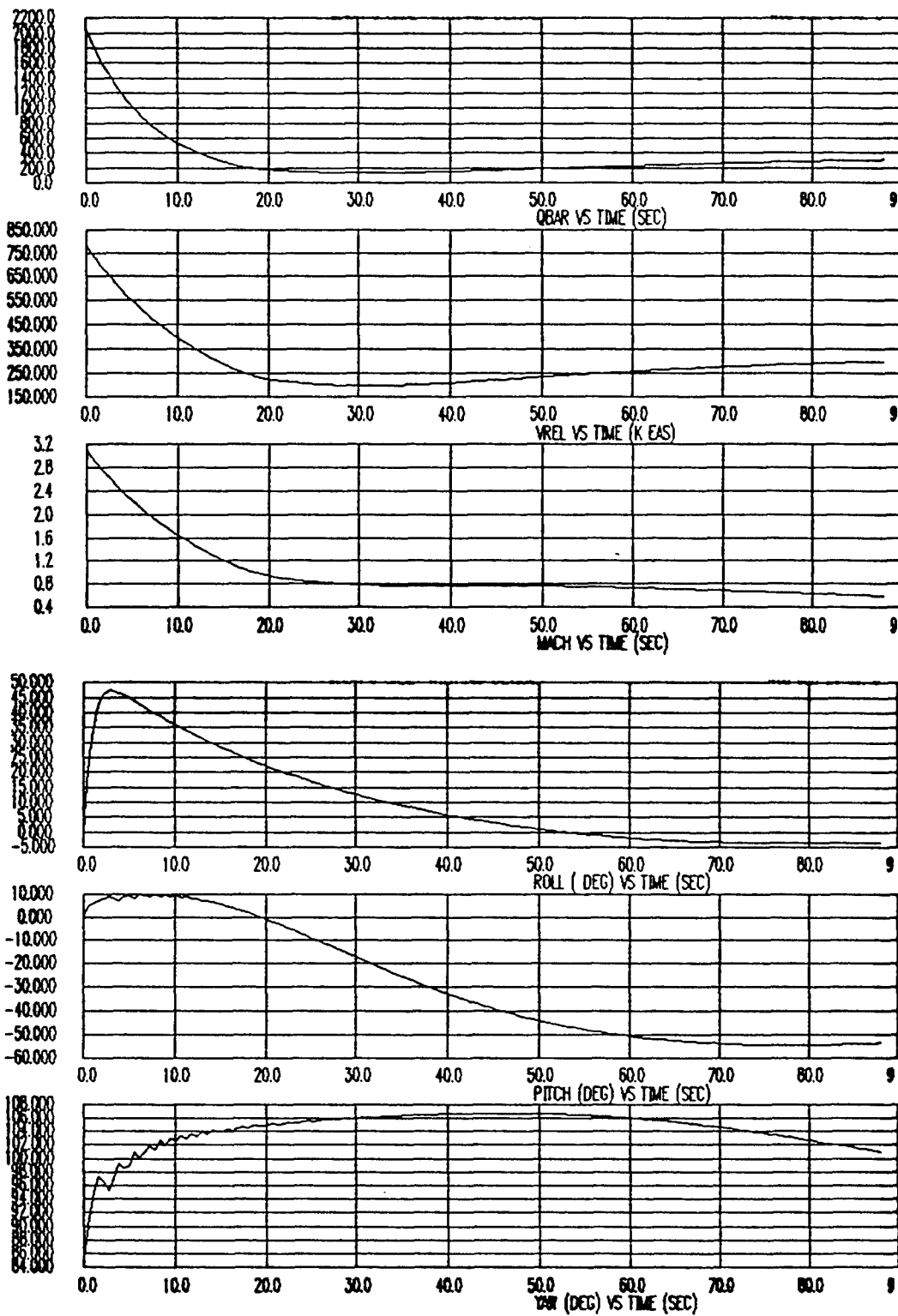


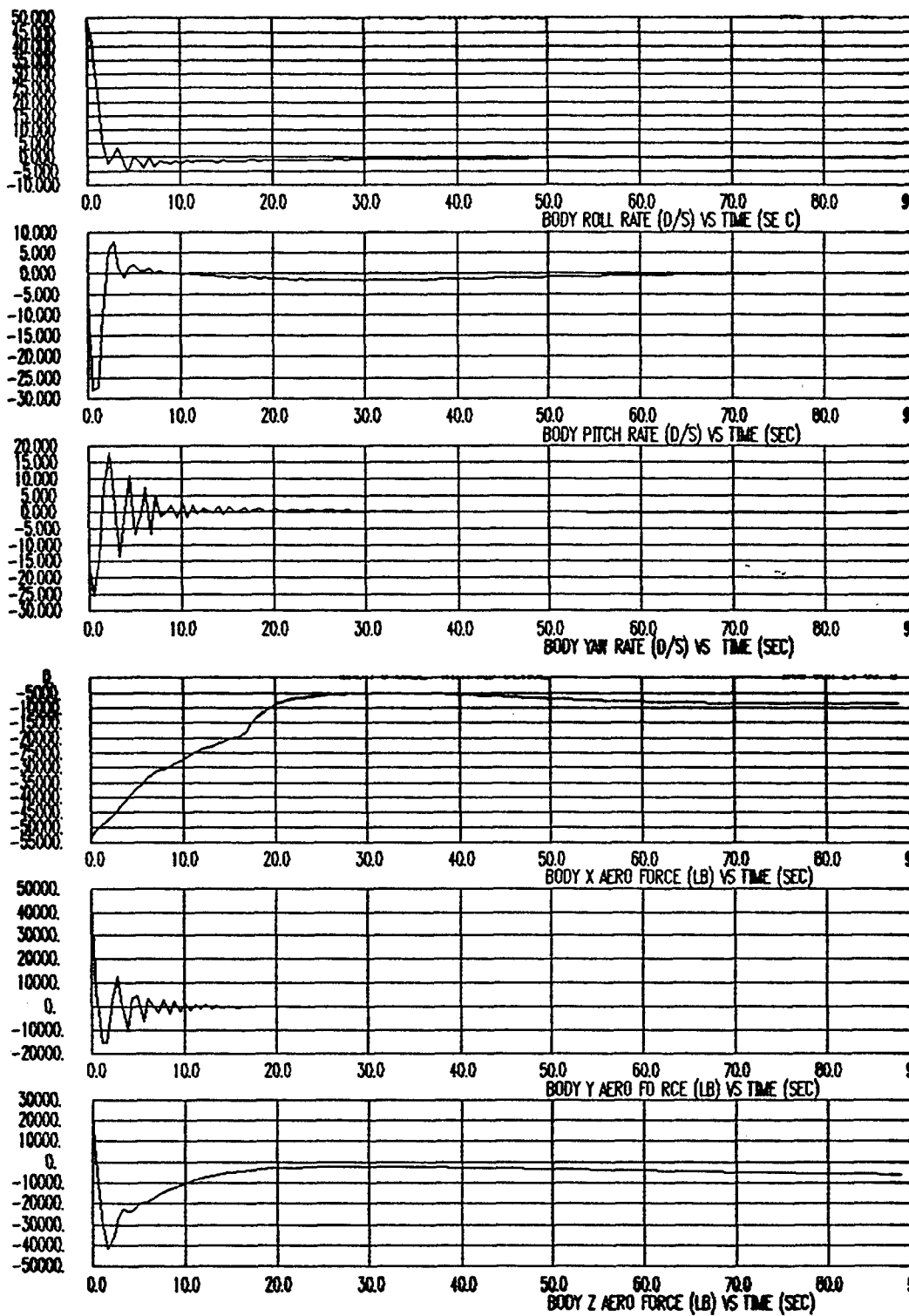


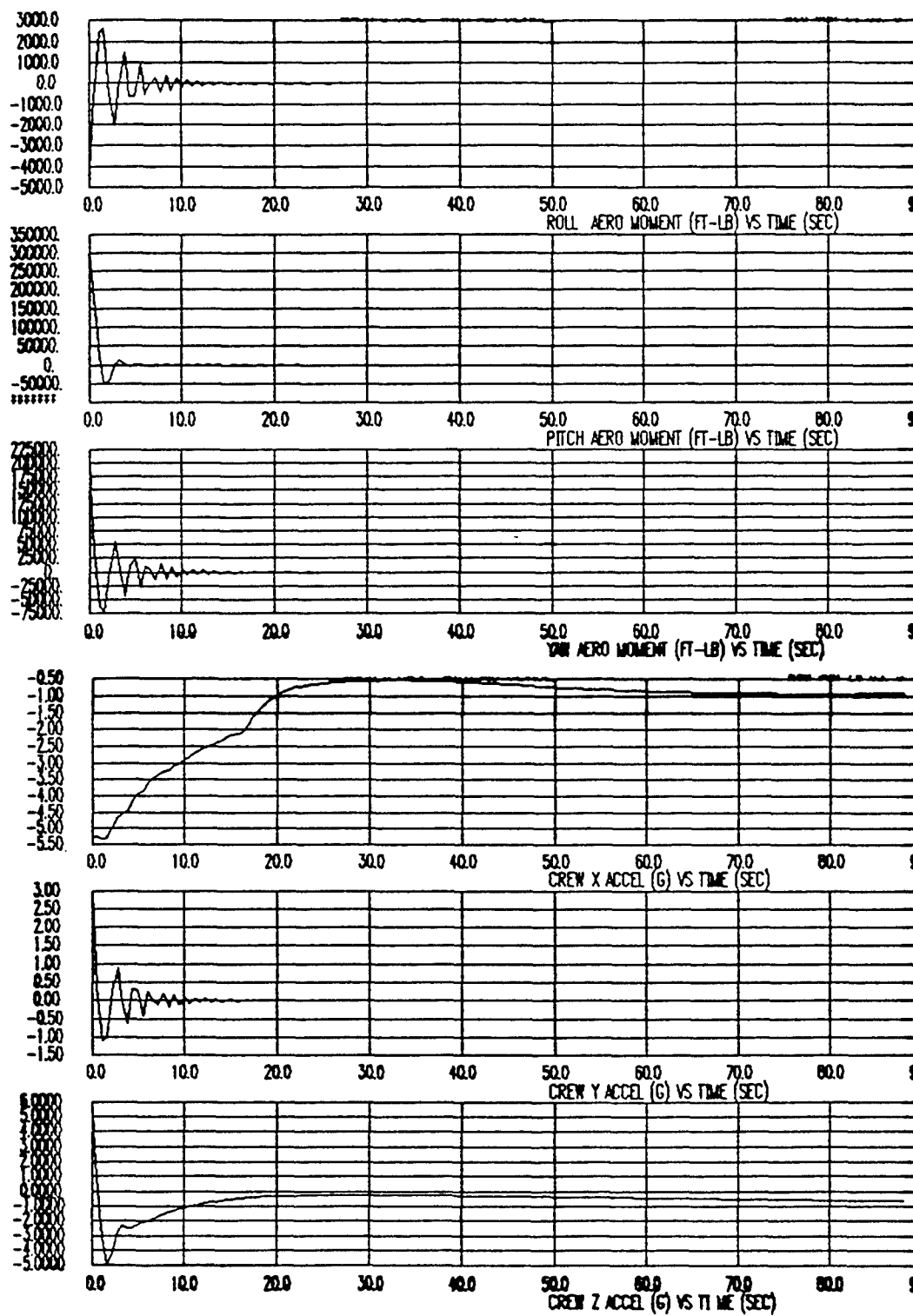


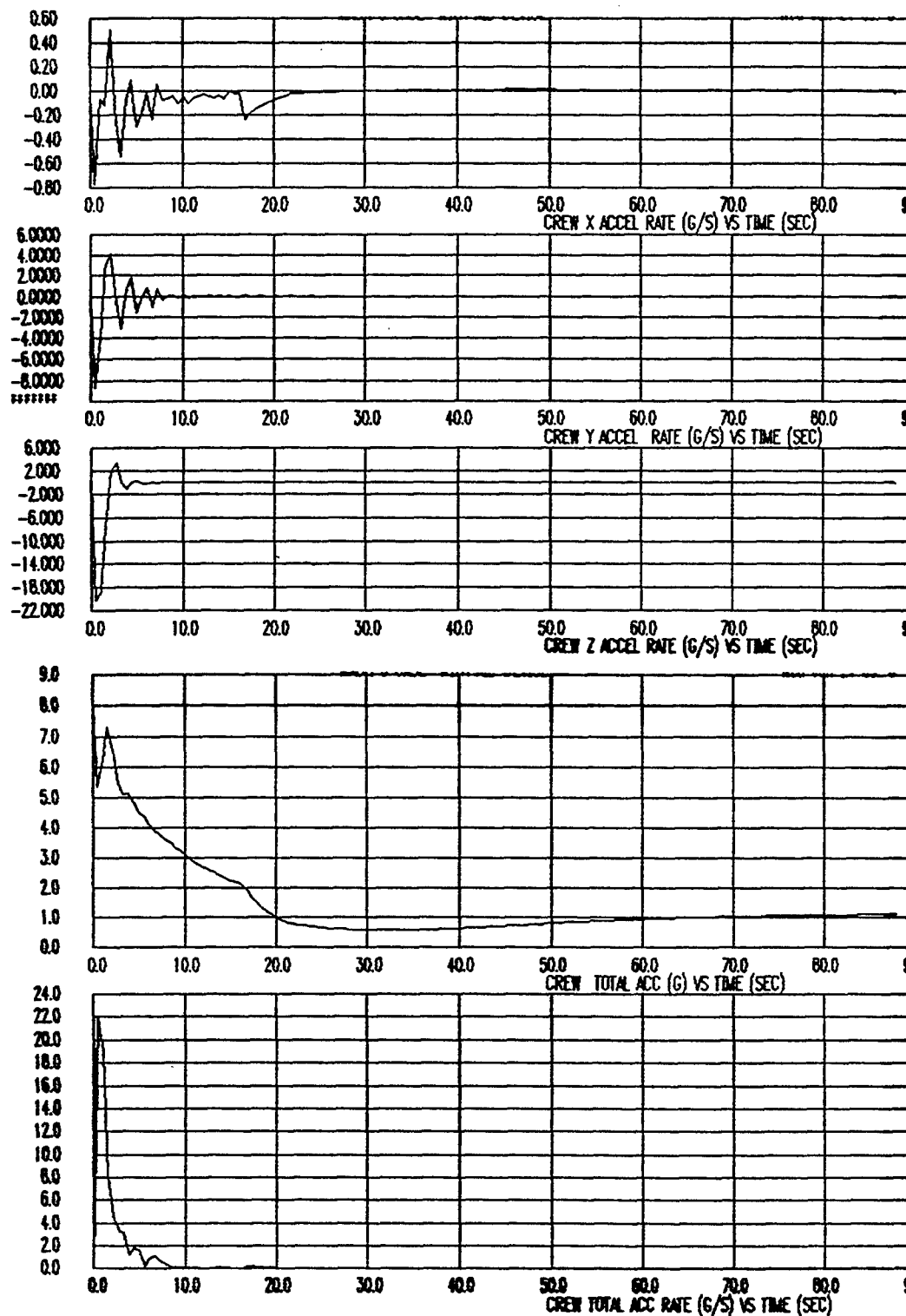
Case 11

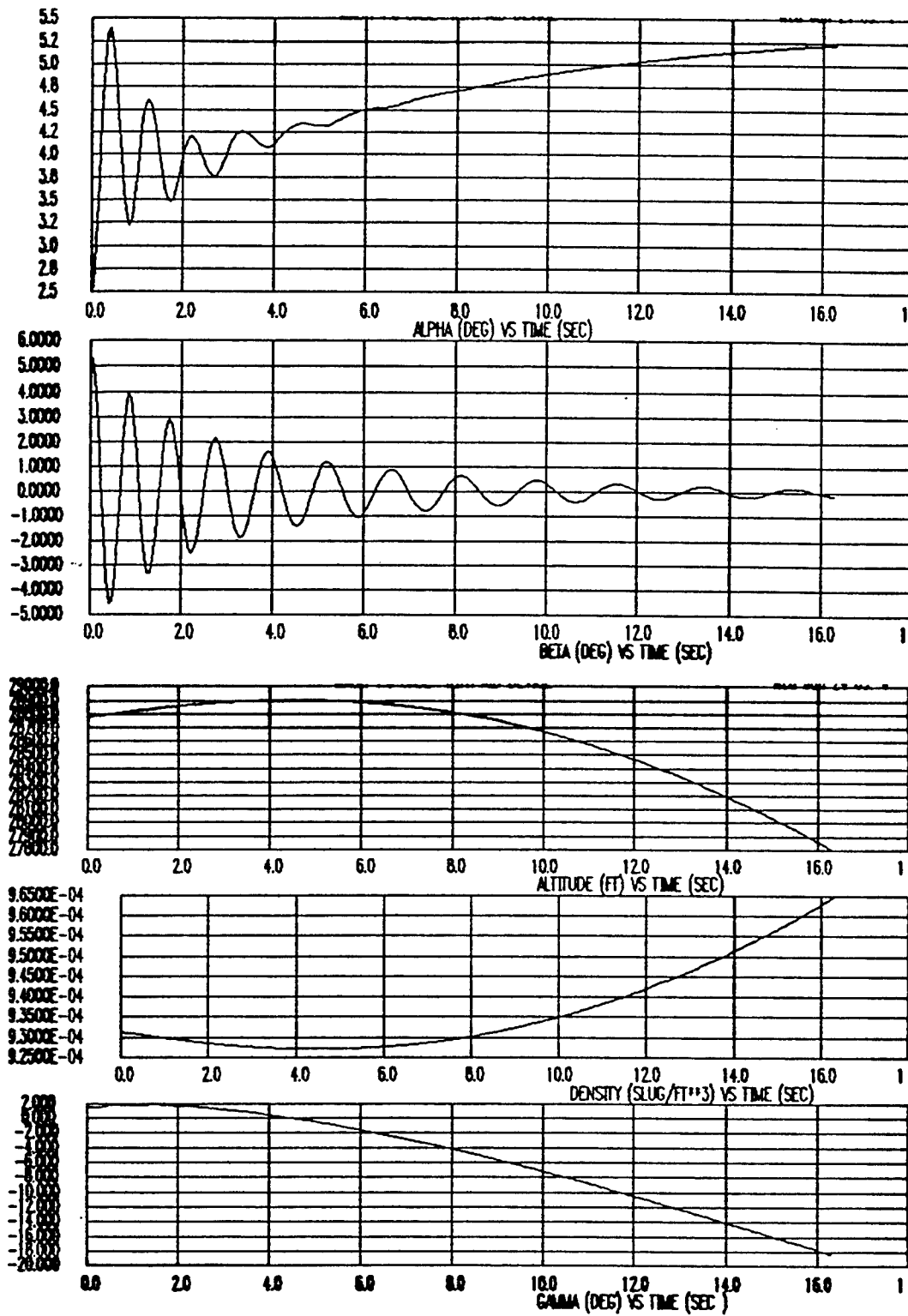


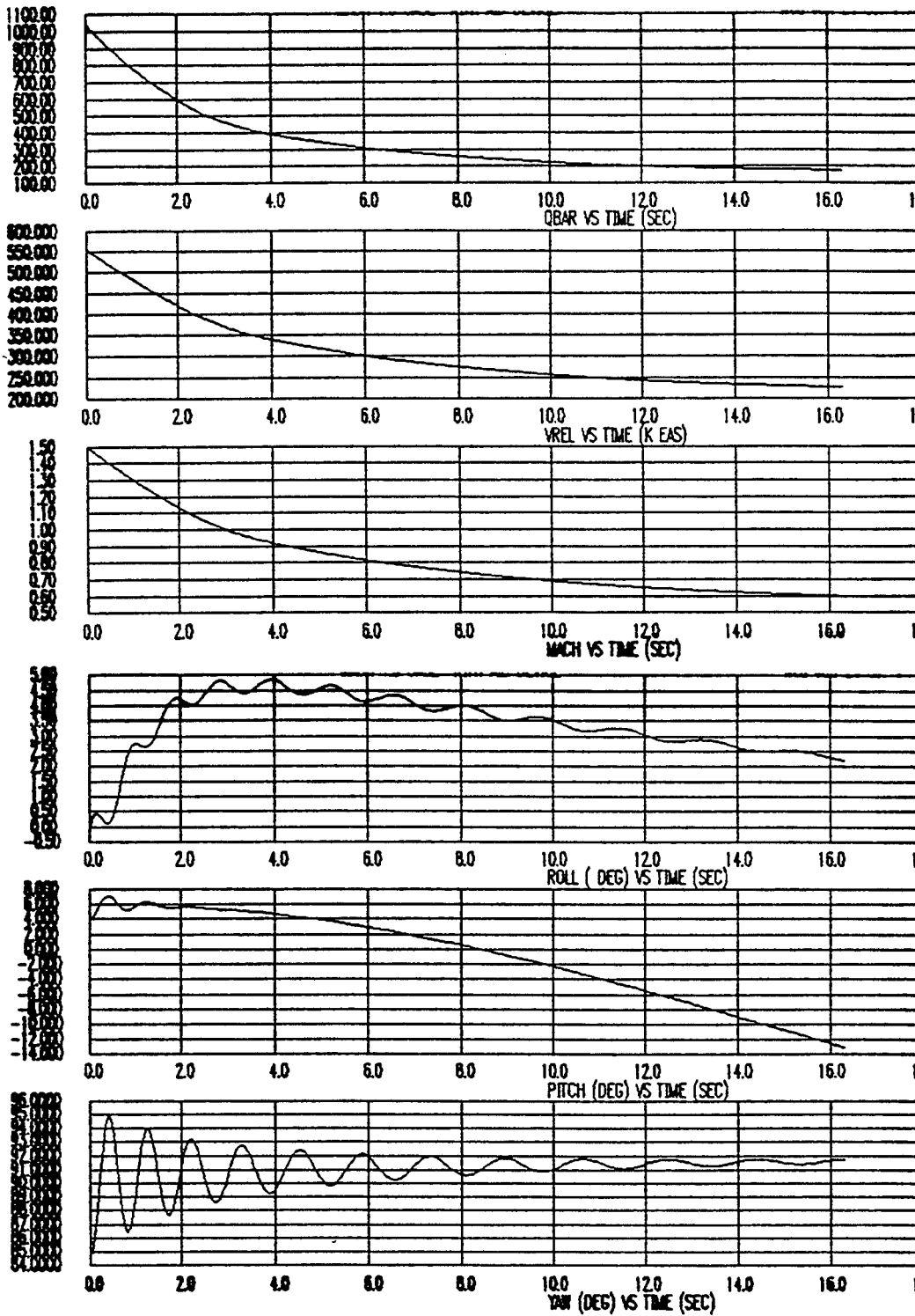




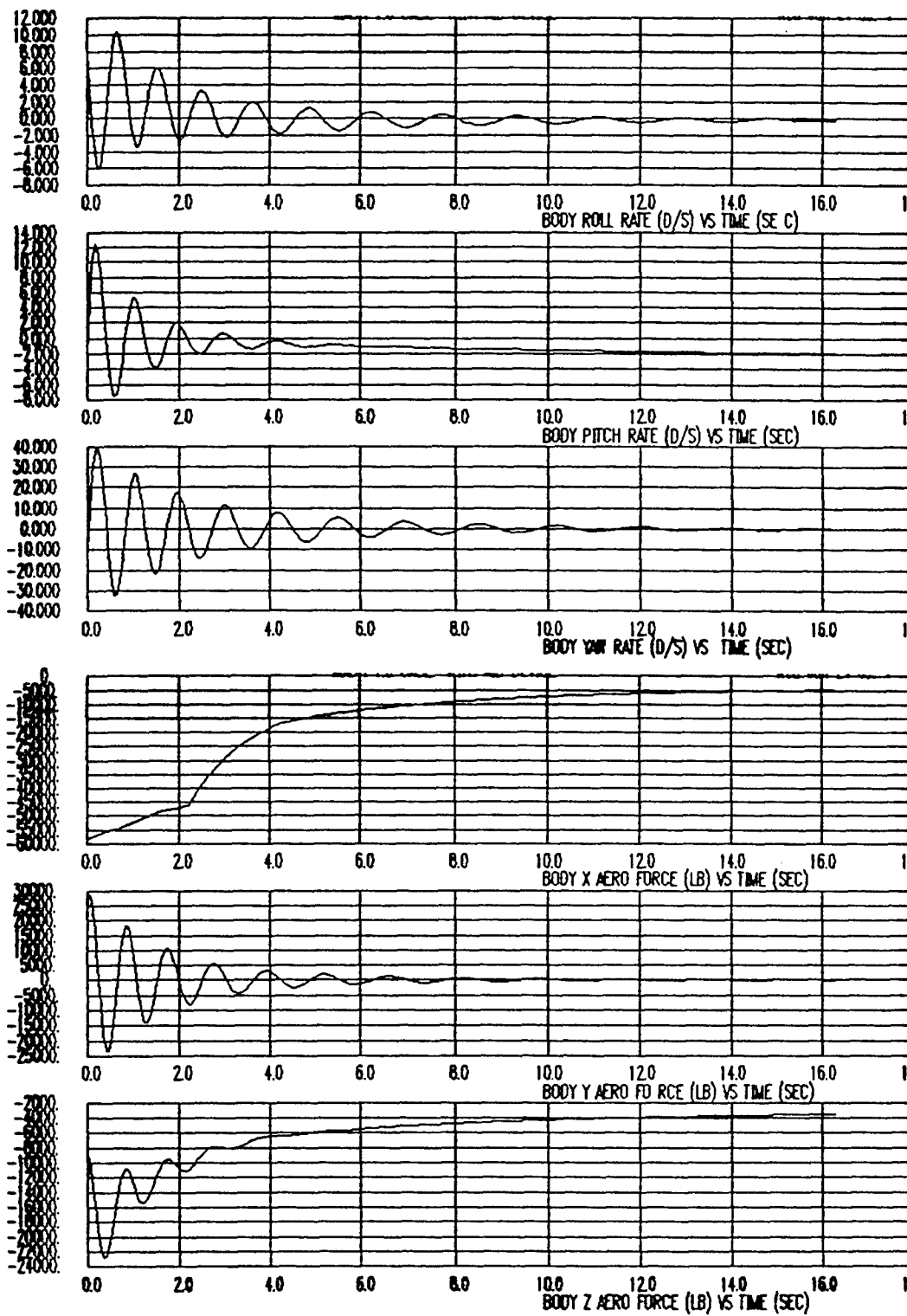


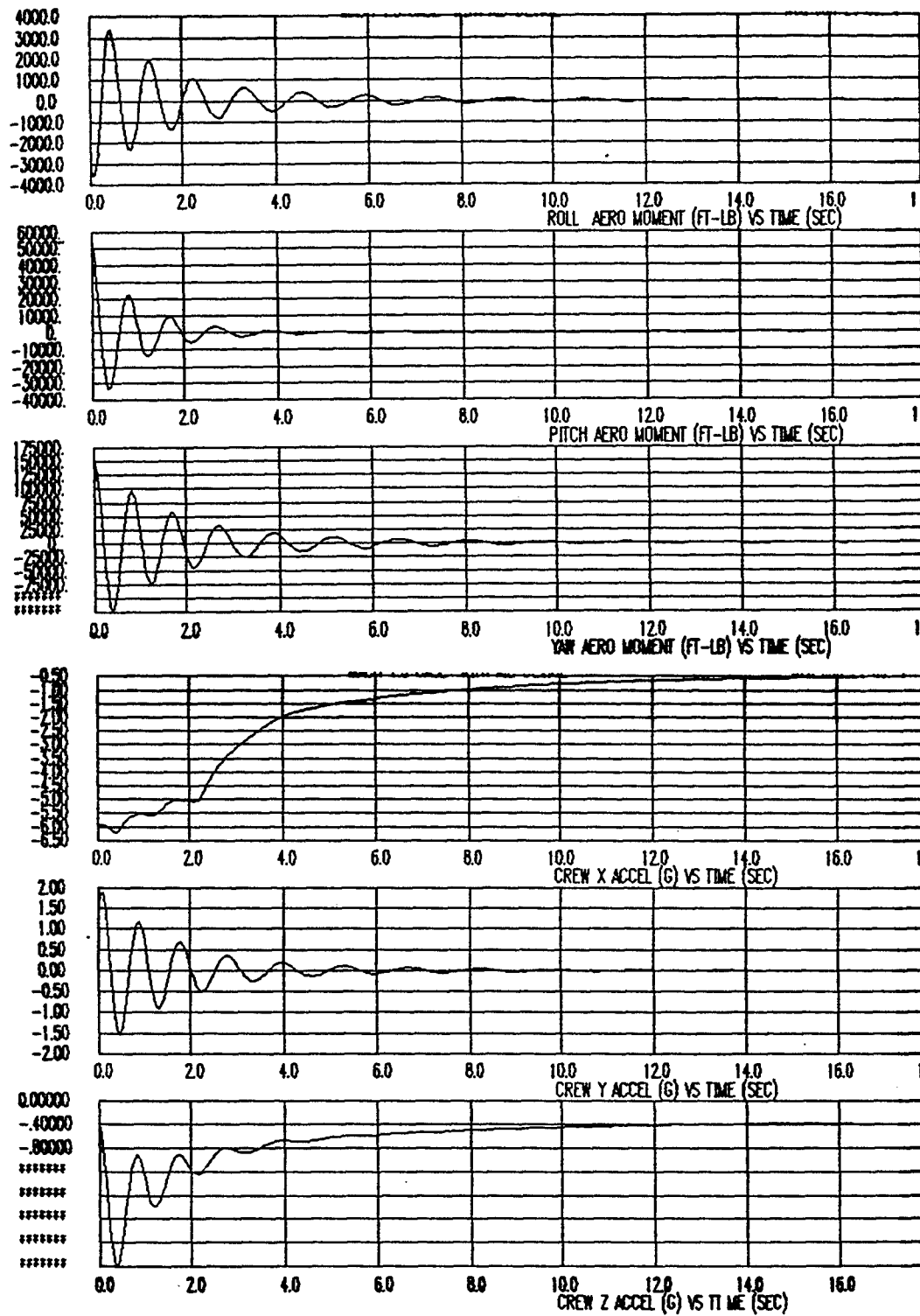


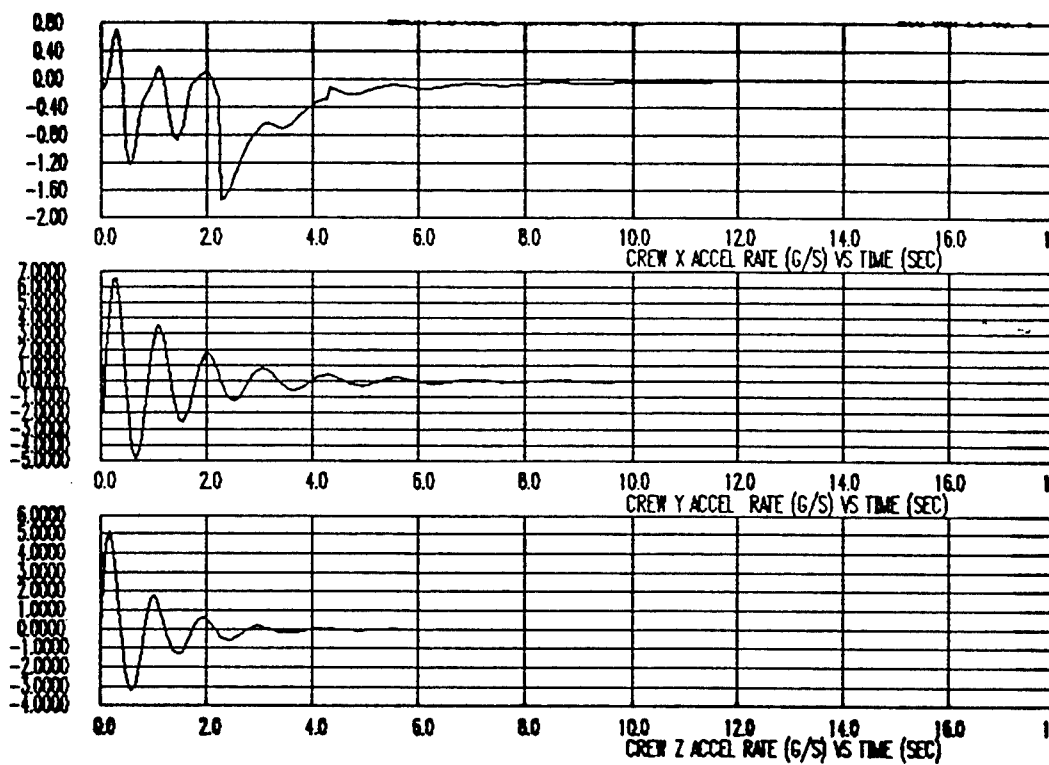




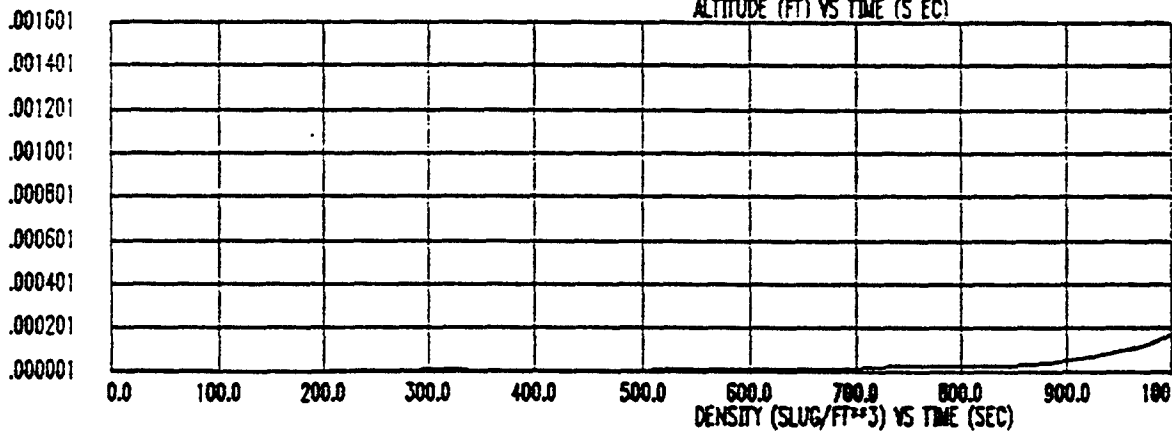
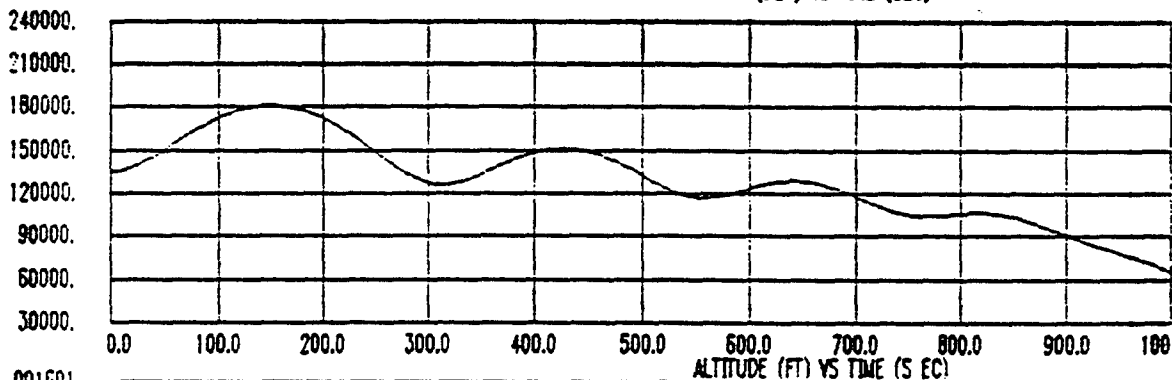
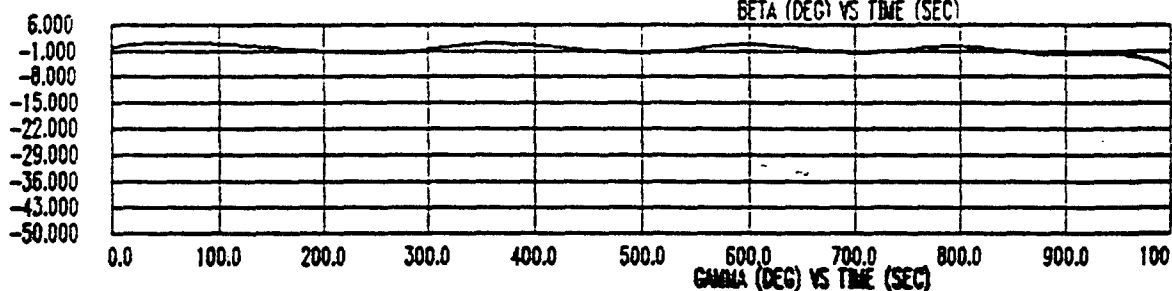
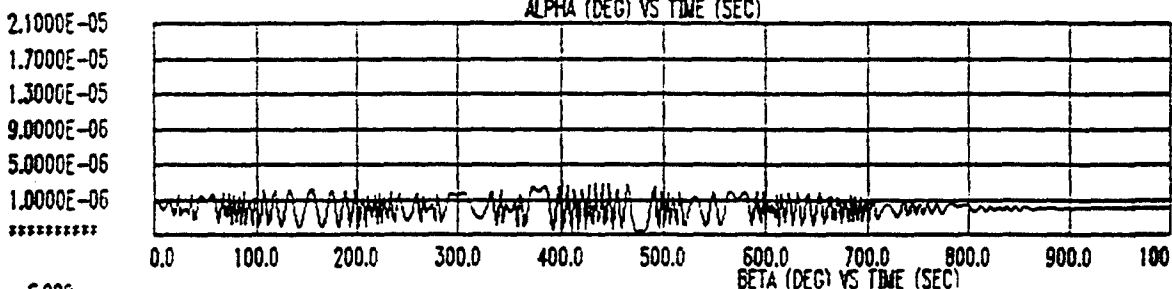
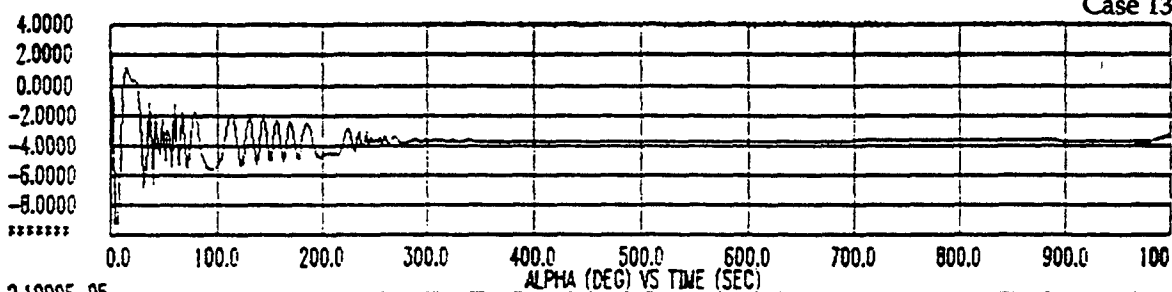




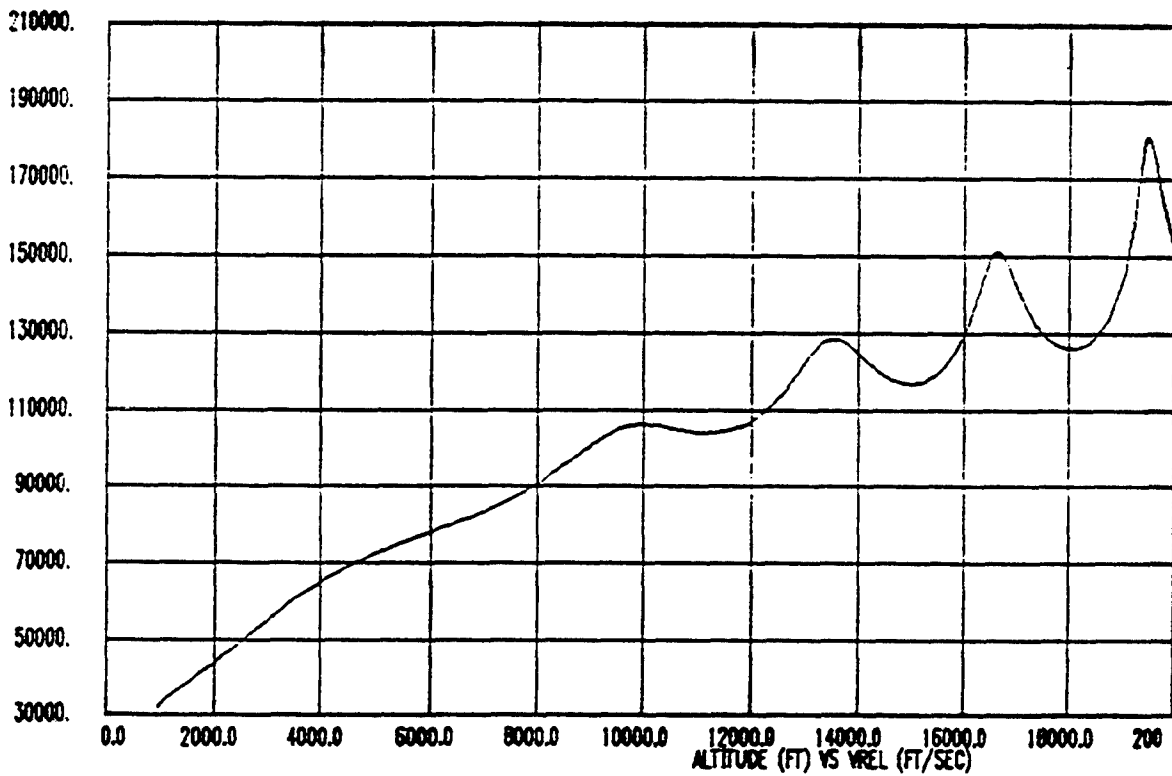
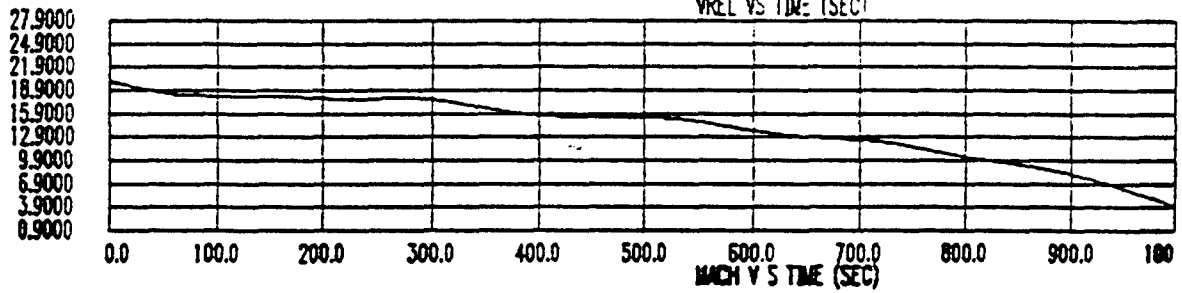
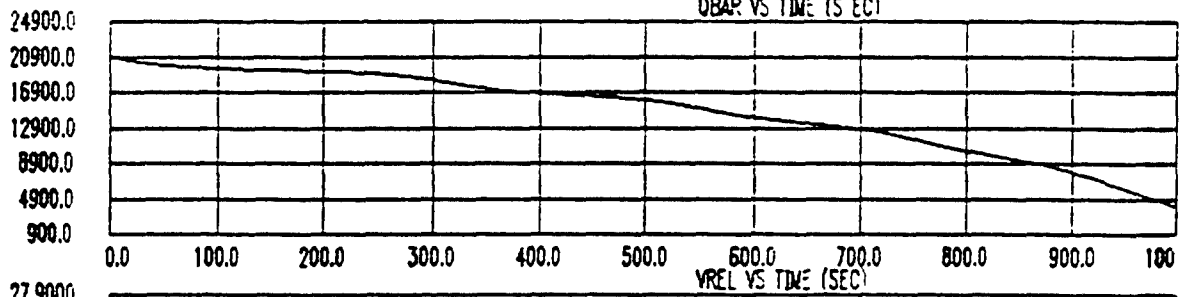
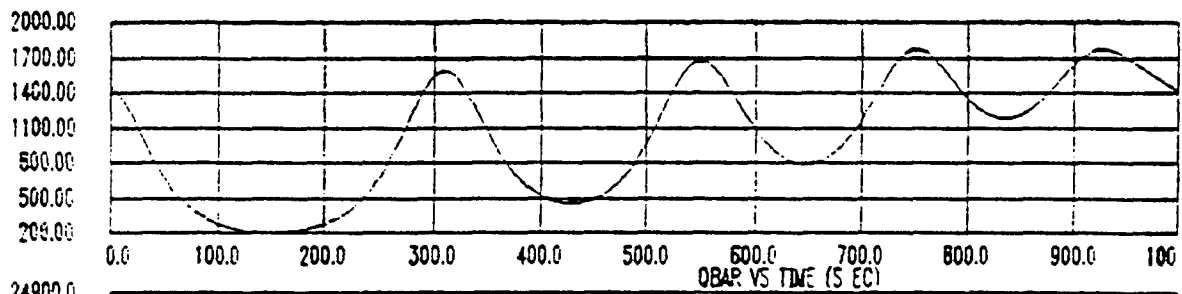


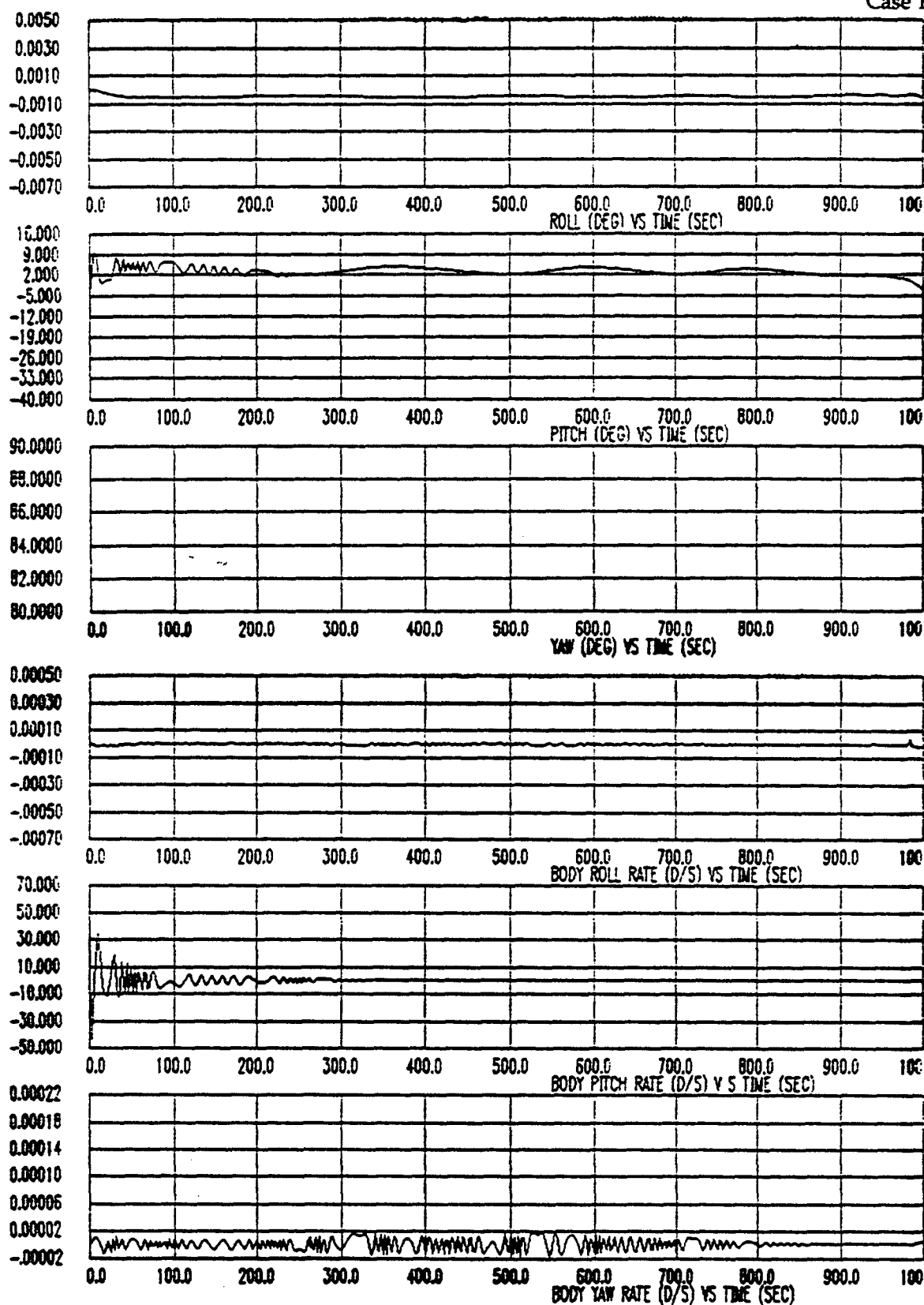


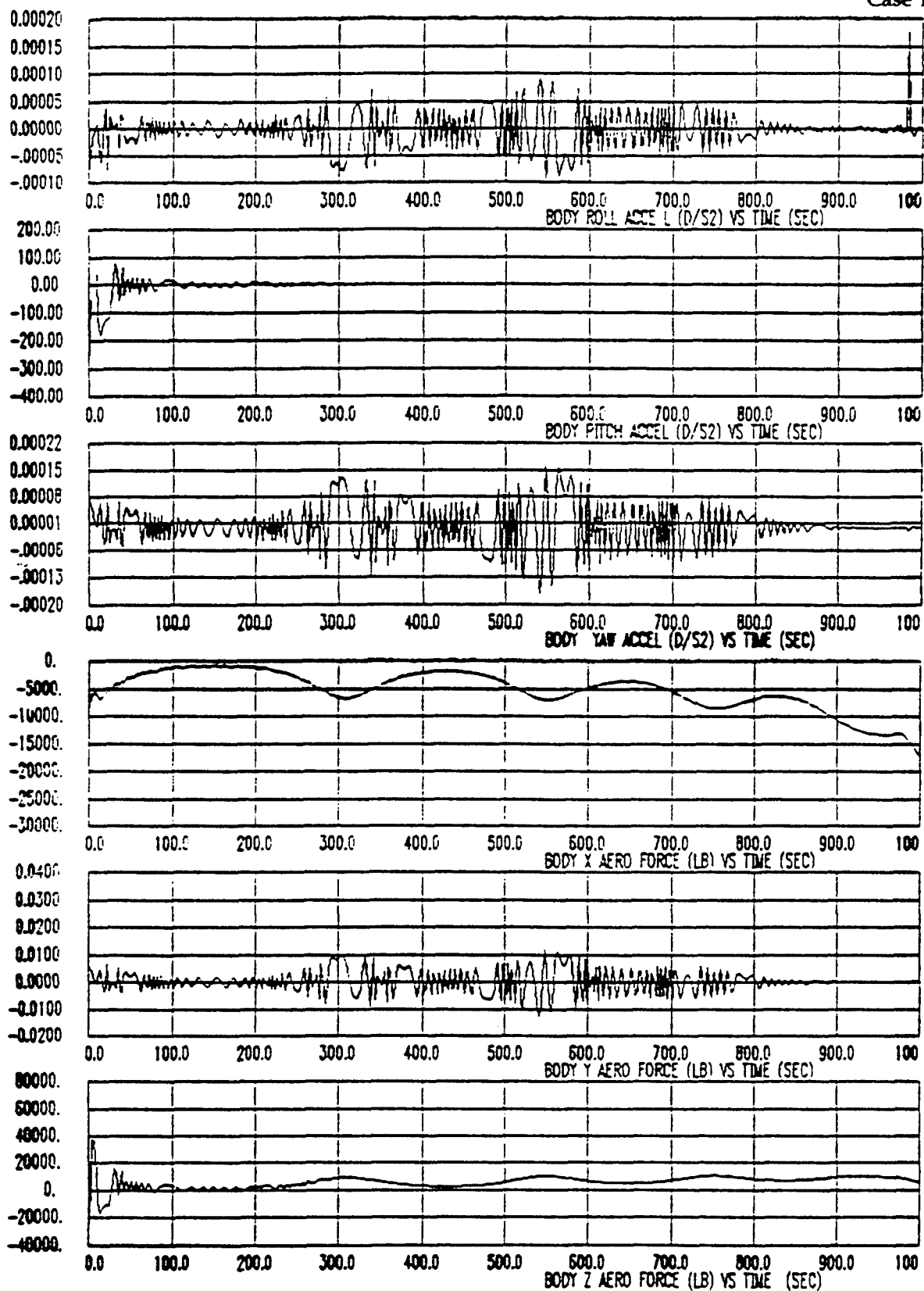
Case 13

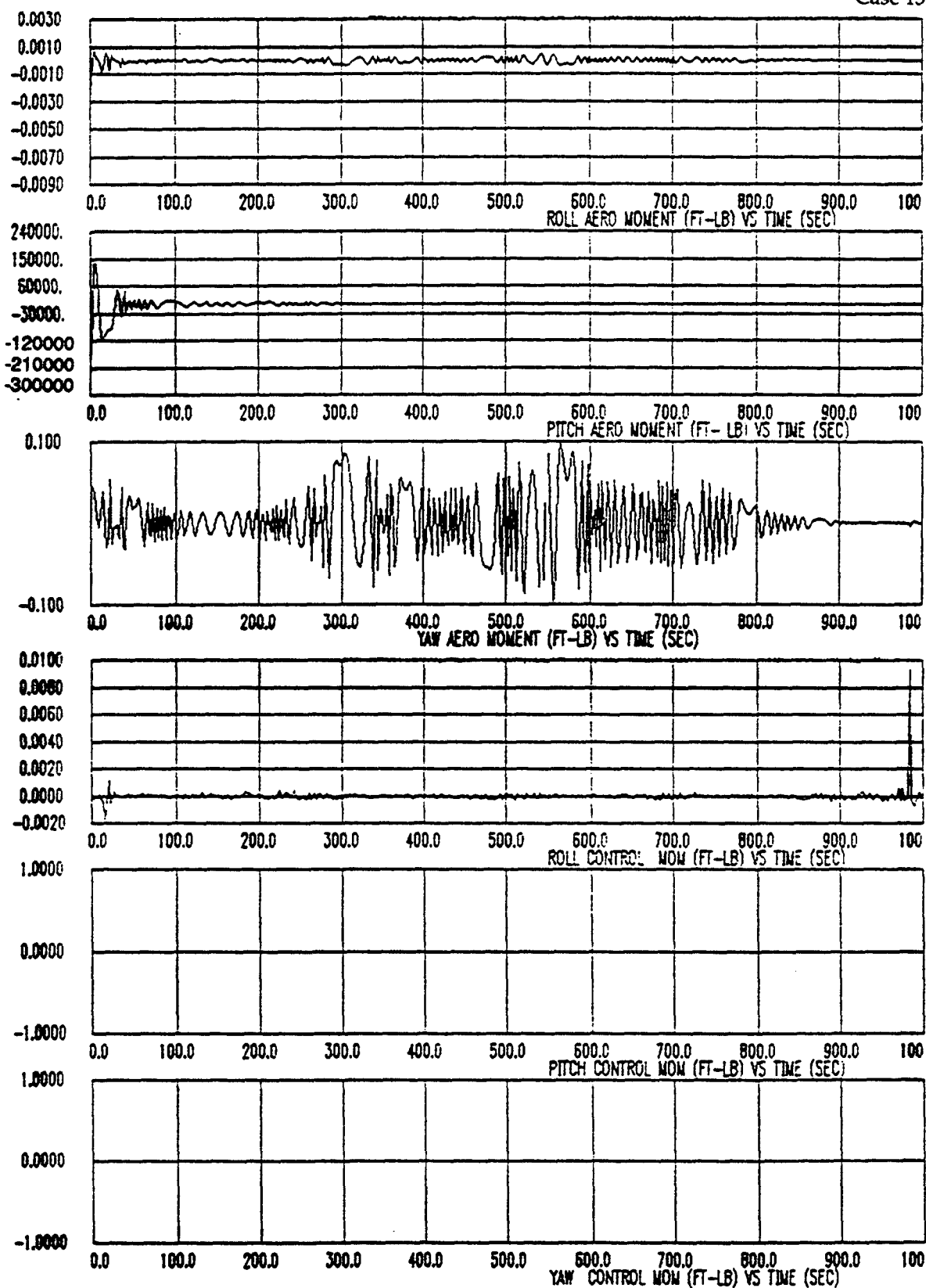


Case 13



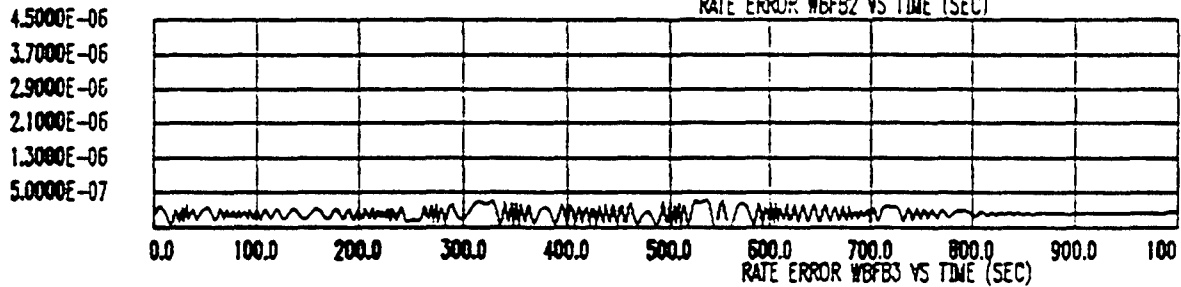
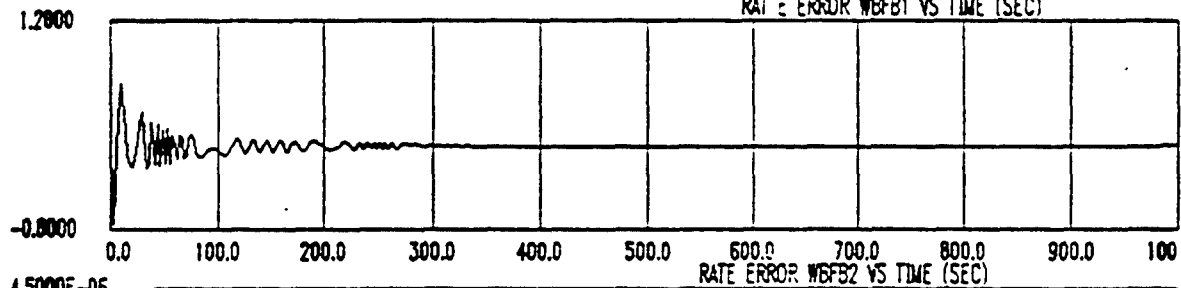
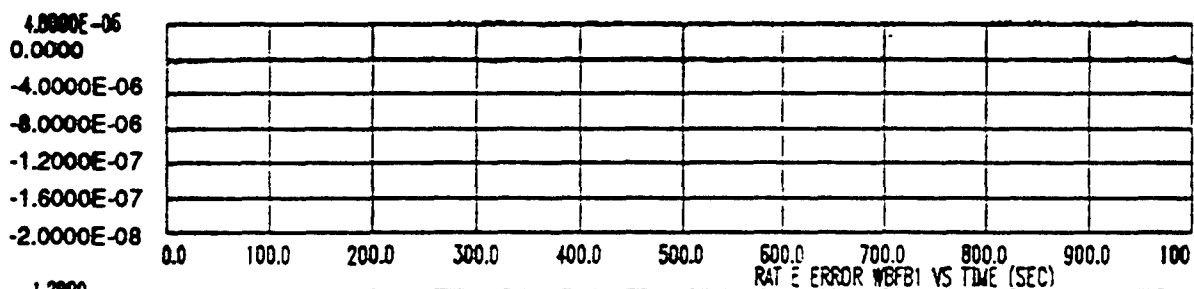
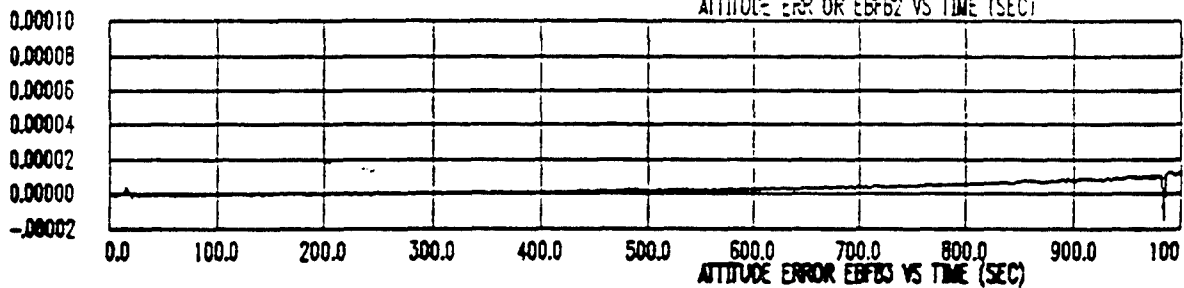
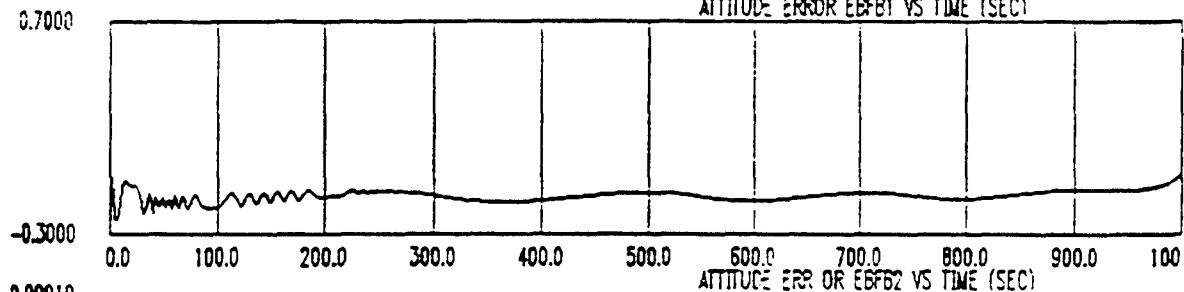
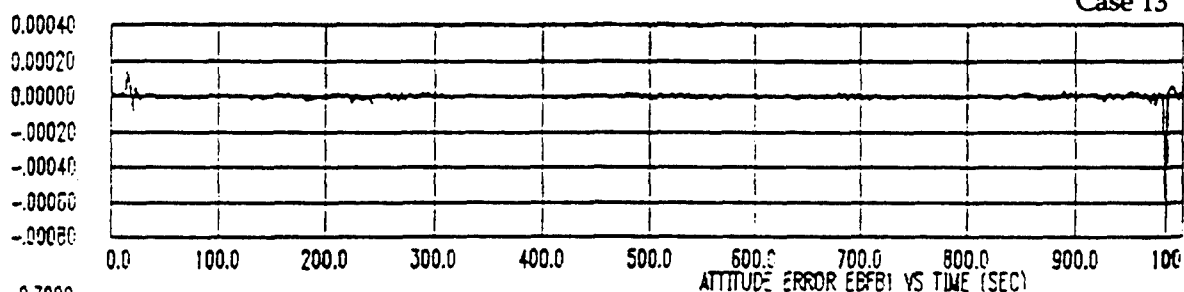


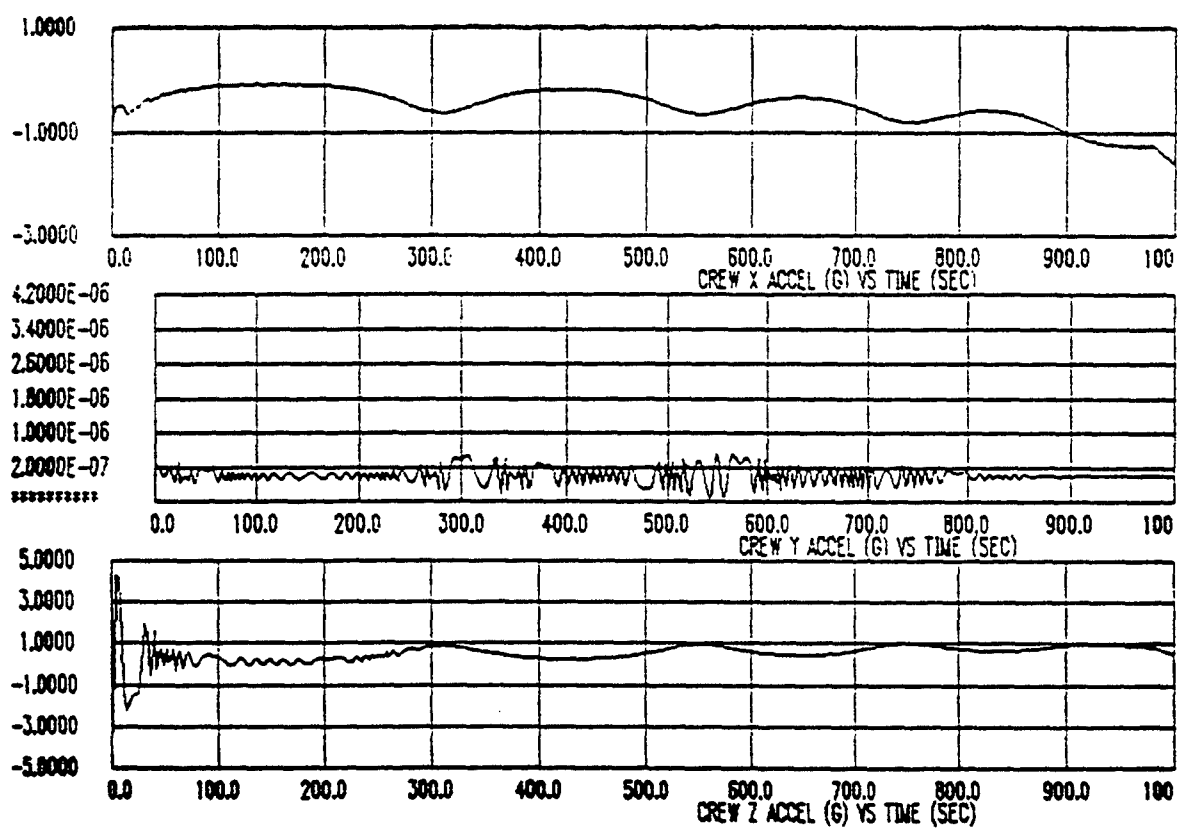






Case 13





THIS PAGE INTENTIONALLY LEFT BLANK



DEPARTMENT OF THE AIR FORCE  
HEADQUARTERS 88TH AIR BASE WING (AFMC)  
WRIGHT-PATTERSON AIR FORCE BASE OHIO

MEMORANDUM FOR: DTIC - OQ

3 March 2005

Attn: Larry Downing  
8725 John J. Kingman Rd.  
Ft. Belvoir VA 22060

FROM: 88 CG/SCCM (FOIA Office)  
Bldg 1455  
3810 Communications Blvd  
WPAFB OH 45433

SUBJECT: Freedom of Information Act (FOIA) Case, WPAFB FOIA Control # 05-098LK

1. On 16 Nov 2004, we received a FOIA request for document ADB 236817, "National Aerospace Plan Special Study on Crew Escape Phase IV, Vol 2, Final Report, R.E. Zegler, A. Bermudez, Jul 1990, 254 pp. Rockwell Intl." The current distribution statement B (unclassified/limited) is no longer applicable. The document has been reviewed by The Air Force Research Lab Human Effectiveness Directorate, (AFRL/HE) and it has been determined that the distribution statement should be changed to statement A (publicly releasable).

2. I am the point of contact and can be reached at (937) 522-3091 or DSN 672-3091.

A handwritten signature in cursive script, reading "Lynn Kane", is positioned above the typed name.

Lynn Kane  
Freedom of Information Act Analyst  
Management Services Branch  
Base Information Management Division

Attachment  
AFMC Form 559  
AFMC Form 556  
FOIA Request