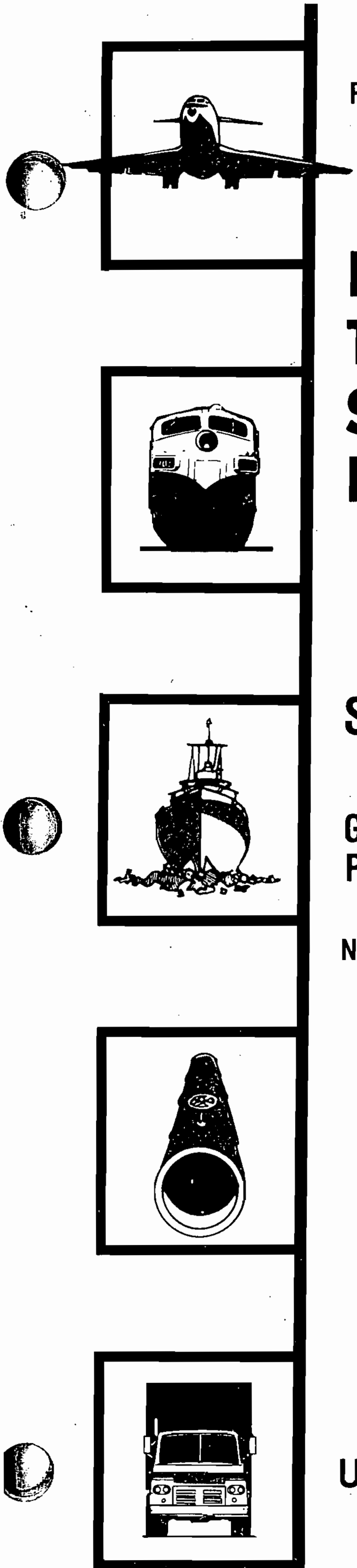


File copy — do not remove

PB83-917004

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SAFETY REPORT

GENERAL AVIATION CRASHWORTHINESS PROJECT, PHASE ONE

NTSB/SR-83/01

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB/SR-83/01	2. Government Accession No. PB83-917004	3. Recipient's Catalog No.
4. Title and Subtitle Safety Report: General Aviation Crashworthiness Project, Phase One.		5. Report Date June 27, 1983
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Technology Washington, D.C. 20594		10. Work Unit No. 3741
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Safety Report 1972 - 1981
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Between 1972 and 1981, more than 21,000, or 25 percent, of the occupants of general aviation aircraft involved in accidents were killed or seriously injured. The standards for occupant protection in general aviation aircraft have remained essentially unchanged for about the last 30 years. During this period, however, there have been major advances in crashworthiness technology. With the application of existing crashworthiness technology, it is not unreasonable to expect a substantial reduction in the over 21,000 deaths and serious injuries.

The general aviation industry recently has expressed a desire to more fully apply crashworthiness technology to aircraft. However, real-world data on the reaction of the airplane, its components, and the occupants to a crash, are needed to develop design criteria. As part of its ongoing work in the area of general aviation crashworthiness, the Safety Board has undertaken a special program of investigation that will provide the real-world data necessary to establish an envelope of typical general aviation accident impact deceleration loads and to describe crash scenarios for a range of general aviation accidents for which design for passenger survivability is feasible.

This report, the first of a projected series, explains the Safety Board's crashworthiness program, its objective, and its goals. It presents a description of the crashworthiness analysis methodology used, demonstrates its validity, and provides an example demonstrating its application.

17. Key Words General aviation accidents; crashworthiness; crash loads; accident investigation; accident investigation methodology; crash pulse; kinematics.		18. Distribution Statement This document is available to the public through the National Technical Information Service Springfield, Virginia 22161	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 94	22. Price

NTSB Form 1765.2 (Rev. 9/74)

CONTENTS

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

SAFETY REPORT: GENERAL AVIATION CRASHWORTHINESS PROJECT, PHASE ONE

Adopted: June 27, 1983

INTRODUCTION

Between 1972 and 1981, 41,319 general aviation accidents of all types 1/occurred. Of the over 83,000 occupants of these aircraft, more than 21,000, or 25 percent, were killed or seriously injured. About 34 percent, or more than 14,000 of the accidents were classified as relatively nonsevere 1/ and resulted in fatal or serious injuries to 1,073 occupants. The accidents which were classified as relatively severe comprised about 59 percent, or over 24,000, and resulted in fatal injuries to over 11,000 occupants and serious injuries to almost 6,000 occupants.

Since its inception, the Safety Board has been concerned about the limited emphasis which has been placed on improving the quality of occupant protection in general aviation aircraft. Since 1970, the Safety Board has issued 23 safety recommendations (see appendix A) and has conducted two special studies 2/ which addressed general aviation crashworthiness 3/ and occupant protection.

The standards for occupant protection in general aviation aircraft have remained essentially unchanged for about the last 30 years. During this period, there have been major advances in crashworthiness technology, many of which resulted from government/industry research and investigative projects conducted in the late 1950's and the early 1960's. The projects, which included full scale crash testing of a variety of aircraft, were performed in all areas of crashworthiness, including postcrash fire, seats/restraints, cockpit/cabin environment, and the crash acceleration environment.

Much of the information obtained from the projects, as well as information from earlier studies, was incorporated into the first and subsequent editions of the Aircraft Crash Survival Design Guide 4/ and first released to the public by the Army in 1967.

1/ To facilitate further analysis, the accident types were divided into two accident categories — relatively severe and relatively nonsevere accidents. The severe accidents included collisions with the ground or other objects, stall/spin accidents, and some accidents following engine failure or malfunction. Typical of the nonsevere accidents were ground loops, hard landings, gear-up landings, nose-overs, or under/overshoots. Not included were accidents such as propeller strikes, inflight structural separations, and midair collisions.

2/ Special Study, "General Aviation Accidents: Postcrash Fires and How To Prevent Or Control Them" (NTSB-AAS-80-2); Safety Report, "The Status of General Aviation Aircraft Crashworthiness" (NTSB-SR-80-2).

3/ Crashworthiness refers to the capability of a vehicle to protect its occupants during a crash.

4/ Aircraft Crash Survival Design Guide, USARTL-TR-79-22, Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, 1980.

Since that time the document has been revised periodically to reflect the changing technology in crash survivability. However, in spite of the availability of the information, only the Army has chosen to apply it fully to their helicopter design standards.

The Safety Board believes that had the existing crashworthiness technology been applied, most of the 1,073 deaths and serious injuries which occurred in the nonsevere accidents would have been avoided. Although the percent reduction in the number of deaths and serious injuries in the more severe accidents would not be as great as in the nonsevere accidents, it is still not unreasonable to expect that there would have been substantially fewer than the 17,000 deaths and serious injuries which did occur in these accidents.

The Federal Aviation Administration (FAA) has not upgraded existing occupant protection standards or incorporated new standards into the existing regulations for civil airplanes in a timely manner. This inaction has influenced the general aviation industry, which has not taken full advantage of existing crashworthiness technology to upgrade occupant protection in newly manufactured airplanes of current design or in the design of new airplanes.

In the last several years, interest regarding general aviation crashworthiness has gained exposure from sources other than the FAA and NTSB. In February 1983, a Government/industry group, including representatives of the General Aviation Manufacturers Association (GAMA), met at the National Aeronautics and Space Administration's (NASA) Langley, Virginia, facility to study small airplane stall speed. The findings of the group regarding crashworthiness included: (1) the mandatory availability and use of upper torso restraints in small aircraft could provide an immediate improvement in crashworthiness; (2) there currently is an adequate body of knowledge for the issuance of initial rules pertaining to structural crashworthiness for small airplanes; and (3) additional research is needed to define a crash scenario representative of survivable accidents on which crashworthiness performance standards can be based.

Also in February 1983, the General Aviation Safety Panel (GASP), an industry task force which was convened at the invitation of the FAA, issued a position paper containing several recommendations dealing with crashworthiness. Like the Government/industry group, the task force recommended mandatory installation and use of shoulder harnesses as soon as practicable. It also recommended that the development of new crashworthiness design standards be expedited. One of the immediate goals for this recommendation was to "provide a means for collecting meaningful accident data on the effectiveness of seat restraints and harnesses. Such "real-world" data would be compared with experimental results in order to provide a broader basis for creating design criteria."

The Safety Board is in a unique position to collect and analyze "real-world" data on crash forces and the effectiveness of seats/restraints, as well as to help to define realistic general aviation crash scenarios. To assist the manufacturers and FAA in defining reasonable design crashworthiness objectives, the Safety Board has undertaken a special program of investigation that will provide the "real-world" data necessary to establish an envelope of typical general aviation accident impact deceleration loads and to describe crash scenarios for a range of general aviation accidents in which design for passenger survivability is feasible. If specific safety problems are observed in the course of these investigations which warrant immediate attention, they will be addressed immediately in separate safety recommendations. The data regarding occupant protection/crashworthiness also will assist the Safety Board in assessing the continuing validity of its past safety recommendations and in developing new recommendations. This initial report explains the crashworthiness program, its objective, and its goals. It presents a description of the crashworthiness analysis methodology used, demonstrates its validity, and provides an example demonstrating its application. It should be noted that the scope of this report is limited to the presentation of the investigative and analytical methodology, and does not include any detailed analyses of data obtained from the Board's accident investigations.

CRASHWORTHINESS PROGRAM

The Safety Board's General Aviation Crashworthiness Program is a multiyear project initiated in October 1981. The field phase of the program was begun on January 1, 1982, concurrent with the introduction of an expanded Safety Board accident/incident report form (NTSB Form 6120.4). (See appendix B.) The program provides for a systematic investigation of general aviation airplane accidents with emphasis on crashworthiness.

Crashworthiness investigations gather data that are useful in determining the adequacy of current airplane design practices which affect occupant survivability. The parameters determined from these investigations include the nature of the impact conditions of the airplane, the amount of structural deformation, the approximate forces imposed on the structure and occupants, occupant injuries, and injury-producing mechanisms -- both mechanical and accelerative.

Program Objective and Goals

The objective of the crashworthiness program is to develop and disseminate to the FAA and the general aviation industry an envelope of likely peak decelerative forces occurring in survivable 5/ general aviation airplane accidents, and their effects on the occupants and airplane structure for the purpose of upgrading occupant protection design standards. The program will describe and categorize, by severity, crash scenarios for a range of survivable airplane accidents. Also, the program will attempt to correlate the scenario categories with the savings in lives and the reduction in serious injuries which might be achieved by upgrading the design standards of general aviation airplanes to levels compatible with these scenario categories.

The following goals have been set to accomplish the program objective:

- o Establish investigative techniques which will facilitate the collection and analysis of crashworthiness data for general aviation accidents.

- o Collect and evaluate, through detailed analysis, crashworthiness data on a select sample of survivable general aviation accidents.

- o Validate analysis techniques which can be applied to the future analysis of the substantial amount of crashworthiness data which will be collected routinely in general aviation accident investigations.

5/ A survivable accident is one in which the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided throughout the crash sequence.

- Define crash pulses that describe the impact severity of survivable accidents in general aviation airplanes currently in use.

- Identify injury-producing mechanisms related not only to the fuselage structure, but to control/display designs, crew/passenger seats, and possible deficiencies in the availability and use of seat belts/shoulder harnesses, and correlate these with the crash loads.

- Describe and categorize crash scenario severity based on changes in velocity and impact angle.

- Use the crashworthiness data to validate past findings and to support future recommendations.

Data Requirements

The crashworthiness evaluation of general aviation airplane accidents requires the collection of data addressing three areas: occupant injuries, impact severity, and the airplane's occupant protection capabilities. The causes of injury can be related to both the severity of the impact and the ability of the structure (including seats and restraints) to protect the occupant from the impact. These three areas are focused on by engineers in all vehicle crashworthiness design efforts.

Occupant Injuries.—The occupant injuries of concern in the crashworthiness study are those resulting from either accelerative or mechanical sources. Abrupt acceleration 6/ (+ or -) of the body or parts of the body may result in injuries, such as hyperextension of the cervical spine (whiplash) from longitudinal acceleration, or transection of the aorta from acceleration in the vertical direction. Mechanical injuries, also referred to as blunt trauma or impact injuries, result from the body's striking or being struck by another object. A typical mechanical injury is a fractured skull or facial laceration which results from head contact with the instrument panel, seat back, or window jamb during a crash sequence. The detailed data concerning occupant injuries are collected from autopsy records, hospital records, and interviews with victims and medical/rescue personnel who responded to the accident.

Identification of the injury mechanisms or the direct causes of the injuries, an important part of the investigation process, will provide information on the occupant protection capabilities of the airplane. Although injuries caused by accelerative forces may be identified as such, the magnitude of the forces causing the injuries must be identified through kinematic 7/ analysis of the airplane crash. Impact injuries, in general, can be traced by physical evidence to occupant contact with particular structures in the cockpit or cabin of the airplane.

Airplane Impact Severity.—The severity of a crash is stated in terms of a crash pulse which relates acceleration ("G") 8/ acting at the airplane's center of mass to time. The pulse is determined by the analysis of the airplane's kinematics which is established

---

6/ Acceleration is the change in velocity with respect to time. In general, the term "acceleration" refers to an increase in velocity with respect to time, and is expressed as a positive (+) number. A decrease in velocity with respect to time is a negative (-) acceleration, or a deceleration.
7/ Kinematics is a branch of dynamics that deals with aspects of motion apart from consideration of mass and force.
8/ Acceleration vs. time where acceleration in G's is the ratio of a particular acceleration to the acceleration of gravity. (See Glossary of Terms.)

through the reconstruction of the crash sequence. The kinematic analysis requires knowledge of the velocity change of the airplane, the distance over which the velocity change took place during the principal impact, 9/ the airspeed, the flightpath angle, the terrain angle, the airplane's attitude at the principal impact, and the sliding distance after the impact. These values are determined from physical evidence, including damage to the airplane structure, damage to objects in the crash path, and ground scars. Additional data that are useful in establishing the required parameters can be obtained from radar data, aerodynamic analyses, and flight data recorders when they are available.

Occupant Protection Capabilities.—The determination of how well an airplane can protect its occupants in a crash depends on more than documentation of injuries and analysis of the airplane's kinematics. Information is required on how much energy of the crash was absorbed by the structure and components through plastic or permanent deformation. Also, information is needed on whether or not the occupants were restrained sufficiently to allow them to have participated in the airplane structure's deceleration, or whether or not they experienced an abrupt, and perhaps nonsurvivable deceleration, because the tiedown chain 10/ failed to restrain them. Such information is gathered during a detailed examination of the airplane wreckage. Also, fuselage deformation must be measured to determine whether a livable volume is maintained in the occupied area. Impact damage must be documented, and matched to the evironmental evidence, i.e., ground scars, tree strikes, and other collisions with obstacles, and evidence must be collected on seats and on the availability and use of restraints, and failures or deformation of these components and the components comprising the rest of the tie-down chain.

ANALYSIS METHOD

Impact Severity

Impact severity can be determined through either an energy management analysis or a kinematic analysis. The energy management analysis uses detailed mathematical modeling of the main airplane structure, using finite element or lumped mass modeling techniques and requires indepth knowledge of the physical properties of major structural members and their responses under dynamic conditions. Similar techniques have been employed to model the human occupant. Sophisticated computer programs, such as KRASH and SOM-LA (Seat/Occupant Model-Light Aircraft), which were developed as design aids and research tools, provide detailed analytical results of the dynamic response of the airplane and the occupant. However, because of the considerable time and technical expertise that are required to model different airplanes in order to utilize such programs, their use is precluded in day-to-day field investigations.

The kinematic analysis adopted by the Safety Board simply requires data that can be collected at the crash scene using standard investigative techniques. The analytical process is straightforward and relatively simple to accomplish. The beginning and end of the principal impact are defined, and the peak decelerative force is derived from the estimated velocity change and the distance traveled by the airplane's center of mass

9/ Principal impact occurs when the major decelerative forces are experienced and the most damage is sustained by the fuselage. The principal impact may not necessarily be the initial impact.

10/ The seat, restraints, seat tracks, bulkhead/floor, subfloor structure, and attachment hardware which act as a system to restrain and to protect the occupant.

during the impact. Because precise engineering information about the reaction of the structure between the starting and the stopping points of the principal impact of a particular crash is not used, the kinematic analysis will not yield a unique crash pulse shape which describes the precise decelerative forces acting on the airplane throughout the crash. However, the analysis will provide a set of peak decelerative force values which should bracket the unique or actual peak force for that crash by determining the minimum possible peak decelerative force and the peak decelerative force for a triangular shaped pulse. In bracketing the actual peak decelerative force, the assumption is made that the decelerative forces are proportional to the mass of structure crushed, which in turn, influences the shape and magnitude of the crash pulse. This analysis methodology worked well when the NTSB applied it to crash tests of general aviation airplanes that were performed by NASA.

To establish an envelope of representative crash forces from the bracketed solutions, it is necessary to use all known facts from field and test data to narrow the bracket for each crash pulse to approach its precise solution. However, as will be discussed further in the Method Verification section, the data available from the crash scene may be so limited that the kinematic reconstruction can be performed only for one direction, i.e., the physical evidence may be sufficient to allow an analysis of the vertical crash loads but may be insufficient to allow an analysis of horizontal crash loads. Also, even if in one accident all data could be measured precisely and loads calculated exactly, that accident would not necessarily be representative of all survivable general aviation accidents. Therefore, a substantial number of crash analyses is required to establish the pulse(s) that are representative of current general aviation airplanes. While it is recognized that there are limits to the accuracy of these individual crash analyses, the overall program is expected to yield an envelope of peak crash pulse values of sufficient accuracy and consistency to be usable in the formulation of requirements for crashworthiness airplane design and testing.

Certain data needed to establish the crash pulses by kinematic analysis are obtained from two procedures. The first procedure is the visualization of the crash sequence, the results of which provide impact attitude and crushing distance. The second procedure is the development of a crash pulse that, when integrated, will generate the documented velocity change and stopping distance.

Visualization

Orthographic Drawing.—The most effective method of visualizing the impact attitude, flightpath angle, and the amount of crush that occurs is to create an orthographic drawing incorporating the impact data gathered in the field. Damage to the airframe, ground scars, and tree strikes can be documented through the use of measurements, photographs, sketches, and drawings and notes made on airplane three-view drawings. When all available impact information is documented, reconstruction of the airplane's impact attitude is possible, and more confidence can be placed in the attitude reconstruction when several ground scars are present. The technique requires that the ground scars be aligned with the airplane components which caused them. Typically, distinctive gouge marks are left by components, such as landing gears, propellers, engine nacelles, and wing tips. Changes in the airplane's attitude may result from these components striking the ground during the crash sequence.

Crush Line.—Another technique for establishing the impact attitude of the airplane is through the use of the crush line. The crush line is formed as a result of the airframe being crushed against a surface and leaving a distinctive flat or "stamped" area on the airframe. In general, the crush line can be identified by small, tight wrinkles in the skin, or by deformation of the airframe surfaces around longerons or stringers. This type of damage is caused by direct contact between the airplane and the ground. Points representing the edges of the damaged areas are plotted on an airplane three-view drawing and straight lines are drawn between these points. (See figure 1.) Several lines intersect to create an imaginary plane or flat surface, i.e., crush line. The impact attitude can be determined graphically by relating the crush line to the impact surface. The rotation required to place the crush line on the impact surface defines the airplane's pitch, roll, and yaw attitudes at impact relative to that surface. Correcting for surface slope will yield these attitudes relative to the horizon.

Once the crush line and impact attitude are established, a drawing is made with the airplane in that attitude. Lines can be added to the drawing parallel to the impact surface which will act as distance marks and will help to display the progressive crushing of the structure up to the crush line or stopping point. (See figure 2.)

The pitch attitude of the airplane at impact also can be calculated by algebraically adding the values for the flightpath angle and the angle of attack. The flightpath angle is determined by aligning sequentially tree or object strikes and the ground impact point. The angle of attack can be estimated based on the airplane's speed and maneuvers just before impact. Although not as precise as using several ground scars, the value for pitch attitude derived by this method is sufficiently accurate for purposes of analysis when no other information is available. (See Glossary of Terms.)

Change in Velocity.—Once the stopping distance has been established, the change in velocity 11/ during the principal impact must be determined. The initial velocity is estimated based on knowledge of the airplane's maneuvers just before impact, the airplane's performance parameters, the pilot's statement, or a witness statement. For example, an airplane may have been seen flying level in a nose high attitude and pitching over just before hitting the ground. From this information, it can be assumed that the airplane was at or near stall speed when the impact occurred. Another example is a twin-engine airplane that crashes out of control after power is lost in one engine. In this case, it is reasonable to estimate that the initial velocity was near the airplane's single-engine minimum control speed (V_{mca}). Witness statements, radar data, and airspeed readouts from flight data recorders, if available, also are helpful in estimating the initial velocity.

The total velocity component of the principal impact acts along the flightpath. The flightpath angle is used to break down the total velocity component into its vertical and horizontal components, relative to the horizon. (See figure 3.) In the vertical direction, the final velocity is used to determine the velocity change. The final velocity usually is zero because the maximum vertical crush is achieved when the downward movement is stopped by the ground during the principal impact. As vertical velocity becomes zero the maximum vertical crush is achieved. In the horizontal direction, most airplanes tend to slide along the ground for some distance after the principal impact, and the difference between the initial velocity and the final velocity (a value greater than zero) must be established for the principal impact.

11/ The change in velocity is the difference between the initial velocity (the velocity just prior to the principal impact) and the final velocity (the velocity just after principal impact).

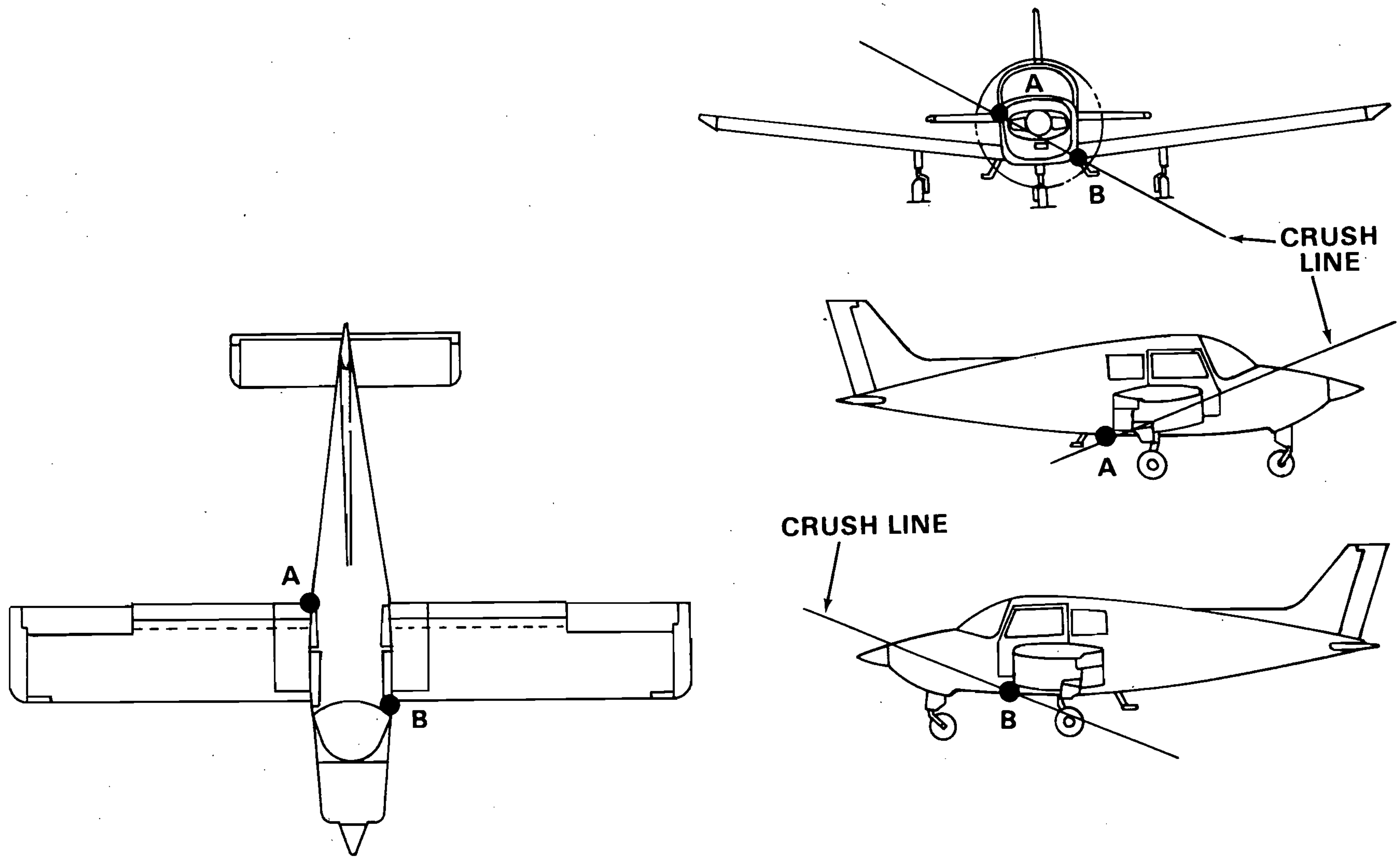


Figure 1.—Crush line documentation.

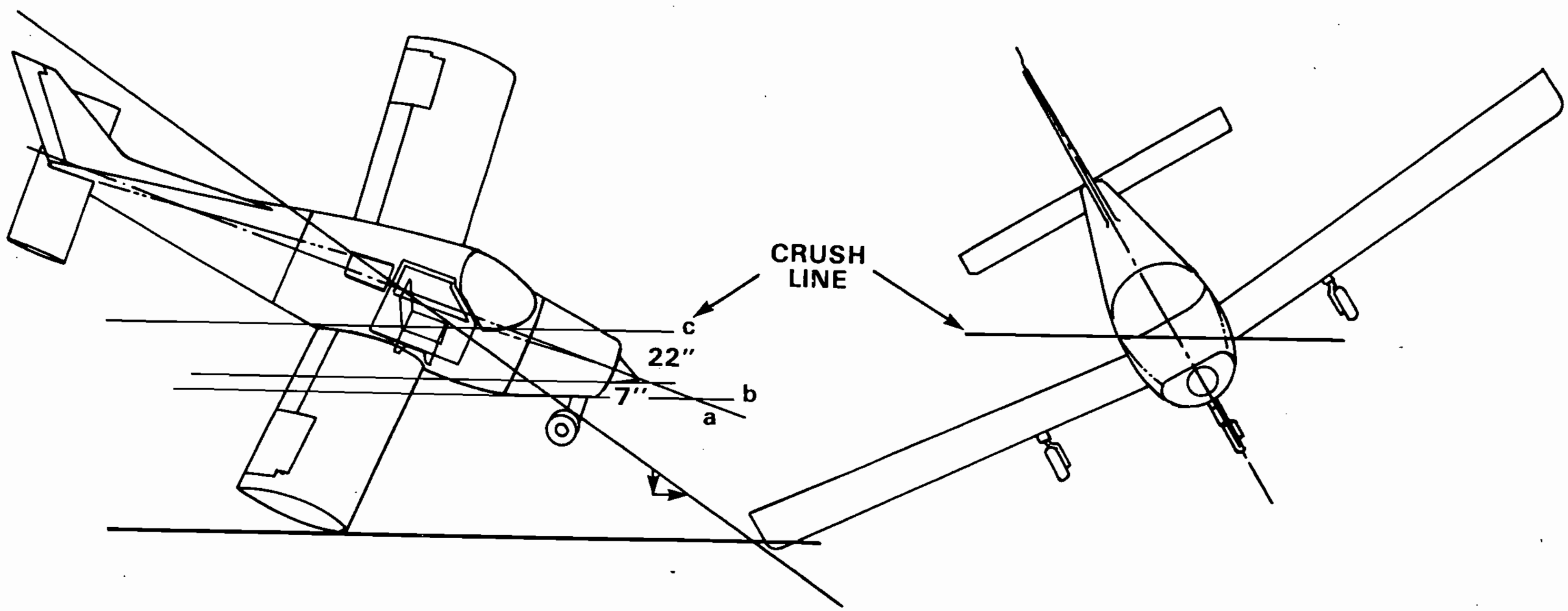


Figure 2.—Crush line and distance marks.

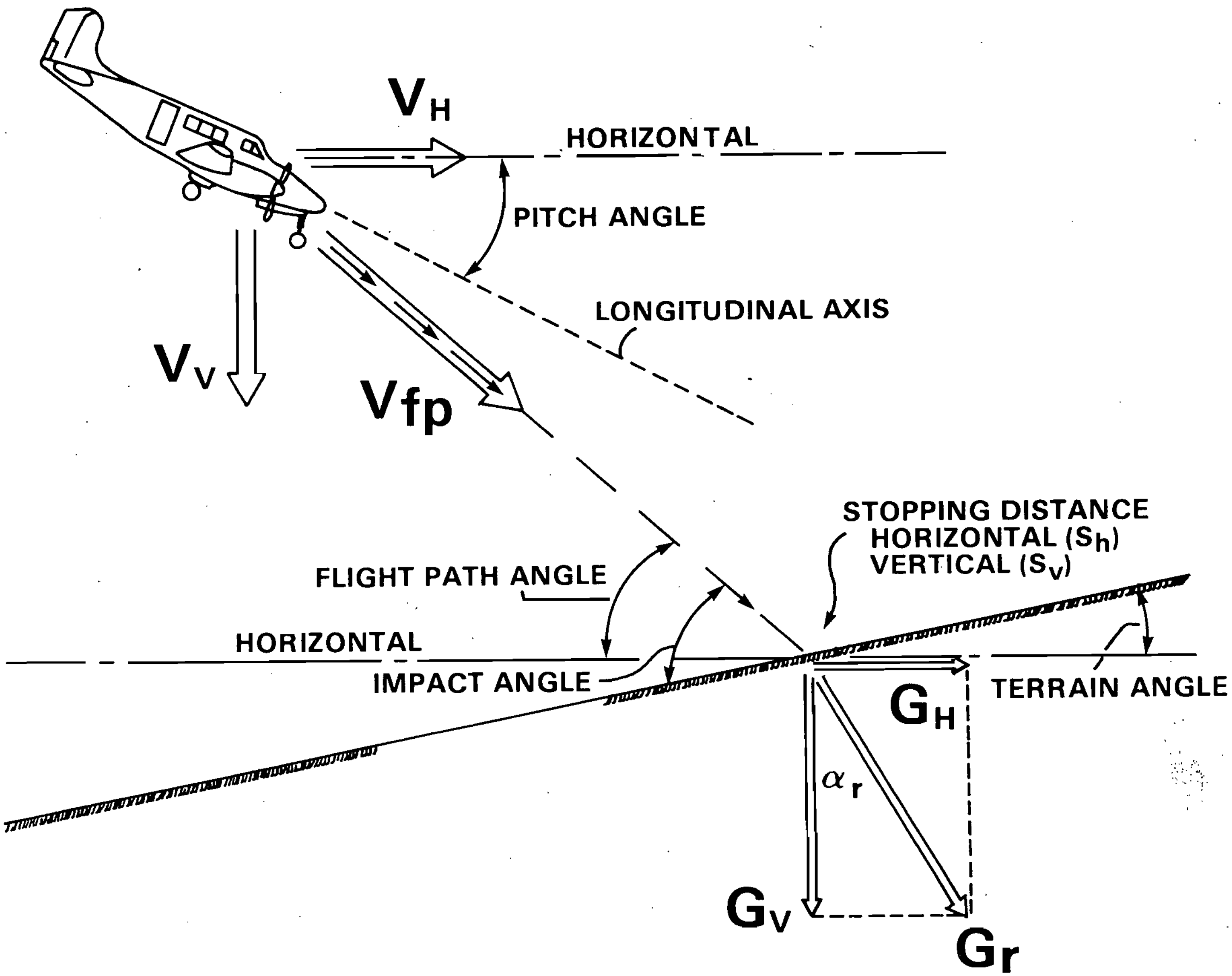


Figure 3.--Vector components.

In crashworthiness analysis, the velocity change is the most critical item and is the most difficult parameter to estimate. In the formulas for the calculation of the G-loads, the velocity appears as a squared factor, thus magnifying small errors in the estimate. Last second maneuvers of the airplane (controlled or uncontrolled) also can change the velocity by a small but important amount. Accounting for these changes is a difficult task and care must be taken to utilize all available information.

After establishing values for distance and velocity changes during the principal impact, the final step is to estimate the horizontal and vertical crash pulses, or a combined pulse, which represents the change in velocity over the measured stopping distance.

Pulse Shape Development

Quick Look Analysis.--Because NASA general aviation crash test data shows that a triangular crash pulse shape accurately describes the principal impact in the test crashes, a triangular pulse shape (T) will be used to calculate the most reasonable peak decelerative force in the Safety Board crash analyses. The following formula will be used for calculating the triangular crash pulse shape:

$$G_T = V^2/gS$$

where V = impact velocity (ft/sec)

g = earth gravitational constant (32.2 ft/sec^2)

S = stopping distance (ft)

The minimum peak decelerative force, based on the same change in velocity and distance, is calculated using the formula for the constant (rectangular shaped) pulse (C). The constant crash pulse shape is calculated using the following equation:

$$G_C = V^2/2gS$$

where V = impact velocity (ft/sec)
g = earth gravitational constant (32.2 ft/sec^2)
S = stopping distance (ft)

The total time of the pulse is calculated as:

$$t = V/gG_C$$

For example, figure 4 depicts an airplane that crashed in a 30° nose down attitude. The 4.6-foot line represents the total depth of crush. Impact velocity was 90 miles per hour, or 131.94 ft/sec. For the vertical crash pulse, the impact velocity would be V_v = 131.94 Sin 30° = 66 ft/sec. The minimum peak pulse in the vertical direction is then calculated as:

$$G_{vC} = V_v^2/2gS = 66^2/2(32.2)\ 4.6 = 14.7\ G_{vC}$$

The triangular (maximum) peak $G_{vT} = V_v^2/gS = 66^2/32.2\ (4.6)$ or 29.4 G's, which, for this shape, is twice the minimum peak value. This results in a range (bracket) of 14.7 to 29.4 G's. Both pulses require a time of:

$$t = V_v/gG_{vC} = 66/32.2\ (14.7) = 0.139 \text{ second}$$

This method results in a fast and reasonably accurate "quick look" evaluation of an accident and only requires that the values for velocity change and total stopping distance be known. However, a more detailed approach will yield a more accurate crash pulse and, with the use of shaping techniques, the range of accelerations between the calculated minimum and maximum peak G-loads can be better defined, as shown below.

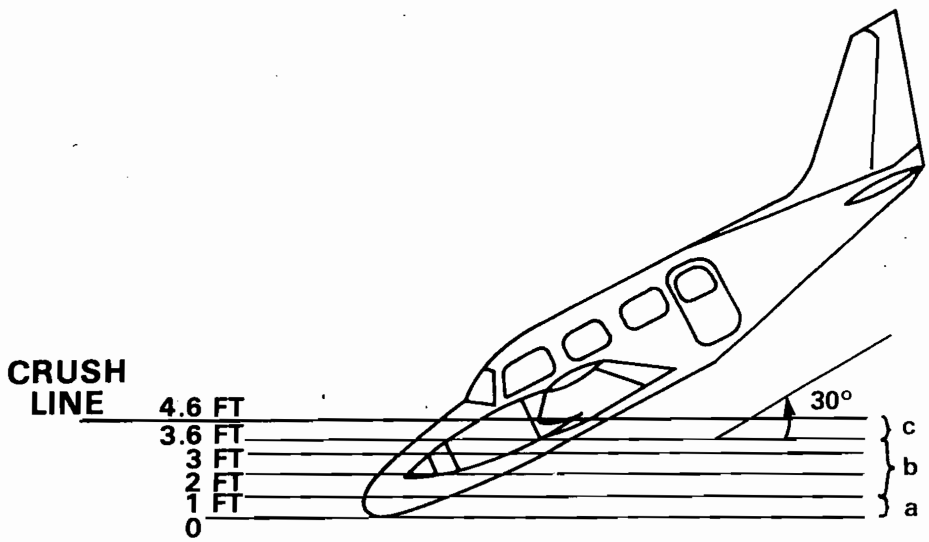


Figure 4.--Crash visualization.

Detailed Analysis Based on Shaping Techniques.—The following example illustrates how a detailed vertical pulse shape is developed. First, as in the "quick look" method, a visualization of the crash is developed, including the parallel lines showing the increasing amount of structure involved as the airplane crushes. Figure 4 shows that the nose area, which is comprised of lightweight material, is involved in the first 1 foot of crush (a). At the 1-foot mark, the components involved include some lightweight skin, the nose gear structure, and small frame structure (b). Starting at the 3.6-foot line, the structure being crushed includes the cockpit bulkhead, engine, engine mounts, cockpit floor, and side walls (c).

As the crush progresses to the areas of increasingly massive structure, higher decelerations, or G-loads, are expected to occur. Allowances are made in the analysis for the differences in the type and mass of the crushed structure. The least massive structure, referred to as nonproductive structure, is unable to support major loads and, thus, collapses easily. This structure has a crushing distance, but it does not produce a significant deceleration. In this example, the distance from 0 to 1 foot is comprised of lightweight material and imparts no crash loads to the occupants while it is crushing; hence, it is nonproductive.

Nonproductive crushing is not considered when estimating acceleration levels in a pulse. However, an increase in the mass of structure involved will cause the crash pulse to be modified (shaped), based on the assumption that the magnitude of the crash pulse generally is proportional to the mass of structure being crushed. Correcting for nonproductive crushing and the increase in the mass of the structure involved is not precise, but these corrections make the results more accurate by eliminating large errors and by skewing the curves in a logical manner.

Also, as in the "quick look" procedure, the minimum and triangular peak G's are calculated for the purpose of establishing a reasonable range of values. Since the first foot of crushing involves nonproductive structure, the stopping distance of 4.6 - 1.0 or 3.6 feet is used in calculations. The minimum peak G then, is $V^2/2gS = 66^2/2\ (32.2)\ 3.6$, or 18.79 G's, and the triangular peak load is $V^2/gS = 66^2/32.2\ (3.6)$, or 37.58 G's. These values become the minimum (19 G's) and maximum (38 G's) limits for the force values in the crash analysis. (See figure 5.) It should be noted that this step is quite easy and can be included in many quick look analysis.

The next step in the detailed analysis is the modification or shaping of the constant (rectangular) pulse. This modification is performed to create a pulse magnitude and shape between the calculated minimum and triangular peak G-loads, which is more representative of the actual impact. (See figure 5). The shaping technique requires that the area under the modified constant deceleration versus time curve remains equal to the area under the unmodified curves, so that the velocity change remains the same.

Target values for changes in distance (crush) and velocity, determined from the visualization and the physical evidence, are used to facilitate shaping of the crash pulse. Although the distance targets are fixed in magnitude, they can be moved along the abscissa, or time axis. Velocity targets also are fixed in magnitude at the end points. The distance targets, which will be labeled (a) through (e) for this example, are set at Ø, 1, 2, 3, and 4.6 feet, respectively. (See figure 6.) The velocity targets, labeled (f) and (g), are set at 66 ft/sec (Ø feet crush and Ø time) and Ø ft/sec (maximum crush and total time).

Once the deceleration versus time curve has been established, it is integrated, generating the curve for velocity change. This curve, in turn, is integrated to generate the curve for distance change. (See figure 7.) A computer program has been written to perform the iterative process necessary for the integrations. (See appendix C.) The results are presented as graphs.

A four-tiered pulse is assumed, based on the previously set distance targets. Each tier of the pulse represents the average G-load over a given distance. For this case, an initial estimated value of 27 G's was assumed as the highest value for the modified constant pulse. Any of the values between the established maximum and minimum values may be chosen for the estimate. However, analytical experience has shown that the midpoint, 27G's in this case, is a reasonable value for the initial estimate. This value can be revised and the analytical procedure can be repeated for the number of iterations needed to satisfy the distance and velocity target criteria.

The 27G value and the distance targets are used to establish values for the relative magnitudes of the deceleration tiers. Judgment again is used in estimating how much of the total deceleration has occurred during each interval of crush. The results of these estimates are presented in table I.

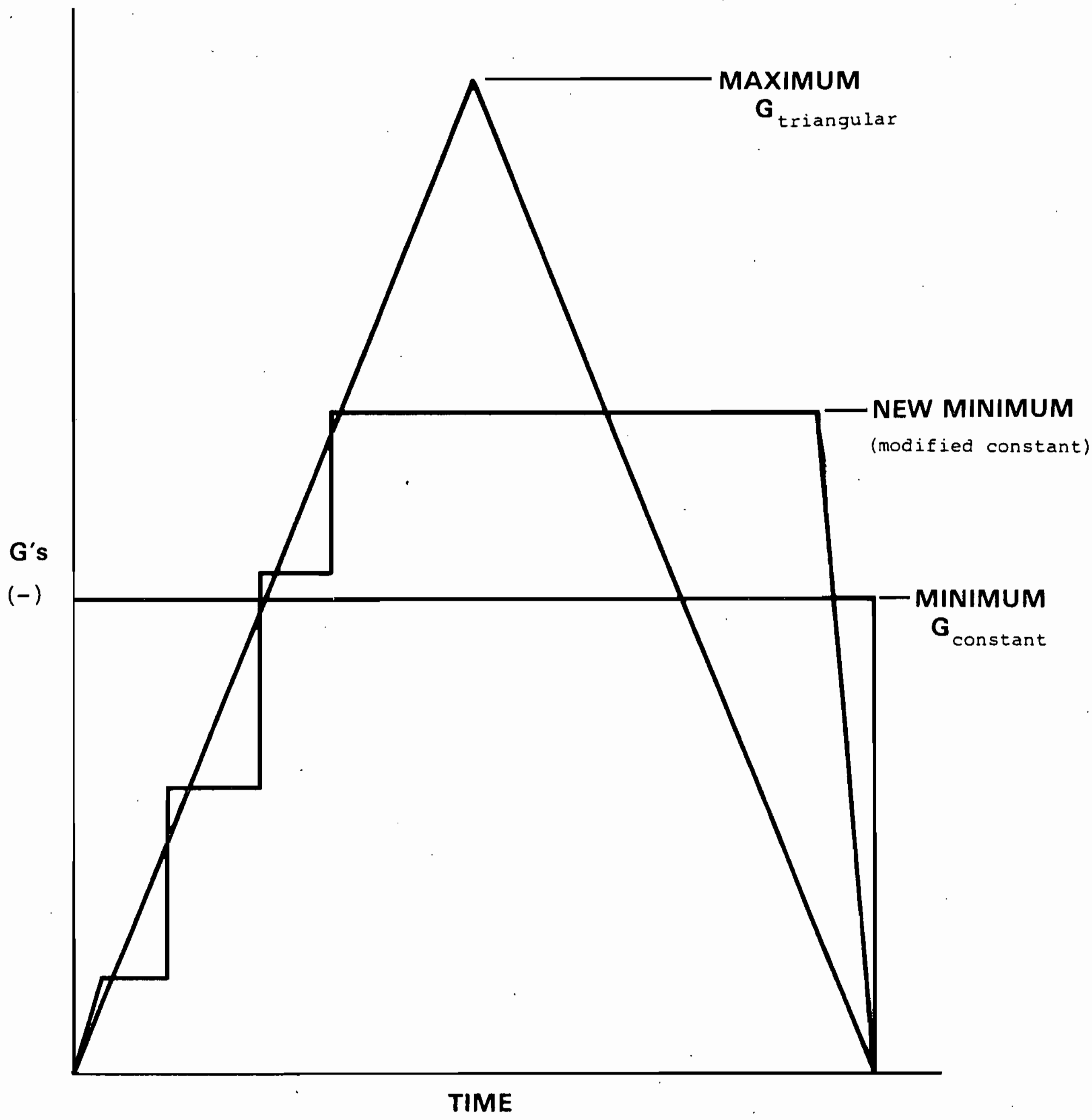


Figure 5.-- Minimum and maximum force limits.

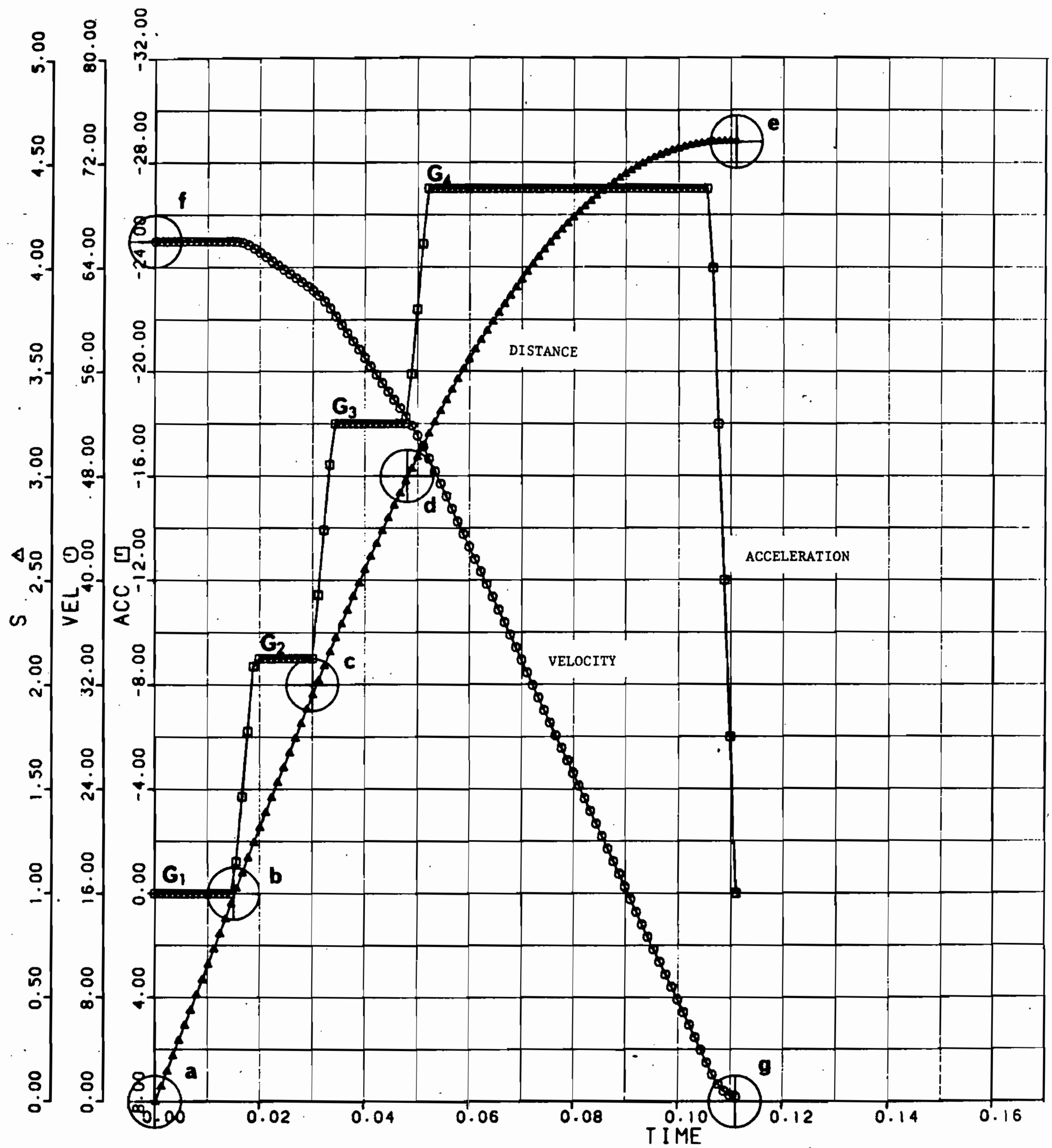


Figure 6.--Tiered crash pulse with targets.

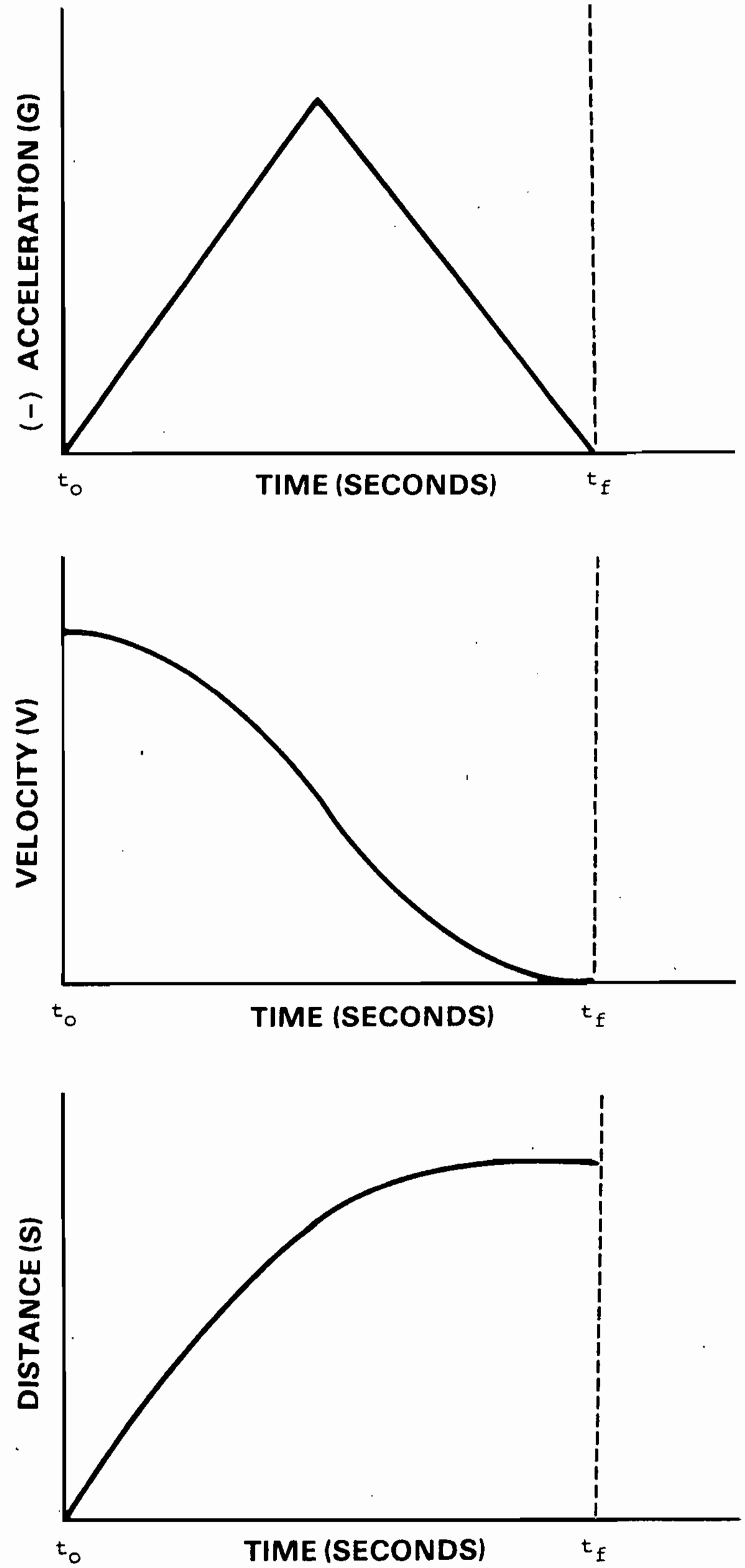


Figure 7.--Relationship of acceleration, velocity, and distance in time.

Table I.-- Estimating target magnitudes for deceleration tiers.

Crush Level (feet)	Percent of Total Deceleration		G's	
0-1	Ø % of 27 G's	=	Ø	(G_1)
1-2	33 % of 27 G's	=	9	(G_2)
2-3	66 % of 27 G's	=	18	(G_3)
3-4.6	100 % of 27 G's	=	27	(G_4)

Although many methods can be used to establish target times, it is advantageous to make the estimates as accurate as possible. This reduces the number of iterations necessary to meet the fixed target values when shaping the pulse. A method for calculating the target time is presented below.

After an average velocity is calculated for each segment, the average time for each segment is calculated, and the distance targets are set at these times. For segment 1 (Ø - 1 ft), it is assumed that there is no change in velocity; therefore, the average velocity is 66 ft/sec. The average time for this segment is calculated as:

$$t_{ave1} = S/V_{ave1} = 1/66 \text{ or } 0.015 \text{ second.}$$

Since there was no appreciable change in velocity in the first segment, the starting velocity for the second segment (1-2 ft) also is 66 ft/sec. For S_2 = 1 ft, t_2 = 1/66 or 0.015 ft/sec. The change in velocity for this segment is:

$$\Delta V_2 = gG_{s2}t,$$ where G_{s2} = the average G estimate for the segment, from table 1.

$$\Delta V_2 = 32.2(9)(0.015) = 4.35 \text{ ft/sec,}$$

giving an ending velocity of 66 - 4.35 or 61.65 ft/sec for this segment. The average velocity for the second segment is V_{ave2} = 66 -2.18 or 63.82 ft/sec. The average time for the segment is t_{ave2} = 1/63.82, or 0.016 second, for a cumulative time of 0.031 second.

Segment 3 (2-3 ft) is treated similarly, resulting in a velocity change of 9.27 ft/sec, an ending velocity of 52.38 ft/sec, and an average velocity of 57.01 ft/sec. The average time for the segment is 0.018 second, for a cumulative time of 0.049 second.

The velocity change in segment 4 (3-4.6 ft.) is from 52.38 ft/sec to Ø ft/sec, the final velocity. The average velocity is 26.19 ft/sec. The average time for this segment is t_{ave4} = 1.6/26.19, or 0.061 second, for a total pulse time of 0.110 second.

The distance targets (a) through (e) and velocity targets (f) and (g), are set at the following times:

Distance Target (ft)		Velocity Target (ft/sec)		Time (sec)
Ø	(a)	66	(f)	Ø
1	(b)			0.015
2	(c)			0.031
3	(d)			0.049
4.6	(e)	Ø	(g)	0.110

The estimated crash pulse magnitude and the velocity and distance targets are entered into the computer program, the integrations are performed, and the curves are printed as graphs. For this case, the distance and velocity plots matched their respective targets, which indicates that the pulse estimates were reasonable. (See figure 6.)

If the targets had not been met, they could have been moved along the time axis, which would have required a corresponding movement of the deceleration tiers so that they remained aligned with the distance targets. The magnitude of the crash pulse estimate (G level) also can be modified, keeping in mind the limits imposed by the assumptions of nonproductive crushing and the proportionality of decelerations to the mass of structure involved in the crushing.

It is possible to generate a number of crash pulse shapes that would be compatible with the estimated velocity change and stopping distance. However, factors which influenced the choice of the triangular deceleration pulse shape included:

- NASA crash research tests which indicated that a representative triangular pulse exists for crashes of general aviation airplanes.

- Deceleration increases as more structure becomes involved in the crush.

Figure 8 shows the tiered pulse of figure 6 with a triangular peak. As stated previously, the tiered pulse in figure 6 represents the minimum limit of the range of peak forces for the crash. The peak value for the triangular pulse in figure 8 represents the new maximum limit for the peak crash forces. As shown in the figure, all of the target values have been met, and the total pulse time has increased slightly so that the area under this curve remains equal to the area under the tiered curve.

The corrections for areas of nonproductive crushing and the differences in the amount of structure involved in crushing developed during the analysis, have resulted in a narrowing of the range of likely forces from 19 G's (18.79 to 37.58 G's) to 9 G's (27 to 36 G's).

METHOD VERIFICATION

Verification of the accuracy of the techniques used to determine the crash pulse was accomplished through the analysis of four NASA crash tests, using NASA's published data. 12/ This effort included comparison of Safety Board analyses based on physical evidence from NASA crash tests of general aviation airplanes with the actual parameters and results from those tests. Crash loads based on rectangular and triangular shaped crash pulses were calculated for each crash test.

Pitch Attitude

Several crash tested airframes, which were stored at the NASA Langley Research Center, were inspected and documented by Safety Board investigators, using the Board's normal accident investigation procedures. The goal of the exercise was to establish the airplane's impact attitude based only on the crush line and other fuselage deformation. Once the damage was documented and an impact attitude was established, a comparison was made with the NASA data, i.e., actual decelerations measured by instrumentation during the crash tests.

12/ Vaughan, V.L., Jr., and R.J. Hayduk, "Crash Tests of Four Identical High-Wing Single-Engine Airplanes," NASA Technical Paper 1699, August 1980; and, "Determination of Crash Test Pulses and Their Application to Aircraft Seat Analysis," Society of Automotive Engineers, Inc., Technical Paper 810611, April 1981.

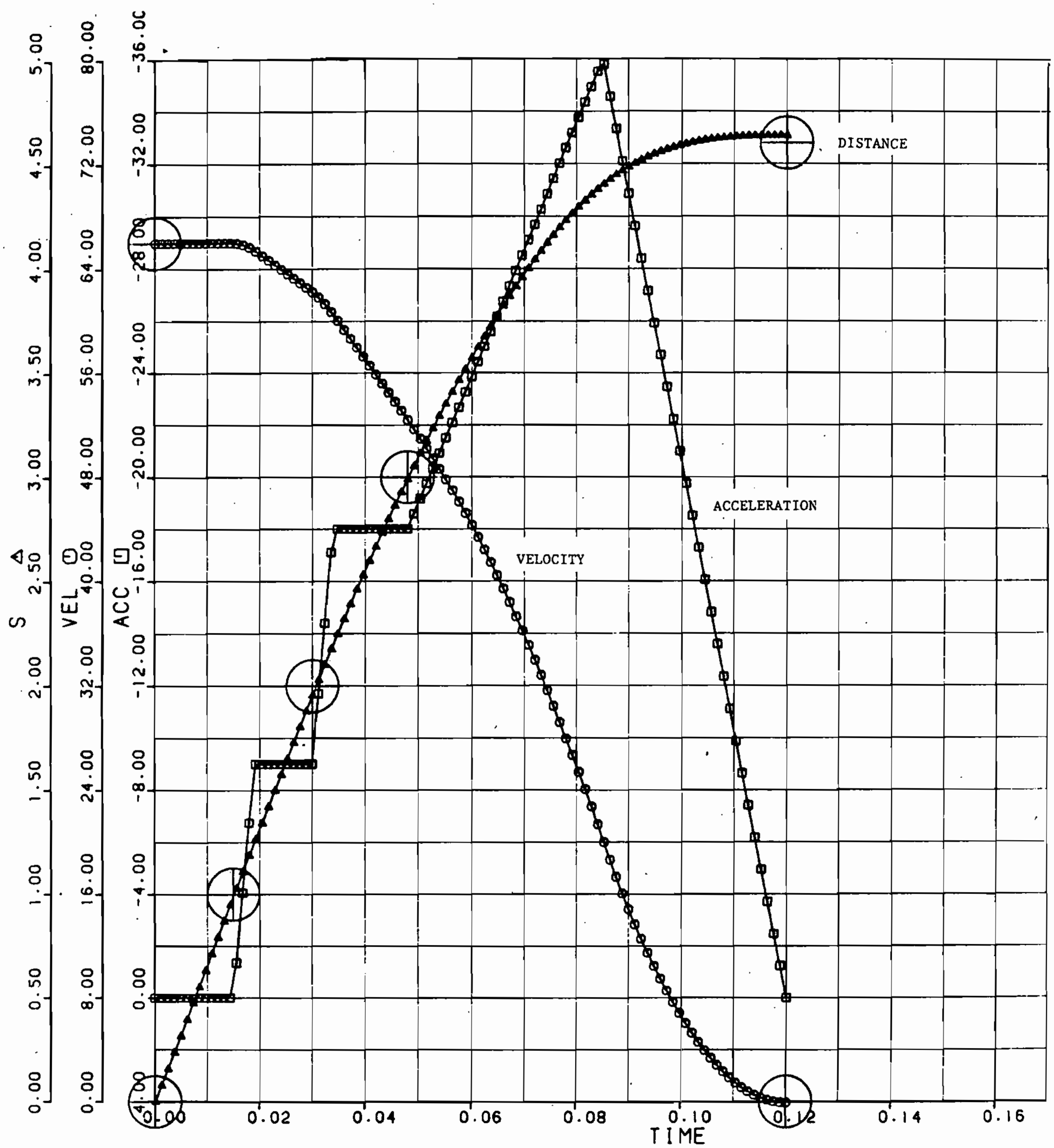


Figure 8.--Triangular crash pulse with targets.

The measurements taken from the crush lines of the test airplanes were found to approximate closely the airplanes' attitudes at full development of the crushing. The comparison measurements were taken from NASA's crash test films. The film analyses showed that when crashed on concrete, the airplanes tended to rotate or bend during the principal impact, causing a change in pitch attitude between 3° and 9°. An example of this pitch rotation was identified in the film of a 45° nose down drop test. The airplane initially contacted the ground at 45°, but at the fully crushed position, the fuselage had rotated to a pitch angle of 36°. In the analyses of other drop test films, it was found that several of the 30° nose down tests resulted in pitch attitudes of 26°, and for 15° nose down tests, the pitch attitudes at full crush development were 12°.

The crush line on test vehicle No. 14 is identified as the flat portion on the nose. (See figure 9.) When measured, the crush line shows a pitch attitude of 10° nose down. (See figure 10.) The actual test resulted in a 12° nose down pitch angle at full development.

Test vehicle No. 18 (see figure 11) illustrates how the use of only the crush line to establish attitude at impact can be misleading. The crush line is measured at 22°, but at full development during the crash, pitch was near 27°. The error in measurement is attributed to buckling of the fuselage top which caused the crush line on the fuselage bottom to stop development. Figure 12 shows the buckled area with a split rivet line. The rivet line is split 4°, so the pitch at full development could be measured as 22° plus 4°, or 26°.

Other techniques for estimating pitch attitude also were verified. One technique was the use of distinct bend lines found in the floor boards of the test vehicles. The floorboards of test vehicles Nos. 7 and 8 (see figures 13 and 14) retained their set after the crash. In vehicle No. 7, the floorboards were set at 40° after a 45° nose down drop test, and the floorboards in vehicle No. 8 were set at 28° after a 31° impact. Parallel wrinkles in the fuselage skin were reasonable indicators of pitch attitude at full development of the crush. In general, the parallel wrinkles were found to be valid indicators if they did not emanate from an area of major structure. Test vehicle No. 17 has three parallel wrinkles on each side which end in an open area forward of the spar. (See figures 15 and 16.) These types of wrinkles were found to be usable with reasonable confidence to estimate pitch attitude.

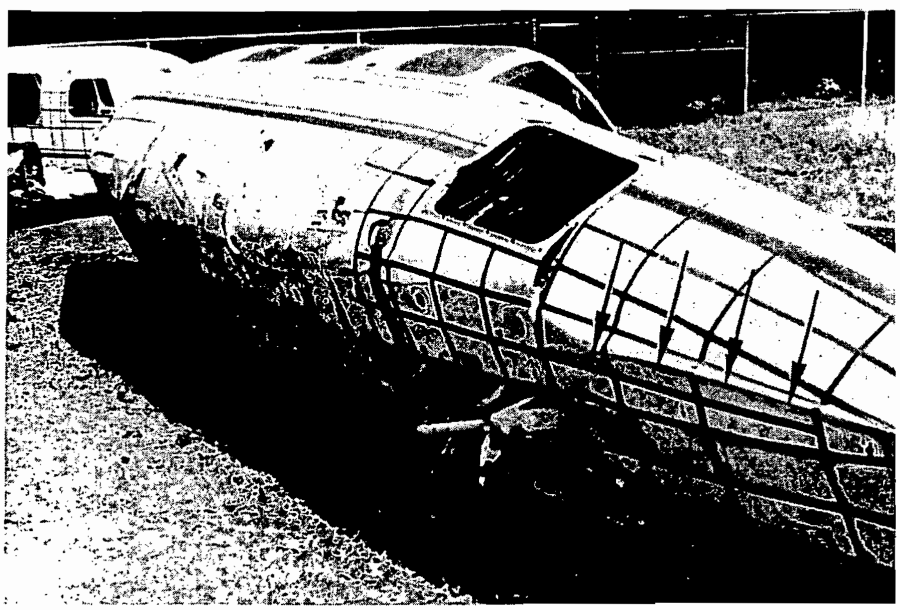


Figure 9.—NASA test vehicle No. 14. (Note flat area under nose in foreground.)

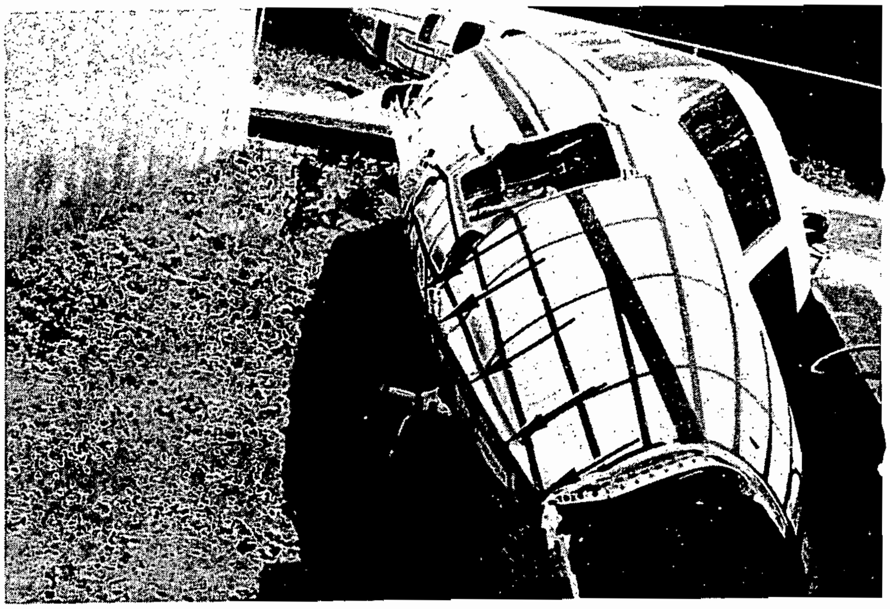


Figure 10.—Crush line on NASA test vehicle No. 14.

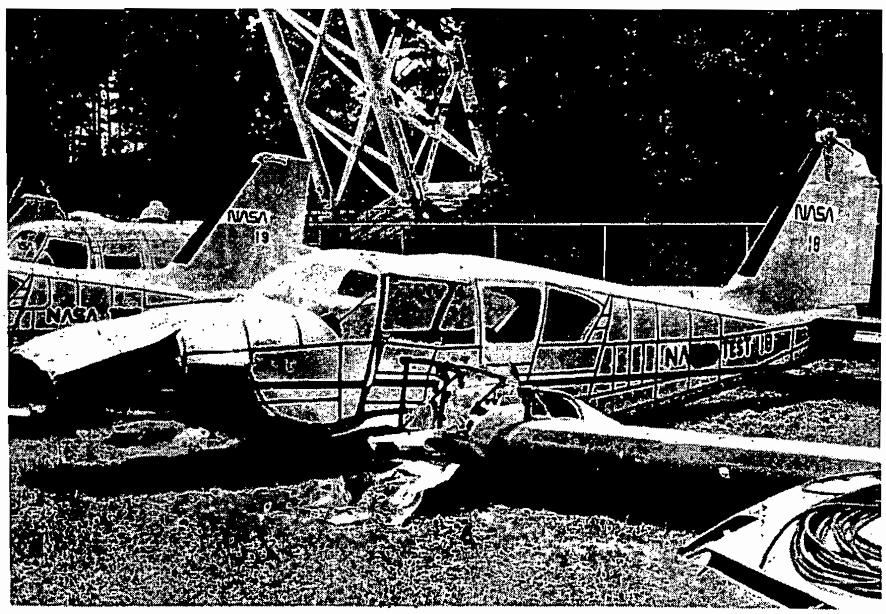


Figure 11.—NASA test vehicle No. 18.

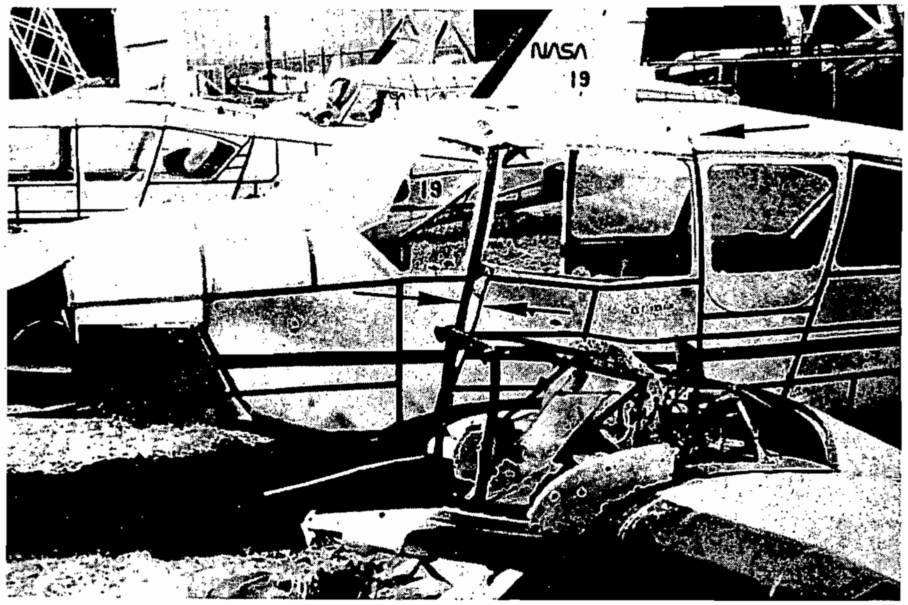


Figure 12.—NASA test vehicle No. 18 showing buckle and split rivet line.

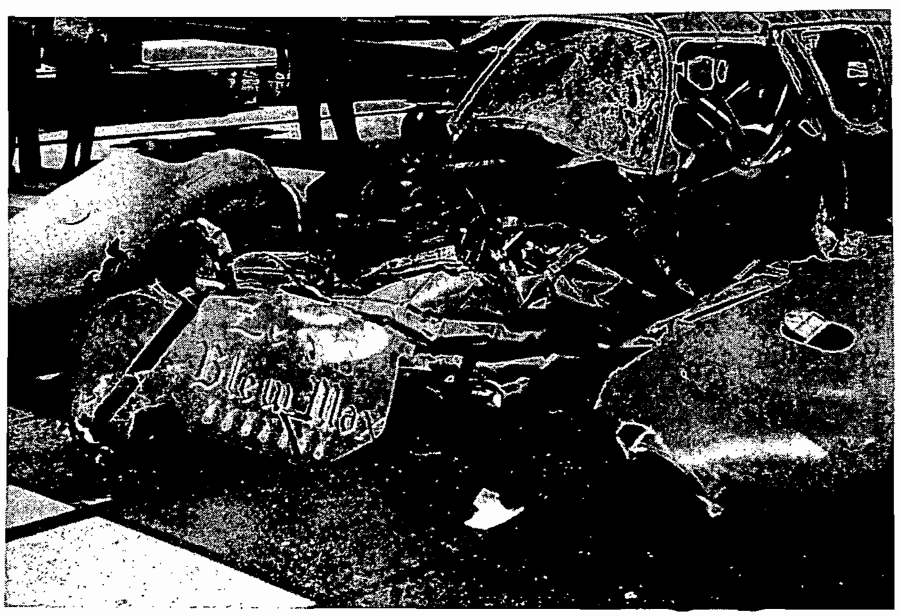


Figure 13.—NASA test vehicle No. 7.

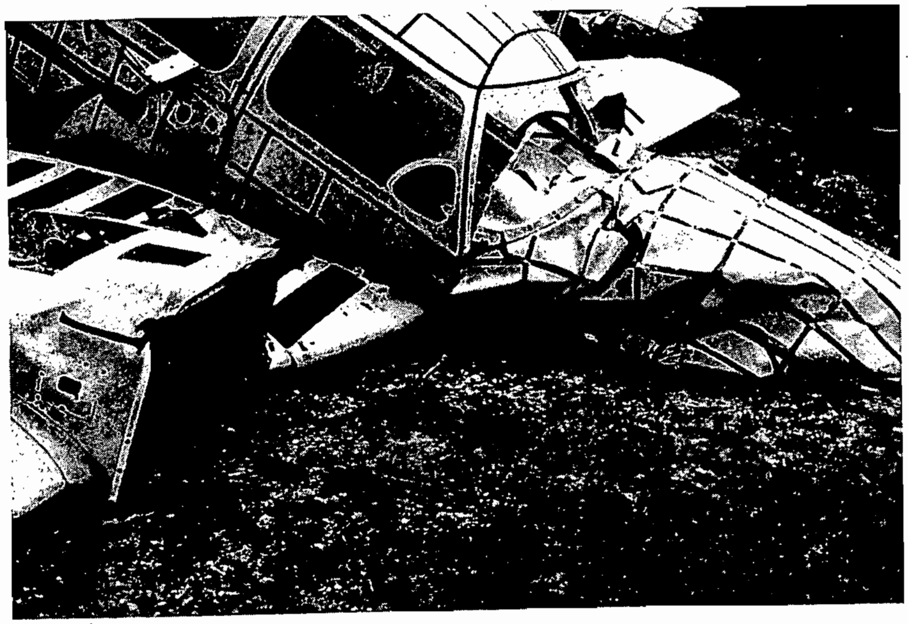


Figure 14.—NASA test vehicle No. 8.

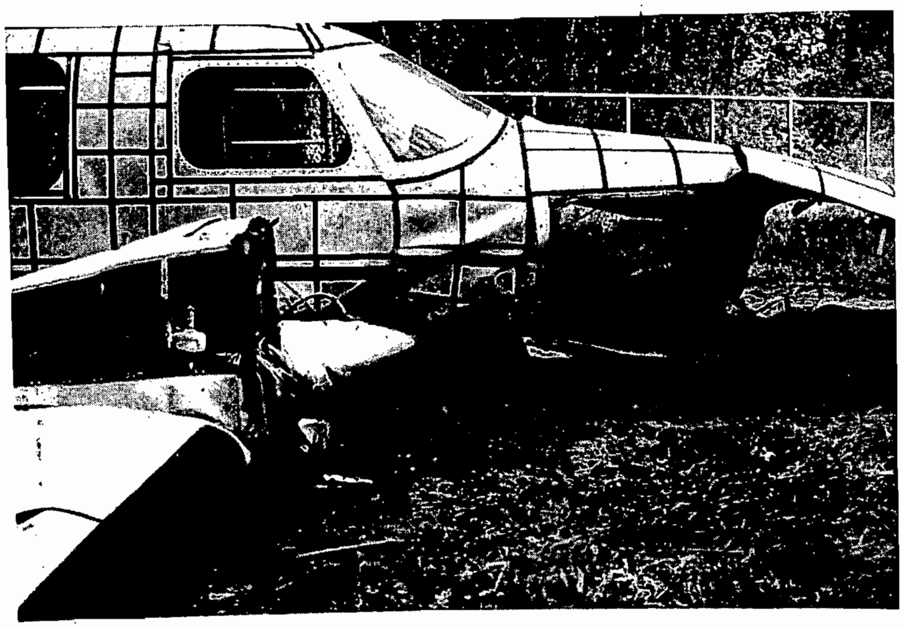


Figure 15.—Parallel wrinkles on right side of nose on vehicle No. 17.

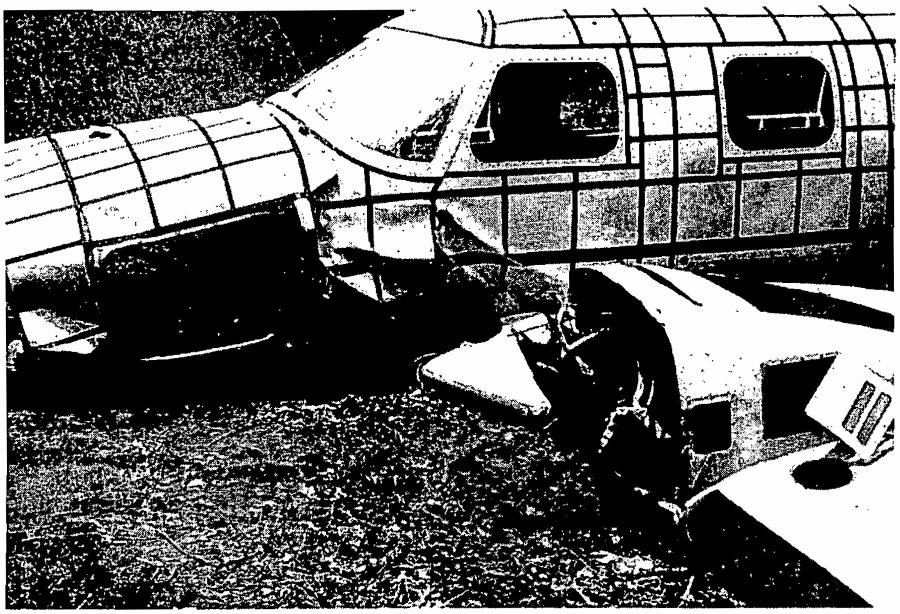


Figure 16.—Parallel wrinkles on left side of nose on vehicle No. 17.

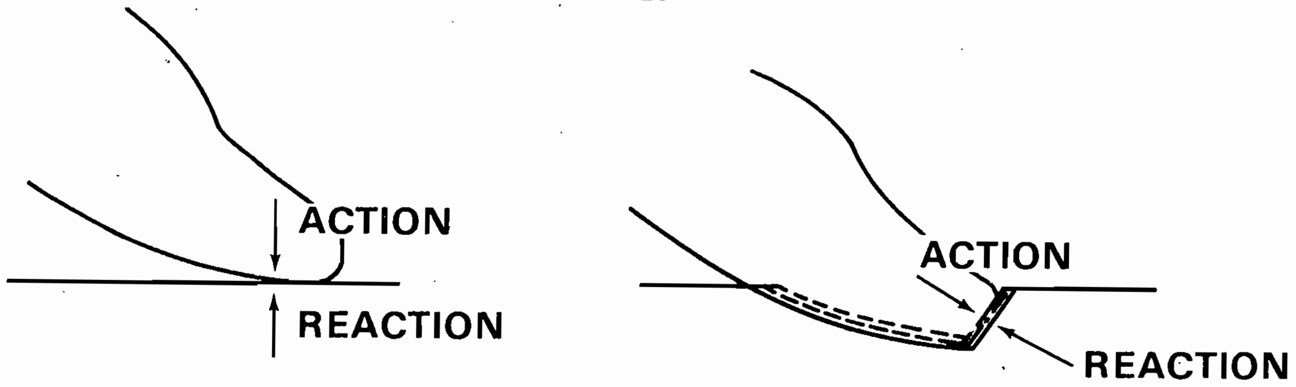
Each of the techniques described is a useful tool for estimating pitch attitude at impact. However, an investigator must exercise sound judgment in basing conclusions on this evidence because each piece, taken by itself, can be misleading. Conclusions with the highest level of confidence result from the use of a number of techniques to confirm an impact attitude.

Crash Pulse.—A visualization of each test was made to establish the target values for distance. The NASA values for velocity and flightpath angle were used in calculating the crash pulse. The impact data could not be generated for the NASA tests as they would be in an NTSB field investigation. Velocity, impact attitude, angle of attack, and flightpath were artificially set for test purposes for the NASA tests and their values could not be estimated by using techniques that would be applied in the field.

Crash pulses first were calculated relative to earth axes, 13/ then converted to airplane axes 14/ to allow comparison with accelerometer data from the NASA tests. Initial evaluations indicated that when the airplane crashed on an unyielding surface, such as concrete, the predominant loading (reaction) occurred in the vertical direction relative to the earth. However, when the crash occurred on a yielding surface, such as dirt, the loads were predominantly longitudinal, relative to the airplane axis as it dug into the ground.

13/ An axis system where the vertical and horizontal axes are normal and parallel respectively to the earth surface.

14/ An axis system where the vertical and horizontal axes are normal and parallel respectively to the airplane's fuselage.



(a) Unyielding Surface

(b) Yielding Surface

Figure 17.—Direction of reactions.

Stated in another manner, in both cases, the reaction to the force of the impact was normal, or at right angles to the impact surface. This reaction follows Newton's third law of motion which states that, for every action, there is an equal and opposite reaction. In figure 17, the principal impact surface in (b) is redefined as the airplane ploughs into the ground, resulting in a predominant loading along the airplane's longitudinal axis, while in (a), the predominant loading occurs in the direction normal to the unyielding surface.

If the airplane crashes on a yielding surface but does not dig in and stop, the physical evidence must be carefully evaluated to determine in which axis the predominant loading occurs. Identification of the predominant axis is important because analysis of the crash loads along this axis is more accurate and more easily accomplished rather than attempting the analysis in a nonpredominant axis, and then translating the results to the predominant axis.

Some disagreement will arise in the comparison of the published test data with the calculated crash pulse data during verification because the time histories of the vertical and horizontal pulses cannot be compared. If the vertical and horizontal crash pulse peaks do not occur at the same time, the vector analysis, using the vector sums, is not entirely accurate. However, the calculations for the predominant pulse and the total vector sum will be reasonably accurate.

Analysis Summaries

The following summaries of the comparative analyses of two NASA crash tests illustrate the application of techniques developed for use in the field.

NASA Test No. 8 (Unyielding surface)

Test Data

Flightpath angle	-30° (down)
Pitch angle	-25° (nose down) at full development
Velocity	88.6 ft/sec
Vertical velocity change	44.3 ft/sec
Horizontal velocity change	20 ft/sec

The test data were taken from NASA publications and crash test films. The flightpath and pitch angles were 30° down at initial contact. By the time the fuselage crush had reached full development, the pitch angle had decreased to 25° nose down, which was in agreement with the measurement of the crush line. The velocity at impact was measured at 88.6 ft/sec. The initial vertical velocity was 44.3 ft/sec (V_y = 88.6 Sin 30° = 44.3 ft/sec) for a vertical velocity change of 44.3 -Ø or 44.3 ft/sec. The horizontal velocity change given in the data was 20 ft/sec, which resulted in an ending velocity of 56.7 ft/sec (V_h = 88.6 Cos 30° = 76.7 ft/sec, and 76.7 -20 = 56.7 ft/sec).

Visualization.--The visualization in figure 18 was derived from field notes and still photographs of the wreckage taken by Safety Board investigators. The initial velocity vectors and flightpath angle are presented on the visualization. Progressive crushing is shown by parallel lines at 1-foot increments, which represent the depth of the crush up to the maximum crush or full development at 3.6 feet. The crush line, which started just under the leading edge of the wing, the floorboards, and the wrinkles in the fuselage skin show that at the 3.6-foot crush mark, the pitch angle was 25° nose down; this was confirmed by the film data.

The structure involved in the various levels of crushing is shown in table II. The crush from Ø to 1 foot involves nonproductive structure. At 1 foot, the nose gear structure becomes involved, and deceleration begins to increase in proportion to the mass of the nose gear structure. As the crush progresses toward the cockpit floor, more substantial structure becomes involved and higher loads are transmitted to the cockpit area.

Table II.—Structure involved in various levels of crushing in NASA Test No. 8.

Crushing Distance (ft)	Structure Involved
Ø - 1	Nose structure (nonproductive)
1 - 2	Nose gear
2 - 3	Engines, cockpit
3 - 3.6	Engines, cockpit (full development)

Vertical Deceleration (G_v, earth axis)

Assume net crush 3.6 -1.Ø = 2.6 ft
Velocity change 44.3 ft/sec

$G_{vC} = V^2/2gS$

$= 44.3^2/2\ (32.2)\ 2.6$

$= 11.72$ G's

$G_{vT} = 2\ (11.72)$

$= 23.44$ G's

$t_v = V_v/g\ G_{vC}$

$= 44.3/(32.2)\ 11.72$

$= 0.117$ sec

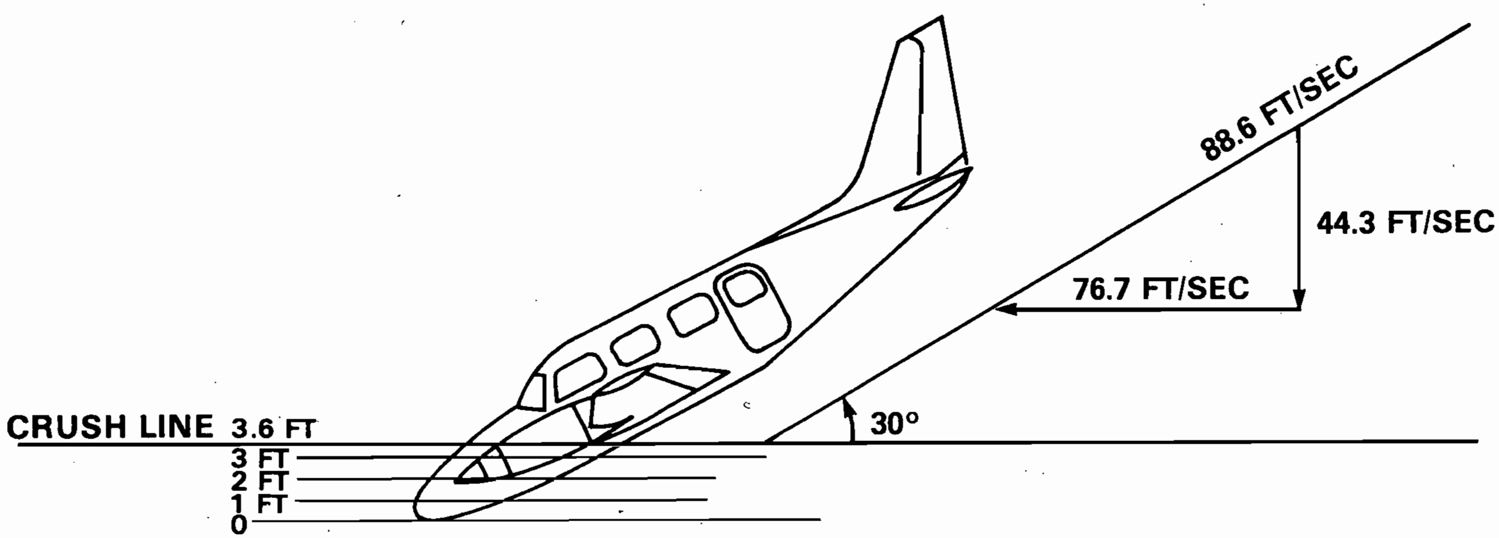


Figure 18.—NASA Test No. 8--visualization.

Since the impact was on a flat, unyielding surface, the predominant loading was in the vertical direction in earth axis. Since the first foot of crush (Ø-1 ft) involved nonproductive structure, the net crush was 2.6 feet. The constant deceleration pulse peak value (G_{vC}) was 11.72 G's; this value was doubled to obtain the triangular shaped pulse peak value of 23.44 G's. The pulse duration was Ø.117 second.

Horizontal Deceleration (G_h, earth axis)

Velocity change 20 ft/sec

t = Ø.117 sec (same as for vertical pulse)

$G_{hC} = V_h /gt$

= 20/(32.2) Ø.117

= 5.31 G's

$G_{hT} = 2(5.31)$

= 10.62 G's

Airplane Axis--The first portion of the analysis yielded a vertical peak pulse of 23.44 G's with a horizontal peak pulse of 10.62 G's in earth axis. The vector sum of the two pulses was a single pulse of 25.73 G's. To compare this analysis to the NASA data, the total pulse was broken down into two vectors relative to the airplane axis to coincide with the accelerometer alignment used in the tests. To obtain these values, the reference axis was rotated 25° from earth axis to airplane axis. (See figure 19.)

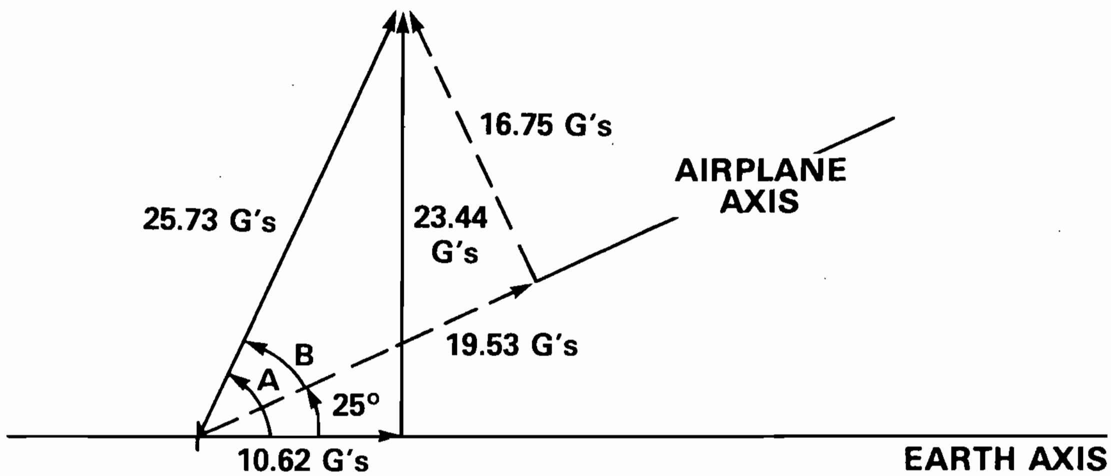


Figure 19.—Translation of forces into airplane axis.

Angle A = $Cos^{-1}(10.62/25.73)$
Angle A = 65.62°
Angle B = 65.62-25 = 40.62°

Solving for the vector components in airplane axis:
G_v = 25.73 Sin 40.62 = 16.75 G's
G_h = 25.73 Cos 40.62 = 19.53 G's

The total vector sum remained at 25.73 G's.

Shaping of the Vertical Pulse.--The shaping technique is completed as in the example for pulse shape development. Distance and velocity targets will be set at 0, 1, 2, 3, and 3.6 feet, and 44.0 and 0 ft/sec, respectively. The highest value for the modified constant pulse is at 18 G's or halfway between the calculated constant and triangular peak G's (G_c = 11.72 and G_t = 23.44).

Table III.—Target magnitudes for deceleration tiers for NASA Test No. 8.

Crush Level (feet)	Percent of Total Deceleration	G's
0 - 1	0% of 18	0
1 - 2	33% of 18	6
2 - 3	66% of 18	12
3 - 3.6	100% of 18	18

The calculated velocities and times for each segment are presented in Table IV with their corresponding distance targets.

Table IV.—Shaped crash pulse generation for NASA Test No. 8.

Distance	Velocity	Incremental Time	Total Time
0	44		0
1	44	.0227	.0227
2	39.6	.0239	.0446
3	30.4	.0286	.0752
3.6	0	.0752	.1146

The results of the first iteration of the computer run are shown in figure 20. The velocity and distance targets were not met. The time increments and the relative magnitudes of the acceleration plateaus were adjusted in subsequent iterations until the fixed target values were met. Figure 21 shows the final iteration of the modified constant pulse.

A shaped triangular pulse was generated using the data from the final iteration of the modified constant pulse. (See figure 22.) The total velocity and distance changes remained the same, while the peak vertical load increased to 24.5 G's and total time increased slightly.

Insufficient detailed data exist for shaping the horizontal pulse. However, since a value for the horizontal pulse must be used in translating the deceleration levels from earth axis to airplane axis, the calculated horizontal value of 10.62 G's was used. Converting to airplane axis, the total pulse is 26.7 G's, the horizontal pulse is 20 G's, and the vertical pulse is 17.7 G's.

The loads from the published test data compared closely with the calculated and shaped analytical results shown in table V.

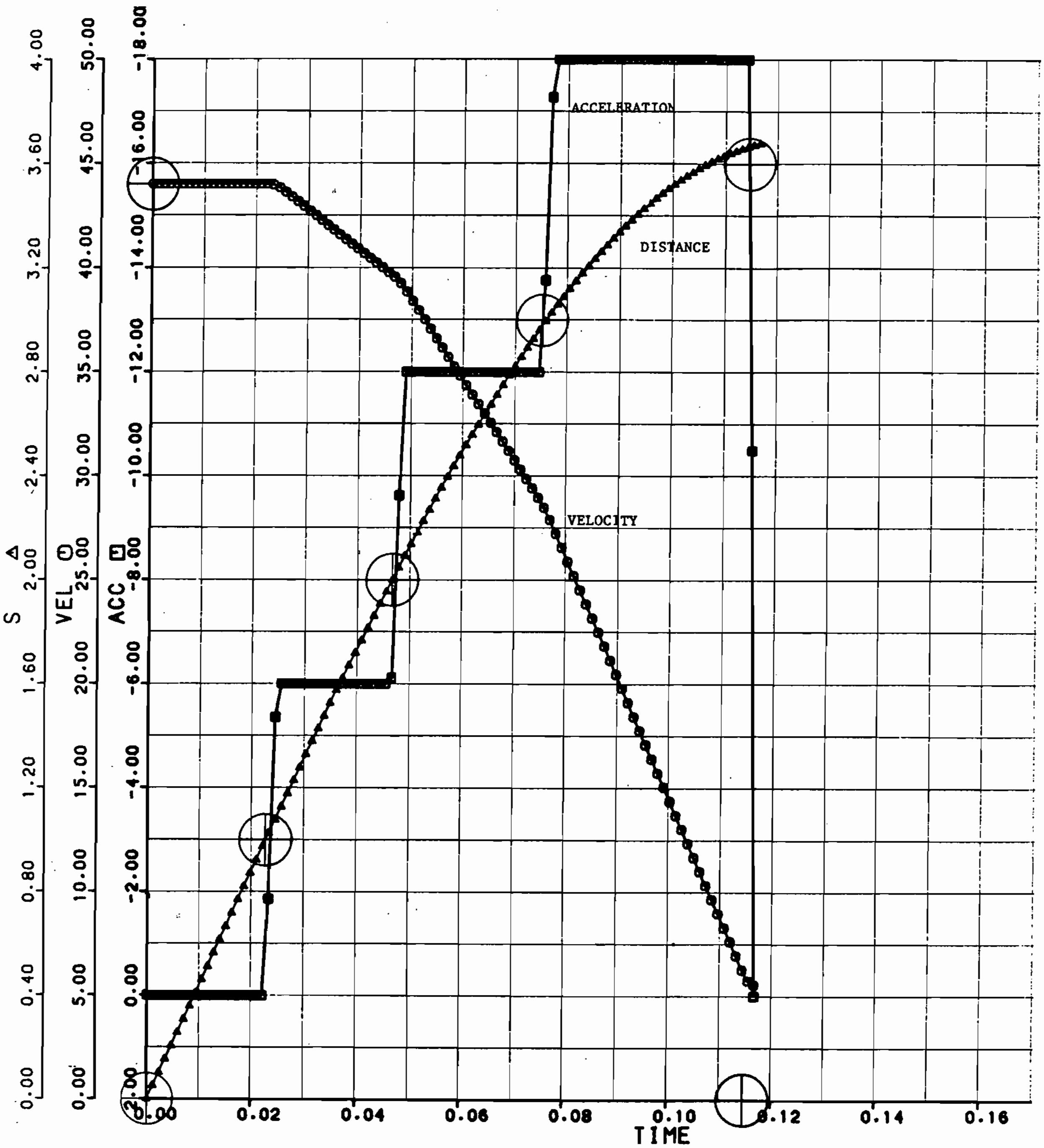


Figure 20.—First iteration of modified constant pulse, NASA Test No. 8.

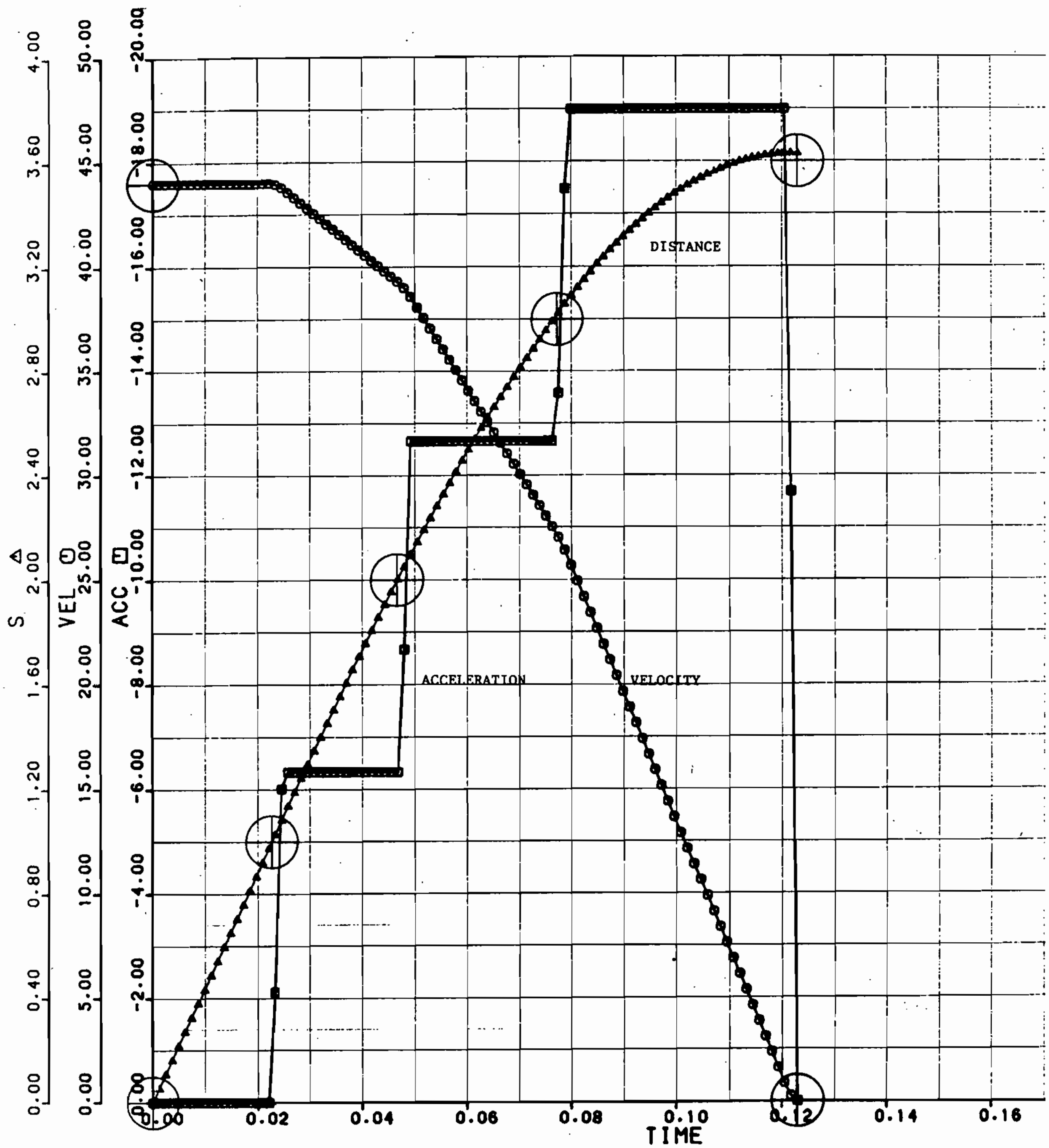


Figure 21.—Final modified constant pulse, NASA Test No. 8.

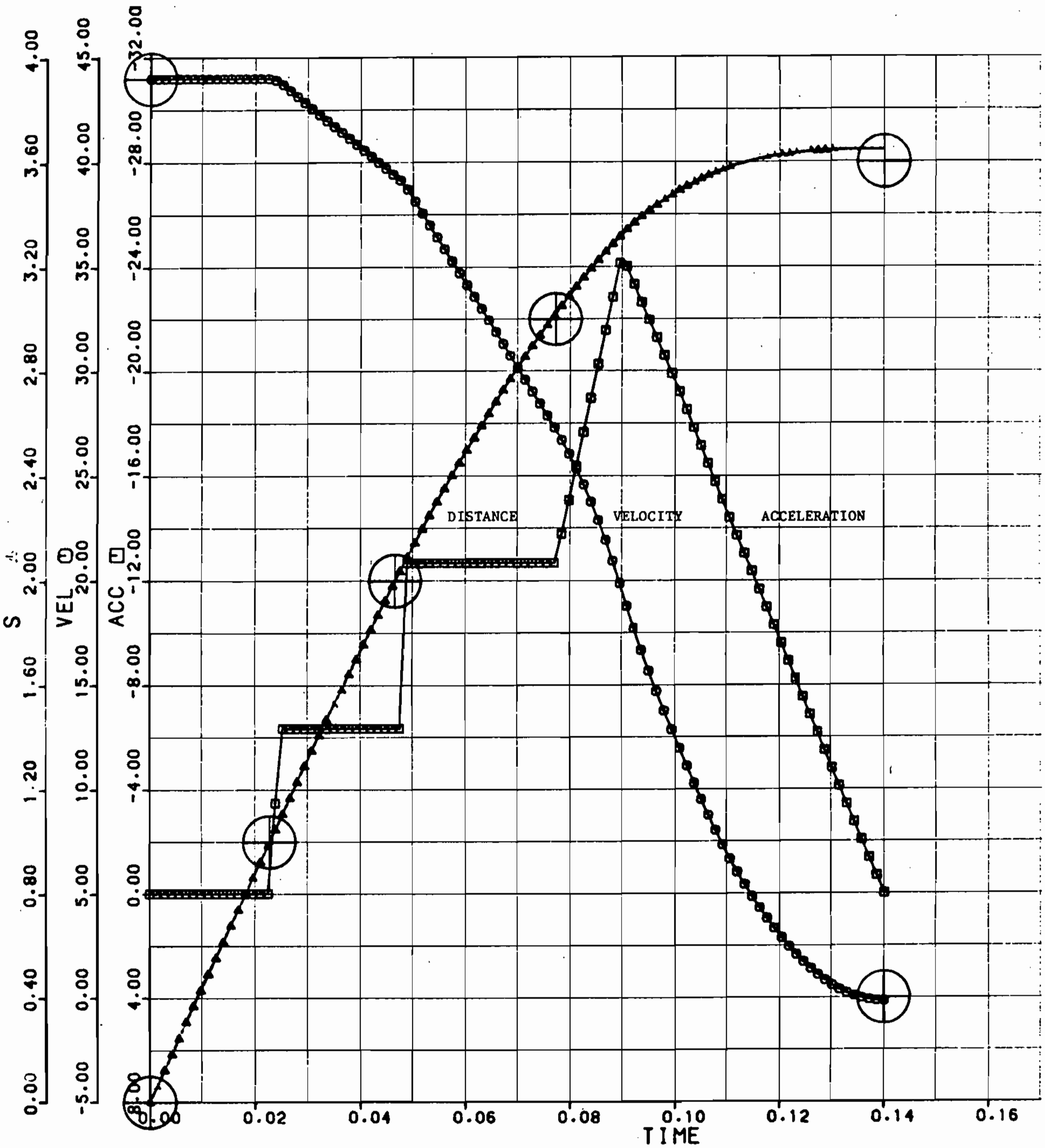


Figure 22.—Final triangular pulse, NASA Test No. 8.

Table V.--Actual NASA results versus NTSB analytic results in NASA Test No. 8

	G-Loads		
	Actual	Calculated Analytical	Shaped Analytical
Total	24	26	27
Vertical	18	17	18
Horizontal	16	20	20

NASA Test No. FAA 4 (Yielding surface)

Test Data

Flightpath angle	-32° (down)
Pitch angle	-34.5° (nose down) at impact
Velocity	83 ft/sec
Vertical velocity change	42 ft/sec
Horizontal velocity change	49 ft/sec

Since the nose of the airplane ploughed into the soil at impact, it was assumed that the predominant loading was along the airplane's longitudinal axis. Test data showed an impact velocity of 83 ft/sec, and a flightpath angle of 32° down. Vertical velocity at impact was 43.98 ft/sec (V_v = 83 Sin 32 = 43.98 ft/sec), for a vertical velocity change of 43.98 -Ø or 43.98 ft/sec. The horizontal velocity component at impact was 70.39 ft/sec (V_h = 83 Cos 32 = 70.39 ft/sec). The horizontal exit velocity (start of slide) was measured at 20 ft/sec from the test film. This value also was calculated, using a sliding coefficient of friction of Ø.5, and a sliding distance of 12 feet. The calculation [V^2 = 2(32.2) Ø.5 (12)] resulted in a velocity of 19.66 ft/sec. An initial velocity of 70.39 ft/sec and an exit velocity of 20 ft/sec, resulted in a horizontal velocity change during the principal impact of 50.39 ft/sec.

Visualization.--The visualization in figure 23 was derived from notes, photographs, and film data. This accident would have been difficult to reconstruct accurately in the field because the forward rotation of the airplane at impact caused crushing that gave the appearance of a 70° to 80° nose down pitch attitude. Reliance only on the crush line would have been inaccurate; reference to ground scars or tree strikes would have been necessary to establish a more accurate impact attitude.

The crush line was identified as starting just aft of the wing strut. As shown in table VI, the structure involved in the first 1.5 feet of crush involved the nose gear only and would have a negligible effect on the deceleration. The next Ø.5 foot of crush involved some of the engine cowl structure and also was nonproductive. The crush from 2.Ø to 3.6 feet included the engine, firewall, and floor structure. Thus, the total effective crushing distance on the airplane was 1.6 feet, and with surface gouging estimated at 6 inches or Ø.5 foot, the total stopping distance was 2.1 feet.

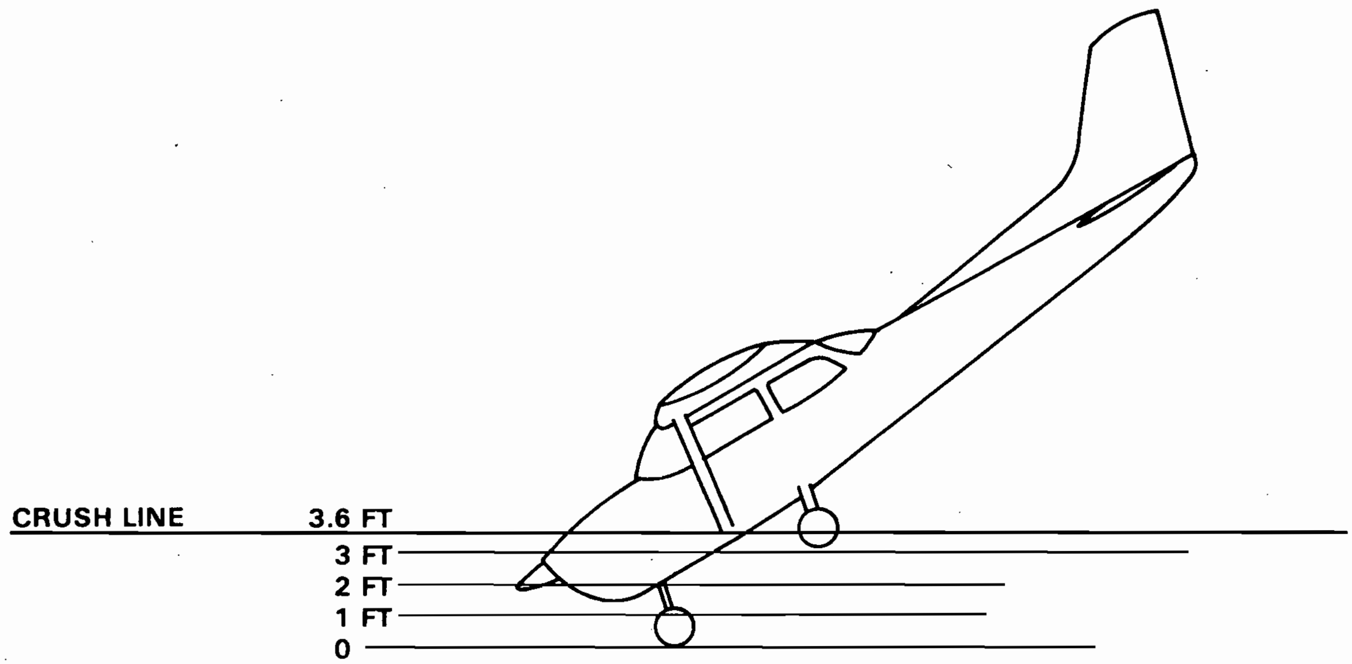


Figure 23.—NASA test No. FAA 4--visualization.

Table VI.—Structure involved in various levels of crushing in NASA Test No. FAA 4.

Crushing Distance (ft)	Structure Involved
Ø - 1.5	Nose gear (nonproductive)
1.5 - 2.0	Engine cowl (nonproductive)
2.0 - 3.6	Engine, firewall, floor structure

Vertical Deceleration (G_v, earth axis)

Assume net crush 2.1 ft

Velocity change 43.98 ft/sec

$G_{vC} = V^2/2gS$

$= 43.98^2/2\ (32.2)\ 2.1$

$= 14.30$ G's

$G_{vT} = 2\ (14.30)$

$= 28.60$ G's

$t_v = V_v/g\ G_{vC}$

$= 43.98/(32.2)\ 14.30$

$= 0.096$ sec

Horizontal Deceleration (G_h, earth axis)

Velocity change 50.39 ft/sec

t = Ø.Ø96 sec (same as for vertical pulse)

$G_{hC} = V_h\ /gt$

$= 50.39/32.2\ (0.096)$

$= 16.30$ G's

$G_{hT} = 2(16.30)$

$= 32.60$ G's

Airplane Axis

The forces in earth axis are translated into airplane axis as follows:

Angle A = 41.26°
Angle B = 41.26 -34.5 = 6.76°

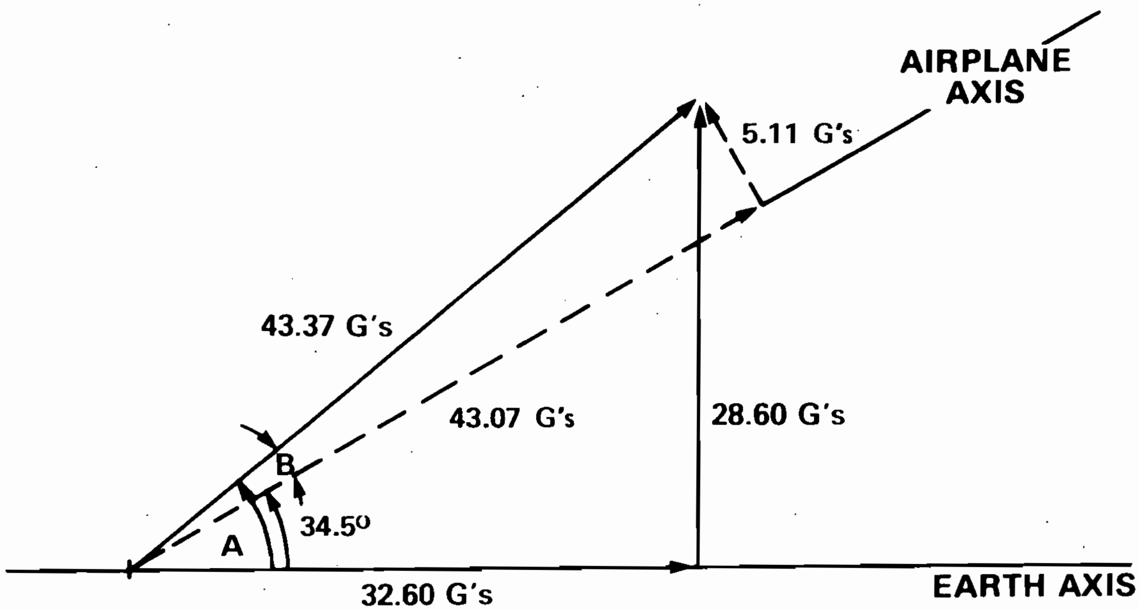


Figure 24.—Translation of forces into airplane axis.

Solving for the vector components in airplane axis:

$$G_v = 43.37 \text{ Sin } 6.76 = 5.11 \text{ G's}$$
$$G_h = 43.37 \text{ Cos } 6.76 = 43.07 \text{ G's}$$

The total vector sum remained at 43.37 G's.

The comparison of actual and analytical results shown in table VII, indicates that in the predominant axis and for the total pulse, the analytical values again compared closely with actual test data.

Table VII.—Actual NASA results versus NTSB analytical results in NASA test No. FAA 4.

	G-Loads	
	Actual	Analytical
Total	40-45	43
Vertical	15	7
Horizontal	40-45	43

In the comparisons of the results of the actual and analytical loads from NASA tests No. 8 and No. FAA 4, in general, the analyses performed by the Safety Board appeared to have a high degree of accuracy and would indicate that the investigative methods and analytical assumptions used in the crashworthiness investigations were valid.

In many cases, insufficient data exist to allow an accurate estimate of exit velocities, especially relative to the horizontal. In these cases, an analysis can be performed which will establish only a relative crash magnitude. The analysis is performed only in the predominant axis.

For NASA test No. FAA 4, the predominant axis is the longitudinal axis of the airplane. The measurement from the visualization shows that the longitudinal stopping distance is 3.6 feet, and with the Ø.5 foot of gouging, the total longitudinal stopping distance is 4.1 feet. The velocity can be estimated as changing from 83 to 20 ft/sec at the start of the slide, for a velocity change of 63 ft/sec. The minimum peak loading can then be calculated as:

$$G_C = (V_1^2 - V_2^2)/2gS$$

$$= (83^2 - 20^2)/2(32.2)\ 4.1$$

$$= 24.58 \text{ G's}$$

The peak of the triangular shaped pulse would be 49.15 G's total longitudinal deceleration. This method does not allow a calculation for the vertical pulse to be performed in airplane axis. Additionally, the velocity change from 83 to 20 ft/sec is not precisely correct because the directions of the velocity vectors were not taken into account; the 83 ft/sec acts at 32,° but the 20 ft/sec acts parallel to the earth. However, the corrections for these errors would be small, and the results would be within acceptable limits for use in this type of analysis.

APPLICATION OF ANALYSIS OF NTSB ACCIDENT INVESTIGATION DATA

The following example is representative of a typical application of analysis from an NTSB accident investigaion:

> A Beechcraft B99 airplane was on an instrument landing system (ILS) approach to an airport in fog and light turbulence. The copilot stated that while on final approach, the "bottom dropped out." The airplane crashed on an ice covered bay, and slid about 350 feet before coming to rest on the shore. (See figure 25.)
>
> Two crewmembers and five passengers were injured. The most extensive injuries, which were received by the captain, included compression fractures of vertebrae, fractured lower legs, and head and internal injuries. The copilot received minor injuries. The passengers received flail-type injuries, including a fractured arm, fractured knee, head and facial injuries, and various contusions and lacerations.
>
> The investigation included interviews of passengers and crew and an onsite documentation of the crash path, fuselage, seats, and restraints. Photographs taken at the accident site showed the crush line and general fuselage damage. (See figures 26 through 29.) The crush line was documented further on a three-view drawing of the airplane. (See figure 30.)
>
> The crush line in the photographs and the three-view drawing were consolidated into a separate drawing in which the crush plane was rotated to the horizontal position. (See figure 31.) Parallel lines, labeled 1 through 5, were drawn to represent the crush levels at which different parts of the structure became involved during the crash. The airplane attitude, measured directly from the drawing, showed a roll angle of 21° left wing down and a nose down pitch attitude of 9°.

Figure 25.--Airplane position and direction of slide.

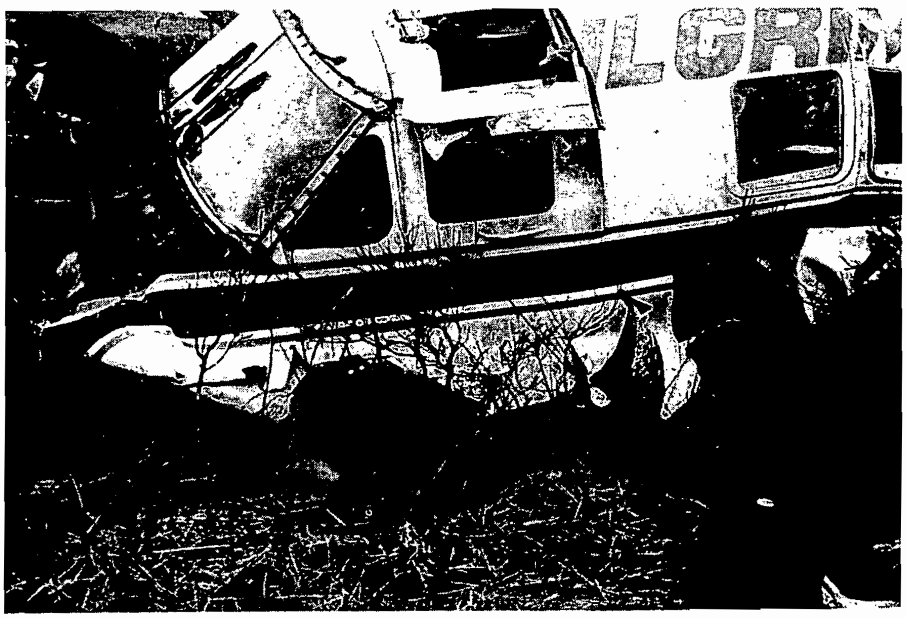


Figure 26.—Left side crush line.

Figure 27.—Right side crush line.

Figure 28.—Interior cabin damage.

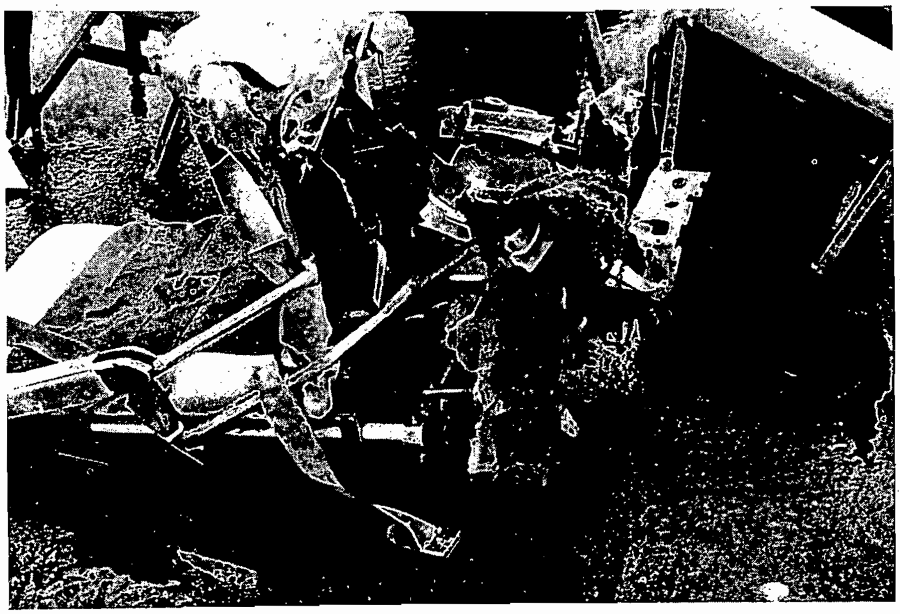


Figure 29.—Damaged seat.

The airplane was assumed to be near stall speed, based on the copilot's statement that the "bottom dropped out." Since the wind was near zero, it was assumed that the ground speed and airspeed were the same, near stall speed. Stall speed for the airplane with the power off and 30 percent flaps, was 86 KTAS (knots true airspeed). A stall angle of attack near 12° with an estimated pitch rotation of 2° and a pitch angle measured at 9° yielded a possible flightpath angle of 23°, based on the following equation:

$$\text{Flightpath angle} = \text{Pitch angle} + \text{angle of attack} + \text{pitch rotation}$$
$$= 9^\circ + 12^\circ + 2^\circ$$
$$\text{Flightpath angle} = 23^\circ$$

Since there was no supporting data, such as ground scars or tree strikes, the estimate of angle of attack and pitch rotation were not used with the same degree of confidence as was the crush line measurement, which was the most accurate datum available for this analysis.

The velocity was calculated by first converting the total velocity of 86 KTAS to feet per second.

$$V = 86\ (1.69) = 145 \text{ ft/sec}$$

Vertical velocity was then calculated as:

$$V_v = V \sin(\text{flightpath})$$
$$= 145 \text{ ft/sec} \sin 23^\circ$$
$$V_v = 57 \text{ ft/sec}$$

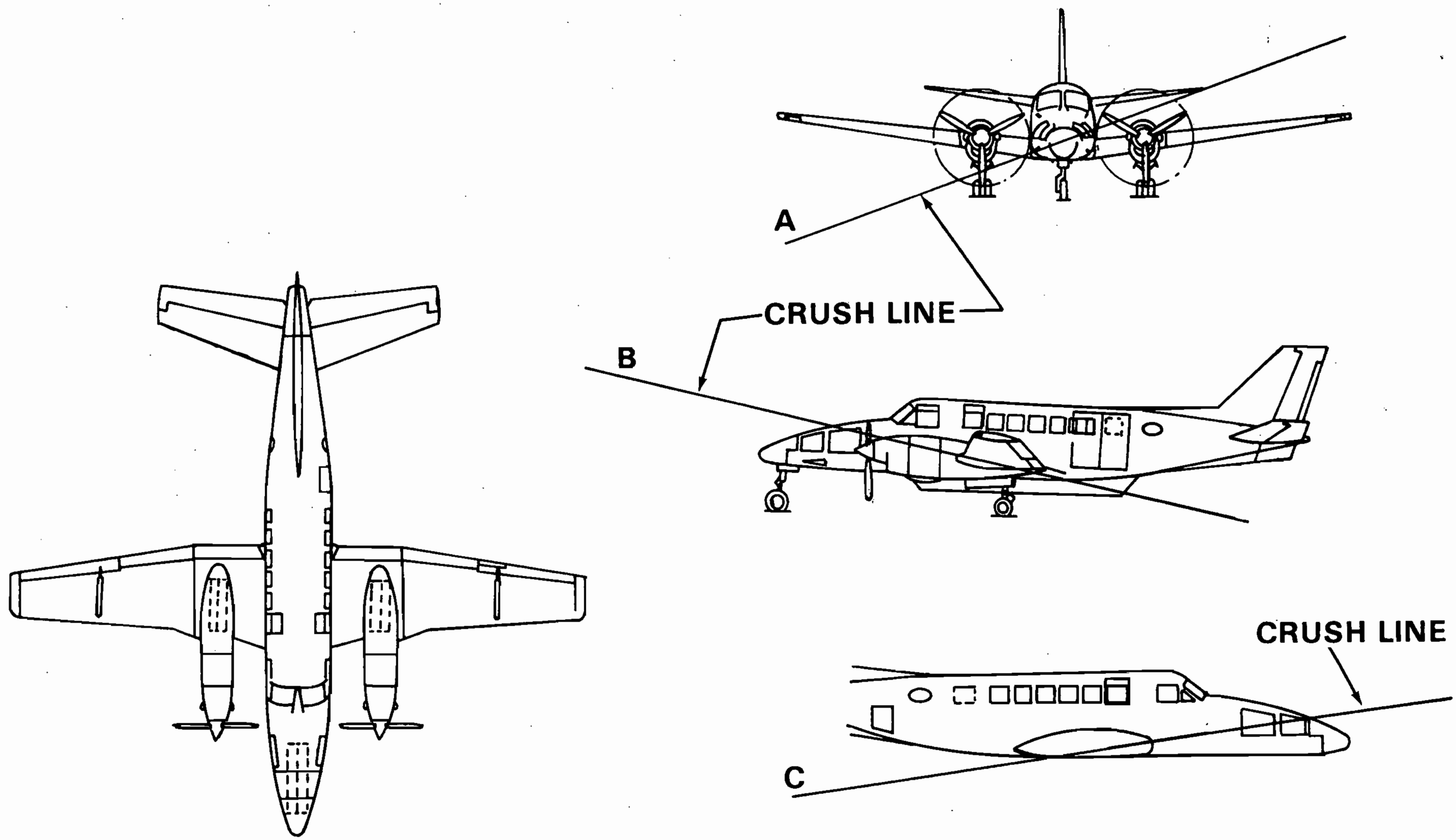


Figure 30.—Three-view drawing showing crush line.

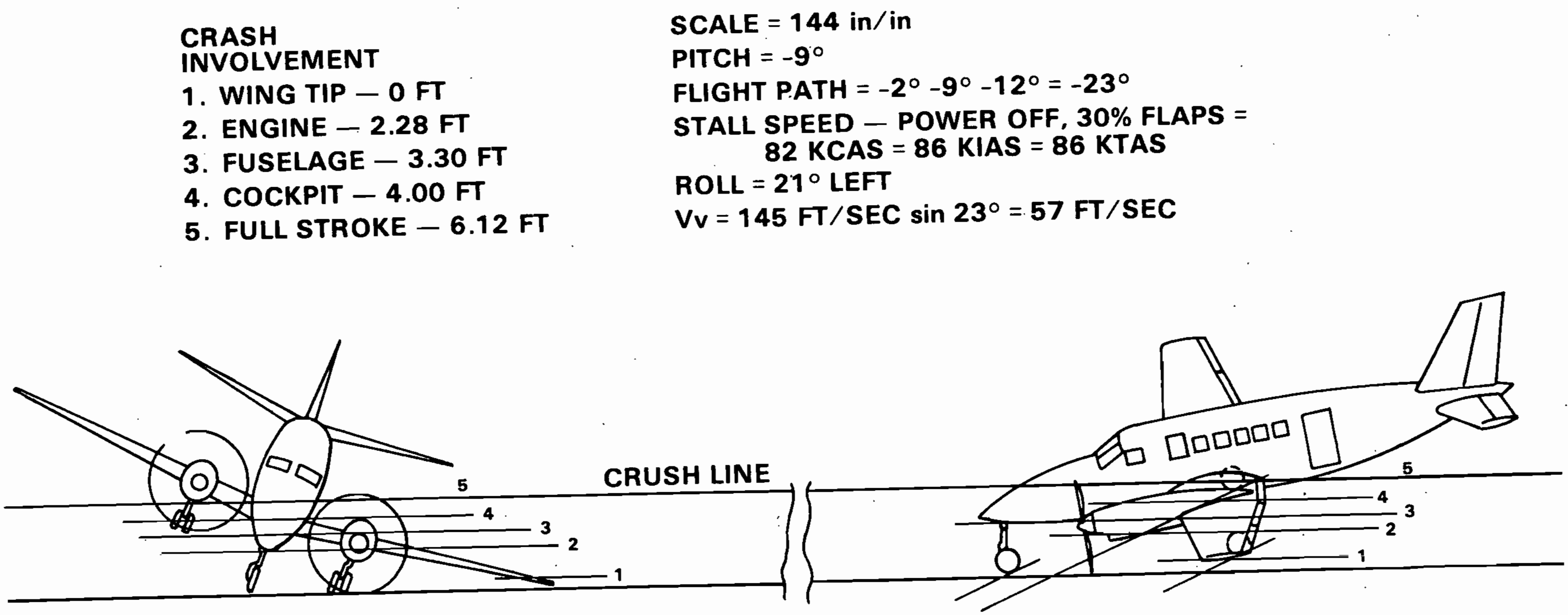


Figure 31.—B99 visualization.

The first distance target was set at 3.3 feet, the distance from the wing tip to the beginnings of fuselage involvement. Using an entering velocity of 57 ft/sec, time for the first segment of the pulse was calculated as:

$$t_1 = S_1/V_1$$
$$= 3.3 \text{ ft}/57 \text{ ft/sec}$$
$$t_1 = 0.058 \text{ sec}$$

This time corresponds to target A (3.3 feet, 0.058 second) in figure 32. The deceleration which began to increase more rapidly as the fuselage was crushed, is shown by a corresponding increase in the magnitude of the crash pulse.

The second distance, target B, was set at 4.0 feet total distance where the cockpit became involved. The time for this segment was calculated as:

$$t_2 = S_2/V_2$$
$$= (4.0 \text{ ft} - 3.3 \text{ ft})/56 \text{ ft/sec}$$
$$t_2 = 0.013 \text{ sec, or about } 0.071 \text{ second cumulative time.}$$

Target B was then plotted at 4.0 feet and .071 second. (The velocity component for each time calculation was estimated, based on the mass of structure involved.)

In the last segment, the velocity was estimated to have dropped to 52 ft/sec; the corresponding distance value was 2.12 feet, (6.12-4). This distance value is used in the calculation of a constant crash pulse because it represents the involvement in the crash of those portions of the structure having the most significant effects on the change in deceleration. The constant pulse was calculated as:

$$G_{vC} = V^2/2gS$$
$$= 52^2/2(32.2)\ 2.12$$
$$= 19.8 \text{ G's}$$

The time for this pulse was calculated as:

$$t = V/gG_{vC}$$
$$= 52/32.2\ (19.8)$$
$$t = 0.082 \text{ sec.}$$

The duration of the total pulse was 0.153 second (0.071 + 0.082).

The calculated data points were entered into the computer, and the program was run. Distance targets, which are fixed in magnitude, were adjusted on the time scale until the final distance target of 6.12 feet and the final vertical velocity target of zero were met simultaneously. This resulted in the calculation of a 19.5G constant vertical crash pulse for a total time of 0.157 second. (See figure 32.)

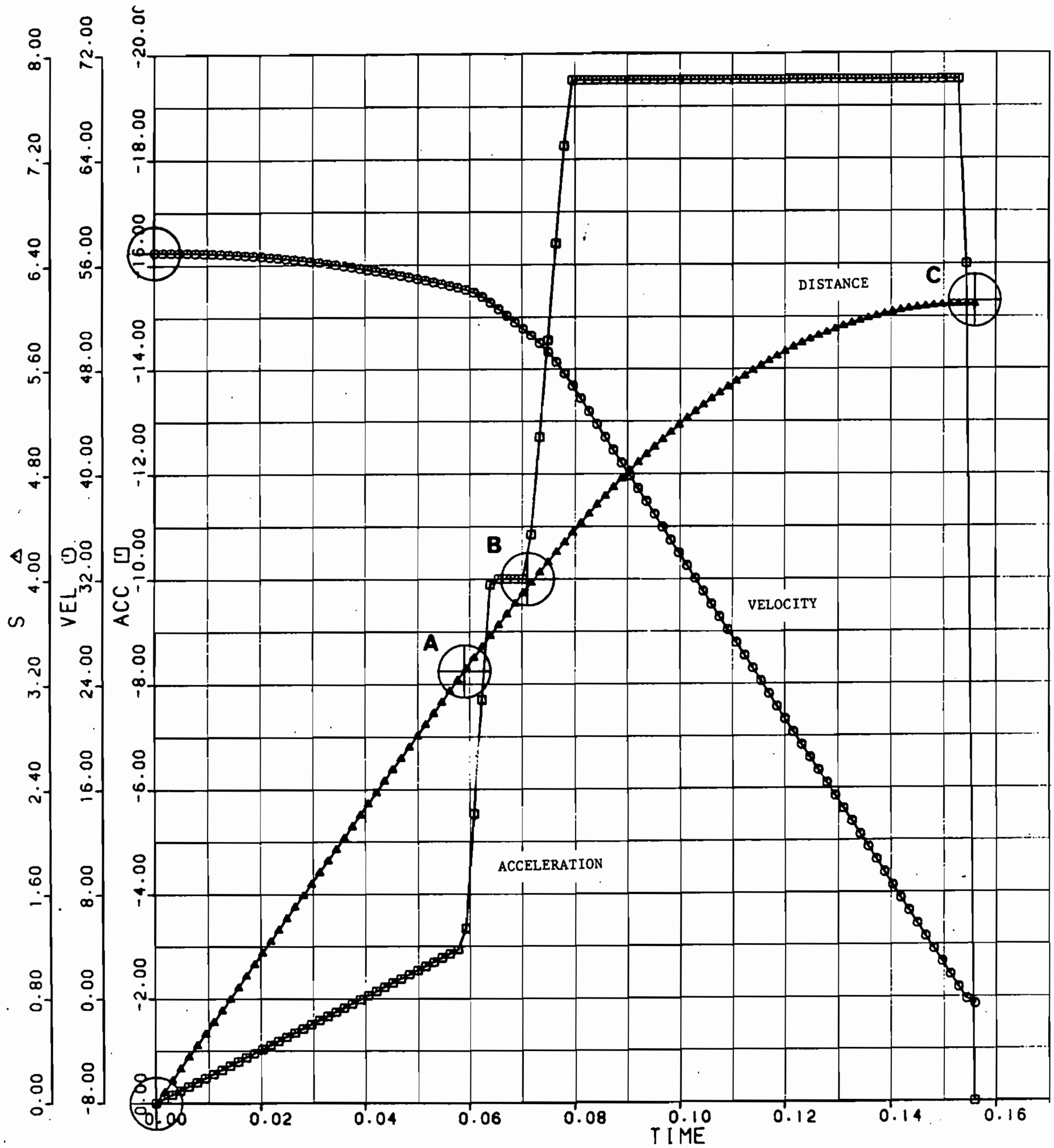


Figure 32.—Crash pulse with targets.

Figure 33 shows the results of substituting the plateau type pulse shape with the triangular pulse shape. Adjustments were made so that the distance and velocity targets still were met. The triangular pulse shape, which is more consistent with pulse shapes resulting from crash tests, showed a short duration peak load of 30 G's acting on the airplane near the point of impact.

This example analysis shows the importance of the visualization technique not only for reconstruction of the impact attitude and the overall crash pulse development. It also explained the differences in the injury patterns of the occupants. In this case, the pilot received serious injuries, while the copilot who received minor injuries, was able to be present at the crash scene the day after the accident. Examination of the cockpit showed that the floor area under the pilot's seat was totally disrupted and that the front edge of the seat had broken in an upward direction. The copilot's seat showed evidence of downward loading.

Figure 31 shows that the crush line on the left side of the airplane was high enough to be above the seat pan of the pilot's seat. However, because of the roll attitude of the airplane at impact, the crush line remained below the seat pan of the copilot's seat. The crushline is equivalent to ground level; therefore, the pilot and his seat physically tried to penetrate the ground -- a rigid surface -- thus, bending the front of the seat up and transmitting loads greater than 30 G's to the pilot. On the other hand, the copilot's seat stayed above ground level, allowing it to act as a buffer or cushion between the copilot and the ground (crush line), and reducing the loads transmitted to him to below the 30 G peak.

CONCLUDING REMARKS

This report, which is a result of the first phase of the crashworthiness program, presents a methodology for the crashworthiness investigation and analysis of general aviation airplane accidents. Results of Safety Board documentation and analysis of two NASA general aviation crash tests using the methodology presented, compared well with NASA's published test data. This indicates that the methodology and assumptions developed for use in this program are valid.

As of November 30, 1982, the Safety Board had conducted 31 full crashworthiness investigations. Of these investigations, 74 percent, or 23, of the airplanes involved in the accidents were Pipers or Cessnas, with Beech representing an additional 16 percent or 5 airplanes. Single engine airplanes represent 87 percent, or 27 airplanes. (See appendix D.)

The current phase of the crashworthiness program, which includes the investigation and full analysis of a select sample of general aviation accidents, is not yet complete. However, preliminary findings tend to confirm the problems defined in past recommendations. Also, some preliminary findings indicate that problems may exist concerning the adequacy of seat and restraint certification and testing, and the ability to maintain these items in a condition in which they will continue to meet at least the minimum standards under which they were certificated.

The second phase of the program will include the presentation of the results of the analyses and correlation of the results. Recommendations addressing safety issues discovered as a result of the investigative process also will be included with the presentation of the second phase results.

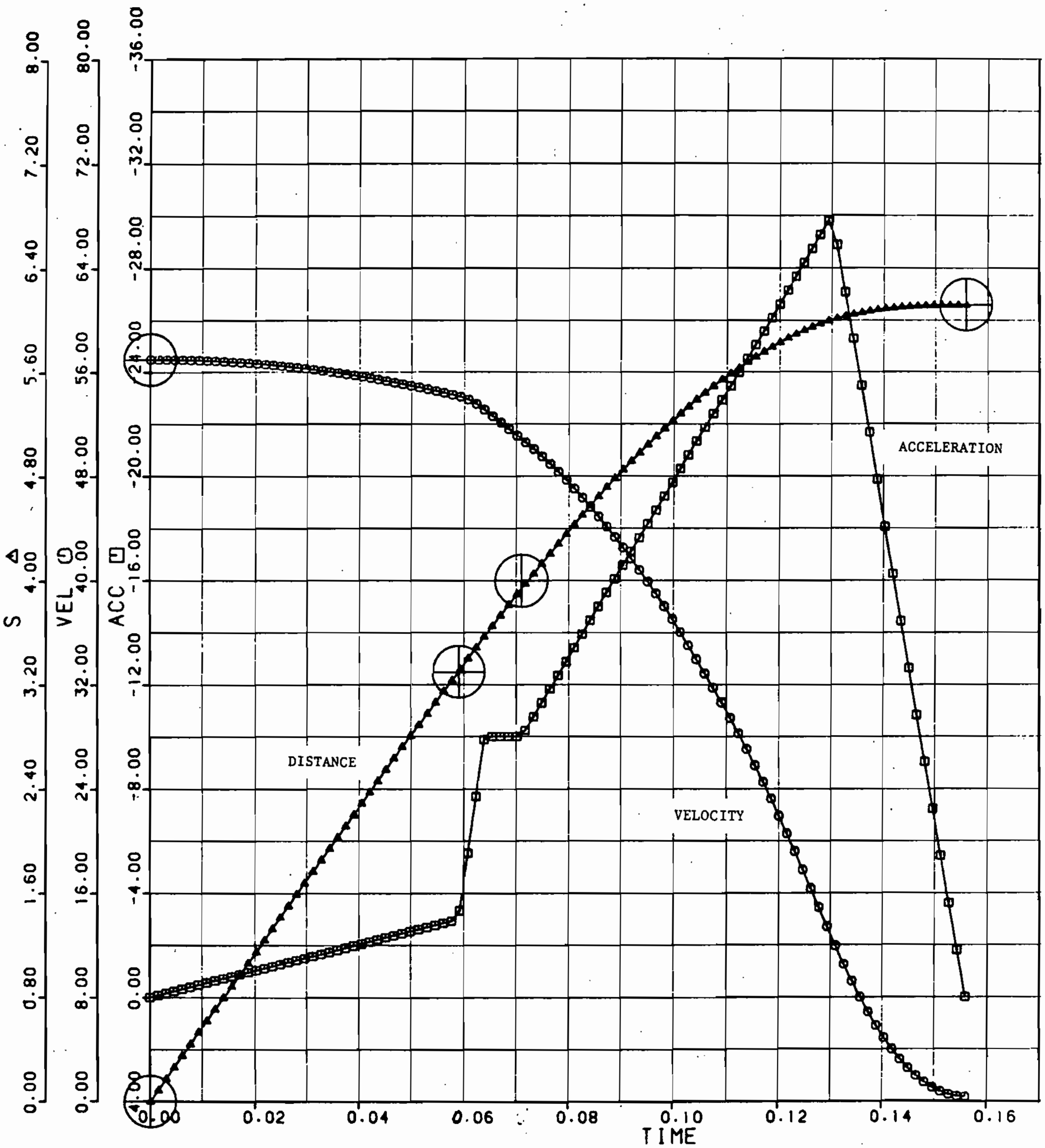


Figure 33.—B-99 shaped triangular crash pulse.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ G. H. PATRICK BURSLEY
Member

/S/ DONALD D. ENGEN
Member

June 27, 1983

GLOSSARY OF TERMS USED IN THE CRASHWORTHINESS PROGRAM 15/

(1) Airspeed — The airplane's velocity along the flightpath, expressed in knots. True airspeed (airspeed corrected to standard atmospheric conditions) is preferred. However, since it is anticipated that the accuracy of the velocity estimates will be coarse, indicated airspeed (airspeed read directly from the airspeed indicator) can be used. Exceptions to this would include accidents occurring at high elevations, or accidents resulting from spins, where the indicated airspeed may be near zero, but vertical velocity is high. The airspeed in knots is converted to feet per second for use in the kinematics equations.

(2) Flightpath — The path the airplane makes through the air. When measured relative to the horizon, the value for flightpath angle is derived. The flightpath angle is expressed as a negative number when the airplane is descending and as a positive number when the airplane is climbing. (See figure A1.)

(3) Pitch Attitude — The direction in which the airplane is pointed. When measured from a longitudinal reference line on the airplane (usually the waterline, rivet line, or window sill line) to the horizon, the pitch angle of the airplane is derived. The pitch angle is expressed as a negative number when the airplane is pointed down and as a positive number when the airplane is pointed up. (See figure A2.)

(4) Angle of Attack — The difference between pitch angle and flightpath angle. For purposes of kinematic analyses, effects of nonhorizontal winds typically are not taken into account (See figure A3.)

(5) Terrain Angle — The difference between the slope of the terrain and the horizon. An upslope relative to the airplane's flightpath is expressed as a positive number, and a downslope relative to the flightpath is expressed as a negative number. (See figure A4.)

15/ The glossary terms are not presented in alphabetical order. Instead, they are presented in order of development; one term combining with a subsequent term to define yet another term.

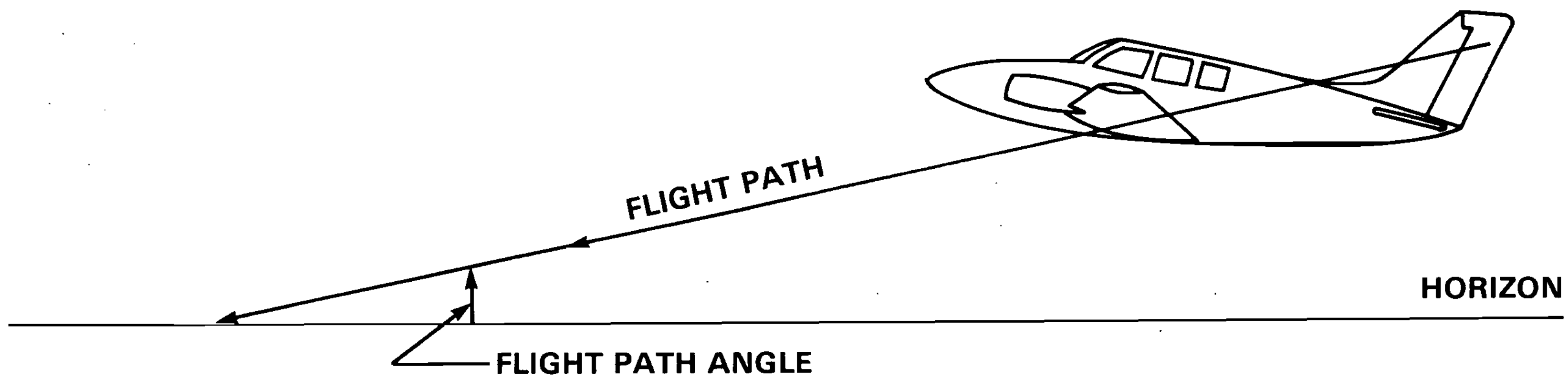


Figure A1.—Flightpath and flightpath angle.

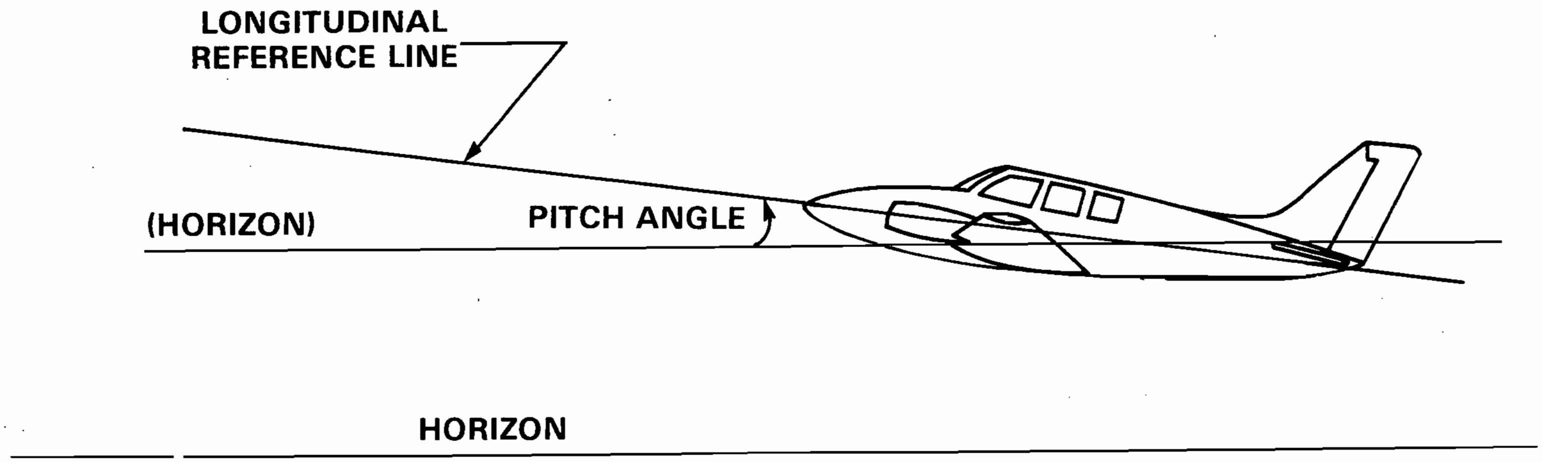


Figure A2.—Pitch angle.

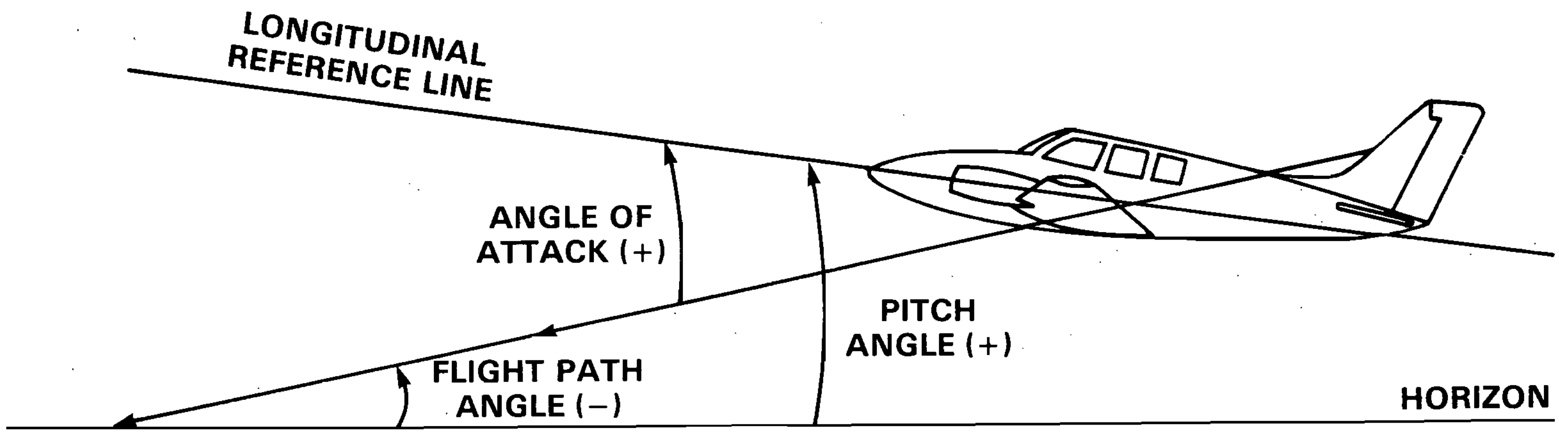


Figure A3.—Angle of attack.

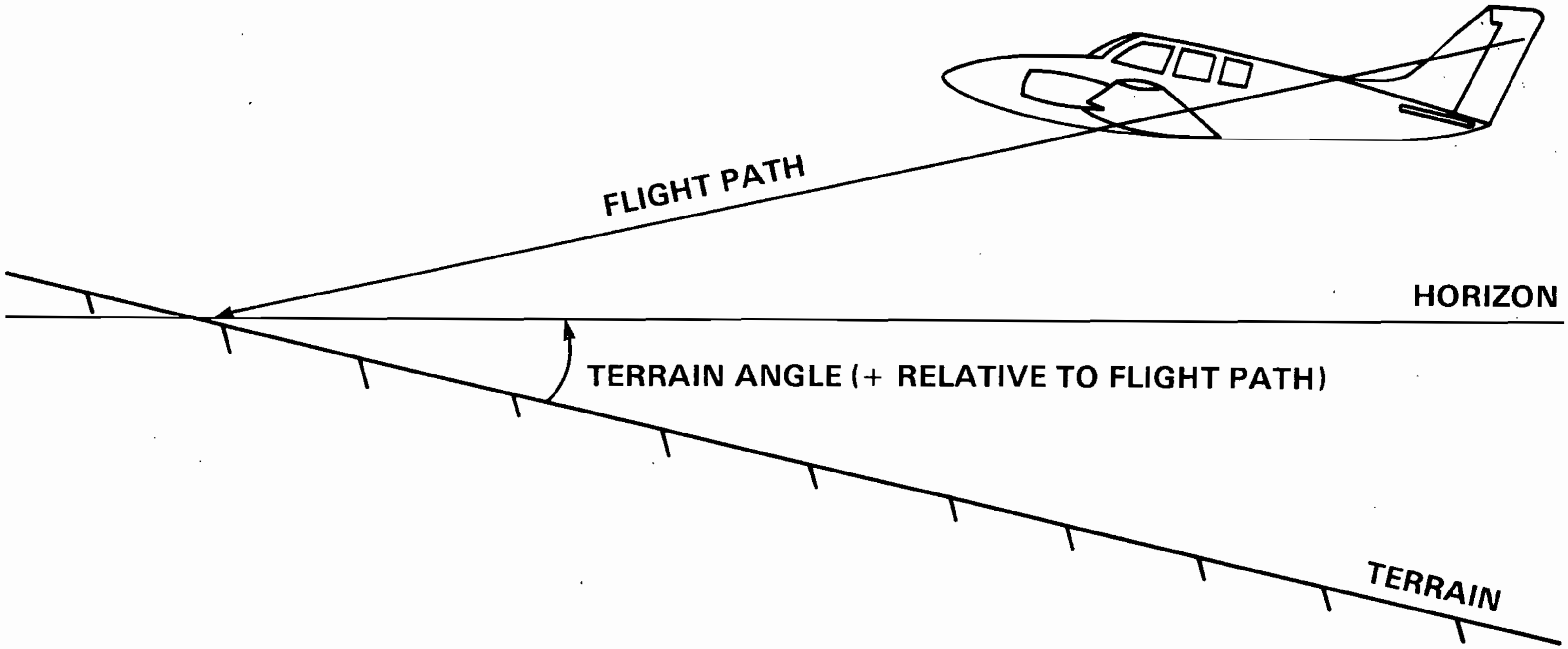


Figure A4.—Terrain angle.

(6) Impact Angle

The algebraic sum of the flightpath angle and the terrain angle. (See figure A5.) Figure A6 shows the relationship of the above definitions.

(7) Impact Speed

The velocity of the airplane at the principal impact, expressed in ft/sec. Airspeed can be corrected for wind to obtain impact speed.

(8) Crush Line

The line denoting the extent of damage caused by the airplane structure crushing against the ground. The crush line, which represents the ground plane, is used to show the depth of crush (stopping distance) and the airplane's attitude at impact. (See figure A7.)

(9) Further Relationships of Definitions

Pitch Angle-Flightpath Angle = Angle of Attack
Flightpath Angle-Terrain Angle = Impact Angle
Pitch Angle-Terrain Angle = Crush Line
Crush Line-Impact Angle = Angle of Attack

(10) Acceleration

The rate of change of velocity.

$a = dV/dt$ where a = Acceleration
V = Velocity
t = Time

(11) G

The ratio of an acceleration (a) to the acceleration due to gravity ($g = 32.2$ ft/sec^2).

$$G = a/g$$

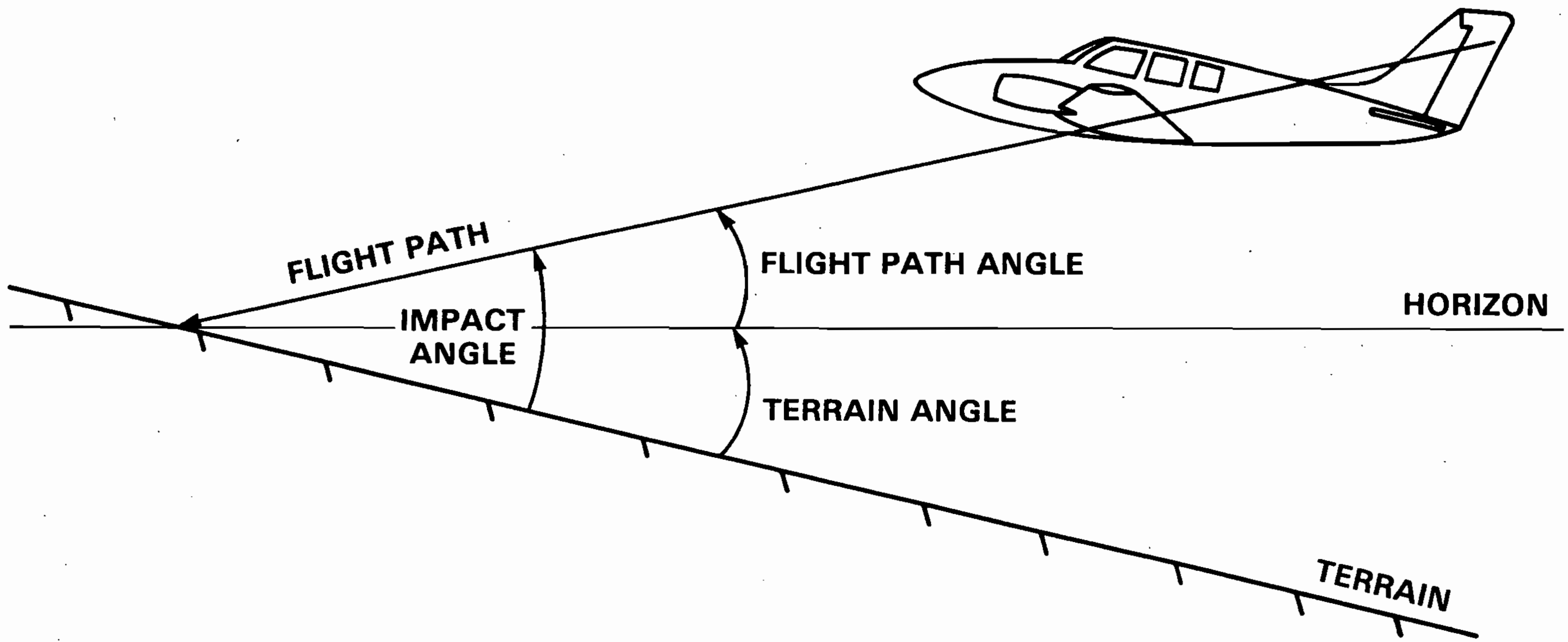


Figure A5.—Impact angle.

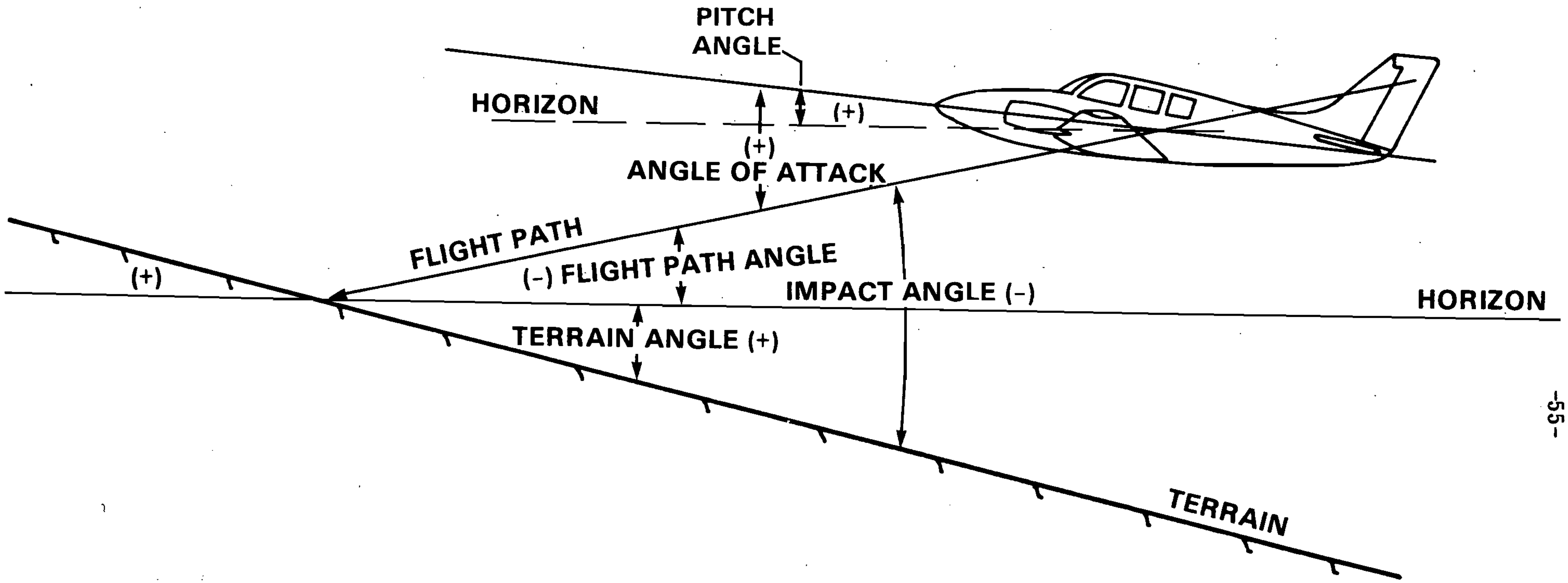


Figure A6.—Relationship of definitions.

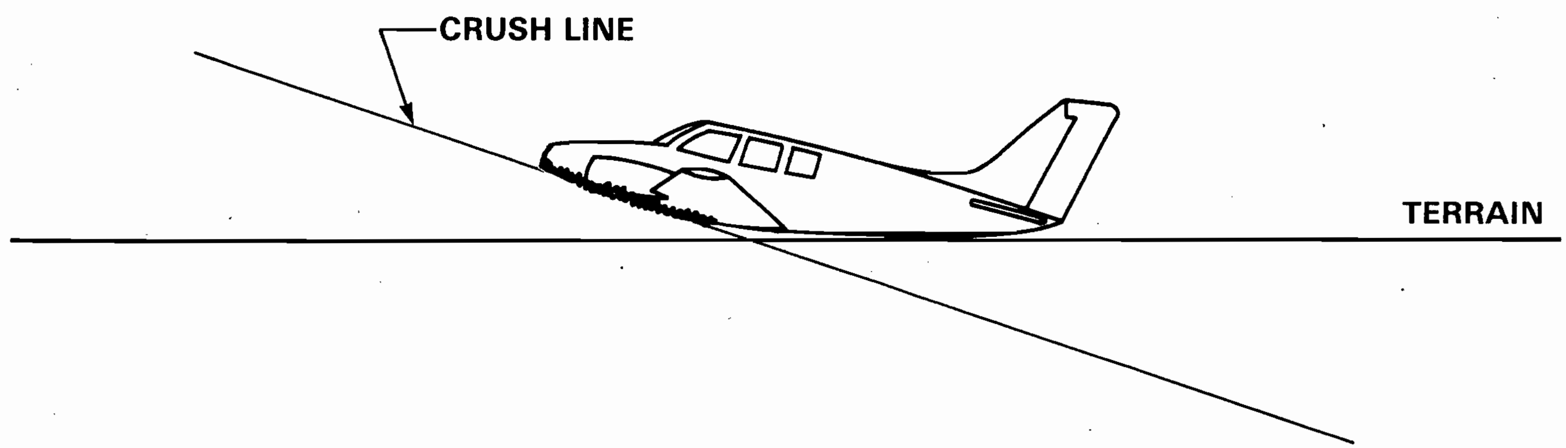


Figure A7.—Crush line.

APPENDIX A

NATIONAL TRANSPORTATION SAFETY BOARD
GENERAL AVIATION CRASHWORTHINESS RECOMMENDATIONS
AND FEDERAL AVIATION ADMINISTRATION RESPONSES

Synopsis: On January 11, 1973, a Piper PA-28-180, N8964J, crashed landed in an orange grove after the engine failed in flight. Three occupants were seriously injured and one was fatally injured. As a result of its investigation of the accident, which disclosed failures in the rear passenger seatbelt cables, the Safety Board recommended on July 31, 1973 that the FAA:

> Issue an Airworthiness Directive for all Piper PA-28-140/180 aircraft, which have the rear bench seat installation, to require replacement of the present 1/8-inch diameter seatbelt attachment cable with a stronger cable, or, alternatively, to reroute the present 1/8-inch cable to eliminate the stress concentration which may result from the cable contact with the seat frame. (A-73-56)

On August 10, 1973, the FAA responded that the static test of the seatbelt installation demonstrated a strength of 12g in the forward direction. The test conditions exceeded requirements, since the test loads included combined loading with forward, upward and sideward components, which resulted in more severe conditions than straight loadings in each design direction applied separately. An FAA review of the seatbelt installation showed that the attachment cable does not come into contact with the seat frame within the design envelope. The seat frame and structure would have to fail and deform before contact can be made. Since the rear seat frame in the area of the cable is a round tubing material, it would not result in an unusually high stress concentration on contact. The strength of the 1/8-inch diameter cable is 2,000 pounds in tension. This is higher than the minimum required seatbelt strength and the strength of the seat. Review of the PA-28 service records showed no previous case of this type of failure since type certification in 1960. The accident report indicated that high impact loads were transmitted to the structure as a result of hitting trees and the ground. The right wing was completely broken off, the left wing was almost severed, and major structural damage was inflicted. The FAA concluded that the installation met strength requirements but that loads in excess of design requirements were imposed. They therefore found no basis for issuance of an Airworthiness Directive.

Status: Although the FAA response indicated that no further action would be taken, its research continued and resulted in fulfulling the intent of the recommendation by the issuance of AD-74-09-04. Therefore, the Safety Board classified safety recommendation A-73-56 as "Closed--Acceptable Action."

Synopsis: On February 17, 1974, a Piper Seneca (PA-34-200) crashed near Taos, New Mexico. The Safety Board's investigation disclosed that the four standard passenger seats and one smaller passenger seat (7th seat) which were installed behind the pilot and copilot seats had separated from their attachments during the crash sequence and were found in a pile in the forward part of the cabin. The seats were attached to the floor by means of "quick disconnect" fittings so that the seats could be removed. Although the seatbelts were attached to the aircraft floor, none had been fastened around the empty seats. As a result of its investigation, the Safety Board made the following recommendations on June 2, 1975, to the FAA:

> Issue an Airworthiness Directive to require that an improved latching device be installed on all Piper aircraft designed with "quick disconnect" seat installations. (A-75-50)

On September 26, 1975, the FAA responded that it had undertaken a "study of the condition described in the recommendation. We have now come to the conclusion, after further investigation, that an unsafe condition may exist. Verification of this possibility and a determination of whether this is a maintenance or design problem will require a survey of actual installations of seats and attachments, evaluation of alternate designs, and operational practices. A plan of action will be completed by November 15, 1975. We will advise you of the action which will be taken."

On December 5, 1975, the FAA stated that "an Airworthiness Directive, AD-75-24-22, Amendment 39-2422, was issued with an effective date of November 21, 1975."

Status: The Safety Board has classified the recommendation as "Closed--Acceptable Action."

The Safety Board also recommended that the FAA:

> Amend 14 CFR 23.785(f) to require dynamic testing of seats to insure more realistic protection of occupants from serious injury in a minor crash. (A-75-51)

On September 26, 1975, the FAA responded that it "is unable to amend 14 CFR 23.785(f) to require dynamic testing unless realistic criteria are established. Necessary data are now being obtained by full scale controlled crash tests being conducted at Langley Research Center. In addition, we are conducting seat/occupant tests at NAFEC and are establishing computer capability through mathematic modeling at our Civil Aeromedical Institute at Oklahoma City. When realistic criteria are established, regulatory action will be taken."

On November 9, 1978, the FAA stated that "in addition to the various research and development contracts in support of the general aviation crashworthiness program, we are in the process of developing a Notice of Proposed Rulemaking to amend TSO-C39a for seats. We expect to complete this project by the end of 1979."

On May 11, 1981, the FAA stated that " Simula, Inc., is currently under contract to the FAA to complete and validate the single occupant, seat-restraint mathematical model. A draft report from Simula is due in September 1981. Following our review and incorporation of any changes, the final report will be available for printing during December 1981. The model's ability to predict seat-occupant-restraint system reaction to a crash pulse will be validated by comparison with test results obtained by the Civil Aeromedical Institute."

Status: The Safety Board has classified safety recommendation A-75-51 as "Open--Unacceptable Action."

Synopsis: On December 2, 1976, a Beech Debonair crashed near Glenville, New York. The airplane cabin remained structurally intact, providing a survivable environment. However, the pilot was killed when he struck the control yoke; a broken rib punctured the pilot's heart. The Safety Board's investigation disclosed that seats did not fail and that, had the pilot been wearing a shoulder harness, upper torso rotation would have been reduced and the thoracic injury would have been prevented. Safety Board investigations of three other general aviation aircraft accidents provided evidence which supported the effectiveness of shoulder harnesses in preventing occupant injury in small airplane accidents.

On June 16, 1977, the FAA amended 14 CFR 23 and 91 to require the installation and use of shoulder harnesses on small general aviation aircraft. The amended airworthiness standards of 14 CFR 23 now require that front seats of general aviation aircraft be equipped with approved safety belts and shoulder harnesses and the amended operating and flight rules of 14 CFR 91 require that shoulder harnesses be installed at each front seat location and be worn during takeoff and landing. These regulations, which became mandatory for flight crewmembers on all aircraft manufactured after July 18, 1978, represented a notable improvement to occupant safety. However, because the Safety Board believed that occupants of the then existing fleet of fixed-wing general aviation aircraft--over 164,000 active airplanes--would be denied the level of protection afforded the occupants of aircraft manufactured after July 18, 1978, it recommended on December 8, 1977, that the FAA:

> Amend 14 CFR 23.785 to require installation of approved shoulder harnesses at all seat locations as outlined in NPRM 73-1. (A-77-70)
>
> Amend 14 CFR 91.33 and .39 to require installation of approved shoulder harnesses on all general aviation aircraft manufactured before July 18, 1978, after a reasonable lead time, and at all seat locations as outlined in NPRM 73-1. (A-77-71)

On February 8, 1978, the FAA responded that it had considered the proposal in NPRM 73-1 and that "it was not considered supportable in the rulemaking process and the Board has provided no new information to justify further rulemaking action." In a February 15, 1979 letter, the FAA stated that "based on the information available to the FAA at the time of their decisions on those amendments, the agency determined that a shoulder harness retrofit requirement was not appropriate. Further it was also believed that delethalization of light aircraft cabins would be preferable to a requirement that all seats be equipped with shoulder harnesses." The FAA stated, however, that it would reconsider its earlier decisions regarding the issues and would advise the Safety Board on its decision.

On March 28, 1980, the FAA advised the Safety Board that it had completed a survey of shoulder harnesses in small airplanes, that it was proceeding with regulatory analysis, and that upon completing of the analysis, it would provide the Safety Board with a detailed response.

Status: The Safety Board has classified safety recommendations A-77-70 and -71 as "Open--Unacceptable Action."

Synopsis: On September 2, 1978, an Antilles Air Boats, Inc., Grumman 21A, struck the water while on a passenger flight from St. Croix to St. Thomas in the Virgin Islands. The aircraft broke apart and the captain and 3 of the 10 passengers drowned. As a result of its investigation, the Safety Board recommended on August 24, 1979, that the FAA:

> Amend 14 CFR 135 to require all aircraft conducting passenger service under Part 135 in any overwater operations be equipped with approved flotation-type seat cushions, and to require aircraft conducting extended overwater operations to also be equipped with an approved life preserver equipped with an approved survivor locator light. (A-79-67)

On June 15, 1981, the FAA Administrator responded that he had directed his staff to assemble operational statistics regarding survival aids in waters landings, analyze the statistics, and present him with a summary of alternative means to mitigate those risks. The Administrator also stated that his staff would also provide a detailed estimate of the costs of each alternative action, considering all relevant data and recommendations from the Board.

Status: The Safety Board has classifed safety recommendation A-79-67 as "Open--Acceptable Action."

Synopsis: The Safety Board's investigation of the Rocky Mountain Airlines DeHavilland DHC aircraft accident near Steamboat Springs, Colorado, on December 4, 1978, illustrated the need for survival training for crewmembers and for the installation of shoulder harnesses on crew seats. As a result of its investigation of this accident, the Safety Board recommended on September 6, 1979, that the FAA:

> Strictly enforce the compliance date for the istallation of shoulder harnesses as required by 14 CFR 135.171. (A-79-70)

On December 5, 1979, the FAA responded that "this agency's action of granting certain operators extensions to the shoulder harness requirment under Part 135 is a logical solution to a supply problem. We are not aware of any abuses by operators in delaying the installation of shoulder harnesses in their aircraft."

In an April 29, 1981 letter, the FAA stated that "all requests for extension of the compliance date were necessitated because of nonavailability of shoulder harness kits by vendors of manufacturers prior to June 1, 1979. The letter further stated that the FAA had conducted a spot check with several regional vendors and had found that air taxi operators granted extensions were in compliance with 14 CFR 135.10.

Status: The Safety Board has classified safety recommendation A-79-70 as "Closed--Acceptable Action."

Synopsis: A special study conducted by the Safety Board on "General Aviation Accidents: Post Crash Fires and How to Prevent or Control Them" showed that postcrash fires occurred in approximately 8 percent of the 22,002 general aviation accidents which occurred between 1974 and 1978. About 59 percent of those accidents involving postcrash fire resulted in fatailities. However, fatalities were involved in only 13.3 percent of those accidents without fire. As a result of its special study, the Safety Board recommended on September 9, 1980, that the FAA:

> Amend the airworthiness regulations to incorporate the latest technology for flexible, crash-resistant fuel lines, and self-sealing frangible fuel line couplings at least equivalent in performance to those used in recent FAA tests and described in report No. FAA-RD-78-28 for all newly certificated general aviation aircraft. (A-80-90)
>
> Amend the airworthiness regulations to incorporate the latest technology for light weight, flexible, crash-resistant fuel cells at least equivalent in performance to those used in recent FAA tests and described in report No. FAA-RD-78-28 for newly certificated general aviation aircraft having nonintegral fuel tank designs. (A-80-91)

Require after a specified date that all newly manufactured general aviation aircraft comply with the amended airworthiness regulations regarding fuel system crashworthiness. (A-80-92)

Fund research and development to develop the technology and promulgate standards for crash-resistant fuel systems for general aviation aircraft having integral fuel tank designs equivalent to the standards for those aircraft having nonintegral fuel tank designs. (A-80-93)

Assess the feasibility of requiring the installation of selected crash resistant fuel system components, made available in kit form from manufacturers, in existing general aviation aircraft on a retrofit basis and promulgate appropriate regulations. (A-80-94)

Continue to fund research and development to advance the state-of-the-art with the view toward developing other means to reduce the incidence of postcrash fire in general aviation aircraft. (A-80-95)

On December 8, 1980, the FAA responded that it believed that the recommendations "merit consideration, but will require indepth investigation with regard to effectivity and feasibility. A project has been established to consider the substance of these recommendations."

Regarding recommendations A-80-90 through -92, the FAA responded on October 15, 1981, that it concurred with the intent of the recommendations and that it had initiated a preliminary effort to study the impact of actions associated with implementation of these recommendations. The FAA stated that if its studies and evaluations "indicate the potential benefits to society outweigh the potential costs of implementation, the FAA will further consider these recommendations and or appropriate alternatives for accomplishing the intent of the recommendations."

Status: The Safety Board has classified safety recommendations A-80-90 through -92 as "Open--Acceptable Action."

Regarding safety recommendation A-80-93 and -95, the FAA responded that "a crashworthiness investigation team specializing in the collection of precise accident and injury information is being formed. Research and development efforts will be undertaken depending on the results of the teams's findings. Any such programs will include a cost/benefit analysis to assure that the cost of installing crash-resistant tanks and fittings are commensurate with expected safety improvements."

On October 15, 1981, the FAA stated that it concurred in the intent of safety recommendation A-80-93 and -95. "Research and development efforts will be dependent upon the results of a review of general aviation accident data currently underway. We are placing a high priority on this review and will continue to keep the Board informed of our efforts in this regard."

Status: The Safety Board has classified safety recommendations A-80-93 and -95 as "Open--Acceptable Action."

Regarding safety recommendation A-80-94, the FAA responded on October 15, 1981, that it had completed an evaluation of this recommendation. "We have concluded that it is not feasible to require the retrofit of existing general aviation airplanes with selected crash resistant fuel system components, such as crash resistant fuel cells. We find that the total economic impact associated with the costs for engineering, recertification, parts, and installation would be prohibitive for the large number of general aviation airplanes presently in operation. In consideration of the necessary supply of parts for these airplanes, coupled with the massive and complex logistics that would be required, we estimate that it would require decades to accomplish a retrofit program."

Status: The Safety Board has classified safety recommendation A-80-94 as "Open--Acceptable Action."

Synopsis: On December 17, 1980, the Safety Board completed an assessment of the adequacy of occupant protection in general aviation aircraft during a crash. The study was conducted because of the Safety Board's longstanding concern that a majority of serious and fatal injuries which occur annually in these aircraft should be preventable. The Safety Board's report reviewed accident investigation findings, crashworthiness research and studies, and the regulatory requirements to assess the adequacy of occupant protection during general aviation conditions which should be survivable.

As a result of the special study, the Safety Board recommended that the FAA:

> Require that those general aviation aircraft manufactured to include attachment points for shoulder harnesses at occupant seats be fitted with shoulder harnesses no later than December 31, 1985, and, in the interim, require this modification as a requisite for change in FAA registration. (A-80-125)
>
> Develop, in coordination with airframe manufacturers, detailed, approved installation instructions for installing shoulder harnesses at each seat location in current models and types of general aviation aircraft in which shoulder harness attachment points were not provided as standard equipment. Publish and provide these instructions to owners of these aircraft by December 31, 1982. (A-80-126)
>
> Require that those general aviation aircraft for which FAA-approved harness installation instructions have been developed be fitted with shoulder harnesses at each seat location no later than December 31, 1985, and, in the interim, require this modification as a requisite for change in the FAA registration. (A-80-127)
>
> Extend the application of all newly established occupant protection provisions of 14 CFR 23 to all newly manufactured general aviation aircraft. (A-80-128)
>
> Revise 14 CFR 23.785(j) to incorporate performance standards and test criteria to insure that an acceptable level of occupant safety is achieved through cabin "delethalization." (A-80-129)
>
> Revise current standards for seat and restraint systems to incorporate needed crashworthiness improvements identified in FAA research project reports. (A-80-130)
>
> Establish standards for the dynamic testing of occupant protection devices required in general aviation aircraft. (A-80-131)

On April 3, 1981, the FAA acknowledged receipt of the recommendations.

Status: The Safety Board has classified safety recommendations A-80-125 through A-80-131 as "Open--Response Received."

Synopsis: On February 26, 1980, a Cessna Model 172K (XP) crashed during normal takeoff from the Eagle Creek Airport near Indianapolis, Indiana. The pilot, a commercial flight instructor and the only occupant of the aircraft, was killed. According to witnesses, the aircraft pitched up to a steep nose high attitude, about 60° or 70°, and the sound of the engine power reduced abruptly from takeoff power to idle. The aircraft then pitched down and rotated about 160° to the left before crashing on the edge of the asphalt runway.

As a result of its investigation, the Safety Board recommended on February 24, 1981, that the FAA:

> Issue an Airworthiness Directive for Cessna aircraft in which interference between seats in the full forward position and door jambs currently exists requiring that the seat rail stops be positioned to permit proper seat locking in all seat positions. (A-81-15)
>
> Require the Cessna Aircraft Company to include an adjustment and locking check of front seats, belts, and shoulder harnesses on the "before takeoff" checklists applicable to all Cessna aircraft. This item should be included on new checklists as soon as possible. (A-81-16)

Regarding safety recommendation A-81-15, the FAA responded on May 26, 1981, that an "analysis of the accident data on the Eagle Creek Airport crash has raised questions concerning the probable sequence of events that caused the actual crash. This has placed in question the part that seat slipping may have had in causing the crash. In order to complete our analysis of whether some Cessna seats may not lock in place properly because of interference with the door jamb, we are analyzing our service difficulty reports, inspections of Cessna production aircraft, and some additional data supplied by the Board on other accidents where slippage of the pilot's seat was determined to be a causal element."

Status: The Safety Board has classifed safety recommendation A-81-15 as "Open--Acceptable Action."

Regarding safety recommendation A-81-16, the FAA responded on May 26, 1981, that "in view of our comments on safety recommendation A-81-15, we believe it prudent to withhold any decision or action on this safety recommendation until we have completed our analysis on the issues surrounding any seat problem that may exist."

Status: The Safety Board has classified safety recommendation A-81-16 as "Open--Acceptable Action."

Synopsis: On August 28, 1970, the Safety Board forwarded a letter to the FAA suggesting that "it is time to take a new look at minimum standards as they are applied in the general aviation crash safety field." In the letter, the Safety Board drew attention to the difference in crash safety philosophy employed by the FAA and the safety philosophy adopted by its sister agency responsible for automotive safety. The Safety Board recommended that the FAA reevaluate its position on minimum general aviation crashworthiness standards, considering at least the five specific recommendations included in the letter.

The Safety Board recommended that:

> (Part 1) Shoulder harnesses should be required on all general aviation aircraft at the earliest practical date.
>
> (Part 2) Delethalization of aircraft interiors - Suitable energy-absorbing padding should be required on all interior structures to protect occupants.
>
> (Part 3) Dynamic testing of aircraft seats should be required.
>
> (Part 4) Emergency landing conditions - Regulatory action be initiated to raise the "minor crash landing" inertia forces of FAR 23.561 to a level comparable to those produced by a moderate-to-severe crash landing.
>
> (Part 5) Crash fire protection - Fuel tanks and fuel systems should be designed to minimize the spillage of fuel in moderate to severe crashes.
>
> (CY-70-42)

On September 3, 1970, the FAA responded that they were "preparing a Notice of Proposed Rulemaking on the subject of this recommendation and that its staff will be in touch with the Board's technical personnel." The FAA enclosed a copy of its Disposition of Petition re. Ralph Nader's Crashworthiness Petition.

On November 7, 1972, the FAA indicated that an NPRM covering parts Nos. 1 and 2 of the recommendation would be released before the end of the year. Regarding parts Nos. 3, 4, and 5, the FAA indicated that there may be need for improvements in those areas, but the information presently available was not sufficient to support rulemaking action.

It took the FAA 7 years to implement the recommendation. Safety Board followup action included responses to NPRM 73-2 and FAA's Notice No. 74-3, Airworthiness Review Program. Evaluation of implemented action on Part 23 and Part 91 are now amended to require the installation of shoulder harnesses for the front seats of all small airplanes manufactured after July 18, 1978. Crewmembers occupying seats with required shoulder harnesses must have them fastened during takeoff and landing. The requirement is not retroactive to previously manufactured small planes. Part 23 was amended with the following paragraph:

> The cabin area surrounding each seat, including the structure, interior walls, instrument panel, control wheel, pedals, and seats, within striking distance of the occupants's head or torso (with the safety belt fastened), must be free of potentially injurious objects, sharp edges, proturberances, and hard surfaces. If energy absorbing designs or devices are used to meet this requirement, they must protect the occupant from serious injury when the occupant experiences the ultimate inertia forces prescribed in Section 23.561(b) (2).

Status: The Safety Board has classified safety recommendation CY-70-42 as "Closed--Acceptable Action." Part 4 of CY-70-42 was reiterated with the issuance of safety recommendations A-80-125 through -131.

APPENDIX B

NTSB EXPANDED ACCIDENT/INCIDENT REPORT (NTSB FORM 6120.4)

1 National Transportation Safety Board **FACTUAL REPORT AVIATION** 1 ☐ ACCIDENT 2 ☐ INCIDENT			2 NTSB Accident/Incident Number 3 INVESTIGATION 1 ☐ NTSB 2 ☐ FAA DELEGATED	
3 Aircraft Registration Number	4 Flight Number	*For collision between aircraft, enter reg. no. and flt. no. for other aircraft*	5 Aircraft Registration Number	6 Flight Number
7 City/Place	8 State	9 Zip Code *(First 5 numbers only)*	10 Accident Site Elevation Feet MSL	
11 Date of Accident *(Nos. for M, D, Y)*	12 Day of Week *(First 2 letters)*	13 Local Time *(24 hour clock)*	14 Time Zone	
15 Narrative Statement of Facts, Conditions and Circumstances Pertinent to the Accident/Incident *Attach additional pages if necessary*				
16 Additional Persons Participating in this Accident/Incident Investigation *(Name, address, affiliation, attach additional pages if necessary)*				
Investigated By:				
17 Date *(Nos. for M, D, Y)*	18 Agency	19 Name/Signature		

NTSB Form 6120.4 (Rev. 1/83)

National Transportation Safety Board

FACTUAL REPORT AVIATION

ACCIDENT/INCIDENT

Airport/Approach/Landing Information

25 Airport Name
A Other

26 Airport Identifier

27 Accident Location
1 ☐ Off airport/airstrip
2 ☐ On airport
3 ☐ On airstrip
A Other

28 Distance From Airport Center *(Nearest SM)*
SM
A Other

29 Direction From Airport
° Magnetic
A Other

30 VFR Approach/Landing *(Multiple entry)*
1 ☐ None
2 ☐ Traffic pattern
3 ☐ Straight-in
4 ☐ Valley/terrain following
5 ☐ Touch and go
6 ☐ Full stop
7 ☐ Stop and go
8 ☐ Simulated forced landing
9 ☐ Forced landing
10 ☐ Precautionary landing
A Other

31 Type Instrument Approach Flown *(Multiple entry)*
1 ☐ None
2 ☐ ADF/NDB
3 ☐ VOR/TVOR
4 ☐ VOR/DME
5 ☐ TACAN
6 ☐ ILS—complete
7 ☐ ILS—localizer
8 ☐ ILS—backcourse
9 ☐ RNAV
10 ☐ MLS
11 ☐ LDA
12 ☐ ASR
13 ☐ PAR
14 ☐ Sidestep
15 ☐ Visual
16 ☐ Contact
17 ☐ Circling
18 ☐ Practice
A Other

32 Runway Used Identifier
A Other

33 Runway Length
Feet
A Other

34 Runway Width
Feet
A Other

35 Airport Elevation
Ft. MSL
A Other

36 Runway/Landing Surface
1 ☐ Macadam
2 ☐ Asphalt
3 ☐ Concrete
4 ☐ Gravel
5 ☐ Dirt
6 ☐ Grass/turf
7 ☐ Snow
8 ☐ Ice
9 ☐ Water
A Other

37 Runway/Landing Surface Status
1 ☐ Dry
2 ☐ Wet
3 ☐ Ice covered
4 ☐ Snow—dry
5 ☐ Snow—wet
6 ☐ Snow—crusted
7 ☐ Snow—compacted
8 ☐ Vegetation
9 ☐ Water—calm
10 ☐ Water—choppy
11 ☐ Water—glassy
12 ☐ Rubber deposits
13 ☐ Soft
14 ☐ Rough
15 ☐ Slush covered
16 ☐ Holes
A Other

38 *If accident/incident occurred during taxi takeoff, approach, landing or appropriate maneuvering phase of operations, check here ☐ and complete airport supplement.*

Aircraft Information

39 Aircraft Manufacturer

40 Aircraft Model/Series

41 Serial No.
A Other

42 Certificated Maximum Gross Weight
A Other

43 Type of Aircraft
1 ☐ Airplane
2 ☐ Helicopter
3 ☐ Glider
4 ☐ Balloon
5 ☐ Blimp/dirigible
6 ☐ Ultralight
7 ☐ Gyroplane
A Specify

44 Type Airworthiness Certificate
Standard
1 ☐ Normal
2 ☐ Utility
3 ☐ Acrobatic
4 ☐ Transport
5 ☐ Unknown
Special
6 ☐ Restricted
7 ☐ Limited
8 ☐ Provisional
9 ☐ Special flight
10 ☐ Experimental
A Other

45 Home Built
1 ☐ Yes
2 ☐ No
A Other

National Transportation Safety Board

FACTUAL REPORT
AVIATION

ACCIDENT/INCIDENT

Aircraft Information (continued)

46 Landing Gear *(Multiple entry)*
1 ☐ Tricycle—fixed
2 ☐ Tricycle—retractable
3 ☐ Tailwheel—all fixed
4 ☐ Tailwheel—all retractable
5 ☐ Tailwheel—retractable mains
6 ☐ Amphibian
7 ☐ Hull
8 ☐ Float
9 ☐ Emerg. float
10 ☐ Ski
11 ☐ Ski/wheel
12 ☐ Skid
13 ☐ High Skid
14 ☐ Body gear
15 ☐ Wing gear
A Other

47 Aircraft Damage
1 ☐ None
2 ☐ Minor
3 ☐ Substantial
4 ☐ Destroyed

48 No. of Seats
A Other

49 Stall Warning System Installed
1 ☐ Yes
2 ☐ No
A Other

50 IFR Equipped
1 ☐ Yes
2 ☐ No
A Other

51 Icing Certification
1 ☐ Yes
2 ☐ No
A Other

52 Engine Manufacturer

53 Engine Model and Series

54 Engine Rated Horsepower
A Other

55 Engine Rated Thrust
Lbs. A Other

56 Engine Type
1 ☐ Reciprocating—carburetor
2 ☐ Reciprocating—fuel injected
3 ☐ Turbo prop
4 ☐ Turbo jet
5 ☐ Turbo fan
6 ☐ Turbo shaft
A Other

57 Number of Engines
A Other

58 Type Maintenance Program
1 ☐ Annual
2 ☐ 100 hour
3 ☐ AAIP/progressive
4 ☐ Continuous airworthiness
A Other

59 Type of Last Inspection
1 ☐ Annual
2 ☐ 100 hour
3 ☐ AAIP/progressive
4 ☐ Continuous airworthiness
A Other

60 Date Last Inspection Performed
(Nos. for M. D. Y)
A Other

61 Time Since Inspection
Hours
A Other

62 Airframe Total Time
Hrs.
A Other

63 Source of Maintenance Information
1 ☐ Tach
2 ☐ Flight
3 ☐ Hobbs
4 ☐ Logbooks Records
5 ☐ Estimate
A Other

Engine Time *(Hours)*	**A** Total Time	**B** Time Since Inspection	**C** Time Since Major Overhaul	**D** Other
64 Engine No 1				
65 Engine No 2				

66 Hazardous Materials on Aircraft
1 ☐ No
A *(Type)*
B Other

67 Hazardous Material Spill/Factor
1 ☐ Yes
2 ☐ No
A Other

Emergency Locator Transmitter (ELT)	1 Yes	2 No	A Other
68 Installed			
69 Required			
70 Operated			

Operator Information

71 Registered Aircraft Owner
Name

72 Address

73 Operator of Aircraft 1 ☐ Same as registered owner
A Name:
B dba
C Other

74 Address 1 ☐ Same as registered owner
A
B Other

75 Operator Certificate No.
A Other

NTSB Form 6120.4 (Rev 1/83)

National Transportation Safety Board

FACTUAL REPORT AVIATION

ACCIDENT/INCIDENT

Operator Information (continued)

76 Operator Status of This Aircraft
1 ☐ Owner
2 ☐ Lessee
3 ☐ Renter
4 ☐ Borrower
5 ☐ Unauthorized
A Other ⌊⌋

77 Pilot Status of This Aircraft
1 ☐ Owner
2 ☐ Lessee
3 ☐ Renter
4 ☐ Borrower
5 ☐ Unauthorized
6 ☐ Employee
A Other ⌊⌋

Type of Certificate(s) Held

78 None ☐ *(Go to block 82)*

79 Air Carrier Operating Certificate
1 ☐ Flag carrier/domestic (121)
2 ☐ Supplemental
3 ☐ All cargo (418)
4 ☐ Large helicopter (127)
5 ☐ Commuter air carrier
6 ☐ On-demand air taxi

80 Operating Certificate
1 ☐ Air travel club
2 ☐ Other operator of large aircraft

81 Operator Certificate
1 ☐ Rotorcraft—external load operator (133)
2 ☐ Agricultural aircraft *(137)*

Regulation Flight Conducted Under

82 Regulation Flight Conducted Under
1 ☐ 14 CFR 91 *(only)*
2 ☐ 14 CFR 91D
3 ☐ 14 CFR 121
4 ☐ 14 CFR 125
5 ☐ 14 CFR 127
6 ☐ 14 CFR 133
7 ☐ 14 CFR 135
8 ☐ 14 CFR 137
9 ☐ 14 CFR 129 *(Foreign flag)*
A Specify ____________

Type of Flight Operation Conducted

*(Complete 83, 84, and 85 **ONLY** if flight was a revenue operation conducted under 121, 125, 127, 129, 135)*

83
1 ☐ Scheduled
2 ☐ Non-scheduled

84
1 ☐ Domestic
2 ☐ International

85
1 ☐ Passenger
2 ☐ Cargo
3 ☐ Passenger/cargo
4 ☐ Mail contract ONLY

*(Complete 86 **ONLY** if flight was **NOT** a revenue flight conducted under 121, 125, 127, 129, 135)*

86
1 ☐ Personal
2 ☐ Business
3 ☐ Instructional *(Including air carrier training)*
4 ☐ Executive/corporate
5 ☐ Aerial application
6 ☐ Aerial observation
7 ☐ Other work use
8 ☐ Public use
9 ☐ Ferry
10 ☐ Positioning
A Specify ____________

Pilot Information

87 Name *(Last, First, Initial)* ____________
A Other ⌊⌋

88 Pilot Certificate No. ____________
A Other ⌊⌋

89 Street Address ____________
A Other ⌊⌋

90 City ____________
A Other ⌊⌋

91 State ⌊⌋

92 Date of Birth *(Nos. for M. D. Y)* ⌊⌋⌊⌋⌊⌋
A Other ⌊⌋

93 Age ⌊⌋ Yrs.
A Other ⌊⌋

94 Sex
1 ☐ Male
2 ☐ Female

95 Seat Occupied
1 ☐ Left
2 ☐ Right
3 ☐ Center
4 ☐ Front
5 ☐ Rear
A Other ⌊⌋

96 Principal Profession
1 ☐ Pilot—civilian
2 ☐ Pilot—military
3 ☐ Other—military
4 ☐ Aircraft mechanic
5 ☐ Business
6 ☐ Lawyer
7 ☐ Doctor/dentist
8 ☐ Police
9 ☐ Student
10 ☐ Clergy
11 ☐ Teacher
12 ☐ Engineer
13 ☐ Farmer/rancher
14 ☐ Retired
A Other ⌊⌋

97 Certificate(s) *(Multiple entry)*
1 ☐ Student
2 ☐ Private
3 ☐ Commercial
4 ☐ Airline Transport
5 ☐ Flight Instructor *(Complete block 101)*
6 ☐ Flight Engineer
7 ☐ Military
8 ☐ None
9 ☐ Foreign
A Other ⌊⌋

National Transportation Safety Board

FACTUAL REPORT
AVIATION

ACCIDENT/INCIDENT

Pilot Information (continued)

98 Ratings—Airplane
1 ☐ Single engine land
2 ☐ Multiengine land
3 ☐ Single engine sea
4 ☐ Multiengine sea

99 Rotorcraft/Glider/LTA
1 ☐ Helicopter
2 ☐ Gyroplane
3 ☐ Airship
4 ☐ Free balloon
5 ☐ Glider

100 Instrument Rating
1 ☐ None
2 ☐ Airplane
3 ☐ Helicopter

101 Instructor Rating(s)
1 ☐ Airplane SE
2 ☐ Airplane ME
3 ☐ Helicopter
4 ☐ Gyroplane
5 ☐ Glider
6 ☐ Instrument airplane
7 ☐ Instrument helicopter

102 Ground Instructor
1 ☐ Basic
2 ☐ Advanced
3 ☐ Instrument
4 ☐ None

103 Rating/Endorsement This Aircraft
1 ☐ Yes
2 ☐ No *(Go to block 105)*
A Other ⌊_⌋

104 Months Since Check/Endorsement
⌊_⌋ Months
A Other ⌊_⌋

105 Biennial Flight Review
(Or equivalent)
1 ☐ Yes
2 ☐ No
A Other ⌊_⌋

106 Months Since Last BFR
⌊_⌋ Months
A Other ⌊_⌋

107 BFR *(or equivalent)* **Aircraft Make/Model**
A Make ______
B Model ______
C Other ⌊_⌋

108 Medical Certificate
1 ☐ Class 1
2 ☐ Class 2
3 ☐ Class 3
A Other ⌊_⌋

109 Medical Certificate Validity
1 ☐ Valid medical—no waivers/limitations
2 ☐ Valid medical—with waivers/limitations
3 ☐ Non valid medical for this flight
4 ☐ Expired
5 ☐ No medical certificate
A Other ⌊_⌋

110 Date of Last Medical *(Nos. for M. D. Y)*
⌊_⌊_⌊_⌋
A Other ⌊_⌋

111 Medical limitation for
1 ☐ Vision
A Specify ______
B Other ⌊_⌋

112 Medical waiver for
1 ☐ Vision
2 ☐ Hearing
A Specify ______
B Other ⌊_⌋

113 Statement of Demonstrated Ability
1 ☐ Yes
2 ☐ No
A Other ⌊_⌋

114 Correcting Lenses *(Multiple entry)*
1 ☐ Required to be in possession
2 ☐ Required to be worn
3 ☐ Worn at time of accident
A Other ⌊_⌋

115 Source of Pilot Flight Time
1 ☐ Pilot log
2 ☐ Company
3 ☐ FAA
4 ☐ Operator
5 ☐ Estimate
6 ☐ Relative
A Other ⌊_⌋

Flight Time	A All A C	B This Make & Model	C Airplane Single Engine	D Airplane Multiengine	E Night	F Instrument Actual	G Instrument Simulated	H Rotorcraft	I Glider	J Lighter Than Air	K Other
135 Total Time											
136 Pilot in Command (PIC)											
137 Instructor											
138 This Make/Model											
139 Last 90 Days											
140 Last 30 Days											
141 Last 24 Hours											

142 Landings—Last 90 Days—All Aircraft
⌊_⌋ Day A Other ⌊_⌋

143 Landings—Last 90 Days—All Aircraft
⌊_⌋ Night A Other ⌊_⌋

144 Landings—Last 90 Days —This Make/Model
⌊_⌋ Day A Other ⌊_⌋

145 Landings—Last 90 Days —This Make/Model
⌊_⌋ Night A Other ⌊_⌋

146 Person at Controls
1 ☐ Pilot in command
2 ☐ Second pilot
3 ☐ Both pilots
4 ☐ Non-pilot
5 ☐ No one
A Other ⌊_⌋

147 Degree of Injury
1 ☐ None
2 ☐ Minor
3 ☐ Serious
4 ☐ Fatal

148 Seatbelts Available
1 ☐ Yes
2 ☐ No
A Other ⌊_⌋

149 Seatbelts Used
1 ☐ Yes
2 ☐ No
A Other ⌊_⌋

150 Shoulder Harness Available
1 ☐ Yes
2 ☐ No
A Other ⌊_⌋

151 Shoulder Harness Used
1 ☐ Yes
2 ☐ No
A Other ⌊_⌋

152 Autopsy Performed *(This pilot)*
1 ☐ Yes
2 ☐ No
A Other ⌊_⌋

National Transportation Safety Board

FACTUAL REPORT AVIATION

ACCIDENT/INCIDENT

Pilot Information (continued)

153 Toxicology Performed *(This pilot)*
1 ☐ Yes A Other ⌊⌋
2 ☐ No

154 Second Pilot
1 ☐ Yes *(Complete second pilot supplement)*
2 ☐ No

Flight Itinerary Information

155 Last Departure Point *(Multiple entry)*
1 ☐ Same as accident/incident location **or**
A Airport identifier ______
B City/Place ______
C State ⌊⌋ D Other ⌊⌋

156 Time of Departure
A Time ⌊⌋ C Other ⌊⌋
B Time zone ⌊⌋

157 Destination *(Multiple entry)*
1 ☐ Same as accident/incident location **or**
2 ☐ Local flight
A Airport Identifier ______
B City/Place ______
C State ⌊⌋
D Other ⌊⌋

158 Flight Plan Filed
1 ☐ Visual Flight Rules (VFR)
2 ☐ Instrument Flight Rules (IFR)
3 ☐ VFR/IFR
4 ☐ Company (VFR)
5 ☐ Military (VFR)
6 ☐ None
A Other ⌊⌋

159 Type of Clearance
1 ☐ None
2 ☐ Special VFR
3 ☐ IFR
4 ☐ Special IFR
5 ☐ VFR on top
6 ☐ Cruise
A Other ⌊⌋

160 Airspace
1 ☐ Uncontrolled
2 ☐ Controlled
3 ☐ Airport traffic area
4 ☐ Control zone
5 ☐ Airport advisory area
6 ☐ Positive control area
7 ☐ Terminal control area
8 ☐ Stage II TRSA
9 ☐ Stage III TRSA
10 ☐ Prohibited area
11 ☐ Restricted area
12 ☐ Military Operating Area (MOA)
13 ☐ Student Jet Training Area
14 ☐ Demo Area
15 ☐ Warning area
16 ☐ FAR 93 (Special air traffic areas)
A Other ⌊⌋

161 Control Area
1 ☐ Victor airway
2 ☐ Jet airway
3 ☐ Control airway
4 ☐ Colored airway
A Other ⌊⌋

162 Route
1 ☐ Standard instrument departure
2 ☐ Standard terminal arrival
3 ☐ Area navigation
4 ☐ Direct
5 ☐ VR route (military)
6 ☐ IR route (military)
7 ☐ SR route (military)
8 ☐ Refueling route (military)
A Other ⌊⌋

163 Two Way Communications Established
1 ☐ No
2 ☐ Yes
A Facility identifier ______
B Other ⌊⌋

Aircraft Loading Information

164 Fuel on Board at Takeoff *(Multiple entry)*
1 ☐ Estimated
2 ☐ Verified
A ______ Gallons **or**
B ______ Pounds
C Other ⌊⌋

165 Fuel Types
1 ☐ 80/87
2 ☐ 100 low lead
3 ☐ 100/130
4 ☐ 115/145
5 ☐ Kerosene
6 ☐ JP 3, 4, 5, 6
7 ☐ Jet A
8 ☐ Jet B
9 ☐ Mixture
10 ☐ Automotive
11 ☐ Anti ice additive added *(If known)*
A Other ⌊⌋

166 Aircraft Weight at Takeoff *(Multiple entry)*
1 ☐ At or below max cert. gross takeoff weight
2 ☐ Above max certificated gross takeoff weight
3 ☐ Estimated
4 ☐ Verified
A Other ⌊⌋

167 Aircraft CG at Takeoff *(Multiple entry)*
1 ☐ Within limits
2 ☐ Exceeded fwd limit
3 ☐ Exceeded aft limit
4 ☐ Exceeded lateral limit
5 ☐ Estimated
6 ☐ Verified
A Other ⌊⌋

168 Aircraft Weight at Accident *(Multiple entry)*
1 ☐ Same as takeoff
2 ☐ At or below max cert. gross takeoff weight
3 ☐ Above max certificated gross takeoff weight
4 ☐ Estimated
5 ☐ Verified
A Other ⌊⌋

169 Aircraft CG at Accident *(Multiple entry)*
1 ☐ Same as takeoff
2 ☐ Within limits
3 ☐ Exceeded fwd limit
4 ☐ Exceeded aft limit
5 ☐ Exceeded lateral limit
6 ☐ Estimated
7 ☐ Verified
A Other ⌊⌋

National Transportation Safety Board

FACTUAL REPORT AVIATION

ACCIDENT/INCIDENT

Aircraft Loading Information (continued)

170 Load Description
1 ☐ None
2 ☐ Passengers
3 ☐ Cargo
4 ☐ Towing glider
5 ☐ Towing banner
6 ☐ Other external
7 ☐ Parachutists
8 ☐ Water
9 ☐ Chemical
10 ☐ Livestock
11 ☐ Illegal cargo
A Other

174 Simulated Instrument Flight
1 ☐ Yes
2 ☐ No
A Other

175 Vision Restricting Device Used
1 ☐ Yes
2 ☐ No
A Other

176 Parachute Required
1 ☐ Yes
2 ☐ No
A Other

177 Parachute Used
1 ☐ Yes
2 ☐ No
A Other

Meterological Information

180 Source of Weather Briefing *(Multiple entry)*
1 ☐ No record of briefing
2 ☐ National Weather Service (NWS)
3 ☐ Flight Service Station
4 ☐ PATWAS (Pilot Automated Tel. WX Answering SVC)
5 ☐ VRS (Voice Response System)
6 ☐ Company
7 ☐ Commercial weather service
8 ☐ TV/radio weather
9 ☐ Military
A Other

181 Method of Briefing *(Multiple entry)*
1 ☐ In person
2 ☐ Teletype
3 ☐ Telephone
4 ☐ Aircraft radio
5 ☐ TV/radio
A Other

182 Completeness of Weather briefing
1 ☐ Weather not pertinent
2 ☐ Full
3 ☐ Partial—limited by pilot
4 ☐ Partial—limited by briefer/forecaster
A Other

183 Investigator's Source of Weather Information
1 ☐ Pilot *(Go to block 185)*
2 ☐ Witness *(Go to block 185)*
3 ☐ Weather observation facility

184 Weather Observation Facility *(Direct entry)*
A Identifier ______
B Time of observation ______ zone ______
C Elevation ______ feet MSL
D Distance from accident site ______ NM
E Direction from accident site ______ ° magnetic

185 Basic Weather Conditions
1 ☐ Visual Meteorological Conditions (VMC)
2 ☐ Instrument Meteorological Conditions (IMC)
A Other

186 Conditions of Light
1 ☐ Dawn
2 ☐ Daylight
3 ☐ Night (Dark)
4 ☐ Night (Bright)
5 ☐ Dusk
A Other

187 Lowest Sky/Cloud Condition
1 ☐ Clear
2 ☐ Scattered
3 ☐ Thin broken
4 ☐ Thin overcast
5 ☐ Partial obscuration
A ______ Feet AGL
B Other

188 Lowest Ceiling
1 ☐ None (Clear)
2 ☐ Broken
3 ☐ Overcast
4 ☐ Obscured
A ______ Feet AGL
B Other

189 Visibility
______ SM

190 Temperature
______ ° F
A Other

191 Dew Point
______ °F
A Other

192 Wind (From)
1 ☐ Variable
A ______ ° Magnetic
B Other

193 Wind Velocity
1 ☐ Calm
A ______ Kts
B Other

194 Gusts
1 ☐ None
A ______ Kts.
B Other

195 Altimeter Setting
__.__ " Hg
A Other

196 Density Altitude
______ Feet
A Other

197 Restrictions to Visibility
1 ☐ None
2 ☐ Haze (H)
3 ☐ Dust (D)
4 ☐ Smoke (K)
5 ☐ Fog (F)
6 ☐ Ice fog (IF)
7 ☐ Ground fog (GF)
8 ☐ Blowing spray (BY)
9 ☐ Blowing dust (BD)
10 ☐ Blowing snow (BS)
11 ☐ Blowing sand (BN)
A Other

198 Type of Precipitation
1 ☐ None
2 ☐ Rain (R)
3 ☐ Snow (S)
4 ☐ Hail (A)
5 ☐ Rain showers (RW)
6 ☐ Freezing rain (ZR)
7 ☐ Snow shower (SW)
8 ☐ Drizzle (L)
9 ☐ Ice pellets (IP)
10 ☐ Snow pellets (SP)
11 ☐ Snow grains (SG)
12 ☐ Freezing drizzle (ZL)
13 ☐ Ice crystals (IC)
14 ☐ Ice pellet shower (IPW)
A Other

200 Intensity of Precipitation
1 ☐ Light
2 ☐ Moderate
3 ☐ Heavy
A Other

201 Aircraft Fire
1 ☐ None
2 ☐ In-flight
3 ☐ On ground
A Other

202 Explosion
1 ☐ None
2 ☐ In-flight
3 ☐ On ground
A Other

203 Damage to Property
1 ☐ None
2 ☐ Residence
3 ☐ Residential area
4 ☐ Commercial bldg
5 ☐ Vehicle(s)
6 ☐ Airport facility
7 ☐ Trees
8 ☐ Crops
9 ☐ Wires/poles
10 ☐ Other property

National Transportation Safety Board

FACTUAL REPORT AVIATION

ACCIDENT/INCIDENT

Part Failure/Incorrect Part

204 Part Failure/Malfunction *(Multiple entry)*
1 ☐ None 3 ☐ Part/component #2 A Other
2 ☐ Part/component #1 4 ☐ Part/component #3

205 Incorrect Part *(Multiple entry)*
1 ☐ None 3 ☐ Part/component #2 A Other
2 ☐ Part/component #1 4 ☐ Part/component #3

Part Name	A Part/Component #1	B Part/Component #2	C Part/Component #3
205 ATA Code			
206 Manufacturer			
207 Mfg. Part #			
208 Mfg. Model #			
209 Serial #			
210 Part Condition			
211 Total Time			
212 TSO			
213 TSI			
214 Cycles Total			
215 Cycles Since Overhaul			
216 Cycles Since Inspection			
217 Service Difficulty Report or Malfunction/Defect Report Submitted	1 ☐ Yes 2 ☐ No	1 ☐ Yes 2 ☐ No	1 ☐ Yes 2 ☐ No

National Transportation Safety Board

FACTUAL REPORT AVIATION

NTSB Accident/Incident Number

Supplement I—Crash Kinematics

1 Accident Site Geographic Coordinates —Latitude

1 ☐ North   A ⌊⌋ ° ⌊⌋

2 ☐ South   B Other ⌊⌋

2 Accident Site Geographic Coordinates—Longitude

1 ☐ East   A ⌊⌋ ° ⌊⌋

2 ☐ West   B Other ⌊⌋

3 Impact Sequence—*(Number in sequence. Multiple entry.)*

1 ☐ None	7 ☐ Ground	13 ☐ Trees/limbs 12" diam. and up	19 ☐ Runway light
2 ☐ Rock face	8 ☐ Dirt bank	14 ☐ Frangible approach aid	20 ☐ Water
3 ☐ Rigid structure	9 ☐ Scrub tree	15 ☐ Non-frangible approach aid	21 ☐ Wire
4 ☐ Rocks to 1' diam.	10 ☐ Trees/limbs to 6" diam.	16 ☐ Submerged obstacle	22 ☐ Pole
5 ☐ Rocks 1'-2' diam.	11 ☐ Trees/limbs 6"-9" diam.	17 ☐ Vehicle	23 ☐ Snow bank
6 ☐ Rocks > 2' diam.	12 ☐ Trees/limbs 9"-12" diam.	18 ☐ Aircraft	A Other ⌊⌋

4 Terrain At Principal Impact Point

1 ☐ Wet cultivated soil	6 ☐ Loose snow	11 ☐ Wet sod	16 ☐ Ice
2 ☐ Dry cultivated soil	7 ☐ Concrete	12 ☐ Water	17 ☐ Mud
3 ☐ Dry packed clay	8 ☐ Asphalt	13 ☐ Tundra	18 ☐ Sand
4 ☐ Boggy swampy	9 ☐ Loose rock	14 ☐ Dirt	19 ☐ None
5 ☐ Packed snow	10 ☐ Dry sod	15 ☐ Rock	A Other ⌊⌋

Principal Impact Kinematics

5 Airspeed At Impact *(Enter direct or mark estimated range)*

1 ☐ 0-15	6 ☐ 75-90	11 ☐ 210 plus knots
2 ☐ 15-30	7 ☐ 90-120	A ______ Knots
3 ☐ 30-45	8 ☐ 120-150	B Other ⌊⌋
4 ☐ 45-60	9 ☐ 150-180	
5 ☐ 60-75	10 ☐ 180-210	

6 Flight Path Angle *(Enter direct or mark estimated range)*

1 ☐ Up	6 ☐ 15-20	11 ☐ 60-90
2 ☐ Down	7 ☐ 20-25	A ______ Degrees
3 ☐ 0-5	8 ☐ 25-30	B Other ⌊⌋
4 ☐ 5-10	9 ☐ 30-45	
5 ☐ 10-15	10 ☐ 45-60	

7 Pitch Attitude At Impact *(Enter direct or mark estimated range.)*

Pitch Attitude

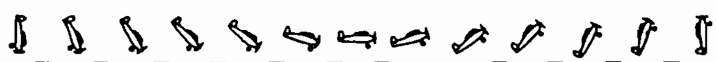
1 ☐ Down

2 ☐ Up

A ______Deg.

Nose Down Angle With Horizon   Nose Up Angle With Horizon

☐ 75 ☐ 60 ☐ 45 ☐ 30 ☐ 15 ☐ 0 ☐ 15 ☐ 30 ☐ 45 ☐ 60 ☐ 75 ☐



90 ☐ 75 ☐ 60 ☐ 45 ☐ 30 ☐ 15 ☐ 0 ☐ 15 ☐ 30 ☐ 45 ☐ 60 ☐ 75 ☐ 90

B or Other ⌊⌋

8 Roll Attitude At Impact *(Enter direct or mark estimated range.)*

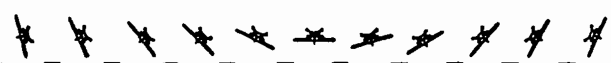
Roll

1 ☐ Left

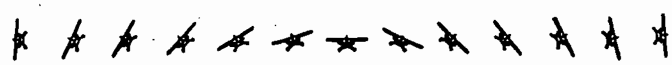
2 ☐ Right

A ______Deg.

Aircraft Rolled Left   Aircraft Rolled Right



☐ 105 ☐ 120 ☐ 135 ☐ 150 ☐ 165 ☐ 180 ☐ 165 ☐ 150 ☐ 135 ☐ 120 ☐ 105 ☐



90 ☐ 75 ☐ 60 ☐ 45 ☐ 30 ☐ 15 ☐ 0 ☐ 15 ☐ 30 ☐ 45 ☐ 60 ☐ 75 ☐ 90

B or Other ⌊⌋

National Transportation Safety Board

FACTUAL REPORT AVIATION

Supplement I—Crash Kinematics (continued)

9 Yaw Attitude at Impact *(Enter direct or mark estimated range.)*

1 ☐ Nose left
2 ☐ Nose right
A ______ Deg.

Aircraft Yawed Left — Aircraft Yawed Right

90 ☐ 75 ☐ 60 ☐ 45 ☐ 30 ☐ 15 ☐ 0 ☐ 15 ☐ 30 ☐ 45 ☐ 60 ☐ 75 ☐ 90

or

B Other

10 Terrain Angle
1 ☐ Level
A Up ⌊⌋ degrees
B Down ⌊⌋ degrees
C Other ⌊⌋

11 Principal Impact Ground Scar Length
1 ☐ None
A ⌊⌋ feet
B Other ⌊⌋

12 Principal Impact Ground Scar Depth
1 ☐ None
A ⌊⌋ inches
B Other ⌊⌋

13 Fuselage Totally Destroyed
1 ☐ Yes *(Go to block 36)*
2 ☐ No
A Other ⌊⌋

14 Cockpit Damage *(Multiple entry)*
1 ☐ Destroyed
2 ☐ Collapsed
3 ☐ Part collapsed
4 ☐ Distorted
5 ☐ Burnt
6 ☐ Intact
7 ☐ None
A Other ⌊⌋

15 FWD Cabin Damage *(Multiple entry)*
1 ☐ Destroyed
2 ☐ Collapsed
3 ☐ Part collapsed
4 ☐ Distorted
5 ☐ Burnt
6 ☐ Intact
7 ☐ None
A Other ⌊⌋

16 AFT Cabin Damage *(Multiple entry)*
1 ☐ Destroyed
2 ☐ Collapsed
3 ☐ Part collapsed
4 ☐ Distorted
5 ☐ Burnt
6 ☐ Intact
7 ☐ None
A Other ⌊⌋

17 Fuselage Split
1 ☐ No *(Go to block 19)*
2 ☐ Longitudinal
3 ☐ Circumferential
A Other ⌊⌋

18 Fuselage Split Behind Seat #
A Other ⌊⌋

19 Fuselage Collapse *(Estimated)*
1 ☐ None
A Horizontal ⌊⌋ inches
B Vertical ⌊⌋ inches
C Other ⌊⌋

20 Fuselage Crush
1 ☐ None
A Horizontal ⌊⌋ inches
B Vertical ⌊⌋ inches
C Other ⌊⌋

Exit Data

Exit Location	A Type of Exit: 1 Door	2 Window	3 Hatch	B Other	C Operable: 1 Yes	2 No	D Other	E Fire Damage: 1 Yes	2 No	F Other	G Impact Damage: 1 Yes	2 No	H Other
21 Cockpit-Left				⌊⌋			⌊⌋			⌊⌋			⌊⌋
22 Cockpit-Right				⌊⌋			⌊⌋			⌊⌋			⌊⌋
23 1L				⌊⌋			⌊⌋			⌊⌋			⌊⌋
24 1R				⌊⌋			⌊⌋			⌊⌋			⌊⌋
25 2L				⌊⌋			⌊⌋			⌊⌋			⌊⌋
26 2R				⌊⌋			⌊⌋			⌊⌋			⌊⌋
27 3L				⌊⌋			⌊⌋			⌊⌋			⌊⌋
28 3R				⌊⌋			⌊⌋			⌊⌋			⌊⌋
29 4L				⌊⌋			⌊⌋			⌊⌋			⌊⌋
30 4R				⌊⌋			⌊⌋			⌊⌋			⌊⌋
31 5L				⌊⌋			⌊⌋			⌊⌋			⌊⌋
32 5R				⌊⌋			⌊⌋			⌊⌋			⌊⌋
33 6L				⌊⌋			⌊⌋			⌊⌋			⌊⌋
34 6R				⌊⌋			⌊⌋			⌊⌋			⌊⌋

NTSB Form 6120.4 Supplement I (1/83)

National Transportation Safety Board

FACTUAL REPORT
AVIATION

Supplement I—Crash Kinematics (continued)

Crash Site Plan/Elevation

36 Sketch of Crash Site—*Show distribution of major components, fire area, obstacles struck, occupants, and magnetic north. Sketch is "NOT TO SCALE"*

Plan View

Elevation View

National Transportation Safety Board

FACTUAL REPORT AVIATION

NTSB Accident/Incident Number

Supplement K—Occupant, Survival and Injury Information

1 Seat No.
A
B If Seat Unknown Enter Persons Name
C Other

2 Position
1 ☐ Pilot in command
2 ☐ Second pilot
3 ☐ Other crewmember
4 ☐ Passenger
A Other

3 Age
A Yrs
B Under 24 mos., enter months
C Other

4 Height
Inches
A Other

5 Weight
Lbs
A Other

6 Injury Index
1 ☐ None
2 ☐ Minor
3 ☐ Serious
4 ☐ Fatal
A Other

7 Condition Prior to Accident
1 ☐ Smoker
2 ☐ Language difficulty
3 ☐ Pre-existing disease
4 ☐ Prothesis
A Other

8 Physically Handicapped
1 ☐ No
2 ☐ Blind
3 ☐ Mobility impaired
4 ☐ Deaf
A Other

9 Seat Belt Adjustment
1 ☐ Not fastened
2 ☐ Loose
3 ☐ Snug
4 ☐ Tight
5 ☐ Not seated
A Other

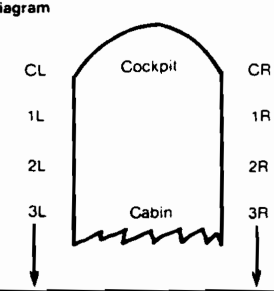
10 Shoulder Harness Adjustment
1 ☐ Not fastened
2 ☐ Loose
3 ☐ Snug
4 ☐ Tight
5 ☐ Seat not equipped
A Other

11 Knew Impact/Accident Coming
1 ☐ Yes
2 ☐ No
A Other

12 Braced for Impact
1 ☐ Yes
2 ☐ No
A Other

13 Direction of Movement at Impact *(Multiple entry)*
1 ☐ Forward
2 ☐ Rearward
3 ☐ Upward
4 ☐ Downward
5 ☐ Left
6 ☐ Right
A Other

Exit Diagram



Use following codes for overhead hatches

Cockpit 99
Cabin 88
Tailcone 77

14 Exit Used *(Use diagram)*
A Other

15 Escape Hampered by
1 ☐ Not hampered
2 ☐ Smoke
3 ☐ Heat
4 ☐ Injuries
5 ☐ Trapped
6 ☐ Darkness
7 ☐ Debris
8 ☐ Disorientation
A Specify
B Other

16 Briefed on Emergency Procedures
1 ☐ No
2 ☐ Before takeoff
3 ☐ Before impact/accident
A Other

17 Difficulty in Using Exit
1 ☐ Yes
2 ☐ No
A Other

18 Escape Hampered
1 ☐ Yes
2 ☐ No
A Other

19 Evacuation Aided by
1 ☐ Passenger
2 ☐ Crew
3 ☐ Bystander
4 ☐ CFR personnel
A Other

20 Injured During Evacuation
1 ☐ Yes
2 ☐ No
A Other

Complete this section if oxygen was used.

21 Type of Equipment
1 ☐ Supplemental
2 ☐ Portable
A Other

22 Difficulty in Use
1 ☐ Yes
2 ☐ No
A Other

23 Type of Oxygen System
1 ☐ Solid state
2 ☐ Gaseous
A Specify
B Other

National Transportation Safety Board

FACTUAL REPORT AVIATION

Supplement K—Occupant, Survival and Injury Information (continued)

Complete this section for accidents involving fire. **24** ☐ No fire involved *(Go to block 29)*

25 Fire First Sighted *(Location)*	26 Smoke Mask or Goggles Used	27 Material of Clothes Worn	28 Exposure to Heat/Fire
1 ☐ Inside aircraft 2 ☐ Outside aircraft 3 ☐ Both A Other	1 ☐ No 2 ☐ Yes 3 ☐ Both 4 ☐ Difficulty in use A Other	1 ☐ Synthetic 2 ☐ Nonsynthetic 3 ☐ Fire resistant 4 ☐ Mix-synthetic and nonsynthetic A Other	1 ☐ Head/face 2 ☐ Arm(s) 3 ☐ Hand(s) 4 ☐ Leg(s) 5 ☐ Torso 6 ☐ Feet A Other

Complete this section for accidents involving ditching/water impact. **29** ☐ No water impact *(Go to block 36)*

Flotation Devices	A Available			C Used			E Familiar With Use			G Problems In Use			I Malfunctioned With Use			K Equipment Damaged		
	1 Yes	2 No	B Other	1 Yes	2 No	D Other	1 Yes	2 No	F Other	1 Yes	2 No	H Other	1 Yes	2 No	J Other	1 Yes	2 No	L Other
30 Liferaft																		
31 Vest-Inflatable																		
32 Vest-Non-Inflatable																		
33 Cushion																		

34 Time in Water	35 Rescued by
A ____ Hrs. B ____ Mins. C Other	1 ☐ Boat 2 ☐ Airplane 3 ☐ Helicopter 4 ☐ None 5 ☐ Swimmer A Other

Occupant Injuries—*Complete applicable parts for survivors and nonsurvivors.*

Items 36 thru 43 apply ONLY to flight crewmembers. For non crew members, go to block 44.

36 Medication Prescribed	37 Medication Being Taken	38 Hours Since Taken	39 Medication Dosage	40 Time Since Last Meal
1 ☐ No A Yes *(Specify: ____)* B Other	1 ☐ No A Yes *(Specify: ____)* B Other	____ Hrs. A Other	____ A Other	____ Hrs. A Other

41 Medication/Drugs Found	42 Location Medication/Drugs Found	43 Pre-existing Disease Found at Autopsy
1 ☐ No A Yes *(Specify: ____)* B Other	1 ☐ On body 2 ☐ In personal effect 3 ☐ In aircraft 4 ☐ Outside aircraft A Other	1 ☐ No autopsy performed 2 ☐ None reported A Yes *Specify:* ____ B Other

National Transportation Safety Board

FACTUAL REPORT
AVIATION

Supplement K—Occupant, Survival and Injury Information (continued)

Results of Toxicological Analyses—*Complete as applicable for survivors and nonsurvivors.*

44 Toxicology

1 ☐ Not ordered
2 ☐ Not ordered—performed
3 ☐ Ordered—performed
4 ☐ Ordered—not performed
5 ☐ Embalmed
6 ☐ Specimen not available/unsuitable for analysis
A Other

Substances	A Test Results 1 Positive	2 Negative	B Other	C Level of Substances Found
45 Ethanol (Alcohol)				Mg %
46 CO (Carbon Monoxide)				% Saturation
47 hb (Hemoglobin)				gm %
48 HCN (Hydrogen Cyanide)				Microgram/ml

List any additional toxicological substances discovered below.

A Substance Code	B Level of Substances Found
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	
60	
61	
62	

Toxicological Substances/Codes

Substance	Code	Substance	Code
Acetamenophen	001	Isopropanol	036
Acetaldehyde	002	Ketamine	037
Acetone	003	Lidocaine	038
Amoxapine	004	Mecloqualone	039
Amitriptyline	005	Meperidine	040
Amobarbital	006	Mephentermine	041
Amphetamine	007	Meprobamate	042
Benzoylecgonine	008	Methanol	043
Brompheniramine	009	Methadone	044
Butalbital	010	Methamphetamine	045
Butabarbital	011	Methaqualone	046
Caffene	012	Loxapine	047
Cannabinoids	013	Methylenedioxyam	048
Chlorazepate	014	Phetamine	049
Chlordiazepoxide	015	Methylphenidate	050
Chlorphentermine	016	Methyprylon	051
Clonazepam	017	Menthol	052
Cocaine	018	Morphine	053
Codeine	019	Medazepam	054
Desipramine	020	Nicotine	055
Diazepam	021	Nortriptyline	056
Dihydrocodeinone	022	Oxazepam	057
Diphenhydramine	023	Pentazocine	058
Diphenylhydantoin	024	Phenobarbital	059
Doxepin	025	Procaine	060
Desalkylflurazepam	026	Propoxyphene	061
Demoxapam	027	Secobarbital	062
Ethchlorvynol	028	Thioridazine	063
Flunitrazepam	029	Temazepam	064
Flurazepam	030	Nordiazepam	065
Fluphenazine	031	Pentobarbital	066
Glutethimide	032	Phencyclidine	067
Haloperidol	033	Phendimetrazine	068
Hexobarbital	034	Prazepam	069
Imipramine	035		

National Transportation Safety Board

FACTUAL REPORT
AVIATION

Supplement K—Occupant, Survival and Injury Information (continued)

63 ☐ *For multiple extreme traumatic injuries, check box, and go to next applicable supplement.*

Occupant Injury Coding Chart *(Complete for survivors and non survivors as applicable.)*

	A Body Region	B Aspect	C Lesion	D System/Organ	E A.I.S. Severity	F 6 Injury Source	G 7 Source of Data
64							
65							
66							
67							
68							
69							
70							
71							
72							
73							

Body Region - A

01 Head (Skull, scalp, ears)
02 Face (Forehead, nose, eyes, mouth)
03 Neck (Cervical spine, C1-C7)
04 Shoulder (Clavicle, scapula, joint)
05 Upper limb (Whole arm)
06 Arm (Upper)
07 Elbow
08 Forearm
09 Wrist
10 Hand—fingers
11 Chest (Anterior and posterior ribs)
12 Abdomen (Diaphragm and below)
13 Back (Thoracsic spine T1-T12)
14 Back (Lumbar L1-L5)
15 Pelvis—hip
16 Lower limb (Whole leg)
17 Thigh (Femur)
18 Knee
19 Leg (Below knee)
20 Ankle
21 Foot—toes
22 Whole body
88 Injured, unknown region
99 Other

Aspect Of Injury - B

01 Right
02 Left
88 Injured aspect unknown
99 Other

Lesion - C

01 Laceration
02 Contusion
03 Abrasion
04 Fracture
05 Concussion
06 Avulsion
07 Rupture
08 Sprain
09 Dislocation
10 Crush
11 Amputation
12 Burn
13 Fracture and dislocation
14 Severence (Transection)
15 Strain
16 Detachment (Separation)
17 Perforation (Puncture)
88 Injured unknown lesion
99 Other

System/Organ - D

01 Skeletal
02 Vertebrae
03 Joints
04 Digestive
05 Liver
06 Nervous System
07 Brain
08 Spinal cord
09 Ears
10 Arteries veins
11 Heart
12 Spleen
13 Urogenital
14 Kidneys
15 Respiratory
16 Eye
17 Pulmonary/lungs
18 Airway
19 Muscles
20 Integumentary
21 Thyroid (Thyroid or other endocrine gland)
88 Injured, unknown system or organ
99 Other

Abbreviated Injury Scale - E

00 Not injured
01 Minor injury
02 Moderate injury
03 Serious injury (Not life-threatening)
04 Severe injury (Life-threatening survival probable)
05 Critical injury (Survival uncertain)
06 Maximum (untreatable)
07 Injured (Unknown severity)
88 Unknown if injured

Source of Data - G

Official

01 Autopsy records with or without hospital/medical records
02 Hospital/medical records
03 Emergency room records
04 Private or treating physicians

Unofficial

05 Lay coroner
06 E.M.S. personnel
07 Interviewee
08 Police
09 Other source

National Transportation Safety Board

FACTUAL REPORT
AVIATION

Supplement K—Occupant, Survival and Injury Information (continued)

Injury Source List - F

01 Windshield
02 Windshield frame
03 Window
04 Window frame
05 Instrument panel
06 Side console
07 Center console
08 Control stick/cyclic stick
09 Collective
10 Control yoke column
11 Throttle quadrant/levers
12 Rudder pedals
13 Ceiling
14 Sidewall
15 Floor
16 Fuselage framing/structure
17 Table
18 Seat
19 Seatback tray
20 Restraints—seatbelt/tiedown
21 Restraints—shoulder harness
22 Unsecured item(s) in cockpit
23 Unsecured item(s) in cabin
24 Other occupants
25 Ground/runway
26 Unsecured seat(s)
27 Outside object(s) entering aircraft
28 Galley item(s)
29 Food/beverage item(s)
30 Other interior objects
31 Other exterior objects
32 Evacuation slide/slide raft
33 Escape rope/tape
34 Escape inertia device
35 Ejected from aircraft
36 Propeller/rotor blades
37 Exterior aircraft surface
38 Engine
39 Wheel/tires
40 Ground vehicle
41 Toxic/noxious/irritant fumes
42 Fire/radiant heat
43 Flying glass
44 Door/hatches
45 Acceleration forces
46 Exposure
88 Unknown
99 Other

National Transportation Safety Board

FACTUAL REPORT
AVIATION

NTSB Accident/Incident Number

Supplement L—Seat, Restraint System and Fuselage Deformation

[illegible]

1 Seat Number
______
A Other

2 Seat Manufacturing Standard
1 ☐ Type certificate *(Airframe manufacturer)*
2 ☐ Non-TSO
A TSO *(Specify)* ______
B Other

3 Seat Orientation
1 ☐ Forward facing
2 ☐ Rearward facing
3 ☐ Side facing
A Other

4 Seat Unit
1 ☐ Fixed
2 ☐ Adjustable
3 ☐ Swivel
A Other

5 Seat Type *(Multiple entry)*
1 ☐ Cockpit crew
2 ☐ Flight attendant single jumpseat
3 ☐ Flight attendant double jumpseat
4 ☐ Folding stowable
5 ☐ Single passenger seat
6 ☐ 2 passenger seat unit
7 ☐ 3 passenger seat unit
8 ☐ Sofa/Bench
A Other

6 Seat Location at Time of Examination
1 ☐ Inside aircraft-attached
2 ☐ Inside aircraft-separated
3 ☐ Outside aircraft
A Other

7 Total Seat Destruction *(Multiple entry)*
1 ☐ Impact *(Go to block 30)*
2 ☐ Fire *(Go to block 30)*
A Other

8 Seat Anchored
1 ☐ Bulkhead/wall
2 ☐ Floor
A Other

9 Seat Primary Structure
1 ☐ Tube
2 ☐ Sheet metal
3 ☐ Composite
4 ☐ Wood
A Other

10 Energy Absorbing Features
1 ☐ Yes
2 ☐ No
A Other

11 Evidence of Fire/Heat Damage
1 ☐ None
2 ☐ Cushions/covers
3 ☐ Structure
4 ☐ Restraints
A Other

Seat Installation/Damage/Displacement

12 Seat Impact Damage
1 ☐ None
(Omit 15-27 type impact damage)

13 Seat Displacement
1 ☐ None *(Omit 15-27 direction of seat displacement)*

Seat Component	A Installed 1 No	A 2 Yes	A 3 Improper Installation	B Other	C Type Impact Damage *(Multiple entry)* 1 None	C 2 Bent	C 3 Distorted/Buckled	C 4 Collasped	C 5 Partially Separated	C 6 Separated	D Other	E Direction of Seat Displacement *(Multiple entry)* 1 None	E 2 Forward	E 3 Rearward	E 4 Left	E 5 Right	E 6 Up	E 7 Down	F Other
15 Pedestal																			
16 Enclosure																			
17 Back Frame																			
18 Seat Pan																			
19 Pan Frame																			
20 Legs																			
21 Leg Attach Fittings																			
22 Seat Attach Fittings																			
23 Structural Attach Fittings, Floor																			
24 Structural Attach Fittings, Wall																			
25 Seat Track																			
26 Arm Rest																			
27 Seat Back Tray																			

[illegible]

30 ☐ **Totally Destroyed** *(Go to block 46)*

31 Restraint System Manufacturer
______
A Other

32 Restraint System TSO
1 ☐ Yes
2 ☐ No
A Other

33 Restraint System Design
1 ☐ 2-point
2 ☐ 3-point
3 ☐ 4-point
4 ☐ 5-point
A Other

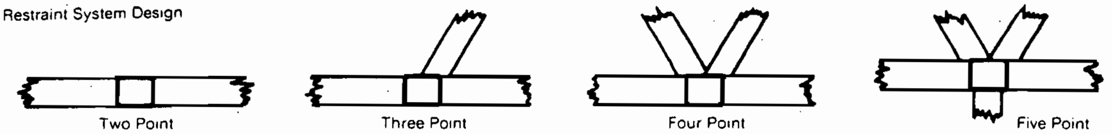
34 Type Release/Buckle
1 ☐ Metal to metal
2 ☐ Fabric/pull thru
A Specify ______
B Other

National Transportation Safety Board

FACTUAL REPORT AVIATION

Supplement L—Seat, Restraint System and Fuselage Deformation (continued)

Restraint System Design



Component	A Installed 1 Yes	2 No	B Other	C Fire Damage 1 Yes	2 No	D Other	E Evidence of Use 1 Yes	2 No	F Other	G Location of Anchor Points 1 Seat	2 Wall	3 Floor	4 Ceiling	5 Bulkhead	H Other
35 Lapbelt															
36 Shoulder Harness															
37 Inertia Reel															
38 Tiedown Strap															

Component	A 1 No Damage	B Webbing/Stitching 1 Destroyed	2 Partially Separated	3 Separated	C Restraint Attach Fittings 1 No Damage	2 Destroyed	3 Bent	4 Partially Separated	5 Separated	D Seat/Structure Attach Fittings 1 No Damage	2 Destroyed	3 Bent	4 Partially Separated	5 Separated
39 Lapbelt														
40 Shoulder Harness														

41 Other Damage—Release Buckle
1 ☐ Yes
2 ☐ No A Other

42 Other Damage—Tie Down Strap
1 ☐ Yes
2 ☐ No A Other

43 Other Damage— Inertia Reel
1 ☐ Yes
2 ☐ No A Other

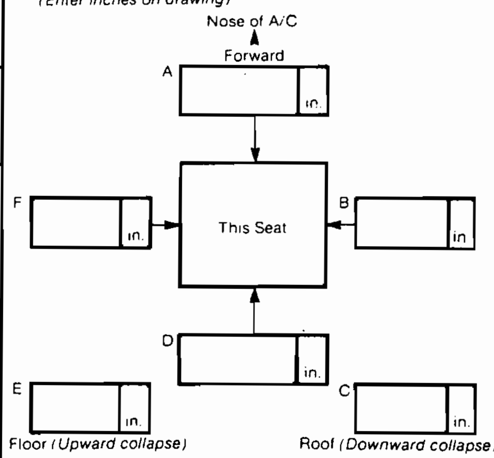
Fuselage Deformation Around This Seat

46 Fuselage Collapse Around This Seat
1 ☐ None
2 ☐ Collapse
3 ☐ Disintegration/Incinerated A Other

47 Interior Surface Damage To This Seat
1 ☐ Yes
2 ☐ No
A Other

Cabin Interior Deformation Around This Seat *(Select codes from list below)*	A Direction of Deformation 1 Forward	2 Rearward	3 Left	4 Right	5 Up	6 Down	B Other
50 Code							
51 Code							
52 Code							
53 Code							

48 Fuselage Collapse Measurements Around This Seat
(Enter inches on drawing)



Note: Arrow (——→) shows direction of displacement

National Transportation Safety Board

FACTUAL REPORT
AVIATION

Supplement L—Seat, Restraint System and Fuselage Deformation (continued)

(Codes to be used in 50-53 above)

01 Windshield
02 Windshield frame
03 Window
04 Window frame
05 Instrument panel
06 Side console
07 Center console
08 Control stick/cyclic stick
09 Collective
10 Control yoke/column
11 Throttle quadrant/levers
12 Rudder pedals
13 Ceiling
14 Sidewall
15 Floor
16 Fuselage framing/structure
17 Table
18 Seat
19 Seatback tray
20 Restraints—seatbelt/tiedown
21 Restraints—shoulder harness
22 Unsecured item(s) in cockpit
23 Unsecured item(s) in cabin
24 Other occupants
25 Ground/runway
26 Unsecured seat(s)
28 Galley item(s)
30 Other interior objects
44 Door/hatches

APPENDIX C

COMPUTER PROGRAM FOR CRASHWORTHINESS ANALYSIS

Computer Program Summary

Data defining the curve for an estimated crash pulse is entered into the computer, and the program is run. The acceleration curve is generated from the data, and the area under the curve is integrated, yielding a curve for velocity. The area under the velocity curve is integrated yielding a curve for distance. This is accomplished by dividing the acceleration curve into 100 equal time increments. The change in velocity and distance for each increment is calculated using an average acceleration and average velocity for that increment.

Additional documentation of the program is included below. Refer to the following lines in the program listing:

Line 56: DV = (y + Y_{old}) *CONST * DT

DV (ft/sec) = velocity change for a given increment

Y, Y_{old} (G's) = The acceleration in G's at the end (Y) and at the beginning (Y_{old}) of each increment

CONST (constant) = 16.1 = 32.2/2, where 32.2 is the gravitational constant, to translate G's to feet per second^2. Division by 2 results in a value for an average G (Y & Y_{old}) for the increment.

DT (sec) = The time increment, equal to the total time of the crash pulse divided by 100.

Line 57: V(I) = V(I - 1) + DV

V(I-1) (ft/sec) = velocity at the start of the increment

V(I) (ft/sec) = velocity at the end of the increment

Line 58: DIS (I) = ((V(I) + V(I-1)) *.5) *DT

DIS (I) (ft) = Distance change for a given increment.

Multiplication by 0.5, results in a value for the average velocity for V(I) + V(I-1).

Line 59: DIS (I) = DIS (I) + DIS (I-1)

DIS (I) (ft) = Cumulative distance of crush, as opposed to the incremental distance change calculated on line 58.

```
FORTRAN IV      V02.2-1          TUE 28-JUN-83 12:51:19          PAGE 001
,LP:=DL1:[1,77]HUMAN

              PROGRAM HUMEAC
      C
      C       CREATED BY MONTY MONTGOMERY OF NTSB TE-60
      C            JULY, 1982
      C
      C       THIS PROGRAM READS ACCELERATION DATA AND TARGET
      C       VALUES FOR VELOCITY AND DISTANCE FROM A USER
      C       CREATED FILE. THE PROGRAM INTEGRATES THE ACCELERATION
      C       AND THE THE VELOCITY TO GET DISTANCE.
      C       THE INTEGRATIONS ARE PLOTTED ON THE BOARD'S DIGITAL
      C       PLOTTER TO ALLOW THE USER TO SEE IF HIS ACCELERATION
      C       ESTIMATES ARE APPROPRIATE.
      C
      C       THE BOARD'S COMPUTER IS A DIGITAL EQUIPMENT CORPORATION
      C       PDP-11/40 RUNNING RSX-11/M SOFTWARE.
      C       THIS PROGRAM IS WRITTEN IN ANSI-66 FORTRAN.
      C
      C       DIMENSIONED VARIABLES AND INITIALIZATION
      C
              REAL*4 MA(100),TA(100),B(100),IHACK(20)
              REAL*4 V(500),DIS(500),T(500),XHACK(20)
              DIMENSION VHACK(20),VTIM(20)
              DIMENSION A(500)
              LOGICAL*1 BUF(80)
      C
      C       PROMPT USER FOR DATA FILE AND OPEN IT
              TYPE 1
         1    FORMAT(' ENTER INPUT FILENAME :   's)
              ACCEPT 2,IC,BUF
              CALL ASSIGN(3,BUF,IC)
         2    FORMAT(Q,80A1)
      C
      C       READ TARGET VELOCITY VALUES AND TIMES
      C
              READ(3,32)NVHACK
              DO 28 I=1,NVHACK
        28    READ(3,33)VTIM(I),VHACK(I)
      C
      C       READ TARGET DISTANCE VALUES AND TIMES
      C
              READ(3,32)IHACK
        32    FORMAT(I8)
              DO 31 I=1,IHACK
        31    READ(3,33)THACK(I),XHACK(I)
              CONST=16.1  !              1 "G         /2
      C
      C       READ ACCELERATION VALUES AND TIMES
      C       AND CONSTRUCT A LINEAR PIECE-WISE FUNCTION ARRAY
      C       IE. SLOPES AND INTERCEPTS FOR ALL DEFINED INTERVALS
      C
              NPART=0
              READ(3,33)TA(1),A1
       100    READ(3,33,END=933)T2,A2
        33    FORMAT(2F10.0)
```

```
FORTRAN IV      V02.2-1          TUE 28-JUN-83 12:51:19        PAGE 002
,LP:=DL1:[1,77]HUMAN

            NPART=NPART+1
            TA(NPART+1)=T2
            MA(NPART)=((A2-A1)/(T2-TA(NPART)))
            B(NPART)=A2-MA(NPART)*T2
            A1=A2
            GO TO 100
      C
      C     INTEGRATION AREA... VELOCITY = VELOCITY + AVG ACCELERATION * TIME
      C     DISTANCE = DISTANCE + AVERAGE VELOCITY * TIME
      C
      C     THE TOTAL GIVEN INTERVAL IS DIVIDED INTO 100 SUBINTERVALS
      C     FOR A PIECE-WISE INTEGRATION.
      C
      C     TIMER IS A SUBROUTINE WHICH RETURNS AN ACCELERATION
      C     VALUE FOR THE SPECIFIED SUBINTERVAL, USING THE
      C     PIECE-WISE LINEAR ARRAY CONSTRUCTED FROM THE ACCELERATION
      C     POINTS IN THE INPUT FILE.
      C
        933 CONTINUE
            TMIN=TA(1)
            TMAX=TA(NPART+1)
            DT=(TMAX-TMIN)/100.
            TA(1)=TA(1)-.00001
            TA(NPART+1)=TA(NPART+1)+.00001
            TO=TMIN
            CALL TIMER(TO,Y,TA,MA,B,NPART,IFLG)
            IF(IFLG.NE.0) GO TO 9000
            A(1)=Y
            YOLD=Y
            T(1)=TO
            V(1)=VHACK(1)
            DIS(1)=XHACK(1)
            DO 10 I=2,101
            TO=TO+DT
            T(I)=TO
            CALL TIMER(TO,Y,TA,MA,B,NPART,IFLG)
            IF(IFLG.EQ.0) GO TO 9900
            TYPE 9800
       9800 FORMAT(' TIMING ERROR IN FORCING FUNCTION TIME')
            GO TO 9000
       9900 CONTINUE
            A(I)=Y
            DV=(Y+YOLD)*CONST*DT
            V(I)=V(I-1)+DV
            DIS(I)=((V(I)+V(I-1))*.5)*DT
            DIS(I)=DIS(I)+DIS(I-1)
            YOLD=Y
         10 CONTINUE
      C
      C     THE INTEGRATED VALUES AND THE ACCELERATION FUNCTION
      C     ARE PLOTTED HERE
      C
            CALL ASSIGN(1,'PL:')
            CALL CLOSE(3)
```

```
FORTRAN IV      V02.2-1          TUE 28-JUN-83 12:51:19          PAGE 003
,LP:=DL1:[1,77]HUMAN

                CALL ASSIGN(2,'NL:')
                CALL PLOTS(0,0,1)
                CALL FACTOR(1.0)
                CALL NEWPEN(1)
                CALL RECT(0.,0.,11.,12.,0,1)
                CALL PLOT(1.5,.5,-3)
                CALL GRID(0.,0.,.5,.5,20,20)
                CALL SCALE(T,10.,101,1)
                CALL SCALE(A,10.,101,-1)
                CALL NEWPEN(2)
                CALL AXIS(0.,0.,4HTIME,-4,10.,0.,T(102),T(103))
                CALL AXIS(0.,0.,6HACC    ,6,10.,90.,A(102),A(103))
                CALL SYMBOL(-.3125,5.25,.14,0,90.,-1)
                CALL LINE(T,A,101,1,1,0)
                CALL NEWPEN(3)
                J=101
                DO 40 I=1,NVHACK
                J=J+1
         40     V(J)=VHACK(I)
                CALL SCALE(V,10.,J,1)
                V(102)=V(J+1)
                V(103)=V(J+2)
                DO 41 J=1,NVHACK
                XP=(VTIM(J)-T(102))/T(103)
                YP=(VHACK(J)-V(102))/V(103)
                CALL PLOT(XP-.25,YP,3)
                CALL PLOT(XP+.25,YP,2)
                CALL PLOT(XP,YP-.25,3)
                CALL PLOT(XP,YP+.25,2)
         41     CALL CIRCL(XP+.25,YP,0.,360.,.25,.25,0.)
                CALL AXIS(-.5,0.,6HVEL    ,6,10.,90.,V(102),V(103))
                CALL SYMBOL(-.8125,5.25,.14,1,90.,-1)
                CALL LINE(T,V,101,1,1,1)
                CALL NEWPEN(4)
                J=101
                DO 42 I=1,IHACK
                J=J+1
         42     DIS(J)=XHACK(I)
                CALL SCALE(DIS,10.,J,1)
                DIS(102)=DIS(J+1)
                DIS(103)=DIS(J+2)
                DO 43 J=1,IHACK
                XP=(THACK(J)-T(102))/T(103)
                YP=(XHACK(J)-DIS(102))/DIS(103)
                CALL PLOT(XP-.25,YP,3)
                CALL PLOT(XP+.25,YP,2)
                CALL PLOT(XP,YP-.25,3)
                CALL PLOT(XP,YP+.25,2)
         43     CALL CIRCL(XP+.25,YP,0.,360.,.25,.25,0.)
                CALL AXIS(-1.,0.,6HS      ,6,10.,90.,DIS(102),DIS(103))
                CALL SYMBOL(-1.3125,5.25,.14,2,90.,-1)
                CALL LINE(T,DIS,101,1,1,2)
                CALL PLOT(14.,-.5,-3)
                CALL PLOT(0.,0.,999)
```

```
FORTRAN IV      V02.2-1             TUE 28-JUN-83 12:51:19          PAGE 004
,LP:=DL1:[1,77]HUMAN

0118     9000 CALL CLOSE(4)
0119          CALL EXIT
0120          END
```

FORTRAN IV STORAGE MAP FOR PROGRAM UNIT HUMFAC

LOCAL VARIABLES, .PSECT $DATA, SIZE = 023042 (4881. WORDS)

NAME	TYPE	OFFSET	NAME	TYPE	OFFSET	NAME	TYPE	OFFSET
A1	R*4	022656	A2	R*4	022666	CONST	R*4	022650
DT	R*4	022702	DV	R*4	022724	I	I*2	022644
IC	I*2	022640	IFLG	I*2	022716	IHACK	I*2	022646
J	I*2	022730	NPART	I*2	022654	NVHACK	I*2	022642
TMAX	R*4	022676	TMIN	R*4	022672	TO	R*4	022706
T2	R*4	022662	XP	R*4	022732	Y	R*4	022712
YOLD	R*4	022720	YP	R*4	022736			

LOCAL AND COMMON ARRAYS:

NAME	TYPE	SECTION	OFFSET	------SIZE-----		DIMENSIONS
A	R*4	$DATA	016540	003720	(1000.)	(500)
B	R*4	$DATA	001440	000620	(200.)	(100)
BUF	L*1	$DATA	022460	000120	(40.)	(80)
DIS	R*4	$DATA	006320	003720	(1000.)	(500)
MA	R*4	$DATA	000000	000620	(200.)	(100)
T	R*4	$DATA	012240	003720	(1000.)	(500)
TA	R*4	$DATA	000620	000620	(200.)	(100)
THACK	R*4	$DATA	002260	000120	(40.)	(20)
V	R*4	$DATA	002400	003720	(1000.)	(500)
VHACK	R*4	$DATA	016300	000120	(40.)	(20)
VTIM	R*4	$DATA	016420	000120	(40.)	(20)
XHACK	R*4	$DATA	016160	000120	(40.)	(20)

SUBROUTINES, FUNCTIONS, STATEMENT AND PROCESSOR-DEFINED FUNCTIONS:

NAME	TYPE	NAME	TYPE	NAME	TYPE	NAME	TYPE	NAME	TYPE
ASSIGN	R*4	AXIS	R*4	CIRCL	R*4	CLOSE	R*4	EXIT	R*4
FACTOR	R*4	GRID	R*4	LINE	I*2	NEWPEN	I*2	PLOT	R*4
PLOTS	R*4	RECT	R*4	SCALE	R*4	SYMBOL	R*4	TIMER	R*4

```
FORTRAN IV      V02.2-1          TUE 28-JUN-83 12:52:11          PAGE 001
,LP:=DL1:[1,77]HUMAN

0001            SUBROUTINE TIMER(T,Y,TA,MA,B,N,IFLG)
          C
          C     THIS ROUTINE USES THE PIECE-WISE LINEAR REPRESENTATION
          C     FOR THE FORCING FUNCTION AND AN INPUT TIME VALUE
          C     TO RETURN AN ACCELERATION VALUE FOR THAT TIME.
          C
0002            REAL*4 TA(1),MA(1),B(1)
0003            IFLG=0
0004            NS=1
0005            DO 1 I=2,N+1
0006            IF(T.GT.TA(I-1).AND.T.LE.TA(I)) GO TO 2
0008            NS=NS+1
0009       1    CONTINUE
0010            IFLG=-1
0011            GO TO 3
0012       2    Y=MA(NS)*T+B(NS)
0013       3    CONTINUE
0014            RETURN
0015            END
```

```
FORTRAN IV STORAGE MAP FOR PROGRAM UNIT TIMER

LOCAL VARIABLES, .PSECT $DATA, SIZE = 000032 (    13. WORDS)

NAME     TYPE   OFFSET        NAME    TYPE   OFFSET        NAME     TYPE   OFFSET
I        I*2    000024        IFLG    I*2 @  000014        N        I*2 @  000012
NS       I*2    000022        T       R*4 @  000000        Y        R*4 @  000002

LOCAL AND COMMON ARRAYS:

NAME      TYPE    SECTION OFFSET  ------SIZE----- DIMENSIONS
B        R*4    @ $DATA   000010  000004 (     2.) (1)
MA       R*4    @ $DATA   000006  000004 (     2.) (1)
TA       R*4    @ $DATA   000004  000004 (     2.) (1)
```

APPENDIX D

CRASHWORTHINESS PROGRAM INVESTIGATIONS TO DATE

SUMMARY OF CRASHWORTHINESS ACCIDENTS

DATE 1982	AIRPLANE MAKE AND MODEL	TOTAL PERSONS ABOARD	INJURIES				PHASE OF OPERATION	TYPE OF TERRAIN	ACCIDENT TYPE
			FATAL	SERIOUS	MINOR	NONE			
1-10	MOONEY M20G	2	1	1			LANDING	TREES, SHRUBS, CUT TREE STUMPS	COLLISION WITH GROUND
2-1	BEECH BE-99	7		5	2		APPROACH	AIRPORT	COLLISION WITH GROUND
2-15	PIPER PA-28R-180	3		1	2		LANDING	AIRPORT	COLLISION WITH OBSTACL
2-27	CESSNA C-150	1		1			APPROACH	AIRPORT	COLLISION WITH GROUND
3-8	PIPER PA-28-180	3	1	2			CRUISE	FARMLAND	COLLISION WITH OBSTACL
3-28	PIPER PA-28-140	4	4				TAKEOFF	HILLS	COLLISION WITH GROUND
5-6	PIPER PA-28R-180	3	1	2			LANDING	MOUNTAINS	COLLISION WITH GROUND
5-9	BEECH BE-B33	4			1	3	LANDING	GOLF COURSE	COLLISION WITH GROUND
6-4	CESSNA C-152-II	2	1	1			MANEUVERING	FARMLAND	COLLISION WITH WIRE/ GROUND
6-13	PIPER PA-28-181	4		2	2		CRUISE	MARSHLAND	COLLISION WITH TREES/ GROUND
6-17	CESSNA C-152	2	1	1			CRUISE	CAMPSITE	COLLISION WITH GROUND
7-9	PIPER PA-24-250	2	1	1			LANDING	AIRPORT	COLLISION WITH GROUND
7-9	PIPER PA-28-160	2		2			APPROACH	DIRT DAM	MIDAIR COLLISION/ COLLISION WITH GROUND
7-21	PIPER PA-34-200P	5	1	4			LANDING	FARMLAND	COLLISION WITH GROUND
8-1	BEECH BE-23	1		1			GO-AROUND	AIRPORT	COLLISION WITH GROUND
8-18	BELLANCA 7ECA	2	2				CRUISE	BEACH	COLLISION WITH GROUND
8-18	PIPER PA-28-235	1		1			LANDING	AIRPORT	COLLISION WITH GROUND
8-27	CESSNA C-207	7			7		TAKEOFF	FARMLAND	COLLISION WITH TELEPH POLE
9-5	PIPER PA-32-300	7	2	5			CRUISE	RIVER BED	COLLISION WITH GROUND
9-20	CESSNA C-182P	3		2		1	TAKEOFF	DESERT	COLLISION WITH GROUND
10-4	BEECH BE-56TC	4		2	2		LANDING	DITCH	COLLISION WITH GROUND
10-5	CESSNA C-T210L	3		2	1		LANDING	DITCH	COLLISION WITH GROUND
10-18	CESSNA C-172	3	1	2			LANDING	MARSHLAND	COLLISION WITH TREES/ GROUND
10-21	PIPER PA-28-181	4	1	3			LANDING	PASTURE	COLLISION WITH TREES/ GROUND
10-23	CESSNA C-172	4	2	2			MANEUVERING	MOUNTAIN SLOPE	COLLISION WITH GROUND
10-24	PIPER PA-32-300	4		4			TAKEOFF	FARMLAND	COLLISION WITH GROUND
11-8	BEECH BE-23	2	1		1		CRUISE	FARMLAND	COLLISION WITH GROUND
11-8	CESSNA C-172	4		4			APPROACH	ROADSIDE	COLLISION WITH GROUND
11-18	PIPER 601P	1		1			GO-AROUND	AIRPORT	COLLISION WITH GROUND
11-21	GRUMMAN AA-5	1				1	LANDING	AIRPORT	COLLISION WITH TREES
11-30	CESSNA C-P210	3	2	1			LANDING	AIRPORT	COLLISION WITH TREES